Science of the Total Environment 458–460 (2013) 486–498

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

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

Rapid decision support tool based on novel ecosystem service variables for retrofitting of permeable pavement systems in the presence of trees

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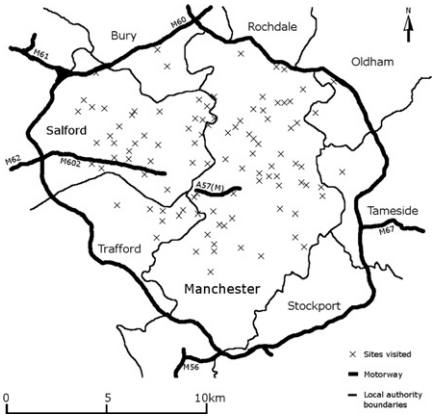
HIGHLIGHTS

- Novel generic ecosystem service variables for combined pavements and trees.
- In built-up areas, the overall ecosystem service scores were relatively low.
- Greater Manchester case study is dominated by Sycamore and Common Lime.
- Retrofitting of permeable pavement systems in green areas is generally possible.
- Some tree species are unsuitable in combination with permeable pavement systems.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 12 December 2012
Received in revised form 15 April 2013
Accepted 21 April 2013
Available online 19 May 2013

Editor: Simon Pollard

Keywords:
Air quality
Best management practice
Expert system
Sycamore
Urban area
Vegetation

ABSTRACT

The retrofitting of sustainable drainage systems (SuDS) such as permeable pavements is currently undertaken ad hoc using expert experience supported by minimal guidance based predominantly on hard engineering variables. There is a lack of practical decision support tools useful for a rapid assessment of the potential of ecosystem services when retrofitting permeable pavements in urban areas that either feature existing trees or should be planted with trees in the near future. Thus the aim of this paper is to develop an innovative rapid decision support tool based on novel ecosystem service variables for retrofitting of permeable pavement systems close to trees. This unique tool proposes the retrofitting of permeable pavements that obtained the highest ecosystem service score for a specific urban site enhanced by the presence of trees. This approach is based on a novel ecosystem service philosophy adapted to permeable pavements rather than on traditional engineering judgement associated with variables based on quick community and environment assessments. For an example case study area such as Greater Manchester, which was dominated by Sycamore and Common Lime, a comparison with the traditional approach of determining community and environment variables indicates that permeable pavements are generally a preferred SuDS option. Permeable pavements combined with urban trees received relatively high scores, because of their great potential impact in terms of water and air quality improvement, and flood control, respectively. The outcomes of this paper are likely to lead to more combined permeable pavement and tree systems in the urban landscape, which are beneficial for humans and the environment.

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http://dx.doi.org/10.1016/j.scitotenv.2013.04.062

1. Introduction

1.1. Rationale, aim and objectives

In times of recession and spending cuts in the public sector, rapid and inexpensive expert assessment systems supporting planners currently undergo a revival in the context of ecosystem services. The application of ecosystem service values to a new area such as sustainable drainage is a novel contribution to knowledge and understanding. The timely and applied nature of such expert systems should have a strong appeal particularly for urban and landscape planners interested in the total environment.

Established tools evaluating a range of SuDS techniques for retrofitting of drainage systems already exist (e.g., CIRIA, 2004). However, sophisticated tools focusing on the retrofitting of permeable pavements on sites with existing trees and taking into account a wide range of ecosystem service variables (including functions associated with trees) do not exist.

With an increasing public awareness of the importance of ecosystems and the services they provide for humans, this paper aims to develop a unique and rapid decision support tool based on novel ecosystem service variables for retrofitting of combined permeable pavements and tree systems in densely populated areas. The key objectives to achieve this aim are (1) to compile a comprehensive dataset of sites within an example case study area (Greater Manchester) where retrofitting of permeable pavements in the presence of trees would be possible, (2) to identify all generic ecosystem service variables relevant for permeable pavement retrofitting, (3) to broadly categorise these ecosystem service variables under the four established categories of supporting, regulating, provisioning and cultural, (4) to assess the

Table 1
Universal ecosystem service categories and variables for combined permeable pavement and tree systems.

Category	Variable	Generic ecosystem service variable description
Supporting services	1. Habitats for species (HS)	Urban habitats should provide everything that an animal needs to survive: food, water and shelter. Each ecosystem provides habitats that can be essential for a species' lifecycle. Migratory species including birds and insects all depend upon different ecosystems during their movements.
	2. Maintenance of genetic diversity (MGD)	Genetic diversity distinguishes different breeds or races from each other, providing the basis for locally well-adapted cultivators. Some urban habitats have an exceptionally high number of species ('biodiversity hotspots'), which make them more genetically diverse than others.
Regulating services	3. Local climate and air quality regulation (LCAR)	Trees lower the temperature by providing shade and influence water availability (e.g., evapotranspiration). Trees and other plants also play an important role in regulating air quality by removing pollutants from the atmosphere (e.g., filtration and absorption of particulates and NO_x).
	4. Carbon sequestration and storage (CSS)	Ecosystems regulate the climate by storing greenhouse gases such as carbon dioxide through burial and sediment accretion. As trees grow, they remove carbon dioxide from the atmosphere.
	5. Moderation of extreme events (MEE)	Ecosystems and living organisms create buffers against natural disasters, thereby preventing or reducing damage from extreme weather events or natural hazards including floods, storms and landslides. Trees stabilise slopes. Flooding may be reduced through regulating runoff.
	6. Storm runoff treatment (SRT)	Physical, chemical and biological treatment takes place within permeable pavement systems. Trees filter effluents such as storm water runoff. Through the biological activity of microorganisms in the soil and sediment, most waste is broken down; thereby pathogens are eliminated, and the level of nutrients and pollution is reduced.
	7. Erosion prevention and maintenance of soil fertility (EPMSF)	Tree cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and agriculture, and well-functioning ecosystems supply soil with nutrients required to support plant growth.
	8. Pollination (P)	Insects and wind pollinate plants including trees, which is essential for the development of fruits and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds.
	9. Biological control (BC)	Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites.
Provisioning services	10. Food (F)	Food comes principally from managed urban horticulture (e.g., fruit trees).
	11. Raw materials (RM)	Some trees deliver a great diversity of materials for construction and fuel, including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species.
	12. Fresh water (FW)	Ecosystems play a vital role in providing cities with drinking water, as they ensure the flow, storage and purification of water. Trees influence the quantity of water available locally.
	13. Medicinal resources (MR)	Some tree products may be used as traditional medicines or provide raw materials for the pharmaceutical industry.
Cultural services	14. Recreation, and mental and physical health (RMPH)	Wildlife viewing, walking, jogging and playing sports in green spaces is a good form of physical exercise and helps people to relax. The role that green space plays in maintaining mental and physical health is increasingly becoming recognised, despite difficulties of measurement.
	15. Tourism and area value (T)	Ecosystems and biodiversity play an important role for local tourism, which in turn provides considerable economic benefits. Cultural and eco-tourism can also educate people about the importance of biological diversity. The value of properties in the area may be positively affected by the presence of an attractive permeable pavement site with trees and street furniture.
	16. Aesthetic and educational appreciation and inspiration for culture, art and design (AEAICAD)	Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and (predominantly natural) landscapes have been the source of inspiration for art, culture and increasingly for science. Trees within urban green spaces may provide soothing and educational benefits, and a sense of beauty for some observers. Some attractive urban areas may also promote health and well-being.
	17. Spiritual experience and sense of place (SESP)	Some urban forms may be considered to have a religious meaning. Trees are a common element of some major religious and traditional knowledge. They can become important for creating a sense of belonging.