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Chapter 10: Accounting for ecosystem assets in monetary terms

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Contents

SECTION D: Valuation and integrated accounting for ecosystem services and assets

10 Accounting for ecosystem assets in monetary terms

10.1 Introduction

10.1 The series of core ecosystem accounts is completed with the ecosystem monetary asset account. This account records the monetary value of ecosystem assets reflecting all of the ecosystem services supplied by the asset taking into consideration the expected future flows of those services. The estimates of monetary value are compiled following the net present value principles described in Chapter 8. The monetary value of ecosystem assets can also be integrated with the monetary valuations of other types of assets, for example produced assets, to provide more complete assessments of net wealth. The estimates provide a measure of the exchange value of the asset and therefore are not intended to be a comprehensive measure of the value of nature.

10.2 The ecosystem monetary asset account also records the changes in the monetary value of ecosystem assets over an accounting period including changes due to ecosystem degradation, ecosystem enhancement, ecosystem conversions and revaluations.

10.3 Estimates of ecosystem assets in monetary terms can support understanding the relative economic significance of different ecosystem assets and ecosystem types and, together with information about the assets in biophysical terms (e.g. measures of ecosystem condition) can be used to assess the sustainability of the flows of ecosystem services. Measures in monetary terms may also be related to general socio-economic drivers of change such as changes in economic activity and population growth.

10.4 Measures of ecosystem degradation in monetary terms will be of particular interest in understanding changes in ecosystem assets relative to measures of economic activity such as industry value added. The derivation of degradation adjusted income measures is explained in Chapter 11, together with description of extended balance sheets and extended institutional sector accounts in an SNA context.

10.5 Chapter 10 sets out the structure of the ecosystem monetary asset account and the associated accounting entries (section 10.2). Section 10.3 describes the key components in valuing ecosystem assets using the net present value approach including the approach to valuing the accounting entries for changes in ecosystem assets over an accounting period. Section 10.4 introduces the measurement of ecosystem capacity.

10.2 Ecosystem monetary asset account

10.2.1 Structure of the ecosystem monetary asset account

10.6 The ecosystem monetary asset account records the monetary values of all ecosystem assets within an ecosystem accounting area at the beginning (opening) and end (closing) of each accounting period; as well as changes in the value of those assets over the accounting period. Changes in the monetary value of ecosystem assets are separated into five broad types: ecosystem enhancement, ecosystem degradation, ecosystem conversions, other changes in the volume of ecosystem assets and revaluations as a result of price changes.

10.7 The basic accounting structure for the ecosystem monetary asset account is shown in Table 10.1. This table shows an account for an ecosystem accounting area classified by ecosystem type using selected ecosystem functional groups (EFG) from the IUCN Global Ecosystem Typology (see Chapter 3). Entries in the ecosystem monetary asset account are conceptually aligned with measures of the monetary value of other assets included in the balance sheet of the System of National Accounts, for example concerning produced assets. A link can also be made to entries in the ecosystem extent account (Chapter 4). The additions and reductions shown in that account in physical terms will align with the additions and reductions in monetary terms that are recorded under ecosystem conversions.

10.8 As required, and where data are available, asset accounts showing the same accounting entries can be compiled for individual ecosystem asset (e.g., a specific grassland), for all ecosystem assets of a single ecosystem type (e.g., all Trophic savannas (EFG T4.1)) or for various types of ecosystem accounting areas (e.g. a country, a large administrative area or a protected area) that includes multiple ecosystem assets of different ecosystem types.

Table 10.1: Ecosystem monetary asset account (currency units)

	Ecosystem type (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																				
	Terrestrial							Freshwater			Marine				Transitional						
	Tropical-subtropical lowland rainforests	Boreal and temperate montane forests and woodlands	Seasonally dry tropical shrublands	Trophic savannas	Semi-desert steppes	Ice sheets, glaciers and perennial snowfields	Croplands	Permanent upland streams	Large permanent freshwater lakes	Large reservoirs	Seagrass meadows	Epipelagic ocean waters	Continental and island slopes	Submerged artificial structures	Tropical flooded forests and peat forests	Deepwater coastal inlets	Rocky shores	Coastal shrublands and grasslands	Artificial shores	Coastal river deltas	**TOTAL**
	T1.1	T2.1	T3.1	T4.1	T5.1	T6.1	T7.1	F1.1	F2.1	F3.1	M1.1	M2.1	M3.1	M4.1	TF1.1	FM1.1	MT1.1	MT2.1	MT3.1	MFT1.1	
Opening value																					
Ecosystem enhancement																					
Ecosystem degradation																					
Ecosystem conversions																					
Additions																					
Reductions																					
Other changes in volume of ecosystem assets																					
Catastrophic losses																					
Reappraisals																					
Revaluations																					
Net change in value																					
Closing value																					

10.2.2 Ecosystem enhancement

10.9 ***Ecosystem enhancement is the improvement in the value of an ecosystem asset over an accounting period that is a result of an increase in the condition of the ecosystem asset.*** Ecosystem enhancement will be reflected in a rise in the net present value of expected future returns. Ecosystem enhancement will incorporate the effects of activities, including those related to a reduction in harmful activities, that improve or are expected to improve the condition of an ecosystem asset beyond activities that may simply maintain an ecosystem asset.

10.10 Not all improvements in value should be recorded as ecosystem enhancement. The focus should be on recording increases in asset value resulting from improvements in condition that can be reasonably expected to increase the future flows of ecosystem services, based on the current and expected patterns of ecosystem management and use. Improvements in value attributable to changes in the expected demand for ecosystem services should be recorded as upward reappraisals. Improvements in value due solely to movements in the unit prices of ecosystem services should be recorded as revaluations.

10.11 Ecosystem enhancement is measured in relation to the extent of an ecosystem asset as recorded at the beginning of the accounting period. Where there are changes in the extent of an ecosystem asset, that is where there is conversion from one ecosystem type to another during an accounting period, a separate recording of that change should be undertaken, and recorded under the entry ecosystem conversions.

10.12 Three types of activities are considered in the context of ecosystem enhancement: restoration, rehabilitation and reclamation. Each of these activities represents different degrees of expected effect on the ecosystems from the activity.[1] Restoration occurs where the aim is to re-establish pre-existing structure and function, including biotic integrity. Rehabilitation occurs where the aim is to reinstate ecosystem functionality with focus on supplying a range of ecosystem services. Both restoration and rehabilitation activities may be achieved by reducing the degree of human impact, for example by reducing stocking rates on grazing land, by reducing the release of pollutants, or by separating or re-zoning areas as being the focus of restoration and rehabilitation. Reclamation occurs where the aim is to return degraded land (e.g. desertified areas) to a useful state (e.g. for agriculture). Where reclamation involves a change in ecosystem type during the accounting period, increases in value due to reclamation should be recorded under ecosystem conversions.

10.13 Since measures of ecosystem enhancement are linked to activities undertaken in the landscape, the changes in extent, condition and value can be directly related to estimates of expenditure and other measures of human input (e.g. volunteer hours) associated with that activity. In particular there will be a connection to the measurement of land improvements as recorded as a component of gross fixed capital formation in the SNA, and to the measurement of environmental protection and resource management expenditure as recorded in the SEEA Central Framework.

10.2.3 Ecosystem degradation

10.14 ***Ecosystem degradation is the decline in the value of an ecosystem asset over an accounting period that is the result of a decrease in the condition of an ecosystem asset.*** Ecosystem degradation will be reflected in a fall in the net present value of expected future returns.

10.15 Not all declines in value should be recorded as ecosystem degradation. The focus should be on recording declines in asset value resulting from reductions in condition that can be reasonably anticipated, considering the current and expected patterns of ecosystem management and use, and expected patterns of environmental variation. Declines may arise from a range of sources including the extraction and harvest of natural resources and the short and long-term effects of pollution and emissions.

10.16 Declines in value due to large scale, discrete and recognisable events that cause a significant loss in the condition of an ecosystem asset should be recorded as catastrophic losses. Declines in value attributable to changes in the expected demand for ecosystem services should be

[1] For details see the UNCCD Land Degradation Neutrality conceptual framework

recorded as downward reappraisals. Declines in value due solely to movements in the unit prices of ecosystem services should be recorded as revaluations.

10.17 Ecosystem degradation is measured in relation to the extent of an ecosystem asset recorded at the beginning of the accounting period. Where there are changes in the extent of an ecosystem asset, that is where there is conversion from one ecosystem type to another during an accounting period, a separate recording of that change should be undertaken, and recorded under the entry – ecosystem conversions.

10.18 The measurement of ecosystem degradation can be undertaken for an ecosystem asset without specific regard to the legal or economic ownership of the ecosystem asset. However, for some analytical purposes and for integration of ecosystem accounts into the general sequence of institutional sector accounts of the SNA, it is necessary to attribute the cost of ecosystem degradation to an economic unit and institutional sector. Approaches to the attribution of ecosystem degradation and integration with the SNA are discussed in chapter 11.

10.19 The SEEA Central Framework, Section 5.4, defines the depletion of natural resources as "*the decrease in the quantity of the stock of a natural resource over an accounting period that is due to the extraction of the natural resource by economic units at a level greater than that of regeneration.*" This definition can be seen as sitting within the definition of ecosystem degradation to the extent that the quantity of a stock of a natural resource is considered part of the structure and composition of an ecosystem asset. The term depletion is retained to refer solely to the cost of using up natural resources. It will be narrower in scope than ecosystem degradation since it will only relate to the loss of future provisioning services. However, it will be broader in scope at an economy wide level to the extent that aggregate measures of depletion will include declines in the stock of non-renewable resources, in particular mineral and energy resources, which fall outside the scope of ecosystem assets.

10.2.4 Ecosystem conversions

10.20 ***Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a distinct change in the ecological structure, composition and function which, in turn, is reflected in the generation of a different set of ecosystem services and different expected future returns.***

10.21 In physical terms, ecosystem conversions that occur during the accounting period should be recorded as changes in ecosystem extent, e.g. a change from forest to agricultural land, following the advice in Chapter 4. An ecosystem conversion may commonly apply only to part of an existing ecosystem asset. In the ecosystem extent account, the increases in the area of one ecosystem type and decreases in another ecosystem type at a given location will net to zero.

10.22 In monetary terms, a reduction in value will be recorded against the ecosystem type which the area has been converted from (e.g. forest) and a rise in value will be recorded against the ecosystem type which the area has been converted to (e.g. agricultural land). Both of these entries should be recorded in the rows for ecosystem conversions as additions or reductions.

10.23 There is no expectation that the value of expected future returns for additions and reductions will be offsetting. Thus, the net effect in monetary terms of ecosystem conversions may be positive or negative depending on the differences in the set of expected ecosystem services that are generated by the different ecosystem types.

10.24 Depending on the information available, it may be of interest to organise information on ecosystem conversions according to reasons for conversion including agricultural expansion, increased urbanisation or reclamation of desert areas to become grazing land.

10.2.5 Other changes in the volume of ecosystem assets

10.25 ***Other changes in the volume of ecosystem assets refer to changes in the value of an ecosystem asset, other than those due to ecosystem enhancement, ecosystem degradation and ecosystem conversion, that are not solely the result of changes in unit prices of ecosystem services.*** The two types of other changes in volume are catastrophic losses and reappraisals.

10.26 Declines in ecosystem assets due to catastrophic losses are identified separately to provide scope for compilers to record declines due to large scale, discrete and recognisable events that cause a significant loss in the condition of an ecosystem asset, i.e. significant losses of structure, function or composition. Examples include earthquakes, bushfires, cyclones and industrial disasters that have a significant impact on the capacity of an ecosystem asset to generate ecosystem services. While these events may be anticipated in general terms, the precise timing, location and magnitude cannot be foreseen in the same way as expectations may be formed about patterns of ecosystem use by people.[2]

10.27 Reappraisals should be recorded when updated information emerges concerning expected future returns that permits a reassessment of the expected condition of the ecosystem assets or the future demand for ecosystem services, such that the expected pattern of future returns at the end of the accounting period is different from the pattern that had been expected at the start of the accounting period.

10.28 Reappraisals may also refer to updated information pertaining to the expected extent of ecosystem assets however, by convention, these are recorded as part of ecosystem conversions.

10.29 Reappraisals concern changes in expectations and are materially different from the use of updated information to improve the quality of compiled estimates. The incorporation of new information concerning expectations does not lead to revisions in previous estimates.

10.30 However, in compiling accounts, where improved or revised source data are used (e.g. through the use of more detailed ecological information and biophysical modelling) or where revised methods are adopted, the changes should be applied consistently across all relevant accounting entries and, as appropriate, revisions to past accounting entries should be made. A separate accounting entry to distinguish revisions due to changes in source data is not required but for data quality assessment purposes maintaining a history of revisions to accounts is strongly recommended.

10.31 Accounting takes an exceptions-based approach to the recording of entries as other changes in volume and entries are generally only made in cases of clearly identifiable events. This is most obvious in the case of recording entries associated with catastrophic losses since by definition these arise when identifiable events occur, but it also applies in the context of the other changes in volume. Thus, unless otherwise separately identified, other changes are likely to be included implicitly in the entries for ecosystem degradation, ecosystem conversions and ecosystem enhancement.

[2] See also 2008 SNA paragraphs 12.46 & 47 and SEEA Central Framework 5.49.

10.2.6 Revaluations

10.32 ***Revaluations refer to changes in the value of ecosystem assets over an accounting period that are due solely to movements in the unit prices of ecosystem services.*** Following the SEEA Central Framework (5.61), a change in the value of an ecosystem asset in response to a change in quality, due, for example, to a change in condition, is considered a change in volume rather than a revaluation.

10.33 Revaluations reflect nominal holding gains over an accounting period and there may be analytical interest in decomposing these gains into the neutral holding gain – equivalent to the nominal gains associated with the general rate of inflation – and real holding gains. Holding gains may be positive or negative since the nominal gains may be greater or less than the general rate of inflation.

10.34 Revaluations should also incorporate change in the value of ecosystem assets due to changes in the assumptions made in the parameters that are used to estimate the net present value, such as the discount rate. Changes in estimated values that are due to changes in methods are treated as revisions.

10.3 Approaches to valuing ecosystem assets

10.3.1 General approach to valuing ecosystem assets

10.35 The net present value (NPV) approach to the valuation of ecosystem assets was introduced in Chapter 8. In mathematical terms, the value of an asset *V* is written as:

$$V_\tau(\boldsymbol{EA}) = \sum_{i=1}^{i=S} \sum_{j=\tau}^{j=N} \frac{ES_\tau^{ij}(\boldsymbol{EA}_\tau)}{(1+r_j)^{(j-\tau)}}$$

where ES_τ^{ij} is the value of ecosystem service *i* in year *j* as expected in base year τ generated by a specific ecosystem asset $\boldsymbol{EA}_\tau$, characterized by its extent, condition and management regime; S is the total number of ecosystem services; *r* is the discount rate (in year *j*, and *N* is the lifetime of the asset, which may be infinite for some ecosystem assets if used sustainably. τ is the starting period or base year, which may be referenced to 0.[3]

10.36 In ecosystem accounting, the ecosystem asset generates a basket of returns in the form of multiple ecosystem services. The NPV formula is therefore applied at the level of individual ecosystem services and the resulting discounted values are aggregated to derive the monetary value of the ecosystem asset. Each ecosystem service is considered separable in the sense of each ecosystem service (i) being able to be measured distinctly, i.e. in a mutually exclusive manner, and (ii) representing a distinct transaction between an ecosystem asset and a relevant user.

10.37 At the same time, in measuring the NPV for each ecosystem service, it is necessary to recognise that while each ecosystem service is generated from an ecosystem asset, different characteristics of that ecosystem asset will be relevant in the generation of each service. Thus,

[3] Preferably, the returns should be assumed to accrue to the midpoint of the accounting period. The assumption made here is that the returns accrue at the start of the accounting period and it is used to simplify the explanation and the associated notation. The assumption has no impact on the underlying relationships described.

while there is a common location there is not a single distinct stock, in the sense usually applied in for example, using NPV to value mineral and energy resources or timber resources as in the SEEA Central Framework.

10.38 Consequently, while each ecosystem service flow and its associated NPV is considered separable, given the single location of the ecosystem asset, it is necessary that the inherent connections among ecosystem characteristics within an ecosystem asset are jointly considered when determining the expected future returns of each ecosystem service. General proposals for providing a reasonable baseline for consistency in measurement are set out below with the general aim of avoiding contradictions within a set of accounts. This ambition provides a suitable basis for meaningful interpretation for monitoring and decision making.[4]

10.39 Assuming that the expected future returns for each service are estimated using the exchange value concept, the NPV for an ecosystem service will provide an exchange value for the capitalised value of that service, and the aggregate NPV will provide an exchange value for the ecosystem asset. In order to decompose the change in asset value from the beginning to the end of an accounting period, for example to record the value of ecosystem degradation, the changes in price and quantity of future returns for each ecosystem service are analysed. Annex 10.1 provides a description of the decomposition approach.

10.40 The general principles just outlined apply to the situation where ecosystem services are attributable to delineated ecosystem assets. The spatial attribution of ecosystem services to different ecosystem assets is discussed in Chapter 6 which notes that for provisioning services and most cultural services this attribution is relatively straightforward while many regulating and maintenance services are jointly supplied by a combination of ecosystem assets. Even in cases where ecosystem services cannot be attributed to a single ecosystem asset, it remains possible to estimate the NPV of each ecosystem service and aggregate to determine a total value of ecosystem assets for an ecosystem accounting area (EAA). Further, in practice, it may be necessary to undertake projections at a more aggregated scale (e.g., with respect to population) rather than for individual ecosystem assets. Nonetheless, where possible, estimation should be undertaken for smaller, sub-EAA spatial areas to assist in recognising variations in local contexts, including differences in ecosystem characteristics and in institutional arrangements.

10.41 As introduced in section 8.2, the measurement of expected future returns involves consideration of five key aspects: (i) the scope and definition of returns; (ii) the valuation of returns; (iii) future flows of ecosystem services in physical terms, including considerations of expected degradation; (iv) asset lives; and (v) expected institutional arrangements. Each of these aspects is considered in turn in more detail in the following sub-sections. In practice, all aspects will be connected and an iterative process will be needed to establish a clear and agreed basis for estimating expected future returns across multiple ecosystem services. Importantly, the integrated approach used in ecosystem accounting, especially the use of consistent classes of ecosystem assets to underpin the organisation of relevant data, provides the structure within which all of the relevant aspects can be consistently approached.

10.42 In addition to estimating expected future returns, the second key component is the discounting of these returns to their present value. Mathematically this is a straightforward calculation but the selection of an appropriate discount rate is a matter of considerable

[4] It will likely be possible with advances in biophysical science, and associated economic modelling, to better estimate expected interactions within ecosystems with respect to the supply of ecosystem services. Indeed, advances in this direction are occurring and an important area of future research will be connecting these advances to the task of improving the valuation of ecosystem assets.

importance since it can have a significant effect on the resulting present value estimate and on its interpretation. The selection of discount rates is discussed in section 10.3.7.

10.43 To support the interpretation of estimates and comparison of results from different sets of accounts, it is necessary that all assumptions used to underpin the measures of the value of ecosystem assets and changes in value are clearly documented.

10.44 It is standard practice to record single, point estimates in the accounts. However, given the assumptions required to underpin valuation in monetary terms, it may be appropriate to provide a range of values that could be obtained under plausible alternative assumptions. For example, estimates of the value of ecosystem assets might be provided using different assumptions concerning the discount rate.

10.3.2 Scope and definition of returns

10.45 The scope of returns concerns the set of ecosystem services that is included in the valuation for any given ecosystem asset. In practice, the set of ecosystem services included for asset valuation should align with the set of services recorded in the ecosystem services supply and use account in monetary terms for each ET. Compilers should include a comprehensive range of ecosystem services in order to best reflect the monetary value of the asset and its changes over time.

10.46 The returns included in the net present value calculation refer to the ecosystem services expected to be supplied by an ecosystem asset. As described in Chapter 8, ecosystem services are the contributions of ecosystem assets to benefits and hence ecosystem services and benefits must be clearly distinguished. By way of example, in the case of timber provisioning services, the ecosystem services will refer to the contribution of the ecosystem, for example valued using a stumpage value or resource rent, and will be distinct from the benefits, namely the harvested timber, commonly in the form of logs, that is sold by the forester.

10.47 Following the treatments of ecosystem services described in chapter 6, the scope of ecosystem services included in the net present value calculation may include flows of intermediate services. Thus, in principle, the returns estimated for a given ecosystem asset should include the supply of intermediate services to other ecosystem assets and should deduct the use of intermediate services from other ecosystem assets.

10.3.3 Valuation of returns

10.48 Returns for each ecosystem service are valued at exchange values consistent with the advice in Chapters 8 and 9. The exchange value of ecosystem services focuses only on the contribution of the ecosystem and hence all costs incurred in supplying the ecosystem services must be deducted in estimating the returns. This is consistent with the valuation of individual environmental assets in the SEEA Central Framework where management and extraction/harvesting costs are not deducted from the estimates of resource rent. Rather these costs are deducted from sales of the extracted/harvested products in deriving the resource rent. In applying this principle, it is important to ensure that the valuation method applied for each ecosystem service provides a result that excludes these costs (i.e. ensuring that these costs have already been deducted).

10.49 To determine the present value of the future returns, assumptions are required concerning the future unit prices for each ecosystem service. When valuing individual environmental assets, such as mineral and energy resources, it is common for national accounting purposes to assume that the current period unit price (or an average of unit prices in recent accounting periods) will apply in future periods.

10.50 However, in valuing future flows of ecosystem services, assuming constant unit prices may not be valid in view of the wider interconnections and factors that will influence an ecosystem asset and which will affect future values. Therefore, where possible, future price changes should be taken into account, for example due to the effects of changing relative scarcity of resources or specific ecosystem characteristics.

10.3.4 Future flows of services in physical terms

10.51 The additional challenge in estimating future flows of ecosystem services in an asset valuation context is to allow for interactions and connections between ecosystem services. Thus, for example, if climate regulation services are estimated under the assumption that a forest can sequester carbon over an infinite time frame, while for the same ecosystem asset, rates of timber provisioning are estimated under the assumption that the forest will be fully depleted within a limited time frame (e.g., 30 years) with no regeneration, then the two estimates of expected service flows will be considered internally inconsistent.

10.52 More specifically, the future flow of services depends upon the condition and regeneration of the ecosystem and future demand for ecosystem services. For example, the future flow of ecosystem services from a forest ecosystem in relation to air filtration services will depend on (a) the extent and condition of the forest; (b) the expected level of pollutants; and (c) the expected size and growth of the local population who benefit from air filtration services. There will be a set of factors to consider for each type of ecosystem service.

10.53 It is not anticipated that compilers will develop comprehensive models of future demand and supply considerations. However, it is reasonable to consider that some factors may be readily identifiable and quantifiable in certain contexts, for example the effects of increases in population or from the adoption of specific legislation that is anticipated to reduce pollution. In these cases, such factors should be considered in the estimation of future flows for a given ecosystem service. Further, over time, as a time series of ecosystem accounts is developed, this should in itself give insights into the factors of most relevance. The following points are set out to outline relevant considerations.

10.54 Since ecosystem services involve both the supply and use of services, the expected socio-economic context must also be considered in estimating the future flows of ecosystem services. This context will include general socio-economic factors (such as population and incomes) as well as more specific factors, including those that are spatially relevant or relevant to individual ecosystem services, such as the changes in the demand for recreation related services following increases in accessibility of ecosystems; and changes in regulations that reduce the concentrations of pollutants will reduce the demand for air filtration services.

10.55 In considering both the future supply and demand of ecosystem services it will be helpful to frame the future flows differently depending on the type of service. Future flows of provisioning services are likely to be functions of well-established natural resource and cultivated biological resource supply and demand considerations. On the other hand, future flows of regulating and maintenance services are more likely to be functions of changes in exposure to risks over time, for example from pollution and emissions and floods. Cultural services are likely to be driven by demand considerations including population growth and specific factors such as urban design and trends in tourism and recreation.

10.56 As introduced in Chapter 8, there are interactions among and within ecosystem assets that should be taken into account when considering the future flows of ecosystem services and their values. Assumptions concerning the expected future degradation which impact on specific ecosystem services will be of particular importance. For example, the flow of timber provisioning services may be expected to decline over time due to the impact of expected ecosystem use. In national accounting, similar assumptions are made when estimating the stock of produced assets.

10.57 In addition, in order to avoid internal contradictions in the measurement of asset values, it should be recognised that some patterns of use, primarily concerning overexploitation of natural resources such as timber, soil or fish, will have detrimental impacts on the supply of other ecosystem services. These impacts may not be apparent immediately but will be subject to different environmental thresholds.

10.58 Further, it will be relevant to consider wider environmental changes, such as expected changes in rainfall and temperature patterns or ocean acidification associated with climate change, that will impact on the future flows of ecosystem services. In estimating the expected future flow of services, it cannot be necessarily assumed that the flow will be ecologically sustainable, i.e. with no loss of ecosystem condition. These various factors can be assessed using concepts of ecosystem capacity, potential supply and resilience as discussed in section 10.4.

10.59 There are some contexts in which economic activity, including household consumption, has indirect and potentially delayed impacts on ecosystem condition. In a present value framing, the fact that the impacts on ecosystem condition (and hence ecosystem service flows) may be well into the future is conceptually straightforward to manage if the timing and magnitude of the impacts is known and can be incorporated into the estimation process. However, a common scenario might be that evidence of impacts emerges such that the expectations of future service flows change. From an accounting perspective, identifying such a change in expectations is possible. It is recommended that the change in value associated with these new expectations is recorded as a reappraisal of the value of the ecosystem asset.

10.3.5 Asset lives

10.60 ***The ecosystem asset life is the time over which an ecosystem asset is expected to generate ecosystem services.*** Estimates of the asset life should be based on consideration of the condition of the ecosystem asset and its capacity to supply the set of ecosystem services being considered in the valuation of the ecosystem asset. It is possible to assume an infinite asset life when it is expected that the ecosystem asset will be used long into the future. An alternative setting is to apply a maximum asset life of 100 years.

10.61 When determining asset lives, assumptions implying sustainable use of the ecosystem should not be applied as they may ignore important environmental information and may assume the adoption of behaviours concerning the use of the ecosystem asset that have not been adopted in the past. Thus, unless there is strong evidence to the contrary, it is recommended that estimates of asset life be based on patterns of ecosystem use that have occurred in the recent past rather than through the use of general assumptions about future sustainability or intended or optimal management practices.

10.3.6 Expected institutional arrangements

10.62 The final aspect in establishing the expected future returns is forming expectations about future institutional arrangements. In general, the starting assumption for accounting purposes would be that the current institutional arrangements will continue to apply.

However, in cases where it is strongly expected that these arrangements will change in the future and the nature of the changes can be clearly understood, the effects of future changes in institutional arrangements and the timing of the changes should be factored in when estimating the future flows of services. Examples of relevant institutional arrangements include natural resource management regimes, taxation arrangements, government environmental conservation programs and markets for environmental services (e.g. carbon markets).

10.3.7 Discounting

10.63 A discounting process involving selection of a discount rate is required to derive net present value estimates. Annex A5.2 of the SEEA Central Framework summarises key issues in the choice of discount rates and describes the mathematical and analytical implications of the choice of discount rates. In particular, it notes the distinctions between individual/private discount rates and social discount rates and also whether those rates are determined descriptively or prescriptively. Descriptively-determined discount rates are those based on the prices (and other measurable factors) facing either individuals or governments, while prescriptively-determined discount rates incorporate assumptions regarding the preferences of individuals and societies, particularly in respect of equity between and within generations.[5]

10.64 For individual ecosystem assets such as mineral and energy resources, and timber resources, the SEEA Central Framework concludes that for the purpose of alignment with the concept of exchange values as defined in the SNA it is necessary to use marginal, private, market-based discount rates – i.e. descriptively-determined individual discount rates. This conclusion can be directly applied in the context of the valuation of provisioning services. However, for other types of ecosystem services, particularly those with strong public good characteristics (e.g., water regulation of extreme events), the use of social discount rates may be considered more appropriate, i.e., taking into account the time and risk preferences of society as a whole.

10.65 In this context, the following conceptual framing should be applied in selecting a discount rate:

- In the valuation of provisioning services and other services that contribute to SNA benefits, individual, market-based discount rates are relevant
- In the valuation of ecosystem services that contribute to non-SNA benefits, social discount rates that are descriptively determined are relevant, noting that for use in ecosystem accounting such rates should be sourced from government determined processes and further, they should be in active use in government decision making.
- If such social discount rates are not available, market rates for long term government issued bonds are relevant.

10.66 In applying discount rates, it is recommended that compilers use a constant rate over the asset life. The primary alternative is to use declining discount rates including hyperbolic, gamma and geometrically declining rates. Declining rates may have some intuitive appeal in that they do not fix the relationship of preferences across generations and hence allow the preferences of future generations to be more explicitly considered. However, there are a range of theoretical (e.g., time inconsistency) and practical challenges, and hence these rates are not recommended for use in ecosystem accounting.

[5] SEEA Central Framework Annex A5.2 Discount rates, A5.52

10.67 Care should also be taken to ensure that the discount rate applied is consistent with the assumptions made in projecting future returns of ecosystem services. Specifically, if future returns are estimated in nominal prices then the discount rate should include an allowance for expected inflation. Most commonly, future returns will be estimated in real terms and thus the discount rate applied should also be in real terms. Since the essential function of a discount rate is to reflect the time value of money, the appropriate measure of expected inflation is likely to be one that is economy-wide in scope, for example, the GDP deflator.

10.68 As part of a general assessment of the sensitivity of monetary valuations to different assumptions, a set of estimates of the monetary value of ecosystem assets might be presented using different discount rates.

10.3.8 Measuring changes in the net present value of ecosystem assets over an accounting period

10.69 Accounting for the change in the value of assets over an accounting period is a core part of asset accounting. As with the assessment of the value of an asset at the beginning and end of an accounting period, the valuation of changes in the asset value, such as those due to ecosystem enhancement, degradation and conversions, is also dependent on the impact that these changes have on expected future returns. Further, since these changes are not usually evidenced by transactions in the assets themselves, their valuation requires the use of the NPV approach to ensure alignment between opening and closing valuations and valuations of the changes.

10.70 A complete accounting for NPV and changes in NPV is presented in Annex 10.1. The annex highlights the relationships between the changes in the quantities of expected flows of ecosystem services, changes in the condition and extent of the ecosystem asset and changes in the prices of ecosystem asset with respect to each ecosystem service. A key conclusion demonstrated in the annex is that it is incorrect to use the unit price of the ecosystem service in the current period to value the ecosystem assets and changes in those assets. Rather the relevant asset prices will be a function of the NPV formula in which expected future returns and discounting will have an effect. The relationship between unit prices for ecosystem services and ecosystem asset prices is also discussed in the annex.

10.4 Measuring ecosystem capacity

<<***Note to reviewers:*** *The connection between the condition of ecosystem assets and the future supply of ecosystem services is clearly of relevance in understanding the value of ecosystem assets. This relationship is embodied in the concept of ecosystem capacity. At this point in the SEEA EEA revision process, significant advances have been made in the description of relevant concepts of ecosystem condition, ecosystem services and ecosystem degradation. Given these advances, a discussion on the definition of ecosystem capacity is planned, bringing together experts from ecology, ecosystem services, economics and accounting.*

Based on this discussion, text concerning ecosystem capacity and related concepts such as potential supply, capability and resilience will be developed for inclusion in the revised SEEA EEA. Note that it is not intended to describe accounts for ecosystem capacity. However, since the concept is of direct relevance in applying and interpreting the accounts, a discussion of possible approaches to measuring capacity and applying the results as part of compiling the core ecosystem accounts is considered important. Those interested in an introduction to the topic of ecosystem capacity may reference the SEEA EEA Technical Recommendations, Section 7.3.>>

Annex 10.1: Application of the net present value method for valuing ecosystem assets and changes in ecosystem assets

Introduction

This annex explains, in some detail, the steps involved in implementing a net present value (NPV) approach for the valuation of ecosystem assets, with a view to deriving valuations of the opening and closing values of ecosystem assets and consistent measures of ecosystem enhancement, degradation, conversions, other changes in volume and revaluations. The conceptual framing for the approach described here is explained in Chapter 10 together with definitions of the relevant accounting entries. A simple, stylized example is used to demonstrate the approach.

Stylised example

In this stylized example the ecosystem accounting area (EAA) covers 9 hectares (ha) consisting of two ecosystem assets (EA). At the beginning of the accounting period, t0 the composition is forest (EA1: green) covering 5 ha and cropland (EA2: yellow) covering 4 ha. (See Figure 10.1)

Figure 10.1: Extent

Area t0				
EA1 - forest	5	EA2		
EA2 - crops	4			
				EA1

The forest is assumed to supply two ecosystem services: climate regulation services (ES1) and nature-based recreation services (ES2), and the cropland supplies one ecosystem service: crop biomass provisioning (ES3). It is further assumed that each of these services is supplied only from the specific areas of each EA (i.e. the service providing areas of each ecosystem service (denoted by a_0 and a_1) coincide with the areas of the respective EAs.

As explained in Section 10. 3, the value V_t of each ecosystem asset is derived as the NPV of the future flows of each ecosystem service that the EA supplies. In this example, as shown in Table 10.2, it is assumed that prices *p* and quantities *q* have been projected for each ecosystem service for a future period of 5 years[6].

Table 10.2 depicts the set of price and quantities as expected at the beginning of the accounting period – denoted by t_0 - and as expected at the end of the accounting period (also the beginning of the next accounting period - t_1 . To provide context, year 1 could be 2010 (which would start at t0 and end at t1) and year 2 could be 2011 (which would start at t1). The prices and quantities shown in Table 10.2 are the totals for the three ecosystem services supplied across the EAA.

To simplify the presentation, the calculations are undertaken using discounted prices. Discounted prices are obtained by multiplying the unit price (shown in Table 10.2) in year *j* with the applicable discount factor for year *j* to express the unit price in the price of the base year. A discount rate of 5%

[6] In more realistic applications, the asset life would be multiple decades, depending on the appropriate asset life. As ecosystems are renewable assets, we work here with a moving asset life of 5 years, rather than assuming a fixed asset life end date.

is used to derive the discount factor. Table 10.2 shows the discount factors one obtains using a 5% discount rate.

Table 10.2: Input data and NPV calculations for three ecosystem services

Discount rate	5%		year1	year2	year3	year4	year5			
		discount factor	1.0	1.0	0.9	0.9	0.8	Q (cumulative stocks)		
	t0	ES 1 - physical unit	40	39	38	37	36	190		38.0
	t0	ES 2 - physical unit	10	10	9	8	8	45		9.0
	t0	ES 3 - physical unit	50	50	50	50	50	250		62.5
	t0	ES 1 - unit price	14	15	16	17	18			
	t0	ES 2 - unit price	2	2	2	2	2			
	t0	ES 3 - unit price	8	7	8	7	8			
								V0 (NPV) p_0^i		
	t0	ES 1 - value (in discounted pric	560	557	551	543	533	2745		14.4
	t0	ES 2 - value (in discounted pric	20	19	16	14	13	82		1.8
	t0	ES 3 - value (in discounted pric	400	333	363	302	329	1728		6.9
								4555		
								Q (cumulative stocks)		
	t1	ES 1 - physical unit	30	28	26	24	22	130		26.0
	t1	ES 2 - physical unit	10	10	10	8	8	46		9.2
	t1	ES 3 - physical unit	65	65	65	64	65	324		81.0
	t1	ES 1 - unit price	15	16	17	18	19			
	t1	ES 2 - unit price	2	2	2	2	2			
	t1	ES 3 - unit price	8	8	8	8	8			
								V1 (NPV) p_1^i		
	t1	ES 1 - value (in discounted pric	450	427	401	373	344	1995		15.3
	t1	ES 2 - value (in discounted pric	20	19	18	14	13	84		1.8
	t1	ES 3 - value (in discounted pric	520	495	472	442	428	2357		7.3
								4436		
						Change in value of EAA		**-119**		

For the derivation of the NPV, using the equation provided in Section 10.3 - the value of the EAA, i.e. of all ecosystem services across all EA – can be written as:

$$V_t \quad = \sum_{i=1}^{3} \sum_{j=1}^{5} p_t^{ij} * q_t^{ij} \qquad [1]$$

Here *i* denotes the number of ecosystem services, and *j* the asset life (number of years). The subscript *t* in equation [1] indicates that in order to estimate the value at time *t* we multiply prices and quantities as they were expected at the beginning of *t*. Note that it is assumed that the value of each ecosystem service is separable and hence the overall asset value of the EAA can be obtained by summing over all ecosystem services.

To explain the calculation for an individual ecosystem service, consider the climate regulation service, ES1. Here the quantities range from 40 to 36 tonnes over the 5 years from t0 and the unit prices increase each year, from $14 to $18 per tonne of carbon (e.g. as the marginal damages of avoided carbon release increases). The value is derived by multiplying the quantity and the associated discounted unit price in each year (e.g. for t0 it is 40*14 = 560) and the NPV for climate regulation at t_0 is 2745.

Using this approach across all ecosystem services and for both ecosystem assets, a total value at t0 of 4555 is obtained. This falls to 4436 at t1. Note that in the calculations, an NPV for each ecosystem service is also obtained.

Decomposition of the change in NPV

In order to compile the entries in the ecosystem monetary asset account that record changes in the NPV between opening and closing values, it is necessary to distinguish between changes due to prices and changes due to volumes (quantities). To distinguish these different changes, V_t^i (the value of the

i^{th} ecosystem service) is defined as the product of (i) the average (discounted) unit price (over all accounting periods) denoted by p_t^i and (ii) the total volume of ecosystem services supplied over the accounting periods) denoted by Q_t^i.[7]

In the context of this example, consider the total value of the nature-based recreation service at t0 (82) which is equal to the total number of visitors over the life of the asset (45) multiplied by the average discounted unit price per visitor (1.8).

Using this framing, equation [1] can be re-expressed to obtain:

$$V_t \;\; = \sum_{i=1}^{3} p_t^i * Q_t^i \qquad [2]$$

$$V_1^i - V_0^i = p_1^i q_1^i - p_0^i q_0^i = (p_1^i - \; p_0^i) q_1^i + \; p_0^i q_1^i - p_0^i q_0^i \qquad [3]$$

$$= \; (p_1^i - \; p_0^i) q_1^i + \; p_0^i (q_1^i - q_0^i)$$

Equation [3] reflects the decomposition of the change in NPV for each ecosystem service *i,* into changes due to price (price effect) and changes due to volume/quantity (volume effect). [8]

Table 10.2 details the various p_t^i and Q_t^i for each ecosystem service. To illustrate the derivation of the p_t^i consider the climate regulation service, ES1. Here the NPV at t_0 is 2745 and the cumulative quantity Q_0^1 over the 5 years from t0 is 190. Dividing the NPV value by Q_0^1 gives the average discounted unit price p_0^1 for ES1 of 14.4.

Using the various p_t^i and Q_t^i for each ecosystem service all decomposition effects derived using equation [3] can be calculated. The results for each ecosystem service are shown in Table 10.3. The key result is that the sum total of all decomposition effects (i.e. price and volume effects) is equal to the overall change in value of -119 shown in Table 10.2. In other words, the decomposition is exact.

In terms of the example itself, the negative volume effect can be seen as explaining more of the observed change in overall value. For individual services, there is a large reduction in the value of climate regulation (-750), which is mostly explained as a volume effect (Q_t^1 drops from 190 to 130). At the same time, there is an upward price effect due to the increasing price path of the service. Note too that there is no price effect for ES2 reflecting that its expected price path does not change.

Table 10.3: Results of the decomposition analysis for three ecosystem services

	Results		
	Volume	**Price**	**Total**
ES1	-894	143	-750
ES2	2	0	2
ES3	525	105	629
	-367	248	**-119**

[7] This average, discounted unit price is derived in a similar manner to the approach taken in the SEEA Central Framework (annex 5.1) to derive estimates of depletion, where the *asset price in situ* for a subsoil asset was defined as the ratio of its NPV value V and the total stock S.

[8] Please note that this decomposition form is not unique. We could have decomposed this into (p1-p0)*q0+(q1-q0)*p1, which results in slightly different factors. As in SEEA CF Annex 5.1, we therefore average the 2 decomposition forms.

Ecosystem monetary asset account

The various decomposition elements can now be used to compile the ecosystem monetary asset account, as shown in Table 10.4. The account is structured to show the opening and closing values for each EA (equal to the sum of ecosystem services relevant for that ecosystem[9]) and the various changes due to enhancement, degradation, conversions, revaluations or other changes.

Table 10.4: The ecosystem monetary asset account

		Forest	Crops	Total
Opening stocks		$2,827	$1,728	$4,555
	Enhancement		$525	
	Degradation	($894)		
	Conversions			
	additions		$0	
	reductions	$0		
	Revaluation	$143	$105	
	Other changes	0	0	
	catastrophic losses			
	reappraisals	2		
Closing stocks		$2,079	$2,357	$4,436

The estimates for the opening and closing values for each EA can be readily obtained from Table 10.2. For Forests it is the sum of the NPV for ES1 and ES2 and for Cropland it is the NPV for ES3. To complete the other accounting entries the first focus is to estimate the entry for revaluations which is equal to the price effect shown in Table 10.3. This equality applies since the price effect measures the change in value that occurs solely due to the change in average (discounted) price (for each ecosystem service. A final section of the annex discusses the relationship between unit prices of ecosystem services and asset prices.

The remaining change in value is associated with the volume effect which measures changes in the total quantity of expected future ecosystem services (for each ecosystem service) due to changes that occur during the accounting period, excluding the effects of price changes. The volume effects can therefore be used to determine the relevant entries for ecosystem enhancement, degradation, reappraisals and catastrophic losses depending on the cause of the change following the definitions provided in in Chapter 10. The process of establishing how a volume effect for a given ecosystem service is treated entails considering (i) whether the volume effect is positive or negative and (ii) the direction of change in ecosystem condition and demand for ecosystem services.[10] By considering the

[9] In this example, the process is made more straightforward since there is a 1-1 correspondence between the EAs and the service providing areas of the ecosystem services. In more complex settings, the value of the individual ecosystem services would need to be apportioned to the underlying ecosystem assets (i.e. when an ecosystem service is supplied over a combination of EAs. This may be undertaken by pro-rating the aggregate supply of the ecosystem service using the share of areas of the relevant EAs in which case there is an assumption of homogeneous distribution of supply of the ecosystem service across the service providing area. More complex allocation methods might also be applied.

[10] In projecting p's and q's (as done in Table 10.2), it is reasonable to assume that ecosystem condition (and expectations how it will develop within the current management regime) and expected demand is taken into account. During the accounting period, many changes happen (changes in demand, but also changes in actual condition), with the end result that at the end of the accounting period there will be updated expectations about p and q's.

various combinations the appropriate treatment of the measured volume effect can be made following the guidance in Table 10.5.

Table 10.5: Attributing volume effects based on cause

volume	condition	demand		
up	up	up	enhancement	
up	up	down	enhancement	
up	down	up	upward reappraisal	
up	down	down	not possible	
down	up	up	not possible	
down	up	down	downward reapprais	
down	down	up	degradation	
down	down	down	degradation	

To apply the guidance from Table 10.5 in the stylized example assume that the associated condition account indicates that the condition of the forest EA declined during the accounting period, but the condition of our cropland EA increased. Considering each ecosystem service in turn

- For climate regulation services (ES1), Table 10.3 shows a negative volume effect (-894) and since the condition also declines, this volume effect is recorded as degradation.
- For nature-based recreation services (ES2), Table 10.3 shows a small positive volume effect (2). Since the condition declines, this is best explained as being due to an increase in demand (reflected in a slight increase in total expected visitor numbers (from Table 10.2)) and hence recorded as an (upward) reappraisal.
- For crop biomass provisioning services (ES3), Table 10.3 shows a positive volume effect (525), and since condition improves, this volume effect is recorded as ecosystem enhancement.[11]

Although not a part of this example, it is noted that in case of significant unexpected changes in quantities (e.g. due to a hurricane uprooting trees) these changes in volume could be recorded as catastrophic losses rather than degradation. In this way, all possible entries of the monetary asset account can be obtained, in a manner that is aligned with and uses information from the extent accounts, condition accounts and ecosystem service supply and use accounts.

The broader interpretation is that the overall value of the forest EA has declined, while the cropland EA has increased in value; the net effect is however a loss of 119 of the value of this EAA.

Accounting for conversions

In the stylized example, the areas of each EA remained the same over the projection period. Consequently, there was no consideration of ecosystem conversions, i.e. changes in ecosystem extent where a particular location changes in ecosystem type during an accounting period. These changes are recorded in biophysical terms in the ecosystem extent account. The following explains the

[11] In case of biomass provisioning services, it may be reasonably assumed that an increase in expected quantities also reflects an increase in demand for biomass. However, as the focus in the asset accounts is on recording increases in asset value resulting from improvements in condition, it is proposed to record it as an enhancement.

appropriate calculations for recording the monetary effects of conversions in the ecosystem monetary asset account.

To explain, the stylized example is adapted such that the extent of the forest is reduced by 1 ha during the accounting period and converted to cropland (see Figure 10.2). To retain the connection with the previous context, all other details of expected quantities and unit prices remain the same and consequently the NPV for each ecosystem service and the total NPV for the EAA remains the same. The difference implied by the ecosystem conversion is therefore that the change values from forests to cropland must be accounted for.

Figure 10.2: Extent (t1 – end of accounting period)

Area t1	a1			
EA1 - forest	4	EA2		
EA2 - crops	5			
				EA1

To incorporate changes in area of each EA, the decomposition formula is re-worked such that changes in extent – denoted by a_t^i – are incorporated. This incorporation is shown in equation [4] which is a rewriting of equation [2].

$$V_t^i = p_t^i * \frac{Q_t^i}{a_t^i} * a_t^i = p_t^i * \bar{q}_t^i * a_t^i \qquad [4]$$

Here $\bar{q}_t^i$ denotes the total (expected) volume of ecosystem service *i* per hectare. Using this expansion the difference between the opening and closing value for each ecosystem service can be expressed as (suppressing the * signs):

$$V_1^i - V_0^i = p_1^i\bar{q}_1^i a_1^i - p_0^i\bar{q}_0^i a_0^i = \ (p_1^i - \ p_0^i)\bar{q}_1^i a_1^i + \ p_0^i\bar{q}_1^i a_1^i - p_0^i\bar{q}_0^i a_0^i \qquad [5]$$

$$= \ (p_1^i - \ p_0^i)\bar{q}_1^i a_1^i + \ p_0^i(\bar{q}_1^i - \bar{q}_0^i)a_1^i + \ p_0^i\bar{q}_0^i a_1^i - p_0^i\bar{q}_0^i a_0^i$$

$$= \ (p_1^i - \ p_0^i)\bar{q}_1^i a_1^i + \ p_0^i(\bar{q}_1^i - \bar{q}_0^i)a_1^i + \ p_0^i\bar{q}_0^i(a_1^i - a_0^i)$$

That is, we have now decomposed the change in NPV (of each ES *i*) into 3 effects: a price effect, a volume (intensity) effect and an area effect.[12] As before, the price effect measures the change in average (discounted) unit prices that occurs during the accounting period. The volume (intensity) effect measures changes in total quantity of future ecosystem services but now normalized to be shown per hectare, hence the reference to intensity. The area effect measures changes in value due to changes in extent of the assets.

To calculate this decomposition, factors $\bar{q}_0^i$ are used that are obtained by dividing, for example, the total quantity of for climate regulation services at t0, i.e. Q_0^1, by the area a_0^1 (5) giving $\bar{q}_0^1$ of 38 (as shown in Table 10.2). Following the same steps as before, but with the extension to consider the effect of the change in area, the decomposition of the change in value can be calculated as shown in Table 10.6.

[12] As with the decomposition into price and volume, this decomposition form is exact but not unique. To see this, notice that in equation [3] the starting point was p1 as a difference, but we could have also started with q1. In equation [5] this is extended to also consider starting with a1. In fact, since equation [5] is a decomposition into 3 factors, there are 3! = 6 possible decomposition forms (see Dietzenbacher & Los, 1998 for a more general proof of this). In order to derive the proper weights, it is necessary to average over all 6 forms. In our example, the proper weight of the area effect is: 1/3* p0q0 + 1/6* p0q1+1/6*p1q0 +1/3*p1q1. With appropriate changes weights for the revaluation and volume effects can be derived.

Table 10.6: Results of the decomposition analysis (3 factors)

	Results			
	Area	**Volume**	**Price**	**Total**
ES1	-525	-368	142	-750
ES2	-19	21	0	2
ES3	452	73	104	629
	-92	-274	247	**-119**

Again, the decomposition is exact as the sum of the changes due to area, volume and price equals the total value change of -119. As expected, the differences in NPV for each ecosystem service are the same (e.g. -750 for ES1 as before), but we now have three explaining factors rather than two. Also as expected, the price effect is virtually the same as in the earlier decomposition, since we have essentially split the volume effect into two effects: a volume (intensity) effect, and an area effect. The area effect can now be interpreted as providing the entries for ecosystem conversions (additions and reductions) in the ecosystem monetary asset account. It should be noted that the area effect is completely consistent with the information in the ecosystem extent account.

The structure of the ecosystem monetary asset account remains unchanged – see Table 10.7 - but compared to the results shown in Table 10.4, there are now entries for ecosystem conversions. The main change is that the previously large entry for degradation of forests (894) is now more evenly split between degradation (368) and ecosystem conversion reductions (543). Thus, by adding an additional factor to the decomposition form, we can now better explain the change in value that occurred during the accounting period.

Table 10.7: Monetary asset account (with conversions)

		Forest	**Crops**	**Total**
Opening stocks		$2,827	$1,728	$4,555
	Enhancement		$73	
	Degradation	($368)		
	Conversions			
	additions		$452	
	reductions	($543)		
	Revaluation	$142	$104	
	Other changes	0	0	
	catastrophic losses			
	reappraisals	21		
Closing stocks		$2,079	$2,357	$4,436

Unit prices and asset prices

Finally, a word on the interpretation of prices. In this valuation and decomposition, discounted unit prices have been used for each ecosystem service. These unit prices (p_t^i) should be considered as average prices for the supply of each of the different ecosystem services. After multiplying the discounted unit prices with their expected quantities (q_t^i) and summing over the asset life we obtain the NPV of each ecosystem service and from there the value of each EA at each point in time can be determined.

When calculating the NPV, the implicit quantity of the underlying ecosystem asset is 1, so that the NPV of the ecosystem asset (i.e. the sum over relevant services) is also the unit price of the asset (and its exchange value). Thus, the basic measurement unit remains the individual EA, characterized by its extent (which will generally be greater than 1 ha) and its condition. Further, in this framing the unit price can be considered an average asset price.

It may also be of interest to calculate a marginal asset price defined as the change in NPV of the EA with respect to a marginal change in extent of the EA (e.g. a change of 1 ha). In this framing, the intuition is that for a large asset (in terms of extent), say a forest, it may be reasonable to suppose that the marginal price of a hectare at the edge of the forest will be different from the marginal price of a hectare at the centre of the forest, i.e. there are different asset prices for different parts of an ecosystem asset and these asset prices might change as the overall size of the EA changes. Put differently, losing a hectare acre when the extent is 100 may be less problematic than losing a hectare when the extent is 5.

In the example, it is *de facto* assumed that the ecosystem services were distributed homogenously across the EA. This implies that the marginal and average asset price coincide by assumption. This is why, in order to separate out the area effect in the decomposition, it was appropriate to normalize the ecosystem services using the area over which they were supplied.

Of course, in real life most ecosystem services would not be supplied homogeneously across the EA, and hence a difference between the marginal and average asset price would arise. In such instances, it would be theoretically possible to break-up the EA into smaller units (e.g. units of 1 ha each), and for each obtain an average asset price following the approach described in this annex. Provided each small unit was homogenous an alignment would emerge between the average and marginal asset prices.

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