Ecosystem Services xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Including uncertainty in valuing blue and green infrastructure for stormwater management

Richard Ashley[a,*], Berry Gersonius[b], Christopher Digman[c], Bruce Horton[d], Brian Smith[e], Paul Shaffer[f]

[a] Ecofutures Ltd., 3 Greendale Court, Honley HD9 6JW, UK
[b] IHE Institute for Water Education, 2611 AX Delft, The Netherlands
[c] Stantec, Unit 2B, Block E, The Boulevard, Leeds Dock, Leeds LS10 1PZ, UK
[d] Stantec, Kelsey House, 1 Papermill Drive, Redditch B98 8QJ, UK
[e] Yorkshire Water, Western House, Halifax Road, Bradford, West Yorkshire BD6 2SZ, UK
[f] CIRIA, Griffin Court, 15 Long Lane, London EC1A 9PN, UK

ARTICLE INFO

Keywords:
Uncertainty
Benefit assessment
Ecosystem services
Valuation
Stormwater
Blue and green infrastructure

ABSTRACT

Blue and green infrastructure (BGI) provides a wide range of ecosystem services (ES) and other benefits when managing stormwater, beyond flow and pollution control. A number of tools have been developed to value these benefits. In the UK, stormwater measures that utilise BGI are known as Sustainable Drainage Systems (SuDS). This paper outlines the Benefits of SuDS Tool (B£ST), developed in the UK by the Construction Industry Research and Information Association (CIRIA) for valuing the benefits of BGI stormwater measures. The tool has been applied to case studies across Europe. B£ST includes a set of benefits based on ecosystem services applied to the use of BGI for stormwater management. The paper focuses on the uncertainties in this multiple benefit assessment, detailing the processes used in the tool. Examples illustrate the scale of the uncertainties in tools like B£ST. The uncertainties when using BGI valuation tools such as B£ST to help inform the delivery of stormwater measures are demonstrated in the paper as potentially of sufficient magnitude to warrant explicit consideration by professionals and decision makers.

1. Introduction

Traditional approaches to urban drainage utilise buried pipes aiming to get the water away from urban spaces safely and quickly, providing various benefits, mainly to human health and safety, via flood control and the disposal of contaminated urban runoff. In contrast, sustainable drainage systems (SuDS, as they are known in the UK), utilise measures for stormwater management comprising blue and green infrastructure (BGI), open bodies of water such as ponds, and naturally vegetated areas, respectively. BGI measures as part of stormwater management schemes aim to utilise nature as infrastructure in order to maximise the overall benefits to society (e.g. Ozdemiroglu et al., 2013; Xing et al., 2017; EEA, 2017).

Worldwide there are many examples that illustrate the added value of BGI used in this way (e.g. Chini et al., 2017; Philadelphia Water Department, 2011; Rosetti, 2013; Fenner, 2017; Silvennoinen, et al., 2017; Alves et al., 2018). Examples of the additional benefits that BGI measures provide are shown in Table 1. Fig. 1 shows an illustration of BGI for stormwater management.

Sector-specific tools that account for aspects of BGI that are amenable to valuation are increasingly available, but few explicitly include uncertainty (Montalto et al., 2011; Ashley et al., 2018a).

The UK water industry and environmental regulators have funded the Benefits of SuDS tool for valuing the benefits of BGI for stormwater management (CIRIA, 2016). B£ST is structured around ecosystems services (ES) and it gives insight into the relative scale of benefits and, importantly, who these benefits accrue to.

Decision makers need to be confident that any SuDS scheme will deliver the benefits as expected. Many of the schemes analysed with B£ST show that the benefits are often greater in areas not typically associated with traditional stormwater control (Ashley et al., 2018b), such as environmental amenities, which are reflected in property values. Uncertainties in the valuation of these benefits need to be identified, included and explored as part of scheme selection. However, although there is a broad literature on uncertainty in analysing stormwater management measures, and many studies on uncertainties

* Corresponding author.
E-mail address: R.Ashley@sheffield.ac.uk (R. Ashley).

https://doi.org/10.1016/j.ecoser.2018.08.011
Received 13 November 2017; Received in revised form 30 August 2018; Accepted 31 August 2018

Table 1
The benefit categories included in B£ST showing the ES categories and the Triple-Bottom-Line categories used in the outputs Key: M – monetised.

Benefit category	What it covers and if physical data variations are linear (L) or non-linear (PNL)	PC (%)	M	Market or non-market	Valuation approach used	Units of measurements and if financial data variations are linear (FL) or non-linear (FNL)	FC (%)	ES type	TBL	Existing green space may provide
Air quality	Damage to health from air pollution (PL)	50–75	✓	Market (avoided cost)	Damage cost	£ per tonne pollutant (FL)	100	R	S/E	Y
Amenity	Attractiveness & desirability of area (PL)	75–100	✓	Non-market (stated or revealed preference)	Value transfer (hedonic)	% house price change (FL)	25–100	C	S/E	Y
Biodiversity and ecology	Sites of ecological value (PL)	< 50–100	✓	Non-market (meta-analysis of stated preference studies)	Value transfer	£ per hectare (FL)	< 50	S	E	Y
Building temperature	Cooling (summer) or insulation (winter) (PL)	< 75–100	✓	Market (energy costs)	Long-run variable cost	£ energy saved (FNL)	< 75	R	F/S	N
Carbon reduction and sequestration	Operational (reduced energy use), embodied (reduced water use), sequestration (planting) (PNL)	50	✓	Non-market (traded/non-traded price of carbon, based on marginal abatement cost)	Marginal abatement cost	£ per tonne (FNL)	100	R	E	Y
Crime	Crimes against property or people		✗	–	–	–		P/C	F/S	Y
Economic growth	Business, jobs, productivity		✗	–	–	–		P	F	N
Education	Enhanced educational opportunities (L)	25–50	✓	Market (cost of investment)	Avoided investment	£ per school trip (FL)	50	C	S	Y
Enabling development	Headroom for housing/other growth		✓/✗	–	–	–		P	F/S	N
Flexibility	Ability to be modified		✗	–	Homogeneity of benefits	% scaled		P	F	N
Flooding	Damage to property/people (PNL)	< 50–100	✓	Market (damage cost)	Damage cost	£ per property (FL)	75–100	R/C	F/S	Y
Groundwater recharge	Improved water availability or quality (L)	75–100	✓	Market (direct use)	Avoided abstraction cost	£ per m^3 (FL)	< 75	P/R	F/E	Y
Health & wellbeing	Physical, emotional, mental health benefits from recreation and aesthetics (L)	75–100*	✓	Market (avoided cost) and non-market (quality-adjusted life years)	Avoided health costs	£ per person (FL)	100* 25–50	C	S	Y
Pumping wastewater	Reduced flows to works (L)	50–100	✓	Market (energy costs) and non-market (traded/non-traded price of carbon)	Long-run variable cost	£ energy saved (FNL)	100	P	F/S	N
Rainwater harvesting	Reduced flows, pollution or mains consumption (L)	50–100	✓	Market (avoided cost)	Avoided investment	£ per m^3 (FNL)	100	P	F	N
Recreation	Involvement in specific recreational activities (L)	75–100	✓	Non-market (revealed preference)	Value transfer (travel cost)	£ per visit (FL)	< 75–100	C	S	Y
Tourism	Attractiveness of tourist sites		✗	–	–	–		P	F	N
Traffic calming	Risk of road accidents or street-based recreation opportunities		✗	–	–	–		C	S	N
Treating wastewater	Reduced volume to treat from combined systems (L)	75–100	✓	Market (cost of treatment)	Avoided treatment cost	£ per m^3 (FNL)	100	P	F/S	N
Water quality	Surface water quality improvements to aesthetics, health, biodiversity, etc. (PNL)	25–100	✓	Non-market (stated preference)	Value transfer (stated preference)	£ per km of watercourse (FL)	75–100	R/C	E	Y

ES – Ecosystem Service type: R – Regulating; C – Cultural; S – Supporting services; P – Provisioning; TBL – Triple Bottom Line: S – Social; E – Environmental; F – Financial; PL – Physical impacts vary linearly; PNL – Physical impacts vary non-linearly; FL – Financial benefits vary linearly; FNL – Financial benefits vary non-linearly; PC – Confidence score suggested (%) for physical data; FC – Confidence score suggested (%) for financial valuation; * Confidence score if the HEAT tool is used.