Biophysical modelling of ecosystem services and ecosystem accounting: making the marriage happier

Paper for the 25th Meeting of the London Group on Environmental Accounting, Melbourne, 7-10 October 2019

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Abstract: The rapid expansion of the ecosystem services and ecosystem accounting communities has been an exciting time, with increasing levels of interaction and understanding. The interaction has been driven by the production of ecosystem accounts that have used a range of information and modelling tools also used in the estimation of ecosystem services (e.g. InVEST, ARIES, ESTIMAP, and a wide variety of other "local" models). Typically, such modelling estimates the physical amounts of different goods or services that emerge from different ecosystem types based on ecosystem condition and other factors, and are fed by information from remote sensing and site-specific calibration data and ecological understanding of processes where possible. Matching this physical information to the supply and use of ecosystem services as defined in the System of Environmental-Economic Accounting has proved problematic at times as some models do not provide information on use by people. In some cases, data on ecosystem services use is missing or incomplete, in other cases there is no use by people, while in still others the same, non-rival, ecosystem service is used by more than one user or the same physical metric may be used to measure more than one ecosystem service. A number of approaches to reconciling the differences have been tried and resulted in the development of the concept of ecosystem capacity, among other things. Practically, the frequent absence of calibration data, the need to (sometimes) interpolate data to generate model inputs and outputs, and the fact that these processes are typically slow and require a great deal of expertise, meaning that it's difficult in places with more limited expertise, such as in low and middle income countries. This paper examines these issues and outlines some practical solutions for the producers of ecosystem accounts.

Feedback from the London Group on these issues would be welcomed as would the identification of other issues associated with the production of ecosystem accounts. Some questions for the London Group to consider are:

- Does the paper reflect your experiences with use of modelling for ecosystem accounting?
- Which models have you used and what is your experience of the models available?
- Do you have other comments or suggestions?

1. Introduction

Currently the SEEA Experimental Ecosystem Accounts (SEEA-EEA)(UN et al. 2014b) and related recommendations (UN 2017) include accounts for: (1) ecosystem extent; (2) ecosystem condition; (3) ecosystem capacity; (4) supply and use of ecosystem services, and; (5) individual components of ecosystems, namely land, water, carbon and biodiversity. Models for a sequence of accounts also presented (p. 143, UN et al 2014b).

This paper examines some of the modelling tools available that are available to estimate the flows of ecosystems services and how they could better account for ecosystem services in the SEEA-EEA framework. It starts by providing a brief introduction to ecosystem services and ecosystem accounting literature and experience. It goes on in Section 2 to examine some of the models or suites of models used to assess to estimate and account for ecosystem service. Section 3 looks at some of the lessons, while Section is the summary and ideas for the way forward.

Ecosystem services and ecosystem accounting

There is a large literature devoted to the study of ecosystem services and this is reviewed by a range of authors (e.g. Seppelt et al. 2011; Martinez-Harms and Balvanera 2012; Bagstad et al. 2013a; Shoyama et al. 2017; Neugarten et al., 2018).

Ecosystem accounting is relatively new, and there are relatively few ecosystem accounts, especially compared with the literature devoted to ecosystem services. Much of the experience to date is consolidated in the *Technical Recommendations in support of the System of Environmental-Economic Accounting Experimental Ecosystem Accounting* (UN 2017), although since then a number of additional accounts have been produced and related research has also continued.

2. Biophysical modelling for ecosystem services and accounting

A range of models have been used is ecosystem service assessments and ecosystem accounting. To support ecosystem service assessments suites of models have been compiled and are available for use. These are briefly described under the subheadings below which are of model name (i.e. InVEst, ARIES and ESTIMAP), country (Australia, United Kingdom) or continent (Europe). All models are spatially-explicit and provides results in biophysical terms (e.g., tons of carbon sequestered), while may also provide results on economic terms (e.g., net present value of sequestered carbon).

The information from these models enables decision makers to assess trade-offs associated with alternative management choices of particular areas and to identify areas where investment in natural capital could enhance human wellbeing or conservation of biodiversity.

ARIES

ARtificial Intelligence for Ecosystem Services (ARIES)[1] was established in2007 and is a system that enables the coupling of data and models supporting the FAIR principles (Wilkinson et al. 2016)[2] and using artificial intelligence to select the most appropriate data and models for a user's region and ecosystem services of interest. Models of ecosystem services of increasing sophistication have been developed and used within the ARIES paradigm since then (Villa et al. 2014). ARIES allows for the simpler reuse of complex models, by allowing the selection of the most context-appropriate data and models from a shared online data and model library, and full provenance information describing the data and models and reasons for their selection. Since the beginning of ARIES, has concentrated on two areas:

- The capability to automatically assemble the most appropriate models to a region of interest, based on a simple user query, using modular model components and data chosen according to context.
- An extension of ecosystem services science to renew its focus on beneficiaries and the spatial and temporal dynamics of flows.

ARIES is a suite of ecosystem services models aimed at supporting science-based decision-making[3]. ARIES is a tool for integrated social-environmental systems modelling, using knowledge and models built independently by many actors and endorsed by the scientific community to produce holistic outputs, making evidence-based environmental decision making easier and more effective.

ARIES uses k.LAB, a software platform designed to integrate models via the use of well-defined scientific concepts. The software gives access to an integrated network of web-accessible models, catalogued and related across scientific disciplines and provides a user-friendly means to query the network (a web browser interface that allows a user to move to the part of the world they are interested in, select the concepts they are interested in modelling, and have models assembled with results, provenance, and reports automatically generated). The system links natural science (e.g., process-based models) and human behaviour (e.g., agent-based models). It resolves differences in spatial units or scale automatically, enabling outputs to support complex, interdisciplinary decisions. As part of the process, specific, detailed models are chosen over more general, coarser alternatives, as long as data exist to support them. This has led to the development of "globally customizable ecosystem service models" (Martiz-Lopez et al. 2019) that can run anywhere in the world but are easily customized with local data and adjustments to model, parameterization and structure. ARIES has been used in the development of ecosystem accounts for Italy[4].

InVEst

Integrated Valuation of Ecosystem Services Tradeoffs (InVEST)[5] is a collection of models for mapping and valuing ecosystem services. It was developed to inform decision making at

[1] See http://aries.integratedmodelling.org/?page_id=632

[2] FAIR stands for Findable, Accessible, Interoperable, and Reusable and is the next step in the evolution toward more open, collaborative scientific data and modeling.

[3] See https://github.com/integratedmodelling/im.aries.global

[4] See https://www.wavespartnership.org/en/knowledge-center/1st-report-state-natural-capital-italy-synthesis

[5] See https://naturalcapitalproject.stanford.edu/invest/#resources

local, national and global scales. InVEST is the most widely used ES modelling tool[6], owing in part to its transparency, level of support, and large user community. InVEST has been used in the development of ecosystem accounts for Rwanda (Bagstad et al., in revision).

InVEST models can be run independently. While InVEST is coded in Pyton, it does not require knowledge of Python programming, but it does require basic to intermediate skills in GIS software.

The InVEST toolset[7] currently includes eighteen distinct ecosystem service models designed for terrestrial, freshwater, marine, and coastal ecosystems, as well as a number of “helper tools” to assist with locating and processing input data and with understanding and visualizing outputs (Sharp et al., 2015). The software and guidebooks can be downloaded free of charge from the website[8].

ESTIMAP

ESTIMAP (‘‘Ecosystem Service Mapping Tool”)[9] is a collection of spatially explicit models of ecosystem services developed to support policies in European as well as providing guidelines to make model customization more scientifically robust and decision relevant (Maes et al., 2015). The suite of models in ESTIMAP is summarised by Zulian et al. (2013). The ESTMAP models are GIS based that run at a continental scale but can be run at finer scales. The main objective of the ESTIMAP is to support EU policies with information on ecosystem services, e.g. for EU Biodiversity Strategy to 2020, as well as ecosystem accounts for the EU. The models are able to be used for scenario assessments.

Zulian et al. (2018) adapted ESTIMAP for use in 10 case studies using three ecosystem service models. Both the usefulness of the models and their results were tested with stakeholders. In general, stakeholders considered the modelling approach useful for stimulating discussion and supporting communication. Major constraints identified were the lack of spatial data with sufficient level of detail, and the level of expertise needed to set up and compute the models.

The outcomes of ESTIMAP for recreation have been used for the Knowledge Innovation Project on an Integrated system of Natural Capital and ecosystem services Accounting (KIP INCA) that aims to develop, in support to MAES, a set of experimental accounts at the EU level, following the United Nations System of Environmental-Economic Accounting-Experimental Ecosystem Accounts (SEEA EEA).

The use of an ESTIMAP model in accounting proved that the biophysical model itself is not self-standing for accounting purposes (Vallecillo et al. 2019a). It assesses the potential of ecosystems to provide a service and thus allows the identification of the ecosystem types on the supply table. However, the ecosystem potential only becomes actual flow when it interacts with the demand (La Notte et al 2019). The demand not only defines the actual

[6] See: https://www.sciencedirect.com/science/article/pii/S2212041615300668
[7] See: http://releases.naturalcapitalproject.org/invest-userguide/latest/
[8] See https://naturalcapitalproject.stanford.edu/invest/
[9] See https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/estimap-ecosystem-services-mapping-european-scale

flow of the ecosystem service used, but it also allows the allocation of this flow in the use table.

All biophysical models that assess the supply from the ecosystems only "start" the assessment relevant for accounting: it is important to assess how much of that supply is used (or overused).

3. Country and continental models used for ecosystem services accounting

There is a great range of individual models that have been used in either ecosystem service assessments or ecosystem accounting. Below we briefly look at the models used in the assessments of ecosystem services in the accounts for the Central Highlands of Victoria Australia, the, United Kingdom, United States of America and Europe. Each of these are examined in the sections below.

These different approaches have sought to find a balance between

- Local trust from decision makers and knowledge by the scientists applying them to a specific model or models,
- Comparability – of metrics, quality of underlying data, etc.,
- Customizability, in terms of model structure and parameterization

Australia

In Australia, Keith et al (2017) estimated a range of ecosystem service flows using a range of models that were calibrated specifically for the region. These services estimated using models were related to carbon and water

Carbon related services of carbon storage and carbon sequestration were derived from a region-specific model of carbon stocks and stock changes. The model used spatial biophysical data and was calibrated with site data (n = 930 sites) of biomass carbon stocks calculated from tree measurements (Keith et al. 2010). Carbon stocks were derived in relation to the environmental conditions at the site, forest type, age of the forest since last stand-replacing disturbance event, and previous disturbance history of logging and fire. A base carbon stock map was developed for 2009 (prior to a major wildfire).

Additions to carbon stock change in forests were derived from species growth curves. Reductions in carbon stock change were derived from site data of losses of carbon from biomass components due to fire and logging, and this was applied to the disturbance history of time and location of disturbance events. Change in carbon stock over time was calculated from the base carbon map using forward projections from 2009 to 2015, and backwards projections from 2009 to 1990. Changes in carbon stocks calculated with these projections included; growth of trees, emissions due to fire, collapse of dead standing trees, decomposition of dead biomass, and losses due to logging.

Ecosystem services of carbon storage and sequestration were calculated for forest areas under different forms of management – conservation, production native forest, and plantation. Region and species-specific estimates of carbon stocks and the factors causing changes in stocks were important to provide the most accurate possible information to assess trade-offs in the use of services.

The water provisioning service was described in physical terms by the runoff or water yield from the catchments in the study area, which provide inflows to the reservoirs. The provisioning service was deemed to be used by the water industry authority, Melbourne Water, at the time when it enters the reservoir, and not when water leaves the reservoir and is supplied to customers. This treatment distinguishes the ecosystem service from the supply of water to consumers, with ecosystem service of water provisioning being the inflow to the reservoir and recorded in the time period of the inflow, and the supply of water to consumers that occurs at a different time and is unlikely to be equal to the inflow. The ecosystem service of water provisioning is used by Melbourne Water as input to the production of water supplied and used in the economy.

Water yield was calculated spatially across the study area and disaggregated for each of the five reservoirs. These data provided information about the spatial distribution of water inflow and the change each year in response to climate variability, land cover change, and disturbance history. Water yield was determined by the balance between rainfall and evapotranspiration, soil water storage capacity, and vegetation cover. Water yield was estimated each year using a spatially-explicit continental water balance model calculated monthly across the study area (Guo et al. 2002, eMAST 2016). Rainfall and pan evaporation data were derived from the eMast database (eMast 2016) resampled to 0.0001 degree to align with the study area. Runoff was calculated as the water in excess of the soil water field capacity of the catchment. The model was calibrated for the ecohydrological region (Stein et al. 2009) against gauged streamflow data (n = 347 flow gauges) (Peel et al. 2000, BoM 2013b), and tested for the gauging stations within the study area. Runoff depth was converted to volume for each grid cell, and accumulated for each stream segment within the catchment to give a volume inflow to each reservoir.

Annual variability in the water balance model is driven by climate variability, in particular, precipitation and evapotranspiration. However, actual water yield is also influenced by the condition of the vegetation in the catchment, with the main factor being age of the forest. Evapotranspiration depends on leaf area index and leaf conductance, which vary with forest age and thereby determine the shape of the water yield response curve (Vertessy et al. 2001). An empirical model of the water yield response to forest age that was develop for the specific forest type (Kuczera 1987), was applied to the estimated runoff. This allowed spatial attribution of the change in water yield due to disturbance events.

United Kingdom

In the UK, a number of spatial models or modelling routines have been run specifically for natural capital accounting purposes. While the models themselves are not always widely available, they illustrate the potential to include all necessary aspects required for accounting purposes: an assumption about the counterfactual against which the volume of the service is measured (i.e. what would happen if the ecosystem was not there) and a quantification of the natural capital assets providing the service, as well as the economic value of service flows calculated directly from the population of users benefitting. These applications include the following examples:

- Air pollution removal: Use of the atmospheric chemistry transport model EMEP4UK to calculate the health and economic benefits of air pollution removal by UK vegetation (Jones et al. 2019). EMEP4UK is based on the open source EMEP model, health calculations used the AlphaRiskPoll model applied to existing morbidity and mortality data from UK local authorities.

- Noise mitigation: Use of spatial routines to estimate the economic benefits from noise mitigation by urban trees (eftec & CEH 2018), based on existing noise mapping, calculating the benefitting residential population, and applying damage costs for noise.
- Flood prevention: Use of the Joint UK Land Environment Simulator (JULES) to estimate the additional volume of flood water potentially avoided by woodland water use or retained by hydraulic roughness of floodplain woodland, compared to an alternative grass cover, with monetary values based on the estimated cost of providing for the same volume of water in a flood storage reservoir[10].

Other models such as the Outdoor Recreation Valuation tool (ORVal)[11] have been used to calculate the benefits of greenspace for recreation. As yet, ORVal has not been used systematically for ecosystem accounting purposes in the UK as it is based on a wide range of data for different years and is designed to provide one-off estimates for a range of different purposes. However, the potential to use the estimates of visitor numbers and/or the resulting values is obvious and will need to be explored further.

United States

Two approaches were used in pilot ecosystem accounts for the U.S.: a series of independently applied, bespoke models for accounts in the South-eastern U.S. and the development of novel models hosted in a common code repository for the development of national-scale urban ecosystem accounts. The object of the latter is to facilitate faster re-computation of ecosystem accounts by future analysts, as opposed to the "kindness of strangers" approach that asks various researchers to rerun their models every time accounts are recomputed is less likely to be sustainable.

Europe

At a continental scale, applications in Europe offer some interesting insights. A pilot exercise in Europe looked at water purification and used a spatially explicit biophysical model called GREEN (Geospatial Regression Equation for European Nutrient losses) and showed that for those ecosystem services where the absorption rate can be exceeded, it is possible not only to calculate an actual flow (that increases with increasing pollutant emissions) but also a sustainable flow (that increases with decreasing pollutant emissions (La Notte et al. 2017). For water purification, spatial explicitness is essential since the river network determines the load of pollutants that move across space.

In addition to nature-based recreation (please refer to the previous paragraph), other models have been developed for INCA, specifically: pollination (ref. chapter 4 in Vallecillo et al. 2018) and flood control (see Chapter 6 in Vallecillo et al. 2019b). The procedure is the same applied for nature-based recreation: ecosystem potential interacts with the ecosystem

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[10] Forest Research (2018). Valuing flood regulation services of existing forest cover to inform natural capital accounts. https://www.forestresearch.gov.uk/research/valuing-flood-regulation-services-existing-forest-cover-inform-natural-capital-accounts/

[11] https://www.exeter.ac.uk/leep/research/orval/

service demand generates the actual flow, then accounted in supply and use tables. The outcomes are consistent from both the ecological and socio-economic perspective:

- by separating ecosystem potential and demand it is possible to assess **what is driver of changes** in the actual flow (e.g. higher actual flow is caused by enlargement and/or enhancements of the ecosystems supplying the service or by an increased demand for that service?)
- by separating ecosystem potential and demand it is possible to assess and spatially locate **unmet demand**, i.e. where there is a need for a service, but the ecosystem does not provide it.

For flood control, **spatial explicitness is essential** since service providing areas are located differently from service benefiting area and their spatial interaction is crucial fro the service assessment. Additional biophysical models are currently being developed for INCA on soil retention and habitat maintenance.

INCA applications also show that **biophysical mapping differs from biophysical modelling**: in the cases of timber provision (ref chapter 4 in Vallecillo et al. 2019b) and global climate regulation (ref chapter 5 in Vallecillo et al. 2019b) the service assessment is undertaken through disentangling ecosystem contribution from official dataset; the actual flow is mapped by using for the spatial disaggregation the Dry Matter Productivity (DMP) from the Copernicus service information data (© European Space Agency).

4. Matching modelling to accounting

Matching the physical information from the models to the supply and use of ecosystem services as defined in the System of Environmental-Economic Accounting has proved problematic at times. The models are built to describe, estimate or predict physical process and there in often little or no systematic information on how these physical flows are used by people and the boundary at which use by people occurs. As such, in some cases, data on ecosystem service use is missing or incomplete. In other, cases there is no use by people and hence there is no ecosystem service associated with the physical flow (e.g. flows of water into lake that is not used by people for water supply),

There are also case where the same, non-rival, ecosystem service is used by more than one user. For example, recreational, cultural and spiritual services from the ecosystems in national parks. While recreation services are congestible, the benefits from knowing that the parks exist and are home to biodiversity is non-rival and not congestible. This was seen in Rwanda, where the same watershed (or parts of the same watershed) provide, for instance, erosion control for hydroelectric dams, irrigation dams, and water treatment plants. Since supply must equal use in accounting, and biophysical models tell us how much soil erosion control is provided by the upstream watershed but not who uses the service. So we know the total supply but how should the use be divided between the different uses. On simple option is to just equally divide the total supply by the numbers of different uses, but this would obscure rival uses.

There are also cases there the same physical metric has been used to estimate rival ecosystem services. For example, carbon sequestration and timber production in plantations forests (Keith et al. 2017) This was also the case for the physical volume of water flowing into an artificical reservoir was deemed to be both the measure of water provisioning and water filtration services (Vardon et al 2019).

A number of approaches to reconciling the differences have been tried and resulted in the development of the concept of ecosystem capacity, among other things.

Before we discuss this further, it is important to recognise that linking of ecosystem services to ecosystem extent and condition is a key area. For example, Eigenraam et al. (2013) demonstrated that it is possible to provide information on ecosystems and their changing condition over time. The accounts developed show how changes in ecosystems can be attributed to human intervention (e.g. revegetation), natural change or environmental events (e.g. flood and fire). The paper also suggests how changes in the condition of ecosystems can be linked with changes in ecosystem services. This is an important area to keep in mind but will not be followed up further in this paper.

Examples from KIP INCA shows that (i) through modelling it is possible to separate the ecosystem potential from ecosystem service demand and only their interaction generates the actual flow; (ii) there are ecosystem services (such as water purification and flood control) that could only be assessed by using spatially explicit models; (iii) through biophysical modelling it is possible to assess and spatially locate unmet demand.

Another point of interest is how much overlap there is between the ARIES, InVEST and ESTIMAP. For example, all three systems have very closely related pollination models. In can be said that goals of these pre-packaged, multi-ES models is to allow trade-off analysis and comparison of multiple ecosystem services, e.g., via accounting.

It is also apparent that the three pre-packaged models have limitations at continental scales and heterogeneous landscapes, particularly where the desire for accuracy is great (e.g. in the US). As Zulian et al. 2018 and others have shown it is possible to customize the general model packages to get more accurate results.

Modelling use vs supply

Returning to the discussion of the modelling for the supply and ecosystem services, the biophysical models show the potential supply, which is broadly equivalent to what has been viewed as ecosystem capacity in the SEEA (UN 2017). That is, the physical flows are available for people to use. But this does not mean that the flows are used and it is the flows that are used that are considered the use of ecosystem services. As such, the biophysical modelling provides the capacity or potential uses and additional data are needed to estimate the actual uses of ecosystem services. The ARIES suite gets to this issue by having models of economic and social actors.

In practice, it seems that the use of ecosystem service is determined before the supply. It also means that if the supply is greater than the ecosystem capacity then this would be an unsustainable use, leading to the depletion or degradation of the ecosystem from which the services are supplied.

Modelling of users can be achieved for certain ecosystem services where spatial context is important, primarily in the regulating services. Examples include flooding where, in principle, it is possible to identify the residential dwellings or industrial premises which would benefit from a reduction in flood peak or flooding frequency. Other examples from an urban perspective include the dwellings benefitting from noise mitigation (eftec & CEH 2018), a local population benefitting from reduced concentrations of $PM_{2.5}$ pollution (Jones et al. 2019), or at a slightly coarser scale, the city regions benefitting from urban cooling due to urban green and blue infrastructure (eftec et al. 2018). Identification of beneficiaries often requires detailed local data and spatially contextual modelling approaches.

Choice of (or lack of) counterfactual

Accounting applications may well influence the choice of counterfactual assumed in standard applications of the models. For example, for air filtration, the model might compare the amount of air pollution taken out of the atmosphere by deposition on vegetation relative to the deposition that would have occurred if the vegetation was absent and replaced by bare earth. Alternatively, the model may make a comparison with deposition what would have occurred on hard bare surfaces such as concrete. Both these assumptions are an approximation to the 'absence of the ecosystem' which is understood to be the underlying concept within SEEA EEA, and so the assumptions used in the models need testing in order to establish how closely they match the accounting conceptual framework.

5. Conclusions (

In this paper, we have mostly looked at supply and use of ecosystem services and the modelling that has been done for the assessment of ecosystem services as well as for the construction of accounts. A wide range of models is available to estimate physical flows related to ecosystem services. No one model or suite of models has emerged usable in all or even most circumstances. Table one presents the "pros and cons" of the pre-package models. Indeed, the experience is that for accounting, the models most likely to used are locally developed models and two of the platforms reviewed – ARIES and ESTMAP – all allow for more detail models to be used instead of global models when and where they are available.

This is also reflected in the country experiences of ecosystem accounts and is probably due to two reasons:

(1) Local models are likely to be more accurate than generic models and
(2) Local models are more familiar than the than generic models to those developing the accounts, scientists and decision makers.

Table 1. Overview of biophysical modelling approaches used in ecosystem accounting.

Biophysical modelling approach	Pros	Cons
ARIES	• Offers very rapid ES assessment through ARIES Explorer tool, high level of expert-level customizability through ARIES Modeler tool • Artificial intelligence approach selects the most appropriate data and models for use in each application, plus provenance for transparency • ”Global yet customizable” modelling approach offers the ability to compile ecosystem accounts in data-scarce regions • Provides infrastructure to make data and models interoperable and reusable, advancing global SEEA EEA efforts	• Benefits of data & model interoperability, path to achieve it are poorly understood by most scientists • Models for incorporating beneficiaries/ ecosystem service use are not yet fully built out
ESTIMAP	• Endorsed by Joint Research Centre to underpin ecosystem accounting in the European Union • Model customizability is possible (Zulian et al. 2018)	• Models are written in different programming languages, so are difficult for external users to apply
InVEST	• Most widely used ecosystem services modelling tool • Very well documented • Large user community	• Relatively limited use to date in ecosystem accounting • Limited accounting for beneficiaries/ecosystem service use
Custom ES models	• Often well known and trusted by scientists and decision makers in the contexts in which they are applied	• Limited comparability between ecosystem accounts compiled for different regions when using widely varying modelling approaches (e.g., differences in output metrics, modelling paradigms used)

The last point is important as the people developing ecosystem accounts are usually developing accounts for areas with which they have existing knowledge and expertise and are endeavouring to adapt what they know to produce ecosystem accounts as a new perspective on what they already know. This was certainly the case in several studies (e.g. Bagstad et al., 2018; Keith et al. 2017; etc.)

As experience with ecosystem accounting grows in time it may be that a particular model or suite of models emerge as best practice for estimating the flows of ecosystem services in an accounting framework. Until such a time, which would seem several years away at least, then a range of modelling will continue to be used and it will be important that modellers, experts in ecosystem services and ecosystem accounting continue to collaborate and share experiences. In the meantime, the development of the ecosystem accounting and related modelling should adopt the FAIR Data Principles proposed by Wilkinson et al. (2016) – that to maximize its value, scientific data should be Findable, Accessible, Interoperable, and Reusable.

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