Valuing Ecosystem Services: a critical review

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1. Introduction

Although much has been written about ecosystem services in the last decade, there has been insufficient which clearly reveals their value. The discussion has been largely classificatory rather than analytical – e.g. the Millennium Ecosystem Assessment, Total Economic Value (TEV), and environmental accounting such as the System of Environmental and Economic Accounting (SEEA) – and has sometimes complicated rather than enlightened. Moreover these frameworks are not necessarily internally consistent, nor consistent with each other. There is no systematic analysis of what economic values ought to be reported within these frameworks although the SEEA would account in value added terms, consistent with a national accounting framework, and TEV focuses on economic surpluses but is often inter-temporally muddled.

Part of the confusion arises because the purposes of analysing ecosystem services can be narrow – such as trying to force ecosystem services into a national accounting framework – or overtly ideological, in seeking to value environmental services as part of a specific environmental policy agenda. However, while good economics is essential to understanding the implications of policy proposals, it is better not to harness economic analysis to specific policy agendas.

Following a review of classification systems for ecosystem services and their value estimation (Millennium Ecosystem Assessment, TEV, SEEA) in section 2, the necessary modelling is explored to properly identify the value of ecosystem services, and to distinguish them from "supporting" biophysical processes that only have indirect and derivative anthropogenic values (section 3). With proper modelling of ecosystem services flows and their relationships to ecosystem processes, it is possible to properly identify the value of ecosystem services (section 4) and provide guidelines for their use (section 5).

2. Ecosystem services & their measurement

There are several ways of considering ecosystem services. These services can be described and classified, as in the Millennium Ecosystem Assessment. Underlying this description of ecosystem services is an implicit understanding of the biophysical structure and functions of these services (section 2.1). Economists have described and classified ecosystem services somewhat differently, focusing on the economic functions of ecosystem services (section 2.2). Neither of these approaches is adequate, as biophysical description and classification tend to ignore economic function, and vice versa. Only when ecosystem services are properly considered within a model which integrates biophysical and economic functions can the economic values of ecosystem services be properly identified and defined.

A parallel strand of thinking focuses on attempting to integrate the economic values of ecosystem services into the national accounting framework (section 2.3). The national accounts were originally developed to support understanding of the national economy and, ultimately, to support (short-term) macroeconomic policy-making and management, and thus focused on consistent ways of deriving relevant macroeconomic aggregates. However, understanding the economic values of the environment, and environmental policy-making and management, is not the same as macroeconomic analysis and management which focuses on the market economy, nor is the same data relevant. Again, proper environmental accounting requires integrated biophysical and economic modelling to identify what activities can and should be valued for national accounting, and appropriate methods for this valuation.

2.1 Ecosystem Services

<u>Millennium Assessment</u>

The key definition in the Millennium Ecosystem Assessment approach was that "Ecosystem services are the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment 2003, p.49). Thus,

• The goal of the Millennium Ecosystem Assessment (MA) is to establish the scientific basis for actions needed to enhance the contribution of ecosystems to human well-being without undermining their long-term productivity.

• The conceptual framework for the MA places human well-being as the central focus for assessment while recognizing that biodiversity and ecosystems also have intrinsic value and that people take decisions concerning ecosystems based on considerations of both well-being and intrinsic value. (Millennium Ecosystem Assessment 2003, p.26)

The Millennium Assessment identified four classes of ecosystem services (Millennium Ecosystem Assessment 2003, pp.56-59):

Provisioning Services: the (quantity of biological) products obtained from ecosystems – food and fibre; fuel; genetic resources; biochemicals, natural medicines, and pharmaceuticals; ornamental resources (both animate and inanimate); fresh water Millennium Ecosystem Assessment 2003, p.56).

• these products include those contemporaneously extracted and used, and those prospectively obtained (i.e. those such as genetic resources and biochemicals which may be the basis of future, not contemporary products); but

• these products do not include once-biological products such as coal, oil and gas.

Regulating Services: "the benefits obtained from the regulation of ecosystem processes", i.e. ecosystem functions which maintain the quantity and quality of provisioning services; including: air quality maintenance; climate regulation; water regulation; erosion control; water purification and waste treatment; regulation of human diseases; biological control; pollination; storm protection (Millennium Ecosystem Assessment 2003, p.57).

Cultural Services: "nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences"; including: cultural diversity; spiritual and religious values; knowledge systems; educational values; inspiration; aesthetic values; social relations; sense of place; cultural heritage values; recreation and ecotourism (Millennium Ecosystem Assessment 2003, p.58).

Supporting Services: "those [ecosystem functions] necessary for the production of all other ecosystem services"; "their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people." (Millennium Ecosystem Assessment 2003, p.59)

These categories are not, however, mutually exclusive: "Some services, like erosion control, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people." (Millennium Ecosystem Assessment 2003, p.59).

Very similar frameworks had been developed earlier (de Groot 1992, p.229). If both "Supporting Services" and "Provisioning/Regulating Services" are valued, then it is likely that double counting will occur.[1]

2.2 Ecosystem services measurement through TEV

A standard economics approach to valuing ecosystem services is through "total economic value" (TEV). The TEV framework parallels – but is not identical to – the Millennium Ecosystem Assessment classification of ecosystem services and functions. Various (but not exhaustive, nor consistent) frameworks of TEV are depicted in Appendix 1. Common features of these TEV frameworks are:

[1] de Groot (1992, n.138) had also noted possibilities of double counting.

- distinction between “use” and “non-use” values
- identification of “direct” and “indirect” forms of use value

There is, however, a diversity of treatments for “non-use” values. All examples in Appendix 1 classify “existence” values as “non-use” values; however, two of the three frameworks classify “option” values as a form of use value, with one of these also classifying “bequest” values as a form of option value. There is also sometimes carelessness in labelling direct use values as “market” (when some, such as some forms of recreation, may be non-market), and erroneously designating a “market to non-market” spectrum from direct use values to non-use values such as existence values.

Even allowing for variations in the classification of TEV, there are several problems with the underlying concepts:

- ambiguity of TEV: economists normally think of “total” as having a quantitative, aggregate meaning – as in “total benefit”, “total cost” – when, in TEV, “total” carries the meaning of “comprehensive”, i.e. including all classes of values.

- nature of values being estimated: it is unclear whether valuation is to be understood in national account terms (e.g. as gross output or valued added) or in neoclassical microeconomic terms (e.g. as producer and/or consumer surplus)

- framework is inherently static in direct use values, where per period flows are considered without reference to changes in the stocks (e.g. of fish, timber, soil) from which they arise.

- lack of clarity between flow and stock (or capital) values: direct use values are normally clearly identified as flows; however existence, bequest and option values are clearly stock values; and indirect use values may be changes in stocks, or resource flows used to manage stocks.

- where capitalised values are considered, they clearly reflect only the values of the current generation (bequest, option), but existence values especially (and also bequest and option values) are also relevant to future generations; further, because the rate of resource extraction can affect future stocks, future generations’ values are also important.[2]

Most importantly, nearly all indirect use values (or “Supporting Services” in the MEA treatment) appear to be double counting, at least in an intertemporal context, because the flows underlying indirect use values of the current period affect the (potential) flows of services which become direct use values in future periods.

2.3 Environmental accounting

Environmental accounts are a possible component of the standard national accounts, whose purpose has been described as:

> ... to provide information that is useful in economic analysis and formulation of macroeconomic policy. The economic performance and behaviour of an economy as a whole can be monitored using information recorded in the national accounts. National

[2] There seems an unwillingness to apply conventional Pareto welfare economics principles (the underpinnings of static neoclassical microeconomics) to intertemporal economics. Crudely, in doing benefit-cost analysis for example, economists sum benefits and costs irrespective of to whom they accrue, unless there is an explicitly-stated reason for non-unitary welfare weights. If this thinking were applied to intertemporal economics for public policy making, then there would not be a debate about “objective” and “normative” discount rates, and the UK Treasury’s approach would be acceptable (HM Treasury n.d.).

accounts data can be used to identify causal relationships between macroeconomic variables and can be incorporated in economic models that are used to test hypotheses and make forecasts about future economic conditions. Using national accounts data, analysts can gauge the impact of government policies on sectors of the economy, and the impact of external factors such as changes in the international economy. Economic targets can be formulated in terms of major national accounting variables, which can also be used as benchmarks for other economic performance measures, such as tax revenue as a proportion of gross domestic product or the contribution of government to national saving. (ABS 2000, p.1)[3]

Underlying the System of National Accounts are macro- and microeconomic concepts:

• macroeconomic: based on the Keynesian framework, flows are consolidated into gross domestic product which might be estimated via production, expenditure or income approaches (ABS 2000, p.87), stocks as the corresponding capital accounts, and

• microeconomic: the methods of valuation are consistent with a neoclassical microeconomic model of supply and demand translated into an accounting framework with adjustments, where possible, for market imperfections (ABS 2000, pp.79-83; e.g. see p.80 on transfer pricing). However, the national accounts do not necessarily collect economically relevant data: for example, the key national accounts variable "value added" does not correspond to relevant microeconomic variables such as producer and consumer surplus.

As both macro- and microeconomics were themselves evolving as the national accounts framework was developed, and continued evolving subsequently, there is not a perfect one-to-one correspondence between economics theory and national accounts practice:

As Norgaard explains, GNP and the other national indicators are not consistently derived from any economic theory and even if they were, they would be incompatible with rival economic theories. The national accounts are a "historical mishmash", as Norgaard puts it, in which neoclassical and Keynesian ideas are mixed with the needs of tax collectors. … Daly (1988), for instance, argues that GNP does not reflect welfare at all, but is the addition of all the *costs* incurred in a society. (de Groot 1992, p.247).[4]

Integrated Environmental and Economic Accounting (commonly known as the System of Environmental and Economic Accounting, or SEEA) provides both a systematic framework and a protocols for environmental accounting.[5] The purpose of SEEA (2003) was described as:

… to explore how sets of statistical accounts can be compiled which will permit investigation and analysis of the interaction between the economy and the environment.

[3] Jaszi (1958, p.20) identified a "real cleavage in the uses of national income statistics" between "two types of economic analysis: one, the objective appraisal of economic results—for want of a better term we may call this normative analysis; two, the study of economic behavior. These two basic uses often call for different types of information." cf. "As economies become larger and more complex, it is increasingly important to have good economic statistics organized in an analytically meaningful way to provide an empirical counterpart of those economies across time and space. Economic accounts have evolved to become the centerpiece of such a system of statistics enabling decision makers to see where the economy has been and its recent status as background for projections of where it may be going and the kinds of policies necessary for governments and private groups or individuals to achieve their objectives." (Kendrick 1996, p.2)
[4] ABS (2000, para.4.12) noted: "GDP is a measure of production and not a measure of economic welfare." Some components of "Final consumption expenditure" might represent a <u>lower bound</u> estimate of welfare, but not consumer surplus.
[5] The 2003 version of SEEA (not yet ratified) was jointly produced by the United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, and the World Bank.

but firmly within a sustainability framework:

> Only by integrating the two areas can the implications for sustainability of different patterns of production and consumption be examined or, conversely, can the economic consequences of maintaining given environmental standards be studied. Policy makers setting environmental standards need to be aware of the likely consequences for the economy. Those determining the development of industries making extensive use of environmental resources either as inputs or sinks, need to be aware of the long-term environmental effects. (SEEA 2003, para. 1.3)

SEEA (2003, para. 1.34) subsequently acknowledges:

> It is clear from the foregoing that the SEEA can serve as at least a partial framework for measuring sustainable development from all three of the broad approaches noted [triple bottom line, ecological and capital approaches to sustainable development cf. paras. 1.11-1.22]. The system has not been designed to serve any particular perspective[6] and, indeed, should be of considerable value regardless of the user's particular point of view on the concept.

The SEEA (2003) presents environmental accounting in four categories:

1. Physical and hybrid flow accounts
   "The objective is to see the extent to which the economy is dependent on particular environmental inputs and the sensitivity of the environment to particular economic activities. … Once the physical data are aligned with economic classifications, an obvious next step is to compare the physical quantities with the matching economic flows. … by means of hybrid accounts … [which] is a means of confronting physical information about the use of environmental resources with information in both physical and monetary terms about the processes of economic production." [paras. 1.41-1.44][7]

2. Economic accounts and environmental transactions
   Augments the hybrid accounting structure "to identify where expenditure is undertaken to alleviate or rectify these pressures. … it is increasingly common for more environmentally friendly behaviour to be encouraged by means of economic instruments [such as] taxes to discourage consumption by increasing prices or … controlling property rights and access to environmental media by … selling licences and permits." [paras. 1.46-1.47]

3. Asset accounts in physical and monetary terms
   "… natural capital falls into three broad categories: natural resources, land and ecosystems. … SEEA includes asset accounts in physical and monetary terms … When natural resources are used in a production process, they are embodied in the final good or service produced. The price charged for the product contains an element which implicitly covers the value of the natural resource. Establishing this implicit element is at the heart of valuing the stock of the resource and seeing the full role of the resource in the production activity of extracting the resource and making it available to other units in the economy." [paras. 1.49-1.50]

4: Extending SNA aggregates to account for depletion, defensive expenditure and degradation

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[6] Except, presumably, "sustainable development" broadly defined.

[7] The physical data element of SEEA's "Physical and hybrid flow accounts" has been extensively reported in Australia's National Land & Water Resources Audit (NLWRA, http://www.nlwra.gov.au/) whose data is presented in the Australian Natural Resources Atlas (http://www.anra.gov.au/); and also in some State of Environment reports at both Commonwealth and state levels.

"… deals with the extension of the existing SNA aggregates to account for depletion and degradation of natural capital, as well as for so-called defensive expenditures related to the environment. … Some of the expenditure in the economy relates to attempts to avoid using the sink function of the environment. This includes environmental protection expenditure and may include other expenditure of a type which might be described generally (albeit not very precisely) as defensive expenditure. … Putting a value on the actual use of the sink function remains a much more difficult problem than the two just mentioned. While it might be possible to make some order of magnitude estimates for marginal changes in the use of the sink function, comprehensive estimates go beyond standard accounting into the realm of modelling." [paras. 1.55-1.58][8]

Because the SEEA is designed to integrate with the national accounts it contains, in Norgaard's words, the same "historical mishmash" of economics ideas. In a market economy with no market failures, the "price charged" does "implicitly cover the value of the natural resource".[9] However, since problems of environmental management are all about market failure, market prices do not "implicitly cover the value of the natural resource". Further, for example, managing sinks is all about managing natural resources over time, and this absolutely requires economic modeling which the SEEA approach eschews. SEEA is possibly of limited use for collecting data for environmental management, although "the realm of modelling" is absolutely critical to identifying the variables that should be measured and valued.

Effective development of SEEA requires not just consideration of how information collection might integrate into the standard System of National Accounts, but requires a prerequisite understanding of contemporary environmental economics, and the data required to implement the models of contemporary environmental economics. Much of this data is non-market economics data, which statistics bureaux do not routinely collect.

In the Australian context, the Wentworth Group (2008) has urged the development of national environmental accounts. Cosier, a member of the Wentworth Group (2009) argued that "The lack of an environmental accounting framework is one of the great failures of public policy of our generation and is at the core of our environmental problems" (Cosier 2009).[10] The Wentworth Group (2008, p.1) had asserted:

> Australia needs an environmental accounting system that will, in an economically effective way:
> 1. Provide annual national, state/territory-wide and regional (catchment) scale reports which measure the health and change in condition of our major environmental assets;
> 2. Underpin the long-term catchment management and land use planning decisions by Commonwealth, state/territory and local governments, and regional authorities; and
> 3. Improve the cost effectiveness of public and private investments in environmental management and repair.

The Wentworth Group (2008, p.2) asserted that "National Environmental Accounts must be based on scientific measurements of specific indicators to measure the health and change in condition of each asset in each region and the threats to those assets."[11] The "health and change in condition" of these assets would presumably reflect national accounting concepts of stocks and flows – the "health" being the stock of an asset (in both quantity and quality terms),

[8] Of course, all data is meaningless without modelling, even if only via intuitive appraisal.
[9] This idea of no market failure reflects practice in the national accounts that commodities and services which are valued have both an owner and a market price.
[10] also with the imprimatur of ABS cf.
http://www.abs.gov.au/ausstats/abs@.nsf/papersbytitle/2E8FFB62654D49D7CA2574C80014613D?OpenDocument
[11] Extensive work had previously be undertaken by the National Land & Water Resources Audit: http://www.nlwra.gov.au/

and the “change in condition” being an asset’s appreciation or depreciation (again, in both quantity and quality terms).

2.4 Summary

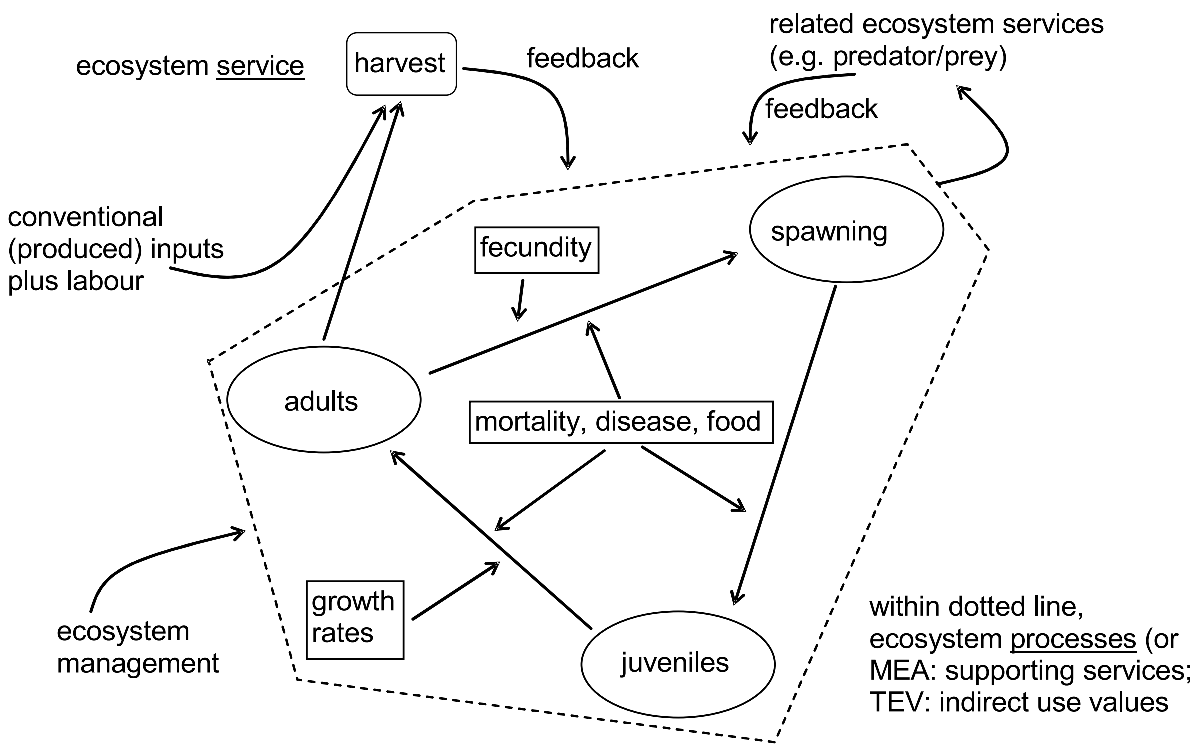
The several classification systems for ecosystem services such as the Millennium Assessment and Total Economic Value are not necessarily internally consistent, nor consistent with each other. The SEEA approach to systematically constructing environmental accounts is not built on an understanding of ecosystem services. There is thus no systematic analysis of the appropriate economic values to report within these frameworks, although the SEEA would account in value added terms consistently with a national accounting framework.

3. Modelling ecosystem services

3.1 Basics

Satisfactory economic modelling of ecosystem services requires a good understanding of the variables that are required for economic analysis. This can be best illustrated by way of example. Figure 1 is a standard representation of ecological relationships in a fishery. The relationships within the dotted line are standard biological activities of reproduction, growth and death, and are functions of species characteristics (e.g. fecundity, lifespan); growth rates for given levels of food supply; predation (e.g. of spawn, juveniles, adults). It is helpful to label these relationships as “ecosystem processes” rather than “ecosystem services” in contrast to other approaches – e.g. the Millennium Ecosystem Assessment denotes these as supporting (ecosystem) services, while they are “indirect use values” in the “total economic value” framework. In this example, ecosystem services arise as the species is harvested; related ecosystem services might arise from harvest of associated predator species. There may be feedback effects in the ecosystem from both harvest and predation, and there may be “ecosystem management”, both negative (e.g. pollution) and positive (e.g. control of exotic species) which affect ecosystem processes (and thus ecosystem services).

Figure 1: Simple representation of a fishery



In this simple example of ecosystem services, ecosystem services other than the target species are ignored for simplicity; similarly, homogenous quality of output is also assumed. The quantity of the ecosystem service in this simple example is just the harvest level. (The relationship between the harvest and stock level will help determine the sustainability of the species.) The value of the ecosystem service in this example is a function of the harvest level. However, because other inputs – capital, labour, other produced inputs etc – are required for production, the value of the ecosystem service is the gross value of the harvest, less the value of all anthropogenic inputs, i.e. the resource rent.

3.2 Getting biophysical systems right

Using the previous example of a fishery, previous conceptual depictions of ecosystem services can be easily amended to make them consistent with an economic framework. Figure 2 is based on Abel et al's (2003 Figure 3.1) "Natural capital and ecosystem services", with the following modifications:

(i) adding "and consumption" to the economic activities to which "Ecosystem services" contribute – because ecosystem services such as those obtained from national parks and beaches etc. directly provide inputs to consumption

(ii) re-labelling "Maintaining natural assets: Regeneration" and "Maintaining natural assets: Assimilation" as "Ecosystem processes". It is preferable not to use "ecosystem services" to represent both "Inputs to production [and consumption]" and "Maintaining natural assets" – if both are directly valued, valuing the second causes double counting; it is preferable to use "ecosystem processes" to denote "maintaining natural assets", to distinguish them from ecosystem services which are directly used anthropogenically; and

(iii) adding the complementary anthropogenic inputs to "Ecosystem services" for "Goods and Services" production – for valuation purposes, anthropogenic inputs such as capital and labour, and intermediate outputs, must be considered otherwise the gross value of "goods & services" is attributed to "ecosystem services".

Figure 2: Ecosystem services

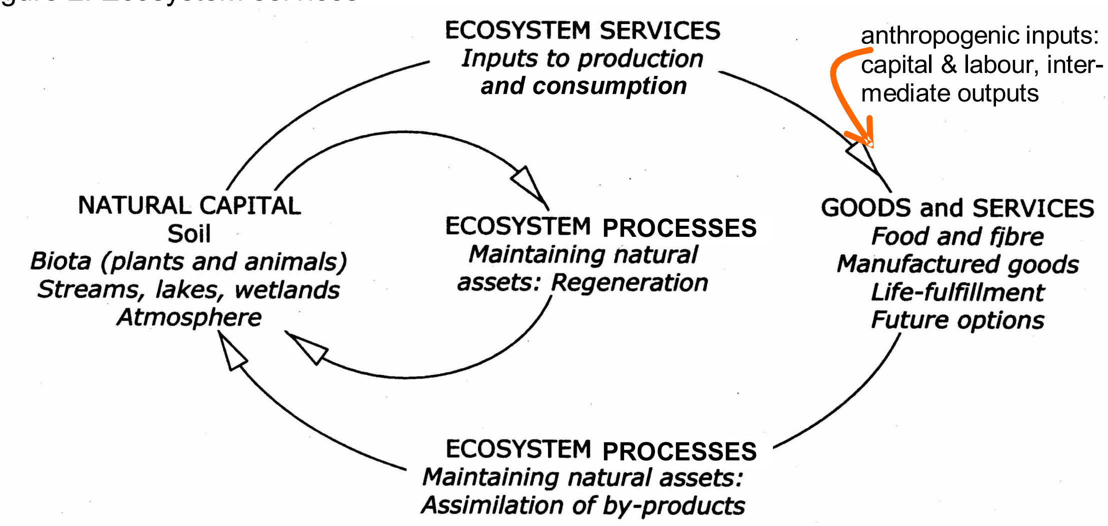


Figure 2
A conceptual framework defining ecosystem services in terms of three types of transformations: (1) transformations of natural assets into products valued economically and in other ways by people in a catchment; (2) transformations of the by-products of Transformation 1 ecosystem services back into natural assets; (3) internal transformations among natural assets to maintain those assets

From Abel et al. (2003) per Cork et al (2007, p.23)

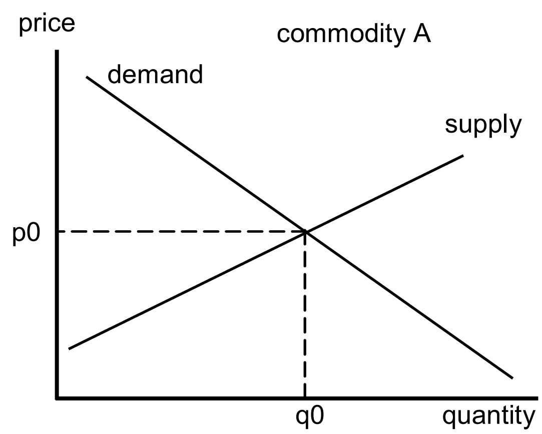
In discussing natural, economic and social capitals, Abel et al (2003, p.10) asserted that "Natural capital is the only type of capital that is self-sustaining." This is inconsistent with environmental/natural resource economics. Some natural capital is "self-sustaining" e.g. renewable (biological) resources although, of course, these resources may be depleted or even exhausted; other natural resources are replenishable (e.g. rainfall, solar radiation). But some natural capital is not "self-sustaining" e.g. non-renewable resources (minerals); whereas some can be managed to be "self-sustaining" in the renewable sense such as soils, or may be renewable given sufficiently long time horizons. Conversely, some non-environmental capital, such as human capital, is also self-sustaining.

4. Valuing ecosystem services

4.1 Basics

Having distinguished between ecosystem services (which have direct anthropogenic values) and ecosystem process (which have indirect anthropogenic values derived from ecosystem services) it is now possible to investigate appropriate methods for valuing ecosystem services. Underlying most of the ideas of value referred to above is the neoclassical marginal economics framework summarised in Figure 3. For given supply and demand schedules of commodity A, an "equilibrium" is posited, with a corresponding price and quantity vector (p0, q0): the marginal value of commodity A in a small neighbourhood of q0 is p0; the total sales revenue is p0.q0. This conceptual model underlies neoclassical economists' notions of value for all commodities, whether marketed or not.[12] Empirically, the model can be operationalised via revealed preference techniques for market and near-market commodities, and stated preference techniques for non-marketed commodities (cf. US EPA 2009 for a summary).

Figure 3: Standard neoclassical value framework



In a national accounting framework, gross output is the sum of total sales revenue for all commodities. Subtracting the value of intermediate outputs from gross output (to avoid double counting) yields value added which, on the production side, is then partitioned into returns to factors of production (e.g. labour income, profits). While producer surplus could conceptually be retrieved from national accounts data, consumer surplus requires additional information such as demand elasticities which do not enter the national accounts framework.[13]

Marginal change is a useful concept for marketed commodities where small changes in production and consumption may be observed at both firm and industry levels. Marginal change is empirically less-useful for non-marketed commodities because it is more difficult to operationalise the hypothesised supply-demand framework. Turner et al's (2003, p.497) partial

[12] Indeed, at the extreme, all human relationships such as love, crime and punishment, and war (cf. Becker)

[13] For both markets for individual commodities (Figure 3) and the national accounts framework, prices and quantities are not constants but functions of the parameters of the supply and demand schedules.

equilibrium diagram demonstrates concepts of value for an incremental change in "nature's services" (i.e. ecosystem services)(Figure 4). Assuming a hypothetical marginal value function, the area under this function represents the gross valuation of the incremental change between any two points to the right of some critical threshold. Below the critical threshold, value is not defined – at least in a neoclassical marginal economics framework – because value in consumption no longer satisfies the neoclassical assumptions; for example, if a person's water availability falls below the level necessary to sustain life.

Figure 4: Valuing ecosystem services

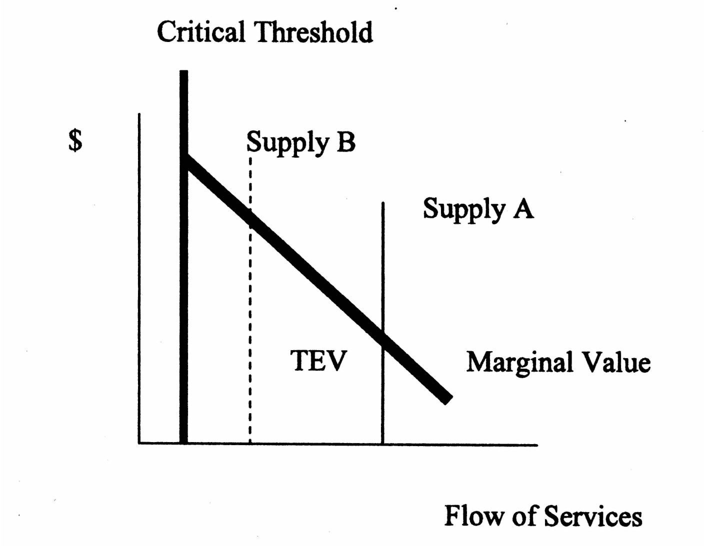


Fig. 2. Valuing nature's services.
Turner et al 2003 p.497

All the above valuation relates to a single period model, but extension to intertemporal economics problems for single commodities is simple given a discount rate. The national accounts framework does not readily extend intertemporally, although it does have an intertemporal element through investment.

In the neoclassical marginal framework, and assuming a separation of resource ownership from resource extraction, resource rent is the resource owners' profit. Similarly, in the national accounts framework, resource rent would appear as resource owners' profit. Where government owns natural resources, resource rents may accrue to government if extraction rights are auctioned in a competitive market. However, if government sets resources prices administratively, resource rents are likely to be appropriated by the resource extraction and/or processing industries.[14]

4.2 Valuing ecosystem services and processes: marketed commodities & services

Many ecosystem services are routinely included in the national accounts because they are traded in markets. Examples include most if not all natural resource commodities from agriculture, forestry, fishing, and minerals and energy.[15] Where ecosystem services are marketed, the value of ecosystem processes is analogous to a derived demand for the input of a marketed commodity. Thus, for example, if a set of ecosystem processes EP(i) ($\forall$i) contributes to the production of ecosystem service ES(j) whose value net of anthropogenic inputs (labour, capital, intermediate outputs) is v(ES(j)) or resource rent, then the marginal value of ecosystem process EP(i) is:

$$\partial v(ES(j))/\partial EP(i)$$

[14] This discussion ignores the effects of taxation; resource rent taxes may appropriate part, or all, or resource rent.
[15] How well ecosystem services are valued in the national accounts is, of course, another matter.

The inferred production process which transforms ecosystem processes EP(i) ($\forall$i) into ecosystem service ES(j) is unlikely to be a well-behaved neoclassical production function, and so the partial derivatives are unlikely to be analytically tractable. However, the marginal values might be empirically recoverable via an hedonic model, or through numerical modelling of the production system.

A corollary of this result is that, if a value model is constructed that contains both an ecosystem service and some or all of its corresponding ecosystem processes, then the parameters of this model are unlikely to be properly estimated. Suppose the actual value function is v(ES(j)), but an ad hoc value function V(ES(j)) for ecosystem service j is constructed as:

V(ES(j)) = f(ES(j)) for some j, EP(i) for some or all i)

If estimated econometrically, there would be at least simultaneous equations bias in estimating the parameters of V(ES(j)). A more likely estimation method is stated preference (e.g. choice modelling). No doubt respondents – especially those not understanding the ecosystem – could respond to the survey questionnaire, but it is unclear what these responses would actually mean.[16] If respondents actually understood the ecosystem, and answered the questions truthfully – i.e. they knew both v(ES(j)) from their knowledge of markets, and they could compute ∂v(ES(j))/∂EP(i) from their knowledge of the ecosystem – then there would be double-counting in their responses unless they formally made the necessary adjustments in their responses. In practice, however, essentially-uninformed respondents are unlikely to either know v(ES(j)) or be able to compute ∂v(ES(j))/∂EP(i). It is improbable – probably wildly improbable – that stated preference methods, especially choice modelling, can meaningfully reveal the value of ecosystem services.

4.3 Valuing an ecosystem service with externality (pollution)

The simple model of Figure 4 may be used to examine some changes in ecosystem services, but it is insufficiently rich to capture the complexity of ecosystem service harvesting represented by Figure 2.

Suppose environmental accounting were used to examine the value of an ecosystem service whose quality was damaged by pollution. Figure 5 is the standard, simplest approach to the problem.

Figure 5:Accounting for pollution impacts

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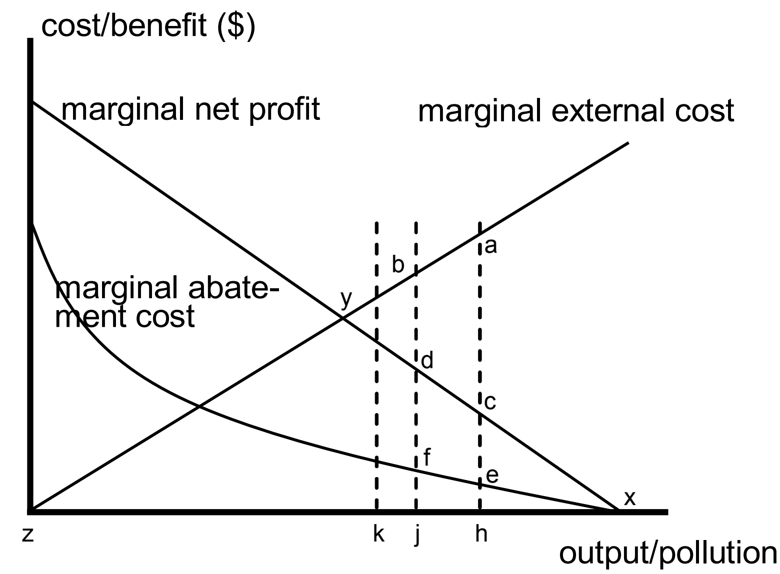
[16] The underlying theory for stated preference is an individual's utility function, defined over a set of (marketed and non-marketed) consumption commodities and services as endogenous variables, some individual characteristics as exogenous variables (e.g. income, family status), exogenous prices, and a set of exogenous parameters reflecting preferences. These techniques (contingent valuation and choice modelling) assume the existence of (cardinal) utility functions which have a standard set of properties (Deaton and Muellbauer 1980, ch.2). Stated preference techniques often make ad hoc additions to conventional utility functions and imply, without proof, that an individual's utility function can be extended to include any variable e.g. employment in a region, the weights in a social welfare function, policy variables (e.g. Mazur and Bennett 2009), or only to include policy variables (e.g. Scarborough et al 2009). But, for these inclusions to be valid, they must satisfy the properties of the utility function itself, and of the implicit demand functions that can be derived from utility maximisation subject to a budget constraint; otherwise it is not clear whether or not the corresponding estimated parameters are actually values. Evidence is required that these properties hold and, therefore, that the presumed "willingness to pay" estimates are, indeed, true willingness to pay.

It is not sufficient to assert that, just because respondents do fill in a contingent valuation or choice modelling questionnaire and that willingness to pay "estimates" can be derived that these estimates are, indeed, true willingness to pay. Respondents generally will answer survey questions; the issue is whether or not the responses are meaningful; in the present case, whether or not they are true willingness to pay.



Assuming underlying marginal net profit, external[17] and abatement cost curves, suppose that "h" had been measured by a statistical agency as the level of pollution in period t-1 (as it would for physical and hybrid flow accounts in SEEA, cf. section 2.3 above). In period t, it would be desirable for the statistical agency to measure for the current period not merely "j" as the new pollution level but also, in the "economic accounts and environmental transactions" framework (cf. section 2.3 above) the change from the previous period's pollution level (h):

- area hefj – the change in abatement cost;
- area hcdj – the change in firm profitability (or value added); and
- area habj – the (gross) change in external cost.

Since the statistical agency is unlikely to be able to estimate the incremental changes, it would be desirable for it to estimate, in each period t, the corresponding total values corresponding to a measured level of pollution z_t:

- total abatement cost: TAC = $c_1(z_t)$
- total firm profitability (or value added): TFP = $c_2(z_t)$
- total external cost: TEC = $c_3(z_t)$

In constructing an environmental account for pollution, could a statistical agency be reasonably expected to estimate TAC and TEC? TAC is less problematic, although still significant: conceptually a firm's capital investment could be separated into "production" capital, and that capital installed for "pollution abatement", at least for "bolt-on" measures. However, when new equipment is installed which has both improved production efficiency and reduced emissions, it is difficult (if not impossible) to allocate its cost separately to "production" and "abatement". There would be similar problems for separating recurrent expenditure into "production" and "pollution abatement" accounts.

The estimation of marginal/incremental or total external costs would be difficult for a statistical agency. External costs are generally inferences, not observed data. Such inferences require information about pollution emissions, the dispersion of such emissions in the environment, human exposure to emissions, and the (health) impacts of exposure. Emissions are possibly the easier to estimate (at least for point source pollutants), but will often be location-dependent

[17] Externalities may be initially identified as biophysical impacts on ecosystem processes (Figure 2). However, external costs represent non-market effects on ecosystem services. For example, air pollutants are measured or identified through their effects on ecosystem processes, but their external costs are their effects on human health inter alia.

(e.g. lead where there is lead mining or smelting; particles where there are large numbers of woodheaters, or open-cut mining or crop residue burning). The fate of emissions in the environment requires either modelling and/or very expensive monitoring. Human exposure requires extensive epidemiological analysis, and identifying the health impacts of exposure requires medical research, especially since other pollutants or non-pollution factors may cause similar health impacts to pollution. Complicating this story is that emission of different pollutants may be highly correlated, so that it may be difficult to identify the effects of individual pollutants. Benefit transfer might be useful, but only if done extremely carefully.[18]

However, from a policy perspective, tracking past change from h to j in Figure 5 (or, indeed, j to h if that occurred) is of limited policy relevance. It is more important to identify the costs and benefits of moving, say, from j to k in the future. If there had been sufficient change over time in pollution levels, econometric methods might be used to estimate the total profit and total external cost functions. However, since future abatement cost depends on future investment, and the impact of past investment on emissions may be a poor guide to the impact of future investment on future emissions, it would be difficult to project future abatement costs using econometric analysis of historical data. Additionally, literature assessing ex ante and ex post estimates of the cost of policy options suggests that ex ante cost estimates are likely to be seriously exaggerated.[19]

4.4 Summary

Where ecosystem services are marketed commodities – e.g. agricultural, forestry, fishing, and minerals and energy products – valuation using conventional national accounting procedures may be straightforward although, without subsequent manipulation, national accounts values do not reveal economic surpluses. Conventional resource economics measures, such as resource rents, provide appropriate measures. Where ecosystem impacts are not (yet) marketed commodities – e.g. externalities like pollutants, or public goods like conserved biodiversity – then standard environmental economic frameworks, such as in the pollution case above, provide appropriate guidelines for valuation.[20] However, making these frameworks operational requires economic analysis, and is not merely a data gathering activity. Because conventional national accounts measures only record past activity, their policy-relevance may be limited if relevant variables such as future damage abatement or remediation costs cannot be inferred from recorded data. Recorded investment data particularly is unlikely to be a good guide for future investment in damage abatement or remediation.

5. Criteria for estimating ecosystem services values

Statisticians' criteria for evaluating data they collect differ considerably from economists' criteria. Statisticians tend to assume the form of the data they are collecting has been established (e.g. ABS 2000), and so they are primarily concerned with statistical properties (there is a European example for earnings and labour costs in Appendix 2). However, as illustrated by the preceding pollution example (section 4.3) the relevant economic form of the data to be collected requires proper determination before the application of statistical criteria.

[18] For example, AEA Technology Environment (2005) reported pollutant costs for $PM_{2.5}$, SO_2, NOx, NH_3 and VOCs, and these could be used to infer values outside Europe via "benefit transfer". However, a summary value like "damage per tonne of pollutant" is a reduced form representation of pollutant emission and residence, exposure, effects on individuals, and size and density of the exposed population, and is therefore unlikely to be directly transferable.

[19] cf. Ruttenberg (2001), Hodges (1997), Mason (1991), ChemSec (2004) – thanks to Koenraad Van Landeghem, Laura Hohnen and Vinita Deodhar for drawing my attention to these citations.

[20] Statistical agencies may require assistance to interpret available environmental data. For example, the value of biodiversity data that has been revealed through processes such as BushTender depends on (a) the nature of the specific auction process that was used to generate that data, (b) the location of the auction, and (c) the auction's budget constraint.

Having identified what ecosystem services can reasonably be valued (cf. sections 3 & 4 above), what methods might be used to undertake this valuation (cf. US EPA 2009 for a list and discussion of standard methods)? Because there is no single, incontrovertibly correct method, it is important to consider the possible relationships amongst estimates that might be derived from this range of methods in the context of the framework outlined in sections 3 & 4 above.

Such a comparison requires a set of criteria for collecting value data. Initially, the criteria depend upon what environmental variable is being estimated – whether ecosystem (E), ecosystem service (ES) or ecosystem process (EP). Secondarily, it is necessary to choose an economic framework which defines the relevant variables and parameters about which to collect data; if this framework is neoclassical microeconomics, then an appropriate set of criteria for choosing data collection procedures includes:

(i) what <u>value variable</u> should be estimated ? price, marginal value, incremental value
(ii) what estimation <u>method</u> can be used? – revealed or state preference, and then what technique within these broad sets
(iii) is there <u>consistency</u> of estimation between ecosystem, ecosystem service and ecosystem process ?
(iv) do the values of all ecosystem processes <u>add up</u> to the value of corresponding ecosystem service(s), or do the values of all ecosystem services add up to the value of corresponding ecosystems ?

These properties are summarised in Table 1 for six classes of estimators that could be used to value ecosystems and their components. Market prices could be used to determine the values of ecosystem services which are commodities entering the market economy; as long as they are price excludable and there are no associated market failures. If all the ecosystem services from a given ecosystem are known and valued, and the costs of conventional inputs deducted to determine resource rent, then value estimation will be consistent and will add up.

If the value of an ecosystem service can be defined and measured, and all the ecosystem processes upon which this ecosystem service are known, then the values of the ecosystem processes can be derived analytically (if the ecosystem "production function" is known algebraically) or numerically (if the ecosystem "production function" can be simulated). If all the ecosystem processes relating to a given ecosystem service are known and valued, then value estimation will be consistent and will add up (as "derived demands").

If an ecosystem service jointly determines with other characteristics the value of a marketed commodity, the value of this ecosystem service may be determined either directly (by the hedonic method) or the levels of the corresponding ecosystem processes used to value the ecosystem service.

Stated preference methods will yield consistent value estimates if ecosystem services are clearly defined and respondents really do know the value of these services. Moreover, particularly in choice modelling, it is essential that the attribute sets for which responses are sought do not confound ecosystem services with ecosystem processes – if they did, the estimates would be neither consistent, nor would they add up. While it is conceptually possible that attribute sets could include all ecosystem processes, and thus their value be sought directly, there are probably far too many processes to reasonably include within attribute sets. Further, since there are biophysical functional relationships among ecosystem processes which it is unreasonable to expect respondents to know, it is unreasonable to expect direct valuation of ecosystem processes to be successful.

Table 1: Comparing methods for Ecosystem Valuation

	Commodity type that technique relevant to	Variable estimated & method	What could be valued ? (E/ESi/EPj)	Consistency (between ESi & EPj)	Adding up
Observed market price	price excludable	price; revealed preference by observ-ation or survey	E/ESi (land area, water permit, ITQ)	OK since only ESi valued; (if not tied, e.g. water not tied to land)	OK since only ESi valued; (if not tied, e.g. water not tied to land)
Derived demand**	price excludable	price; based on revealed preference and modelling observed data	value EPj as ∂value(ES(i), $\forall$i)/∂EP(j)	OK, uses value of ESi to derive value of EPj	OK*, by definition vESi(.)≡∑j v(EPj,∀j) requires all EPj known
Hedonics	price excludable related commodity	marginal value; based on revealed preference by survey and modelling	value ESi (separately from related commodity – e.g. environmental amenity & housing)	OK, uses EPj to derive value of ESi	OK*, by definition vESi(.)≡∑j v(EPj,∀j) requires all EPj known
Contingent valuation	especially non-price excludable (but also price excludable)	willingness to pay (possibly for large "incremental" change in variable); stated preference by survey and analysis	value E or ESi or all EPj	problematic: estimate <u>one</u> of E/ES/EP; having estimated one, <u>derive</u> others	(i) requires all EPj known (ii) requires <u>either</u> ESi or <u>all</u> EPj but not both investigated (iii) potential double-counting
Choice modelling	especially non-price excludable (but also price excludable)	willingness to pay (marginal value); stated preference by survey and modelling	value E or ESi or all EPj	problematic: distinguish E/ES/EP? having <u>estimated</u> one, <u>derive</u> others	(i) requires all EPj known (ii) requires <u>either</u> ESi or <u>all</u> EPj but not both investigated (iii) potential double-counting
Purchase	any activity	price; revealed preference by participation (e.g. tender or auction)	value E or ESi or EPj	problematic: distinguish E/ES/EP? having <u>estimated</u> one, <u>derive</u> others	potential double-counting (policy might duplicate payments, incl. for both ESi and EPj)

6. Conclusions

By themselves, the conventional approaches to defining and valuing ecosystem services – Millennium Ecosystem Assessment, Total Economic Value, and environmental accounting such as the System of Environmental and Economic Accounting – are not adequate to serve as a basis for developing a comprehensive, meaningful and policy-relevant set of environmental data that could be routinely collected to ground policy making. Considerable effort is still required to satisfactorily define ecosystem services consistent with both biophysical understanding and economic valuation requirements. Effort is also required to ensure that methods of defining value data, partiucarly from stated preference study, yield consistent data with adequate adding up properties that will be suitable for inclusion in national accounts frameworks.

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Appendix 1

Figure 1A

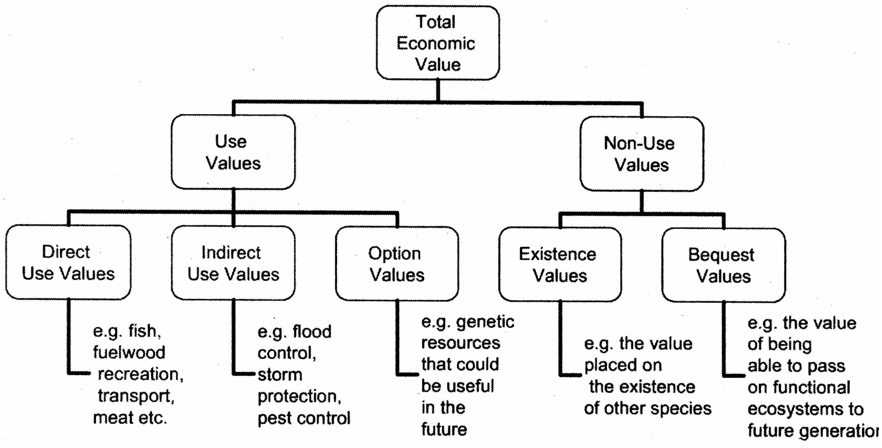

Figure 15
The concept of total economic value

After Barbier et al. (1997) and OECD (2002)
from Cork et al (2007, p.68)

Figure 1B

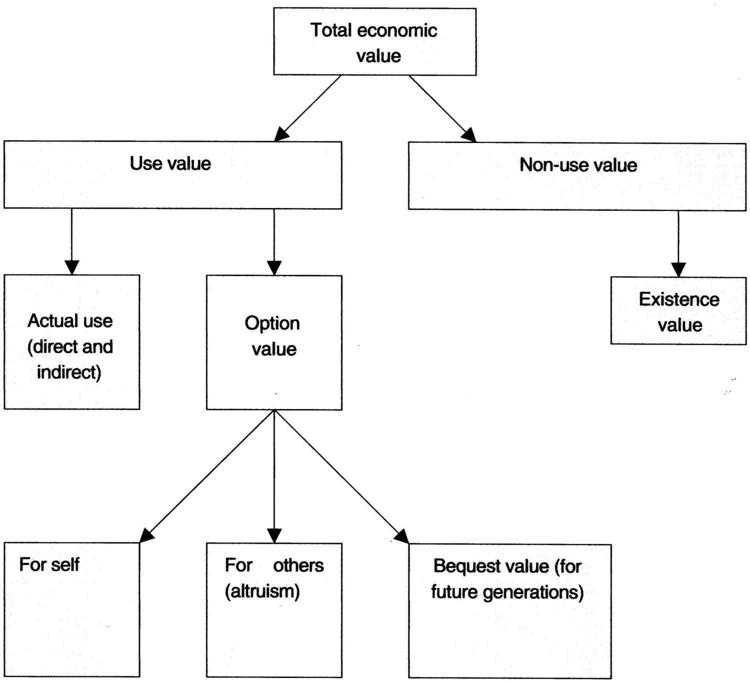

Figure 3.1 Components of total economic value
from Pearce, D. and Özdemiroglu, E. et al., (2002, p.24)

Figure 1C

Table 12: Total Economic Value of the Great Barrier Reef

TOTAL ECONOMIC VALUE

Non-use Values

EXAMPLES

- Existence;
- Bequest;
- Option;
- Quasi-option; and
- Religious &/or spiritual [indigenous & non-indigenous].

Use Values

Direct Use Values	Indirect Use Values
Examples **EXTRACTIVE USE:** – Commercial fishing; – Mariculture; – Genetic and medical resources; – Biochemicals; and – Raw materials. **NON-EXTRACTIVE USE:** – Indigenous cultural values; – Non-indigenous cultural values; – Tourism; – Recreation [extractive & non-extractive]; – Aesthetic values; – Scientific knowledge; – Education; – Historical information & places; and – Research. **SERVICES:** – Shipping & other transport; – Storage & assimilation of human refuse [e.g. sea dumping, nutrients]; and – Artistic inspiration.	***Examples*** **GOODS:** – Vicarious use. **SERVICES:** – Shoreline protection; – Regulation of local energy balances; – Sediment binding [from river run-off]; – Biomass production & fixation of solar energy; – Storage & recycling of organic matter; – Storage & recycling of nutrients; – Maintenance of migration & nursery habitats; – Maintenance of biological diversity; – Regulation of local chemical composition of seawater & microclimate; and – Global life support.

from Hand (2003)

Appendix 2

Annex: Quality Evaluation Criteria and Content of the Report on Quality for Labour Costs Statistics

1. Relevance
2. Accuracy
    - 2.1. Sampling errors
        - 2.1.1. Probability sampling
            - 2.1.1.1. Bias
            - 2.1.1.2. Variance
        - 2.1.2. Non-probability sampling
    - 2.2. Non-sampling errors
        - 2.2.1. Frame errors
        - 2.2.2. Measurement and processing errors
        - 2.2.3. Non-response errors
        - 2.2.4. Model assumption errors
3. Timeliness and punctuality
4. Accessibility and clarity
5. Comparability
    - 5.1. Spatial comparability
    - 5.2. Comparabilityover time
6. Coherence
    - 6.1. Coherence with statistics from labour force survey
    - 6.2. Coherence with structural business statistics
    - 6.3. Coherence with national accounts
7. Completeness

Commission Regulation (EC) No 452/2000 of 28 February 2000 implementing Council Regulation (EC) No 530/1999 concerning structural statistics on earnings and on labour costs as regards quality evaluation on labour costs statistics

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:055:0053:0058:EN:PDF