Analyzing the Implication of Blue Green Solution in the Toronto Area

Yilei Ao

Department of Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, Ontario, Canada

17ya13@queensu.ca

Abstract. Increased precipitation intensity and frequency associated with climate change were observed in a lot of studies. In the case of poor stormwater management, it is more likely for flooding to happen with extreme weather. As a city facing challenges related to flooding, the city of Toronto needs to have an efficient stormwater management system. This study, therefore, explores the Blue Green Solution (BGS) and its feasibility in Toronto. Suggestions were proposed according to common barriers identified for green infrastructure development at different stakeholder levels. This study suggests BGS would have better effects on stormwater management compared to Low Impact Development. Governments are advertised to take a leadership role in raising funds, providing political guidance and promoting stakeholders to be involved in BGS development. Modelling and monitoring as a highlight of BGS, should be performed when designing a project. Involvement of all stakeholders seems to be one of the solutions to ensure interactive and integrative BGS design which allows better performance of urban stormwater management.

Keywords: Blue Green Solution, Stormwater Management, Flooding.

1. Introduction

With the impact of climate change, global precipitation patterns change in terms of amount, intensity, seasonality and spatiality. According to the Clausius-Clapeyron equation and analysis by Dai (2006), the surface-specific humidity increases by around 5% with a 1˚C rise in temperature. Increased moisture in the air will lead to more intense precipitation and flooding risk. An increase of 30% in extreme precipitation was found in the coastal area in the fall and 15% during the winter (Erler & Peltier, 2016). Gaur et al. (2019) revealed that more than 40% of selected populous cities in Canada are expected to increase flood risk and frequency in the future due to the impact of climate change and urbanization. Thus, research in efficient stormwater management is significant to prevent flooding.

Various Natural-Based Solutions developed among different countries, such as Low Impact Development (LID), Water-Sensitive Urban Design, and Blue Green Dream System project (BGS). These strategies aimed to mitigate challenges that arise with climate change and urbanization, including reducing water pollution, water flooding and shortage of resources. BGS is designed in a similar concept, to help build up resiliency in the city and to minimize the impacts of climate change (Bozovic et al., 2017). Additional benefits among multiple systems could be found using BGS, including mitigating air pollution, preventing flooding hazards and reducing ecological footprint. For example, tree planting in an urban center could mitigate outdoor air quality and flood risk, change the microclimate, reduce energy consumption in the building, and improve the comfort citizens perceive.

As one of the largest urban centers in North America, the city of Toronto is experiencing issues including flood risk at Lake Ontario Waterfront, deteriorated water quality in the Toronto Harbour, beach closure, and degradation in aquatic wildlife populations and habitat (Toronto and Region Conservation Authority). The Toronto Region were identified as one of the Areas of Concern (AOCs) in 1985 by the International Joint Commission due to industrialization and urban sprawl. Criteria and Remedial Action Plans (RAP) were then developed and implicated based on Beneficial Use Impairments (BUIs) (Toronto and Region Conservation Authority, 2015). The RAP progress report in 2015 indicated that the restoration of aquatic wildlife populations and habitats and the improvement of water quality need further investment.

With successful BGS projects such as the Gardens by the Bay in Singapore, the Blue Green Wave in Paris, and the Multifunctional Green Roof constructed at Imperial College London, it was proposed that the BGS would inspire the design of RAP in the Toronto and Region with better stormwater management and wildlife habitat protection. Therefore, this study focused on assessing the current progress of BGI implementations and investigating the feasibility of BGS in Toronto to ensure better stormwater management and mitigate the impact of urbanization and climate change. This objective is achieved by first, analyzing the current BGIs in Toronto. Meanwhile, this paper will explore the potential implications of BGS in Toronto. Finally, this paper will propose some suggestions to improve the water management system in Toronto.

2. Blue Green Solutions

The Blue Green System is a systematic approach based on the Blue Green Dream project and is sometimes referred to as Blue Green Solutions. BGS aims to ensure the resilience of urban with urbanization and climate change. The BGS was generated based on Nature-Based Solutions, where societal issues regarding the environment were remediated by using the ecosystem design (Cohen-Shacham, et al., 2016). However, BGS stands out as it integrates a wide range of stakeholders in the planning stage while using modelling and quantification to maximize the possibility of a systematic design with higher cost-effectiveness (Bozovic et al., 2017). Some examples of BGS measures include multi-functional green walls, multi-functional roof gardens, and tree pits.

Blue Green Infrastructures (BGIs) is still an umbrella term that needs a clearer definition. BGIs are used in the BGS and other nature-based systems, highlighting the connectivity of various elements without large-scale construction such as a drainage system (Ghofrani et al., 2017). BGIs could be developed in a natural setting or engineered, in which blue refers to the water bodies while green refers to elements such as vegetation, and green roofs (Probst et al., 2022). BGIs focus on creating multifunctional systems with different scales, including urban areas and semi-urban regions (Ghofrani et al., 2017). Examples of BGIs include green/blue roofs, permeable pavement, and bio-retention swales. Compared with BGS, BGIs emphasize the construction design while BGS focus more on benefiting an integrated multifunctional ecosystem. Besides, BGSs stress the ecological benefits for an urban system while the design of BGIs targets different levels.

BGIs have been generally proven to be effective in terms of reducing the amount of overall runoff and peak flow as well as delaying the peak flow. A large-scale analysis of nine cities around the world with various climate conditions, from Continental to Oceanic, concluded a 5% - 15% decrease in total runoff (Cristiano et al., 2021). This large-scale study showed the effectiveness of BGIs across different regions and climate conditions. Rain tanks with water reuse design were installed at the University of Leuven in Belgium, with modelling results showing an annual runoff reduction of 14% - 18% (Wu et al., 2024). The same study demonstrated a 58% decrease in overall runoff and a 50% peak flow reduction with the replacement of permeable pavement. Further, Wu et al. also showed that combined BGIs of green roofs, rain tanks and permeable pavement will maximize the management effectiveness. Overall, BGIs are believed to be an effective sustainable measure to mitigate flooding due to insufficient stormwater management without large-scale hard surface construction.

3. Bgs imlication analysis in toronto

3.1. Current BGS Implemented in Toronto

Stream channel constructions and land use changes in Toronto sometimes lead to sewage and runoff increases in rivers and the Ontario Lake (Toronto and Region Conservation Authority). The existing combined sewage system of rainfall and sewage remains an issue in the Great Toronto Region (GTA) as rainfall overflow will flush pollutants and bacteria (e.g. E. coli) into rivers such as the Don River, Humber River and the Toronto Harbour Front, which impairs the water quality (Toronto and Region Conservation Authority, 2015). Despite the fact stated, stormwater management in Toronto and Region RAP in 2015 was not emphasized, possibly due to the remediation missions. Only a short section of the RAP report mentioned some LID technologies implemented including permeable pavements, retention trenches and green roofs.

The city of Toronto listed various types of green infrastructure as a resource guide, including stormwater tree trenches, bioretention, bioswales, permeable pavement, infiltration trenches, rain gardens, etc. (City of Toronto). The city of Toronto has the predominant advantage of adopting the Green Roof Bylaw, stating that the green roof has to be utilized when having a new development or additions (City of Toronto). This regulation ensured contribution to urban stormwater management as a BGS and provided legal protection for constructing BGIs at the same time. However, the implementation scale was not clear and the law does not apply to other BGIs in general.

3.2. Difficulties in Advancing BGS in Toronto

Johns (2019) carried out interviews with 15 participants from public, private and non-profit sectors to understand the current barriers to constructing green infrastructures in the city of Toronto. Among all the factors summarized by Johns, the most commonly mentioned was the urban form, meaning the current land use in Toronto does not support green infrastructure development. Land for buildings and water use were critical issues as land resources are competitive in large urban centers. In addition, according to the participants, the general topography of clay makes the soil layer to be impervious.

Other barriers also include political, funding, institutional, and engagement issues while some actors mentioned limited knowledge of the technical construction. Interviewees in the study commented on a lack of leadership performed at the provincial level. Meanwhile, the policy did not indicate support for green infrastructure design to better manage stormwater in the city of Toronto. Some participants also indicated that private owners owned a large percentage of land in Toronto and, therefore, it was more difficult to encourage them to invest in implementing green infrastructures. Additionally, the investment in green infrastructures remains controversial despite its stormwater management effectiveness.

4. BGS Implementations in Toronto

4.1. Uniqueness of BGS

Tillekeratne (2024) suggested the implementation of LIP to assist water management in the City of Toronto. However, this paper proposes that adopting BGS could generate further benefits and be more cost-effective due to its interactivity and integrality.

First of all, BGS focus on multi-level participation, meaning that it interacts with more stakeholders and more actors will be involved during development. The BGS guide compared the standard project design and design with BGS, indicating that users, asset managers, and approval bodies will be involved in the process while they were not included in a conventional design (Bozovic et al., 2017). In this way, the BGS design could be further customized, and the deigning goal would be better understood, so unnecessary money can be saved.

Furthermore, modelling and monitoring are two keys to BGS highlighted by the guide (Bozovic et al., 2017). Modelling is used as a flooding control method in the Greater Toronto Area in terms of projecting precipitation and determining the flooding-vulnerable regions, so proper risk management measures can be taken (Tillekeratne, 2024; Toronto and Region Conservation Authority, 2024). This modelling result can be used as an indication of some main regions which need BGIs installation and BGS implementation. In this way, upgrading stormwater management projects can be prioritized and be more efficient in controlling flood risks. Modelling and monitoring used in the BGS project could accurately reflect the impacts of BGIs on the site and provide opportunities for adjusting the system design to maximize BGIs' effects.

In addition, the BGS design focuses on a more integrative ecosystem. To compare, both LIP and BGS benefit multiple systems and would achieve the goal of stormwater management (Bozovic et al., 2017; Ministry of the Environment, Conservation and Parks, 2022). However, taking developing tree pits on the street as an example, the design of BGS further considered providing more comfort and cooling areas to citizens, mitigating the heat island effect by evapotranspiration, and reducing energy use in the building nearby. With a multi-functional system mindset of BGS design, the project would be more effective and influential.

4.2. Moving Forward with BGS

Besides the mandatory green roof installation for new construction projects by law, more effort such as emphasizing BGIs and BGS is required to prevent further flooding in the City of Toronto. Upgrading BGIs and introducing the BGS would not only improve stormwater management in the City of Toronto but also improve water quality in reaching the Toronto Harbour, which would assist in completing the Toronto and Region RAP. A study developed bioretention cells and permeable pavement in a parking lot in Montreal, Canada highlighted that above 80% of suspended solids, chemical oxygen demand, total phosphorus and total nitrogen were removed from the original sewer (Guay et al., 2024).

In the study by Johns (2019), interviewees mentioned the limited land use opportunities to develop green infrastructures in the City of Toronto was one of the most challenging barriers. However, extra land will not be required for a majority of BGIs and BGS measures, such as rooftop gardens and permeable pavement. Rooftop gardens could be designed based on the existing building rooftops. Similarly, permeable pavement could be built when designing a parking lot, instead of traditional impermeable concrete or asphalt pavement.

Different actors could take various actions to provide additional support for developing BGIs and BGS. In terms of political barriers mentioned in Johns's research, the Ministry of the Environment, Conservation, and Parks should promote regulations regarding BGIs installations and BGS designing. Besides, the City of Toronto and regional authorities such as the Toronto and Region Conservation Authority should encourage landlords, land developers, and architects to follow the regulations and guidance provided by provincial governments.

The federal government plays an important role in financial support while funding is one of the challenging barriers to developing green infrastructures, as mentioned over 50% of participants in a survey conducted with 565 citizens in New Jersey (Rowe et al., 2016). The federal government could introduce incentive funding for developers or landowners who are willing to develop BGIs. In addition to providing direct funding for developers, funding could be used for educating landowners, developers and building designers in terms of the possibility and benefits of installing BGIs and implementing a BGS. A study on green infrastructure installation in 10 US cities concluded that the "cognitive barrier" is one of the challenges, as people do not have a mindset that can encourage them to implement BGIs (Dhakal & Chevalier, 2017). Raising people's awareness by emphasizing the cost-effectiveness of developing BGS would better encourage developers to adopt BGS and construct BGIs, which is a practical and sustainable solution for preventing flooding.

5. DISCUSSIONS

As discussed in Section Two, various studies have concluded the effectiveness of implementing BGIs in regulating stormwater discharge. However, people should notice that conditions at different sites will generate different scales of stormwater management effects. Therefore, modelling and monitoring would be essential to understand the site details and design details, despite its requirement for more investment from the landowners or developers.

Knowledge gaps still exist regards large-scale BGS implementations, as BGIs are always developed at a small scale such as on one rooftop or one parking lot. The effectiveness of BGS on a large scale needs to be better understood. Interviews of different actors reviewed the knowledge gap existing among the engineering design team while limited knowledge was accessible for teams who pursue a BGS design. The federal government should raise funds for scholars who focus on BGS and BGI design research. The provincial government should be responsible for collecting information about BGS and BGI design and advertising for actors at all levels to be involved in learning. The city government should be more engaged in organizing events to pass on information about BGS and BGI design so that actors such as developers and design teams can be actively involved and have the potential to carry out BGI development according to the BGS guide.

Lastly, it seems difficult to perform modelling and monitoring in large-scale urban regions because it consumes resources and energy to take measurements and monitor. Considering funding as one of the existing barriers for land developers, modelling and monitoring may not be a focus when developing BGS and BGI. Therefore, it appears that having multiple stakeholders participate in the planning stage is more than important to optimize the BGS design from the beginning.

6. Conclusions

This study focused on the possibility of advancing BGS in the city of Toronto based on the current BGS guide and BGI implementation barriers identified. This paper summarized some major challenges to implementing BGI or BGS may include the current land use in Toronto, funding issues, political guidance and technical knowledge gaps. Based on these barriers, this study advises the implementation of BGS which does not impair the current land use in Toronto, different roles the federal, provincial and local governments can perform to provide funds and political support to implement BGS and further develop BGI in the city of Toronto. The results of this study would contribute to Toronto’s stormwater management as a potential proposal to adopt BGS and invest in BGI and as a guide for different stakeholders to take action. More research on the effectiveness of BGS and BGI in a large-scale region and better design of BGI to further achieve cost-effectiveness are necessary.

Reference

[1] Bozovic, R., Maksimovic, C., Mijic, A., Smith, K. M., Suter, I., & Reeuwijk, M. 2017. *Blue Green Solutions: The Guide*. March 31, 2017.

[2] City of Toronto. *City of Toronto Green Roof Bylaw*. Retrieved on August 11, 2024. Retrieved from: https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/green-roofs/green-roof-bylaw/

[3] City of Toronto. Green Infrastructure Resources. Retrieved on August 13, 2024. Retrieved from: https://www.toronto.ca/services-payments/streets-parking-transportation/enhancing-our-streets-and-public-realm/green-streets/green-infrastructure-resources/

[4] Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. 2016. *Nature-based solutions to address global societal challenges*. IUCN: Gland, Switzerland, 97, 2016-2036.

[5] Cristiano, E., Farris, S., Deidda, R., & Viola, F. 2021. Comparison of blue-green solutions for urban flood mitigation: A multi-city large-scale analysis. *PloS One*, *16* (1),e0246429.

[6] Dai, A. 2006. Recent Climatology, Variability, and Trends in Global Surface Humidity. *Journal of Climate*, *19* (15), 3589–3606.

[7] Dhakal, K. P., & Chevalier, L. R. 2017. Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. *Journal of Environmental Management*, *203* (Pt 1), 171–181.

[8] Erler, A. R., & Peltier, W. R. 2016. Projected Changes in Precipitation Extremes for Western Canada based on High-Resolution Regional Climate Simulations. *Journal of Climate*, *29* (24), 8841–8863.

[9] Gaur, A., Gaur, A., Yamazaki, D., & Simonovic, S. P. 2019. Flooding Related Consequences of Climate Change on Canadian Cities and Flow Regulation Infrastructure. *Water*, *11* (1), 63.

[10] Ghofrani, Z., Sposito, V., & Faggian, R. 2017. A comprehensive review of blue-green infrastructure concepts. *International Journal of Environment and Sustainability, 6* (1), 15-36. 10.24102/ijes.v6i1.728

[11] Guay, V., Binesh, N., Duchesne, S., Pelletier, G., & Grégoire, G. 2024. Performance Assessment of Stormwater Management Infrastructures in a Parking Lot near Montreal, Canada. *Journal of Sustainable Water in the Built Environment, 10* (1).

[12] Johns, C. M. 2019. Understanding barriers to green infrastructure policy and stormwater management in the City of Toronto: a shift from grey to green or policy layering and conversion? *Journal of Environmental Planning and Management, 62* (8), 1377–1401.

[13] Ministry of the Environment, Conservation and Parks. (January 2022). Draft LID Stormwater Management Guidance Manual 2022. Retrieved on August 20, 2024. Retrieved from https://prod-environmental-registry.s3.amazonaws.com/2022-01/Draft%20LID%20Stormwater%20Management%20Guidance%20Manual%202022.pdf__

[14] Probst, N., Bach, P. M., Cook, L. M., Maurer, M., & Leitão, J. P. 2022. Blue Green Systems for urban heat mitigation: mechanisms, effectiveness and research directions. *Blue-Green Systems, 4* (2), 348–376.

[15] Rowe, A., Rector, P. & Bakacs, M. 2016. Survey Results of Green Infrastructure Implementation in New Jersey. *Journal of Sustainable Water in the Built Environment, 2* (3): 1-6.

[16] Tillekeratne, K. 2024. Water Polity Design for the Greater Toronto Area. *Toronto's Water Policy Design for the Greater Toronto Area.*__

[17] Toronto and Region Conservation Authority. 2015. *Within Reach: 2015 RAP Progress Report*. Retrieved on July 19, 2024. Retrieved from:

[18] Toronto and Region Conservation Authority. 2024. Flood Risk Management. Retrieved on August 24, 2024. Retrieved from https://trca.ca/conservation/flood-risk-management/

[19] Toronto and Region Conservation Authority. *Issues & Challenges – Lake Ontario Waterfront*. Retrieved on July 31, 2024. Retrieved from https://trca.ca/conservation/watershed-management/lake-ontario-waterfront/hot-topics/

[20] Wu, X., Moustakas, S., Bezak, N., Radinja, M., Alivio, M. B., Mikoš, M., Dohnal, M., Bares, V., & Willems, P. 2024. Assessing the performance of blue-green solutions through a fine-scale water balance model for an urban area. *The Science of the Total Environment, 948*,174750.