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Rapid expert tool for different professions based on estimated ecosystem variables for retrofitting of drainage systems

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ABSTRACT

There is a need for a geospatial decision support tool for different professions such as drainage engineers and urban planners, which is useful for a quick assessment of the potential of ecosystem services when retrofitting sustainable drainage systems (SuDS) in urban areas. Therefore, the aim of this paper is to develop an innovative rapid decision support tool based on ecosystem service variables for retrofitting of key SuDS techniques by different professionals such as drainage engineers, developers, ecologists, planners and social scientists. This unique and transparent spreadsheet-based tool proposes the retrofitting of a SuDS technique that obtained the highest ecosystem service score for an urban site. This approach is based on a novel ecosystem service philosophy adapted to SuDS rather than on traditional engineering judgement associated with variables based on quick community and environment assessments. For the Greater Manchester example case study area, a comparison with the traditional approach of determining community and environment variables indicates that infiltration trenches, soakaways and belowground storage systems are usually less preferred than permeable pavement systems regardless of the professional perspective. However, ponds also received relatively high scores, because of their great potential impact in terms of water quality improvement and flood control. The estimation of variables was undertaken with high confidence and manageable error.

1. Introduction

In times of recession and spending cuts in the public sector, rapid and inexpensive computer-based expert assessment systems supporting urban and landscape planning currently undergoes a revival in the context of ecosystem services (Dobbs, Escobedo, & Zipperer, 2011; Scholz, Hedmark, & Hartley, 2012). Estimating rather than measuring complex ecosystem service variables reduces the overall cost and length of a project considerably. Euliss et al. (2011) show the successful integration of estimated ecosystem service variables within models used for decision-support processes.

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 to environmental managers, and urban and landscape planners.

With an increasing public awareness of the importance of ecosystems and the services they provide for humans (Butler & Davies, 2004; Scholz, 2010), the aim of this paper is to develop a rapid decision support tool for a range of professions based on estimated ecosystem service variables for retrofitting of SuDS in densely populated areas. The key objectives to achieve this aim are:

1. to broadly categorise identified generic ecosystem service variables relevant for SuDS retrofitting under the four established categories of supporting, regulating, provisioning and cultural;
2. to compare the suitability of potential SuDS sites within Greater Manchester based on the traditional 'community and environment' variables, new ecosystem service variables and a combination of the traditional and new approach for sites within Greater Manchester.
3. to evaluate the variability of estimated example variables and the learning process of estimation by students (non-experts); and
4. to develop a decision support tool for SuDS retrofitting taking into account the perspectives of drainage engineers, developers, ecologists, planners and social scientists.

Traditional drainage frequently leads to flooding and pollution challenges in the lower catchment (Scholz, 2006, 2010). The implementation of sustainable drainage systems (SuDS; UK), also known as best management practices (more recently stormwater control measures; USA), and water sensitive urban design (Australia), can

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help to alleviate these problems. The main objective of SuDS is to mimic the natural drainage into the ground, as closely as possible, prior to its development (CIRIA, 2007). Most SuDS techniques are able to do this in number of ways such as attenuation of runoff before entering the watercourse, storage of water in natural contours, infiltration of partially treated runoff into the ground and evapotranspiration of water by vegetation (CIRIA, 2010; Scholz, 2006, 2010).

Sustainable drainage techniques should reduce the impact of urbanisation on the quantity and quality of surface runoff, while increasing amenity and biodiversity opportunities at the same time. Some of the techniques control surface runoff through infiltration, detention, attenuation, conveyance and water harvesting (CIRIA, 2007; Scholz, Corrigan, & Yazdi, 2006; Scholz et al., 2012). In general, they make use of physical, chemical, and/or biodegradation processes to improve the quality of surface runoff by minimising the amount of storm water-based pollutants washed into nearby watercourses (Eriksson et al., 2007; Scholz, 2010). However, improvement opportunities with respect to ecosystem services including amenity and biodiversity by introducing SuDS are frequently ignored by engineers (Scholz, 2010).

Costanza et al. (1997) introduced the concept of ecosystem services, associated values and corresponding categories. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. The increasing human population size, economic growth and global consumption patterns place pressure on environmental systems. It follows that the provisioning of ecosystem goods and services is affected (Seppelt, Dormann, Eppink, Lautenbach, & Schmidt, 2011). The concept of ecosystem services stayed much the same until de Groot, Wilson, and Boumans (2002) published a framework diagram and a table in an attempt to distinguish between ecosystem functions, processes, goods and services. Brown, Bergstrom, and Loomis (2007) subsequently defined ecosystem services as the results of ecosystem processes that either directly sustain or enhance human life or maintain the quality of ecosystem goods.

The benefits that the public may obtain from the urban environment can also be considered as ecosystem services (Busch, Notte, Laporte, & Erhard, 2012; Millennium Ecosystem Assessment, 2005; Moore and Hunt, 2012). Defra (2011) defines ecosystem services as the benefits individuals gain from the goods and services produced by nature and its natural systems. The natural resources and functioning natural systems such as fertile soils, clean water (Walsh, Fletcher, & Burns, 2012) and air and a regulated climate are essential for human wellbeing, security and economic development (Millennium Ecosystem Assessment, 2005).

A number of official documents such as the Natural Environment White Paper (Defra, 2011), the UK National Ecosystem Assessment (2011) and TEEB (2011) have identified four broad categories of ecosystem services generally referred to as supporting, regulating, provisioning and cultural. All existing ecosystem services are strongly linked to one another and to other types of ecosystem services.

Tzoulas et al. (2007) provided a detailed literature review on ecosystem services in the urban environment. A list of ecosystem service variables and their respective categories used in this paper is provided in Table 1. The listed ecosystem services have been reinterpreted to make them relevant to SuDS retrofitted in urban areas and are categorised in broad agreement with TEEB (2011) and other guidance documents such as Moore and Hunt (2012). TEEB (2011) proposed a comprehensive list of ecosystem service variables of generic nature, while Moore and Hunt (2012) chose a smaller set of variables particularly adapted for constructed wetlands and ponds.

Ecosystem service assessment is dynamic considering that the built environment constantly changes (Eigenbrod et al., 2011) and the scientific knowledge of associated processes develops further. For example, surface permeability and green roof run-off estimates may be different in the future. It follows that SuDS recommendations will change over time.

An example case study to test the generic tools discussed in this paper has been chosen. Greater Manchester, a sub-region in the Northwest of England, is made up of ten Local Authorities. The six authorities of relevance for this study (in order of decreasing importance: Manchester, Salford, Trafford, Bury, Oldham and Tameside) have been highlighted in Fig. 1. The whole of Greater Manchester covers a total surface area of 1300 km^2 and is home to approximately 2.5 million people. Salford and Manchester form the core of the conurbation and are the most densely built-up areas in Greater Manchester. The remaining eight Local Authorities form an urban fringe around Salford and Manchester, and are considerably less urbanised (White & Alarcon, 2009).

Section 2 outlines the proposed methodology. Results are discussed in Section 3. Subsections discuss the site assessment (Section 3.1), the new methodology (Section 3.2), comparisons between methodologies (Section 3.3), certainty estimations (Section 3.4), estimation variability (Section 3.5) and different professional perspectives (Section 3.6). Conclusions and recommendations for further research are summarised in the final Section 4.

2. Methodology

2.1. Overview of methodology

All information collected in the following methodological steps is fed into a transparent computer-based Microsoft Office Excel spreadsheet decision support model, providing virtually instant output regarding the preferred SuDS technique. Section 2.2 explains the standard site assessment variables for potential SuDS sites in Greater Manchester, which addresses objective 1. Section 2.3 outlines a set of additional ecosystem service variables (objective 2). Section 2.4 explains the determination of SuDS techniques with traditional community and environment variables, the new ecosystem service variables and a combination of the traditional and new approach with each other (objective 3). Sections 2.5–2.6 explain how to estimate confidence values (objective 4), a range of different example variables (objective 5) and variables weighted according to different professional judgements (objective 6), respectively. Fig. 2 provides an overview of the new ecosystem service assessment approach.

2.2. Site assessment

A total of 100 sites that were large enough for the retrofitting of SuDS to have a positive urban drainage impact (i.e. improved drainage, water quality, and enhanced biodiversity and recreation) were identified by assessing Ordnance Survey and Google maps of Greater Manchester. Local Authorities, United Utilities (water authority) and major private land owners were consulted regarding suitable SuDS sites. A map of Greater Manchester highlighting all sites visited was created using the computer software GNU Image Manipulation Program (Fig. 1). The purpose on focusing the study on Greater Manchester was to demonstrate that the implementation of SuDS even within densely built-up cities is possible.

The site assessment template was based on the frameworks developed by Scholz (2006) and Scholz et al. (2006) for retrofitting of SuDS techniques in Glasgow, Edinburgh and elsewhere, and the Construction Industry Research and Information Association