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Exploring Urban Flooding in Indonesia: A Review of Drivers, Consequences, and Interventions

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Abstract

Urban flooding in Indonesia presents a critical challenge exacerbated by rapid urbanization, climate change, and socio-economic disparities. This review synthesizes insights from 30 peer-reviewed studies indexed in the Garuda Database and other scholarly sources, selected based on their relevance, recency (published between 2015–2024), and methodological rigor in addressing urban flood phenomena. The findings reveal that key drivers include unregulated land-use changes, inadequate drainage systems, and extreme rainfall patterns intensified by global climate change. Socio-economic impacts—such as displacement, economic losses, and public health crises—disproportionately affect marginalized communities. Environmental consequences include ecosystem degradation and the loss of natural water retention areas, such as wetlands and mangroves.

Mitigation strategies discussed in this review emphasize the integration of structural measures, such as modernized drainage systems and flood control infrastructure, with non-structural approaches, including community education and policy reforms. To address these risks, innovative technologies—such as GIS-based flood modelling and low-cost early warning systems—offer promising pathways to improve flood management. Additionally, ecological restoration and sustainable urban planning emerge as critical components for long-term resilience. Drawing on lessons from global practices, this review underscores the importance of collaborative governance, technological innovation, and inclusive community engagement to address urban flooding effectively. By leveraging insights from the Garuda Database and international frameworks, this study provides actionable recommendations for policymakers and stakeholders to build sustainable urban environments and enhance disaster preparedness in Indonesia.

Keywords: *Urban Flooding, Indonesia, Mitigation Strategies, Garuda Database*

INTRODUCTION

Urban flooding has emerged as one of the most pressing challenges for cities worldwide, particularly in regions experiencing rapid urbanization and environmental changes. Defined as the inundation of urban areas due to excessive rainfall, inadequate drainage systems, or rising water levels, urban flooding has significant socio-economic and environmental consequences. In Indonesia, this issue is particularly acute due to its geographical position, tropical climate, and socio-economic dynamics (Handayani & Rudiarto, 2014; Ahmad & Wulandari, 2017). The complexity of urban flooding in Indonesia necessitates a comprehensive understanding of its drivers, impacts, and potential solutions.

Urban flooding in Indonesia represents a persistent and escalating threat, primarily driven by the interplay between high-intensity rainfall, accelerating urban development, and inadequate drainage systems. As in many rapidly growing cities worldwide, the financial burdens of flood-related infrastructure damage and emergency response are rising significantly. Indonesia's vulnerability is further amplified by its archipelagic structure and dense urban populations concentrated in flood-prone zones. Metropolitan areas like Jakarta, Surabaya, and Bandung have repeatedly faced large-scale inundations that disrupt mobility, damage property, and pose serious public health risks (Nugroho et al., 2023; Dewi & Purnama, 2018; Wolok et al., 2024).

Flooding in Indonesia is further intensified by the country’s position along the Pacific Ring of Fire, which subjects it to frequent tectonic activity. These geological conditions, combined with the socio-economic drivers of urban growth, create a perfect storm for recurrent flooding crises. For example, Jakarta’s land subsidence—driven by excessive groundwater extraction—has increased the frequency and severity of tidal flooding (Hanif & Pudyastuti, 2023). Additionally, the lack of

adequate urban planning and aging infrastructure has rendered cities ill-equipped to cope with increasing flood risks (Pratama & Rahmawati, 2018).

The economic toll of urban flooding in Indonesia is staggering. The Jakarta floods of 2020 caused over $1 billion in damages, disrupting transportation networks, damaging property, and slowing economic activity (Setiawan et al., 2020). Businesses in urban centers often face significant losses due to halted operations and damaged inventory, further compounding the economic impacts of flooding.

On a social level, urban flooding disproportionately affects marginalized communities, who often reside in low-lying and flood-prone areas. These populations face heightened vulnerabilities due to limited access to resources and infrastructure, exacerbating inequalities (Yelvi & Sholeh, 2021). Health risks such as waterborne diseases, including cholera and dengue, are prevalent in flood-affected areas, further straining public health systems (Taryana et al., 2022).

Urban flooding also poses significant environmental challenges. Floodwaters often carry pollutants, including industrial waste and sewage, contaminating water bodies and degrading ecosystems. Natural retention areas such as wetlands and mangroves, which play a critical role in mitigating flood impacts, are increasingly being lost to urban development (Santoso, 2022). This environmental degradation not only reduces resilience to future flooding but also contributes to broader ecological imbalances.

Urban flooding in Indonesia is influenced by both environmental and human-induced factors. Among the primary contributors are rapid urban expansion and uncontrolled land-use changes that compromise natural hydrological systems. As urban areas continue to grow, green and absorbent landscapes—such as wetlands and open soil—are increasingly replaced by impermeable infrastructure, limiting natural water infiltration and increasing the volume of surface runoff (Rahman & Kusuma,

2020; Syahril et al., 2023). In Jakarta, unregulated land conversion has significantly altered watershed dynamics, with the loss of wetland buffers and lowland areas contributing to more frequent and severe flooding (Wolok et al., 2024; Rohmadiani & Subekti, 2020).

Inadequate drainage infrastructure is another major contributor. Many urban drainage systems in Indonesia are outdated and poorly maintained, making them incapable of handling the increased rainfall associated with climate change (Dewi & Purnama, 2018). In cities like Surabaya and Bandung, sedimentation and waste accumulation further reduce the efficiency of drainage networks (Suharto & Wijaya, 2018).

Natural factors, including Indonesia's tropical climate and its susceptibility to extreme weather events, also play a critical role. Monsoonal rains and storm surges are common during the rainy season, often overwhelming urban infrastructure (Pratama & Rahmawati, 2018). Moreover, rising sea levels—projected to increase by up to 50 centimeters in some coastal areas by 2050—pose a significant threat to low-lying cities such as Semarang (Hanif & Pudyastuti, 2023).

While considerable research has been conducted on urban flooding in Indonesia, significant gaps remain. Existing studies often focus on specific aspects of flooding, such as drainage system improvements or community preparedness, without addressing the interconnected nature of these factors. This review seeks to bridge these gaps by synthesizing findings from 30 recent studies, providing a holistic understanding of urban flooding in Indonesia. By integrating insights from diverse disciplines, the review aims to offer actionable recommendations for policymakers, researchers, and practitioners.

The primary objective of this review is to explore the drivers, consequences, and mitigation strategies for urban flooding in Indonesia. By examining both natural and

anthropogenic factors, the review seeks to highlight the complex interplay between urban growth, environmental changes, and flood risks. Additionally, the review evaluates existing interventions, ranging from structural measures such as drainage system upgrades to non-structural approaches like community education and disaster preparedness (Santoso, 2022; Yelvi & Sholeh, 2021).

This review also aims to identify lessons from international flood management practices that can be adapted to Indonesia's context. By drawing on global best practices and local experiences, the review provides a framework for sustainable and equitable flood management strategies.

CAUSES OF URBAN FLOODING

1. Rapid Urbanization and Land-Use Changes

Rapid urban growth in Indonesia has led to significant transformations in land use, often replacing natural water retention systems, such as wetlands and forests, with impermeable surfaces like concrete and asphalt. This shift reduces the capacity for water infiltration and increases surface runoff, contributing to frequent urban flooding (Rahman & Kusuma, 2020; Yulianto & Prasetyo, 2017). In Jakarta, extensive land conversion driven by urban development has drastically reduced the availability of natural water retention areas. These changes have intensified flood risks as green open spaces and wetland buffers give way to impervious structures, leading to higher surface runoff and diminished infiltration (Wolok et al., 2024; Syahril et al., 2023; Rohmadiani & Subekti, 2020).

In cities like Bandung and Surabaya, unregulated development has intensified flooding by reducing natural drainage and altering hydrological cycles. A study by Setiawan et al. (2020) highlights the role of improper zoning and construction practices in increasing flood vulnerability. These developments prioritize economic growth over environmental sustainability, resulting in long-term consequences for urban resilience.

2. Inadequate and Aging Drainage Systems

Indonesia's urban areas are often characterized by drainage systems that are outdated, poorly maintained, and insufficient to handle the demands of growing populations and increased rainfall intensity. Many drainage networks, constructed during the mid-20th century, were designed for smaller urban populations and are now overwhelmed during extreme weather events (Dewi & Purnama, 2018). Sedimentation, waste accumulation, and lack of regular maintenance further reduce the capacity of these systems, as observed in cities like Surabaya and Bandung (Suharto & Wijaya, 2018).

For example, studies in Semarang reveal that drainage systems in densely populated areas operate at less than 60% efficiency due to blockages and inadequate capacity (Hanif & Pudyastuti, 2023). Addressing these issues requires not only upgrading infrastructure but also implementing systematic maintenance programs to prevent blockages and optimize performance.

3. Climate Change and Extreme Rainfall Patterns

Indonesia's tropical climate, combined with global climate change, has significantly increased the frequency and intensity of extreme rainfall events. According to Pratama & Rahmawati (2018), annual rainfall in several regions is projected to rise by 20% by 2050, placing additional stress on urban infrastructure. Flash floods and storm surges are becoming more common, particularly during the monsoon season, overwhelming drainage systems and inundating low-lying areas (Ahmad & Wulandari, 2017).

Rising sea levels further compound the risk of urban flooding, particularly in coastal cities such as Semarang and Jakarta. Projections from the National Agency for Disaster Countermeasure (BNPB) indicate that sea levels in these areas could rise by 25 to 50 centimeters by mid-century, significantly increasing the risk of tidal flooding

(Hanif & Pudyastuti, 2023). These climatic changes necessitate proactive measures to enhance urban resilience and mitigate the impacts of future flooding events.

The drivers of urban flooding in Indonesia are often interconnected, creating a compounding effect that amplifies flood risks. For instance, rapid urbanization exacerbates the impacts of climate change by reducing natural water retention areas, while inadequate infrastructure limits the capacity to manage increased runoff (Rahman & Kusuma, 2020). Understanding these interdependencies is crucial for developing integrated flood management strategies that address the root causes of urban flooding.

IMPACTS OF URBAN FLOODING

Urban flooding exerts profound socio-economic and environmental impacts, disrupting urban life and threatening sustainable development. In Indonesia, these impacts are magnified due to the country's rapid urbanization, socio-economic disparities, and inadequate flood management infrastructure (Dewi & Purnama, 2018; Ahmad & Wulandari, 2017). This section explores the socio-economic and environmental consequences of urban flooding, with a particular focus on vulnerable communities.

1. Socio-Economic Consequences

In early 2020, flooding events in Jakarta displaced tens of thousands of residents, highlighting the city's ongoing struggle with extreme weather impacts and inadequate housing in high-risk zones. The concentration of vulnerable populations in low-lying districts, compounded by insufficient drainage infrastructure, exacerbates the severity of disaster impacts (Nugroho et al., 2023; Dewi & Purnama, 2018; Syahril et al., 2023). These displacements disrupt social cohesion, destabilize family structures, and exacerbate economic inequalities.

Flooding also disrupts livelihoods, particularly for small businesses and informal sector workers who lack insurance or savings to recover from losses. Studies in Surabaya and Bandung reveal that repeated flooding events lead to substantial income reductions for families reliant on daily earnings, further entrenching poverty cycles (Yulianto & Prasetyo, 2017).

Flood-induced economic losses are immense, with damage to infrastructure, businesses, and residential properties accounting for billions of dollars annually. The Jakarta floods of 2020 alone caused economic losses exceeding $1 billion, highlighting the vulnerability of urban economies to recurrent flooding events (Setiawan et al., 2020). These losses are compounded by repair and reconstruction costs, which often divert resources from critical development projects.

Flooding also affects national and regional supply chains, disrupting transportation networks and delaying goods delivery. In Semarang, for example, tidal flooding frequently disrupts operations at key ports and industrial zones, reducing productivity and export revenues (Pratama & Rahmawati, 2018).

Urban flooding exacerbates public health challenges, particularly in densely populated areas with inadequate sanitation systems. Stagnant floodwaters serve as breeding grounds for vector-borne diseases such as dengue and malaria, while contaminated water supplies lead to outbreaks of waterborne illnesses like cholera and diarrhea (Taryana et al., 2022). In Surabaya, studies report a significant increase in hospitalizations due to flood-related illnesses during the monsoon season (Suharto & Wijaya, 2018).

2. Environmental Consequences

The environmental impacts of urban flooding in Indonesia are severe, leading to the degradation of critical ecosystems such as wetlands, rivers, and mangroves. Floodwaters often carry pollutants, including industrial waste, agricultural runoff,

and untreated sewage, which contaminate water bodies and disrupt aquatic ecosystems (Santoso, 2022). The loss of biodiversity in these ecosystems further weakens natural flood mitigation systems, creating a vicious cycle of vulnerability.

Urbanization-driven land-use changes have significantly reduced Indonesia's natural water retention capacity. Wetlands and mangroves, which act as buffers during flooding, are increasingly being replaced by urban infrastructure. In Jakarta, over 30% of mangrove areas have been lost to urban expansion, exacerbating tidal flooding and reducing biodiversity (Hanif & Pudyastuti, 2023).

In Semarang, the reclamation of coastal areas for industrial development has similarly diminished natural water absorption capacities, increasing flood risks and environmental degradation (Pratama & Rahmawati, 2018). These losses underscore the need for integrated urban planning that prioritizes ecological sustainability.

Flooding contributes to soil erosion and sedimentation, particularly in areas with steep slopes or deforested landscapes. In Bandung, studies have shown that urban flooding accelerates soil degradation, reducing agricultural productivity in peri-urban areas (Rahman & Kusuma, 2020). Sedimentation from floodwaters also clogs drainage systems, further exacerbating urban flooding risks (Suharto & Wijaya, 2018).

3. Impacts on Vulnerable Communities

Urban flooding disproportionately affects marginalized communities, who often reside in high-risk areas with inadequate infrastructure. These communities face heightened vulnerabilities due to limited access to resources, emergency services, and recovery mechanisms (Yelvi & Sholeh, 2021). Studies in Jakarta and Surabaya highlight that women, children, and the elderly are particularly at risk during flooding events, emphasizing the need for inclusive disaster management strategies (Santoso, 2022).

Community-based flood preparedness programs have shown promise in mitigating these impacts. For example, biopore implementation projects in Depok have improved water absorption in low-income neighborhoods, reducing localized flooding and associated risks (Hanif & Pudyastuti, 2023). However, scaling these initiatives requires greater investment and government support to ensure widespread impact.

MITIGATION STRATEGIES

Effective flood mitigation strategies are critical to reducing the impacts of urban flooding in Indonesia. These strategies encompass structural and non-structural approaches, as well as innovative technologies, that address the multifaceted nature of urban flooding. This section evaluates various mitigation measures implemented in Indonesia and highlights best practices and areas for improvement.

1. Structural Approaches

Indonesia's urban areas are increasingly investing in upgrading drainage systems to cope with rising flood risks. Studies in Bandung and Surabaya emphasize the need for modernized drainage networks designed to handle higher rainfall volumes (Suharto & Wijaya, 2018). Regular maintenance of drainage channels, including the removal of sedimentation and waste, is also crucial to ensuring their effectiveness (Dewi & Purnama, 2018).

Innovative designs, such as porous asphalt and retention basins, have been proposed to improve urban drainage. Research on Topmix Permeable asphalt shows its potential to absorb stormwater and reduce surface runoff, making it a cost-effective solution for flood-prone areas (Setiawan et al., 2020). Incorporating such materials into urban infrastructure could significantly enhance Indonesia's flood resilience.

Large-scale flood control projects, including reservoirs, embankments, and floodgates, play a vital role in managing flood risks. Jakarta's East Flood Canal (Banjir

Kanal Timur) is a prime example of a structural intervention that has successfully diverted floodwaters and reduced the city's vulnerability to inundation (Pratama & Rahmawati, 2018). However, the effectiveness of such projects depends on regular maintenance and integration with other mitigation measures.

In coastal areas, tidal flooding is being addressed through the construction of seawalls and mangrove restoration. For instance, the Green Waterfront City initiative in Semarang combines ecological restoration with infrastructure development to create a sustainable flood management model (Hanif & Pudyastuti, 2023). This approach highlights the importance of balancing environmental conservation with engineering solutions.

2. Non-Structural Approaches

Community-based disaster preparedness programs have proven effective in mitigating the impacts of urban flooding. Educational initiatives, such as training workshops and awareness campaigns, empower communities to take proactive measures during flood events (Santoso, 2022). For example, residents in Depok have been trained to implement biopore techniques, which enhance water absorption and reduce localized flooding (Hanif & Pudyastuti, 2023).

Integrating disaster preparedness into school curricula is another promising approach. Studies in Bandung highlight the success of flood education programs in increasing awareness among students and fostering a culture of resilience (Yelvi & Sholeh, 2021). These initiatives not only prepare individuals for emergencies but also promote long-term behavioral changes that reduce flood risks.

Implementing effective flood mitigation strategies requires a comprehensive regulatory framework that integrates land-use planning with environmental sustainability. One key approach is the enforcement of spatial zoning policies that prohibit or limit development in areas with high flood susceptibility. Such measures

can help preserve natural retention zones and reduce exposure to hazard-prone zones (Wolok et al., 2024; Yulianto & Prasetyo, 2017). Nonetheless, in practice, enforcement is often undermined by weak institutional capacity, overlapping jurisdiction, and the prioritization of short-term economic gains over long-term environmental resilience (Hanif et al., 2023; Rahmadani et al., 2024).

Urban planning frameworks that incorporate green infrastructure, such as rain gardens and urban forests, can mitigate flooding while enhancing the quality of urban environments. In Jakarta, pilot projects integrating green roofs and permeable pavements have demonstrated their potential to reduce runoff and improve urban sustainability (Rahman & Kusuma, 2020).

Women often play a central role in disaster preparedness and response, particularly in community-based settings. Programs in Serang have highlighted the effectiveness of engaging women in flood mitigation activities, such as early warning dissemination and community mobilization (Yelvi & Sholeh, 2021). Empowering women through targeted training and leadership opportunities can strengthen community resilience and improve disaster outcomes.

3. Innovative Techniques

Technological advancements in flood modeling and prediction are transforming flood management in Indonesia. Tools such as the EPA Storm Water Management Model (SWMM) and Support Vector Machine (SVM) algorithms are being used to simulate flood scenarios and identify high-risk areas (Pratama & Rahmawati, 2018). Studies in Bandung demonstrate that these models can achieve high accuracy rates, enabling better planning and resource allocation (Rahman & Kusuma, 2020).

Geographic Information Systems (GIS) and remote sensing technologies have also been instrumental in mapping flood-prone areas and monitoring land-use

changes. Research in Manado, for instance, used NDVI and NDBI indices to assess vegetation and building density, providing critical data for urban flood management (Setiawan et al., 2020).

Early warning systems (EWS) are essential for reducing the impacts of urban flooding. Low-cost technologies, such as LoRaWAN and ZigBee, have been successfully implemented in cities like Surabaya to provide real-time flood alerts (Suharto & Wijaya, 2018). These systems are particularly beneficial for low-income communities, as they are affordable, energy-efficient, and easy to deploy.

Scaling up these technologies requires collaboration between government agencies, private sector actors, and local communities. Investments in training and infrastructure are also necessary to ensure the sustainability of EWS initiatives.

Nature-based solutions, such as mangrove restoration and wetland conservation, offer sustainable alternatives to traditional flood management methods. In Semarang, the restoration of mangrove forests has not only reduced tidal flooding but also provided additional benefits such as carbon sequestration and habitat protection (Hanif & Pudyastuti, 2023). Wetland conservation projects in Jakarta have similarly enhanced natural water retention capacities, reducing the severity of urban flooding (Pratama & Rahmawati, 2018).

These initiatives demonstrate the potential of integrating ecological restoration with urban planning to create resilient cities. However, their success depends on strong policy support and community engagement to ensure long-term maintenance and impact.

4. Challenges and Opportunities

Although advancements have been made in disaster risk management, Indonesia continues to face multiple institutional and technical barriers in implementing urban flood mitigation. Budget constraints remain a major issue,

particularly at the local government level, limiting investments in sustainable infrastructure and early warning systems (Nugroho et al., 2023). Moreover, weak law enforcement, fragmented institutional roles, and resistance from interest groups often hinder the application of land-use and zoning regulations (Maharani et al., 2024; Rahmadani et al., 2024). The absence of inter-agency coordination and the shortage of skilled human resources in hydrological modeling and community-based adaptation further diminish the efficacy of mitigation programs (Dewi & Purnama, 2018; Hanif et al., 2023).

However, these challenges also present opportunities for innovation and collaboration. Strengthening partnerships among government agencies, private sector actors, and local communities can mobilize resources and expertise to address flood risks. Furthermore, leveraging digital tools and technologies can enhance flood prediction and management capabilities, reducing the impacts of future events.

Mitigating urban flooding in Indonesia requires a multifaceted approach that integrates structural, non-structural, and innovative techniques. Structural measures such as drainage system upgrades and flood control infrastructure provide immediate relief, while non-structural approaches like community education and policy reforms address underlying vulnerabilities. Innovative technologies and nature-based solutions offer sustainable pathways to resilience, emphasizing the importance of ecological conservation and technological advancement.

By addressing the challenges and opportunities highlighted in this section, Indonesia can build a more resilient urban environment that minimizes the socio-economic and environmental impacts of flooding. These strategies, when implemented effectively, provide a foundation for sustainable urban development and disaster risk reduction.

COMPARATIVE PERSPECTIVES

Flood management practices across the globe offer valuable insights for Indonesia, which continues to grapple with recurrent urban flooding. By examining international approaches and identifying their applicability to the Indonesian context, this section aims to highlight strategies that could strengthen Indonesia's flood resilience. Additionally, the integration of cross-cultural policies and practices is explored to understand how local conditions can influence the adoption of global best practices.

1. Lessons from International Flood Management

Japan: Holistic and Technological Approaches

Japan is globally recognized for its comprehensive flood management strategies that integrate advanced technology, infrastructure development, and public awareness. The country's extensive network of levees, reservoirs, and underground flood channels, such as the Metropolitan Area Outer Underground Discharge Channel (MAOUDC), has significantly reduced flood risks in urban areas (Hanif & Pudyastuti, 2023). Furthermore, Japan's early warning systems leverage cutting-edge technology to provide real-time updates, enabling timely evacuation and disaster response.

Indonesia could adapt Japan's holistic approach by incorporating advanced flood modeling and monitoring systems, such as the use of geographic information systems (GIS) and remote sensing (Rahman & Kusuma, 2020). However, differences in socio-economic conditions and resource availability necessitate tailored solutions that address Indonesia's unique challenges.

The Netherlands: Living with Water

The Netherlands' "living with water" philosophy promotes sustainable and adaptive ways to coexist with flood risks. Although Indonesia faces challenges like

limited infrastructure and governance issues, this approach can be adapted through nature-based solutions, community involvement, and water-sensitive urban design to build local flood resilience. Key initiatives include the Room for the River program, which restores natural floodplains and reduces pressure on levees (Setiawan et al., 2020). Additionally, the country has invested heavily in flood-resilient urban design, including floating houses and permeable surfaces.

For Indonesia, adopting similar approaches could involve restoring wetlands and mangroves, particularly in coastal cities like Jakarta and Semarang. The Green Waterfront City initiative in Semarang reflects this philosophy, combining ecological restoration with flood management infrastructure (Hanif & Pudyastuti, 2023). However, implementing such strategies requires strong policy support and community participation.

Bangladesh: Community-Based Solutions

Bangladesh, one of the most flood-prone countries in the world, has successfully implemented community-based disaster management programs. These initiatives emphasize local knowledge, capacity building, and grassroots involvement in flood mitigation efforts (Santoso, 2022). Early warning systems and flood shelters are also tailored to meet the needs of vulnerable communities.

Indonesia can learn from Bangladesh's emphasis on community engagement. Programs in Depok and Serang have demonstrated the potential of empowering local communities to implement flood mitigation measures, such as biopore techniques and early warning dissemination (Yelvi & Sholeh, 2021). Scaling up these efforts could enhance Indonesia's flood resilience while addressing socio-economic inequalities.

United States: Integrated Urban Planning

Several countries have demonstrated effective integration between urban planning and flood mitigation strategies. In the United States, for instance, cities

vulnerable to flooding have implemented a combination of green infrastructure, strict zoning policies, and community-based preparedness programs to reduce disaster risks. Such approaches include the preservation of open spaces, utilization of retention basins, and promotion of flood-resilient building codes through intergovernmental collaboration (Nugroho et al., 2023; Maharani et al., 2024).

Indonesia can draw valuable lessons from these practices by embedding flood risk assessments into spatial planning frameworks. In Jakarta, early pilot initiatives such as urban green open space development, rooftop gardens, and revitalization of retention lakes (situ) have shown promise in reducing runoff and improving ecological resilience (Wolok et al., 2024; Hanif et al., 2023; Syahril et al., 2023).

Cross-Cultural Integration of Policies and Practices

While global best practices provide valuable insights, their implementation in Indonesia must consider local socio-economic and environmental conditions. For instance, the high costs associated with advanced infrastructure projects, such as Japan's underground flood channels, may be prohibitive for Indonesian cities (Dewi & Purnama, 2018). Instead, cost-effective alternatives, such as community-based approaches and nature-based solutions, may offer more feasible options.

Similarly, policies promoting wetland restoration and mangrove conservation, inspired by the Netherlands' Room for the River program, must account for land-use conflicts and urban expansion in Indonesia. Collaborative efforts between government agencies, private sectors, and local communities are essential to resolving these conflicts and ensuring the sustainability of such initiatives (Hanif & Pudyastuti, 2023).

Cultural perceptions and institutional dynamics are critical determinants of the effectiveness of flood management strategies. In Indonesia, resistance to land-use regulations and spatial planning often arises from entrenched socio-political interests,

land tenure conflicts, and the prioritization of short-term economic gains (Maharani et al., 2024; Rahmadani et al., 2024). Enhancing public awareness, fostering participatory planning, and promoting inclusive stakeholder engagement are essential to breaking down these barriers. Evidence from flood risk education programs in urban communities has shown that collaborative approaches—especially those incorporating local knowledge and citizen involvement—can significantly improve preparedness and policy acceptance (Hanif et al., 2023; Syahril et al., 2023).

Institutional coordination is another critical challenge. Fragmented responsibilities among government agencies often delay project implementation and reduce the effectiveness of flood mitigation measures. Lessons from the United States, where integrated planning and public-private partnerships have streamlined flood management efforts, highlight the importance of cohesive institutional frameworks (Rahman & Kusuma, 2020).

Technological advancements, such as GIS and remote sensing, offer significant potential for improving flood management in Indonesia. While these tools are widely used in countries like Japan and the United States, their adoption in Indonesia has been limited by financial and technical constraints (Pratama & Rahmawati, 2018). Expanding access to training programs and funding mechanisms could accelerate the adoption of these technologies, enhancing Indonesia's capacity to predict and respond to flood risks.

International collaboration provides opportunities for knowledge exchange, capacity building, and resource mobilization. Partnerships with countries like Japan and the Netherlands could facilitate the transfer of technical expertise and innovative solutions to Indonesia. For instance, joint research initiatives on flood modeling and nature-based solutions could enhance Indonesia's flood resilience while fostering global solidarity (Hanif & Pudyastuti, 2023).

Comparative perspectives on flood management reveal a wealth of strategies that Indonesia can adapt to address its unique challenges. While advanced infrastructure projects and cutting-edge technologies offer promising solutions, their success depends on contextual adaptation, cultural acceptance, and institutional coordination. By learning from international experiences and integrating global best practices with local knowledge, Indonesia can develop a holistic and sustainable approach to urban flood management. These insights underscore the importance of collaboration and innovation in building resilient urban environments for the future.

CHALLENGES AND GAPS

Despite the significant progress made in addressing urban flooding in Indonesia, numerous challenges and gaps remain that hinder effective flood management. These barriers span socio-political, technical, and economic dimensions, requiring a multi-stakeholder approach to overcome them. This section explores the key challenges and gaps identified in the literature and offers insights into potential areas for improvement.

1. Socio-Political Resistance

Socio-political resistance from local stakeholders remains a major barrier to implementing effective flood management policies in Indonesia. Initiatives such as zoning enforcement, spatial planning, and community relocation programs frequently encounter opposition, largely driven by perceived threats to livelihoods, tenure insecurity, and deep-rooted cultural ties to land (Maharani et al., 2024; Hanif et al., 2023). In flood-prone districts of Jakarta, for instance, resistance has emerged from informal settlement groups and local businesses that fear economic displacement, complicating policy execution and infrastructure development (Syahril et al., 2023; Wolok et al., 2024).

In addition, public trust in government-led mitigation programs is often undermined by past experiences of poor coordination, lack of community consultation, and concerns over transparency in budget allocation (Rahmadani et al., 2024). Strengthening participatory governance—through inclusive planning forums, clear communication of risks and benefits, and community-based monitoring—has been shown to increase support for risk-reduction measures and facilitate more equitable policy outcomes (Hanif et al., 2023; Maharani et al., 2024).

2. Limited Adoption of Advanced Technologies

The integration of advanced technologies, such as flood modeling tools and real-time monitoring systems, has been slow in many Indonesian cities. Financial constraints, coupled with a lack of technical expertise, have limited the adoption of these innovations (Pratama & Rahmawati, 2018). For instance, while GIS and remote sensing have proven effective in identifying high-risk areas in Manado, their widespread implementation across other cities remains a challenge (Setiawan et al., 2020).

Moreover, existing early warning systems often lack the infrastructure and connectivity needed to ensure timely dissemination of alerts, particularly in rural and low-income urban areas. Investments in affordable and scalable technologies, such as LoRaWAN-based systems, could address these gaps and improve disaster preparedness (Suharto & Wijaya, 2018).

3. Fragmented Institutional Frameworks

Indonesia's flood management efforts are often hampered by fragmented institutional responsibilities and poor coordination among government agencies. Multiple agencies oversee flood mitigation, including the Ministry of Public Works and Housing, the National Agency for Disaster Countermeasure (BNPB), and local

governments, leading to overlapping mandates and inefficiencies (Dewi & Purnama, 2018).

The lack of a unified flood management framework exacerbates these challenges, delaying project implementation and reducing the overall effectiveness of interventions. Lessons from integrated planning models in countries like the United States highlight the importance of cohesive institutional arrangements in achieving successful flood mitigation (Hanif & Pudyastuti, 2023).

4. Insufficient Funding and Resource Allocation

Urban flood management in Indonesia suffers from inadequate funding and resource allocation, particularly in low-income regions. Budget constraints often result in the prioritization of short-term solutions over long-term resilience-building measures (Santoso, 2022). For example, maintenance programs for drainage systems are frequently underfunded, leading to sedimentation and blockages that exacerbate flood risks (Suharto & Wijaya, 2018).

Limited access to international funding mechanisms, such as climate adaptation grants, further restricts the ability of local governments to invest in sustainable flood management initiatives. Strengthening partnerships with international organizations and leveraging private sector investments could help bridge these funding gaps (Hanif & Pudyastuti, 2023).

5. Knowledge and Awareness Gaps

One of the persistent barriers to effective flood risk reduction in Indonesia is the limited awareness and technical capacity among both local communities and decision-makers. Empirical studies in urban areas such as Depok and Serang show that while residents recognize the risks of flooding, many lack access to accurate information, training, and institutional support to implement adaptive strategies (Syahril et al., 2023; Maharani et al., 2024). Likewise, at the policy level, environmental priorities are

often overshadowed by short-term economic development agendas, resulting in the marginalization of long-term resilience planning (Hanif et al., 2023; Rahmadani et al., 2024).

To close these knowledge and capacity gaps, a more strategic emphasis is needed on educational programs, participatory outreach, and the mainstreaming of disaster risk awareness into public services. Initiatives that integrate flood preparedness into school curricula, urban planning workshops, and policymaker training have demonstrated positive impacts on stakeholder engagement and behavioral change (Maharani et al., 2024; Hanif et al., 2023). Strengthening local knowledge systems and aligning them with technical expertise is essential for building inclusive and adaptive urban resilience.

These challenges underline the importance of comprehensive reforms and interdisciplinary strategies in urban flood governance. Overcoming socio-political resistance, adopting evidence-based technologies, enhancing institutional coordination, ensuring budgetary support, and closing awareness gaps will be critical to strengthening Indonesia's flood resilience. Through integrated and participatory efforts, cities across the country can reduce the socio-economic and ecological consequences of recurrent urban flooding.

RECOMMENDATIONS

To address the persistent challenges and gaps in urban flood management, Indonesia requires a multifaceted approach that integrates policy reforms, technological innovations, community engagement, and ecological restoration. This section provides actionable recommendations based on insights from 30 studies, offering pathways to enhance urban resilience and mitigate flood risks.

1. Fostering Partnerships Among Stakeholders

Collaboration among government agencies, private sector actors, non-governmental organizations (NGOs), and local communities is essential to improving flood management. Indonesia's fragmented institutional frameworks and overlapping responsibilities often hinder effective decision-making (Dewi & Purnama, 2018). Establishing multi-stakeholder platforms can facilitate resource sharing, policy coordination, and the implementation of integrated flood management strategies.

Public-private partnerships (PPPs) offer a promising model for mobilizing resources and expertise. For example, the construction of Jakarta's East Flood Canal involved collaboration between government entities and private contractors, resulting in improved flood protection for the city (Pratama & Rahmawati, 2018). Expanding PPPs to include green infrastructure projects, such as urban forests and permeable pavements, could further enhance Indonesia's flood resilience (Hanif & Pudyastuti, 2023).

2. Scaling Up Digital Tools and Technologies

Technological advancements provide opportunities for improving flood prediction, monitoring, and response. Indonesia should prioritize the adoption and scaling of digital tools such as geographic information systems (GIS), remote sensing, and early warning systems (Rahman & Kusuma, 2020). These technologies enable accurate mapping of flood-prone areas, real-time data collection, and timely dissemination of alerts to at-risk populations.

Low-cost early warning systems (EWS), like those using LoRaWAN and ZigBee technologies, have proven effective in cities such as Surabaya (Suharto & Wijaya, 2018). Scaling these systems nationwide could significantly reduce flood-related casualties and damages. Training programs for local officials and communities

on the use of these technologies are crucial to ensuring their effectiveness and sustainability.

3. Prioritizing Ecological and Sustainable Urban Planning

Integrating ecological considerations into urban planning is essential to addressing the root causes of urban flooding. Restoring natural water retention areas, such as mangroves, wetlands, and floodplains, can enhance resilience while providing co-benefits like biodiversity conservation and carbon sequestration (Santoso, 2022).

In Semarang, the Green Waterfront City initiative demonstrates the potential of combining ecological restoration with flood management infrastructure. Similar projects should be replicated in other coastal cities, particularly Jakarta and Surabaya, where land subsidence and tidal flooding pose significant risks (Hanif & Pudyastuti, 2023). Policies promoting green roofs, rain gardens, and permeable pavements can further reduce surface runoff and mitigate urban heat island effects (Rahman & Kusuma, 2020).

4. Enhancing Community Engagement and Education

Community involvement is critical to the success of flood mitigation strategies. Educational campaigns, training workshops, and participatory planning processes empower communities to take ownership of flood management initiatives. For instance, biopore implementation projects in Depok have demonstrated the benefits of involving residents in improving local water absorption capacities (Hanif & Pudyastuti, 2023).

Flood resilience should also be integrated into school curricula to foster a culture of preparedness among younger generations. Studies in Bandung reveal that students exposed to flood education programs are more likely to adopt proactive behaviors during emergencies (Yelvi & Sholeh, 2021). Expanding such programs to

rural and underserved areas can bridge knowledge gaps and enhance nationwide resilience.

5. Strengthening Policy and Regulatory Frameworks

Effective urban flood management hinges on the formulation and enforcement of robust regulatory frameworks that emphasize long-term resilience and environmental sustainability. Strategic zoning policies play a critical role by limiting development in flood-prone areas while encouraging the implementation of adaptive infrastructure and resilient construction standards (Wolok et al., 2024; Yulianto & Prasetyo, 2017). Despite these policy intentions, enforcement in Indonesia is often constrained by fragmented institutional mandates, political bargaining, and conflicting land-use priorities. The lack of coordination among agencies and insufficient public support further weakens compliance and slows the integration of risk-sensitive urban planning (Hanif et al., 2023; Rahmadani et al., 2024).

National and local governments must strengthen their commitment to integrated water resource management (IWRM), which promotes coordinated development and management of water, land, and related resources. Incorporating climate adaptation measures into urban planning policies is also essential to addressing the long-term impacts of climate change on flood risks (Pratama & Rahmawati, 2018).

6. Leveraging International Collaboration

International partnerships offer opportunities for knowledge exchange, capacity building, and resource mobilization. Collaborations with countries like Japan, the Netherlands, and Bangladesh, which have extensive experience in flood management, can provide valuable insights for Indonesia. For example, Japan's advanced flood modeling tools and Bangladesh's community-based disaster

management programs offer scalable solutions for Indonesia's unique challenges (Hanif & Pudyastuti, 2023; Santoso, 2022).

Participation in international climate adaptation initiatives and access to global funding mechanisms, such as the Green Climate Fund, can support Indonesia's flood management efforts. Joint research initiatives on nature-based solutions and innovative technologies could further enhance Indonesia's capacity to tackle urban flooding (Setiawan et al., 2020).

7. Improving Funding Mechanisms and Resource Allocation

Adequate funding is critical to the successful implementation of flood mitigation strategies. Indonesia should explore diverse funding sources, including international grants, private sector investments, and community-based financing mechanisms. Establishing dedicated disaster management funds at the national and local levels can ensure consistent resource availability for flood mitigation projects (Santoso, 2022).

Innovative financing models, such as green bonds and climate-resilient investments, can attract private sector participation in flood management initiatives. Public awareness campaigns highlighting the economic and social benefits of flood resilience can also encourage community contributions to local mitigation projects (Yelvi & Sholeh, 2021).

The recommendations outlined in this section emphasize the need for an integrated and collaborative approach to urban flood management in Indonesia. By fostering partnerships, leveraging technology, prioritizing ecological planning, engaging communities, strengthening policies, and enhancing funding mechanisms, Indonesia can build a more resilient and sustainable urban environment. These actions, informed by global best practices and tailored to local contexts, provide a

roadmap for mitigating flood risks and ensuring the long-term well-being of urban populations.

CONCLUSIONS

Urban flooding remains a critical challenge for Indonesia, exacerbated by the country's rapid urbanization, climate change, and socio-economic vulnerabilities. This review has synthesized insights from 30 studies to provide a comprehensive understanding of the drivers, impacts, and mitigation strategies related to urban flooding in Indonesia. The findings underscore the urgent need for integrated approaches that combine structural and non-structural measures, technological innovations, and community-driven initiatives to address this pressing issue.

Urban flooding in Indonesia stems from a complex interplay of human and environmental factors. Major drivers include rapid urbanization, uncontrolled land conversion, and underdeveloped drainage networks that are unable to accommodate increasing runoff volumes in expanding metropolitan areas (Rahman & Kusuma, 2020; Syahril et al., 2023). These risks are exacerbated by extreme precipitation patterns and tidal inundation events, both of which are expected to become more severe as climate variability intensifies (Hanif et al., 2023; Rohmadiani & Subekti, 2020).

The impacts of urban flooding are far-reaching, affecting socio-economic stability, public health, and environmental sustainability. Displacement, economic losses, and waterborne diseases disproportionately affect marginalized communities, highlighting the need for inclusive and equitable flood management strategies (Taryana et al., 2022; Santoso, 2022). Environmentally, the degradation of natural water retention systems, such as wetlands and mangroves, reduces urban resilience to future flooding (Hanif & Pudyastuti, 2023).

The review identifies a range of effective mitigation strategies, including structural measures like drainage system upgrades and flood control infrastructure, as well as non-structural approaches such as community education and policy reforms (Suharto & Wijaya, 2018; Yelvi & Sholeh, 2021). Innovative technologies, such as GIS-based flood modeling and low-cost early warning systems, offer promising solutions for improving flood management and preparedness (Rahman & Kusuma, 2020).

To achieve long-term resilience, Indonesia must prioritize ecological restoration and sustainable urban planning. Restoring mangroves and wetlands, implementing green infrastructure, and promoting climate-adaptive policies are essential to reducing the socio-economic and environmental impacts of flooding (Santoso, 2022; Pratama & Rahmawati, 2018). Strengthening institutional frameworks and fostering international collaboration can further enhance Indonesia's capacity to tackle urban flooding effectively (Hanif & Pudyastuti, 2023).

Addressing the challenges of urban flooding in Indonesia requires a holistic and collaborative approach that engages all stakeholders, from policymakers and researchers to local communities. By integrating global best practices with locally tailored solutions, Indonesia can build a more resilient and sustainable urban future. This review serves as a foundation for continued research and policy development, emphasizing the importance of innovation, inclusivity, and ecological stewardship in mitigating urban flood risks.

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