Trees and Rain:

How the Urban Forest can Supplement Gray Infrastructure Stormwater Management Strategies

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This paper was written in partial fulfillment of application requirements for the Master of Environmental Science program at The Evergreen State College.

December 23, 2022

Abstract

The role played by the urban forest in managing stormwater and improving urban ecosystem integrity is currently of interest for Washington State's Departments of Ecology (DOE) and Natural Resources (DNR). I'm conducting research with forest ecologist Dr. Dylan Fischer to quantify tree-sap flow and flux dynamics for these agencies to inform decision-making for stormwater and urban planning. In this literature review, my objective is to elucidate the potential for urban forests to supplement best stormwater management practices (BMPs). This objective can be broken down into three questions: 1) what challenges do stormwater managers currently face, 2) what are the shortfalls of gray infrastructure, and 3) how can green infrastructure help stormwater managers meet their goals? To answer these questions, I explore the interface between habitat degradation and BMPs employed by stormwater managers in the Pacific Northwest (PNW) region since the mid-20th century.

Keywords: Habitat, Forest, Stormwater, Trees, Urban

Introduction

Stormwater managers in Washington State are tasked with the unsurmountable responsibility of balancing public and ecological health. During the environmental movement of the 1960's and 1970's, the impacts of industrialization and urbanization on habitat quality, like pollution, erosion, and loss of biodiversity, demanded a lot of attention. Despite greatly improved chemical accumulation rates in soils surrounding Puget Sound (West, 2022), and stagnant urban development rates surrounding critical stream habitat (Bartz et al., 2015), wildlife abundance and habitat quality continue to suffer statewide (Cram et al., 2018). One of the primary ways that urban development degrades habitat quality is by changing flow patterns, therefore, reestablishing natural flow regimes deserves particular consideration.

Until the 1990's when managers' preferences shifted to more natural structures and systems (e.g., woody debris and in-stream interventions), the most common stormwater mitigation strategy was detention. However, Booth and Jackson's widely cited 1997 study likely contributed to the shift to natural system preferences and attention to in-stream symptoms, because they determined that detention was largely ineffective at managing flow-related consequences. Unlike stormwater detention ponds, which are empty, dry, and only provide temporary services, *retention* ponds are artificial bodies of water with surrounding vegetation designed to hold additional volume resulting from rain events and snowmelt, while contributing other ecological benefits to wildlife and the public. While retention ponds seem like a worthwhile solution, they're limited by land area – incorporating them in meaningful ways can be a complex and often costly endeavor – and in constant competition with imperviousness of surrounding surfaces (Booth & Jackson, 1997).

Impervious surfaces, like concrete roads and rooftops, become rivers and waterfalls during rain events that prevent stormwater from percolating into the soil. This change from predominantly subsurface flow prior to development to a surface flow in urban environments today may be a primary driver of increased contaminant concentration, erosion, and loss of biodiversity in pacific northwestern ecosystems (Zank et al., 2016). Stormwater managers have increased attention to in-stream symptoms of flow-related issues, but efficiency remains uncertain or circumstantial at-best (Booth & Jackson, 1997; Booth, Hartley, & Jackson, 2002; Booth, 2005; Foote, 2020).

Challenges

From an analysis of economic and ecological interfaces between stormwater management activities and stormwater-related damage reduction, financing, monitoring, and public awareness seem like the primary contenders for greatest obstacle for stormwater managers. While there's no shortage of money going into the problem, a lot of it is wrapped up in *reactive* projects, and managers nationwide have highlighted the need for developing *proactive* and *preventative* solutions. Considering the City of Seattle's average annual capital improvement budget of nearly $20 million, 60% is committed to flooding and drainage, 18% to water quality, 15% to landslide mitigation, and 7% to habitat improvements. However, the order of perceived impact for these categories was quite the opposite. Stakeholders believed that the greatest impact was on habitat improvement despite relatively low funding, and the least impact in flooding and water quality. Less than half of the respondents offered any substantive method for measuring stormwater impacts or project success at all. Inconsistent monitoring efforts make data difficult to process or inconclusive. The most frequently suggested improvements for stormwater management programs also included increasing public awareness, education, and accountability; and improving regulations and the permitting process. Some jurisdictions expressed frustration with existing regulations and permitting because they're too costly or too difficult to implement (Visitacion & Booth, 2009). There likely won't be a one-size-fits-all solution for stormwater managers, but attention to these challenges in policy and urban planning discussions can help improve the effectiveness of their programs and solutions.

Shortfalls of Gray Infrastructure

Just before the turn of the 21st century, interest in the efficiency of stormwater detention and retention strategies was growing rapidly. While these strategies may have improved urban flooding and chemical water quality, at the time, little attention was given to flow-related consequences of stormwater events (Konrad & Booth, 2002). Undisturbed, natural forests are capable of adequately storing precipitation in the O-horizon soil layer with minimal resulting runoff, which indicates the dominance of a subsurface hydrologic flow regime. Development often removes this O-horizon soil layer while exposing and compacting the underlying A- and B-horizons. Several studies determined that detention and retention strategies were inadequate for restoring pre-development flow regimes, even when paired with riparian corridors (Booth & Jackson, 1997; Booth et al., 2002). Booth and Jackson (1997) identify 10% effective impervious surface area as the level that irreversible stream ecosystem impairment begins. Effective impervious area is one of the most common measures of urbanization and imperviousness, as it represents impervious surfaces that connect directly to the surface drainage system to collect runoff water and prevent combined sewer overflows. High volumes of stormwater runoff travel over land and influence hydrologic flow regimes and cause unwanted erosion both in the stream channel as well as in route to these bodies of water. It may also present hazards as the chemicals carried by runoff water enter the waterway, called nonpoint source pollution. Nonpoint source pollution is a primary point of concern for the Department of Ecology's Water Quality Permitting administrators, especially in waterways adjacent to agricultural land.

Potential for Green Infrastructure

Green Infrastructure can be described as a network of natural systems and technologies that provide solutions to urban and climatic challenges by building and planning with nature. Unlike detention and retention ponds discussed above, assets in this category might include rain gardens, green roofs, and permeable pavement which use proprietary soil mixtures and plants to increase biological filtration and percolation. These examples of engineered technologies are referred to as Low Impact Development (LID) which contrast with examples of natural systems like wetlands, parks, and in our case, urban forests (Figure 1). Generally, green infrastructure tends to generate environmental benefits by improving the landscape and enhancing biodiversity, which is easily accomplished by natural systems.

The urban forest provides a host of ecosystem services to the public and the greater environment. These benefits are not always clear or easy to measure and they're often negatively influenced by urbanization (Zank et al., 2016), but they can be categorized as economic, social, and ecological. Economic and social benefits associated with proximity to urban forests include positive trends in real estate valuations, reduced property and violent crime, and many surprising mental and physical health benefits (Oleyar et al., 2008; Bowler et al., 2010; Thompson Coon et al., 2011; Hanson & Jones, 2015). Ecological impacts associated with the degree of urbanization for a given area is also well documented for both plant and animal species (Hansen et al., 2005), but stormwater-related benefits of urban forests are still a relatively new area of study. Recently, studies have shown that urban trees can retain high volumes of precipitation in their crowns, delay the flow of stormwater runoff, substantially increase the infiltration capacity of urban soils, and provide transpiration of sequestered runoff for additional stormwater storage (Kuehler et al., 2016). Research over the last 20 years strongly contends that maintaining and restoring forest functionality in urban ecosystems may help reduce stormwater runoff and improve water quality at a lower cost compared to gray infrastructure (Rose & Peters, 2001; Lockaby & Helms, 2006; Boggs & Sun, 2011; Kuehler et al., 2016).

Conclusion

My objective in this literature review was to evaluate the potential for urban forests to supplement gray infrastructure and help stormwater managers meet their goals by identifying obstacles faced by stakeholders, shortfalls of the current BMPs, and potential for urban forests to serve as green infrastructure. Managers are limited by financial constraints and a lack of scientific monitoring which is improving for green infrastructure, as is public awareness of its technologies. Gray infrastructure has effectively improved flooding and chemical water quality, despite the enormous cost, while having little effect on flow-related consequences that erode our waterways. Imperviousness is invariably associated with losses of ecosystem services and habitat degradation, while maintaining and restoring forest functionality may help *use* a lot of the water that gray infrastructure seeks to hold onto. This research should contribute to public awareness of the benefits and potential of trees as green infrastructure.

Figures

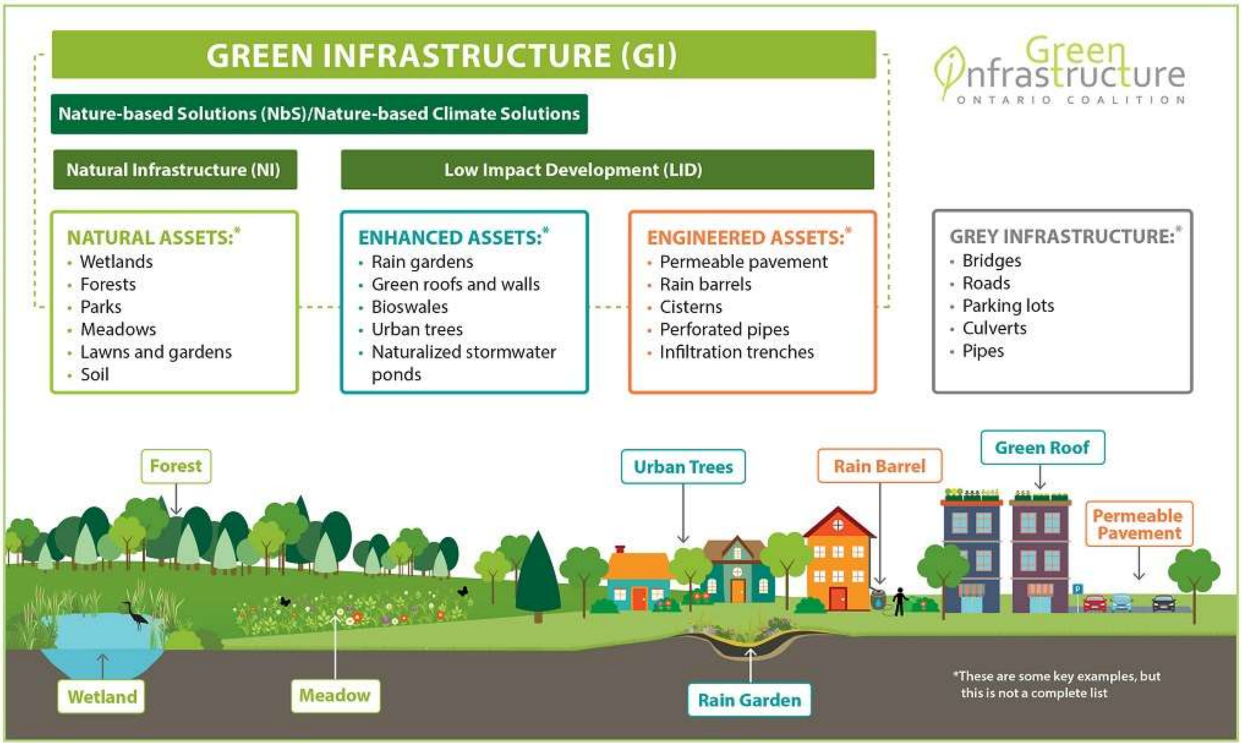

Figure 1: An infographic demonstrating some key examples and differences of green and gray infrastructure. Source: Green Infrastructure Ontario Coalition

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