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Understanding spatial patterns in the production of multiple urban ecosystem services

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ABSTRACT

Urbanisation is a key driver of land use change and urban growth is set to continue. The provision of ecosystem services depends on the existence of greenspace. Urban morphology is potentially an important influence on ecosystem services. Therefore, it may be possible to promote service provision through an urban structure that supplies the processes and functions that underpin them. However, an understanding of the ability of urban areas to produce multiple ecosystem services, and the spatial pattern of their production, is required. We demonstrate an approach using easily accessible data, to generate maps of key urban ecosystem services for a case study city of Sheffield, UK. Urban greenspace with a mixture of land covers allowed areas of high production of multiple services in the city centre and edges. But crucially the detection of such 'hotspots' depended on the spatial resolution of the mapping unit. This shows there is potential to design cities to promote hotspots of production. We discuss how land cover type, its spatial location and how this relates to different suites of services, is key to promoting urban multifunctionality. Detecting trade-offs and synergies associated with particular urban designs will enable more informed decisions for achieving urban sustainability.

1. Introduction

Urbanisation causes profound changes to natural systems (Grimm et al., 2008), and may result in a decline in ecosystem services – the benefits that humans derive from ecosystems (Millennium Ecosystem Assessment, 2005; Niemelä et al., 2010; Tratalos et al., 2007). To adopt urban planning that can enhance ecosystem services requires an understanding of the spatial pattern of multiple ecosystem service production in and around cities. Urban ecosystems can provide a wide range of ecosystem services such as food supply, air purification, climate regulation (cooling), carbon sequestration, runoff mitigation and noise reduction, as well as recreational services and those that provide psycho-physical and social health benefits (Bolund and Hunhammar, 1999; Gómez-Baggethun and Barton, 2013; Niemelä et al., 2010). However, the diversity and level of service provision depends largely on the green spaces that exist in and around urban areas, for instance road verges, cemeteries, allotments, gardens, parks and adjacent rural areas (Bastian et al., 2012).

The need to manage urban green spaces for services has become of policy importance at the UK and the EU level. For example, the UK Natural Environment White Paper (HM Government, 2011) outlines a concern for the decline in the quality and quantity of urban greenspace in the UK, and recognises its role in reducing the risk of flooding and the heat island effect. The EU-wide strategy on Green Infrastructure (GI), Enhancing Europe's Natural Capital (COM/2013/0249 final), identifies the importance of GI (a strategically planned network of green and blue spaces designed and managed to deliver a wide range of ecosystem services) in urban environments for providing health benefits through clean air and improved water quality. It also states that the consideration of GI is necessary in planning and decision-making processes to reduce the loss of ecosystem services as a consequence of land take (land that is converted for housing, industry, roads or recreation) and to help improve and restore soil functions.

Evidence is emerging to support the assertion that urban morphology (the biophysical structure of the urban environment, including green space, that is largely determined by urban planning processes) may be an important factor influencing the provision of multiple ecosystem services (Bierwagen, 2005; Kroll et al., 2012; Radford and James, 2013; Schneider et al., 2012; Tratalos et al., 2007; Whitford et al., 2001). If this is so, the combination of types and levels of ecosystem services produced could be optimised for particular circumstances through the creation of an urban morphology that enhances the environmental processes and functions that underpin them. However, such urban planning requires an understanding of the ability of urban areas to produce

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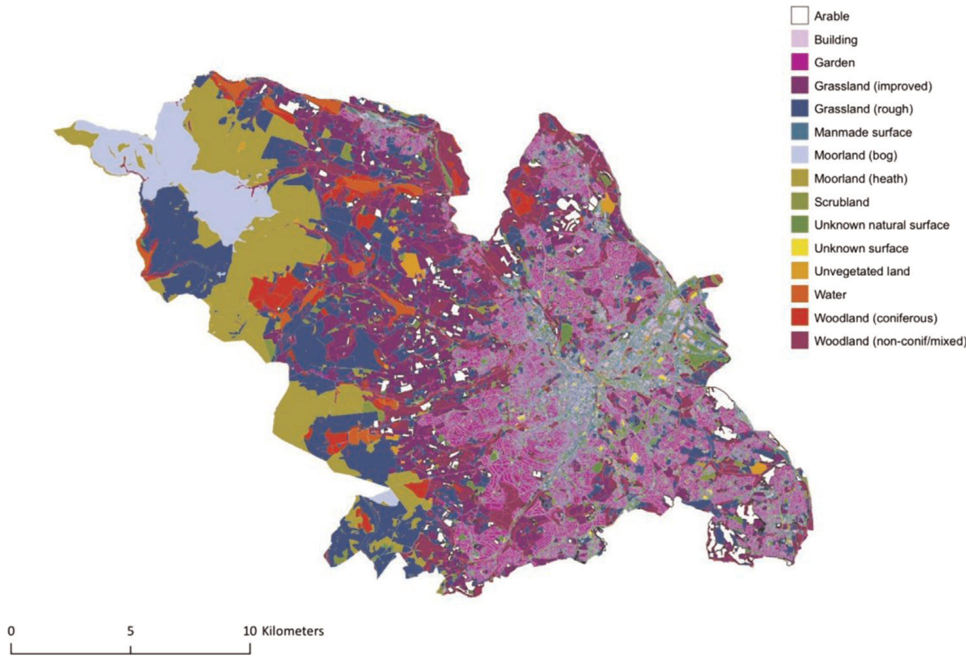

Fig. 1. Land cover map of the metropolitan borough of Sheffield.

multiple ecosystem services, and the spatial pattern of multiple ecosystem service production in and around cities, of which there remains very little understanding (Haase et al., 2014).

Frameworks and methodologies have recently emerged that aim to assess ecosystem service provision and demand for urban and landscape scale planning (e.g. Bastian et al., 2012; Burkhard et al., 2012; Kopperoine et al., 2014; Koschke et al., 2012). But, accurate mapping of urban ecosystem service provision at different scales is necessary for effective spatial planning (UK NEA, 2011), and a better understanding of their trade-offs and relationships to land cover change is crucial (Haase et al., 2012, 2014; Lin and Fuller, 2013). The challenge remains the lack of accurate data with which to quantify ecosystem services or proxies of them (Naidoo et al., 2008; Seppelt et al., 2011; Wallace, 2007), particularly at the scales required for urban planning, management and policy-making. Indeed, most studies of this kind have mapped the supply of multiple ecosystem services at a much courser grain (global, continental, national and sub-national see Crossman et al., 2013). Despite more recent studies at finer scales (e.g. Vorstius and Spray, 2015) less is known about the flows of ecosystem services at local to regional scales (de Groot et al., 2010). There have been few attempts to quantify and map variation in ecosystem service provision across a city as a whole, and most have focused on single ecosystem services (Haase et al., 2014). In the absence of primary data at appropriate scales, the alternatives are the collection of the necessary field data and the use of ecological production functions. The former is resource intensive (Maes et al., 2012), even just for one ecosystem service, and for many practical applications, collection of significant new field data is unlikely to be possible. It is important, therefore, to explore the utility and effectiveness of alternative approaches that can combine the use of field data where available with land cover and soils information, and other data likely to be readily available for urban areas (and therefore to urban planners), to generate maps of ecosystem service provision in urban systems.

In this paper, we demonstrate how multiple ecosystem services can be quantified using easily accessible/publically available data, to produce maps of a number of key ecosystem services in a large urban area: the city of Sheffield, UK. Importantly, this approach allows us to analyse the extent to which ecosystem services in urban systems may co-occur and are correlated, and the similarities in spatial pattern of the levels of production between them. Furthermore we explore whether these patterns change depending on the spatial unit at which the services are mapped. This enables an assessment of the extent to which urban ecosystem services may be managed and/or conserved together, whether it is possible to identify priority areas for creating hotspots of ecosystem service provision, and whether the unit at which services are mapped matters for decision-making.

2. Material and methods

2.1. Study area

The city of Sheffield, (53° 23′N, 1° 28′W), is the ninth largest urban area in the UK (Fuller et al., 2008), with a human population of ca. 530,000 (Lovatt, 2007), in an area of 368 km^2. Sheffield is hilly and lies over a wide altitudinal range, from 592 m above sea level in the west to 19 m a.s.l. in the east. There is a strong longitudinal pattern in land cover and land use in Sheffield due to soils of loam and clay in the east and peat soils to the west, with blanket peat at higher altitudes (Cranfield University, 2009; Fine, 2003). Ninety five percent of the population live in the urbanised eastern part of the city (Beer, 2003). The west includes a substantial area of the Peak District National Park (moorland and upland bogs), arable and pasture land interspersed with areas of woodland where the density of buildings is low (see Fig. 1).

We used the administrative boundary of the metropolitan borough of Sheffield as the study area because it is the unit most relevant to city-wide decision-making. Sheffield city is particularly suitable to this study as it (i) has an established and valued urban greenspace infrastructure, indicating that although management is not targeted at ecosystem services, they are indirectly valued, and (ii) the city boundary contains within it a number of broad ecological and environmental gradients giving rise to considerable variation in land use, land cover and thus the quality and quantity of ecosystem services produced.