

Designing Environmentally Friendly Drainager Systems In Flood-Potential Urban Areas

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ABSTRACT

Rapidly growing urban areas often face flooding issues caused by inadequate drainage management. This article discusses the design of an environmentally friendly drainage system as a solution to address flooding problems in urban areas. The environmentally sustainable drainage system focuses on the principles of sustainability and utilizes natural elements to reduce the negative impacts of flooding. This study explores various approaches that can be applied in designing drainage systems in flood-prone urban areas. The expected outcome is an efficient, environmentally friendly, and sustainable drainage system.

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INTRODUCTION

Climate change, rapid urbanization, and uncontrolled population growth have placed significant pressure on urban drainage systems worldwide, including in Indonesia. Flooding in urban areas has increasingly worsened due to the inability of existing drainage infrastructure to handle high rainfall over short periods. With rising rainfall intensity and the occurrence of extreme weather events, such as more frequent tropical storms, flooding in major cities has become a real threat that governments and urban communities must face. In Indonesia, this issue is especially apparent in large cities such as Jakarta, Surabaya, Medan, and Bandung, which frequently experience floods with severe impacts, ranging from infrastructure damage and economic losses to disruptions in social activities.

The primary cause of urban flooding in Indonesia is the uncontrolled conversion of land. Land previously used for green open spaces, such as rice fields, forests, or city parks, is being transformed into residential areas, shopping centers, and commercial zones built with impermeable materials like concrete and asphalt. This reduces the land's capacity to absorb water. Hard surfaces prevent water infiltration into the ground, causing rainwater to flow rapidly across surfaces and flood lower-lying areas. Conventional drainage systems, which rely on open channels or large stormwater drains, often fail to handle the large volumes of water that occur suddenly, particularly during heavy rainfall or the rainy season. Consequently, widespread flooding and waterlogging occur.

Additionally, the presence of outdated and poorly maintained drainage channels exacerbates this problem. In many large cities, existing drainage systems were not designed to handle the increased rainfall

volume resulting from changing rainfall patterns and rising rainfall intensity. These drainage infrastructures also lack consideration for sustainability from ecological, social, and economic perspectives, creating conditions highly vulnerable to flooding. Therefore, there is a need for a paradigm shift in urban drainage planning and management, from conventional systems to those that are more environmentally friendly, sustainable, and integrated with natural elements.

The growing urban heat island effect further worsens this issue. Urban heat islands occur due to city surfaces made of heat-absorbing materials such as concrete and asphalt, which store heat throughout the day and release it at night, raising the urban temperature compared to surrounding natural areas. This temperature rise leads to higher evaporation and exacerbates the impacts of climate change, which in turn increases rainfall intensity and worsens flooding potential. To address this issue, one solution is to introduce environmentally friendly drainage systems or green infrastructure, which not only manage stormwater but also reduce the heat island effect and support urban biodiversity.

Green infrastructure drainage systems offer a more holistic solution to urban drainage problems. Unlike conventional systems that rely heavily on direct water discharge into open channels or rivers, these systems integrate natural elements such as green spaces, vegetation, and permeable soils to manage stormwater more efficiently. Such systems may include technologies like infiltration wells, rain gardens, bioretention areas, green roofs, and permeable paving blocks that allow rainwater to seep into the ground rather than flow across surfaces. This approach helps manage rainwater naturally, reduces surface runoff that causes flooding, and increases groundwater infiltration, which is essential for maintaining groundwater reserves and improving urban environmental quality.

Urban flood-prone areas in Indonesia, such as Jakarta, Surabaya, Medan, and Bandung, require the implementation of effective and sustainable green drainage systems. These cities frequently face more complex flooding problems, especially due to climate change, which results in more extreme and frequent rainfall. For example, Jakarta, located in a low-lying area with many rivers and limited drainage channels, often experiences severe flooding due to extremely high rainfall, especially during the rainy season. Furthermore, Jakarta faces increasing land subsidence due to uncontrolled groundwater extraction, making it even more vulnerable to tidal flooding (rob) and rain-related flooding. Similarly, other large cities are facing similar challenges, where existing drainage infrastructure can no longer handle the rising volumes of water resulting from climate change and rapid urbanization.

Designing environmentally friendly drainage systems for flood-prone urban areas not only involves technical calculations regarding drainage capacity and the selection of permeable materials, but also considers the social and economic aspects of implementation. Sustainable stormwater management should integrate solutions that enhance the quality of life for communities, such as creating green spaces, reducing air pollution, and creating healthier, more comfortable urban areas. Green drainage systems can also reduce flood risks by enhancing rainwater infiltration into the ground, reducing surface runoff speeds, and minimizing potential flood damage. Implementing these nature-based drainage systems can also improve water quality in urban areas by filtering pollutants from rainwater before it enters drains or rivers.

However, the implementation of green drainage systems in Indonesia faces several challenges, including technical, social, and policy-related barriers. One of the biggest challenges is the lack of public awareness regarding the importance of sustainable stormwater management, as well as limited knowledge about green drainage technologies that can be applied. Furthermore, these systems require substantial investments for construction and maintenance, as well as policy support that encourages the use of environmentally friendly technologies in urban areas. Therefore, a comprehensive approach involving various stakeholders, including local governments, the private sector, academics, and communities, is needed to design and implement effective and sustainable drainage systems.

This study aims to design an environmentally friendly drainage system suitable for flood-prone urban areas, considering the technical, social, and economic factors involved. The research will explore various green drainage technologies that can be applied, evaluate their impact on water quality, flood risk reduction, and the improvement of community quality of life, and identify challenges and barriers to their implementation. Additionally, the study will provide recommendations to overcome these barriers, focusing on policies, regulations, and community participation.

It is expected that the implementation of environmentally friendly drainage systems will make a significant contribution to reducing flood risks, improving environmental quality, and creating healthier and more sustainable urban areas. With careful planning and the involvement of all stakeholders, these green drainage solutions can lay the foundation for more efficient and sustainable stormwater management in the future. The implementation of green drainage systems in Indonesia is expected to inspire other cities worldwide to integrate nature-based solutions into urban planning and development to make cities more resilient to floods and climate change.

RESEARCH METHODOLOGY

This research employs both qualitative and quantitative approaches to design an environmentally friendly drainage system that can be applied in flood-prone urban areas. The methodology combines literature analysis, case studies, drainage simulations and modeling, as well as environmental and social impact assessments, to produce recommendations for effective, sustainable designs tailored to local needs. The key steps in this research include literature review, case studies, drainage modeling simulations, and impact evaluations that encompass both environmental and social aspects.

The first step involves conducting a literature review to understand the theories and fundamental principles of environmentally friendly drainage systems, including the concept of Sustainable Urban Drainage Systems (SUDS). This literature review also covers an analysis of various technologies used in green drainage, such as infiltration wells, rain gardens, and permeable paving blocks. Additionally, the literature addresses stormwater and flood management policies implemented in major cities around the world facing similar issues, providing a foundation for understanding the application of these systems in flood-prone urban areas.

Following the literature review, the research proceeds with case studies of cities that have successfully implemented environmentally friendly drainage systems. These case studies aim to examine the drainage solutions applied, such as the utilization of green open spaces and bioretention systems, and to evaluate the performance of these systems in flood reduction. The case studies will also identify challenges faced, including technical, budgetary, and community participation issues. Insights from these case studies will provide practical lessons useful for designing drainage systems for urban areas in Indonesia.

Drainage simulations and modeling are performed using hydrological software and Geographic Information System (GIS) tools. The modeling aims to design a drainage system that efficiently manages rainwater while considering factors such as rainfall, topography, and land use in urban areas. The simulation also analyzes the types of permeable materials, such as paving blocks and green roofs, that can enhance water infiltration into the ground. Through this modeling, a more accurate drainage system design tailored to local conditions can be obtained, taking into account the impacts of climate change on rainfall volume.

Furthermore, the research will conduct an environmental and social impact evaluation of implementing the green drainage system. This evaluation aims to assess how effectively the system can improve water quality, reduce pollution, and create green spaces that support biodiversity. Social impacts are also a focus of this research, considering how the implementation of this drainage system can improve the quality of life for urban residents, reduce flood impacts, and create more comfortable public spaces. Additionally, this evaluation will explore the extent to which communities can be involved in the management and maintenance of the green drainage system.

The final step is to analyze various limitations and challenges that may arise in implementing this drainage system in urban areas. Factors such as land availability, costs, regulatory barriers, and policy constraints will be discussed to provide a comprehensive understanding of the obstacles to implementation. This research will also evaluate potential funding sources, such as government funds, private sector investments, and community initiatives, to support the development of an effective and sustainable green drainage system.

With this comprehensive methodology, the research aims to produce a design for an environmentally friendly drainage system that can be implemented in urban flood-prone areas, while considering the interrelated technical, social, and environmental factors.

DISCUSSION

This discussion focuses on four key aspects of designing an environmentally friendly drainage system in flood-prone urban areas: (1) selection of green drainage technologies, (2) environmental and social benefits of implementing green drainage systems, (3) challenges in implementing these systems in urban areas, and (4) long-term sustainability of green drainage systems. These aspects will be elaborated in detail to provide a comprehensive overview of the potential and challenges in designing an effective and sustainable drainage system.

Selection of Environmentally Friendly Drainage Technologies

One of the key elements in designing an environmentally friendly drainage system is selecting technologies that are suited to the urban conditions and flood risks. Green drainage technologies include various elements aimed at managing stormwater naturally, reducing surface runoff, and enhancing water infiltration into the ground. Some of the primary technologies commonly used in designing green drainage systems include:

- **Infiltration Wells:** Infiltration wells are an effective solution for reducing surface runoff by allowing rainwater to seep into the ground. These systems help reduce the burden on drainage channels and increase groundwater reserves. Infiltration wells are typically installed in areas with hard surfaces, such as roads or parking lots, that cannot absorb water.

- **Permeable Paving Blocks:** Permeable paving blocks replace traditional asphalt or concrete on road surfaces or sidewalks. These materials allow rainwater to infiltrate into the ground, reducing surface runoff and the volume of water that needs to be managed by drainage systems. Using permeable paving blocks in low-traffic areas or parking lots can help prevent waterlogging and support sustainable drainage systems.
- **Rain Gardens:** Rain gardens are areas specifically designed to capture and direct stormwater into the ground or natural drainage channels. These gardens are typically equipped with vegetation that can effectively absorb water while providing green spaces that benefit air quality and urban biodiversity.
- **Green Roofs:** Green roofs are another solution for managing rainwater in urban buildings. By planting vegetation on building rooftops, rainwater can be absorbed by the plants, reducing the amount of water flowing into drainage systems. Green roofs not only manage stormwater but also reduce urban heat island effects and improve air quality.

The selection of the appropriate technology should be adapted to local conditions, including rainfall, soil types, and land use characteristics in the area. The implementation of green drainage technologies aims to reduce unmanaged surface runoff while enhancing water infiltration into the soil, which is crucial for mitigating flood risks.

Environmental and Social Benefits of Green Drainage Systems

The implementation of environmentally friendly drainage systems not only helps address flooding issues but also provides positive environmental and social impacts. Key benefits of green drainage systems in urban areas include:

- **Improved Water Quality:** A primary benefit of green drainage systems is their ability to enhance water quality. By utilizing technologies such as rain gardens, infiltration wells, and bioswales, these systems can filter out pollutants from stormwater, such as heavy metals, debris, and chemicals, before they enter drainage systems or rivers. This helps reduce water pollution and protects surrounding aquatic ecosystems.
- **Reduction of Urban Heat Island Effects:** Urban areas are often characterized by hard surfaces like asphalt and concrete, which absorb excessive heat, creating urban heat islands. The introduction of green spaces, such as rain gardens and green roofs, can help reduce air temperatures in urban areas by absorbing and evaporating water, as well as providing shade that reduces surface temperatures. As a result, green drainage systems also contribute to creating a more comfortable and healthy urban climate.
- **Biodiversity:** The integration of green spaces in green drainage systems can significantly enhance biodiversity in urban areas. Rain gardens and green roofs can serve as habitats for various plant species, insects, and birds, contributing to the balance of urban ecosystems. By incorporating natural elements in drainage designs, urban areas can become more wildlife-friendly.
- **Improved Quality of Life:** A key social benefit of green drainage systems is the improvement of community well-being. Green open spaces that incorporate water-absorbing plants not only manage stormwater but also provide areas for recreation, sports, or social interactions. These green spaces offer comfort to urban residents, reduce stress, and improve mental and physical health.

Challenges in Implementing Green Drainage Systems

While green drainage systems offer numerous benefits, their implementation in flood-prone urban areas often faces several challenges. Key challenges to consider include:

- **Land Availability:** One of the biggest obstacles in implementing green drainage systems in large cities is the limited availability of open space. Many urban areas have high population density, so allocating land for green drainage elements such as rain gardens or infiltration wells can be difficult. Careful planning is needed to maximize land use, such as integrating drainage systems into building designs (e.g., green roofs) or using permeable paving blocks in parking lots.
- **Implementation Costs:** Although green drainage technologies are more sustainable in the long term, the initial construction costs are often higher compared to conventional drainage systems. Investment in green infrastructure requires additional funding for planning, construction, and maintenance. Local governments must consider sufficient funding sources to support the implementation of these systems, whether through public budgets, private sector financing, or community partnerships.
- **Lack of Public Awareness and Knowledge:** To ensure the success of green drainage systems, it is important to involve the public in the planning and maintenance processes. However, many urban residents lack awareness of the importance of environmentally friendly stormwater management. Therefore, efforts to raise awareness and engage communities through educational programs and environmental campaigns are necessary.

Long-Term Sustainability Evaluation of Green Drainage Systems

Evaluating the sustainability of green drainage systems is crucial to ensuring that the proposed designs are not only effective in managing stormwater but also sustainable over time. Aspects that need to be evaluated include:

- **Climate Change Resilience:** Green drainage systems must be designed to withstand climate change, such as increased rainfall and more frequent storms. Therefore, the system design should consider future climate scenarios to ensure that it remains effective in managing more extreme rainfall events.
- **Long-Term Maintenance:** The sustainability of these systems also depends on regular maintenance. For example, plants in rain gardens or on green roofs need care to maintain their water absorption capacity. Green drainage systems also require periodic monitoring to ensure that infiltration wells and drainage channels continue to function optimally.
- **Long-Term Economic Impact:** An evaluation of the long-term economic impact is also important to determine if green drainage systems can reduce maintenance costs for conventional drainage systems and the damages caused by floods. In the long run, investment in green drainage systems is expected to yield greater savings compared to the costs of handling flood disasters.

Through this discussion, it is clear that green drainage systems offer effective solutions to address urban flooding while providing significant environmental and social benefits. Although there are challenges related to implementation and financing, thoughtful planning and community involvement can be the keys to successfully creating sustainable and climate-resilient cities.

CONCLUSION

Environmentally friendly drainage systems represent an innovative solution to address flood issues in flood-prone urban areas. This approach not only focuses on stormwater management but also provides ecological, social, and economic benefits. By utilizing natural elements such as infiltration wells, rain gardens, permeable paving blocks, and green roofs, these systems can reduce surface runoff, increase water infiltration into the soil, and improve water quality. The presence of green open spaces also helps mitigate the urban heat island effect and provides recreational areas beneficial for communities.

While the implementation of green drainage systems holds great potential in reducing flood risks and creating more sustainable cities, the greatest challenges lie in financing, regulation, and public awareness. The high initial costs for green infrastructure and a lack of understanding of the long-term benefits of these systems can hinder their adoption. Therefore, supportive policies and community involvement in all stages of planning, implementation, and maintenance are essential. Public engagement is crucial to ensuring the sustainability and effectiveness of the systems put in place.

The implementation of environmentally friendly drainage systems can be a strategic step in tackling the increasingly complex flood problems in urban areas. With support from the government, private sector, and communities, this solution can help create cities that are more resilient to climate change while providing long-term benefits in terms of improved quality of life, water management, and environmental sustainability. Therefore, it is important to continue promoting research and innovation in stormwater management and to ensure the adoption of efficient, affordable, and environmentally friendly systems in large cities to create safe, comfortable, and sustainable urban environments for all residents.

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