Principles of ecosystems accounting

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C) Hedonic pricing methods

D) Averting / defensive expenditures

E) Travel cost and associated methods

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1. Introduction

In December 2012, the Office for National Statistics (ONS) published a Roadmap, Accounting for the value of nature in the UK, which set out a strategy to incorporate natural capital into UK Environmental accounts by 2020. The Roadmap includes the development of a number of ecosystem accounts based around the eight broad habitats set out in the UK National Ecosystem Assessment. This paper sets out the basic principles to be followed when developing these ecosystems accounts (rather than the broader concept of Natural Capital Accounts (see below). The aim is to establish a number of key approaches before significant further development work on the accounts is completed, and to identify those issues on which a methodological principle cannot be established in advance of further analytical and development work. In this sense the paper is a live document which will be periodically revised as progress is made.

Within each section the rationale and issues are only described in relatively brief terms. However references to the UN guidance on experimental ecosystems accounts and other references are given in each section in case a fuller discussion is sought. SEEA Ecosystem Accounting provides a comprehensive glossary of terms, and we adopt the same definitions unless otherwise indicated.

Within each section the main conclusions are recorded either as ‘Principles’ (numbered as Px.x) or as ‘Actions’ (numbered as Ax.x). These are collated into two lists in the final section, establishing those principles which we think can now be adopted and those areas where more work is needed.

2. Ecosystems accounting within the framework of Natural Capital Accounting

In this paper we emphasise the measurement of ecosystems and ecosystem services. Natural Capital Accounting is seen as having a broader compass, including other elements of environmental accounting covered by the SEEA Central Framework such as subsoil assets and fossil fuels.

A) Treatment of subsoil assets

The Natural Capital Committee has established a categorisation of natural capital assets, not all of which are covered by ecosystems accounts:

- NCA assets covered by ecosystems accounts include species, ecological communities, soils, rivers and land

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1 The Roadmap and related documents on natural capital accounting can be found at http://www.ons.gov.uk/ons/guide-method/user-guidance/natural-capital/index.html


NCA assets not covered by ecosystems accounts include atmosphere, minerals, subsoil assets and oceans.

The main issue arising from this division is the treatment of subsoil assets within the marine ecosystem accounts. For the purposes of this project, **Subsoil assets are not part of the ecosystem accounts (P2.1)** although we recognise that the process of exploration and extraction will have impacts upon the ecosystem.

**B) Relationship of ecosystem accounts to cross-cutting accounts** (SEEA Para 4.56)

In general the elements of the individual accounts (water, land, carbon, etc.) will provide the basis for the cross-cutting accounts. For example, estimates of carbon in standing timber, woodland soils and peatland could be used to populate the relevant elements of the carbon account. However, it should be noted that the carbon accounts include stocks of carbon in sub-soil assets (as distinct from flows of carbon sequestration), which goes beyond the ecosystem accounts and may involve different valuations of those stocks. **The valuation of subsoil carbon should be reviewed within the context of wider Natural Capital Accounting (A2.1).**

**C) Relationship of ecosystem accounts to aggregate estimates of UK natural capital**

In May 2014, and as part of the Roadmap, the ONS published [*UK Natural Capital - initial and partial monetary estimates*](#), which set out some experimental methods to estimate the value of a selected number of natural capital assets. Those estimates provide an initial overview of the possible value of certain components of natural capital but they also highlight the importance of developing physical, more detailed and spatially disaggregated ecosystem-based accounts. As ecosystem accounts are developed we would expect to see growing convergence and integration with “top-down” accounting approaches.

### 3. Basic spatial units for ecosystems accounting (SEEA Section 2.3.2)

The SEEA sets out three types of spatial units to be used in the development of ecosystems accounts. The basic spatial unit (BSU) is the smallest unit from which the other units are compiled. In principle a BSU can be any shape: grid squares or variably shaped polygons. The type of BSU used depends on the source data and information being sought. Grid square BSUs are typically used for remotely sensed data (e.g. satellite, air photos, radar) on the physical environment, and can be at any level of resolution, from 10 metre squares up to say 100 hectare blocks. Grid based BSU’s should be of the same size, so that they can be aggregated consistently. However the level of resolution may vary depending upon the homogeneity of the land cover type being measured. Data for grid based BSUs from remote sensing is known as raster data.

Variably shaped polygons can also form the basis of BSUs, for example BSUs based on the cadastre. While these are irregularly shaped and sized, BSUs based on the cadastre can be related directly to
the owners or managers of areas, and hence linked to land use and other information that help to determine the benefits and beneficiaries of ecosystems services.

Each BSU will have certain characteristics attributed to it, such as land cover, soil type, elevation etc., for raster data; while ownership, zoning, valuation (e.g. for land tax), presence of residence, agricultural production, etc., may be available from other sources (e.g. the cadastre).

Data from raster and cadastre based BSUs may be combined at high levels of aggregation. This is usually necessary as it is likely that some combination of the land use and land cover will be required, based on land cover maps built from raster based BSUs and integrated with other sources such as the Agricultural Census and the Forest Inventory. The cadastre has been the bridge between land cover and land use in the work completed in Australia.\(^4\)

In the first instance, ecosystem accounts should be constructed around the comprehensive and mutually exclusive categories of the Land Cover Map (LCM) applied to raster based BSUs. However, where there is more detailed and relevant data available on land use, such as the Forest Inventory, this should be used instead, with the results reconciled with the LCM at higher levels of aggregation (P3.1).

The SEEA recognises that coastal and marine ecosystems are especially problematic: delineation of rivers and flood plains, and how best to record linear features and varying depths of aquatic ecosystems, are matters which are unresolved and have as a result been included in the UN research agenda (SEEA Para 2.81).\(^5\) Further work on coastal and marine ecosystems, and on linear and point features, is required before their treatment in the accounts can be resolved (A3.1).

4. Land cover ecosystem units (LCEUs) (SEEA Section 2.3.3)

LCEUs combine contiguous sets of BSUs into those having the same characteristics, based on the predominant characteristics within each BSU. Characteristics are typically based on land cover type, which in many cases also provides information on the degree of human intervention (e.g. enclosed farmland) or altitude (e.g. mountain moorland). This perspective was adopted in the UK Roadmap which aimed to build the accounts on an underlying land cover account, working through the broad habitat categories used in the UK National Ecosystem Assessment (NEA). It follows that for UK purposes the LCEU represents the geographical coverage of the account for each ‘ecosystem’: together they should cover the whole of the UK and should be mutually exclusive although the extent of each may change over time.

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5 Open water and marine habitats can also be viewed as providing carrier services. The SEEA notes that the environment provides the space in areas of land and water for economic and other human activities (SEEA 2.28). These are viewed as abiotic services, in the sense that they do not arise as a result of biophysical processes and other interactions within and between ecosystems. However, freshwater and potentially marine navigation is dependent upon ecosystems functioning well and can therefore arguably be included within the list of key services provided by those ecosystems.
The classification of LCEUs was left open in the Roadmap, which recognised that the broad habitats used in the NEA might need to be adapted to reflect the diversity of land cover and range of services within each category. One possibility is to adopt the LCM categorisation which gives 20 categories and can be mapped to the standard EEA CORINE classification. This option needs revisiting in the light of ongoing ONS scoping work on land cover accounts and plans for future LCMs and Countryside Surveys being developed within Defra.

Table 1 Mapping of Land Cover Map classes to UK NEA broad habitats

<table>
<thead>
<tr>
<th>LCM 2007 class</th>
<th>UK NEA class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaved Woodland; Coniferous Woodland</td>
<td>Woodlands</td>
</tr>
<tr>
<td>Arable and Horticulture; Improved Grassland</td>
<td>Enclosed farmland</td>
</tr>
<tr>
<td>Rough Grassland; Neutral Grassland; Acid Grassland; Calcareous Grassland</td>
<td>Semi-natural grassland</td>
</tr>
<tr>
<td>Fen, Marsh and Swamp; Bog; Freshwater</td>
<td>Open water, wetlands, floodplains</td>
</tr>
<tr>
<td>Heather; Heather grassland; Montane Habitats; Inland Rock</td>
<td>Mountains moorland heaths</td>
</tr>
<tr>
<td>Supra-littoral rock; Supra-littoral Sediment; Saltmarsh</td>
<td>Coastal margins</td>
</tr>
<tr>
<td>Littoral Rock; Littoral Sediment; Saltwater</td>
<td>Marine</td>
</tr>
<tr>
<td>Urban; suburban</td>
<td>Urban</td>
</tr>
</tbody>
</table>

In some areas the full LCM classification is probably too refined for the initial accounts, but will nevertheless prove useful for identifying particular land cover types where the services may be quite different. It follows that the NEA Broad Habitats should be seen as providing working titles for each account, with the precise coverage determined more by the availability and precision of data from the LCM and other sources. The ecosystem accounts should continue to be developed for each of the NEA Broad Habitats, with a formal link where possible to the classifications used in the Land Cover Map (P4.1).

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6 SEEA Table 2.1 gives a provisional list of standard classes which is to be further developed as part of the research agenda. However, these do not map well to either the UK NEA or LCM categories.

7 Bog includes upland bog which might be better dealt with in the montane account, and lowland bog which may be included in wetlands accounts. The treatment of these ecosystems within the UK accounts is still under review.

8 The LCM does not separate out floodplains so further consideration of their treatment is required.
5. Statistical accounting units

These are aggregations of BSUs to form accounts for particular geographical areas. Most commonly this will be at the UK level, but feasibly they can be compiled for UK countries and regions. Other aggregations are possible, for example for River Basin Districts and National Parks. An extended version of coastal ecosystems (covering for example areas up to x kilometres from the Mean High Water Mark as well as supra-littoral rock and sediment) would also fall into this category. A stylized depiction, following SEEA, of how the three types of accounting units are related is given in Figure 1.

Ownership of assets is a standard dimension within the National Accounts and the compilation of accounts by sector of ownership can be facilitated through the aggregation of data relating to particular ownership categories (e.g. Public Forest Estate), which is made easier through the use of cadastre based BSUs.

Accounts should be compiled initially at UK level (P5.1). Separately the usefulness of accounts for other geographic areas e.g. UK countries (including the Public Forest Estate (PFE) for England) or specific protected landscapes (e.g. National Parks) should be explored (A5.1).

6. Criteria for prioritisation (SEEA Table 3.5)

The SEEA recommends a number of criteria in order “initially [to] select a limited rather than a comprehensive set of ecosystem services for inclusion in ecosystem accounting”. This applies both to physical and monetary accounting. These criteria are:

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9 SEEA uses the term Ecosystem Accounting Units (EAUs), see Section 2.3.4
• Environmental policy concerns (sensitivity of services to changes in ecosystems; risk of irreversible losses)
• Economic context (which ecosystem services can be influenced through decision-making; the economic relevance of the service)
• Data and methods (existence of adequate data and acceptable methods for quantifying and valuing the services)

For monetisation of services and assets, a judgement will need to be made on the relevance to each of these criteria, and there will need to be a balance between them. For example, it could be misleading solely to estimate the value of relatively trivial services simply because they have the best data and ignore more important services where measurement or valuation is more challenging. Not excluding other sources, we will make full use of the UK NEA’s matrix of services and habitats for assessing the state / risk and relative significance of services within a habitat (P6.1).

For each account, a succinct, transparent Red-Amber-Green (“RAG”) assessment will be made of all relevant services against these criteria, which will identify which services to include and exclude (P6.2). Services with moderate or high indicative value or environmental policy relevance and at moderate or high risk will take priority. In some cases, further research will need to be conducted and new sources established before a more comprehensive account can be compiled.

7. Ecosystem assets in physical terms

A) Structure of asset account

The basic asset account has a standard format, although the characteristics of the stock described in the accounts may vary according to the type of asset and the availability of data. A typical account might have the following dimensions:

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Structure of asset account in physical terms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type of ecosystem e.g. woodland (area)</td>
</tr>
<tr>
<td>Opening stock</td>
<td></td>
</tr>
<tr>
<td>Additions to stock(^\text{10})</td>
<td></td>
</tr>
<tr>
<td>Reductions in stock (^\text{10})</td>
<td></td>
</tr>
<tr>
<td>Closing stock</td>
<td></td>
</tr>
</tbody>
</table>

\(^{10}\) The SEEA (Table 4.4) envisages disaggregating the additions/reductions by cause (anthropogenic or not) but in practice the distinction is expected to be extremely problematic.
The key objective of the asset account is to enable us to monitor changes in the stock in terms of its capacity to deliver services. The capacity to deliver can be influenced by three key characteristics: quantity, quality and spatial configuration. Within these parameters, a range of choices are possible which means that the characteristics described in each asset account have to be those that are related to the delivery of different services.

Because the services and the availability of data vary between different ecosystems, this approach is likely to mean that it will be challenging to compile an overall account for the UK with the same standard dimensions for all individual accounts\(^\text{11}\). An obvious example is biodiversity as different indicators cannot readily be combined on a completely consistent basis. The standard format for asset accounts in physical terms should be adopted (P6.1), whilst recognising that further work on increasing consistency between accounts for different ecosystems is required (A6.1).

**B) Reference condition (SEEA Para 4.15)**

The SEEA discusses the option of measuring condition by reference to the state of the ecosystem in some previous period such as before the period of British industrialisation. There are weaknesses in this approach in terms of difficulty of assessments and their relevance to the current set of services derived from ecosystems and for the UK accounts it is recommended that the reference condition approach should not be adopted and that changes should simply be measured as the differences between the opening and closing stocks (P7.1).

**Environmental thresholds and limits**

Using the previous period as the reference condition has limitations in terms of assessing whether any reduction in stock is at such a level as to cross environmental thresholds and limits. Incorporating limits and thresholds (which may include concepts of social acceptability) would require an extension to the accounts. Where there are significant gaps in scientific understanding regarding ecosystem functioning (including the possibility of non-linear thresholds), there is limited ability to reflect potential limits and thresholds in prices in the short term. Physical accounts/assessments are therefore important to complement monetary accounts in understanding thresholds. We recognize that conceptual work on valuation can often be ahead of empirical understanding of ecosystem processes (e.g. pollination) and in general more scientific research is needed to increase overall confidence in the accounts. The question of environmental thresholds in accounts is, however, an unexplored area and general principles for its treatment have yet to be established. The position taken in the SEEA (para 4.35) is that it does not fit well within a model based on assessment of change over successive accounting periods. Further work is required on how to incorporate limits and thresholds into the accounts (A7.2).

\(^{11}\) See SEEA 4.69.
8. **Ecosystem services in non-monetary terms**

A) **Classification of services** (*SEEA Section 2.2*)

The Common International Classification of Ecosystem Services (CICES\(^{12}\)) sets out a potential standard to be followed. It is based on the well-established split into Provisioning, Regulating and Cultural Services.\(^{13}\) It is, however, rather cumbersome to apply in practice and some of the definitions could be described in more accessible terms. It therefore works better as a checklist than as a standard to be followed in all its detail. **CICES should be adopted in a flexible way (P8.1).**

**Treatment of biodiversity** (*SEEA Section 4.5*)

The SEEA follows the CBD and defines biodiversity at three levels – genes, species and ecosystems.\(^{14}\) Although aspects of biodiversity (e.g. wildlife and/or game; active principles for pharmaceutical products) can be viewed as services, the SEEA takes a broader view and also sees it as a characteristic of ecosystem assets as well as an indicator of condition. It therefore recommends the use of proxy indicators in the accounts. Birds indicators provide a limited but readily available view of changes in biodiversity. Units for other dimensions of condition are challenging though e.g. water filtration, flood protection. This area clearly needs further work. We may need to rebalance our focus in biodiversity monitoring from individual species to ecosystem functioning. To some extent we may be able to capture this (in a very limited way) when looking at habitat conditions. **We should use wild bird species and other relevant indicators pro tem for biodiversity (P8.2) but review the way in which the accounts reflect the role of biodiversity in ecosystem functioning (A8.1).**

**Treatment of disservices** (*SEEA Para 3.36*)

There are potentially different ways of approaching these. One view is that these are flows between ecosystems which impact negatively on the provision of benefits from another environmental asset. An example is agricultural run-off which pollutes water bodies; or severely degraded upland peatland which emits greenhouse gases into the atmosphere. A clear distinction would need to be made between impacts which are directly anthropogenic (for example an industrial accident which releases pollution directly to a water course) and those which arise because the ecosystem cannot manage the pollutant load. These distinctions may be difficult to make in practice and it is not yet clear how best to represent such impacts in the accounts. It may be sufficient to report them in the appropriate emissions accounts and as changes in quality in the asset accounts.

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\(^{12}\) Common International Classification of Ecosystem Goods and Service (CICES) [http://cices.eu/](http://cices.eu/)

\(^{13}\) Supporting services are excluded from the basic accounts as they could otherwise lead to double-counting of benefits; however the possibility of supplementary accounts covering supporting services is not ruled out.

Another view sees disservices as natural events confined within the ecosystem (such as allergies, pests and diseases which have adverse effects on economic production or people’s health) which negatively impact on the benefits received. These dis-benefits should be easily recorded by netting them off the gross benefits, possibly by including a separate line if they can be separately measured.

It is of course possible to adopt both approaches. Whichever approach is adopted, in line with the SEEA, it is clear that more work is needed on the definition and treatment of disservices (A8.2).

B) Structure of flow accounts

The SEEA (Tables 3.2 and 3.3) sets out two relevant tables to be used in the ecosystem services accounts. The first describes the different types of services provided by an ecosystem (Table 3 below). In both cases the unit are fairly obvious but in others measurement is a challenge and further work is likely to be needed. The second table (Table 4 below) relates to the sectors owning the assets which provide the services and those sectors that use or benefit from the services, recognising that the beneficiaries may not be located in the same area as the location of the asset. Non-profit Institutions Serving Households (NPISH) often plays a key role in the provision of services and ideally need to be accounted for separately.

Table 3  Physical flows of ecosystem services for an Accounting Area

<table>
<thead>
<tr>
<th>Type of asset</th>
<th>Woodland</th>
<th>Wetlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning services</td>
<td>Usually readily measured in volume terms e.g. tonnes of timber</td>
<td></td>
</tr>
<tr>
<td>Regulating services</td>
<td>Apart from CO2 capture, these are difficult to measure in non-monetary terms</td>
<td></td>
</tr>
<tr>
<td>Cultural services</td>
<td>Can sometimes be measured through proxies e.g. numbers of visitors</td>
<td></td>
</tr>
</tbody>
</table>

Table 4  Generation and use of ecosystem services for an Accounting Area

<table>
<thead>
<tr>
<th>Generation of ecosystem services</th>
<th>Use of ecosystem services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprises</td>
<td>Households</td>
</tr>
<tr>
<td>Provisioning</td>
<td></td>
</tr>
<tr>
<td>Regulating</td>
<td></td>
</tr>
<tr>
<td>Cultural</td>
<td></td>
</tr>
</tbody>
</table>

This table may have important policy uses, for example in monitoring the services provided by the Public Forest Estate. We should adopt the standard structure for tables for ecosystem services in non-monetary and monetary terms (P8.3).
9.  Basic principles for valuing services and assets

Section 9-16 draw directly on the papers and discussions in the Defra-ONS convened International Expert Seminar “Valuation for Natural Capital Accounting” held in London in November 201315, as well as from initial work on ecosystem accounts and the SEEA guidance.

Fundamentally, we should aim to reflect wherever possible the contribution of ecosystems to goods and services that benefit people (P9.1). Valuation would therefore look at the value of goods and services produced during an accounting period (for flows accounts) and at the present value of current and future goods and services (for asset accounts).

An important distinction is made within the SEEA (Section 3.2.2 and para 3.32) 16 about the difference between capacity and actual use of services. This is an area which has not been fully resolved but could potentially affect valuations. Our approach wherever possible will be to value actual use of services (P9.2). This seems to be more consistent with general national accounting principles and highlights the fact that many regulating and cultural services will provide greater value where there are more people or businesses that make use of the service (for example, recreational paths in woodland), or receive that service locally (for example, local air quality or flood risk alleviation).17

Expected service flow is a measure of all future services from an asset which would generally be based on the current pattern of use (SEEA Para 2.40) unless there is strong evidence to think otherwise (e.g. because of current incidence of tree disease).

Edens and Hein18 identify two options for the presentation of monetary flows in the ecosystem services accounts, either with the ecosystem as an asset or as a producing unit. Our preference is to view the ecosystem as an asset in recording monetary flows (P9.3).

10.  Consistency with SNA valuation principles

Extending the production boundary of the accounts is not unique to natural capital (for instance, housing services) and is accepted by SEEA/accounting community (including the inclusion of some non-use values). The key challenge is to estimate values that are consistent with the SNA exchange value concept i.e. “to value the quantity of ecosystem services at market prices that would have occurred if the services had been freely traded and exchanged” (SEEA 5.20).

16 Although this is more about location of users vis-à-vis location of generation of services
17 UK NEA Follow-On (published in June 2014) work on assessing cultural ecosystem services may potentially have implications for accounting for these services.
18 Edens B. and Hein L., Towards a consistent approach for ecosystems accounting, Ecological Economics 90 (2013), p. 44.
Two key steps are in principle needed to derive such marginal prices for use in ecosystem accounting:

i. estimate a demand curve for the good/service in question, relating prices to quantity demanded;

ii. Establish a reasonable exchange value (marginal price) on those demand curves.

It is permissible to depart from these principles for the purposes of other forms of analysis that do not seek to extend the accounts, such as assessing natural capital within comprehensive wealth. Non-use values are admissible in natural capital accounting if based on real or hypothetical transactions, but there is also an issue about whether and how such values vary with quantity.

In general, a range of established valuation techniques can be used to estimate exchange as well as welfare values, but the rationale for using particular techniques will be clearly explained within each account, and where possible breaking values down into their “price” and “quantity” elements (P10.1). The exact fit will depend upon the type and nature of services and goods that are being valued, and much will depend upon scrutinizing the actual empirical record. The techniques and key issues are summarized below; Annex 1 provides a fuller description.

A) Adjusted market prices and resource rent approaches

These typically apply to marketed natural resources (as set out in SEEA Central Framework) and in general they should be used for valuing provisioning services. Care needs to be taken where certain approaches, such as the residual value method (SEEA 5.122) results in low or negative resource rents, in which case other options, such as the appropriation or access price methods, should be used instead. In calculating the resource rent using the residual value method, the return to produced capital should be based on a market rate. Observed prices from environmental trading schemes can indicate exchange values where such markets are functioning reasonably efficiently but can be problematic where such markets are highly sensitive to the regulatory framework or local characteristics.

B) Production function approaches

These are similar to resource rent approaches, as they attempt to value certain provisioning or regulating services, by estimating the contribution of ecosystem services (e.g. wildflower pollination) or habitat extent/condition (e.g. coastal wetland areas) to production processes (e.g. yields of fresh produce/coastal fisheries) and ultimately market values. In general, the aim would be to disentangle the contribution of the ecosystem service to SNA outputs.

C) Hedonic pricing methods

These methods aim to extract values for environmental services from market-based transactions, typically where quantities of an environmental good form an attribute of some other good that can be purchased (e.g. residential property). Robust values rely on large datasets, and this method will not be appropriate for environmental goods that do not exhibit spatial variation. Such values do not add a new item to the SNA but can be used to disentangle the contribution of ecosystem services.

D) Averting expenditure methods

In contrast to hedonic methods, here the consumer reveals their value for non-market environmental quality by buying substitute products (e.g. air filters, bottled water) when that environmental quality is damaged in some way e.g. through air or water pollution. Use of this method will be constrained by appropriate data and applications, but can provide lower bound marginal prices for the services in question, which could in principle be applied to the overall service flow.

E) Travel cost and associated methods

These methods identify a complementary relationship between market goods (travel) and environmental goods (esp. nature-based recreational visits); it effectively reclassifies existing market-based transactions (travel expenditure) to environmental goods. Probability-based Random Utility models extend basic travel cost methods to multiple sites. We will explore further how Random Utility Models, based on work done as part of the NEA Follow-on, can be applied to derive accounting values.

F) Stated Preference methods

These methods, based on contingent valuation or choice experiments, can be problematic in terms both of robustness and consistency with SEEA. On the other hand, such methods have increased in robustness in recent years, and they can estimate a wider range of values than other methods. We will not rule out stated preference methods but only use them where they are consistent with SEEA concept of exchange value, and where they can capture values that other methods cannot, in particular non-use values. Where there is no obvious point on a demand curve to choose (e.g. for pure public goods), a simulated exchange value approach could be explored. We will review whether to include non-use values within the context of each account, and the extent to which

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21 Day B. (2014) op. cit.

22 Day B. (2014) op.cit.
they can be consistent with SNA principles (A10.2) (including how such values break down into price and quantity, and how they change with quantity).

11. Value transfer

Value transfer is an increasingly used approach to non-market valuation for cost-benefit analysis. Rather than develop bespoke values, value transfer techniques make use of existing values in the literature, identifying the most relevant for the appraisal in question, and making appropriate adjustments to this value. It is essentially a statistical question of assessing how well the measured values represent the non-measured values. In an accounting context, there is a greater challenge, for two reasons: first, because many values in the literature relate to changes in welfare values / demand curve and may not be suitable for exchange values; second, because a limited number of values are available which need to be applied to the whole region or country - where values vary spatially this becomes problematic. These may not be problems for more sophisticated forms of value transfer, using meta techniques and functions (e.g. for wetlands). Defra’s guidelines on value transfer (Eftec, 2010) are also relevant for the purpose of identifying suitable accounting values. We will encourage the appropriate use of value transfer techniques including the adoption of standard statistical grossing procedures, and explore how Defra’s best practice guidance could be adapted for accounting purposes (A11.1). Derivation of values should be transparently set out in relevant annexes to accounts (P11.1).

12. Decomposition of values – between ecosystem types and between SNA and non-SNA

Natural capital accounting is not simply an exercise in valuing things which are new and outside the SNA production boundary – a key aim is to understand the actual extent to which natural values are already included but hidden in standard national accounts, both services (e.g. pollination in crops) and assets (e.g. the value of green space views in property prices). In drawing up accounts we will seek explicitly to highlight conceptual and empirical overlaps between market and non-market values, linkages and consistency with SNA within each account (P12.1)

13. Valuing ecosystem assets and the role of cost-based approaches (SEEA 5.4.4)

According to SEEA and Edens & Hein²³, degradation or rehabilitation of assets would be assessed by comparing the net present value of ecosystem services supply between accounting periods. An alternative is to adopt a cost-based approach whereby degradation of ecosystem assets is valued on the basis of the cost that it would take to restore the ecosystem to a reference/benchmark

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condition, with a rise in restoration costs signalling degradation. There are a number of arguments in favour of a cost-based approach: (i) it is based on a strong sustainability approach; (ii) it resonates with corporate accounting and other aspects of National Accounting (in terms of the written down replacement approach); (iii) it appears to be more practical than gathering data on values, and does not involve making assumptions regarding the bundle of services, future management regimes, future prices and preferences and discounting (see sections 14-16 below).

On the other hand, such approaches raise important conceptual and practical difficulties, including: (i) reliance on ex-ante hypothetical costs which is inconsistent with SNA principles; (ii) the need to identify an appropriate reference level, which is contestable in the absence of specific policy targets; (iii) the need to access disparate and spatially heterogeneous cost data; (iv) decision-makers may be unpersuaded of the need for restoration without evidence on benefits.

Cost-based asset valuation may nevertheless play a role where strong sustainability considerations apply to specific assets; where the purpose of the exercise is to prompt debate about the value of ecosystem assets relative to other forms of natural capital; or in response to specific policy questions regarding the maintenance of natural capital. Moreover, we recognise that there is not necessarily a direct linear link between service and asset values, because of thresholds, depletion and other physical considerations. That is why it is important to have physical asset accounts tracking extent and condition alongside monetary asset accounts.

Following SEEA and Edens & Hein, and discussion at the London Seminar:

- we will adopt a net present value approach to estimating the accounting value of ecosystem assets in order to be consistent with SEEA asset valuation principles (P13.1)
- where appropriate with specific accounts, we will consider / pilot the feasibility of restoration-cost accounts, including through assessing experience in other countries (A13.1).

Ecosystem asset valuation involves identifying and making assumptions for a number of parameters (see sections 14-16). The future flow of benefits is always uncertain – this is demonstrably true even for non-natural capital assets. As a principle, we will state explicitly the assumptions underlying

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24 In accounting terms, this would mean valuing assets on the basis of the costs associated with restoring/creating the asset and assuming an asset lifetime, then running down the value of assets to reflect this depreciation in the balance sheet and adjusting GDP to reflect negative savings (unless actual expenditure offsets this depletion).


asset valuation, and undertake sensitivity analysis where appropriate to test the range of possible values (P13.2).

The structure of a monetary ecosystem asset account for a single year is summarised in Table 5:

<table>
<thead>
<tr>
<th>2012</th>
<th>Type of ecosystem</th>
<th>£ million</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coniferous woodland</td>
<td>Deciduous woodland</td>
</tr>
<tr>
<td>Opening stock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additions to stock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reductions in stock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closing stock</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14. **An expected ecosystem service flow path**

A simple default assumption would assume quantity (and unit value) as constant (in real terms). However, depending upon the asset and service in question, it may be more plausible to include an increasing or declining flow which would better represent “business as usual” for example if tree disease was likely to affect the future flow of benefits from woodland. Shadow prices may also be likely to change over time (e.g. because of a positive income elasticity of demand for recreational values). **Any departure from a constant service flow assumption would need to be justified and evidenced (P14.1).**

Closely linked to the flow path is an appropriate management practice assumption. Edens and Hein propose current management practices, which is simplifying but also consistent with SEEA Central Framework.

15. **A time period over which to value flows**

Unlike non-renewable assets, ecosystem flows can be indefinite if managed sustainably (SEEA 2.97). The key issue arguably is the change in value between accounting periods rather than the absolute value (which would be higher for a longer asset life). For consistency across accounts, an arbitrary time period could be used (e.g. 25 years) but there also needs to be consistency within accounts. Thus for timber a 50 year lifespan has been used, so other woodland services should also be capitalised over 50 years, taking into account the current life of the asset. Note that if an infinite asset life is assumed, non-negligible discounting would render future values beyond say 50 years

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27 The SEEA (Table 4.4) envisages disaggregating the additions/reductions by cause (anthropogenic or not) but in practice the distinction is expected to be extremely problematic.
relatively immaterial. Sensitivity analysis is relatively straightforward and different values could be shown. **We will keep the appropriate time period for asset valuation under review as we produce initial accounts (A15.1)**

### 16. An appropriate discount rate

There is a vast literature on selecting discount rates, and whether a market or social discount rate should be used. Market failure is likely to be a factor in intergenerational flows, and there are strong reasons to suggest that social rates would be lower (reflecting pooled risk; social time preference etc). Using a social discount rate is arguably at variance with SNA principles, but in practice SNA has never been explicit about what discount rates are used; and a social discount rate does not violate the exchange principle in the way that inclusion of consumer surplus does. At any rate, we need to be clear on the concept and on choice of discount rate.

The HM Treasury Government’s Green Book social discount rate offers a means of reconciling practical and principled perspectives. It is an appropriate rate to use for decisions of allocation on publicly owned assets, made in the interest of society; nor, at 3.5% is it too far from the risk-free interest rate on long-term government bonds that SEEA requires for subsoil assets (of around 4%).

The Green Book also allows for a lower discount rate for estimating present values of costs and benefits beyond 30 years, to reflect greater uncertainty in the future. Thus 3% is used for values between 31 and 75 years; and 2.5% for values from 76 to 125 years. Finally, the Green Book guidance on discounting has been applied for ten years across innumerable public policies and projects, and therefore has a widely recognised legitimacy in public policy appraisal and valuation.

As with time periods, sensitivity analysis is straightforward, although, as the Green Book states, the rationale for undertaking it should be clearly explained.

**We propose to use the recommended Green Book Discount Rate whilst allowing for sensitivity analysis to assess the effect of different rates (P16.1)**

### 17. Periodicity

Ideally we would propose to maintain annual accounts (though for water the hydrological year is different and quarterly or seasonal accounts are likely to be more useful). However changes in assets are often not significant on an annual basis and sources of data such as the Countryside Survey or the Forest Inventory are unlikely to be able to support such frequent accounts. One solution is to produce annual accounts, updating those elements which can readily be updated, but with the option of reporting change by reference to a baseline determined by the more

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28 In practice the market vs. social discount rate debate can be overdrawn, since market rates can be low and social discount rates can vary between 0.5 and 5%. HMT Green Book recognises these issues in proposing a 3.5% rate that declines in steps beyond 30 years.

comprehensive but intermittent data source. This is an issue which is likely to be guided by the availability of data: sufficient annual data may simply not be available, although even then there may be process advantages to be gained by setting up production systems on an annual cycle. We recommend the adoption of a flexible approach to periodicity, aiming for annual accounts wherever possible (P17.1).

18. Uncertainty and quality

Uncertainty in an accounting context is difficult to measure (SEEA Section 2.5.5), as accounts traditionally present point estimates which are balanced with other accounts. However, many of the procedures and descriptions of quality used in the SNA are relevant to ecosystems accounting and provide a useful starting point for assessment of data quality and fitness for purpose.30 For each account we will provide a transparent assessment of confidence levels in the estimates (based on a red-amber-green “RAG” approach), the nature of the likely errors and uncertainties and other quality criteria. This will help to communicate the degree of uncertainty effectively and transparently (P18.1).

We accept that in many areas we will only have a partial coverage of ecosystem services or total economic value. We will indicate this degree of coverage clearly in the final presentation of the accounts (P18.2).

Summary of Principles to be adopted and areas for Action

Summary of principles

P2.1 Subsoil assets are not part of the ecosystem accounts.

P3.1 Ecosystem accounts should be constructed around the categories of the Land Cover Map. However, where there is more detailed and relevant data available on land use, this should be used instead, with the results reconciled with the LCM.

P4.1 The ecosystem accounts should continue to be developed for each of the NEA Broad Habitats, with a formal link where possible to the classifications used in the Land Cover Map.

P5.1 Accounts should be compiled initially at UK level.

P6.1 The standard format for asset accounts in physical terms should be adopted.

P6.2 The reference condition should not be adopted and changes should simply be measured as differences between opening and closing stocks.

P7.1 We will make full use of the UK NEA’s matrix of services and habitats for assessing the state / risk and significance / value of services within a habitat.

P7.2 For each account, a brief transparent red-amber-green (RAG) assessment will be made of all relevant services against these criteria, which will identify which services to include and exclude.

P8.1 The Common International Classification of Ecosystem Services (CICES) should be adopted in a flexible way.

P8.2 We should use birds and other relevant indicators pro tem for biodiversity.

P8.3 We should adopt the standard structure for tables for ecosystem services in non-monetary and monetary terms.

P9.1 We should aim to reflect wherever possible the contribution of ecosystems to goods and services that benefit people.

P9.2 Our approach wherever possible will be to reflect actual use of services.

P9.3 We should view the ecosystem as an asset in recording monetary flows.

P10.1 A range of established valuation techniques can be used to estimate exchange as well as welfare values, but the rationale for using particular techniques will be clearly explained within each account, and where possible breaking values down into their “price” and “quantity” elements.

P10.2 We will not rule out stated preference methods but only use them where they are consistent with SEEA concept of exchange value, and where they can capture values that other methods cannot, in particular non-use values.

P11.1 Derivation of values should be transparently set out in relevant annexes to accounts.

P12.1 In drawing up accounts we will seek explicitly to highlight conceptual and empirical overlaps between market and non-market values, linkages and consistency with SNA within each account.
P13.1 We will adopt a net present value approach to estimating the accounting value of ecosystem assets in order to be consistent with SEEA asset valuation principles.

P13.2 We will state explicitly the assumptions underlying asset valuation, and undertake sensitivity analysis to test the range of possible values.

P14.1 Any departure from a constant service flow assumption needs to be justified and evidenced.

P16.1 We propose to use the recommended Green Book Discount Rate whilst allowing for sensitivity analysis to assess the effect of different rates.

P17.1 We should adopt a flexible approach to periodicity, aiming for annual accounts wherever possible.

P18.1 An assessment of uncertainty needs to be made against a range of quality criteria.

P18.2 We will indicate the degree of coverage of ecosystem services and total value clearly in the final presentation of the accounts.

Summary of Actions

A2.1 The valuation of subsoil carbon should be reviewed within the context of wider Natural Capital Accounting.

A3.1 Further work on coastal and marine ecosystems, and on linear and point features, is required before their treatment in the accounts can be resolved.

A5.1 The usefulness of accounts for geographic areas e.g. UK countries (including the PFE for England) or specific protected landscapes (e.g. National Parks) should be explored.

A6.1 Further work on increasing consistency between asset accounts for different ecosystems is required.

A6.2 Further work is required on how to incorporate limits and thresholds into the accounts.

A8.1 We should review the way in which the accounts inform the role of biodiversity in ecosystem functioning.

A8.2 More work is needed on the treatment of disservices.

A10.1 We will explore further how Random Utility Models, based on work done as part of the NEA Follow-on, can be applied to derive accounting values.

A10.2 We will review whether to include non-use values within the context of each account, and the extent to which they can be consistent with SNA principles.

A11.1 We will encourage the appropriate use of value transfer techniques and the adoption of standard statistical grossing techniques and explore how Defra’s best practice guidance could be adapted for accounting purposes.

A13.2 Where appropriate with specific accounts, we will consider / pilot the feasibility of restoration-cost accounts, including through assessing experience in other countries.

A15.1 We will keep the appropriate time period for asset valuation under review.
Annex 1

Valuation techniques for ecosystem accounting

A) Adjusted market prices and resource rent approaches

These typically apply to marketed natural resources (as set out in SEEA Central Framework) and in principle they could be used for valuing provisioning services. But there are two caveats to this: (i) in principle, unit resource rent approaches should exclude labour and produced capital inputs where possible (cf Edens & Hein, p. 44); and (ii) the use of resource rents to estimate value may assume that the resource is being extracted sustainably, which may not be true, and so would misstate the “true” value of ecosystem services in terms of capturing all of the relevant missing prices. Observed prices from trading schemes involving environmental or ecosystem services can indicate exchange values where such markets are functioning reasonably efficiently but can be problematic where such markets are highly sensitive to the regulatory framework or local characteristics.

B) Production function approaches

These are similar to resource rent approaches, as they attempt to value certain provisioning or regulating services, by estimating the contribution of ecosystem services (e.g. wildflower pollination) or habitat extent/condition (e.g. coastal wetland areas) to production processes (e.g. yields of fresh produce/coastal fisheries) and ultimately market values. These approaches focus on marginal contributions and therefore can produce suitable accounting prices. However, as one of the Valuation Seminar papers, on pollination services, showed, these rely on bio-physical data and assumptions about substitute inputs which may be very uncertain or unavailable. More generally these approaches rely on an understanding of ecosystem production functions. In each case, the aim would be to disentangle the contribution of ecosystem service to SNA outputs.

C) Hedonic pricing methods

These methods aim to extract values for environmental services from market-based transactions, typically where quantities of an environmental good form an attribute of some other good that can be purchased. The standard example is property and the environmental quality of its location. A hedonic price function (HPF) describes the price at which a unit of a heterogeneous good with particular attributes will sell for in a market as the attribute of interest changes. In the presence of an HPF there is no single market clearing price (rather, there is a continuum). However, the value of the last marginal change (e.g. the marginal increase in the value of properties in the closest proximity to an environmental amenity) can be regarded as a lower-bound accounting price. Robust values rely on large datasets, and this method will not be appropriate for environmental goods that

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do not exhibit spatial variation; transferring values to other places where demand and supply factors differ is also problematic. Such values do not add a new item to the SNA but can be used to disentangle the contribution of ecosystem services.

D) Averting / defensive expenditures

These are based on individual preferences for health or amenity and can provide lower-bound accounting values. In contrast to hedonic methods, here the consumer reveals their value for non-market environmental quality by buying substitute products (e.g. air filters, bottled water) when that environmental quality is damaged in some way e.g. through air or water pollution. Use of this method will be constrained by appropriate data and applications, but can provide lower bound marginal prices for the services in question, which could in principle be applied to the overall service flow. Such values are likely to understate the true value where consumers do not have perfect information, or where expenditures are “lumpy” but could overstate the true value where the defensive expenditures confer other non-environmental benefits (e.g. taste).

E) Travel cost and associated methods

These methods identify a complementary relationship between market goods (travel) and environmental goods (esp. nature-based recreational visits). With basic travel cost methods, typically a demand curve would be derived and an appropriate marginal price could be identified. This method does not add a new item to the accounts as it effectively reclassifies existing market-based transactions (travel expenditure) to environmental goods. Opportunity cost of time is excluded, to ensure consistency with other SNA items. Random Utility models extend such methods to multiple sites and predict the probabilities that a household will choose to visit each site based on quality and cost of travel. Accordingly, an “accounting price” might be arrived at by taking the travel costs to each of those recreational sites and calculating the probability-weighted sum of expenditures on outdoor recreation across the course of a year, which would form the lower bound of a possible accounting price.

F) Stated Preference methods

These methods use carefully structured questionnaires to elicit individuals’ preferences for a given change in a natural resource or environmental attribute. Stated preference methods can take the form of contingent valuation surveys (where participants are asked questions about their willingness to pay for an environmental good) or choice experiments (where participants are asked to choose between different bundles of attributes). However, they can be problematic in terms both of

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33 Day B. (2014) op. cit.

34 Day B. (2014) op.cit.
robustness and consistency with SEEA. On the other hand, such methods have increased in robustness in recent years, and they can estimate a wider range of values than other methods. Where there is no obvious point on a demand curve to choose (e.g. for pure public goods), a simulated exchange value approach could be explored. Making non-use values consistent with SNA principles would involve understanding how such values break down into price and quantity, and how they change with quantity.