System of Environmental Economic Accounting

Discussion paper on valuation 2: Valuation method selection criteria – a proposal

for the Forum of Experts in SEEA Experimental Ecosystem Accounting 2018 – breakout 1, area 4

Version: 13 June 2018

Prepared by: SEEA EEA Revision Working Group 4 on spatial units (led by Rocky Harris, DEFRA, UK)

18 – 20 June 2018

Glen Cove, New York, USA

Table of Contents

1 Introduction

The intention of this Working Paper is to propose a draft set of evaluation criteria that could be used to select valuation methods for their appropriateness for use in SEEA EEA. The overall approach is to screen valuation methods for particular ecosystem service applications. As such it complements the Working Paper "List of key Ecosystem Services from a valuation perspective", by offering a structured way of assessing the "Potential indicator for monetary value of service" discussed there.

The proposed selection criteria follow a hierarchy[1]:

1. Consistency between accounting concepts and methods
2. Practical consideration for application
3. Institutional capacity to conduct valuation
4. Other policy applications of valuation information

A starting point for the discussion is also Table 6.1 (Appendix 2) in The SEEA Experimental Ecosystem Accounting Technical Recommendations (SEEA EEA TR[2]) providing an overview of valuation techniques potentially appropriate for measuring exchange value. We suggest that (i) a screening of methods using a wider set of criteria, in (ii) ecosystem service specific applications, may help to identify methods that are more robust than others for a number of purposes and conditions.

The paper demonstrates the application of a draft criteria set for three examples of valuation methods applied to a specific provisioning, regulating and cultural ecosystem service. The three valuation methods and their application setting have been chosen based on contexts the author is familiar with. These are examples of how to interpret the criteria, rather than conclusions on the appropriateness of the method in question for SEEA. The appropriateness of the method could change in another specific ecosystem service setting the reader may be more familiar with.

The reader is encouraged to work through some familiar examples of their own using the templates at the end of the paper. This aim is to encourage thinking about whether the criteria are

(i) clearly formulated?
(ii) redundant ?
(iii) missing any key considerations? and
(iv) which criteria are *essential* or *supporting considerations* (and why from a theory or implementation point of view)?

2 Draft criteria for selection of monetary valuation methods for ecosystem accounting

Our initial proposal for valuation method selection criteria, include

1. **Conceptual consistency**
    a. **Production boundary?** Does the method address ecosystem services that fall inside/outside SNA production boundary?[3]

[1] Adapted from a hierarchy suggested by Atkinson and Obst (2017)

[2] White cover draft 20 December 2017

[3] This could be an example of a redundant criteria because the purpose of SEEA EEA is to extend the boundary to all ecosystem services.

   b. **Individual services? Double counting?** Is the method able to identify the ecosystem service individually? Does this identification reduce the likelihood of double counting.
   c. **Exchange values?** Does the method use exchange values?
   d. **Sensitivity to scarcity**? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?
   e. **Institutional compatibility?** Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?

Criteria a-c are discussed at some length in the SEEA EEA TR.

2. **Practical considerations for application (to policy analysis)**
   a. **Significance?** Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)
   b. **Robustness?** Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)
   c. **Accuracy?** Can valuation method variance/uncertainty be quantified? (is the method sensitive to spatial and temporal variation in the accounting area and period?)

3. **Institutional capacity to conduct valuation**
   a. **Technical complexity?** Does the method require a specialist in a particular software?
   b. **Information cost?** Is the method costly to implement (time to completion)

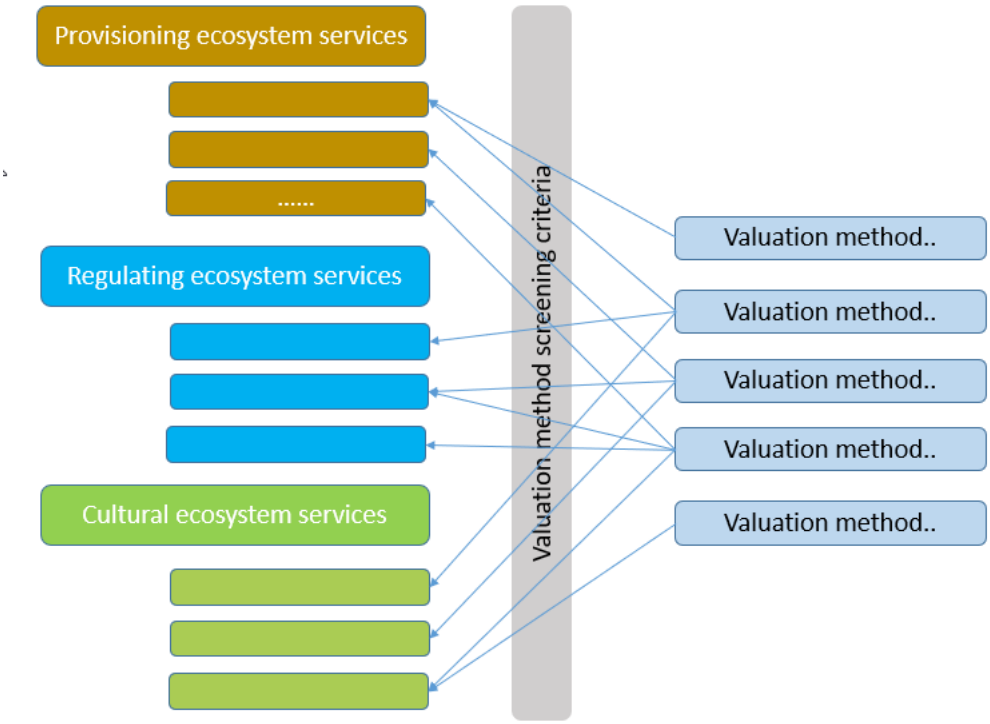
4. **Other policy applications?** Are the results of the method applicable to many other policy analysis purposes, than those of accounting?

Similarly to the other accounts, the information value of the monetary valuation for supply and use accounts is higher the more additional policy applications it has. AN overview of different valuation purposes is provided in Appendix 1.

3 Ecosystem service – valuation – criteria assessment tables

Figure 1 outlines a possible comprehensive approach to evaluating ecosystem service specific valuation methods. A comprehensive screening would aim to populate tables such as those exemplified in Table 1.1(provisioning), 2.1(regulating) and 3.1(cultural) for each ecosystem service for a particular accounting area.

Figure 1: A comprehensive evaluation of monetary valuation methods with regards to specific ecosystem services.



An ecosystem service specific evaluation of potential valuation methods could be simplified and speeded up by initially selecting only valuation methods that are known from the literature. For each ecosystem service there may not be any choice among methods due to data limitations, but as data becomes available with future accounting practice, documentation of method choice will be useful in future.

However, a systematic review of all valuation methods across all services should be revealing regarding key data, method or institutional assumptions that make a method ineligible.

The tables below indicate a possible way of documenting the comprehensive use of valuation methods selection criteria for each specific ecosystem service.

Some examples of how to use the criteria tables are provided below. The scores shown in Tables 1.1, 2.1 and 3.1 are meant to provide a quick summary of the more detailed discussion of each method after each table. The scores are 1=suitable; 0.5=conditional on assumptions (discussed in the tables); 0=not suitable. Further on this could be improved using colour coding.

Provisioning services – potable water supply

Table 1.1 illustrates the comparison of three valuation methods for potable water supply. We have not assessed all methods from Table 6.1 (SEEA EEA TR) in this ES context – nor possibly relevant methods (indicated by rows in grey) - but chosen three examples that are known in the literature. This simple and selective example shows that the same ecosystem service may be supplied and used in ways that call for different valuation methods. The three contexts of drinking water supply could easily be found in low income countries across a rural-urban gradient.

A take away message from this simple exercise is that a standardisation of a valuation method for an ecosystem service in national level ecosystem accounts could ignore the spatial context specificity of values, especially resources that are not easily transported and have local markets.

Ecosystem accounts aim to make the spatial distribution of ecosystem services explicit. A discussion is needed on the extent to which context sensitive monetary valuation are expected as well. This is analogous to collecting statistics on spatially segregated markets.

Regulating services - run-off / flood control

Table 2.1 illustrates the comparison of three valuation methods for urban flood control services provided by vegetation and unsealed soil.

A take away message from these simple examples is that several monetary valuation methods are not technically difficult, and exchange values might available from readily already collected data. However, complexity resides in biophysical modelling of off-site service provision by specific green space locations. There is great spatial heterogeneity in service provision. Simple land cover proxy indicators of services (e.g. run-off coefficients) are required to implement at larger accounting scales.

Using PES to identify values of regulating services, raises the question of how SNA treats market transaction costs. PES markets have high institutional set up and running costs, which are usually covered by the regulator. Most PES schemes are not financially sustainable if these transaction costs are accounted for (Vatn et al. 2014).

Cultural services

Table 3.1 illustrates the comparison of three valuation methods for local outdoor recreation, provided by green spaces in urban areas.

A take away message from the simple examples below is that most methods have significant deficiencies when seen across all criteria. The benefit to be valued is not well targeted by the value concept in any of the cases, for very different reasons (service bundles rather than individual service; single attribute of a complex good; endogeneity of the value metric with other values).

A general observation is that remote sensing data provides biophysical resolution that far exceeds the spatial resolution of economic use data and most monetary valuation methods. Average unit value scaling/valuation of highly spatial resolved biophysical data gives a false cartographic impression of spatial accuracy of monetary valuation.

Table 1.1 Ecosystem service specific valuation methods: potable water

Ecosystem service: raw water supply for potable water	**Method selection criteria:**										
Monetary valuation methods (Y)	Production boundary	Double counting	Exchange values	Sensitivity	Institutional compatibility	Significant	Robustness	Accuracy	Technical complexity	Information cost	Other policy applications
1. Unit resource rent/net factors of production	1	0.5	1	0.5	1	0.5	1	1	1	1	1
2. Production function, cost function and profit function											
3. Payments for ecosystem services											
4. Hedonic pricing											
5. Replacement cost	1	1	1	1	0.5	1	1	1	1	1	0
6. Damage cost avoided											
7. Averting behaviour											
8. Restoration cost											
9. Travel cost, random utility models											
10. Stated preference (contingent valuation, choice experiments)											
11. Simulated exchange values[4]											
13. Value of quality adjusted statistical life											
14. Value of household time	0	1	1	1	0	0	1	0	1	0.5	1

Possible scoring options as a starting point for discussion: 1=suitable; 0.5=conditional on assumptions; 0=not suitable

[4] "Marginal values from demand functions" in the SEEA EEA TR

Table 1.1.1 **Criteria:**	**Ecosystem service:** ***Potable water supply*** **Valuation method:** ***Unit resource rent/net factors of production <u>of municipal supply</u>***	
1.Conceptual consistency		Suitability score
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?	Yes	1
Individual services? Double counting? Is the method able to identify the ecosystem service individually? Does this identification reduce the likelihood of double counting.	Partially. Municipal potable water supply is used for drinking, hygiene, gardening, and recreation. Surveys of final household uses can apportion value by use, but not by demand. Reclassification of the service definition to "potable water supply" can sidestep this issue, but reclassificiation then makes comparison with other methods imperfect.	0.5
Exchange values? Does the method use exchange values?	Yes. But prices are often fixed by regulator.	1
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	Depends on regulator. Example: Municipal water charges often set at cost recovery level. Prices change if municipality has to shift to another source of supply during scarcity	0.5
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Yes	1
2.Practical considerations for application (to policy analysis)		
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	Yes. Depends on the actual case.	0.5
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	No. Average unit resource rent Yes. Modelling of optimal rents, removing transfers and barriers to entry	1 0
Accuracy? Can valuation method variance/uncertainty be quantified? (is the method sensitive to spatial and temporal variation in the accounting area and period?)	No. The variance in water supply costs locally and for a single accounting period is determined by the weather. Yes. At national level variance in supply costs across municipalities can be observed.	0 1
3.Institutional capacity to conduct valuation		
Technical complexity? Does the method require a specialist in a particular software?	No. Average unit costs Yes. Optimal rents	1 0

Information cost? Is the method costly to implement (time to completion)	No. Yes. Optimal rents. But some agencies have established research that lowers implementation time.	1 0.5
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	No. Low resource rents in water supply are indicative of regulations to supply basic needs. (in fisheries and forestry resource rents may indicate a number of competing policies)	0

Table 1.1.2 **Criteria:**	**Ecosystem service:** ***Drinking water supply*** **Valuation method:** ***Replacement cost (bottled water)***	
1.Conceptual consistency		Suitability score
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?	Yes	1
Individual services? Double counting? Is the method able to identify the ecosystem service individually? Does this identification reduce the likelihood of double counting.	Yes	1
Exchange values? Does the method use exchange values?	Yes	1
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	Yes	1
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Yes. In locations with no potable municipal supply. No. In locations with potable municipal supply, drinking water on tap at cost may be seen as a right.	1 0
2.Practical considerations for application (to policy analysis)		
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	No	1
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	No	1
Accuracy? Can valuation method variance/uncertainty be quantified? (is the method sensitive to spatial and temporal variation in the accounting area and period?)	Yes	1
3.Institutional capacity to conduct valuation		
Technical complexity? Does the method require a specialist in a particular software?	No	1

Information cost? Is the method costly to implement (time to completion)	No	1
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	No	0

Table 1.1.3 **Criteria:**	**Ecosystem service:** ***Drinking water supply*** **Valuation method:** ***Opportunity cost of household time (contexts without municipal or bottled supply)***	
1.Conceptual consistency		Suitability score
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?	No. Household production of services – here collection of drinking water for own final use - is outside the production boundary of SNA.	0
Individual services? Double counting? Is the method able to identify the ecosystem service individually? Does this identification reduce the likelihood of double counting.	Yes	1
Exchange values? Does the method use exchange values?	Yes. The opportunity cost of time spent fetching and boiling water could be valued at foregone wages after tax. But there is a coincidence of water collection with low income and unemployment	1
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	Yes. Increased scarcity leads to longer water transportation times from sources further afield	1
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Probably not. Household memners that must collect water have low opportunities for work and low income.	0
2.Practical considerations for application (to policy analysis)		
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	Yes. In places where water is collected manually, typically women and children without employment opportunities do so, meaning that monetary opportunity costs are low or zero.	0
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	No	1
Accuracy? Can valuation method variance/uncertainty be quantified? (is the method sensitive to spatial and temporal variation in the accounting area and period?)	No. In the low income contexts where water needs collecting, and because household time contribution to own	0

	subsistence is not within SNA, data is not collected systematically	
3.Institutional capacity to conduct valuation		
Technical complexity? Does the method require a specialist in a particular software?	No	1
Information cost? Is the method costly to implement (time to completion)	No. Simple field observations, but relatively large sample representing the population	0.5
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	Yes. Time spent, combined with low opportunity cost is an indicator of poverty, and unemployment.	1

Table 2.1

Ecosystem service: run-off control **Benefit: reduced flood damage risk**	**Method selection criteria:**										
Monetary valuation methods (Y)	Production boundary	Double counting	Exchange values	Sensitivity	Institutional compatibility	Significant	Robustness	Accuracy	Technical complexity	Information cost	Other policy applications
1. Unit resource rent/net factors of production											
2. Production function, cost function and profit function											
3. Payments for ecosystem services	0	0	1	0	1	1	0	0	0	1	1
4. Hedonic pricing											
5. Replacement cost	0	1	1	0	1	1	1	1	0.5	0.5	1
6. Damage cost avoided	0	0.5	1	1	1	1	0.5	1	0	0	1
7. Averting behaviour											
8. Restoration cost											
9. Travel cost, random utility models											
10. Stated preference (contingent valuation, choice experiments)											
11. Simulated exchange values[5]											
13. Value of quality adjusted statistical life (new to TR Table 6.1)											
14. Value of household time (new to TR Table 6.1)											

[5] "Marginal values from demand functions" in the SEEA EEA TR

Table 2.1.1 **Criteria:**	**Ecosystem service: run-off control** **Valuation method: Payments for watershed services (PWS/PES)**
1.Conceptual consistency	
Production boundary? Does the method address ecosystem services that fall inside the SNA production boundary?	No
Individual services? Is the method able to identify the ecosystem service individually? **Double counting?** Does this identification reduce the likelihood of double counting.	In some exceptional local cases. A number of strict conditions need to be fulfilled for PWS to make conditional payments targeted at a single service. In most cases PES are heavily regulated instruments (Vatn et al. 2014[6]) with multiple policy objectives (Porras et al. 2018)[7]. For spatially non-uniform with off-site impacts regulating services, attribution of the marginal effect to specific landuses requires site specific calibration of hydrological models. Models are used to identify marginal service provision of a given property.
Exchange values? Does the method use exchange values?	Yes (provided payments are conditional, but the exchange value may represent a bundle of services)
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	No, not by a market alone. Or only sensitive through recalculation of hydrological models and regulatory adjustment.
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Yes. If a PWS exists it has by definition passed the institutional feasibility test. However, in many countries PWS schemes are not financially sustainable, relying on outside transfers, indicating that conditional payments do not represent the full costs of payments and administration.
2.Practical considerations for application (to policy analysis)	
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	No. Conditional payments must by definition be equal to land owners' and managers' opportunity costs.
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	Yes. Hydrological modelling of attribution, full cost accounting including transaction costs, payments conditional on individual service delivery.
Accuracy? Can valuation method variance/uncertainty be quantified? (the variance is determined by the size and heterogeneity of the accounting area, but is the method sensitive to this variation?)	No. To reduce transaction costs PWS at national level usually have a very limited or no differentiation of payments relative to service levels.
3.Institutional capacity to conduct valuation	
Technical complexity? Does the method require a specialist in a particular software?	No. Once PWS is in place exchange values are directly observable.
Information cost? Is the method costly to implement (time to completion)	Not for the valuation step itself. But information costs are very high in establishing the PWS institution.
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	Yes. PWS are used for poverty alleviation (Porras et al. 2018) and integrated in a policy mix (Barton et al. 2017)[8]

[6] Vatn et al. (2014) https://www.norad.no/en/toolspublications/publications/2014/payments-for-nature-values-market-and-non-market-instruments/

[7] Porras et al. (2018) https://www.iied.org/conditional-transfers-for-poverty-reduction-ecosystem-management

[8] https://www.researchgate.net/publication/320470557_Payments_for_Ecosystem_Services_as_a_Policy_Mix_Demonstrating_the_institutional_analysis_and_development_framework_on_conservation_policy_instruments

Table 2.1.2 **Criteria:**	**Ecosystem service: run-off control** **Valuation method: replacement cost** **(e.g. stormwater water run-off networks)**
1.Conceptual consistency	
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?	No
Individual services? Is the method able to identify the ecosystem service individually? **Double counting?** Does this identification reduce the likelihood of double counting.	Yes. But attribution of stormwater run-off control costs to loss of particular green space requires run-off coefficients or hydrological model, and some annualization assumptions of investment costs. Yes.
Exchange values? Does the method use exchange values?	Yes. Contractor prices
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	No. Costs of large infrastructure projects with decadal lag time. Average unit costs, allocated proportionally to run-off contribution.
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Yes. Existing urban flood management approach.
2.Practical considerations for application (to policy analysis)	
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	No. Not for construction costs. But estimating full costs, including lifetime maintenance is challenging, and means that construction costs are underestimates.
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	Yes. Based on spatially explicit run-off coefficients modelling and/or calibrated hydrological model.
Accuracy? Can valuation method variance/uncertainty be quantified? (the variance is determined by the size and heterogeneity of the accounting area, but is the method sensitive to this variation?)	Partly. Use data on contractor bids and realised costs for specific projects to estimate variation across sites, as well as deviations. If a hydrological model is calibrated, uncertainty estimated
3.Institutional capacity to conduct valuation	
Technical complexity? Does the method require a specialist in a particular software?	No. Run-off coefficients by landcover type Yes. Hydrological model.
Information cost? Is the method costly to implement (time to completion)	Partially. Storm water construction costs have to be collected.
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	Yes. Cost-effectiveness analysis of storm water management at different sites. Full cost-recovery accounting is needed as a basis for design financially sustainable PWS.

Table 2.1.3 **Criteria:**	**Ecosystem service: run-off control** **Valuation method: damage cost avoided** **(e.g. insurance claims on urban flooding)**
1.Conceptual consistency	
Production boundary? Does the method address ecosystem services that fall inside/outside SNA production boundary?	No
Individual services? Is the method able to identify the ecosystem service individually? **Double counting?** Does this identification reduce the likelihood of double counting.	Yes. But spatial distributed insurance claims must be attributed to specific green space locations. Yes.
Exchange values? Does the method use exchange values?	Yes
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	Yes. Insurance claims are made "on demand" when an incident occurs.
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Yes
2.Practical considerations for application (to policy analysis)	
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	No. But uninsured property owners with flooding damage will not be identified.
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions?(methods with few data transformation steps and assumptions are more robust)	Yes. Damage claims procedures are well known in the insurance industry, but attribution to green infrastructure requires a spatially distributed hydrological model.
Accuracy? Can valuation method variance/uncertainty be quantified? (the variance is determined by the size and heterogeneity of the accounting area, but is the method sensitive to this variation?)	Yes. Using insurance statistics and simulation of hydrological models
3.Institutional capacity to conduct valuation	
Technical complexity? Does the method require a specialist in a particular software?	Yes
Information cost? Is the method costly to implement (time to completion)	Yes
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	Yes. Improved estimation of insurance premia.

Table 3.1 Ecosystem service: accessible local outdoor green space Benefit: local outdoor recreation	**Method selection criteria:**										
Monetary valuation methods (Y)	Production boundary	Double counting	Exchange values	Sensitivity	Institutional compatibility	Significant	Robustness	Accuracy	Technical complexity	Information cost	Other policy applications
1. Unit resource rent/net factors of production											
2. Production function, cost function and profit function											
3. Payments for ecosystem services											
4. Hedonic pricing	0	0	1	1	1	1	0	1	0	0	1
5. Replacement cost	0	1	1	1	0.5	1	1	0.5	1	1	0
6. Damage cost avoided (health)											
7. Averting behaviour											
8. Restoration cost											
9. Travel cost, random utility models											
10. Stated preference (contingent valuation, choice experiments)											
11. Simulated exchange values[9]											
13. Value of quality adjusted statistical life											
14. Value of household time	0	1	1	0	0.5	0	1	1	1	1	1

[9] "Marginal values from demand functions" in the SEEA EEA TR

Table 3.1.1 **Criteria:**	**Ecosystem service: local outdoor recreation** **Valuation method: Hedonic property pricing**
1.Conceptual consistency	
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?	No
Individual services? Is the method able to identify the ecosystem service individually? **Double counting?** Does this identification reduce the likelihood of double counting.	No. Identifies a bundle of amenity services. No
Exchange values? Does the method use exchange values?	Yes
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	Yes. Marginal values.
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Yes.
2.Practical considerations for application (to policy analysis)	
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	Yes. In some urban contexts accessibility to vegetation may have unobservable effects on overall property prices. In complex urban environments many degrees of freedom are used in specifying real estate preferences. Site specific differences may be small, requiring very large datasets.
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	Yes. Econometric regressions need to control for e.g. spatial autocorrelation.
Accuracy? Can valuation method variance/uncertainty be quantified? (the variance is determined by the size and heterogeneity of the accounting area, but is the method sensitive to this variation?)	Yes
3.Institutional capacity to conduct valuation	
Technical complexity? Does the method require a specialist in a particular software?	Yes. Assigning marginal amenity values across a population of households to

	multiple specific green spaces is an unresolved GIS modelling task.
Information cost? Is the method costly to implement (time to completion)	Yes
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	Yes. Can be used to adjust property taxes to account for value-added to private property by public management of public green spaces.

Table 3.1.1 **Criteria:**	**Ecosystem service: local outdoor recreation** **Valuation method: Replacement cost (indoor gym/physical exercise)**
1.Conceptual consistency	
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?	No
Individual services? Is the method able to identify the ecosystem service individually? **Double counting?** Does this identification reduce the likelihood of double counting.	Yes. But the substitute is only for one attribute - the physical space in which to carry out physical exercise, not for the vegetation and landscape qualities. Yes.
Exchange values? Does the method use exchange values?	Yes
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	Yes. Marginal
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Partly. It is acceptable to compensate for loss of access to outdoor recreation areas with indoor recreation areas, if outdoor recreation areas for specific physical activities become scarce (e.g. because of weather, seasons, climate change).
2.Practical considerations for application (to policy analysis)	
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	No.
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	No
Accuracy? Can valuation method variance/uncertainty be quantified? (the variance is determined by the size and	Partly. The valuation is of only on attribute of outdoor recreation, the estimate may

heterogeneity of the accounting area, but is the method sensitive to this variation?)	have precision, but is not accurate in relation to the valuation target.
3.Institutional capacity to conduct valuation	
Technical complexity? Does the method require a specialist in a particular software?	No
Information cost? Is the method costly to implement (time to completion)	No
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	No

Table 3.1.1 **Criteria:**	**Ecosystem service: local outdoor recreation** **Valuation method: Value of household time at recreation site** **(opportunity cost)**
1.Conceptual consistency	
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?	No. Household time spent on production of goods and services for own subsistence is not considered.
Individual services? Is the method able to identify the ecosystem service individually? **Double counting?** Does this identification reduce the likelihood of double counting.	Yes. Time spent at a recreation site is commonly used to express the importance of a recreational visit. Yes. If separately identified from time allocated to reaching the site. For local recreation there is little or no travel time (going for walks).
Exchange values? Does the method use exchange values?	Yes. Opportunity cost of time , as foregone wages after tax.
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?	No. This monetary measure is insufficient where household members are not employed and/or do not have remunerated flexible working time. As demand for recreation by a household increases, the opportunity cost per hour may also shift, if terms of salary must be renegotiated. Also, opportunity costs may be a step function, if overtime is paid differently. However, in labour markets with flexible working hours (accumulative, non-remunerated overtime), opportunity cost of wages after tax may be a

	good proxy for the foregone monetary value of recreation time.
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?	Depends on the labour market. Individual specific.
2.Practical considerations for application (to policy analysis)	
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)	Yes. Unemployed.
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)	No
Accuracy? Can valuation method variance/uncertainty be quantified? (the variance is determined by the size and heterogeneity of the accounting area, but is the method sensitive to this variation?)	Yes
3.Institutional capacity to conduct valuation	
Technical complexity? Does the method require a specialist in a particular software?	No
Information cost? Is the method costly to implement (time to completion)	No
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?	Yes. Accounting for and valuing recreation time addresses can help answer questions about recreation access of different sectors of society, impacts of unemployment. The choice of monetary valuation method versus the physical indicator highlights issues of income inequality.

4 Appendix 1 - Applications purposes of valuation methods

Table 1 Range of study purposes of each ES appraisal method scored by case study representatives (Barton et al. 2017)

Explorative	**Conduct research** aimed at developing science and changing understanding of research peers
E1	Theory and concept development
E2	Hypothesis formulation and testing
E3	Method development and testing
Informative	**Change perspectives** of public & stakeholders
I1	Assessment of current state
I2	Assessment of long-term historic trends
I3	Assessment of potential future conditions
I4	Evaluation of existing projects and policies
I5	Raising awareness of the importance of ES
I6	Raising awareness of trade-offs and conflicts between ES
Decisive	**Generate action** in specific decision problems by stakeholders
D1	Decision problem formulation and structuring
D2	Criteria for screening alternatives
D3	Criteria for ranking alternatives
D4	Criteria for spatial targeting (zoning & planning of alternatives)
D5	Arguments for negotiation, shared norms & conflict resolution
Design	**Produce outcomes** through design and implementation of policy instruments with stakeholders
T1	Standards & policy target-setting
T2	Land and natural resource management rules & regulations
T3	Licencing / permitting / certification
T4	Pricing, setting incentive levels
T5	Establishing levels of damage compensation

Table 6.1: Summary of valuation techniques and their use in ecosystem accounting (Source: SEEA EEA TR White cover paper, Dec 20, 2017)

Valuation technique	Description	Comments	Suitability for valuation of individual ecosystem services	Applicable for the following ecosystem services
Unit resource rent	Prices determined by deducting costs of labour, produced assets and intermediate inputs from market price of outputs (benefits).	Estimates will be affected by the property rights and market structures surrounding production. For example, open access fisheries and markets for water supply often generate low or zero rents.	In principle, this method is **appropriate** but care is needed to ensure that the residual estimated through this approach is limited to the target ecosystem service	Provisioning services involving harvest or abstraction (e.g. concerning timber, fish, crops, livestock, etc.) Potentially, also applicable to cultural services such as recreation provided by established businesses.
Production function, cost function and profit function methods	Prices obtained by determining the contribution of the ecosystem to a market based price using an assumed production, cost or profit function.	In principle, analogous to resource rent but generally can be better targeted to focus only on specific ecosystem services and models more able to take into account ecological connections. However, likely more data intensive and require benefit transfers methods for higher level aggregates.	**Appropriate** provided the market based price being decomposed refers to a product rather than an asset – e.g. value of housing services rather than the value of a house.	Prices for all type of ecosystem services may be estimated using this technique provided an appropriate production or similar function can be defined. This will require that the ecosystem services are direct inputs to the production of existing marketed goods and services. It is likely to be of most relevance in the estimation of prices for provisioning services and for certain regulating services that are inputs to primary production, e.g. water regulation.
Payment for Ecosystem Services (PES) schemes	Prices are obtained from markets for specific regulating services (e.g. in relation to carbon sequestration)	Estimates will be affected by the type of market structures put in place for each PES (see SEEA EEA 5.88-94)	**Possibly appropriate** depending on the nature of the underlying institutional arrangements.	Given the most common focus of PES schemes, the price information will be most applicable to the valuation of regulating services, e.g. carbon sequestration.
Hedonic pricing	Prices are estimated by decomposing the value of an asset (e.g. a house block including the dwelling and the land) into its characteristics and	Very data intensive approach and separating out the effects of different characteristics may be difficult, unless there are large sample sizes.	**Appropriate in principle**, if an individual service can be identified. Heavily used in the pricing of computers in the national accounts.	Most commonly applied in the context of decomposing house and land price information and hence will be relevant for those ecosystem services that impact on those prices. Examples include

	pricing each characteristic through regression analysis			access to green space, amenity values and air filtration. A challenge is attributing the estimated prices to the location of supply.
Replacement cost	Prices reflect the estimated cost of replacing a specific ecosystem service using produced assets and associated inputs.	This method requires an understanding of the ecosystem function underpinning the supply of the service and an ability to find a comparable "produced" method of supplying the same service.	**Appropriate** under the assumptions (i) that the estimation of the costs reflects the qualities of the ecosystem services being lost; (ii) that it is a least-cost treatment; and (iii) that it would be expected that society would replace the service if it was removed. (Assumption (iii) may be tested using stated preference methods and should take into account the potential scale issues in replacing the service.)	The idea of replacement cost assumes that a service can be replaced, i.e. that a man-made alternative can be developed. In general, this engineering type focus will mean that the method would be applied for various regulating services such as water regulation, water purification and air filtration.
Damage costs avoided	Prices are estimated in terms of the value of production losses or damages that would occur if the ecosystem services were reduced or lost due to ecosystem changes (e.g. as a result of pollution of waterways).	May be challenging to determine the value of the contribution/impact of an individual ecosystem service.	**Appropriate** under the assumptions (i) that the estimation of the damage costs reflects the specific ecosystem services being lost; (ii) that the services continued to be demanded; and (iii) that the estimated damage costs are lower than potential costs of abatement or replacement.	Similar to replacement costs, the focus will generally be on services provided by ecosystems that are lost due to human activity impacting on environmental condition, particularly through pollution. Regulating services are likely to be the most commonly estimated using this method.
Averting behaviour	Prices are estimated based on individual's willingness to pay for improved or avoided health outcomes.	Requires an understanding of individual preferences and may be difficult to link the activity of the individual to a specific ecosystem service.	**Possibly appropriate** depending on the actual estimation techniques and also noting the method relies on individuals being aware of the impacts arising from environmental changes.	
Restoration cost	Refers to the estimated cost to restore an ecosystem asset to an earlier, benchmark condition.	The main issue here is that the costs relate to a basket of ecosystem services rather than a specific one. More often used as a means to estimate ecosystem degradation but	**Likely inappropriate** since it does not determine a price for an individual ecosystem service but may serve to inform valuation of a basket of services.	

	Should be clearly distinguished from the replacement cost method.	there are issues in its application in this context also.		
Travel cost	Estimates reflect the price that consumers are willing to pay in relation to visits to recreational sites.	Key challenge here is determining the actual contribution of the ecosystem to the total estimated willingness to pay. There are also many applications of this method with varying assumptions and techniques being used with a common objective of estimating consumer surplus. Finally, some travel cost methods include a value of time taken by the household which would be considered outside the scope of the production boundary used for accounting purposes.	**Possibly appropriate** depending on the actual estimation techniques and whether the approach provides an exchange value, i.e. excludes consumer surplus. A distinction here is that the total of actual travel costs is not a measure of the value of the ecosystem services but it may be appropriate to use the demand profile associated with the travel cost (the estimation of this demand curve is referred to as use of the travel cost method).	This will relate to valuation of recreational ecosystem services.
Stated preference	Prices reflect willingness to pay from either contingent valuation studies or choice modelling.	These approaches are generally used to estimate consumer surplus and welfare effects. Within the range of techniques used there can be potential biases that should be taken into account.	**Inappropriate** since does not measure exchange values. However, while the direct values from stated preference methods are not exchange values, it is possible to estimate a demand curve from the information and this information may be used in forming exchange values for ecosystem services.	
Marginal values from demand functions	Prices are estimated by utilising an appropriate demand function and setting the price as a point on that function using (i) observed behaviour to reflect supply (e.g. visits to parks) or (ii) modelling a supply function.	This method can use demand functions estimated through travel cost, stated preference, or averting behaviour methods. The use of supply functions has been termed the simulation exchange value approach (Campos & Caparros, 2011)	**Appropriate** since aims to directly measure exchange values. However, the creation of meaningful demand functions and estimating hypothetical markets may be challenging.	In principle, may be applied for many types of ecosystem services but most likely to be relevant in the estimation of values for regulating and cultural services.

TEMPLATE **Ecosystem service:**	**Method selection criteria:**										
Monetary valuation methods:	Production boundary	Double counting	Exchange values	Sensitivity	Institutional compatibility	Significant	Robustness	Accuracy	Technical complexity	Information cost	Other policy applications
1. Unit resource rent/net factors of production											
2. Production function, cost function and profit function											
3. Payments for ecosystem services											
4. Hedonic pricing											
5. Replacement cost											
6. Damage cost avoided (health)											
7. Averting behaviour											
8. Restoration cost											
9. Travel cost, random utility models											
10. Stated preference (contingent valuation, choice experiments)											
11. Simulated exchange values[10]											
13. Value of quality adjusted statistical life											
14. Value of household time											

[10] "Marginal values from demand functions" in the SEEA EEA TR

TEMPLATE **Valuation method: <insert>** **Criteria:**	**Ecosystem service application:** **<insert>**		
1.Conceptual consistency			Suitability score
Production boundary? Does the method address ecosystem services that fall inside SNA production boundary?			
Individual services? Double counting? Is the method able to identify the ecosystem service individually? Does this identification reduce the likelihood of double counting.			
Exchange values? Does the method use exchange values?			
Sensitivity to scarcity? Is the method sensitive to changes in ES supply and demand? Are they average unit or marginal values?			
Compatibility of value articulating institution? Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?			
2.Practical considerations for application (to policy analysis)			
Significance? Is the method vulnerable to zero or low monetary values? (relative to level of biophysical flows)			
Robustness? Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)			
Accuracy? Can valuation method variance/uncertainty be quantified? (is the method sensitive to spatial and temporal variation in the accounting area and period?)			
3.Institutional capacity to conduct valuation			
Technical complexity? Does the method require a specialist in a particular software?			
Information cost? Is the method costly to implement (time to completion)			
4.Other policy applications? Are the results of the method applicable to many other policy analysis purposes, than those of accounting?			