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## Cost-benefit analysis of green infrastructure for urban stormwater source control

### Analyse coûts-avantages des infrastructures vertes pour le contrôle à la source des eaux pluviales en milieu urbain

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#### RÉSUMÉ

Ce travail de recherche consiste en une analyse coûts-avantages des infrastructures vertes (IV) pour le contrôle à la source des eaux pluviales dans les secteurs drainés par des réseaux d'égouts unitaires. Tout d'abord, une revue de la littérature est présentée, portant sur l'évaluation des coûts et des bénéfices des IV, des coûts et des bénéfices de leur entretien (incluant les difficultés liées à l'entretien) et sur les outils existants pour quantifier et comparer ces coûts et ces bénéfices, comme les analyses coûts-bénéfices et les analyses du cycle de vie. Une analyse coûts-avantages actuellement en cours pour une zone de drainage à Montréal, Canada, est ensuite présentée. Cette analyse vise à évaluer les coûts et l'efficacité des IV pour réduire la fréquence des débordements de réseaux d'égout unitaires en temps de pluie. Pour cette analyse coûts-avantages, le secteur à l'étude est simulé avec SWMM selon divers niveaux d'implantation de cellules de biorétention pour 10 saisons sans gel (mai à octobre).

#### ABSTRACT

This research work consists of a cost-benefit analysis of green infrastructure (GI) for stormwater control in areas drained by combined sewer systems. This research began with a literature review on the evaluation of the costs and benefits associated with GI, the costs and benefits related to their maintenance (including the difficulties associated with maintenance), and the existing tools to quantify and compare these costs and benefits, such as life-cycle cost and cost-benefit analyses. A cost-benefit analysis is currently being conducted for a drainage area in Montreal, Canada, to evaluate the costs and effectiveness of stormwater control measures in reducing the frequency of combined sewer overflows. For this cost-benefit analysis, the case study sewer system is modelled in SWMM with various levels of bioretention systems implementation for 10 non-freezing seasons (May to October).

#### KEYWORDS

Benefits, cost-benefit analysis, green infrastructure, life-cycle cost, maintenance

## 1 INTRODUCTION

Source control has proven its performance in many contexts. However, there are still some barriers that hinder stormwater control measures (SCMs) implementation in urban centers, as demonstrated in O'Donnell et al. (2017), Piacentini & Rossetto (2020), and Back & Collins (2022). In those studies, interviews were conducted with different stakeholders to characterize and group the main barriers affecting the implementation of SCMs. The barriers found can be classified into five groups: lack of funds (Back & Collins, 2022; O'Donnell et al., 2017; Piacentini & Rossetto, 2020), reluctance to change (O'Donnell et al., 2017; Piacentini & Rossetto, 2020), difficulty to include benefits in the cost-benefit analyses (O'Donnell et al., 2017), lack of consciousness and understanding (Back & Collins, 2022; O'Donnell et al., 2017; Piacentini & Rossetto, 2020), and conflict of priorities (national policy) (Back & Collins, 2022; O'Donnell et al., 2017; Piacentini & Rossetto, 2020). The research presented in this paper consists of i) a literature review to quantify the benefits of implementing SCM to reduce CSO; and ii) a cost-benefit analysis applied to a case study in Canada.

## 2 BENEFITS OF STORMWATER CONTROL MEASURES IMPLEMENTATION

When the SCM practices began to be implemented, their main objective was to control flooding caused by stormwater, by reproducing the natural process of the water cycle (Huang et al., 2020). Since then, many of their additional benefits have been investigated (Kumar et al., 2019). Table 1 shows the different benefits associated with SCMs; these benefits were first divided between public and private benefits. According to Johnson et al. (2019), private benefits are directly related to monetary benefits and their associated costs can be evaluated through marketed price methods. Whereas social benefits correspond to those that do not have a direct monetary value (since there is no market for them); their monetary value can be calculated through transferred benefits or avoided damages methods (Johnson & Geisendorf, 2019).

Table 1 Benefits associated with SCMs (Alves et al., 2018; Johnson & Geisendorf, 2019; Kumar et al., 2019)

Type of benefit	Sustainability dimensions	Benefit
Public	Environmental	Water quality of receiving bodies
		Groundwater recharge
		Biodiversity and ecology enhancement
		Temperature reduction
		Air quality improvement
		Carbon sequestration
		Reduction of combined sewer overflows
		Runoff reduction
	Social	Amenity and aesthetics
		Recreation and health
Food security		
Employment opportunity		
Private	Economic	Reduced burden on existing infrastructure
		Rainwater harvesting
		Pumping and treatment reduction
		Energy savings in buildings
		Real estate value appreciation
		Increasing building longevity
Rainwater fee		

## 3 ECONOMIC QUANTIFICATION

Cost-benefit analysis (CBA) evaluation helps practitioners and decision-makers plan stormwater management projects (Johnson & Geisendorf, 2019; Singh et al., 2020). Previous studies showed that the optimal combination of SCM practices with other technologies could drastically reduce the enlargement requirements of existing networks (Singh et al., 2020) and reduce CSO volumes and frequencies (Jean et al., 2022; Joshi et al., 2021). It should be noted that none of the studies mentioned above included social or environmental benefits (Johnson & Geisendorf, 2019). Besides, operation and maintenance (O&M) costs considered in previous studies were percentages of capital costs (Singh et al., 2020). Indeed, the variability of O&M costs was investigated in several research articles as a percentage of the capital cost, as shown in Figure 1 (USEPA, 1999; Weiss et al., 2007; Houle et al., 2013; Tavakol-Davani et al., 2016; Chui et al., 2016; Wang et al., 2020; Kourtis et al., 2020; Singh et al., 2020; Joshia et al., 2021; Jato-Espino et al., 2022).

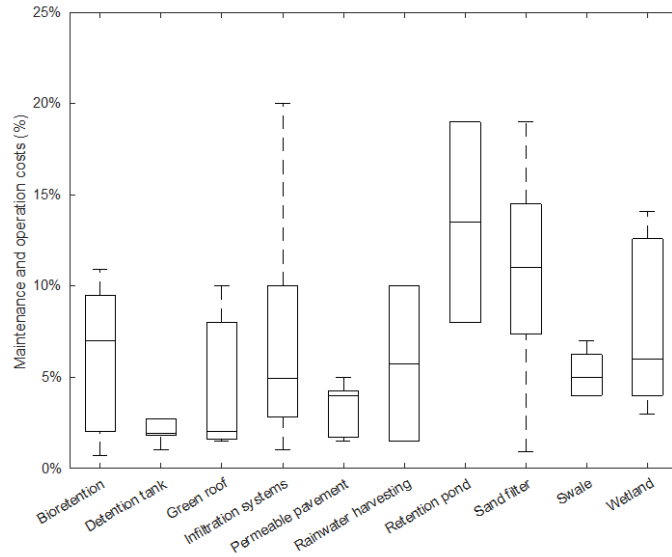


Figure 1: Maintenance costs as a percentage of capital cost (from USEPA, 1999; Weiss et al., 2007; Houle et al., 2013; Tavakol-Davani et al., 2016; Chui et al., 2016; Wang et al., 2020; Kourtis et al., 2020; Singh et al., 2020; Joshia et al., 2021; Jato-Espino et al., 2022)

#### 4 COST-BENEFIT ANALYSIS CASE STUDY

The research presented in this paper focuses on quantifying the benefits related to runoff volume reduction and CSO reduction. Real construction costs will be considered, and the maintenance costs will be estimated from an exhaustive survey. The study area comprised the Mount Royal and Lafontaine Park districts in Montreal, Canada (Figure 2). More specifically, Gilford Street, where new bioretention systems are currently being built, will be studied in more detail. Simulations with SWMM will be conducted for various scenarios, with and without SCMs, for the non-freezing season (May to October) with 10 years of historical rainfall data. The area's average seasonal precipitation from May to October is 696 mm, and CSOs occur frequently. Regulation and environmental awareness call for the implementation of effective solutions to reduce the frequency of those CSOs.



Figure 2: Overview of the study area of Montreal, Canada.

#### 5 CONCLUSIONS

SCMs have proven, in different ways, that they can contribute positively to the resilience of sustainable urban drainage networks and even to the reduction of O&M costs compared to gray systems (Huang et al., 2020; Kourtis et al., 2020). However, the local circumstances of the study area (e.g., availability of economic resources, and climatic variations) must always be considered before implementation (Kumar

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et al., 2019). The final decision about the type of infrastructure to implement must be supported by a thorough analysis of the costs and benefits of all options, considering the regulations in force for the final decision-making (Huang et al., 2020; Kourtis et al., 2020). Completing a cost-benefit analysis on the study area intends to quantify the benefits of reducing runoff volume and CSO frequency, in order to propose strategies to maximize the benefits mentioned above, especially for highly populated urban areas.

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