ASSESSING THE EFFECTIVENESS OF STORMWATER GREEN INFRASTRUCTURES IN THE FACE OF HISTORICAL AND FUTURE CLIMATE CHANGE SCENARIOS ACROSS THE STATE OF FLORIDA

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ABSTRACT

Climate change significantly impacts urban stormwater management, presenting complex challenges that necessitate adaptive and sustainable solutions. This dissertation evaluates the effectiveness of stormwater green infrastructures (GI) in mitigating the adverse impacts of urban runoff and nutrient loads across Florida under both historical and future climate scenarios. Through comprehensive analysis and the development of innovative tools, this research aims to provide valuable insights for urban planners, policymakers, and researchers, enhancing the planning, implementation, and performance of GI practices.

The study begins by addressing the critical challenges posed by urbanization and climate change on stormwater systems. Urbanization increases impervious surfaces, leading to higher runoff volumes, while climate change intensifies the frequency and severity of precipitation events. These changes overwhelm existing stormwater infrastructure, resulting in increased flooding, pollutant loads, and environmental degradation. The benefits of GI, such as reducing runoff volumes, improving water quality, and enhancing urban resilience, are well-documented. However, there are significant gaps in current planning practices, particularly regarding spatial allocation, life cycle cost analysis, and the availability of scalable, open-source tools.

To address these gaps, this research develops a large-scale geospatial analysis tool to identify optimal sites for GI implementation, incorporating environmental justice considerations. The tool assists urban planners in making informed decisions about GI placement, ensuring that benefits are distributed equitably across different urban areas. The tool uses various environmental and socio-economic criteria to identify suitable locations for GI, considering factors such as land use, soil type, topography, and social vulnerability indices.

Next, the research introduces the IPLANTGREENS^2 tool, which integrates multi-objective optimization and life cycle cost analysis to evaluate the economic efficiency and environmental performance of various GI practices. This tool provides a robust framework for long-term stormwater management, enabling the comparison of different GI strategies based on their costs and benefits over their entire lifecycle. The life cycle cost analysis encompasses initial construction costs, long-term operational and maintenance expenses, and end-of-life considerations, providing a comprehensive assessment of GI's financial viability. This approach ensures that selected GI strategies offer the best economic value and environmental effectiveness over their lifespan.

In addition to optimizing GI planning, the dissertation enhances climate projections for South Florida using a hybrid statistical bias correction technique. This method improves the accuracy of temperature and precipitation extremes, providing more reliable data for future climate scenarios. The refined projections are applied to a case study of the Sweetwater Creek Watershed, evaluating the effectiveness of GI in reducing runoff and nutrient loads under various future scenarios. The case study demonstrates the potential of GI to mitigate climate-induced impacts, highlighting the importance of adaptive management strategies.

The results show that GI can significantly reduce runoff volumes and nutrient loads, even under high-emission scenarios like SSP585. However, the performance of GI varies depending on site-specific conditions and the intensity of future climate impacts. The study underscores the necessity for flexible and adaptive GI designs that can maintain their effectiveness under changing climate conditions. It also highlights the need for advanced modeling techniques and high-resolution spatial data to capture the complexity of urban landscapes more accurately.

The findings from this research have significant implications for urban planners, policymakers, and researchers. Implementing GI as part of a broader integrated water management strategy can provide multifaceted benefits, including improved water quality, enhanced urban resilience, and reduced flood risks. Policymakers should consider incentivizing the adoption of GI through regulatory frameworks and funding mechanisms, ensuring that urban areas are better equipped to handle the impacts of climate change.

This dissertation concludes with several key recommendations for future studies. First, there is a need for more sophisticated downscaling techniques, such as dynamical downscaling using regional climate models (RCMs), to provide a more detailed representation of local climate conditions. Second, integrating finer-scale hydrological models with high-resolution spatial data can improve the accuracy of GI performance assessments. Finally, future research should explore the development of flexible and adaptive GI designs that can respond to evolving climate threats, ensuring the sustainability and resilience of urban watersheds.

Keywords: Climate change, sustainability, stormwater management, green infrastructure, urban resilience, life cycle cost analysis, environmental justice, geospatial analysis.