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Cross-scale analysis of ecosystem services identified and assessed at local and European level

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ABSTRACT

In recent years a consistent number of studies carried out at different spatial scales have proposed options for mapping and integrated assessment of ecosystem services. Examples of cross-scale assessments are limited and open questions remain on the extent to which general assessments are able to capture local phenomena. This study aims at investigating what the relation is between ecosystem services analysis carried out at different spatial scales, and to what extent approaches based on input data at different resolution can be reconciled.

In particular, the challenges and limitations involved in attempting holistic assessments of ecosystem services at the level of a management unit in the UK were investigated using two sets of ecosystem service indicators: (i) identified by local land managers and (ii) derived from EU-based spatially explicit data coupled with process-based models. The difference in the ecosystem services estimated for 11 sites of the Environmental Change Network (ECN) by the two methodologies was compared using (i) total ecosystem service index (TESI), (ii) regression analysis of comparable ecosystem service indicators, and (iii) multivariate techniques to determine site comparability. The comparative analysis revealed robust grouping of sites by both methods coupled with weak correlation between the different ecosystem service indicators assessed. This study indicated that both methods characterised the general landscapes in a similar way, but total ecosystem service index was critically dependent on indicators selected.

1. Introduction

The concept of ecosystem services is recognised as valuable when deciding resource allocation whether that be in terms of economics (Farley, 2012; TEEB, 2010), human wellbeing (Braat and de Groot, 2012; MA, 2005) or biodiversity (Harrison et al., 2010; Haslett et al., 2010; Maes et al., 2012a). However, collecting sufficient data for a holistic assessment of ecosystem services from an area is recognised as a problem when operationalising the concept (de Smedt, 2010; Dick et al., 2011a; Helming et al., 2011a,b; Smith et al., 2011) and therefore different methods of assembling ecosystem service indicators have been attempted (for a review see Crossman et al., 2013). While the integrated assessment of ecosystem services at a defined scale of analysis is a complex exercise that can be supported by a consistent bulk of literature (Lautenbach et al., 2011; Kareiva et al., 2011; Bateman et al., 2013), the understanding of the potential and the limitations of cross-scale assessments has been much less explored and still needs further advancements. Assessments at local scale are very often based on stakeholders consultation to capture the needs and visions of local communities (Raudsepp-Hearne et al., 2010; Hauck et al., 2013), while at larger scale tend to be mostly data driven to capture macro-trends in spatial distribution of ecosystem service provision and their change over time (Schröter et al., 2005).

In Europe, the EU Biodiversity Strategy to 2020 calls on the member states to map and assess ecosystems and their services by 2014 (Action 5, Maes et al., 2012b). The spatial resolution at which ecosystems and ecosystem services need to be mapped and assessed will vary depending on data availability and the purpose for which the mapping and assessment is carried out (Braat and de Groot, 2012; de Jonge et al., 2012). Different policy sectors have different information needs and the level of detail required for local level decisions will not be the same as the indicators used for informing EU policy development. Furthermore, some member states, such as the UK, are quite advanced in collecting data and considering suitable indicators (UK NEA, 2011) while many other member states are in the initial process of ecosystem assessment, and may rely on data available at continental level to map

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some ecosystem services. The need to know how well a top down methodology to assess ecosystem services at local or regional scale performs is consequently becoming urgent.

In summary, the degree to which results at one scale are representative of results at a different scale of analysis and how messages conveyed by the two can be used, linked, and integrated for a more comprehensive site characterisation and ecosystem service assessment is the core of the present analysis. In this study we compare two contrasting methods, developed at different spatial scales, which are commonly utilised for assessing ecosystem services: (i) a local place-based assessment which uses locally derived data in participatory mode with local land managers (Dick et al., 2011b) and (ii) a mapping assessment using spatially explicit data downscaled from national or international data sets (Maes et al., 2011). In this study we compare these two approaches to assess the ecosystem services delivered for 11 sites in the Environmental Change Network (ECN), the UK's long-term ecological research network. In essence these two approaches could be described as bottom-up compared with top-down approaches.

More specifically we compare the methodologies with a focus on their utility to describe sites and aid decision makers in the context of policy *ex ante* impact assessments. The ecosystem service approach recommends measuring, mapping, and valuing ecosystem services as fundamental knowledge required for governing the use of ecosystem services (Braat and de Groot, 2012; de Smedt, 2010; Primmer and Furman, 2012). The ecosystem service concept with its focus on spatial extent of ecosystem services delivered to humans as well as underlying functions of ecosystems and the reliance of services on these functions draws the attention of decision makers to a holistic vision of services delivered to society. In this study we explore the hypothesis that site characterisations using ecosystem services depend on the spatial scale of the underpinning data sources.

The two ecosystem service assessment methodologies were compared in terms of (i) total ecosystem service index, which is a simple matrix suitable for impact assessments, (ii) regression analysis of comparable ecosystem service indicators, to test the linearity of relationship between the methods, and (iii) multivariate clustering techniques, to determine the robustness of the overall site descriptions by the two sets of ecosystem service indicators. The first two analyses are designed to compare the assessment methodologies at each site and the last the between site comparisons.

2. Methods

2.1. Ecosystem service indicators

The ecosystem services of 11 sites (Fig. 1) were identified by two methods (i) stakeholder participatory meeting of land managers and (ii) assessment using spatial indicators for ecosystem services collated at the European scale. Details of the methods for each assessment have been reported by (i) Dick et al. (2011b), Dick et al. (2011c) and (ii) Maes et al. (2011, 2012a) respectively. To summarise Dick et al. (2011b) an ecosystem services indicator list was identified at a two day participatory workshop and values for the ecosystem services indicators were obtained from three sources: (i) data collected by the standard protocol of the Environmental Change Network (http://www.ecn.ac.uk/protocols/index.asp), (ii) data obtained by land managers from a variety of other sources for their site e.g. post-graduate students and project reports, and (iii) expert knowledge of land managers. The land managers agreed on 73 ecosystem service indicators based on the Millennium Ecosystem Assessment typology (MA, 2005) and reported the values for their site in the year 2009. Area-dependent indicators were scaled by the area of the site (Table 1). The site managers took a wide definition of ecosystem services including both biotic and abiotic indicators. In contrast Maes et al. (2011) selected 16 ecosystem service indicators from the TEEB typology (TEEB, 2010) using pan-European databases often based on remote sensing of vegetation or on data and results captured in environmental databases, agricultural statistics or simulated by environmental models (Table 2) at varying spatial resolution. For simplicity these methods will be referred to as the ECN and EU methodologies respectively throughout this paper and the reader is referred to the two source publications for detailed methodology of the ecosystem service indicators.

2.2. Statistical analysis

The Total Ecosystem Service Index (TESI) essentially follows the Total Ecosystem Service Value of Maes et al. (2012a), but the term value has been replaced by index to better reflect the nature of the statistic and avoid confusion with economic terminology. TESI is an average of normalised values (between 0 and 1) of each ecosystem service amount using

$$ES_{\text{norm}} = \frac{X_{\text{ES}} - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}}$$

where ES_{norm} is the normalised value of the ecosystem service for the site, X_{ES} is the (original) site value of the ecosystem service, X_{min} is the lowest value of X_{ES} at any site, and X_{max} is the highest value of X_{ES} at any site. The ES_{norm} values are averaged separately to give a TESI for each of the MA categories of provisioning, regulating and cultural services. An overall TESI then is calculated by using the individual category TESI values as the data to be normalised and averaged as above, which effectively gives equal weight to each MA group within the total index. A visual, spatial comparison and a correlation analysis are used to compare the TESI values for the two assessment methods.

The linear relationships between six ecosystem services were also investigated using regression between pairs of composite indicators derived using the two assessment methods. These six composite indicator pairs were selected for in-depth analysis as they purported to directly assess the same underlying ecosystem services, and represented food, air quality, carbon sequestration, pollination, erosion risk and recreation potential.

Additional to the individual site comparisons, the between site comparisons of the two methods was explored by deriving separate between site similarity matrices using the city-block or Manhattan measure, as recommend for complex ecological datasets (Digby and Kempton, 1987; Faith et al., 1987), and this matrix was decomposed into principal coordinates scores to facilitate visualisation with larger distances reflecting less similarity. A hierarchical agglomerative clustering determined site groupings and this led to a canonical variate analysis for each assessment method exploring the potential degree of separation between the site clusters. Finally a generalised procrustes rotation determined a common configuration from the ECN and EU datasets, where the graphs show which sites are moved furthest for their individual configurations to achieve the common configuration, and this provides an indication of the sensitivity of the site configurations to the dataset used.

3. Results

3.1. Total Ecosystem Service Index

The 11 sites used in this study provide a wide geographical spread of mainland UK (Fig. 1). The TESI ranking of the provisioning, regulating and cultural services by the ECN and EU methodologies are similar for four of the sites (Cairngorm, Glensaugh, Drayton and Porton) but obvious differences are apparent at the other seven