論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Enhancing Urban Stormwater Management under Climate Change through Integrated Modeling and Multi-Objective Optimization of Green Infrastructure
著者(和文)	LIUKexin
Author(English)	Kexin Liu
出典(和文)	学位:博士(学術), 学位授与機関:東京科学大学, 報告番号:甲第28号, 授与年月日:2024年12月31日, 学位の種別:課程博士, 審査員:木内 豪,髙木 泰士,中村 恭志,中村 隆志,VARQUEZ ALVIN CHRIST
Citation(English)	Degree:Doctor (Academic), Conferring organization: Institute of Science Tokyo, Report number:甲第28号, Conferred date:2024/12/31, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	融合理工学 地球環境共創	系 コース	
申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Philosophy)	
学生氏名： Student's Name	Liu Kexin		
審査員主査： Chief Examiner	Tsuyoshi Kinouchi		

要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

Climate change poses significant challenges to urban stormwater management, with frequent floods affecting society, the economy, and public health. Traditional grey infrastructure often proves inadequate due to limited capacity and high costs. This dissertation proposes a comprehensive framework to enhance urban stormwater management by implementing green infrastructure (GI). Integrating hydrological modeling, sensitivity analysis, and multi-objective optimization, the study develops climate-resilient solutions for urban flood risk reduction and water quality improvement. Phnom Penh, Cambodia, serves as a case study, addressing challenges in GI planning, parameterization, and cost-effectiveness.

The research begins by investigating the impacts of climate change on urban hydrology, particularly flood volumes and pollutant transport (Chapter2). These challenges are especially pronounced in vulnerable regions like Phnom Penh, where data scarcity complicates hydrological assessments and planning. To address these issues, the study introduces a novel framework that integrates diverse data sources and modeling approaches to overcome data limitations. This framework enables detailed analysis of urban drainage dynamics under historical and future climate scenarios, providing actionable insights into how extreme events affect flood risks and water quality. The findings emphasize the importance of understanding urban hydrological responses to climate change to design effective mitigation strategies. By offering a robust methodology for identifying critical flood risks, this work contributes to advancing stormwater management practices in developing cities with limited resources and high vulnerability to extreme weather events.

Building on this foundation (Chapter2), the study evaluates the performance of various GI systems under changing climate conditions, focusing on their hydrological effectiveness and cost-efficiency (Chapter 3). Key systems analyzed include Bioretention Cells (BRC), Permeable Pavements (PP), and Green Roofs (GR). Extensive parameterization and sensitivity analysis reveal critical factors that influence GI performance, such as infiltration rates, soil moisture, and structural design. To address uncertainties in performance, the research quantifies the impacts of these parameters on runoff reduction and pollutant removal efficiency. Furthermore, the study includes a detailed cost-effectiveness analysis, identifying optimal combinations of GI systems tailored to different budgetary scenarios. This evaluation demonstrates that GI systems not only provide significant environmental benefits but also offer economic advantages when strategically deployed. By addressing uncertainties and identifying practical, cost-effective configurations, this research provides urban planners with actionable recommendations for maximizing the performance of GI systems while balancing hydrological benefits and financial constraints.

To ensure that GI systems are deployed strategically and effectively, the dissertation introduces a multi-objective optimization framework for GI spatial allocation (Chapter4). This framework integrates flood risk spatial heterogeneity, climate projections, and land use considerations, enabling the design of targeted GI deployment strategies that account for diverse urban challenges. Using the NSGA-II algorithm, the study identifies Pareto-optimal solutions that balance multiple objectives, including flood risk reduction, water quality improvement, and cost-effectiveness. The optimization framework also incorporates a Multi-Criteria Decision Analysis (MCDA) to address the limitations of data-scarce

environments, helping prioritize high-risk areas for GI implementation. By combining these advanced methodologies, the research offers urban planners a flexible and scalable tool for allocating GI systems in ways that maximize their impact on flood resilience and sustainability. This innovative approach represents a significant advancement in urban stormwater management, ensuring that mitigation strategies are tailored to local environmental and socio-economic contexts.

Throughout the dissertation, the integration of these methodologies highlights the multifaceted contributions of the research to the field of urban stormwater management. First, the framework for assessing climate impacts on urban hydrology offers a robust tool for identifying flood risks and pollutant transport dynamics in data-scarce regions, contributing to improved strategic planning for climate-vulnerable cities. Second, the evaluation of GI systems provides a comprehensive understanding of the factors influencing their performance, as well as practical insights into their cost-effectiveness under future climate conditions. Third, the optimization framework advances the strategic deployment of GI systems by balancing hydrological, environmental, and economic objectives, ensuring that cities can enhance their flood resilience while optimizing resource use. Finally, the innovative use of MCDA addresses decision-making challenges in resource-constrained settings, offering a practical solution for prioritizing flood mitigation efforts and improving resource allocation.

In conclusion, this dissertation presents a comprehensive and integrative framework for urban stormwater management that combines climate projections, hydrological modeling, sensitivity analysis, and optimization techniques. By focusing on the strategic implementation of GI systems, the research provides sustainable solutions for addressing the long-term impacts of climate change on urban flood risks and water quality. The findings offer valuable guidance for urban planners and policymakers, particularly in rapidly urbanizing and data-limited regions, highlighting the potential of GI systems as cost-effective, adaptable, and sustainable components of climate-resilient urban planning. This work serves as a critical resource for cities navigating the growing challenges of climate change, advancing the development of more resilient and sustainable urban water management practices.