Ecosystem Tools Literature Review

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1. Introducing Ecosystem Tools

Ecosystem tools differ from the more generic tools within our typology in that they have incorporated ecosystem services and/or ecosystem assessments explicitly in order to capture and assess ecosystem benefits for policy and decision making. Thus ecosystem tools seek bring together evidence across the natural and social sciences with economic assessment to **integrate ecosystem services and the wider values of the natural environment within a context of practical decision- and policy-making** and tools assisting this leading to "a superior basis for future decision-making" (UK NEA, 2011a, p1303).

The range of benefits that society obtains from ecosystems is huge, yet largely has remained hidden, and their identification will reflect the inherent complexity of values systems across diverse yet interdependent stakeholder groups. Therefore, ecosystem benefits should identify both monetary and non-monetary assessments as their combined inclusion can radically alter the outcome of conventional economic analyses (UK NEA, 2011b, p42, 50; UK NEA, 2011a, p1303; Spash, 2008).

This review:

1. Unpacks 'ecosystems' and the general complexities that ecosystem tools have to grapple with.
2. Reviews the roots and rise of 'ecosystem services' in science and policy.
3. Reviews the development of influential and emerging ecosystem tools and methods that are used in policy and practice signposting the individual tool reviews that have been carried out as part of the TABLES project.
4. Identifies key issues that affect the use and potential misapplication of ecosystem tools in policy and practice.

2. 'Ecosystem' Vocabulary

Terms commonly found associated with ecosystem tools include 'ecosystem goods'[1], 'ecosystem services'[2], 'ecosystem (service) benefits'[3] and 'natural capital'[4] (e.g. TEEB, 2010; MEA, 2005; UK NEA

[1] Ecosystem goods are obtained from both ecosystems and non-living (abiotic) resources (e.g. Costanza *et al.* 2006, pii).

[2] Ecosystem services can be defined as "the direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010, p36).

[3] Ecosystem benefits (benefits provided by natural capital) include both goods (from ecosystems and abiotic sources) and services (associated mainly with provisions from ecosystems) (e.g. Costanza *et al.* 2006, pii).

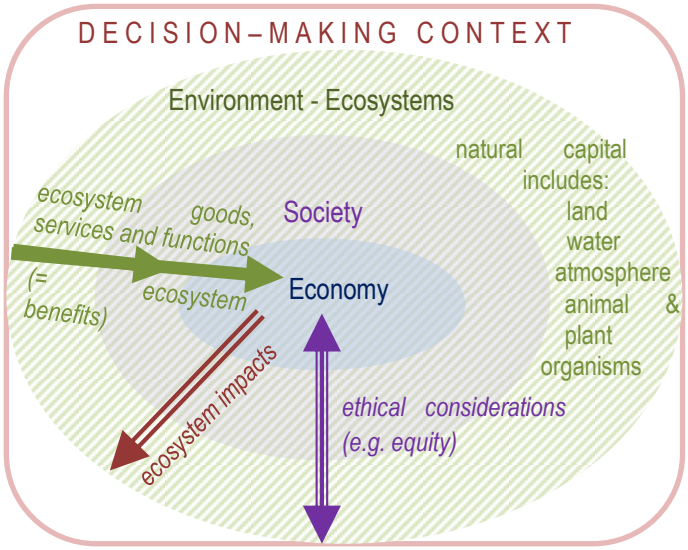
[4] Natural capital can be defined as "an economic metaphor for the limited stocks of physical and biological resources found on earth, and of the limited capacity of ecosystems to provide ecosystem services" (TEEB, 2010, p36).

2011a, b). They are often used interchangeably and uncritically set within the context of the goods and services of what nature provides and how this might be conceptualised within policy- and decision-making processes (e.g. Haines-Young and Potschin, 2009). These concepts form integral parts of the overarching ecosystem approach which is an holistic concept embracing social, economic and ethical dimensions (see Figure 1).

Figure 1: The Ecosystem Approach with its key components in the decision-making context

"… 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"

(Convention on Biological Diversity, COP 7 Decision VII/11)



Ecosystems[5] thinking has largely been informed by the natural and environmental sciences (cf. Defra 2007a, b). Concepts leading to modern understanding of ecosystem services have their roots in international development particularly as it affects people with livelihoods most directly linked to primary natural resources (see e.g. Pagiola *et al.* 2005; MEA, 2005; WRI *et al.* 2005). However, much of the more recent ecosystems assessment and valuation vocabulary has its roots in accounting or ecological economics (Spash, 2008; O'Neill, 2007). This is unsurprising as it reflects attempts to 're-couple' economic production and development with the environmental resource base (e.g. Ehrlich and Mooney 1983; Arrow et al. 1995) and more generally integrating social, economic and ecological knowledge in decision-making (see Spash 2012). Significantly, 'ecosystem' includes humans as an integral part of the system and as agents interacting with the biotic (animal and plant organisms) and abiotic (land - encompassing minerals and any geological resources, water, atmosphere) components (e.g. MEA, 2005; Scott *et al.*, in press).

For any given decision within a geographical area, the quantity and supply of ecosystem goods and services at any given moment in time depends on the underlying natural capital, which consists of the biotic and abiotic components of an ecosystem, their interactions and structure (e.g. Costanza and Daly 1992). Natural capital is, in this sense, the capacity of the natural system to deliver ecosystem goods and services now and into the future. It is therefore a measure of both current

[5] Ecosystems, or ecological systems, can be defined as "a dynamic complex of plant, animal, and microorganism communities and their nonliving environment, all interacting as a functional unit" (Costanza *et al.* 2006, pii).

capacity and future potential. Natural systems deliver ecosystem goods and services through the processes and properties that constitute these systems (e.g. Daily 1997). The UN's Millennium Ecosystem Assessment (MEA, 2005), a global scale of the status and trends of the planet's major habitat types and the prognosis for human wellbeing based on ecosystem service production, highlighted this direct linkage between natural capital and services. **The tools that assess and quantify ecosystem goods, services and functions need to capture and reflect these underlying natural processes and properties**. This is not a trivial exercise, for the following reasons:

1. **Complexity – Ignorance, uncertainty and incomplete data**. Natural systems are complex, and our understanding of their functioning (e.g. climate) is imperfect (see e.g. Funtowicz and Ravetz 1994; Funtowicz *et al.* 1999; Holling 2001; Spash 2002). Many things we do not know or are unaware of (ignorance), others we do not fully understand or know how they plan out (uncertainty) (see e.g. Munda, 2000). Even if we were to fully capture the complexity of natural processes in a model, or tool, applying this locally requires accurate, current information on the state of the system (e.g. soil conditions, vegetation type and coverage, species composition, etc.). This is rarely available and **therefore makes an accurate assessment of the current state of delivery of ecosystem goods and services difficult and uncertain** (e.g. Giampietro 2002; UK NEA 2011a, b).
2. **Multiple spatial and temporal scales**. Natural systems have intrinsic scales of operation. These are not necessarily the scales at which management interventions occur at (time) or over (space) (Risbey *et al.*, 1999; Giampietro and Ramos-Martin, 1995; UK NEA, 2011a, b). Moreover, the point or scale at which the service is created (e.g. a field of winter wheat crop) is very rarely the scale at which it is consumed (city/nationally) (Pagella, 2011). With global trade and modern technologies the supply of ecosystem goods and services has been heavily modified, increasing exploitation, interlinkages and potential future vulnerabilities, relating to natural ecosystem **capacities** and **thresholds** transgressions (Holling, 1986; Kasperson and Kasperson, 2001; Spash, 2002). Like natural systems, disciplinary approaches and tools also have operational scales (e.g. Gibson *et al.*, 2000), which again can be different to the production scale and consumption scale (e.g. a GIS layer with polygons reflecting biodiversity, their scale is often operationally defined).
3. **Interactions and dependencies**. Any given ecosystem will, at a given point in time and at any given location in space, supply numerous ecosystem functions with complex interactions (Pagella, 2011). The consequences of interactions between the ecosystem functions, both in terms of the spatial and temporal 'inputs' of environmental properties and processes and also the 'outcomes' will be of particular significance to understanding the **resilience** of ecosystem functions and consequently sustainable social and economic development (e.g. Berkes *et al.*, 2002; Folke, 2006; Holling, 1986; TEEB, 2010).
4. The **interdependence on human use of natural resources with their long-term vitality** (MEA, 2005; UK NEA, 2011a, b).

Considerably more effort has been spent on classifying and assessing terrestrial ecosystems compared with coastal and marine ecosystems (e.g. Medcalf *et al.*, 2012). Ecosystem services entailing freshwater (e.g. flood control, the provision of hydropower, and water supply), on the other hand, have received the greatest attention in both scientific, management and policy terms.

3. The Rise of Ecosystem Services Tools in Science and Policy

The use of 'ecosystem services' has dominated the development of ecosystem tools in science, policy and environmental activism. However, it is prone to different underlying understandings and applications (Daily *et al.*, 2009; Dempsey and Robertson, 2012). Indeed, the focus on ecosystem services is a simplification from the more complex original conceptualisation that included ecosystem goods and functions (e.g. de Groot *et al.*, 2002; MEA, 2005). The Millennium Ecosystem Assessment (2005) conceptualisation of ecosystem services integrates the multiple values that ecosystems provide to all sectors of society, and by implications their equally diverse value systems. Thus, systemic analysis of the outcomes of development schemes or management decisions using the framework of ecosystem services can reveal the range of consequent benefits and disbenefits, and the distribution of the gains and costs across societal sectors. Ecosystem services are therefore being increasingly used proactively to appraise options or innovate new solutions that 'optimise' the cumulative benefit to all in society, set within longer-term effects and consideration of the needs of future generations (Everard and Scott (under review).

However, the inherent complexity of ecosystem services and their interdependencies with abiotic and biotic factors means that often **highly simplified tools are used to take account of ecosystem services in policy- and decision-making**. Such uncritical and "quick and dirty" use of ecosystem services in theory and practice has led to some commentators claiming that the resultant tools are potentially misleading resulting in perverse policy goals (e.g. Norgaard, 2010; Spash, 2008). Commonly found simplifications in ecosystem services assessments include:

i. Only specific services are picked and considered in isolation of the wider context and complex interactions (see e.g. Bennett *et al.*, 2009; TEEB, 2010);
ii. They are considered as linear functions, ignoring thresholds and complex non-linear realities where a relatively small additional change or loss may signify the collapse or dramatic change of a system (see e.g. Haines-Young and Potschin, 2010; MEA, 2003);
iii. Data used are often averages (sometimes not even derived from the area but 'transferred' from elsewhere, time and spatial scales are also important here) rather than actuals showing the range of actual data and considering associated implications (e.g. MEA, 2003).
iv. The commodification and financialisation of nature, where its elements are subjected to a simple exchange value (e.g. Kosoy and Corbera, 2010; Vatn, 2000, O'Neill, 2001; 2011)

The understanding and application of ecosystem services, ecosystem benefits and natural capital, more generally, is important and often overlooked. Depending on the disciplinary or policy 'lens', definitions vary considerably. For example Boyd and Banzhaf (2006) offer a very narrow definition of ecosystem services as "components of nature, directly enjoyed, consumed, or used to yield human well-being" (*ibid*, p.8). Such tightly determined services are typical for neoclassical economic approaches, including cost-benefit analysis (CBA) studies. In those situations the broader picture of the ecosystem approach has been lost. TEEB (2010), presents a wider interpretation, recognising and accounting for externalities, value plurality and governance considerations explicitly. Thus embracing the widest possible set of natural assets (processes and services including goods) in policy- and decision-making and **through entering into new kinds of ecosystem-based accounting, trading and incentive schemes.**

The Economics of Ecosystems and Biodiversity **(TEEB)** study merits particular attention here through its landmark report (TEEB, 2010) to "highlight and illustrate the approach adopted by TEEB: namely to show how economic concepts and tools can help equip society with the means to incorporate the values of nature into decision making at all levels" (*ibid*, p.3). Key contributions to shaping tool development have been through:

i. exploring the relationship between biodiversity and ecosystem services;
ii. testing applications across important environmental, social and economic domains (forests, cities, mining respectively);
iii. highlighting the significance of indirect use values of ecosystems that are largely "invisible" in assessment and accounting endeavours (*ibid*, p.8);
iv. advocating the embedding of value diversity and consideration of trade-offs in policy and decision-making (*ibid*, p.11); and
v. explicitly acknowledging uncertainty and tipping points/thresholds through advocating precautionary approaches or safe minimum standards (*ibid*, p.12).

A further significant contribution to our research is **TEEB's 3-step framework to inform decision-making,** where the first step would be universally applicable and the other two steps depend on the specific context (TEEB, 2010, p. 13):

> "**Step 1:** For each decision **IDENTIFY and ASSESS the full range of ecosystem services affected** and the implications for different groups in society. Consider, and take steps to involve, the full range of stakeholders influencing and/or benefiting from the affected ecosystem services and biodiversity.
>
> **Step 2**: **ESTIMATE and DEMONSTRATE the value of ecosystem services**, using appropriate methods. Analyze the linkages over scale and time that affect when and where the costs and benefits of particular uses of biodiversity and ecosystems are realized […].
>
> **Step 3**: **CAPTURE the value of ecosystem services and seek SOLUTIONS to overcome their undervaluation,** using economically informed policy instruments. Tools may include changes in subsidies and fiscal incentives, payments for ecosystem services, […] eco-labelling and certification [...]."

In the following sections we consider international and UK efforts of embedding the ecosystem approach in policy- and decision-making and specific tools that have been designed around particular ecosystems or for mapping, assessing and valuing ecosystem services.

4. Review of Specific Ecosystem Tools

There are several mechanisms which exist in their own right for implementing the ecosystem approach although some cross into other categories of our tools typology, especially the tools classified as 'Levers' (e.g. **Payment for Ecosystem Services** has a valuation component). Some ecosystem tools are developed for use by (natural and/or social science) experts to support specific decisions, with some being highly sophisticated and expert-dependent (e.g. **ARIES, MIMES),** whereas others take a broad brush "quick and dirty" approach with some specialist input but are more easily used and understood by non-specialists (e.g. **National Character Areas, Asset Check, InVEST, LEDE**).

Finally, there are tools that aim to stimulate ecosystem thinking across a wide range of professionals and citizens more generally (e.g. **Ecosystem Assessment).**

4.1 International scale ecosystem assessment

The **Millennium Ecosystem Assessment** (2005) conceptual framework distinguished between four categories of services – provisioning, regulating, cultural and supporting and still remains the most widely recognised and applied framework (e.g. Defra, 2007a; Haines-Young and Potschin, 2009; Welsh Assembly Government, 2012). For example, Defra adopted this classification (Defra 2007a, b; Defra, 2010a, b) and the UK National Ecosystem Assessment (UK NEA, 2011a, b) used this framework but in addition distinguished between whether services were 'final' or 'intermediate processes/services' (see Figure 2). Using the same framework potentially facilitates cross-comparison between different assessments and areas, although in practice the actual definition and measurement of specific services have tended to differ substantially between applications (Haines-Young and Potschin, 2011). Inconsistencies can also arise from difficulties in distinguishing between different categories of services and delineating between specific functions and services because of the manifold interrelations and interdependencies, in addition to variations in context, including geographical and temporal scales (MEA, 2003; Haines-Young and Potschin, 2011).

Figure 2: Ecosystem services classification used by the UK National Ecosystem Assessment (Source: UK NEA 2011b, p.17)

Table 2.2 Ecosystem services in the UK NEA classified according to both ecosystem service type (provisioning, regulating, cultural and supporting) and whether or not they are final ecosystem services or intermediate services and/or processes. For each final ecosystem service an example of the good(s) it delivers is provided in italics.

Ecosystem processes/intermediate services		Final ecosystem services (*example of goods*)	
Supporting services	• Primary production • Soil formation • Nutrient cycling • Water cycling	**Provisioning services**	• Crops, livestock, fish (*food*) • Trees, standing vegetation, peat (*fibre, energy, carbon sequestration*) • Water supply (*domestic and industrial water*) • Wild species diversity (*bioprospecting, medicinal plants*)
• Decomposition • Weathering • Climate regulation • Pollination • Disease and pest regulation • Ecological interactions • Evolutionary processes • Wild species diversity		**Cultural services**	• Wild species diversity (*recreation*) • Environmental settings (*recreation, tourism, spiritual/religious*)
		Regulating services	• Climate regulation (*equable climate*) • Pollination • Detoxification and purification in soils, air and water (*pollution control*) • Hazard regulation (*erosion control, flood control*) • Noise regulation (*noise control*) • Disease and pest regulation (*disease and pest control*)

4.2 National scale ecosystem assessment

At a national level, **research** commissioned by **Defra** (e.g. Haines-Young and Potschin 2008; Potschin *et al.*, 2011; Smart *et al.*, 2012) and several of their **guidance documents** (e.g. 2007a, b; 2010a, b) influence how the ecosystem approach is being embedded in the UK, and particularly England. Concerning the development of ecosystem tools, the existence of three complementary, yet distinctive, perspectives have been identified on assessing ecosystem services, namely the habitats perspective (identifies the distinct role of habitats to ecosystem services provision and their multifunctional characteristics); services perspective (linking ecosystem services directly to societal

benefits / opportunities and problems) and place based perspective (particularly relevant to the Government's Localism agenda and considering the health and future development of specific geographical areas and how this affects human wellbeing and place-making) (cf. Haines-Young and Potschin, 2008). **These perspectives are directly relevant to new policy instruments associated with the National Policy Planning Framework (Neighbourhood Development Planning; Local Enterprise Partnerships) and the Government Environment White Paper (Nature Improvement Areas; Local Nature Partnerships) and influence the characteristics and range of different ecosystem tools**. The Defra Report by Smart *et al.* (2012) highlights the potential user needs associated with these new policy instruments as well as more generally as:

i. The need for providing data about conservation designation, species and habitats at a range of spatial scales, and particularly the fine-grained spatial resolution (e.g. in the form of maps and exportable data sets).
ii. The need for information about different drivers (e.g. land use, climate change) and their possible future impacts (especially on biodiversity and the distribution and quality of habitats)
iii. The need for land-use planning decision-support tools to assist in identifying and balancing competing demands (e.g. help identify potential win-win options between social, environmental and economic interests). (*ibid*, p.4)

In terms of requirements for the development of **spatial decision-support tools**, Smart et al. (2012, pp. 4-5) identify as the main constraints "data availability and matching tool developments to user's current and longer term needs", identifying five requirements:

i. Increasing data and knowledge availability (e.g. new up-to-date datasets)
ii. Clearly matching tools to users' needs (including considering amending existing tools to creating new tools)
iii. Disseminating the results of complex multi-scale analyses in a user-friendly way
iv. Adding to existing functionality (e.g. bespoke or widely compatible 'add-ins')
v. Progressing complex ecosystem services analysis and impacts modelling (cross-sector; cross-scale relationships; trade-offs) drawing on local knowledge and interdisciplinary research.

Despite the barriers to assessing specific ecosystems and ecosystem services, the **UK National Ecosystem Assessment** represented the first national attempt worldwide to do so (UK NEA 2011). It assessed the status and trends of the UK's ecosystems and the services they provide at multiple spatial scales identifying key drivers of change and testing their impacts using plausible future scenarios. This then enabled considering policy and/or societal response options to secure (maintain or improve) the delivery of ecosystem services into the future. A large part of the assessment specifically focused on identifying and, as far as possible, quantifying the value of ecosystem services' contribution to human well-being through both economic and noneconomic analyses. The UK NEA divided the economic analyses for ecosystem services assessment into two types: (i) sustainability analyses, assessing stocks of natural assets; and (ii) programme evaluation analyses, seeking to determine the value of the flow of services provided by these natural assets. Both types of analyses were found useful, the former to inform macro-level policy, and the latter to support economic calculations of Payment for Ecosystem Services (UK NEA, 2011b, p. 1071).

4.3 Ecosystem tools that operate as levers

Payment for Ecosystem Services (PES) is a market-based approach based on the creation of markets linking the 'suppliers' of ecosystem services with their 'users' or 'consumers'. Some services (mainly provisioning services) are already traded, however, most are external to today's market, yet are crucial to society (e.g. pollination and nutrient cycling) and therefore considerable potential exists for the creation of markets for more effective incorporation into decision-making and protection. The OECD estimated the existence of over 300 PES initiatives worldwide in 2010 (Defra, 2010). In all cases, for an economic transaction to be considered a PES, it must consist of a *voluntary* contract; payments *conditional* on achieving service enhancement of protection (i.e. agreed action/outcome); be *additional* to basic regulatory requirements and not displace detrimental activities elsewhere (known as *leakage*). The tool is criticised by some for focusing on a single ecosystem service; loss of consideration of multiple values by adopting a single exchange value; and possibly creating power imbalances that create or prolong inequalities (Kosoy and Corbera, 2010; Spash,2008).

4.4 Broad-brush ecosystem tools for decision support

To assist the need for ecosystem tools to be accessible and usable by a wide range of decision-makers and other actors, visual representation techniques (e.g. geographic information systems) are commonly used to map natural capital assets / ecosystem services. Sometimes this is coupled with an evaluation of their economic value through **ecosystem assessments** or **asset checks**. Haines-Young and Potschin (2009: 37) explain that "most of the published assessments approach the problem [of identifying services] by attempting **to map services, their flows and the external pressures upon them**". Essentially, mapping forms a core focus of many current attempts to identify particular ecosystem services within an area (see e.g. Lovell, 2010; Medcalf *et al.*, 2012; SCAAN, 2012). Such visual support tools have proved relatively successful in breaking down barriers between experts and the public, creating relatively easy to use and understand interfaces for assessing (and sometimes also valuing) ecosystem services and benefits (e.g. Sussex Biodiversity Partnership & Sussex Wildlife Trust, 2012). For instance, Maes *et al.* (2011a) promote the mapping of the services and consequent quantification and valuation, with the aim to forming "an economic argument to protect biodiversity" (p. 11). This approach has been implemented by a variety of organisations and authorities throughout the UK (see e.g. e.g. (e.g. Bridgend County Council[6]) Hölzinger, 2011; Pape and Johnston, 2011).

Medcalf *et al.* (2012) provide a general guide for the implementation of spatial mapping for ecosystem services; acting as a best practice guide and outlining the benefits of adopting such a strategy. Furthermore, the Ecosystem Knowledge Network (2012) has been holding events to promote the tool which they see as "in principle, the process of mapping ecosystem services allows decision makers to express how those services are delivered in particular places" (http://ekn.defra.gov.uk/).

Ecosystem services assessments at the local or landscape scale are being adopted by local councils in relation to green infrastructure planning for example, and as part of 'geographical' units such as a valley or Area of Outstanding Natural Beauty or National Park. **The Gaywood Valley project**, as part of a EU Interreg Project, carried out a broad-brush ecosystems services assessment to inform their vision for a multiple use and beneficial green space development/management plan on the fringe of

[6] See e.g. http://www.youtube.com/watch?v=YpMuLTuo2kg

the King's Lynn to create environmental, social and economic benefits. Stakeholder involvement from the beginning and throughout the project to inform decisions has formed a crucial part of this project and its successful outcomes to date (*ibid*). Similarly, **Birmingham City Council** undertook an ecosystem services assessment of its Green Infrastructure to inform its future development strategy (Hoelzinger, 2011).

National Character Areas (NCAs) are a decision support tool to help develop strategic thinking about landscape, biodiversity, geodiversity and landscape change within an ecosystem services framework (Natural England, 2012). The NCAs tool builds directly on Landscape Character Areas and Joint Character Areas work that informed landscape policy approaches at the turn of the century.

Using a template it allows layers of environmental evidence to be built up across 159 identified NCAs with each profile condensing data (including ecosystem service data and analysis) to identify key environmental opportunities. It is noteworthy that the data analysis pays explicit attention to cultural services in their distinctive forms. The process is bespoke and undertaken by Natural England staff using available evidence and then making assessments with justifications.

In terms of decision-support tools based on modelling two broad types exist: (semi-)empirical approaches which aim to represent the underlying processes to some degree (e.g. **InVEST, Polyscapes**) which are outlined next and expert knowledge based approaches (e.g. **ARIES, MIMES**) which are discussed in the following section.

Modelling individual ecosystem functions is not a novel exercise and there are countless models of functions in the scientific literature. For example, water regulation and water movement can be described by a myriad of hydrological models such as SWAT, INCA, TOPmodel, SHE (Vigerstol and Aukema, 2011; Corstanje, 2012). There are also a significant number of soil process models that describe nutrients, soil formation and indirectly climate regulation through carbon sequestration, such as CENTURY, ROTHC (Corstanje, 2012). These models can be captured in a Geographic Information System (GIS) environment and their outputs aggregated (i.e. some weighted averaging or addition of the different services for a given area; e.g. carbon sequestration + water storage + biodiversity) to generate an assessment of the current state of ecosystem services delivery. In this same environment, different scenarios can then be introduced to assess the impact of decision-making or climate change.

InVEST is a GIS based joint project funded by WWF, the Nature Conservancy, and Stanford University that uses land use/cover patterns to estimate levels and economic values of multiple ecosystem services, biodiversity conservation, and the market value of the commodities provided by the landscape (Nelson *et al.*, 2009). Advantages of this type of modelling environment is that it is generally based on the 'physical principals' of how the system operates, and therefore there is a clear underlying scientific basis to the ecosystem services assessment. The outcomes are therefore more 'defensible' if challenged under policymaking or decision making processes. The outcomes are also easier to explain, and where the tool fails, diagnostics (what natural process did we fail to capture? what data are we missing?) are easier to apply. The disadvantage of this type of modelling approach is that detailed representations of natural systems require detailed knowledge and ample data on the state and dynamics of the natural system in the area of interest. As this is rarely available, the underlying process models are often simplified into functional models which tend to be more operationally defined. They are simpler models, derived to obtain a process outcome as

simply and as efficiently as possible. This often functions effectively but loses somewhat on scientific rigour (Corstanje, 2012).

The Local Economic Development and Environment (**LEDE**) tool is another 'specialist' tool designed to embed ecosystem thinking within Local Enterprise Partnerships project[7] to assist strategic decision-making for economic development (Sunderland 2012). The tool only requires economic expertise but also demands the ability of establishing and assessing the linkages between specific ecosystem services and proposed developments. The tool is built around gross value added (GVA) targets, i.e. an existing economic technique which uses market values and designed to work at a particular scale, namely economic areas. However, in addition to its economic perspective, LEDE encourages a more holistic lens through including perspectives from the environmental and health sectors. LEDE is undergoing a stage 2 pilot project in East Anglia in 2012-2013 as part of a wider green strategy.

4.5 Sophisticated ecosystem tools for decision support

In many cases, collecting, collating and combining data and processes over diverse ecosystems is not a cost-effective or practical approach. The alternative is to survey experts in the particular ecosystems and collate their knowledge on this system. This can then be represented in a GIS environment for decision-making. Representation of this expert knowledge can still be within a 'cause-effect' modelling framework, where a statistical modelling environment is in all likelihood the most effective way to represent the 'expert opinion' on the factors and controls which determine the supply of ecosystem goods and services within given areas. Such expert knowledge based modelling approaches include **ARIES** and **MIMES**. The advantage of such approach is that it can be based on sparse data and relatively simple models, and therefore can readily give estimates of ecosystem goods and services delivery in most situations. The disadvantage of this approach, however, is that it is ultimately based on opinion, and therefore is less scientifically robust (or can be perceived to be less robust). A second limitation to this method is that every time a new factor needs to be considered (e.g. climate change, planning changes), unless these have been considered in the original expert knowledge elucidation, a follow-up has to be executed. Current, state of the art, approaches, is to capture the expert opinion is a 'belief network', which graphically represents the relationships between the drivers and supply of Ecosystem Goods and Services but underlying this is a probabilistic environment which can supply some of the computation and numerical rigor which is usually associated with empirical models.

Expert-based mapping and modelling approaches (such as ARIES and MIMES) have been criticised for restricting accessibility and use (Vigerstol and Aukema, 2011). In response, some attempts are underway to alter data so that it is more accessible to the public and those without such software: configuring not only the data, but the interface in which it is created (cf. CCW, *circa* 2010; Raudsepp-Hearne *et al.,* 2010). Medcalf *et al*.'s (2012) reason for pursuing the guide for mapping ecosystem services was to shed light on the process and output of the mapping tool so that policy-makers and other users can understand the processes involved with this technique. Maes *et al.* (2011b) identify a further shortfall arguing that when mapping is completed and converted into an approachable

[7] The tool has been developed as a collaborative effort between Natural England, the Environment Agency, DEFRA and the Forestry Commission and several Local Enterprise Partnerships (LEPs).

format, the end result tends to focus on provisioning services and that data on other services, goods or functions (e.g. cultural services) are lacking.

On a national (devolved) level, the newly created **Natural Resources Wales** (NRW)has devised a framework for embedding the ecosystem approach within its policy and decision-making remit, encouraging staff to consider the concept within their working operations (NRW, *circa* 2012). The proposed approach sets out seven ways in which the ecosystem approach should be applied (adapted from: NRW, draft 2012):

- **Integrative** – it should be integrated with existing decision-making.
- **Timely** – it should be engaged early in the decision-making process.
- **Participative** – the process should involve multiple stakeholders.
- **Visionary** – The use of the approach should be ambitious (but realistic).
- **Iterative and Adaptable** – The approach employed should be constantly reviewed and adapted.
- **Outcome Driven** – Providing environmental benefits above all.
- **Risk Based** – The environment should be taken into account.

5. Conclusion

Research and tools relating to implementing the ecosystem approach in the form of assessing and valuing ecosystems services have been heavily influenced by (i) ecological economics and environmental accounting on the one hand and (ii) resource mapping and/or modelling land use / environmental change and impacts on the other hand. There is a danger of oversimplifying and regarding ecosystem services merely as new 'goods' to trade or isolated features or commodities to map. To successfully use the ecosystems services framework within its overarching concept ('the ecosystem approach') ecosystem services need to be defined heuristically and become a 'new lens' through which to view and proceed with policy and decision-making. Significantly, there are signs of some ecosystem tools emerging that systematically attempt to assess ecosystem functions and benefits across the full spectrum of services rather than doing so on a fragmented service-by-service basis (e.g. ARIES; MIMES; ecosystem assessments). This is a crucial point as many tools previously have addressed services but have done so in isolation with negative outcomes for other services and/or system resilience and integrity (e.g. flood defence projects in certain area without considering the whole range of services and the whole system affected). Using the term 'ecosystem tools' signals that the whole system needs to be / is being considered to the best knowledge and abilities.

> "The challenge we face is to make the ecosystem services framework credible, replicable, scalable, and sustainable. There are many hurdles [… and] scientific challenges for ecologists, economists, and other social scientists, in understanding how human actions affect ecosystems, the provision of ecosystem services, and the value of those services. At least as difficult are the social and political questions associated with incorporating this understanding into decision making. We must design effective and enduring institutions to manage, monitor, and provide incentives that reflect the social values of ecosystem services." (Daily *et al.*, 2009, p.27)

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