Understanding the economic benefits of the urban forest from a reduction of stormwater nitrogen loads

Comprendre les avantages économiques de la forêt urbaine résultant d'une réduction des charges d'azote des eaux pluviales

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RÉSUMÉ

Depuis les années 1990, les décideurs des villes du monde entier ont compris les bénéfices des infrastructures vertes pour la santé, la dépollution de l'air, l'atténuation des ilots de chaleur, ainsi que pour la rétention, l'infiltration et l'évapotranspiration des eaux pluviales. Cette prise de conscience a contribué à une extension importante de la canopée urbaine. La ville de Melbourne utilise depuis des décennies le logiciel i-Tree pour calculer le coût total de remplacement des arbres qu'elle gère. Cependant, ce logiciel ne prend pas en compte la vulnérabilité des milieux récepteurs aux charges en azote total (N) provenant du ruissellement urbain. Dans cette communication, nous utilisons la modélisation du bilan hydrique du bassin versant pour évaluer les bénéfices environnementaux et les retombées économiques de la réduction des flux d'azote, grâce à l'expansion de la canopée urbaine. L'évaluation se base sur l'estimation de la réduction du volume ruisselé et considère un bassin fortement urbanisé à Melbourne. Les résultats montrent qu'un doublement de la couverture de la canopée urbaine pourrait générer une économie de 1.000.000 $ (AUD) avec la réduction du flux de N. Notre travail met donc en évidence un avantage économique supplémentaire des arbres publics qui devrait être pris en compte par les décideurs.

ABSTRACT

Since the 1990s decision-makers in cities around the world have come to realise the benefits of green infrastructure. The result of this has been efforts to vastly expand urban canopy cover in the hope that it will deliver benefits in public health, air pollution removal, heat mitigation and stormwater retention, infiltration and evaporation. The City of Melbourne is a municipality that has employed for decades an estimate for the full replacement cost of a public tree using the i-Tree suite. However, this software does not take advantage of research on the vulnerability of large receiving waters to N-loads from urban stormwater runoff. In this paper, we use water balance modelling to predict the environmental and economic benefit of reducing N-loads, estimated simply as a function of reduction in runoff volume, through expanding urban canopy cover. We base our work on a highly urbanized catchment in Melbourne, Australia. We found that doubling the urban canopy cover in the catchment could deliver an N-load removal benefit of ~$1,000,000 ($AUD). Our work highlights an additional benefit of public trees which should be accounted for by policy makers.

KEYWORDS

Ecosystem service, Interception valuation, Nitrogen load, Stormwater, Urban forest canopy cover, Water storage capacity,

1 INTRODUCTION

Since the 1990s decision-makers in cities around the world have come to realise the benefits of ‘green infrastructure’ (Mell, 2017). The result of this have been efforts to vastly expand urban canopy cover in the hope that it will deliver benefits in public health (Ulmer et al., 2016), air pollution removal (Nowak et al., 2006), heat mitigation (Coutts et al., 2012) and stormwater retention, infiltration and evaporation (Berland et al., 2017). The City of Melbourne is a municipality in Australia that has employed for decades an estimate for the full replacement cost of a public tree using the i-Tree suite (https://www.itreetools.org/). However, this software does not take advantage of research on the vulnerability of large receiving waters to nitrogen loads (hereafter N-load) from urban stormwater runoff (Harris et al., 1996). Expanding the urban canopy cover could reduce the export of N-loads to receiving waters—through interception— but this potential remains relatively untested. The study aims to improve our understanding of the environmental and economic benefits of reducing N-loads through expanding the urban canopy cover.

2 METHODS

We base this work on the Elizabeth St Catchment in Melbourne, Australia (Figure 1). The catchment drains 308 ha of mostly impervious land and constitutes a major hub of commerce in Melbourne. The current level of canopy cover on public land is 21.8%, with most trees covering hard surfaces (75%). We employ experimentally-derived figures for estimates of tree storage capacity (M. Baptista; unpublished data), rainfall data for Melbourne (reference year 1959) and stormwater quality characteristics (Duncan, 1995) to estimate annual N-loads based on the following scenarios:

- *No trees*—for this scenario we assumed 0% canopy cover on public land. The pollutant load estimate represents the annual mass of total nitrogen generated from *all impervious surfaces within public land*.
- *Current canopy*—considers the current level of canopy cover on public land, but only trees covering hard surfaces.
- *Canopy expansion*—a doubling of the current level of canopy cover on public land covering hard surfaces.

The analysis is simplified, in that it does not account for interception chemistry, but simply uses the modelled runoff reduction, combined with published nitrogen concentrations in stormwater, to estimate the reductions in annual N-loads. A range is presented for each scenario (based on the variation of total nitrogen concentrations presented in Duncan, 1995). We also present the difference in annual N-load between *No trees* and the scenarios with canopy cover and this represents the water quality benefit of trees (i.e. N-load avoidance). These values are converted to an economic benefit using an estimated cost of stormwater treatment calculated by the local water authority (Melbourne Water, $7,236/kg N).

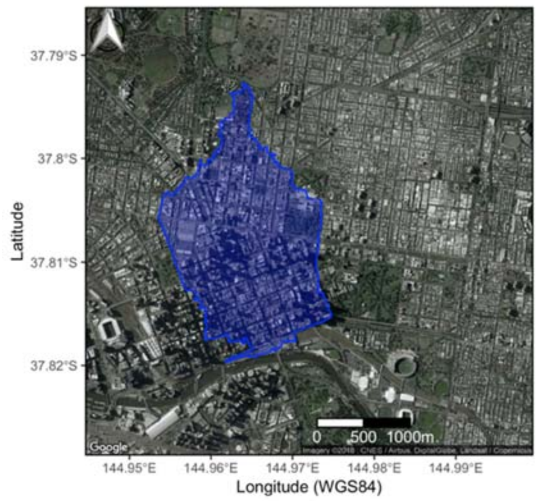

Figure 1: Map of the Elizabeth St Catchment in Melbourne, Australia.

3 RESULTS

We predicted that the current level of canopy coverage in the catchment reduces the amount of runoff delivered to the receiving water by ~14% (Table 1). Expansion of the urban canopy cover could result in even further losses to interception (Table 1). These reductions in runoff volume translated to small benefits in terms of annual N-load avoidance (Figure 2 and Table 1). The economic benefit of the urban canopy cover in terms of annual N-load avoidance amounts to ~$1,000,000 ($AUD) today. Doubling the current level of canopy cover could accrue an additional ~1,000,000 ($AUD) of benefit.

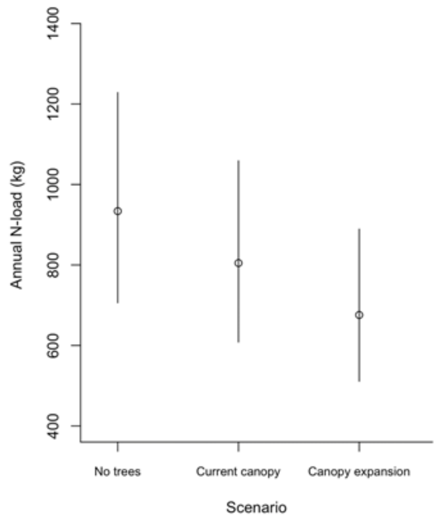

Figure 2: Predicted range of annual N-load from the impervious parts of public land within the Elizabeth Street Catchment. Trees covering hard surfaces provide some N-load avoidance through interception (*Current canopy*), with further reductions possible with expansion (*Canopy expansion*).

Table 1: The water quality and economic benefit of urban canopy cover based on current levels as well as under a future expansion scenario.

Scenario	Annual runoff (ML)	Avoided annual runoff (ML)	Annual N-load (kg)	Avoided annual N-load (kg)	Economic benefit ($AUD*$10^3$)
No trees	447	-	933 (706-1229)	-	-
Current canopy	385	62	805 (608-1059)	129 (98-170)	933 (709-1230)
Canopy expansion	323	123	676 (511-889)	258 (195-340)	1867 (1411-2460)

4 MANAGEMENT IMPLICATIONS

Our results suggest that urban canopy cover in highly urban areas provides only a small benefit in terms of N-load avoidance by interception. The main reason for this is because the trees intercept a small fraction of the rain falling on the catchment. However, studies have shown the importance of trees on redirecting stormwater via stemflow in urban areas (Schooling and Carlyle-Moses, 2015) which is an opportunity to increase infiltration in highly urbanised areas by using tree pits (Grey et al., 2018a; Grey et al., 2018b). Complimentary green infrastructure measures—e.g. biofilters and green roofs—which drain both private and public land will be required for substantial N-load reductions. That said, urban trees provide many benefits which other types of green infrastructure simply do not (e.g. considerable shading). Our work highlights an additional environmental and economic benefit of public trees which should be accounted for by policy makers. Future research is needed to integrate interception chemistry, in order to understand the fate of nitrogen directly intercepted by the vegetation layer.

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