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Further development of a spatial framework for mapping ecosystem services

Briefing paper 3 - Mapping ecosystem service valuations

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Contents

1 Approaches that support the valuation of ecosystem services 1

1.1 What is a "valuation" in the context of ecosystem services? 1

1.2 Concepts behind the valuation of ecosystem services 1

1.3 Mapping techniques 2

1.4 In which situations is it best to use benefit mapping techniques? 4

1.5 Examples of benefit mapping 5

1.6 Future considerations 6

1 Approaches that support the valuation of ecosystem services

1.1 What is a "valuation" in the context of ecosystem services?

Ecosystems deliver a broad range of services, some of which have associated environmental, economic and social values placed upon them by human beings. The UK NEA[1] regards ecosystem service 'goods' as those aspects which include all use and non-use, material and non-material outputs from ecosystems that have value for people. 'Benefits' are the direct and indirect outputs from ecosystems that include perceived cultural and spiritual experiences. They also have value in terms of human well-being and encompass a wide spectrum of benefits, for instance, health benefits from clean air and social benefits from recreation. Goods and benefits, therefore, can be either explicitly or implicitly given a value by society (either in monetary or social terms); assigning a value allows them to be more readily integrated with other information to inform decision making.

1.2 Concepts behind the valuation of ecosystem services

Valuation gives decision makers a more complete understanding of the range of benefits and costs arising from policy action. This includes valuation of some types of ecosystem goods and services that may not be taken into account in conventional decision-making (e.g. cultural benefits). As a result, the 'true' value of natural assets can be better accounted for. Locations which are most likely to be of value in some way can be identified. Valuation also helps identify the extent to which stakeholders depend on and impact upon ecosystem services, and can be used to identify the stakeholders who could contribute actions to benefit ecosystem service outputs. The 'winners' and 'losers' from any intervention can be identified and this, in turn, can inform compensation and incentive based policy actions, such as Payment for Ecosystem Services' (PES) schemes, which are market-based instruments that connect sellers of ecosystem services with buyers (e.g. for the restoration of species, carbon sequestration schemes). Alternative options can be examined, so that the best option is chosen.

In principle it is possible to value ecosystems in qualitative, quantitative or monetary terms[2].

Monetary valuation: a monetary value is placed on the impact, to translate quantitative evaluation into a single common currency to enable aggregation and comparison.

Quantitative assessment: describes the nature of the value in terms of the relevant quantitative information (e.g. estimated 25% decline in catch, for 24 fishermen from three villages etc.).

Qualitative valuation: describes the value and ideally indicates the relative scale of value (for example in terms of high, medium and low). The scaling needs to be relative in terms of all ecosystem services being assessed at a specific geographic level (e.g. site level, global etc.).

It is desirable to use a combination of these approaches[2] because not all benefits and costs can be quantified or given a financial value (e.g. cultural and spiritual costs and benefits).

[1] UK National Ecosystem Assessment, 2011. *UK National Ecosystem Assessment* [online] Available at: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx [Accessed 14th January 2013].
[2] WBCSD, 2011. *Guide to corporate ecosystem valuation: A framework for improving corporate decision-making* [online] Available at: http://www.wbcsd.org/Pages/EDocument/EDocumentDetails.aspx?ID=104 [Accessed 3rd September 2013].

Incorporating some qualitative value ensures all benefits and costs are given some weighting in analysis.

Commonly used valuation techniques derive from cost-based approaches (in cases where costs are readily determined) and techniques that use knowledge elicitation with stakeholders and benefit transfer methods (Table 1).

Table 1. Commonly used valuation techniques.

Cost-based approaches[1]	Rely on market costs to provide a proxy for the true value. The value of wetland flood control could be estimated from the cost of providing man-made flood control structures (replacement cost) or by estimating the cost of damage from predicted flood events (damage costs avoided). These approaches are well-suited to regulating services, and the costs readily determined.
Revealed preference techniques[1]	Rely on people's behaviour to reveal their preferences. This includes using market prices where they exist and estimating changes in yield associated with altered ecosystems. The value of visitor trips (travel cost method) and price premium associated with an environmental attribute (hedonic pricing) are methods used in this approach.
Stated preference techniques[1]	Involve questionnaire surveys that ask individuals about their preferences. Contingent valuation techniques ask individuals about their 'willingness to pay' to secure their desired environmental option. Choice experiments ask people to select their preferred option from costed alternatives. These techniques are good for valuing recreational visits and the only primary techniques available to estimate non-use values. Due to the potential bias involved expert involvement in their design is essential.
Value (or benefit) transfer	Uses value estimates that have been made in other settings and applies (or transfers) them, with adjustments to take account of any differences. Thus the benefit transfer method does not model the output of ecosystem service at the location directly, but directly infers their value by arguing that situations are somehow analogous. This can be relatively inexpensive and quick but must be applied carefully and transparently to avoid significant errors.

[2] *Source: Guide to Corporate Ecosystem Valuation. World Business Council for Sustainable Development*

1.3 Mapping techniques

Mapping ecosystem 'goods' in terms of describing their value relies on giving each area of land either an actual monetary value, an explicit quantitative value or an explicit qualitative value. The majority of ecosystem valuation studies use simple tailor-made spreadsheet models. Various web-based tools, data models and GIS based approaches have recently begun to be developed[3,4]. Mapping ecosystem valuations provides an indication of where ecosystem costs (e.g. risk of environmental degradation) and benefits are occurring and may reveal unexpected benefits and costs. Creating an inventory of ecosystem services within

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[3] BARTON, D. N., *et al*, 2012. Bayesian Networks in Environmental and Resource Management. *Integrated Environmental Assessment and Management*, **8(3)**: 418–429.
[4] McCANN, R., *et al*, 2006. Bayesian belief networks: applications in natural resource management. *Canadian Journal of Forest Research*, **36**: 3053-3062.

the area under consideration is a starting point to understanding the current situation and starts the processes of understanding how to value the services present. From this baseline, any tradable goods or public benefits can be revealed and valuation of these can begin to be explored. In order to represent the variations in the value spatially it is necessary first to undertake a 'benefit mapping' exercise using one of the techniques outlined in Table 2; these being the same techniques used for opportunity mapping.

Table 2. Supporting techniques to undertake a benefit mapping exercise.

Supporting techniques	Description
Overlay Mapping	Overlay analysis is one of the most basic, and well-established methods available in the GIS toolkit whereby as series of thematic layers are manipulated and analysed to create new spatial units. Overlay methods have been widely used to produce land suitability maps of different kinds.
Multi-criteria analysis (MCA)	MCA methods involve the use of explicit 'decision rules' that define the relationships between multiple inputs and outputs. They are more transparent about the assumptions on which the calculations are based and there are two broad sets of MCA approaches which include multi-attribute and multi-objective.
Artificial intelligence (AI)	AI methods are appropriate when dealing with complex problems using exploratory methods. Fuzzy logic and Bayesian methods[5] illustrate some of the features of the broad group of AI methods. Both methods depend on designing membership functions or rules in order to assign the variable states to classes; these rules or functions are often derived from previous experience or the elicitation of expert knowledge.
Participatory mapping methods	Participatory mapping methods reflect the belief that stakeholder involvement in making management decisions is essential if they are to be effective, and also that consultation is fundamentally part of 'good governance' as represented by the ecosystem approach. Mapping methods usually depend on some kind of knowledge elicitation with stakeholders.

Benefit mapping can be used:

- Where the value of an ecosystem 'good' or 'benefit' is being considered. It is viewed as a particular example of 'suitability mapping' in the sense that the aim is to identify which locations are most likely to be of value in some way to people. Such maps could be derived directly from those showing an ecosystem service where the service-benefit relationship is well established, but may also involve the combination of these data with additional constraints to predict spatial patters in value. For example, a habitat map might be used to identify the location of sites that, in biophysical terms, are capable of supplying a service such as recreation. To understand the particular benefits that these sites provide, however, may require information about their location in relation to where people live, the distance they are prepared to travel and/or how much they spend during a visit.

[5] HAINES-YOUNG, 2011. Exploring ecosystem service issues across diverse knowledge domains using Bayesian Belief Networks. *Progress in Physical Geography*, **35(5)**: 681-700.

- To analyse and map the 'multi-benefit' situation, where consideration of several ecosystem services provided by the same ecosystem is the requirement. 'Bundles' of benefits that might potentially be derived from a given area, and the synergies and trade-offs that might exist between them are assessed in this situation.

- Two examples of the tools which can be used within the techniques described in Table 2:

    - InVEST[6]: The InVEST tool quantifies, maps and values ecosystem service impacts using alternative resource scenarios and is most effectively used within a decision making process that starts with stakeholder consultations. The current tool uses modelling approaches to map ecosystem services and values based on underlying production functions and can be described in terms of a set of 'tiers'. The tool allows for simple economic valuation with a particular focus on direct and indirect market valuation and includes aspects like market price and avoided damages. Supplementary analysis, such as contingent valuations can be carried out to examine the InVEST output further.

    - ARIES[7] (ARtificial Intelligence for Ecosystem Services): The ARIES toolkit provides models that can be either parameterised by the user or automatically trained to extract the quantitative relationships between their inputs using machine learning techniques.

Benefit mapping may be accomplished by first using an ecosystem inventory calculation to model the output of an ecosystem service and then proceeding with a valuation exercise of some kind. Such studies often require detailed site specific information that is either unavailable or too expensive to collect. In these situations 'benefit transfer' methods might be used to undertake the mapping. An example might be 'contingent valuation' where a survey is made of people's willingness to pay for certain 'Goods'. Alternatively, choices are offered and people select the one that they are most happy with.

1.4 In which situations is it best to use benefit mapping techniques?

Benefit mapping identifies which locations are most likely to be of value in some way to people and in common with 'opportunity' mapping is well-suited to those situations where the intention is to:

- identify the changes in ecosystem service output; and
- determine where the best and worst place for action might be.

[6] Natural capital project (nd) *Integrated Valuation of Environmental Services and Tradeoffs*. [online] Available at: http://www.naturalcapitalproject.org/InVEST.html [Accessed 8th April 2013].
[7] The ARIES Consortium (2013) *ARIES: Artificial Intelligence for Ecosystem Services.* [online] Available at: http://www.ariesonline.org/ [Accessed 8th April 2013].

1.5 Examples of benefit mapping

The West Country Rivers Trust have demonstrated the importance of mapping the provision of ecosystem services at the catchment scale for five broad services[8] (provision of water quality, provision of water resources, provision of habitat and ecological networks, provision of recreation and regulation of climate gases). For each ecosystem service they have produced examples of catchment scale benefit maps and explained how these could be used to support specific ‘Payment for Ecosystem Services’ (PES) schemes with applicability at the catchment scale. These are market-based instruments that connect sellers of ecosystem services with buyers (e.g. for the restoration of species, carbon sequestration schemes).

When combined together the maps of these broad service areas reveal ‘multi-functional’ parcels of land that play a key role in the delivery of multiple benefits for ecosystem services. When combined with other maps, such as those depicting the current intensity of farming, areas of potential competing interest or conflict were identified, including areas where the provision of multiple ecosystem services are likely to be compromised. Such maps are of potential use for catchment management interventions to improve ecosystem function. Parts of the catchment that are not connected with the provision of wider ecosystem services are also identified; these are most likely to be suited to sustainable farming with limited impact on wider services and in these areas food, fuel and fibre should continue to be encouraged.

Artificial intelligence (AI) techniques have been used in research to represent the responses of land managers or communities as conditions change. A study in the Netherlands illustrated the use of artificial intelligence for modelling changes in land management and their impact on ecosystem services. The study used a typology of different ownership types to represent land managers. Each ownership type was assigned different propensities to act in certain ways (say in terms of diversification of farm operations, cease farming, or participate in various management programmes). The model was driven by a series of external factors relating to the biophysical and socioeconomic context of the area. The mapping generated showed how land management strategies (with their resulting consequences) varied across the study area. For example, mapped outputs included the percentage and average numbers of farms that are likely to participate in a policy to protect linear landscape features (Figure 2).

[8] West Country Rivers Trust (nd) *Tamar Plan Draft* [online] Available at: http://rivergateway.org.uk/catchments/Tamar/Tamar_Plan_121122_1st_Draft_ver_2-1.pdf [Accessed 26th September 2013].

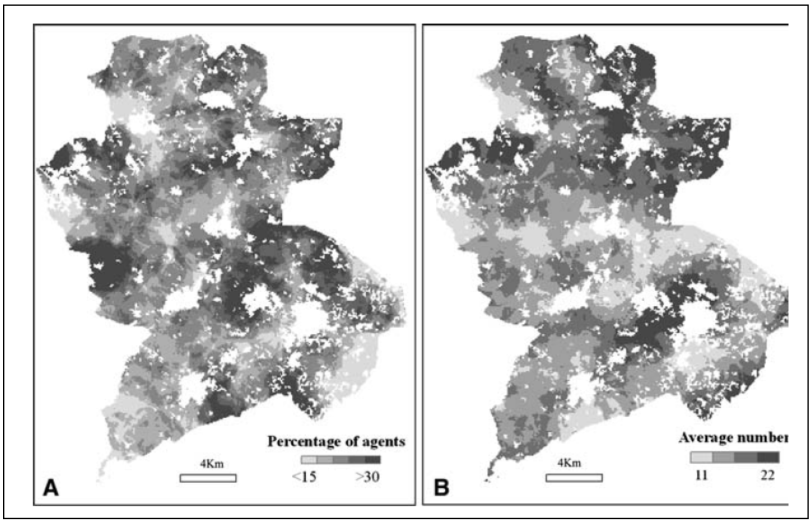

Figure 2. Likely uptake of policies to protect linear landscape features in the Netherlands.

This approach also has potential for assessing the applicability of PES schemes in a particular locality Agri-environment schemes, for example help recognise the value to the economy of historically undervalued services, such as hedgerows and other semi-natural habitats. They are also of value for planning biodiversity offsetting, where a developer takes account of any biodiversity loss associated with development by buying credits from a provider of equivalent biodiversity established elsewhere.

1.6 Future considerations

In terms of how the *Ecosystem Spatial Framework Database* can be used and developed, it is clear that conceptually it can most easily support work that seeks to adopt a production function approach, but with refinement it may also assist in benefit-transfer type studies. To do this it would be necessary to ensure that the services covered in the database were described in such a way that the valuations used in the wider literature could be linked to them.

In order to make use of the growing body of literature on valuation, the summarised benefit mapping approaches described here and in Haines-Young and Potschin (2013)[9] should use a standard typology of ecosystem services so that experience and examples gained in one area can be transferred to other places. The use of CICES in the current project will be helpful in this respect, but future work may be needed to understand better how it could be linked to the various valuation databases such as ENVI[10] that are now available. The problem here is that they do not index data by any specific habitat categories, but allow users simply to search for relevant studies using keywords. The habitat translation tools that are currently being developed may help ensure the more systematic use of these kinds of data for the application of benefit transfer methods.

[9] HAINES-YOUNG, R., POTSCHIN, M., 2013. *Multi-benefit and opportunity mapping: A Briefing paper*, Fabis Consulting. Nottingham.
[10] Environment Canada (nd) EVRI: Environmental Valuation Reference Inventory [online] Available at:https://www.evri.ca/Global/Home.aspx [Accessed 26th September 2013].