Experimental monetary valuation of ecosystem services and assets in the Netherlands

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Note for the London Group

For the last year Statistics Netherlands and Wageningen University have worked on the compilation of the first experiments monetary ecosystem accounts for the Netherlands. This document is the result of this study. The main outcomes will be officially published before the end of this year. For this reason, we had to remove from this version of the document the overview with the aggregated results and some of the analysis based on the key results. The aim of presenting this document to the London group is to ask for a reflection on the methodology that has been applied. In particular, we would like the London group to reflect on the following questions:

1. We distinguish three approaches to value ecosystem services, of which the first (exchange values) should be the focus for SEEA EEA (see section 2.3). Is this a useful way to describe the general approach to ecosystem service valuation ?
2. We argue that it important to distinguish between exchange values that are already included in GDP and that are not, as this is important for understanding how these values should be integrated into the accounting framework and it helps with the selection of the most adequate valuation techniques. Do you agree with this ? Do you agree with Table 3.2.1 where we have linked the valuation approaches linked to the different valuation methods ?
3. A key finding with regard to methodology is that in most cases the resource rent method is inadequate to value ecosystem services (see discussion on page 68). Do you agree with this conclusion ?
4. In section 4.7 we describe the expenditure method that we have used to value nature related recreation and tourism. Do you agree that this is an adequate method to value these ecosystem services ? What would be the most appropriate scope with regard to expenditure to use ?
5. In section 5.2 the make some assumptions to calculate values of ecosystem assets (a constant future flow of income, discount rate, asset life). Are these the right assumptions ?

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Acknowledgements

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Summary

Ecosystems contribute to economic activities and provide economic value. A considerable part of that value is not visible in standard national accounts. One of the purposes of SEEA experimental ecosystem accounting (EEA) is to provide sound statistical information on the economic value of ecosystem services and assets and present them in an accounting framework.

In this study we have produced the first experimental ecosystem service supply and use account and ecosystem asset account for the Netherlands based on the SEEA EEA framework.
The results do not represent to total or 'true' value of nature:

- We only estimate the *economic value* of *human benefits* produced by ecosystems. Non-economic values and 'non-human' benefits have been excluded. The intrinsic value of nature, which by definition cannot be expressed in monetary terms, is also excluded in the monetary accounts of the SEEA.
- We only assign values to *final ecosystem services* (produced by ecosystems and used in production or for consumption) and not to intermediate ecosystem services (produced by one ecosystem for use in another ecosystem).
- Our focus is on the *actual use* of ecosystem services rather than the capacity of ecosystems to deliver ecosystem services.
- We calculate exchange values for ecosystem services (consistent with the principles of the System of National Accounting) rather than welfare values.

We have estimated the value of ten ecosystem services: crop production, fodder production, timber production, air filtration, carbon sequestration in biomass, water filtration, pollination, nature recreation, nature tourism, and amenity services. For each ecosystem service we have selected valuation methods that are conceptually valid and that produce values that are consistent with the SNA. In addition, these methods can be applied using sound statistical data, enhancing their reliability and credibility. Subsequently, the values for the ecosystem services were used to calculate monetary values for the ecosystem assets, using the NPV method.

Four ecosystem services, for which physical estimates are available, have been excluded from the current analysis, namely biomass from non-agricultural sources, pest control, erosion prevention, and protection against heavy rainfall. Physical estimates of fishing and other marine ecosystem services have yet to be developed.

The general conclusion of this study is that it is feasible to compile monetary accounts for ecosystems on a national scale using several different statistical data sources and different valuation techniques. However, important challenges remain, particularly with regard to developing time series, improving the spatial allocation of values, increasing the scope of the ecosystem services, testing the applicability of the data on a more local level, and valuing tourism and recreation related ecosystem services.

Main methodological results

In this study, we have distinguished three approaches to valuation:

1. the compilation of exchange values, which is the recommended approach to apply in SEEA ecosystem accounting,
2. the compilation of welfare values, that are often used for cost benefit analysis, and

3. the Gross or Net Value Added approach, that provides broader insight into the economic significance of ecosystems.

In addition, we found that it is important to distinguish between exchange values already incorporated in the GDP of SNA and exchange values that are not. These approaches lead to different value indicators and the resulting value estimates may not be added up when different approaches have been used. The identification of these three approaches and the distinction between different kinds of exchange values helps (a) to select what valuation method to use for each ecosystem service, (b) to integrate the values into the accounting framework of the SNA, (c) to better understand the scope of the values included in the SEEA EEA, and (d) to better interpret and use the results.

Where possible different methods were applied to arrive at the best possible results. We found that, from a conceptual and practical point of view, the best valuation techniques to apply are:

- *Provisioning services*: Rent-based methods (e.g. stumpage prices, rent prices for agricultural land)
- *Regulating services*: Replacement costs or avoided damage costs methods
- *Cultural services*: consumer expenditure and hedonic pricing

The delineation of nature-related tourism and recreation is the largest source of variation between the estimates. The outcome of the expenditure method that was chosen to value these services is highly dependent on the scope of the expenditure that is included. Therefore, three different delineations were tested:

1. *Limited scope*: travel costs, admissions fees.
2. *Medium scope*: travel costs, admissions fees, accommodation costs, other costs.
3. *Broad scope*: travel costs, admissions fees, accommodation costs, other costs, costs for food and drinks, other related expenditure (mainly consumer durables).

We also conclude that in practice the resource rent method does not produce reliable results. In the SEEA EEA the resource rent method is considered the method of choice, particularly for provisioning services. The general idea is that the value of the contribution of an ecosystem service to production is included in the price or rent and that this value can be calculated by subtracting all other inputs, leaving a residual or rent that represents the value of the ecosystem service. We have estimated resource rents for a number of ecosystem services and compared the results to alternative valuation methods. This revealed two problems. The first problem is that the resource rent method produces estimates with high margins of uncertainty and, consequently, high annual volatility. The second problem is that in many industries, market conditions eliminate rents. Hence, estimates of the resource rent are very low, sometimes even negative.

The net present value (NPV) approach was used to convert the estimated flow of ecosystem services into an estimate of the associated asset value. This required assumptions on the future flow of ecosystem services, the discount rate, and the economic lifespan of ecosystem assets.[1] The assumptions are:

1. The future flow of income for each ecosystem services is assumed constant and equal to the flow observed most recently.

[1] The value of amenity services was estimated the other way around. Here, our method produced asset values – a percentage of the current value of houses that was attributed to nearby nature areas – which were converted to the value of ecosystem service flows using the same NPV approach.

2. The discount rate equals 3 percent, unless the ecosystem asset is thought to become scarcer and there are limited substitution possibilities, in which case a discount rate of 2 percent is used. This concerns the regulating ecosystem services (carbon sequestration, pollination, water filtration, air filtration).
3. The asset life is 100 years for all ecosystem assets.

Limitations

The results presented in this report should be handled with care. These are first experimental outcomes that should be improved and verified in the future. There are methodological limitations and ethical considerations, and there is the possibility of irresponsible use.

Valuation inevitably involves assumptions and uncertainties. Valuation according to SNA principles requires exchange values, but most ecosystem services and assets are not traded in markets in the same way as other goods, services, and assets (SEEA EEA, 5.1). It has proven necessary to impute 'missing prices' and to extract from the price of marketed goods and services that part which is attributable to ecosystem services. A critical caveat of the latter approach is that we must assume that the value of an ecosystem service is fully included in the market price.

In this study, we have valued 'only' ten ecosystem services. The scope is not yet comprehensive as we have not included a number of important ecosystem services, such as coastal protection (a regulating service) and marine ecosystem services. In that regard, the aggregated values presented here represent an underestimation. Furthermore, for some ecosystem services we have only included part of the exchange value. For example, for nature tourism and recreation the values now include only the part that is already included in GDP and not the exchange values related to all kinds of (positive) health effects that are not included in GDP.

Assigning an economic value to ecosystems gives rise to a number of ethical and cultural concerns. It can be argued that economic valuation turns nature into a commodity to be used by humans, that efforts to monetize the value of nature detract from its true (intrinsic) value, and that imputed non-market values are misleading (e.g. Silvertown 2015).

There is a risk that the statistics presented in this report may be misinterpreted. For example, a particular method may suggest that the economic value of an ecosystem service is zero or negative. It would be irresponsible to conclude that the associated asset truly has no value. This is particularly relevant when the resulting values are used to compare alternatives in policy decision making.[2] The statistics measure value within a narrow focus. The fact that we explain our focus does not relieve us from the obligation to strongly advise our readers to be careful when using the statistics presented in this report.

Valuation is, however, considered essential for communicating the economic value and scarcity of nature. We recognize that monetary values always have to be presented and analysed together with information from the other ecosystem accounts, that is, on extent, condition, and physical output. Monetary accounting must be developed in parallel with physical accounting in

[2] This involves the Hicks compensation paradigm, in which decisions that involve a particular cost (such as cutting down a forest with a particular monetary value) are considered responsible because there exist potential compensating measures, even when those measures are not actually taken.

order to provide an overall view of the status and trends in ecosystem assets and the ecosystem services they supply.

1. Introduction

Natural resources contribute to economic activities and provide economic value. Natural resources include both non-renewable resources such as oil and natural gas, and renewable resources such as land, water and timber provided by forests. Part of this value is internalised in economic processes and in the national accounts. The value of non-renewable natural resources is well visible in markets, both for what is extracted and for the stocks that remain. The same is true for the goods and services produced in agriculture, forestry, and fisheries. The value that is not visible – that remains external – is that of the ecosystems that directly and indirectly make it possible to produce these goods and services in agriculture, forestry or fisheries, or that contributes directly to human well-being.

When analysing the value of ecosystems it is important to distinguish between ecosystem assets and ecosystem services. Ecosystem assets are the ecosystems, covering a specific area, analysed from the perspective of the value they generate for people. The use of the term 'ecosystem assets' reflects that in accounting an anthropocentric perspective is taken. The accounts aim to establish the value of ecosystems for people, including where feasible all ecosystem services generated by these ecosystem assets. In this analysis accounting conventions are used. Specifically, this means that *individual* ecosystem services are analysed, as supplied by specific types of ecosystems. In reality, ecosystems are not independent entities: there are multiple interactions among them (e.g. nutrient webs, species migrations, water flows) and the condition (health) of any ecosystem on the planet depends upon the condition of multiple other ecosystems connected to it. However, in accounting, a compartmental approach is followed, as a means of understanding the value provided by ecosystems to people.

In the context of ecosystem accounting, the objective of valuation is to provide sound statistical information on the economic value of ecosystem flows and assets and present them in an accounting framework. This information serves a number of purposes (Melman & Van der Heide, 2011; EU, 2015; DEFRA, 2007; SEEA EEA, 5.5). It reveals the dependency of economic sectors on ecosystems, in both physical and monetary terms. It also supports decision making in public policy, for example to determine the optimal level of taxation for the sustainable use of ecosystem assets; to weigh alternative policy options (e.g. land use); or to carry out cost-benefit analyses. It is input for political debates and decision making, providing an instrument for the protection of the natural environment on which our well-being depends. The information is also necessary for insurance purposes (e.g. to calculate the value of environmental damage) and for private financing of climate change adaptation and mitigation measures (e.g. to calculate collateral).

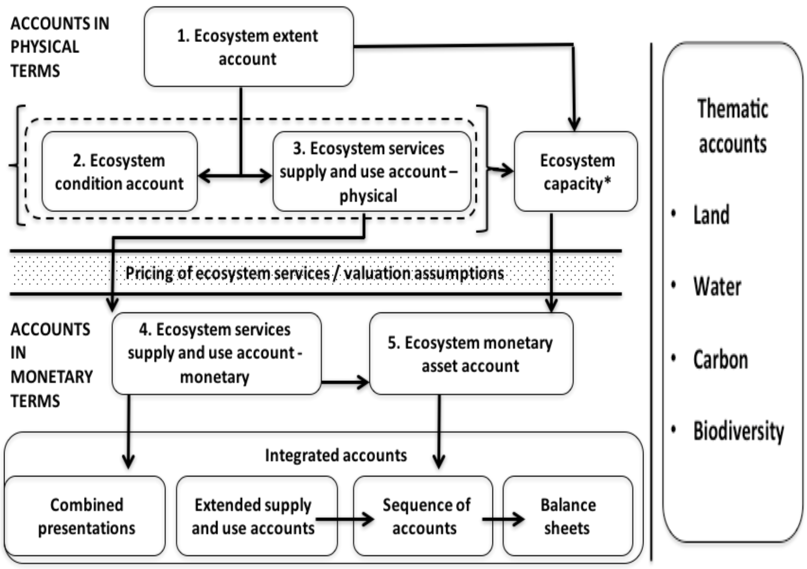
Valuation plays a role in signalling the scarcity and quality of ecosystem services and assets. Without market prices or some other form of economic valuation, there is no economic signal for scarcity and quality. Without such a signal, there is no way for people to perceive the economic value of ecosystem services and assets. Nijkamp et al. (2008, p. 222) point out that "goods do not have a value per se, but their value is related to people's perceptions." Information on economic values provides a signal to producers, consumers, and government, and supports sustainable management of natural resources. Over time, it can help in creating markets for ecosystem services (DEFRA, 2007). This is particularly important for resources in public ownership where there is a possibility of overuse and underuse.

1.1 SEEA ecosystem accounting

SEEA Ecosystem accounting is an approach to systematically measure and monitor ecosystem services and ecosystem condition over time for decision making and planning. Under the auspices of the United Nations, the System of Environmental Economic Accounting – Experimental Ecosystem Accounting (SEEA EEA) has been developed to guide the implementation of ecosystem accounting (UN et al., 2014b). One of the main objectives of the SEEA EEA is to measure ecosystem services in a way that is aligned with the System of National Accounting (SNA) (UN et al., 2009). Worldwide, the SNA forms the basis for national accounts statistics and is used to calculate macroeconomic indicators such as gross domestic product (GDP) in a consistent manner.

For ecosystem accounting, the SEEA EEA prescribes the development of a series of connected core accounts (see figure 1.1.1), representing the extent and condition of ecosystems (in biophysical terms), the supply and use of ecosystem services (in biophysical and monetary terms) and ecosystem assets (in monetary terms). Within the group of biophysical core accounts, the extent account and condition account record information on the size and state of ecosystems, which, in combination with the use of the ecosystem by people, determine the flow of physical ecosystem services (supply account).

Figure 1.1.1. Connections between ecosystem and related accounts and concepts, as presented in the SEEA EEA.



Source: UN et al., 2017.

In SEEA ecosystem accounting, the primary purpose of valuation in monetary terms is the integration of information on ecosystem condition and ecosystem services with information in the standard national accounts (SEEA EEA TR, 1.12). This enables comparison of the supply and use of ecosystem services with the production and consumption of other goods and services and supports the use of ecosystem information in standard economic modelling and productivity analysis.

1.2 Description of the Dutch ecosystem accounting project

In 2016 Statistics Netherlands and Wageningen University started a three-year project 'Ecosystem Accounting for the Netherlands', on behalf of the Ministry of Economic Affairs and the Ministry of Infrastructure and the Environment of the Netherlands. The project's aim is to test and implement SEEA EEA ecosystem accounting for the Netherlands. The choice was made to develop the core accounts and include carbon and biodiversity as thematic accounts (Figure 1.2.1). The focus of the research project is primarily on terrestrial ecosystems (land and inland waters) and not on marine ecosystems (sea and ocean).

Figure 1.2.1. Accounts in the SEEA experimental ecosystem accounting to be developed for the Netherlands. Bold indicates the accounts presented in this report.

Core ecosystem accounts	
Ecosystem extent account	Records the size of ecosystems
Ecosystem condition account	Records indicators that describe the quality and state of ecosystems
Biophysical ecosystem service supply and use account	Records the biophysical flows of ecosystem services to society and identifies its users
Monetary ecosystem service supply and use account	**Records the monetary flows of ecosystem services to society and identifies its users**
Ecosystem asset account	**Records the monetary value of the stocks of ecosystems, given the basket of ecosystem services that they produce**
Thematic accounts	
Carbon account	Records the stocks and flows of carbon in the country, related to the geosphere, biosphere and economy
Biodiversity account	Records the current status and trends in biodiversity. in the country, based on multiple indicators

Note: In this report we present both the monetary ecosystem services supply and use account and the monetary ecosystem asset account.

The biophysical ecosystem service supply and use account was published in 2018 (Statistics Netherlands and WUR, 2018). In this report, biophysical supply models are combined with additional data to develop monetary supply models. These are used to calculate monetary ecosystem service supply and use tables (which record monetary ecosystem service flows; both geographically explicit) and the monetary ecosystem asset account, which records the value of ecosystem assets (stocks) based on their long-term ability to provide a basket of ecosystem services.

1.3 Aim and approach of the study

The aim of this study is to provide experimental monetary values for ecosystem services and ecosystem assets in the Netherlands and organize these values into an accounting framework. It is not the purpose of this report to provide statistical information on all aspects of value nor do the results present the 'true' value of nature. Also, valuation as done in this report will not solve the absence of scarcity signals in the market.

This study has a very precise focus. First, we only estimate the *economic value* of the contribution of ecosystems to *human benefits*. Non-economic values (e.g. the cultural value of a landscape) and so-called 'non-human' benefits (e.g. ecosystems as habitats for animals) have been excluded in this report. These non-monetary values are, however, in scope for the SEEA EEA, for instance in the Biodiversity Account.

Second, we only assign values to *final ecosystem services* – produced by ecosystems and used in production activities (e.g. crops, timber) or consumption activities (e.g. avoided health damage of air filtration). Intermediate ecosystem services, produced by one ecosystem and used by another ecosystem, are excluded, even though they do represent economic value. In the future, it should be examined how important intermediate services can also be valued as part of the Netherlands SEEA EEA accounts.

Third, in line with recommendations in the SEEA EEA (3.32), we focus on the *actual use* of ecosystem services rather than the capacity of ecosystems to supply services in a sustainable manner.[3] This is consistent with the concept of actual transactions as recorded in the SNA. The principle also applies to expected future use of services in the estimation of asset values. For example, a forest may be able to provide more timber than it actually does. It may also be that the sustainable service flow (i.e. the capacity to provide services) is lower than the actual flow, i.e. the actual harvest rate.[4] The question of how overuse and underuse affect asset values is another aspect for future improvement of the Dutch SEEA EEA accounts.

Finally, we use valuation techniques that are consistent with the principles of the System of National Accounts. This implies that we calculate exchange values for ecosystem services rather than so-called welfare values. There are three reasons for aligning with the SNA:

1. *We need to be able to aggregate the statistical results for all ecosystem services and assets*. A single definition of value is needed to make an integrated assessment of the value of the bundle of ecosystem services produced by each individual ecosystem asset, of the value of all ecosystem assets of a particular type, and of the value of all ecosystem services produced by all ecosystem assets. We can only aggregate if we adhere to a single standardised approach.
2. *We want to integrate the values for ecosystem services and assets with the other monetary data of the SNA*. SEEA and SNA are all part of one consistent accounting framework based on the same definitions, concepts and classifications. Therefore, the principles for valuation must be the same. This makes all values comparable to for example GDP, the dominant indicator of value (SEEA EEA, 5.8).
3. *This particular definition of value is the most practical definition to apply for accounting*. Valuation methods may produce different numbers depending upon the assumptions underlying the methodology. Some methods produce estimates of consumer surplus, while other methods focus on production costs or rents. To estimate consumer surplus for each ecosystem service, we need to know the characteristics (e.g. price sensitivity) of the demand for ecosystem services and estimate willingness-to-pay using contingent valuation or similar methods. In the case of the Netherland, such information is currently not available and the associated methods are often not practicable or valid for all ecosystem services.

These principles will be discussed in more detail in chapter 2.

The results presented in this report do not encompass every ecosystem service in the Netherlands. We valuate the ecosystem services for which physical supply and use tables and

[3] "The concept of 'potential ecosystem services' relates to the capacity of ecosystems to supply ecosystem services without reference to any current or future demand for those services." (Brouwer et al. 2013)

[4] Note that in the Netherlands, as shown in the physical ecosystem services supply and use account, harvest rates are lower than capacities, and harvest rates are sustainable across the country.

maps have been produced (Statistics Netherlands and WUR, 2018) and for which the economic value of human benefits can be defined unambiguously. The starting point is the replication of the methods in the SEEA EEA framework and Technical Recommendations, also applied in Remme et al. (2015) for the Limburg province and the estimates of the UK Office of National Statistics (ONS, 2016; 2018). In order to compile the monetary ecosystem services and asset accounts, we have applied a range of valuation techniques.

1.4 Structure of the report

In chapter 2 we explain the valuation principles of ecosystem accounting within the SEEA EEA framework. We give a concise introduction to the most important valuation methods in chapter 3 and provide some criteria for selecting the valuation techniques. In chapter 4 we apply these methods to estimate the value of ten ecosystem services in the Netherlands. The estimated values are used to calculate the value of ecosystem assets in chapter 5, using a net present value approach. In chapter 6, the results of chapters 4 and 5 are combined and integrated into the framework of the System of National Accounts.. Finally, in chapter 7 we present the main conclusions and discuss the methodological limitations and ethical considerations as well as the possibility of irresponsible use of the statistics presented in this report.

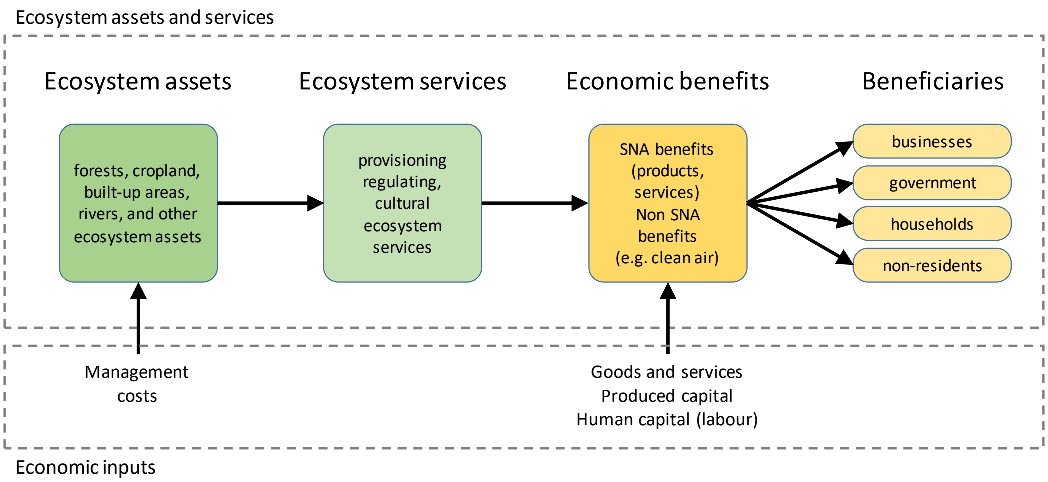
2. Key principles for ecosystem valuation

Environmental economic accounting has emerged in response to the global call for integrated social, economic and environmental data and information that enables decision making on sustainable development. In this chapter, we outline the key principles for valuation within the SEEA ecosystem accounting context. The focus is on defining what exactly will be valued and how this relates to the principles of the SNA. Understanding of value concepts is essential for the correct interpretation and application of the monetary ecosystem accounts.

2.1 What needs to be valued?

Monetary valuation concerns three specific components of the SEEA EEA framework: ecosystem assets, ecosystem services, and the associated benefits. These are shown in Figure 2.1.1 which represents a so-called logic chain that links the ecosystem services supplied by ecosystem assets to the benefits and their specific beneficiaries or economic users.

Figure 2.1.1. Key components for monetary valuation in the SEEA EEA



1 *Ecosystem assets*. Ecosystem assets are the basic building blocks of the SEEA EEA accounting framework. They represent the *stock* of ecosystems. An ecosystem asset is defined as a distinct contiguous spatial area covered by a specific ecosystem (e.g. a single deciduous forest). The spatial delineation of an ecosystem asset is required for accounting purposes and should be considered a statistical representation of an ecosystem. Based on common characteristics, ecosystem assets can be aggregated to ecosystem types (e.g. forests, cropland, built-up areas, etcetera).
The net present value (NPV) approach is most commonly used in the SEEA to calculate the value of the asset (SEEA EEA; Obst et al., 2016 for further details). The NPV method involves the calculation of the discounted value of future returns, using projections of the flows of ecosystem services from the ecosystem asset. Consequently, the valuation of ecosystem services is the starting point for the valuation of ecosystem assets. For economic accounting purposes, values observed in markets are the preferred source for asset prices. These are, however, unavailable for most ecosystem assets, because these market prices do not generally indicate all the services (including the non-market ecosystem services) that are provided by ecosystems. In this situation, an attempt should be made to estimate what the prices would be if the asset or the services it provides could

be exchanged in a market. In such analyses, all ecosystem services provided by an asset need to be considered.

2 *Ecosystem services.* Ecosystem services are defined as the contributions of ecosystems to benefits used in economic and other human activity. Valuation of ecosystem services involves assigning a monetary value to these contributions to benefits rather than to the benefits themselves. The value of inputs of products (intermediate consumption), human capital (labour) and produced capital should be excluded. This approach is clearly articulated in the resource rent method, in which all human-induced costs are subtracted from the output (the benefit) in order to calculate the so-called resource rent. In specific cases, however, other indicators of value – such as net and gross value added generated in the economy on the basis of specific ecosystem services – are also relevant, as is explored in this report. Other ecosystem services do not directly contribute to the production of goods and services, but are consumed by households, government or non-residents. Since there is no market price for the benefits of these services, alternative valuation strategies must be pursued.

3 *Economic benefits*. An economic benefit is defined as a (monetary) gain or positive utility arising from an action. We can distinguish SNA and non-SNA benefits. SNA benefits are the goods and services that are produced by economic units using ecosystem services as input. Their value can be measured as the total value of the output or as the gross value added (GVA) generated by their production. The value of these benefits is generally higher than the value of the ecosystem services, as they usually also require the input from labour and produced capital. Non-SNA benefits do not generally require additional input of labour and produced capital. Their value is therefore generally equal to the estimated value of the ecosystem service.

2.2 Which values matter?

Monetary valuation in the SEEA EEA is not intended to capture all kinds of value or to calculate the total value of the natural environment. The focus is on measuring the contribution of ecosystems to human consumption and production in a manner that is consistent with the national accounts.

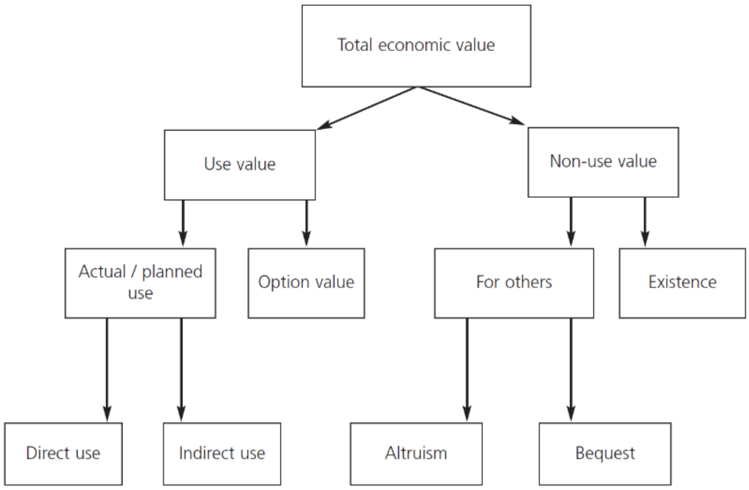
The valuation approach of the SEEA can be compared with that of the Total Economic Value (TEV) framework. TEV provides a convenient framework for organizing the different types of value (see Figure 2.2.1) and explains the particular focus of valuation in the SEEA EEA. The TEV distinguishes between use values (three types) and non-use values (three types). Each value is economic and is therefore dependent on human preferences and perceptions.

Use values concern the human benefits derived from the present or future use of ecosystem assets. There are three types of use value:

1. *Direct use value* is derived from the actual use by humans of an ecosystem asset to produce a benefit, such as timber, crops, fish, or recreation.
2. *Indirect use value* concerns the benefits for humans produced through the natural functioning of an ecosystem asset, such as air filtration, pollination, or carbon sequestration.
3. *Option value* is a special case of use values. It refers to someone's willingness to pay in the present to retain the option of using a resource in the future. Option values arise when people are uncertain about future demand for an ecosystem service or when the

long-term impact of decision are unknown. An example is the value of forest that may in the future supply plants for medicinal purposes.

Figure 2.2.1. The Total Economic Value framework



Non-use values are derived from attributes inherent in the ecosystem itself. There are three types of non-use value:

4. *Existence value* is based on utility derived from knowing that something exists.
5. *Altruistic value* is based on utility derived from knowing that somebody else benefits.
6. *Bequest value* is based on utility from knowing that the ecosystem may be used by future generations.

Using the TEV framework we can delineate the scope of monetary valuation in the SEEA EEA. The primary focus of the SEEA EEA is on direct and indirect *use values*. Use values concern ecosystem services and ecosystem assets that are actually used by the economy and society. However, there is a crucial difference in how direct and indirect use values are calculated in the TEV when used for an assessment of the welfare implications of using ecosystems in one way or another. In a welfare-based assessment, both (changes in) consumer and producer surpluses need to be considered, i.e. welfare impacts on both consumers and producers of a certain good or service. However, in SNA, the consumer surplus is not considered. There are several reasons for this, that have to do with aggregating values consistently across an economy, and with balancing the value of consumption with that of production in the accounts. Hence, *sensu stricto*, the SEEA also does not consider consumer surplus. There are calls for examining how a broader scope of values (including consumer surplus) may be accommodated in SEEA ecosystem accounting, but this is still under discussion.

In the same context, it is also still being debated whether option values and non-use values should be part of the ecosystem accounting framework. It may be argued that these values should be excluded: ecosystem services are defined as the contribution to benefits and hence should be measured only when SNA or non-SNA benefits can be identified. Thus, if there are no beneficiaries (users), there can be no ecosystem service flows (SEEA EEA, 3.33). In this report, option and non-use values are not considered, in line with the 2012 SEEA EEA framework.

The intrinsic value of nature, which by definition cannot be expressed in monetary terms, is also excluded in the monetary accounts of the SEEA. Intrinsic value is “a value that resides in the assets, especially in the environmental assets, but that is independent from human preferences” (Pearce and Moran, 1994, cited in Nijkamp et al., 2008, p. 222; see also DEFRA, 2007). The concept of intrinsic value means that an object, in this case nature, is valuable *for its own sake* as opposed to being valuable *for the sake of something else* to which it is related in some way. Since by definition TEV relates to preferences of individual human beings, it cannot encompass an intrinsic value.[5] Intrinsic value is also not considered explicitly in SEEA ecosystem accounting, even though the biodiversity account provides indicators that relate, among others, to the presence of rare, endemic and/or threatened species, which could be interpreted as being indicative of part of the intrinsic value of an ecosystem. This is further discussed in the physical biodiversity account and not part of the monetary accounts.

2.3 Approaches to ecosystem service valuation

The valuation of ecosystem services is meant to provide an estimate of the value of the contribution of ecosystems to economic production and consumption. As explained above this is different from ‘the value of nature’, because intrinsic values are by definition excluded in the ecosystem accounts. Hence, value estimates provided in the ecosystem accounts should be interpreted with caution. Aggregation of value estimates is possible, where commensurate value indicators are used, but these values only depict the value of the considered ecosystem services while excluding intrinsic values.

A second purpose of valuation in monetary terms is the integration of information on ecosystem services and ecosystem assets with information in the standard national accounts (SNA). A direct consequence of the extension of the production boundary (see section 2.4) is that in some cases ecosystem services provide extra value added to GDP. A key issue for integration in the SNA is thus to determine what value provided by ecosystem services is already included in GDP and what value is not.

There are different approaches to valuing ecosystem services in the context of the SEEA. These approaches lead to different value indicators and the resulting value estimates may not be added when different approaches have been used. Below we describe three different approaches and their usefulness for ecosystem accounting. The identification of these three approaches helps (a) to determine what valuation method to use for each ecosystem service, (b) to integrate the values into the accounting framework of the SNA, (c) to better understand the scope of the values included in the SEEA EEA, and (d) to better interpret and use the results.

Approach 1: Exchange values

Exchange values are those values that reflect the price at which ecosystem services and ecosystem assets are exchanged or would be exchanged between willing buyers and sellers if a market existed.[6] Since the ecosystem assets themselves are not actual market participants, the challenge in valuation for accounting lies in establishing the assumptions about the institutional arrangements that would apply if there was an actual market involving ecosystem assets (SEEA TR, 6.13). Exchange values are of interest because they allow direct comparison of values of

[5] See also De Groot et al. (2002) on ecological value and socio-cultural value.

[6] The term exchange values was introduced in the SEEA EEA since the term market prices as used in the SNA is often misunderstood to mean that national accounting only incorporates values of goods and services transacted in markets (SEEA EEA TR, 6.10).

ecosystem services and assets with existing national accounting values. Therefore, this is the recommended approach to apply in SEEA ecosystem accounting (SEEA EEA TR, 6.10).

We can distinguish between exchange values incorporated in GDP and exchange values not incorporated in GDP:

(a) Exchange values incorporated in GDP (as defined in the SNA)
The value of ecosystem services that are used in SNA production or consumption activities may already be incorporated in the value of GDP (as measured in the SNA). For SNA production activities this is the case when (a) an actual rent payment takes place when the user is not the same as the legal owner of the underlying ecosystem asset, or (b) the user-owner has bought the ecosystem asset that provides the ecosystem service on the market. Examples include biomass provisioning services from agricultural (e.g. crop production) and forestry activity (e.g. timber production). In all other cases, the ecosystem service is provided 'for free' and does not contribute to GDP as defined in the SNA. Ecosystem services may also directly contribute to household consumption, for example the expenditure related to nature-based tourism and recreation. This (extra) final household consumption is already included in GDP as measured in the SNA.

(b) Exchange values not incorporated in GDP (as defined in the SNA)
The value of all ecosystem services that are directly used for final household consumption, final government consumption, and exports are often provided 'for free' and thus not included in GDP (as defined in the SNA). Examples are air filtration and carbon sequestration. In addition, as discussed above, the value of some ecosystem services used by production activities is not included in GDP. Examples are marine fishing (when there is no direct payment for fishing licenses or quotas) or pollination for agriculture. When the value of an ecosystem service is not incorporated in GDP of the SNA, exchange values may be imputed using alternative valuation methods, such as the replacement costs and avoided damage costs methods.

Approach 2: Welfare values
Welfare economic values entail obtaining valuations that measure the change in the overall costs and benefits associated with ecosystem services and assets. It includes so-called consumer surplus, i.e. the monetary gain obtained by consumers because they are able to purchase a product for a price that is less than the highest price that they would be willing to pay. Welfare values are most commonly used in economic and environmental cost-benefit analysis where the focus is on the impacts of various policy choices on economic outcomes that are of common interest.

The SEEA EEA does recognize that the approach of welfare valuation can be highly relevant for decision making in public policy, for example in the assessment of costs and benefits of additional investments in regional planning, although the current focus is on producing estimates in exchange values. In time, a complementary set of ecosystem accounts in monetary terms may be developed using non-exchange value concepts. Confrontation of both value concepts may reveal new insights as well (SEEA EEA TR, 6.24).

Approach 3: GVA or NVA approach
The third approach calculates (net or gross) value added generated by economic activities that directly depend upon natural capital (SEEA EEA TR, 6.36).[7] This indicator reflects the economic activity that is supported by natural capital including the return obtained on labour (and produced capital) used to generate economic output on the basis of natural capital.[8] The GVA/NVA approach provides a broader insight into the economic significance of ecosystems compared to, for example, only the resource rent. This indicator can be relevant measure of value, in particular, where there is a lack of alternative employment opportunities outside of the use of natural resources, as in the case of many rural communities including areas dependent upon fishing or livestock rearing. It is also aligned with GDP, which reflects the gross value added in a given year at the national scale.

In general, exchange values are smaller than GVA/NVA values which in turn are smaller than welfare values. In principle, the results of the three approaches cannot be added since they reflect different aspects of value. In principle, all exchange values can be added up, i.e. exchange values derived from market and non-market based methods. The non-market based valuation approaches (such as avoided damage costs) reflect the return on natural capital and are most comparable to the residual approach. However, they sometimes reflect a part of the market value of a good which may be more aligned with NVA (as in the case of hedonic pricing). There are different approaches to calculating the marginal social damage costs of carbon that are usually aligned with value added (as when the impacts of climate change on GDP are estimated) and sometimes with the expenditure approach. Also, welfare-based assessments of climate change impacts may be conducted, or elements thereof may be included in specific marginal damage estimates, and further work is needed to obtain damage costs of CO_2 emissions and benefits of carbon sequestration that are aligned with the SEEA. Exchange values derived from household expenditure provide a special case which are discussed in more depth in section 4.7.

The suitability of the application of the three approaches differs for the main categories of ecosystem services:

- **Provisioning services** are always related to a contribution to SNA production activities.[9] The exchange value of ecosystem services that can be closely connected to activities in markets, i.e. provisioning services contributing to the production of food, fibre, fuel and energy will be included in the net operating surplus of a production activity. When the provisioning services are ‘ free services’, i.e. not incorporated in net operating surplus, exchange values usually cannot be determined using the available valuation techniques. The calculation of welfare values for provisioning services is quite difficult, as the willingness of businesses to pay extra when an ecosystem service becomes more scarce is probably limited. The GVA/NVA approach is particularly relevant for provisioning services.

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[7] Gross value added (GVA) represents the contribution of labour and capital to the production process. Gross value added is also equal to the gross revenues (production) minus the costs of intermediate inputs, in the case of the net value added (NVA) also the depreciation of fixed assets is deducted.
[8] Note that the impact on GDP may be higher still, for instance in case crop production is reduced due to the depletion of soils in the Netherlands, also the output of the Netherlands’ agrofood sector may be reduced - unless raw materials can be imported from elsewhere. These knock-on effects are generally hard to assess.
[9] Note that when households are using provisioning services (timber, water etc.), according to the SNA and SEEA they should be treated as production activities, as households by definition cannot produce goods.

- Exchange values for **regulating services** are, as a general rule, not included in GDP of the SNA, and thus have to be imputed using alternative valuation methods. Welfare values may be determined based on information on the willingness-to-pay of its users. The GVA/NVA approach can only be applied when the regulating service directly supports a specific production activity (for example water filtration in the water production industry).
- **Cultural services** are always provided to individuals and thus related to a contribution to consumption activities by households or non-residents.[10] Exchange values may already be included in GDP, for example as expenditures for nature-related tourism, or may not be included in GDP, for example as avoided health costs due to recreating in nature. Welfare values may be determined using information on the willingness-to-pay of its users. Applying the GVA/NVA approach is problematic as cultural services are usually not used as a direct input into production activities except possibly for nature tourism and recreation.

Figure 2.3.1 Indicators of value most relevant for the three main classes of ecosystem services (green = relevant; orange = potentially relevant; white = likely not relevant).

	Exchange values				
	Exchange values incorporated in GDP of the SNA		Exchange values not incorporated in GDP of the SNA		
	Contribution to production activities	Contribution to consumption activities		**Welfare values**	**GVA/NVA approach**
Provisioning ecosystem services	X			x	X
Regulating ecosystem services			X	X	x
Cultural ecosystem services		X	X	X	x?

[10] The only exception concerns the amenity services, as the production of housing services for their own final consumption by owner occupiers has is included in the production boundary of the SNA.

3. Valuation methods

In this chapter, we describe the most relevant methods for the valuation of ecosystem services that were used in this study. More detailed descriptions of the valuation methods can be found in chapter 2 of the technical background report. In the conclusion of the chapter, we select the appropriate method(s) for each ecosystem service.

3.1 A review of valuation methods

There are basically four categories of valuation methods:

- Market-based methods
- Revealed preference methods
- Cost-based methods
- Stated preference methods

3.1.1 Market-based methods: Resource Rent

The resource rent is the economic rent that accrues in relation to environmental assets, including natural resources and ecosystems (SNA, 2008). The resource rent can be derived from the national accounts by deducting costs of labour, produced assets and intermediate inputs from the market value of the outputs (benefits). The use of this approach to pricing is commonly associated with provisioning services like those related to the outputs of agriculture, forestry, and the fishing industry, in particular where there are limited or no possibilities for using land leases and prices as an indicator of the price of ecosystem services (SEEA EEA, 5.79).

The standard derivation of gross operating surplus based on SNA data is shown in Table 3.1.1. The resource rent is calculated by deducting consumption of fixed capital, return on produced assets and labour of self-employed persons from gross operating surplus.

Table 3.1.1 Derivation of the resource rent

Output	
	less intermediate consumption
	less compensation of employees
	less other taxes on production
	plus other subsidies on production
Equals gross operating surplus	
	less consumption of fixed capital (depreciation)
	less return on produced assets
	less labour of self-employed persons
Equals resource rent	
	= depletion + net return on environmental assets

3.1.2 Market-based methods: Rent prices

Rent is the income receivable by the owner of a natural resource (the lessor or landlord) for putting the natural resource at the disposal of another institutional unit (a lessee or tenant) for use of the natural resource in production (SNA, 7.109). There are several cases where rental prices can be used as a proxy for the value of ecosystem services. One example is the rent associated with agricultural land. Farmers may rent land for crop production or for livestock farming. These payments are directly related to the ecosystem services that are provided by the land. When the farmer owns the land, an imputed rent can be calculated from the value of the land. This is discussed in more detail in section 4.1.

Another example is the stumpage price for timber. Stumpage prices represent “the maximum amount potential concessionaires would pay for harvesting rights” with “full knowledge of the resource and competitive bidding” (Repetto et al., 1989). Observed stumpage prices are thus a good indication for the value of the related ecosystem service. This is discussed in more detail in section 4.2.

3.1.3 Cost-based methods: Replacement Costs

The replacement cost method estimates the value of an ecosystem service based on the costs that would be associated with mitigating actions if it would be lost (SEEA EEA, 5.84). The method is particularly relevant for regulating services (SEEA EEA, 5.85), such as flood protection and water filtration. The core assumption of the replacement cost method is that a service can be replaced, i.e. that a man-made alternative can be developed. It may be difficult to find perfect substitutes for ecosystems services. Some ecosystem services may be irreplaceable. For these services the replacement cost method cannot be used.

3.1.4 Cost-based methods: Avoided Damage

The avoided damage method estimate the value of ecosystem services based on the costs of the damages that would occur due to the loss of these services (Farber, Costanza, Wilson, 2002; De Groot et al., 2002). Similar to replacement costs, the focus will generally be on services provided by ecosystems that are lost due to human activity impacting on environmental condition, particularly through pollution. The avoided damage method is particularly useful for regulating services such as erosion, flood control, sedimentation control, air purification, and carbon sequestration. The avoided damage method presumes that individuals are willing-to-pay to avoid the associated damages (SEEA EEA TR, 5.101).

3.1.5 Revealed preference methods: Travel Costs

The Travel Cost Method is used to calculate the monetary value of recreational ecosystem services. Recreation in nature requires physical access, which may require travel. The amounts consumers spend to visit a recreational site (e.g. transport, fuel, parking fees, bike rentals) are a proxy for their willingness-to-pay for recreational ecosystem services. In principle, this method reclassifies existing market-based transactions (travel expenditure) to environmental services (ONS, 2014). Travel time and visiting time can be valued as well, although this value is usually seen as a welfare value (SEEA EEA, 5.103; ONS, 2014). For the valuation of ecosystem services, nature recreation and tourism need to be carefully defined as discrete activities so as to avoid double counting (see section 4.7). Note that there are two interpretations of the Travel Cost Method. In the first, the Travel Cost Method uses actual travel costs as an indicator of the value of the service. In the second, a demand curve for visiting a specific site is constructed based on travel costs and relative annual visitation rates – this method leads to an estimate of the consumer surplus generated through recreational visits to a site. In this report, the Travel Cost Method is meant to be the first of these two approaches.

3.1.6 Revealed preference methods: Hedonic Pricing

The hedonic pricing method is used to determine the value consumers attach to one particular attribute of a (marketed) product in relation to all the product’s other attributes. The most common application is the analysis of variations in housing prices in relation to physical attributes, properties of the neighbourhood, and the proximity to and quality of the natural environment (King, Mazzotta & Markowitz, 2004; SEEA EEA, 5.99).

3.1.7 Stated preference methods

Methods such as contingent valuation and choice experiments are applied to measure the stated preferences of a population (SEEA EEA; ONS, 2014). They can be used to identify willingness-to-pay for ecosystem services and thus calculate welfare values. These methods will not be used in this report.

3.2 Selection of valuation methods for ecosystem services

A key question in monetary valuation is what methods should be used to measure the monetary value of each ecosystem service. The choice of the applied valuation technique will significantly affect the outcomes. Our selection of methods is guided first of all by the overview and assessment of suitable valuation techniques as presented in the SEEA EEA technical recommendations. The nature of the value that is derived from each technique can be related to the four valuation approaches that have been identified in section 2.3 (Figure 3.2.1). When we combine Figures 2.3.1 and 3.2.1 we can select the most appropriate method(s) for the individual ecosystem services (Figure 3.2.2). Note that the tables give an indication only, in specific cases methods may also be applicable for value types which are not marked in the tables. Furthermore, we have selected methods that can (as much as possible) be based on existing statistical economic data, such as national accounts statistics, production statistics, price statistics, tourism statistics, etcetera.

Figure 3.2.1. Valuation approaches linked to methods described in this chapter

		Exchange values				
		Exchange values incorporated in GDP of the SNA		Exchange values not incorporated in GDP of the SNA		
Approach	**Method**	Contribution to production activities	Contribution to consumption activities		**Welfare values**	**GVA/NVA approach**
Market-based	resource rent method	X				
	rent prices	X				
	user costs	X				
	payments for ecosystem services	X				
	production function method	X				
	GVA/NVA method					X
Cost-based	replacement costs			X		
	avoided damage costs			X		
	social cost of carbon			X		
Revealed preference	consumer expenditure (including travel costs)		X			
	hedonic pricing	X				
Stated preference	contingent valuation				X	
	choice modelling				X	

Figure 3.2.2. Most appropriate methods for estimating the value of ecosystem services

		Exchange values				
		Exchange values incorporated in GDP of the SNA		Exchange values not incorporated in GDP of the SNA		
Class	**Ecosystem service**	Contribution to production activities	Contribution to consumption activities		**Welfare values**	**GVA/NVA approach**
Provisioning ecosystem services	crop production	resource rent				GVA
		rent prices				
		user costs				
	fodder production	resource rent				GVA
		rent prices				
		user costs				
	timber production	resource rent				GVA
		rent prices				
Regulating ecosystem services	air filtration			avoided damage		
	carbon sequestration			avoided damage		
	water filtration			replacement costs		
	pollination			avoided damage		
Cultural ecosystem services	nature recreation		household expenditure			
	nature tourism	resource rent	household expenditure			
	amenity services	hedonic pricing				

4. The value of ecosystem services

In this chapter we describe the methods, data, and assumptions that have been used to estimate the value of ten ecosystem services in the Netherlands The main results are presented and discussed. All values are estimated according to SEEA and SNA definitions and valuation principles. The descriptions in this chapter are brief; full details can be found in the technical background report. At the end of this chapter monetary supply and use tables are presented that show which ecosystems are supplying the ecosystem services and who are their users.

Four ecosystem services, for which physical estimates are available (Statistics Netherlands and WUR, 2018), have been excluded from the current analysis, namely biomass from non-agricultural sources, pest control, erosion prevention, and protection against heavy rainfall. The main reason for this exclusion is that there are several issues with regard to the definition of the ecosystem service, to their relevance to the situation in the Netherlands, and to the design of valuation methods, which could not be fully solved within the time budget of the current project. Physical estimates of fishing and other marine ecosystem services have yet to be developed. In the compilation of future monetary accounts for the Netherlands, valuation of these services will be reconsidered.

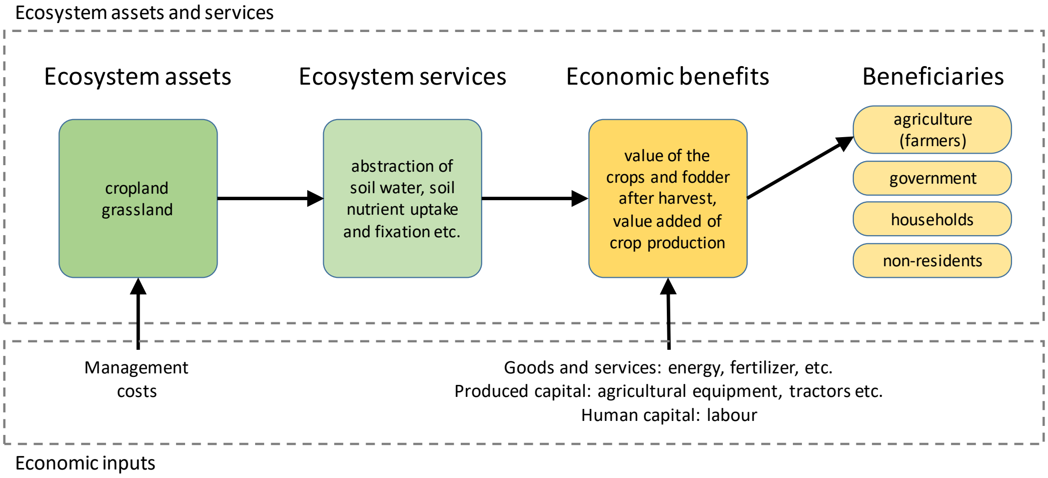
4.1 Crop and fodder production

Agriculture is highly dependent on the supply of ecosystem services. Here, we concentrate on the valuation of provisioning services related to agricultural production, namely crop production and grass/fodder production. Since the valuation techniques are very similar for these two services, they will be described together in this section. Three different valuation methods have been tested, namely the resource rent method, the rental price method, and the user cost of land (or land price) method. The results and the appropriateness of each method is discussed in this section. In addition, we have applied the GVA method to calculate the total economic benefits and show the importance of agriculture.

Definition of the ecosystem services

Determining the role of inputs of ecosystem services in the production of benefits for agriculture is not a straightforward task (SEEA EEA, 3.21). In practice, it is difficult to determine all of the various ecosystem processes as well as intra- and inter-ecosystem flows for different cultivated biological resources. For the physical accounts (supply and use tables) it is appropriate to apply the harvest approach for cultivated crops and other plants, based on the assumption that the various flows, such as nutrients from the soil and soil water that constitute inputs into the growth of the mature crop, are in fixed proportion to the quantities of harvested product (SEEA EEA, 3.30). Accordingly, the ecosystem service can be expressed as the physical value of the products harvested. Using the harvest approach, however, does not work for the monetary accounts: we have to value only the contribution to the benefits (i.e. the harvest) and thus correct for all other inputs. Accordingly, we have to define precisely the scope of the ecosystem service and the associated benefits.

Figure 4.1.1 Definition of the ecosystem service and benefits for crop and fodder production



The ecosystem services 'crop production' and 'fodder production' are defined here as the total and combined contributions of ecosystem processes that are directly supplied by the cropland and grassland respectively to the production of crops, grass, and fodder. This includes infiltration, storage and release of soil water, plant nutrient storage and release, and other soil related processes. They are, by themselves, a function of soil type, climate and past and current farm management practices. This is consistent with the general approach taken in the SEEA: all ecosystems are influenced by people, and their supply of ecosystem services is a function of natural characteristics inherent to the ecosystem and human management. The ecosystem service as defined here thus includes a mix of different contributions and processes provided by the cropland and grassland. The ecosystem services pollination and pest control are not included as these ecosystem services are primarily provided by adjacent plots of land or ecosystem assets and not by the cropland or grassland itself (see section 4.6). Therefore, they can be valued, and this value should be attributed to these adjacent ecosystems (e.g. hedgerows, forest patches that act as habitat for pollinating insects).

The economic benefits for these services are the monetary values of the crops and grass/fodder after harvest or as the value added of crop and fodder production. These benefits are the result of the combined input of ecosystem services, goods and services, produced capital and human capital. The beneficiaries are the farmers.

Methods and data
Here a short description is provided of the three methods we have applied to value the ecosystem services crop production and fodder production. A more detailed description can be found in the technical background report.

1. *Resource rent method*
   The resource rent method is often applied to calculate provisioning services, including crop production and grass/fodder production. The resource rent, which is in this case equal to the value of the ecosystem service, is calculated by subtracting all costs and normal returns from the total marketed output (see section 3.1.1 for more details). To calculate the resource rent for crop production and fodder production, data were obtained from the SNA production and income accounts for two sub-activities of ISIC 1 (agriculture), namely crop production and livestock farming.

2. *User cost method*
   According to the user cost method the value of the ecosystem service is directly derived from the ecosystem asset value, in this case the value of agricultural land. The user cost of capital can be viewed as the price that the owner/user of a capital good "pays to himself" for the service of using his own assets. In a perfect market, and defining away any transaction costs for supplying a rental, the user cost would take the same value as the rental price that the owner of a capital good could achieve if he rented out the asset during one period for use in production (OECD, 2009). Alternatively, the user cost corresponds to the marginal returns generated by the asset during one period of production. According to the user cost method the value of the ecosystem service crop production/fodder production is calculated based on the value of agricultural land, an assumed long-term average rate of return on investment (c. 0.9%, see technical background report for details; Wageningen Research, 2018), and an assumed service life (here 100 years).

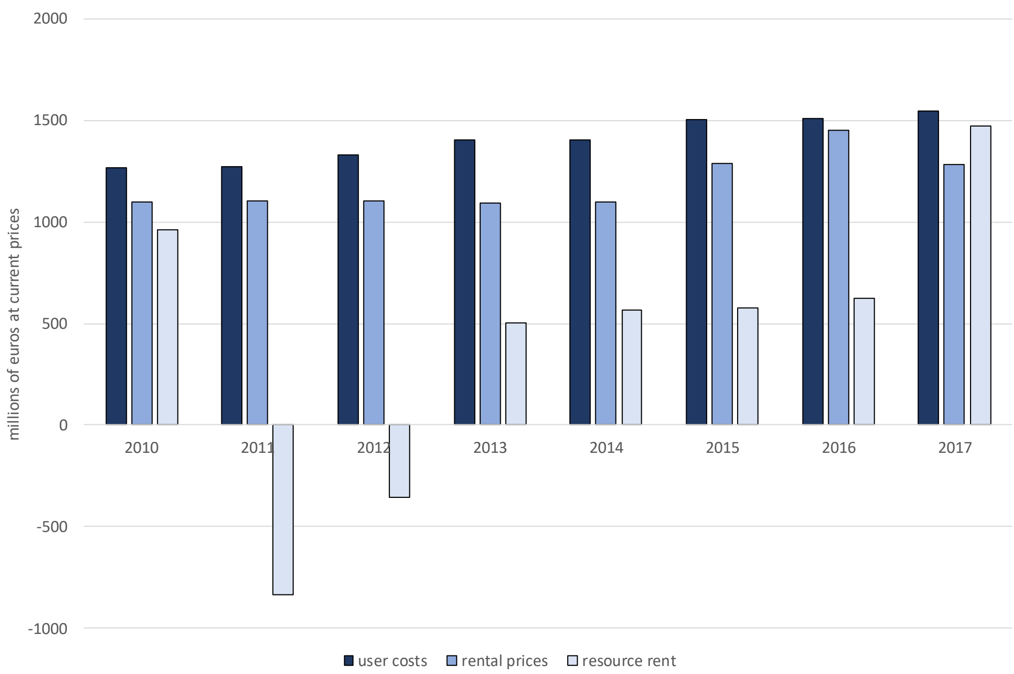
3. *Rental price method*
   Leases (rents) on land are a form of property income. They consist of the payments made to a land owner by a tenant for the use of the land over a specified period. Currently, around 30% of agricultural land in the Netherlands is leased. According to the rental price method the total value is calculated based on rent prices and data on the extent of agricultural land (cropland and grassland). It is assumed that the rental price is also a good approximation for the price of the ecosystem service provided by land owned by farmers.

Results
The results for the total value of the ecosystem services 'crop production' and 'fodder production' combined, based on the three alternative methods is shown in Figure 4.1.2. The user cost method puts the value of the ecosystem services at around 1.4 billion euros on average over the period 2010-2017. This boils down to 12.4% of the total value added of crop production and livestock farming. According to the rental price method the value of the ecosystem services is around 1.2 billion over the period 2010-2017 or 10.5% of the total value added of crop production and livestock farming.

The user cost and rental price methods provide estimates of the same order of magnitude. The estimates based on the user cost method are slightly higher, but this depends crucially on the assumptions about the rate of return and the service life. In the technical background report, we present the results for each agricultural activity as well as the results of a sensitivity analysis regarding different assumptions in the user cost method.

On average, the resource rent for total agriculture equalled 160 million euro between 2010 and 2017. Due to negative rents in livestock farming, this method gives negative estimates of the value of ecosystem services for some years. Another drawback of this method is that the estimates cannot be broken down regionally.

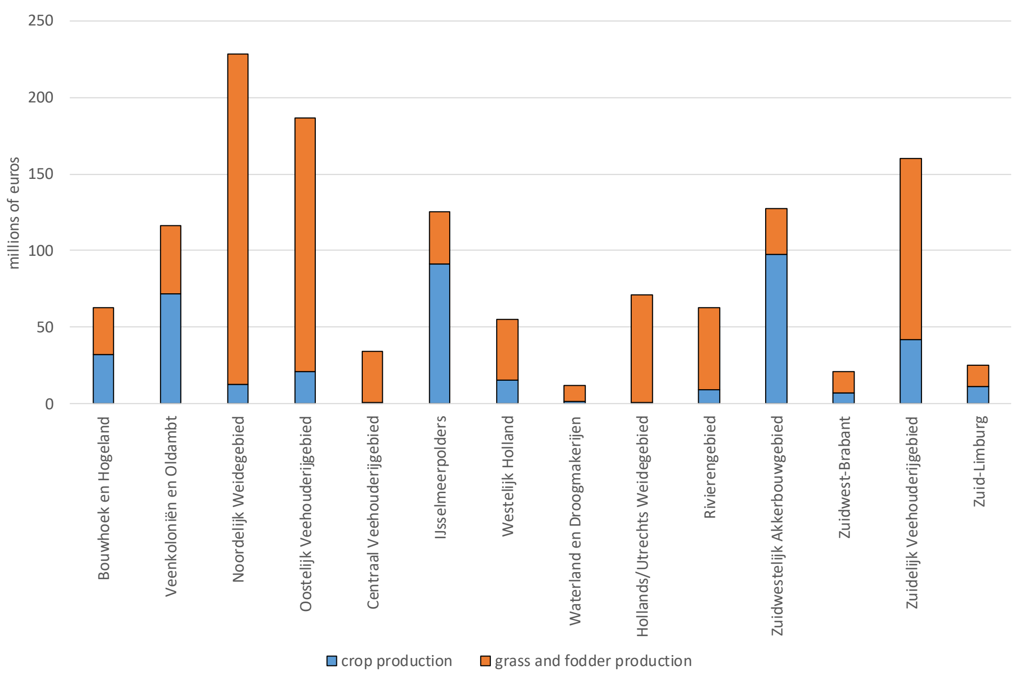
Figure 4.1.2 Value of total ecosystem services provided by agricultural land for crop and fodder production, 2010-2017



Notes: a) User cost of land based on long-term average of real rate of return, and an asset life of 100 years. b) Figures for 2010 and 2017 are based on extrapolation.

Values obtained by the rental price method and user cost method can also be disaggregated to agricultural areas. Figure 4.1.3 shows the results of the rental price method per agricultural area. Values are highest for the 'Noordelijk weidegebied' and 'Oostelijk veehouderijgebied'. These high values are both the result of the extent of these areas and the high price per hectare for this service.

Figure 4.1.3 Values obtained using the rental price method per agricultural area in 2015



Gross value added of agriculture in the Netherlands equalled c. 11.5 billion euro in 2015, which was 1.7% of GDP. Crop production and livestock farming contributed 3.4 billion gross value added, which was 0.5 % of GDP.

Table 4.1.4 Gross value added of agriculture (ISIC 1) in the Netherlands (million euros)

	2010	2011	2012	2013	2014	2015	2016	2017
Crop production	1291	1166	1347	1543	1053	1094	1267	1203
Livestock farming	2321	1984	1995	2500	2758	2289	2546	3520
Total crop production and livestock farming	3612	3150	3342	4043	3811	3383	3813	4723
Other agriculture	7352	6728	7091	7437	7505	8094	8215	8449
Total ISIC 1	10964	9878	10433	11480	11316	11477	12028	13172

What is the preferred method to use?
The resource rent calculations show that the values for agricultural production (a) are relatively low and sometimes negative, and (b) fluctuate significantly over the years. This is because the estimate of the resource rent is highly sensitive to assumptions, errors and uncertainties in the underlying information. The resource rent method calculates a residual, equal to the difference between total revenues and total costs plus normal returns. Errors and uncertainties pertaining to each individual item in the calculation accumulate and affect the overall estimate of the resource rent. Furthermore, this method is sensitive to price changes. Any difference in price changes between revenues (agricultural products) and costs (wages, energy, materials) will affect the estimated resource rent. A practical drawback of the resource rent method is that the national accounts data, needed for the calculations, are not available at a subnational level, thereby precluding any regional breakdowns. In all, we conclude that the resource rent method is not suitable to value the ecosystem services crop production and fodder production in the Netherlands.

The value of land as recorded in the SNA asset account for the total economy can provide a useful comparison point with respect to the value of ecosystem assets (SEEA EEA, 6.66). The value of agricultural land incorporates many ecosystem services, at least with regard to those ecosystem services contributing to benefits that are within the scope of the SNA production boundary. When a farmer buys or leases land to grow crops, the price reflects the potential to grow crops as a function of the ecosystem characteristics of the area, such as acreage, soil fertility, and hydrological properties. Therefore, the user costs of land (i.e. capital services) that can be derived from the land values or lease price of the land reflects the value of the relevant ecosystem services provided by the land.

Based on our analysis and assessment of the advantages and disadvantages of each method (for a more in-depth discussion see the technical background report) we propose to value crop production with the rental price method. On a per-hectare basis, the value reaches the highest provincial maximum in Flevoland, at 791 euro per hectare per year. The value is low compared to that of some other services (e.g. recreation, water filtration), which reflects that the high productivity of agriculture in the Netherlands is a function of, especially, the knowledge and high capital intensity of Dutch farming practices, rather than the extent of the natural capital used by the farmers. Nevertheless, without this natural capital (soils, water), the turn-over of the Dutch farming sector would not be achieved. Therefore, we chose to also present the GVA as an indicator of the economic importance of land for agriculture (see Table 4.1.4).

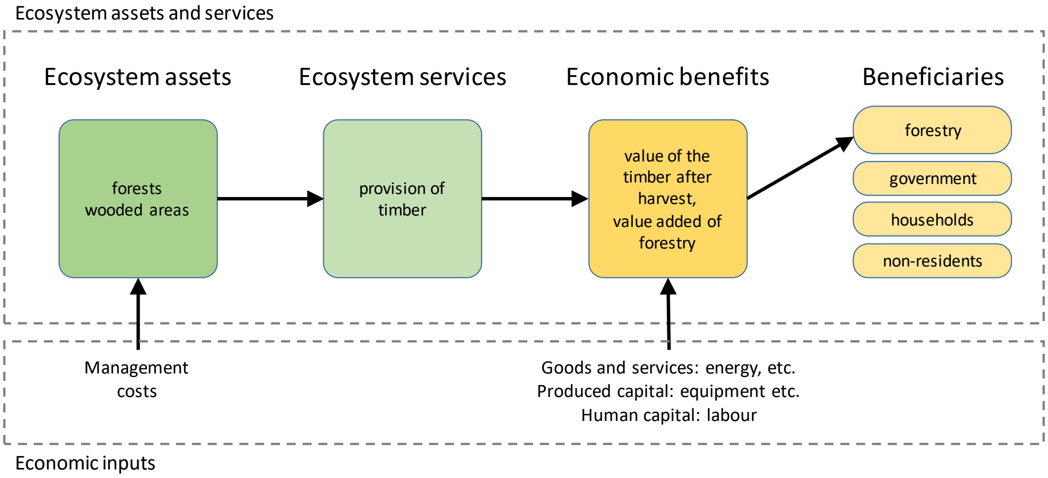
4.2 Timber production

Forests and other wooded areas provide timber that can be used for economic activities. The provisioning service timber production represents all timber extracted for use as input for economic activities, both as building material or for the use of energetic purposes. In the Netherlands, the forestry sector (ISIC 2) is the only economic sector involved in timber production.[11] For timber production we have tested two valuation methods, namely the resource rent method and stumpage prices method.

Definition of the ecosystem service

The ecosystem timber production is defined as the contribution of wood by ecosystem assets (forest, other wooden areas) to the production of timber by forestry. The economic benefit is the value of the timber after harvest, i.e. the value of the produced timber, or the value added of forestry. These benefits are the result of the combined input of ecosystem services, goods and services, produced capital and human capital. The beneficiaries are the companies engaged in the forestry activities.

Figure 4.2.1 Definition of the ecosystem service and benefits for timber production



Methods and data

We have applied two methods to value the ecosystem service timber production:

1. *Resource rent*
   The resource rent for timber production was calculated using data obtained from the SNA production and income accounts for ISIC 2 (forestry). The resource rent was calculated using the methodology described in section 3.1.1. The total output of the forestry industry in the Netherlands was about 254 million euro in 2015. Around 60 percent of total output is related to timber production[12]. The resource rent for timber

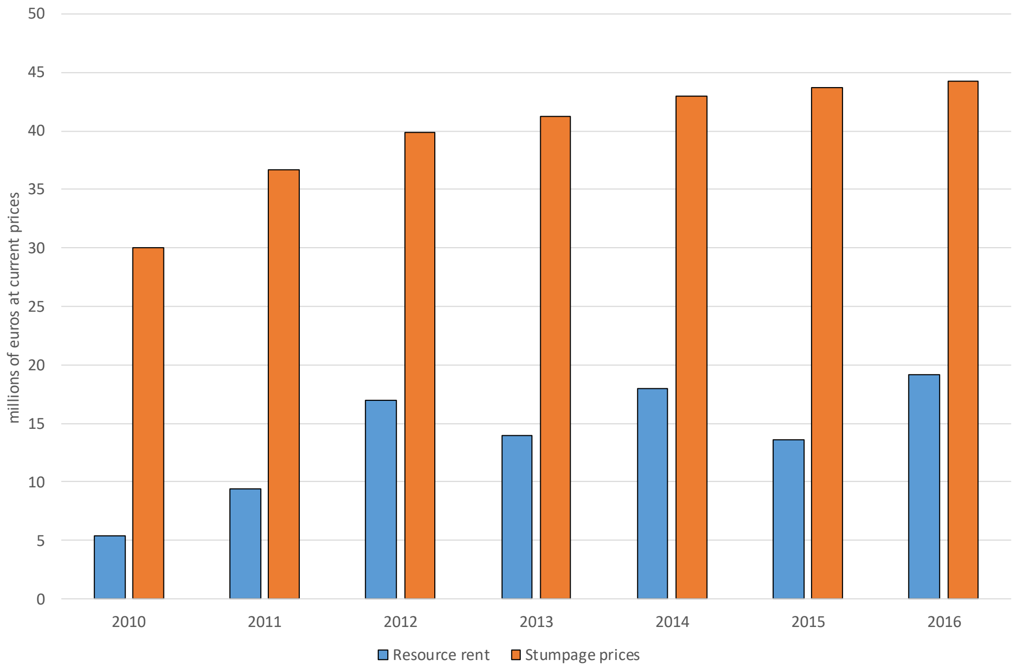
[11] In the Netherlands, ISIC 2 includes both private forestry companies and 'Staatsbosbeheer', a governmental body responsible for the management of a large part of the Dutch forests.
[12] In addition to timber, the forestry sector also produces forest management services and recreation services.

production was calculated by multiplying the resource rent of the forestry industry with this percentage.

2. *Stumpage prices*
   Stumpage prices (in Dutch ‘hout op stam’) are the prices paid per standing tree, including bark, for the right to harvest from a given land area. These are actual market prices that are paid and thus represent exchange values for the ecosystem service timber production. Prices are collected and published by Wageningen Research.[13] Stumpage prices are available for different timber categories (pine, douglas, larix, other coniferous wood, willow, poplar and other deciduous wood). Here, an average stumpage price was taken. There is no further regionalization of the prices. The value of the ecosystem service timber production is calculated by multiplying the stumpage price (euros/m^3) with the total amount of wood harvested (m^3) as was determined for the physical supply and use tables (Statistics Netherlands, 2018).

Results
The value of ecosystem service timber production calculated using the stumpage prices increased from 30 million euros in 2010 to 44 million euros in 2016. The main reason for the increase is that prices for timber have increased by 42 percent. The volume of timber harvested increased by only 4 percent. in 2016, the contribution of the ecosystem service to the total output of the forestry industry and to its value added were 17 and 37 percent respectively.

Figure 4.2.2 Value of total provisioning services for timber production, 2010-2016



What is the preferred method to use?
For the ecosystem service timber production, stumpage prices are the preferred methodology to calculate monetary values. The stumpage price most directly reflects the value of the ecosystem service. In addition, the resource rent method is subject to considerable

[13] http://www.agrimatie.nl/Binternet_Bosbouw.aspx?ID=1005&Lang=0

uncertainties on labour costs, costs of equipment, etcetera. The situation for this service is comparable to that in agriculture. The resource rent method also produces lower estimates than the stumpage price method. In addition, whereas total output of the forestry industry remained more or less constant between 2010 and 2016 (240-267 million euro) the calculated resource rent varies strongly between 5 million and 19 million euro. Stumpage prices are actual market prices paid to harvest wood and are thus fully consistent with SNA exchange values.

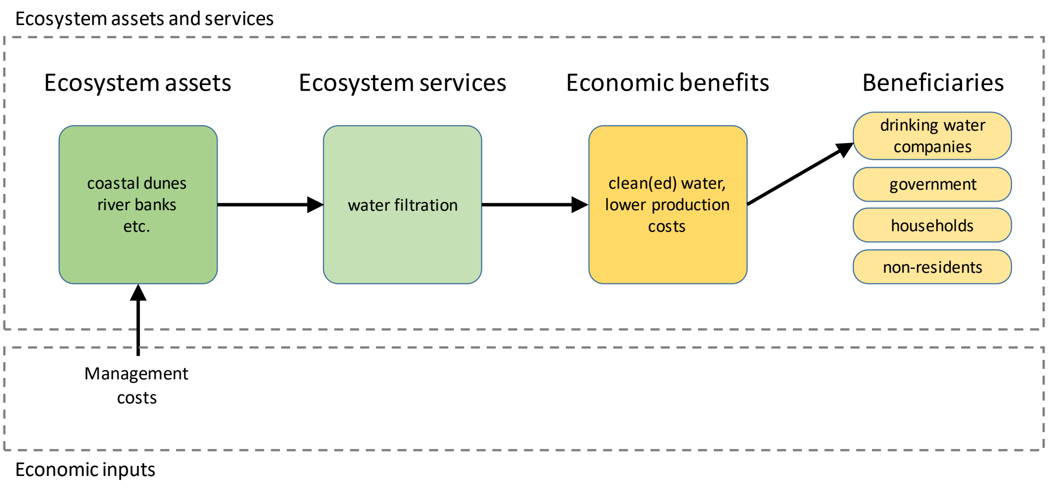
4.3 Water filtration

The provision of drinking water is an essential input for human well-being and for several economic production processes. The physical supply of surface water or groundwater by the environment is, in a strict sense, an abiotic service, and is as such not directly within the scope of the SEEA EEA. However, there are several ways where ecosystems directly contribute to the supply of (clean) drinking water. For example, ecosystems may contribute in the form of natural filtration of (ground)water. In the biophysical accounts of the Netherlands it is described how natural filtration by coastal dunes, river banks and phreatic aquifers contributes to 30% of the total water extraction in the Netherlands (Statistics Netherlands and WUR, 2018).

Definition of the ecosystem service

The ecosystem service water filtration is defined as the subsurface natural filtration and storage of groundwater by the ecosystem, which is subsequently pumped up and (after some final treatment) distributed to be used as drinking water. This is a regulating service. The economic benefit is the reduced production costs for drinking water. The beneficiaries are the water companies that subsequently provide the drinking water to households and industries. The ecological processes that support the availability of clean groundwater are intermediate products; their value is not measured directly but is assumed to be embodied in the value of the ecosystem services of drinking water production (Boyd and Banzhaf, 2007, p. 619). Ecosystem services not covered here include the provision of soil water for agriculture (e.g. irrigation) and groundwater supply for the production of industrial water, used mainly for cooling (Graveland and Edens, 2014; Fisher and Turner, 2008).

Figure 4.3.1 Definition of the ecosystem service and benefits for water filtration



Methods and data

We have applied the replacement cost approach to estimate the value of water filtration, as was applied also in Remme et al. (2015). The method they developed for the Limburg province was here applied for the whole of the Netherlands. The replacements costs are estimated by measuring the difference in production costs of drinking water from groundwater relative to surface water. It is likely that, in case groundwater would not be available, the resulting shortage of water for drinking water production would be overcome by using river water. Dutch drinking water companies are currently already using river water, although they generally prefer to use groundwater because of its higher quality and lower production costs.

The replacement cost method compares an existing ecosystem asset or service (e.g. groundwater abstraction for drinking water supply) with a substitute. Switching from groundwater to surface water abstraction raises production costs. By valuing the ecosystem service at the difference between the production costs of groundwater and surface water companies, we implicitly assume that the value of groundwater is zero. This is consistent with the SEEA EEA focus on final ecosystem services, but disregards the value of groundwater embodied in the price of drinking water.

Information on the total volume of drinking water supplied to households within distribution areas as well as the total volume of water abstracted from groundwater, riverbanks, dunes, and surface water in 2010-2016 was found in the drinking water statistics of VEWIN (the association of drinking water companies in the Netherlands). Total revenues, total costs, and production costs by cost category (taxes, depreciation, capital costs, and operating costs) were taken from the annual monitoring reports of the Authority for Consumers and Markets (*Autoriteit Consument en Markt*; ACM), from the statistical publications of VEWIN, and where necessary from the annual reports of drinking water companies.

The unit value of the ecosystem service that provides clean drinking water through the natural filtration and storage of groundwater is calculated by measuring the difference in unit production costs of companies that mainly extract groundwater and companies that mainly extract surface water. Each drinking water company has been classified as a groundwater, surface water or mixed-type company based on VEWIN (2012). This is the same classification as that of Remme et al. (2015). 'Groundwater companies' are companies that extract water from groundwater reservoirs or riverbank groundwater reservoirs. Production costs concern operating costs, costs of capital, and depreciation; taxes are excluded. The unit value of the ecosystem service is the difference in production costs weighted by the volume of water supplied to households by each drinking water company.

Results

The production cost difference between surface water and groundwater companies was about 0.40 euros per m^3 in 2012, the same as estimated by Remme et al., and gradually increased to 0.49 euros per m^3 in 2016 (Table 4.3.2).

Table 4.3.2. Weighted average production costs of drinking water by company type in euro per m³ at current prices)

	2012	2013	2014	2015	2016
groundwater companies	1.07	1.09	1.09	1.09	1.01
surface water companies	1.47	1.50	1.53	1.51	1.51
cost difference between surface water and groundwater	0.40	0.41	0.44	0.42	0.49

Note: Company type was determined based on Remme et al. (2015) and VEWIN (2013) for the year 2012. The unit value of the ecosystem service is the difference in production costs weighted by the volume of water supplied to households by each drinking water company.

The calculation of the value for ecosystems service water filtration is shown in Table 4.3.3. Total value of this service increases from 146 million euro in 2011 to 210 million euro in 2016. In the same period, total value added of the water companies varied between 987 and 1063 million euro. Note that the value of this service as measured in an accounting approach is low compared to the value it would have had in a welfare-based valuation approach. Note also that the method assumes that sufficient river water, of sufficient quality, is available to be used as an alternative to using groundwater. River water also presents a natural resource, if it would not be available then as an alternative sea water would have to be desalinated (at substantially higher costs). Hence, the estimate provided is an underestimate, given that we do not (in this first version of the account) value river water. In the future, this part of the valuation could be reconsidered to assess if a more appropriate value can be retrieved.

Table 4.3.3. Calculation of the value of the ecosystem service water filtration

	2010	2011	2012	2013	2014	2015	2016	2017
Difference between the weighted average production costs of groundwater and surface water companies (euro per m3, current prices)		0.35	0.40	0.41	0.44	0.42	0.49	
Total volume of groundwater abstracted for the supply of drinking water (million m3)	417	414	413	418	415	420	426	428
Total value of the ecosystem service water filtration ('contribution to the benefit') related to phreatic and river groundwater, in millions of euros at current prices		145.8	163.7	172.4	181.5	176.8	210.2	
Total value added of drinking water companies ('the benefit') in millions of euros at current prices	1012	987	1046	1063	1059	1064	1038	1026

4.4 Air filtration

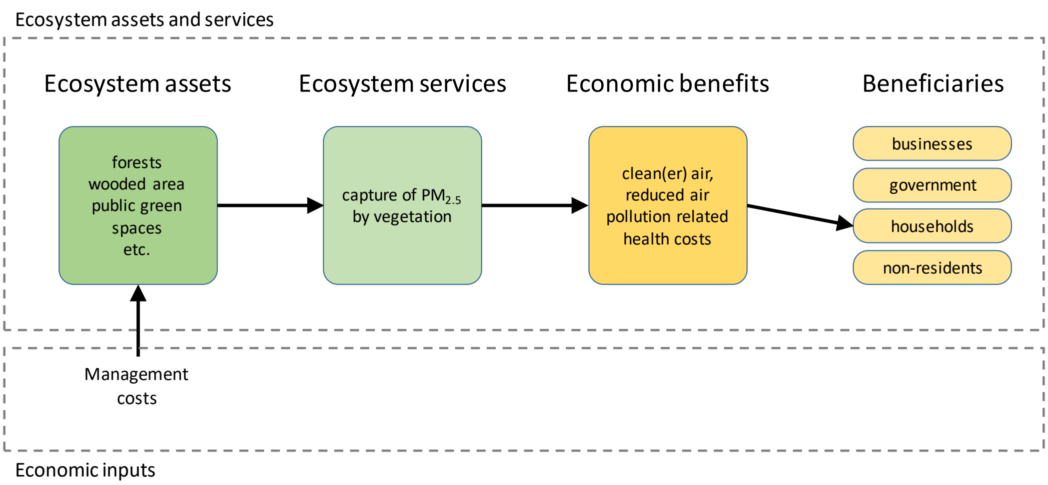
Particulate pollution covers a broad spectrum of pollutant types that permeate the atmosphere. Particulate matter is commonly referred to by size groupings: coarse and fine. PM_{10} includes particles up to 10 µm in aerodynamic diameter, whereas $PM_{2.5}$ only represents the smallest particles (i.e. <2.5 µm). In recent years it has become clear that $PM_{2.5}$ particles pose a higher health risk because these smaller particles penetrate deeper into the lungs. Data from epidemiological studies indicate that long-term exposure to $PM_{2.5}$ can increase both human morbidity and human mortality risks (Kunzli et al., 2000; Burnett et al., 2018). Therefore, in the monetary account we focus on the smaller particles.

Trees and other vegetation play an important role in the reduction of air pollution (Powe and Willis, 2004). To value the ecosystem service air filtration (or air quality regulation) an avoided damage cost approach was used, with $PM_{2.5}$ capture by forests and other vegetation as the biophysical indicator.

Definition of the ecosystem service and the associated benefits
The ecosystem service air filtration is defined as the contribution of forests and other vegetation to the reduction in $PM_{2.5}$ concentration. Reducing $PM_{2.5}$ concentrations should reduce air-pollution related health costs as well as age-specific mortality risk in a population and consequently result in an increase in population statistical life expectancy. The economic benefits of lower $PM_{2.5}$ concentrations are avoided damage costs. The increase in air quality provides benefits for society as a whole. Households are the beneficiary.

Methods and data
To value air filtration we compare three measures, all of which represent a measure for avoided damage costs. The first involves valuing the avoided health costs, similar to Remme et al. (2015) for the Dutch province Limburg.

Figure 4.4.1 Definition of the ecosystem service and benefits for air filtration



The second approach involves valuing avoided health costs and avoided costs of mortality, using the value of a statistical life year (VOLY). Strictly speaking, this is a welfare measure which is not compatible with SEEA ecosystem accounting, but it is added to obtain a first indication of how exchange and welfare-based values differ. There are different approaches to estimate the VOLY from a survey on mean willingness-to-pay (WTP) asking people for their WTP to increase their (statistical) life expectancy by a given amount of time. Here we have used WTP for an increase in life expectancy of 3 months based on a study of Desaigues et al. (2011). This study is often used in cost-benefit analysis (CE Delft, 2017).

The third approach also values both avoided health effects and avoided mortality, but mortality is valued with the maximum societal revenue VOLY (MSR-VOLY) as proposed by Hein, Roberts and Gonzalez (2016). This is a potentially relevant indicator to capture the benefit of clean air in a natural capital accounting approach. The MSR-VOLY represents the VOLY that would theoretically apply in case there was 'market' for clean air, based on the demand curve for clean air and assuming that there are no costs related to supplying the ecosystem service. It corresponds with the Simulated Exchange Value proposed by Caparros et al. 2015, and is a type of posited exchange value as stipulated in the UK SEEA accounting work (White et al., 2015).

The monetary value for all three measures were spatially modelled using data on ambient $PM_{2.5}$ concentration (RIVM), forest and other vegetation cover (LCEU map) and population size (Statistics Netherlands). The two metrics for VOLY are coupled with an age-specific mortality risk, so that age distribution (Statistics Netherlands) and age-specific mortality risks are also taken into account. The amount of $PM_{2.5}$ capture is estimated based on the physical ecosystem services supply and use account. We use the mapping of this service in the physical account (in terms of a deposition rate per hectare per year) to a reduction in PM concentration. PM_{10} deposition in kilogram per hectare is recalculated to a reduction in $PM_{2.5}$ concentration by assuming mixing, on a daily basis, in a tropospheric boundary layer of 2000 meters high (annual average). The $PM_{2.5}$ fraction comprises 0.58 of the PM_{10} fraction in the Netherlands. The analysis we use is relatively coarse and can be enhanced with more sophisticated models in a next version of the accounts.

Health costs

Similar to Remme et al. (2015), health impact categories were used that were identified in a study by Preiss et al. (2008) on health costs of air pollution (divided in costs related to $PM_{2.5}$ and costs related to PM_{10}) in the European Union. In line with the SEEA EEA approach, categories that were based on direct costs were included while categories that include components of consumer surplus were excluded. Damage costs for a person due to an increase of 1 $\mu g/m^3$ $PM_{2.5}$ was estimated at about 7.36 euro per person (at 2015 prices) and damage cost for a person due to an increase of 1 $\mu g/m^3$ $PM_{2.5}$ was estimated at 2.68 euro per person (see technical report for additional data). For the costs related to PM_{10}, we correct the reduction in $PM_{2.5}$ concentration with the fraction of $PM_{2.5}$ in PM_{10}. In 2015, this fraction ranges from 0.30 to 0.75, with a mean of 0.58. The value of avoided exposure to 1 $\mu g/m^3$ $PM_{2.5}$ per person is in this case about 12.00 euro per person (at 2015 prices).

MSR – VOLY and mean VOLY

In addition to the reduced health costs we have calculated reduced mortality costs. We used an estimate for the MSR-based on the mean and median value of a WTP survey in several EU countries and Switzerland by Desaigues et al. (2011) in which people were asked to value a three-month increase in life expectancy. The damage costs based on the MSR for a statistical life year lost due to an increase in $PM_{2.5}$ is estimated at 16,270 euro (at 2015 prices). The mean value of an avoided exposure to 1 µg/m3 per person is in this case about 10.10 euro. This value, however, depends on the spatial distribution of the reduction in $PM_{2.5}$ and the spatial distribution of the population and the spatial age distribution.

The mean VOLY is based on a WTP survey and therefore represents a consumer surplus. However, as it is the preferred metric in cost-benefit analysis to analyse and inform on monetary benefits resulting from improvements in air quality (Hein et al., 2016; Desaigues et al., 2011) we include it in the analysis to determine the bandwidth of the avoided damage costs associated with air filtration. The damage costs based on the mean VOLY for a statistical life year lost due to an increase in $PM_{2.5}$ are estimated at 49,607 euro (at 2015 prices). The value of an avoided exposure to 1 µg/m3 per person is in this case about 30.90 euro. This value also depends on the spatial distribution of the reduction in $PM_{2.5}$ and the spatial distribution of the population and the spatial age distribution.

Results

The reduced damage cost for the ecosystem service air filtration at the national scale is estimated for 2015 ranging from 42.1 million euro per year, when only air pollution related health costs are taken into account, to 85.8 million euro (MSR-VOLY) or 175.3 million euro (mean VOLY) when both avoided morbidity and avoided mortality costs are included (Table 4.4.2).

Table 4.4.2 Avoided air pollution related health costs and avoided costs of air pollution related mortality in the Netherlands per province, with mean reduced damage costs in euro per hectare and total reduced damage in million euro per province

Province	Mean reduced damage (euro/ha/year)			Total reduced damage (mln euro / year)		
	Health	MSR-VOLY	Mean VOLY	Health	MSR-VOLY	Mean VOLY
Groningen	4.1	4.0	12.3	1.0	1.0	2.9
Friesland	3.6	4.1	12.5	1.3	1.4	4.4
Drenthe	5.6	6.4	19.6	1.5	1.7	5.3
Overijssel	8.6	9.3	28.4	2.9	3.2	9.7
Flevoland	8.7	7.1	21.6	1.3	1.0	3.2
Gelderland	13.4	13.2	40.4	6.8	6.8	20.7
Utrecht	28.7	28.4	86.7	4.1	4.1	12.5
Noord-Holland	18.2	16.4	50.0	5.2	4.7	14.3
Zuid-Holland	17.4	17.5	53.4	5.3	5.4	16.3
Zeeland	3.9	5.1	15.6	0.7	0.9	2.9
Noord-Brabant	16.0	17.3	52.8	8.1	8.8	26.7
Limburg	17.7	21.5	65.6	3.9	4.8	14.5
Netherlands	12.0	12.5	38.0	42.1	43.7	133.2
Netherlands (morbidity plus mortality)					85.8	175.3

Table 4.4.3 Reduced damage costs due to air filtration (contribution of ecosystem types to reduction in air pollution related morbidity and mortality costs, in million euro per ecosystem type, 2015 €)

Ecosystem type	Health	MSR-VOLY	Mean VOLY
Non-perennial plants	3.2	3.4	9.4
Perennial plants	0.6	0.6	1.6
Meadows (grazing)	4.8	4.8	13.5
Hedgerows	0.2	0.2	0.5
Dunes with permanent vegetation	0.8	0.9	2.4
Deciduous forest	11.2	12.1	33.7
Coniferous forest	4.0	4.4	12.4
Mixed forest	6.5	7.3	20.3
Heath land	0.1	0.1	0.2
Fresh water wetlands	0.1	0.1	0.4
(semi) Natural grassland	0.4	0.4	1.2
Public green space	3.6	3.3	9.3
Other unpaved terrain	6.0	5.4	15.1
River flood basin	0.7	0.7	2.0

Table 4.4.3 shows the contribution of ecosystems to the reduced damage due to air filtration. It shows that deciduous forests contribute most to the total reduction in health costs and mortality cost. Other ecosystem types that have a high contribution to the reduction in health and mortality costs are mixed forests, other unpaved terrain, meadows, public green spaces, coniferous forests and non-perennial plants. When we compare mean contribution per hectare, deciduous forest again contributes the most to the reduction in health costs, followed by mixed

forests, dunes with permanent vegetation, public green spaces and coniferous forests (Table 4.4.4, b). The mean contribution per hectare of non-perennial plants and meadows is relatively low.

Table 4.4.4 Reduced damage costs due to air filtration (contribution of ecosystem types to reduction in air pollution related health costs 2011-2015)

a) total contribution in million euro per year per ecosystem type (2015 €)

	Reduced damage costs - health			Reduced damage costs – MSR-VOLY		
ecosystem type	2011	2013	2015	2011	2013	2015
Non-perennial plants	4.5	3.9	3.2	3.9	3.6	3.4
Perennial plants	0.8	0.7	0.6	0.7	0.7	0.6
Meadows (grazing)	6.9	5.8	4.8	5.6	5.2	4.8
Hedgerows	0.2	0.2	0.2	0.2	0.2	0.2
Dunes with permanent vegetation	1.2	1.0	0.8	1.1	1.0	0.9
Deciduous forest	15.9	13.6	11.2	13.3	12.4	12.1
Coniferous forest	5.4	4.9	4.0	4.9	4.8	4.4
Mixed forest	9.2	7.9	6.5	8.0	7.6	7.3
Heath land	0.1	0.1	0.1	0.1	0.1	0.1
Fresh water wetlands	0.2	0.1	0.1	0.1	0.1	0.1
(semi) Natural grassland	0.6	0.5	0.4	0.5	0.5	0.4
Public green space	5.1	4.3	3.6	3.7	3.4	3.3
Other unpaved terrain	8.3	7.1	6.0	5.8	5.5	5.4
River flood basin	0.9	0.8	0.7	0.7	0.7	0.7
Netherlands	59.3	50.8	42.1	48.8	45.6	43.7
Netherlands (health plus MSR-VOLY)				108.1	96.4	85.8

b) mean contribution in euro per ha per year per ecosystem type (2015 €)

	Reduced damage costs-health			Reduced damage costs-MSR-VOLY		
ecosystem type	2011	2013	2015	2011	2013	2015
Non-perennial plants	5.8	5.0	4.1	5.0	4.6	4.3
Perennial plants	9.9	8.5	7.0	9.0	8.3	7.4
Meadows (grazing)	7.4	6.2	5.1	6.1	5.6	5.2
Hedgerows	6.0	5.1	4.2	5.3	5.1	5.1
Dunes with permanent vegetation	75.8	61.8	52.3	68.2	61.0	53.7
Deciduous forest	145.5	124.3	103.1	121.4	113.4	110.6
Coniferous forest	66.4	59.9	49.1	59.3	58.6	54.0
Mixed forest	77.4	66.9	55.1	67.2	63.7	61.2
Heath land	2.2	1.9	1.6	1.6	1.7	1.7
Fresh water wetlands	4.9	4.1	3.4	3.3	3.7	3.7
(semi) Natural grassland	10.5	8.9	7.4	8.9	8.4	8.2
Public green space	75.0	63.1	53.1	53.5	49.3	48.8
Other unpaved terrain	28.3	24.1	20.3	19.8	18.7	18.4
River flood basin	12.7	11.1	9.2	9.9	9.6	9.7

Table 4.4.4 show the trend in time of the contribution of ecosystem types to the mean and total reduction in health costs. There is a declining trend in the contribution of ecosystems to the reduction in health costs. For instance, the mean reduction in health costs of an hectare forest has reduced from 145.5 euro/ha in 2011 to 103.1 euro/ha in 2015. This solely caused by the reduction in the mean annual $PM_{2.5}$ concentration in the Netherlands. The air has become cleaner in the Netherlands, and, as a result, total avoided morbidity and mortality damage costs have decreased from 108.1 million euro in 2011 to 85.8 million euro in 2015.

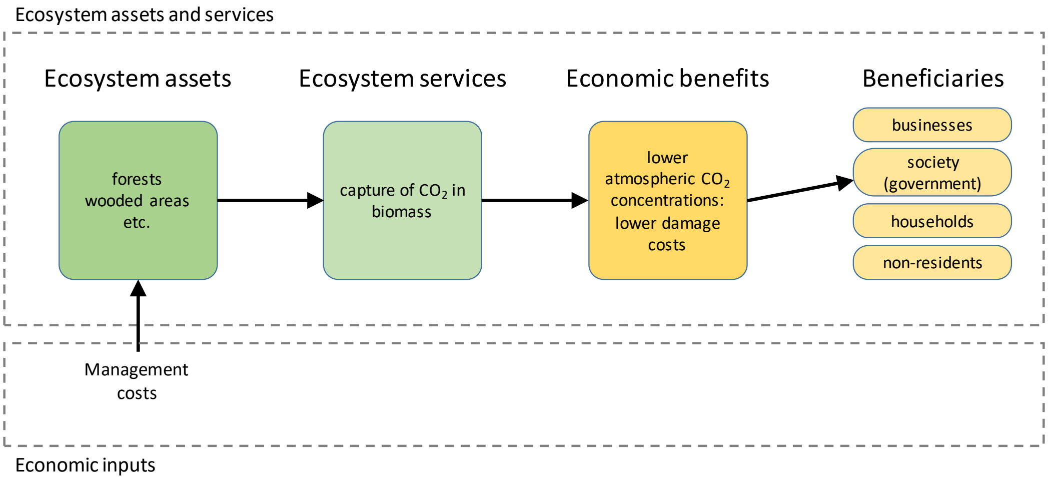
What is the preferred method to use?
To determine avoided damage costs associated with air filtration we have calculated reduced air pollution related health costs, and two additional metrics for reduced air pollution related mortality: MSR-VOLY and mean VOLY. The MSR-VOLY is a measure for reduced air pollution related mortality based on exchange values rather than welfare-based values (Hein et al., 2016). Therefore, it is the preferred metric to use in a natural accounting setting. The mean VOLY was calculated to obtain a first indication of how exchange and welfare-based values differ. The mean VOLY is generally used in cost-benefit analysis, but as it is based on willingness-to-pay, it is deemed less suitable in a natural accounting setting.

4.5 Carbon sequestration in biomass

Carbon sequestration in biomass is “the process by which atmospheric carbon dioxide is taken up by trees, grasses, and other plants through photosynthesis and stored as carbon in biomass”.[14] Carbon emissions are a major driver of global climate change. Climate change is associated with long-term economic and social costs as well as (localised) benefits (Nordhaus, 2016). Every ton of carbon that is sequestered in biomass today avoids damage in the future. Carbon sequestration is a regulating service.

Definition of the ecosystem service
The ecosystem service carbon sequestration is defined as the capture and storage of carbon in biomass contributing to climate regulation.[15] Crucial is that this storage is long-term; so-called short carbon cycles are excluded in the assessment of carbon sequestration for accounting. The service of sequestering carbon is equal to the net accumulation of carbon in an ecosystem due to both growth of the vegetation and accumulation in below-ground carbon reservoirs (SEEA EEA, A3.17). The economic benefits of reducing atmospheric CO_2 concentrations are avoided damage costs. Carbon sequestration provides benefits for society as a whole. The beneficiary is therefore the government, as a representative for the whole of society.

Figure 4.5.1 Definition of the ecosystem service and benefits for carbon sequestration in biomass



[14] US Forest Service, https://www.fs.fed.us/ecosystemservices/carbon.shtml.
[15] Carbon sequestration and carbon storage are often seen as two separate services (SEEA EEA, A3.16). Here we focus on carbon sequestration, i.e. the actual capture of CO_2 from the atmosphere into biomass.

Methods and data

We have used two approaches to estimating the economic value of carbon sequestration, both of which represent a measure for avoided damage. The first approach involves the social cost of carbon; the second approach concerns the carbon price of policy targets.

1. *Social cost of carbon*
   The social cost of carbon (SCC) represents the monetary value in the present of damages that occur in the future as a result of an additional ton of carbon emissions in a given year. Remme et al. (2015) used the American SCC (the SC-CO2) to estimate the value of carbon sequestration in the Dutch province of Limburg. The SC-CO2 represents the future damage *avoided* as a result of one ton of carbon sequestration in a given year (IAWG 2016).

2. *Carbon price*
   The second approach is to calculate the costs of achieving a policy-defined target of reduction in CO_2 emissions. This calculation produces a carbon price. By valuing carbon sequestration in biomass at this carbon price, we estimate in monetary terms the contribution of ecosystems to achieving the policy target.

The Netherlands Environmental Assessment Agency (PBL) and the Netherlands Bureau for Economic Policy Analysis (CPB) have calculated a carbon price – the efficient carbon price - for the Netherlands. The efficient carbon price is the price at which the necessary cumulative reduction in CO_2 emissions is achieved at the lowest costs (PBL, 2018). There are different scenarios for what will be necessary: a high-reduction scenario, a low-reduction scenario, and a two-degree temperature increase scenario.

In the high-reduction scenario, the efficient price is 160 euros per ton of CO_2 in 2050; in the low-reduction scenario it is 40 euros per ton; and in the two-degree policy target it ranges from 200 to 1000 euros per ton. For the year 2015, the corresponding figures are 48 euros for the high-reduction scenario, 12 euros for the low-reduction scenario, and 60 to 300 euros for the two-degree policy target. The discounted net present value is calculated using a discount rate of 3.5 percent.[16] Table 4.5.2 presents the net present value per ton of carbon (C) in 2010 thru 2017.

Table 4.5.2. The Dutch carbon price: net present value per ton of carbon in 2012-2017

	high-reduction scenario	low-reduction scenario	2°-scenario lower boundary	2°-scenario upper boundary
2010	148	37	185	925
2011	153	38	192	958
2012	159	40	198	991
2013	164	41	205	1026
2014	170	42	212	1062
2015	176	44	220	1099
2016	182	46	228	1138
2017	188	47	235	1177

Source: PBL (2018).

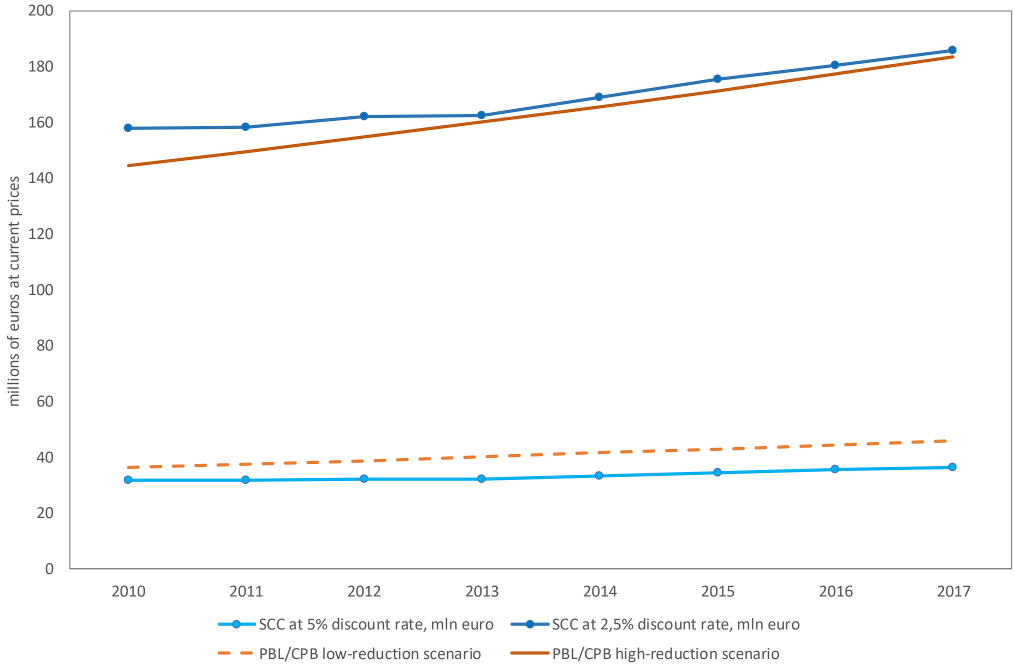
Which scenario is most relevant? Remme et al. (2015) opted for the SCC at a 5 percent discount rate, producing a conservative (i.e. low) net present value. CE Delft take the high-reduction

[16] Normally, this discount rate is 3%. PBL/CPB argue that a higher discount rate is warranted because the growth potential of economies in Southern and Eastern Europe is higher (Aalbers, Renes & Romijn 2017, p. 10).

scenario as the central scenario (between low and high). In this report we follow CE Delft's recommendation of the high-reduction scenario (see Table 4.5.2, left hand column). This puts the marginal value of the ecosystem service of carbon sequestration in biomass at 176 euro per ton C in 2015 (equivalent to 48 euro per ton CO_2).

Results
The estimates of the value of the ecosystem service carbon sequestration in biomass is presented in Figure 4.5.3. This figure compares the amounts of carbon sequestered valued at the social cost of carbon with the amounts valued at the efficient carbon price for the Netherlands. Using the high-reduction scenario carbon price, the value of the ecosystem service of carbon sequestration in biomass equals 171.5 million euros in 2015.

Figure 4.5.3. The value of the ecosystem service carbon sequestration in biomass at the social cost of carbon and the efficient carbon price, 2010-2017



Sources: See technical background report, section 3.5.

What is the preferred method to use?
The carbon price seems preferable over the social cost of carbon, and we propose to use it for the Netherlands ecosystem accounts:

- The social cost of carbon is less dependent on policy than the efficient carbon price. The efficient carbon price is dependent on the level of political ambition. Higher ambitions raise the carbon price. The efficient carbon price is the optimum where marginal willingness-to-pay for CO_2 emission reduction is equal to marginal unit prevention costs. However, the SCC also depends upon policies: it is likely that the marginal costs of carbon vary with the amount of carbon being emitted as a function of the implementation of climate policies.
- The efficient carbon price has lower uncertainty than the SCC. The SCC is estimated based on complex models that predict CO_2 emissions, climate change, and output into the far future. These models are incomplete and highly uncertain – in particular how they deal with low probability-high impact events (CE Delft,, 2017; Tol, 2009; IPCC,

2007). The result is an enormous variation in estimates and no instrument for prioritisation. The efficient carbon price is calculated based on a present-day assessment of the costs of reduction measures (i.e. prevention costs).

- Aalbers, Renes and Romijn (2017) argue that the SCC does not adequately measure willingness-to-pay for a unit reduction in CO_2 emissions or the costs of preventing damage due to CO_2 emissions. Willingness-to-pay and the SCC are unknown. On the other hand, marginal prevention costs (used to calculate the carbon price) can be known.
- The efficient carbon price is more viable and more relevant than the SCC. The American SC-CO2 that was used by Remme et al. is produced by a government working group that was recently disbanded by president Trump. It remains to be seen if the SC-CO2 will be estimated again. The Dutch carbon price is calculated specifically for the Netherlands and will most likely be updated.

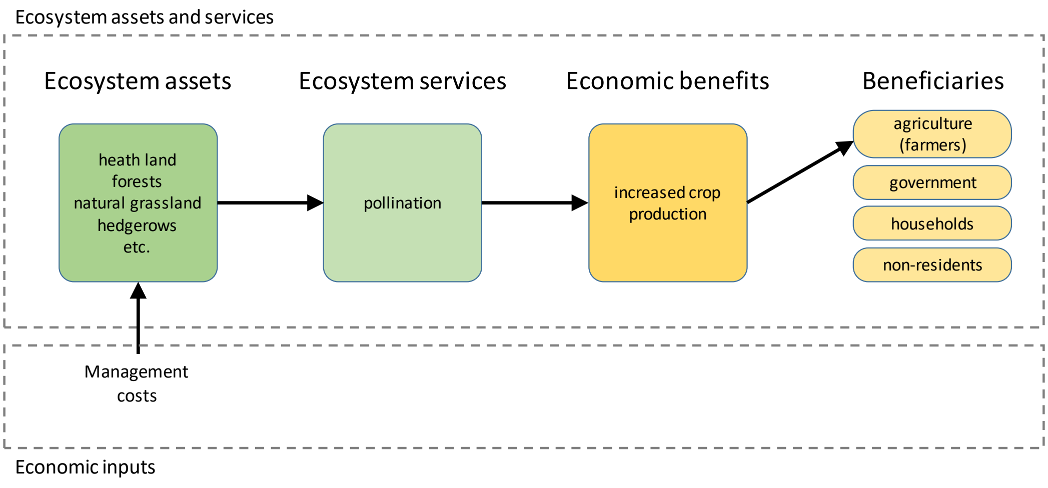
4.6 Pollination

About 75 percent of the leading global food crop species depend on animal pollination (Klein et al., 2007). Together these crop species produce 35 percent of the global production volume. Without animal pollination the production of these crops would be up to 90 percent lower (with substantial variations between crops and crop varieties). Crop pollination is a regulating service defined as the fertilisation of crops by pollinators that increase crop production. However, pollination is unlike other provisioning services. This service contributes to a product – the pollinator-dependent crops – that is already measured in the SNA; and crop pollination is primarily provided by the ecosystem assets in the landscape surrounding the crop fields and not by the cropland itself.

Definition of the ecosystem service

The regulating service crop pollination is defined as the increased crop production in pollinator-dependent crops that are supplied by the semi-natural ecosystem assets in the local landscape of the cropland to the economic user of the land (i.e. the farmer). The economic benefit is the monetary value of the crops. We use gross revenue to value the crop pollination service, because it is a 'free' service supplied by the ecosystem types in the landscape surrounding the cropland. Note that, as defined here, pollination is a final ecosystem service.

Figure 4.6.1 Definition of the ecosystem service and benefits for pollination



Methods and data
Crops differ in pollination requirements. Klein et al. (2007) divided crops into five classes, ranging from crops where pollination is essential for production, to crops that have a high, modest, or low dependence on pollination, to crops that do not depend on pollination. These are used to assign pollination demand to crops in the Netherlands (see the technical background report). As a proxy for pollinator abundance we used data on habitat suitability for nesting by pollinators and habitat suitability for floral resources based on a meta-analysis on 39 studies conducted by Kennedy et al. (2013). Based on this study we assigned a suitability value for each ecosystem type (for more details see technical background report). Different species of pollinators move across different distances. We use a kernel model that calculates visitation based on a relationship found in a meta-analysis of Ricketts et al. (2008). This distance relationship includes both species that forage over long distances and species that remain close to their nesting site. We furthermore assume that pollinators from all suitable habitats in the local landscape contribute to pollination.

The maps for pollination are generated based on the spatial location of crops that require pollination (Basisregistratie Gewaspercelen 2015, 2016 and 2017) and the spatial location of ecosystems that are suitable for pollinators on the Ecosystem Type map 2013. Crop production is based on annual production statistics when available and, if these are not available, data are taken from the standard production as calculated by Wageningen Research (2017) based on average production in five consecutive years (i.e. 2011-1015). For apples and pears, production statistics are available per region of the Netherlands (Statistics Netherlands); all other production data are for the Netherlands in total.

Results
The annual contribution of the ecosystem service crop pollination to total crop production was approximately 359 million euros in 2015. The contribution is highest in Gelderland (95 million), Noord-Brabant (78 million) and Limburg (53 million). River flood basins, which are often situated near fruit orchards, relatively contribute the most to crop pollination services, with an average of 479 euros per hectare. Grasslands, due to their large extent, have a large contribution to the total crop pollination service.

Table 4.6.2. Increased crop yield in the Netherlands due to pollination per province, with mean contribution to yield in euro per hectare suitable pollinator habitat (supply), mean crop yield euro per hectare cropland (use) and total yield in million euro per province in 2015 and 2016

	Mean yield (supply) (euro/ha pollinator habitat)		Mean yield (use) (euro/ha cropland)		Total yield (supply) (mln euro)	
province	2015	2016	2015	2016	2015	2016
Groningen	10	10	379	398	1.2	1.1
Friesland	4	4	3,057	2,904	1.2	1.1
Drenthe	35	35	8,952	8,801	5.6	5.6
Overijssel	22	22	6,516	8,798	5.3	5.4
Flevoland	231	231	5,102	5,068	13.6	13.6
Gelderland	261	240	14,017	13,259	94.6	87.1
Utrecht	385	360	18,096	16,451	40.4	37.8
Noord-Holland	96	101	6,651	6,761	16.0	16.7
Zuid-Holland	85	83	5,987	5,907	14.1	13.7
Zeeland	567	574	3,799	4,052	36.0	36.5
Noord-Brabant	278	297	10,494	10,815	77.8	83.3
Limburg	446	488	10,961	11,787	53.1	58.0
Netherlands	170	171	8,306	8,426	358.8	359.9

Table 4.6.3. Increased crop yield due to pollination; contribution of ecosystem types to crop yield (supply), with mean yield in euro per hectare of the given ecosystem type and total yield in million euro per ecosystem type in 2015 and 2016

	Mean yield (euro/ha)		Total yield (mln euro)	
ecosystem type	2015	2016	2015	2016
Grassland	128	127	119.1	117.6
Hedgerows	352	355	12.9	13.0
Vegetated dunes	12	12	0.2	0.2
Active coastal dunes	5	4	0.2	0.2
Deciduous forest	417	424	45.5	46.2
Coniferous forest	119	129	9.8	10.6
Mixed forest	170	181	20.1	21.4
Heath land	139	154	5.7	6.3
Inland dunes	26	28	0.1	0.1
Fresh water wetlands	134	136	4.6	4.7
Natural grassland	300	300	16.2	16.2
Public green space	172	173	11.8	11.8
Other unpaved	260	260	76.7	76.8
River flood basin	479	462	35.1	33.9
Tidal salt marshes	154	160	1.7	1.8

4.7 Nature-related tourism and recreation

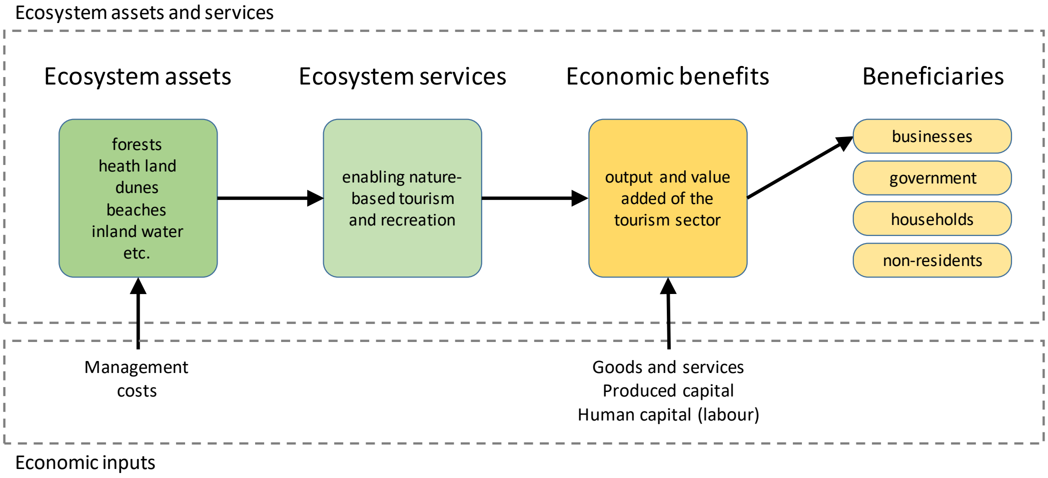
Tourism is an important economic activity. In the Netherlands, tourism activities contribute 28.6 billion euro to value added, which is 4.3 % of total GDP (2017), and provide approximately 761 thousand jobs (Dutch Tourism Satellite Accounts; TSA). Nature provides an important contribution to tourism-related economic activities and the well-being of people by providing attractive environments for leisure activities. We can distinguish between nature tourism and nature recreation, where recreation considers only single-day activities and tourism includes only multiple-day activities away from home (with at least one overnight stay at an accommodation).

Definition of the ecosystem services

The ecosystem service can be defined as ‘providing opportunities for or enabling nature-related tourism and recreation activities’. Nature-related tourism and recreation includes a broad range of activities such as hiking, cycling, water sports, but also beach recreation and relaxing in nature areas. These activities have in common that they are outdoor activities taking place in a ‘natural’ environment. In principle, there are two ways to describe this service.

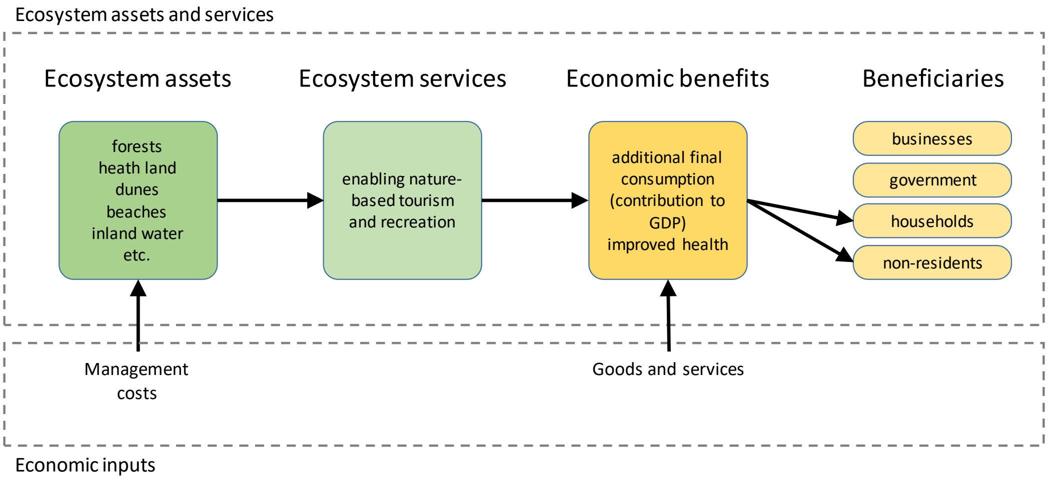
First, the ecosystem service can be seen as a contribution to the production of tourism services by businesses (Figure 4.7.1). The economic benefits are the output and value added of the businesses in the tourism sector that are dependent on nature. These benefits are the result of the combined input of the ecosystem service, goods and services, produced capital and human capital (labour). The beneficiaries are the businesses in the tourism sector. Examples are hotels, campings and restaurants located in nature areas, but also specialized shops selling camping equipment or hiking boots. In turn, the tourism services produced by businesses are supplied to the end users, the households and (when households from abroad come to enjoy nature) non-residents. In this interpretation, a resource rent-based valuation method may be most appropriate to value this ecosystem service.

Figure 4.7.1. Definition of the ecosystem service and benefits for nature-based tourism and recreation: defined as an input to production activities



Second, the ecosystem service can also be seen as a service that is directly supplied to the actual users, namely households and non-residents who would be the direct beneficiaries (Figure 4.7.2). In this situation, the contribution of ecosystems to recreation and tourism is combined with human inputs (e.g. in the form of hotels, restaurants, walking paths) to produce recreational benefits. In SNA terms, the economic benefits are increased consumer expenditure (which contributes to GDP), but also reduced health costs for the people who enjoy nature (which indirectly contributes to GDP). Furthermore, the ecosystem also contributes to the general well-being of those who enjoy nature, but these welfare values are not part of SNA exchange values (see section 2.3).

Figure 4.7.2. Definition of the ecosystem service and benefits for nature based tourism and recreation: defined as an input to consumption activities



Methods and data

Valuation of tourism and recreation related ecosystem services is not a straightforward task (for a review of potential methods see Ricardo, 2016, and Barton and Obst, 2019). Here, we will consider two methods to value these services: the resource rent method and the consumption expenditure-based method. Below we provide a short description of these methods, more details can be found in de technical background report. In the last section we will discuss the appropriateness of these methods and how the results should be interpreted.

1. *Resource rent*
   The resource rent was calculated for nature-related tourism. When applying this method it is assumed that the ecosystem service is a contribution to the production of tourism services by businesses (see figure 4.7.1). Furthermore, it is assumed that the value added provided by nature for recreational activities is incorporated in the net operating surplus of businesses active in nature tourism and recreation and that this value (which equals the resource rent) can be obtained from the data of the national accounts. First, the tourism sector was delineated based on the definitions and data from the Dutch TSA. Second, the resource rent was calculated for all relevant industries based on the standard methodology described in section 3.1.1 using data from the SNA production and income accounts. The three relevant industries are Accommodation (ISIC 55), Food and beverages service activities (ISIC 56) and Sports, amusement and recreation activities (ISIC 93). In the final step, we have to determine what part of the resource rent is related to nature. For this we used the expenditure data from the tourism statistics. By relating total expenditure for nature-related recreational and tourism activities to total expenditures the share for the different industries was calculated.

2. *Consumer expenditure*
   According to the consumption expenditure method, total consumer expenditure related to nature tourism and recreation can be taken as an approximation for the value of the related ecosystem service. Applying this method it is assumed that the ecosystem service is a direct contribution to consumption activities of households and non-residents (see figure 4.7.2). This method is related to the travel costs method that is often applied to value outdoor recreation (for a discussion see the next section). Consumer expenditure was determined separately for a) nature recreation, b) nature tourism by residents and c) nature tourism by non-residents. Data were obtained from Dutch tourism and recreation statistics, which in turn are based on survey data. Only expenditure related to outdoor activities were selected which was done based on the types of recreational activities and holidays that are distinguished in the source statistics. With respect to expenditure categories we included and analyzed several categories, namely a) travel costs, b) accommodation costs (only for tourism), c) costs for food and drinks, and d) other related costs, which include admission fees, etcetera.

Results
The results of the resource rent method indicate that the contribution of nature has increased from about 100 million euro between 2010 and 2013 to about 480 million euro in 2017 (Figure 4.7.3). The calculated resource rent is still only 1% of the total output of the three tourism related industries.

Between 2015 and 2017, total consumer expenditure on nature-related tourism and recreation increased from 9.8 billion euro to 10.8 billion euro, including all expenditure categories (Figure 4.7.4). The consumer expenditure approach allows differentiation between nature-related recreation, nature tourism by residents, and nature tourism by non-residents. Expenditures are highest for nature based recreation and nature tourism by non-residents.

Figure 4.7.3. Resource rent for nature-based tourism, 2010-2017

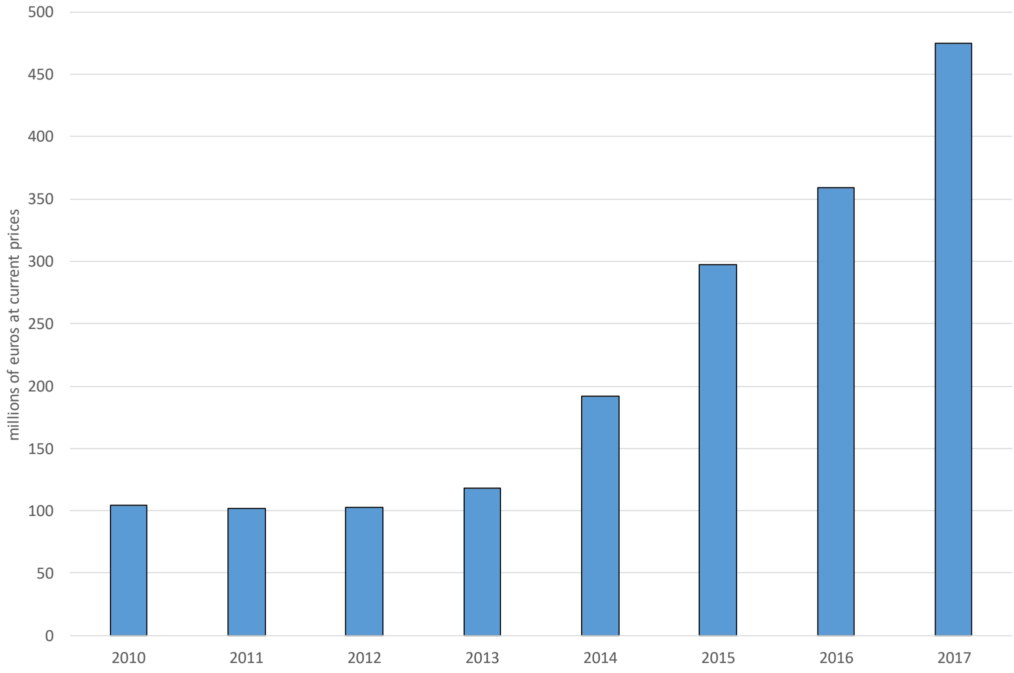
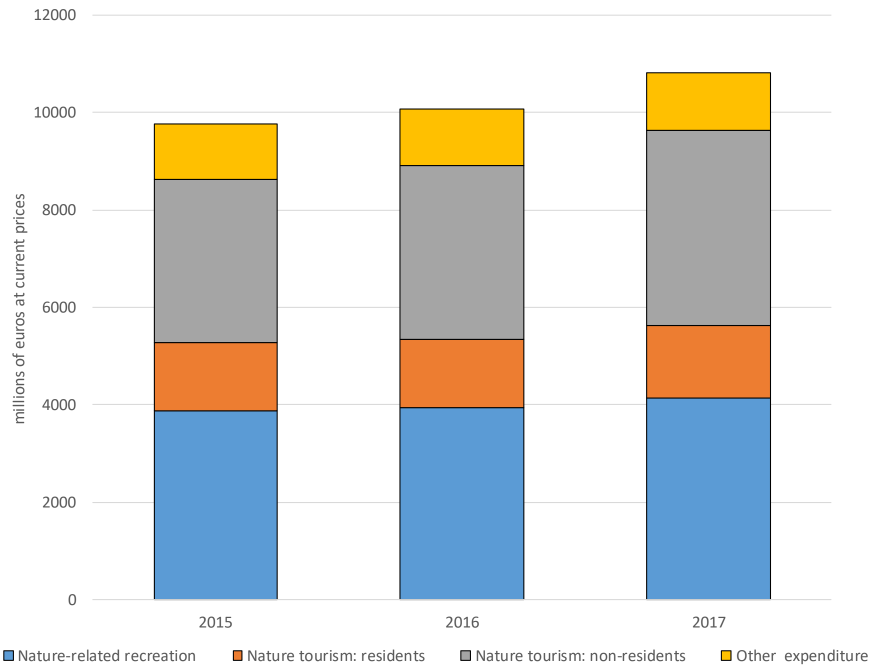


Figure 4.7.4. Total consumer expenditure on nature-related tourism and recreation, 2015-2017



Data from the consumer expenditure approach are also available on a regional level (Figure 4.7.5). The highest values were calculated for the provinces of North Holland, Friesland, and Gelderland. Here, respectively beach tourism, water sports activities and hiking/other outdoor activities play a key role in these high values.

Figure 4.7.5. Total consumer expenditure on nature-related tourism and recreation by province in 2015

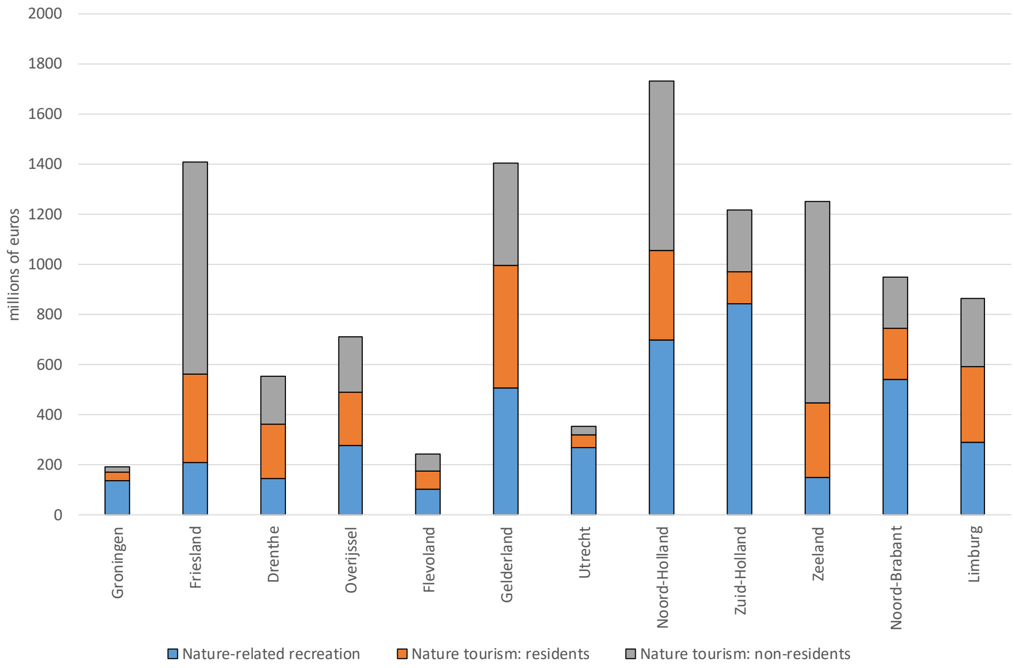
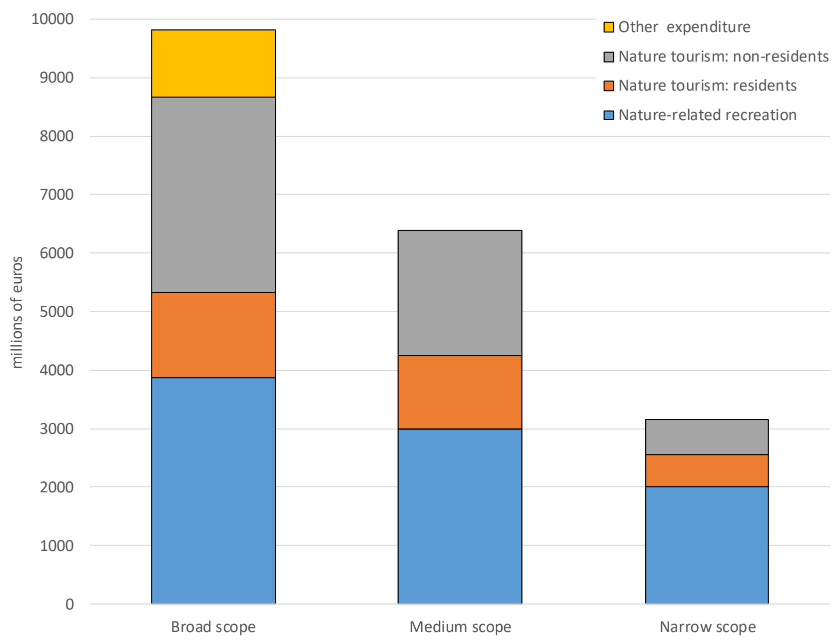


Figure 4.7.6 Nature-related expenditure for tourism and recreation activities calculated according to three scenarios in 2015



As the results of this method are dependent on the scope of the expenditure, we have tested three scenarios and calculated the associated nature-related expenditures:

1) *Limited scope*: travel costs, admissions fees.
2) *Medium scope*: travel costs, admissions fees, accommodation costs, other costs.

3) *Broad scope*: travel costs, admissions fees, accommodation costs, other costs, expenditure on food and drinks, other related expenditure (mainly consumer durables).

The results show that the range is quite considerable (from 3.2 billion to 9.8 billion euro; see figure 4.7.6). More discussion is needed, also on an international level, about what would be the most appropriate scope of the expenditure to include.

What is the preferred method to use?
To determine what is the most appropriate method to value nature-related tourism and recreation we have to address two issues:

(1) What is the nature of this ecosystem service?
As discussed above, these ecosystem services could be interpreted as a service that contributes to production activities (businesses) or consumption activities (households and non-residents). Here we argue that this service should be interpreted as the latter, namely a direct supply of an ecosystem service to households and non-residents. The main argument is that cultural services, which are defined as '*giving rise to intellectual and symbolic benefits obtained by people from ecosystems through recreation, knowledge development, relaxation and spiritual reflection* (SEEA EEA par. 3.2), are by definition supplied to people. People (households) are thus the direct beneficiaries from the opportunities that nature provides for recreational activities. Businesses active in the tourism sector are only indirect beneficiaries as they benefit from the increased demand of goods and services related to the activities by households. Accordingly, the resource rent method is by definition not suitable to calculate the contribution of nature-related tourism.

(2) Is the consumer expenditure method an appropriate approach to value this ecosystem service? To address this issue we have to answer three questions:

1. *Does this method provide exchange values?* Expenditures by households are key examples of market transactions and consequently represent exchanges values, so the answer is affirmative.
2. *Do the values provided by this method represent a contribution to an economic benefit?* Expenditures by households on accommodation, travel, consumer durables and so on are, in SNA terms, part of final household consumption. Final consumption by households plus consumption by government plus gross capital formation plus exports less imports equals GDP. So, these values indeed represent a contribution to an economic benefit.
3. *Do the values provided by this method represent a contribution by ecosystems?* The tourism and leisure activities under consideration can only take place, resulting in the (extra) spending, because of the presence of nature areas. The argument is that without the ecosystems and the cultural services they provide this expenditure would not occur and GDP would be lower. Thus, the expenditure can be taken as a measure for the value of the ecosystem service.

Assigning expenditure values to ecosystems reattributes consumer expenditure values that are already recorded elsewhere in the SNA. In section 6.2 it is shown how these values can be integrated into the accounting framework while avoiding double counting.

We conclude that, at this moment, the consumer expenditure method provides the best approximation for valuing nature-related tourism and recreation. The advantage of this method is that it provides a pragmatic approach: it draws upon existing statistical data, is relatively straightforward to understand and easy to undertake. Furthermore, it incorporates the direct economic benefits provided by nature for recreation and tourism and is therefore fully consistent with SNA exchange values.

The values obtained by consumer expenditure only capture part of the economic benefits provided by these ecosystem services. Recreational activities in nature provide all kinds of (positive) health effects for people. This will provide economic benefits in the form of reduced healthcare costs. These values are not yet included in the SNA and thus will increase GDP. The exact health effects are often difficult to quantify, so further research is needed to find out whether this value component can be added for a future update of the monetary accounts. Furthermore, nature based tourism and recreation also provide welfare values that are probably much higher than the exchange values presented here. Consumers are willing to pay much more to enjoy nature than they are actually spending on travel costs or admission fees. In a future update, it may be worthwhile to present welfare values for tourism and recreation alongside the exchange values.

4.8 Amenity services

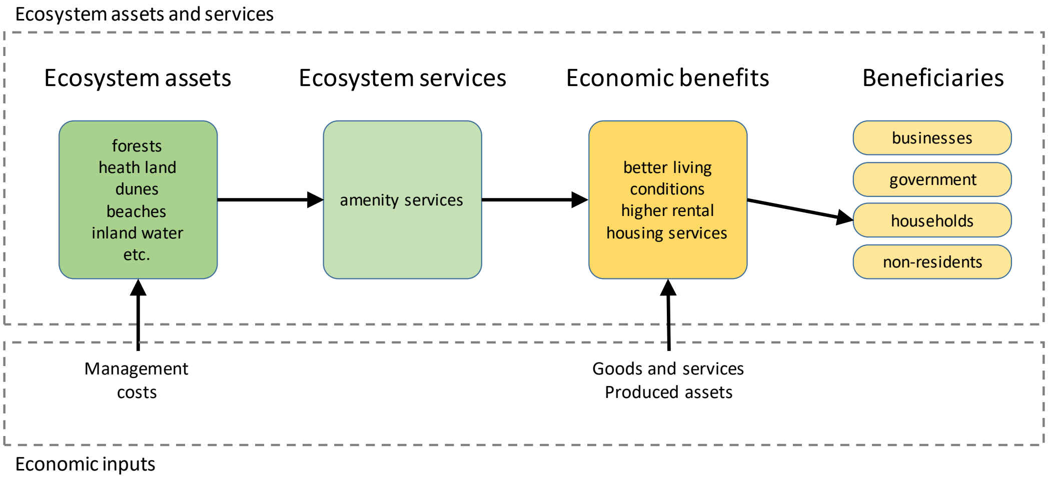
People usually prefer to live in a green neighbourhood as this provides healthier living conditions and more possibilities for all kinds of recreational activities close to home. Green neighbourhoods thus provide an important ecosystem service to people living nearby. Proximity to nature will be reflected in housing prices. The hedonic price model provides a method to determine how much households are willing to pay for living close to nature and to derive a value for this ecosystem service.

Definition of the ecosystem service

In real estate and lodging, an amenity is something considered to benefit a property and thereby increase its value. The amenity services of ecosystems are defined here as benefits for housing related to living near nature, which include recreation, visual aesthetics, and lower levels of air and noise pollution. The value of the service represents the amount house buyers are willing to pay extra for a dwelling and its underlying land for living in green and/or blue surroundings. The amenity services created by ecosystems are a cultural service. The economic benefit is the value of increased production of housing services by owner-occupiers provided by proximity to nature (Figure 4.8.1).

The amenity services may partly overlap with two other ecosystem services. First, recreational activities in nature may be partly captured in the amenity services. To prevent double counting here, we have defined nature recreation as all leisure related activities for which one is away from home for two hours or longer (see also par. 4.7). It is assumed that these activities take place not in the intermediate neighbourhood and consequently will not overlap much with the amenity services as calculated here. Second, there may be an overlap with the ecosystem service air filtration. Reduced air pollution due to a green environment may indeed have an effect on housing prices. However, the way we value these services ensures there is no double counting, namely increased housing prices for the amenity services and reduced health expenditure for air filtration, which should not overlap. The first is already captured in GDP, the second is not.

Figure 4.8.1. Definition of the ecosystem service and benefits for amenity services



Methods and data

The method is based on a hedonic pricing model, developed by Daams, Sijtsma and Van der Vlist (2016). Using regression analysis the price of a dwelling is disentangled based on characteristics of the building and the underlying land. The characteristic of interest is the distance to nature areas.

In this research we used two different classifications of natural space. First, we have used clusters of Nationally Attractive Nature Areas of the Netherlands (CANA) from the Greenmapper dataset (Daams et al, 2016). Greenmapper is a value mapping survey in which people are asked to identify nature areas that they perceive as attractive, valuable or important (see technical background document). Second, Other Natural Areas (ONA) have been defined based on the Ecosystem Units map of the Netherlands for 2013 (van Leeuwen et al, 2017; Statistics Netherlands, 2017).

Using the housing stock registry (Statistics Netherlands, 2018) a dataset was created with information on 4.5 million single-family dwellings. The information concerns the assessed property value (WOZ-value) as well as characteristics of the dwelling and underlying land. Using the location of each dwelling from the building and address register, Euclidean distances to the nearest CANA and ONA were calculated.

Regression analysis of the natural logarithm of WOZ-value on the distance to nature areas and other control variables was performed by first differencing on a local level. First differencing controls for factors that are locally constant and could correlate both with WOZ-value and the distance to nature areas. Different regressions were performed according to urbanity of the location of the dwelling (Statistics Netherlands, 2013). This analysis gives for each dwelling an estimated portion of the WOZ that could be attributed to nearby nature. These values have been distributed equally over the nature areas within a certain distance of the dwelling, that is, 7 kilometers for values attributable to CANA-areas and 500 meters for values attributable to ONA-areas. This is in accordance with the results of the analysis.

Results

Table 4.8.2 shows the results of the regression analysis. The main conclusion from this table is that the effect of CANA on the willingness-to-pay of buyers is larger and is felt along a greater distance than for the effect of ONA. Additionally, there are large differences between areas with different levels of urbanisation. In (highly) urbanised areas the effect of being close to nature areas is larger, especially for CANA. Moreover, the distance to where this effect is measured is much longer compared to areas with low levels of urbanisation. In other words, the value of nature in urban areas is much higher than the value of nature in rural areas for three (mutually reinforcing) reasons: 1) a higher percentage of the value of a house is attributed to nature areas; 2) the density of houses is higher, so that more houses contribute a percentage of their value to each nature area in the vicinity; and 3) the average price per m^2 is higher.

Table 4.8.2. Results of the hedonic pricing model for the Netherlands and different urbanization levels (Numbers indicate the percentage of the value of a property that house buyers are willing to pay to live nearby a CANA or ONA)

	(1)	(2) Urbanization level				
	Netherlands	1	2	3	4	5
Distance to nearest CANA						
Within 0-500 m	6.7	21.9	6.9	4.7	2.9	2.2
Within 500-1000 m	4.2	16.6	4.9	2.1	1.4	
Within 1000-2000 m	3.5	12.0	5.6		0.9	
Within 2000-3000 m	3.0	9.4	5.5			
Within 3000-4000 m	2.1	9.5	2.7			
Within 4000-5000 m	1.1	6.7	2.1			
Within 5000-6000 m	1.1	5.2				
Within 6000-7000 m	0.7					
Distance to nearest ONA						
Within 0-50 m	4.9	4.4	6.0	5.5	4.2	2.8
Within 50-100 m	3.5	3.6	4.2	3.8	3.2	1.7
Within 100-150 m	2.1	2.8	2.7	2.5	1.6	0.6
Within 150-200 m	1.4	2.2	2.2	1.6	0.7	0.3
Within 200-250 m	0.8	1.2	1.5	1.2	0.3	
Within 250-300 m	0.4	0.6	0.9	0.9		
Within 300-350 m	0.1		0.5	0.5		
Within 350-400 m			0.3	0.3		

Using the results of table 4.8.2, the value attributable to nearby nature areas can be calculated for each dwelling depending on its WOZ-value, urbanisation level, and distance to nature. These values can be allocated to all nature areas close to each dwelling.

The calculated asset value of the amenity services is 31.8 billion euros for 2013.[17] Of this, 71 percent is contributed by CANA and the remaining 29 percent by ONA. Table 4.8.3 shows the result per ecosystem type. Especially water areas (26 percent), forests (23 percent), public green space (20 percent), and dunes and beaches (11 percent) contribute to the amenity services.

The result of this method is an asset value. We have used the net present value approach to derive the value of the annual flow of ecosystem services (see chapter 5). Using the formula presented in section 5.3, assuming a discount rate of 3% and an asset life of 100 years (which implicitly assumes that existing houses that are replaced by newer houses enjoy the same value

[17] In the tables presented in sections 4.9, 6 and 7 the amenity services and asset value are re-calculated using the year 2015. This has been done with a volume-index based on the non-financial balance sheet of dwellings and its underlying land of the national accounts (retrieved from https://opendata.cbs.nl/statline/#/CBS/en/dataset/82641ENG/table?dl=20B50)

increase due to proximity to nature), the annual flow of benefits is estimated at 1017 million euro in 2013. Note that this is also an underestimation of the value of this service, since contributions of proximity to natural areas to apartments are excluded.

Table 4.8.3. Contribution of ecosystem type to house values in 2013

Ecosystem type	million euro	percentage
(Non)-perennial plants	856	3
Meadows	1,576	5
Hedgerows	199	1
Greenhouses, farmyards and barns	31	0
Forest	7,233	23
Heath land and inland dunes	745	2
Dunes and beaches	3,503	11
Fresh water wetlands	284	1
(semi) Natural grassland	729	2
Public green space	6,252	20
Other unpaved terrain	1,059	3
River flood basin and salt marshes	413	1
Built up areas	579	2
Water (sea, lakes, rivers)	8,336	26
Other	2	0
TOTAL	31,796	100

4.9 The monetary supply and use account for ecosystem services

The supply of ecosystem services by ecosystem assets and the use of these services by economic units, including households, is one of the central features of ecosystem accounting. The supply and use account records the actual flows of ecosystem services supplied by ecosystem assets and used by economic units during an accounting period and may be compiled in both physical and monetary terms (SEEA EEA TR, 2.27). Here we present how the monetary supply and use account for the Netherlands was complied.

In the monetary supply table the value of ecosystems services, as described in the previous sections, is allocated to different ecosystem types, i.e. the producers of the ecosystem services. This was done using the biophysical maps of ecosystem services that were developed during an earlier part the Dutch NCA project to compile the physical supply and use tables for ecosystem services (Statistics Netherlands and WUR, 2018). The monetary values calculated on a national level (for example timber) or on a regional level (for example crop production of nature recreation) were distributed to ecosystem types based on the physical values in the biophysical maps of ecosystem services.

In the monetary use table the value of ecosystems services is allocated to the users of these services. Users include economic units classified by industry, government sector and household sector units, following the conventions applied in the national accounts. The users of the ecosystem services correspond to the beneficiaries identified for each ecosystem service as discussed in the previous sections of this chapter.

For accounting purposes, the supply of ecosystem services is always equal to the use or receipt of the services during an accounting period. That is, supply is not recorded if there is no corresponding use. The results of these accounts are further analysed in chapter 7.

Table 4.9.1. Monetary supply table for ecosystem services, 2015 (using the broad scope estimates of tourism and recreation)

	millions of euros	Agriculture	Dunes and beaches	Forest	Heath land and inland dunes	Fresh water wetlands	(Semi) Natural grassland	Public green space	Other unpaved terrain	River flood basin and salt marshes	Built-up terrain	Water	Other	TOTAL
Provisio-ning services	Crop production	415	0	0	0	0	0	0	1	0	0	0	0	415
	Fodder production	849	0	0	0	0	0	0	2	21	0	0	0	872
	Timber production	0	2	41	0	0	0	0	0	0	0	0	0	44
Regulating services	Water filtration	36	42	35	7	1	2	5	15	5	23	6	0	177
	Carbon sequestration	35	5	102	1	2	2	3	11	10	1	0	0	171
	Pollination	132	0	75	6	5	16	12	77	37	0	0	0	359
	Air filtration	18	2	46	0	0	1	7	11	1	0	0	0	86
Cultural services	Nature tourism	2489	1791	602	100	52	97	113	463	115	6	116	0	5946
	Nature recreation	910	327	949	135	78	75	547	532	58	26	237	1	3873
	Amenity service	87	114	236	24	9	24	204	35	13	19	272	0	1037
TOTAL	Total	4970	2283	2085	274	146	217	891	1147	260	74	631	1	12981

Table 4.9.2. Monetary use table for ecosystem services, 2015 (using the broad scope estimates of tourism and recreation)

	millions of euros	A - Agriculture, forestry and fishing	B,C - Mining and manufacturing	D - Electricity	E - Water supply	F-H - Contruction, wholesale and transportation	I,R - Accommodation and food service, culture, sports and recreation	Export	Households	Government	Investments	Inventories	TOTAL
Provisio-ning services	Crop production	415											415
	Fodder production	872											872
	Timber production	44											44
Regulating services	Water filtration				177								177
	Carbon sequestration									171			171
	Pollination	359											359
	Air filtration								86				86
Cultural services	Nature recreation								3873				3873
	Nature tourism							3341	2605				5946
	Amenity service								1037				1037
TOTAL	**Total**	1690	0	0	177	0	0	3341	7601	171	0	0	12981

5. The value of ecosystem assets

In this chapter, we describe how the value of assets has been derived from the estimated value of ecosystem service flows. We have used a net present value (NPV) approach, using assumptions on the future flow of ecosystem services, the discount rate, and the economic lifespan of ecosystem assets.

5.1 Introduction

From a national accounts point of view, an asset is a store of value representing a (series of) benefit(s) for the economic owner (SNA, 2008). It follows from this general concept that an asset is limited to those situations in which property rights can be enforced. In the SEEA, environmental assets are defined as the naturally occurring living and non-living components of the earth, together comprising the bio-physical environment, that may provide benefits to humanity (SEEA CF, 2.17). In physical terms, the asset boundary of the SEEA Central Framework is broader than the SNA as the ownership criterion does not apply. The SEEA CF basically includes all natural resources within an economic territory that may provide resources for use in economic activities (SEEA CF, 1.47).

The SEEA EEA considers environmental assets from a different perspective than that of the SEEA CF. The focus of the SEEA EEA is on the biophysical environment as viewed through the lens of ecosystems in which the various biophysical components (including individual resources) are seen to operate together as a functional unit. Ecosystem assets are environmental assets viewed from a systems perspective (SEEA EEA, 2.130). Furthermore, in the SEEA EEA the extended asset boundary as defined in SEEA CF is used, which means that all ecosystems (regardless of ownership) are within scope for the (physical) accounts.

In the national accounts, the value of produced assets is commonly derived from investment series, which can be used to determine the economic capital stock through a perpetual inventory method (PIM), making assumptions about depreciation and service life (OECD, 2009). In addition, in some instances, such as the valuation of land, the national accounts capital stock estimates are based directly on available market prices for the pertinent asset.

In the case of natural resources and ecosystem assets, there is no investment, except for possible expenditures on restoration, extension and improvement, which are already recorded in the national accounts. Where market prices are available for the assets that deliver ecosystem services, such as land, it is often difficult to disentangle the part of the price that can be attributed to any of the ecosystem services, from the part that is determined by other market factors.

As an alternative, an estimate of the overall value of an ecosystem asset can be derived from aggregate values of future flows of ecosystem services, following the standard approaches to capital accounting, using the net present value approach (SEEA EEA, 5.51). Such an approach requires assumptions about the future flows of income, as well as about the discount rate used to convert the future income to current values and the corresponding time horizon. Statistics Netherlands applies this method for the valuation of the Dutch oil and gas reserves in the national accounts (see De Bondt and Graveland, 2016). In this chapter we describe how the NPV approach can be implemented to derive asset values for ecosystem types from the value of the associated services.

5.2 Assumptions

Implementation of the net present value approach for the calculation of the value of ecosystem assets involves three assumptions.

5.2.1 Assumption 1: The future flow of income for each ecosystem services is constant, and equal to the flow observed most recently.

In the case of oil and gas reserves, which are not part of the ecosystem assets considered here, scenarios are available for the physical extraction of these reserves. These scenarios are used in the determination of future flows of income. Similar information on depletion or degradation is lacking for the ecosystem services that are valued in this report. Neither are there scenarios for predicted future flows. For the moment, we assume that no (future) degradation takes place and that the future flow of income in each year equals the flow observed in the most recent year. This assumption is not necessarily realistic. There is no overharvesting (where offtake exceeds mean annual increment) of wood in Dutch forests, but potentially water or air pollution may affect future flows of services from ecosystems. We anticipate that these effects are, for now, modest for most services (given that there are no clear indications that ecosystems reaching a point where they are close to collapse in the Netherlands, and given ongoing efforts to rehabilitate ecosystems). There is one exception. It is likely that the near future may show important changes in amenity services, given the pace of construction and current plans to expand the number of dwellings, in particular in the western part of the country. Such changes should show up in the updated accounts in the coming years. For now there is no clarity on where exactly most of these new houses will be built and such forecasts cannot be made.

5.2.2 Assumption 2: The discount rate equals 3 percent, unless the ecosystem asset is thought to become scarcer and there are limited substitution possibilities.

The discount rate reflects the time preference of money: it captures the trade-off between consumption today and consumption in the future. It takes into account a risk-free return on investment and a risk-premium. The value that is chosen for this discount rate is an important determinant of the asset value.

Over the years, there have been various consecutive interdepartmental working groups to determine the discount rate to be used by the Dutch government in public cost-benefit analyses (Werkgroep Discontovoet, 2015). Since 2009, a risk-weighted discount rate of 5.5% for public investment has been maintained, and 4% for investments with irreversible negative externalities. The latter rate has been used to determine the value of oil and gas reserves in the Dutch national accounts. The 2015 working group advised adjusting the discount rate for public investments to 3 percent. For nature, the advice is to take into account increases in the relative price, due to increased scarcity and limited substitution possibilities, resulting in an effective discount rate of 2 percent. However, the Netherlands Environmental Assessment Agency (PBL) recommends using the normal discount rate of 3 percent for provisioning services, such as in agriculture or timber production (Koetse et al., 2017). For services that can hardly be replaced, they recommend a discount rate lower than 2 percent.

In line with these recommendations, in this report, we apply the 3 percent discount rate for provisioning services and cultural services. For regulating services, which are scarcer and harder to substitute, we use a discount rate of 2 percent. This is summarized in Table 5.2.1. An additional assumption is that the discount rate applies equally to all geographical areas. In other words, we assume that there is no spatial variation in the degree of scarcity and substitutability.

Table 5.2.1. Discount rate used for the different ecosystem services based on assumed relative scarcity and substitutability

Type	Ecosystem service	Discount rate used
Provisioning services	Crop production	3
	Fodder production	3
	Wood production	3
Regulating services	Carbon sequestration	2
	Pollination	2
	Water filtration	2
	Air filtration	2
Cultural services	Nature recreation	3
	Nature-related Tourism	3
	Amenity services	3

5.2.3 Assumption 3: The asset life is 100 years for all ecosystem assets.

The asset life is the expected period of time over which the ecosystem services are to be delivered and determines the time-horizon over which the net present value is calculated. The longest asset life that is used in the estimation of the value of produced assets is 75 years for dwellings (see Statistics Netherlands, 2019, forthcoming). For nature, it therefore makes sense to set an asset life substantially longer than 75 years. In their experimental estimates for ecosystem assets, the British Office of National Statistics (ONS, 2018) sets the asset life to 100 years.

5.3 Calculation of net present value

The value of an ecosystem asset can be determined by calculating the net present value of the future flows of income associated with the different ecosystem services. The asset value K_0 is calculated using the NPV formula:

$$K_0 = \sum_{t=1}^{T} \frac{d_t}{(1+r)^t}$$

assuming a flow of income d_t in year t, a discount rate r, and an asset life T.
If we assume that the stream of future of flows is constant, i.e. $d_t = d$, then the formula simplifies to:

$$K_0 = d \times a$$

where a is the annuity factor, given by

$$a = \frac{1}{r} - \frac{1}{r(1+r)^T}$$

Note that when asset life is assumed to be infinite ($T \rightarrow \infty$), the NPV formula is applied to a so-called perpetuity and the asset value is simply equal to the income flow divided by the discount rate ($K_0 = d/r$), as a converges to 1. In addition, the changes over time in the asset values are the same as those for the associated services, because the calculation only entails a multiplication of the flow by a scaling factor. Finally, because the discount rate and the time horizon may differ across asset types and each ecosystem asset may provide a basket of ecosystem services, it is necessary to calculate asset values for the different ecosystem service separately before aggregating to an overall value.

Beyond a certain value, the asset life (T) does not have much impact on the ultimate asset value, for a sufficiently high value of the discount rate. For example, at a discount rate of 3 percent the difference in asset value between choosing an asset life of 100 years versus infinity is 5.5 percent. At a discount rate of 2 percent, the difference amounts to 16 percent. A discount rate lower than 2 percent is unlikely, while a discount rate higher than 3 percent will only have an effect of a few percentage points on the estimated asset value.

5.4 Results

The monetary ecosystem asset account records the monetary value of opening and closing stocks of all ecosystem assets within an ecosystem accounting area and additions and reductions in those stocks (SEEA EEA TR). The monetary asset account for the Netherlands is shown in Figure 5.4.1. The entries in the rows have been simplified to very basic asset account entries. If more detail is required to account for changes in assets, particularly those related to provisioning services, then additional entries can be incorporated, following the structure of the monetary asset account in the SEEA Central Framework. These additional entries include growth and normal losses of stock, catastrophic losses (e.g. changes due to natural disasters), upward and downward reappraisals and reclassifications. A separate entry is used to record changes between the opening and closing values of ecosystem assets that are due to revaluations – i.e. changes in the value that are due solely to changes in prices rather than changes in volumes.

In the current project assets values by ecosystem type have been calculated for only one year (2015). Therefore it was not yet possible to fill in all other entries and calculate the closing stock by ecosystem type. Once time series become available the monetary asset account can be completed.

Figure 5.4.1. Monetary ecosystem asset account, 2015

million euro	Agriculture	Dunes and beaches	Forest	Heath land and inland dunes	Wetlands	(semi)natural grassland	Public green space	Other unpaved terrain	River flood basin and salt marshe	Built up terrain	Water	Other	TOTAL
Opening stock	159500	76400	66900	8600	4700	7100	28300	37500	8800	2600	17900	0	418300
Additions to stock													
Reductions to stock													
Revaluations													
Closing stock													435500

6. Aggregation and integration into the SNA

The integration of ecosystem accounting information with standard economic data is an important component of work within the context of the SEEA. This reflects that the SEEA has been developed as a system that extends and complements the standard economic accounts of the SNA (SEEA EEA TR). Aggregation of the estimates and integration into the SNA are important for obtaining an impression of the order of magnitude and composition of the value of all natural capital and for deriving key performance indicators. In this chapter we discuss aggregation and present the integrated extended supply and use accounts and extended balance sheets.

6.1 Is aggregation possible?

Is it possible to add up the monetary values of the ecosystem services estimated in this report? The answer to this question depends on three criteria. After examining these criteria we can conclude that aggregation is possible.

Criterion 1: All estimates need to be similar in nature
All estimates need to be conceptually similar. For aggregation we have to distinguish clearly between flow estimates (values of the ecosystem services) and stock estimates (values of the ecosystem assets). Furthermore, we have to use either exchange values or welfare values and not mix them up. Finally, all values must be expressed in prices of the same year.

Three measures have been taken to ensure that all estimates are similar in nature:

- For each ecosystem service we have carefully distinguished between estimates of the value of the flow of services (chapter 4) and estimates of the value of assets (chapter 5).
- All estimates have been expressed in SNA exchange values or an equivalent.
- All estimates have been expressed in prices of the same year.

One of the decisions we had to make concerns the precise scope of the results for the ecosystem services of nature-related tourism and recreation (see section 4.7). The SEEA EEA does not provide clear guidelines on this subject. Yet, the differences in terms of monetary valuation are enormous. In our estimates, a delineation of nature-related tourism and recreation with a broad scope (travel costs, admissions fees, accommodation costs, other costs, food and drinks, other related expenditure, mainly consumer durables) results in an ecosystem value of 9.8 billion euros compared to 6.4 billion euros for a delineation with a medium scope (travel costs, admissions fees, accommodation costs, other costs) and 3.2 billion euros for a delineation with a limited scope (travel costs and admissions fees).

Criterion 2: There must be no double counting
Double counting must be avoided. For example, the amenity services provided by nearby nature must not also count the value of recreational ecosystem services.[18] Similarly, the pollination

[18] In our approach, the flow of amenity services derives from an investment in a house on a location that provides nearby recreational opportunities. The value is what house buyers willingly pay to live in a house near nature areas, regardless whether they actual visit those areas. The total value willingly paid by all house owners living near a specific nature area is assigned to that area and represents the value of the amenity services provided by that nature area to those house owners. Recreational expenditure, by contrast, represent the value associated with actual use of those nature areas, not necessarily by people living nearby.

services of an ecosystem asset must not also be included in the ecosystem services provided by grassland and cropland. In chapter 4, we have tried to ensure that the value of each ecosystem service does not also include (parts of) the value of other ecosystem services.

Criterion 3: The aggregate must be representative of the whole
A key characteristic of national and environmental accounting is that it is comprehensive. This means, for example, that we want to account for all production activities in a country in order to calculate GDP or that we want to account for all physical flows from the environment to the economy to determine total domestic resource inputs. For ecosystem accounting this means that we want to account for all relevant final ecosystem services and all ecosystem assets in order to calculate the contribution of ecosystems to GDP as well as the total value of ecosystem assets. Meeting the criterion of comprehensiveness is quite difficult. Ecosystem classifications like CICES provide a sense of all possible ecosystem services, but the scope and structure of these classifications are still under discussion. Furthermore, some ecosystem services may not be relevant for a certain country or region or may be very small. When compiling these accounts for the first time the focus must be on including the most relevant ecosystem services for which data are available.

We must therefore be certain that the ecosystem services that have been valued account for a substantial proportion of total ecosystem value and that there is no selection bias in the estimates. We compared our estimates with those of ONS (2016, 2018) and compared to this study we are not missing any major ecosystem services from terrestrial ecosystems other than the abiotic ecosystem services (such as the exploitation of oil and gas wells) which were deliberately excluded in this report. Neither is there an imbalance between provisioning, regulating, and cultural ecosystem services.

A key recommendation for the future is to investigate if some key ecosystem services are still missing and if these can be valued. Particularly the five ecosystem services that have thus far been excluded from our estimates have to be investigated: two provisioning services (biomass from non-agricultural sources; fishing) and three regulating services (natural pest control; erosion prevention; protection against heavy rainfall).

6.2 Results for the Gross Value Added (GVA) approach

As discussed in chapter 2, the GVA/NVA approach calculates (net or gross) value added generated by economic activities that directly depend upon natural capital. This provides a broader insight into the economic significance of ecosystems compared to the exchange values presented in the previous part of this study.

The GVA approach works well for provisioning services. Agriculture, forestry and fisheries are directly dependent on provisioning services and contribute c. 5,600 million euro to GDP (2017).[19] For regulating services, the GVA method can only be applied when the service is directly used by a specific industry, for example water production that depends on the supply of water from the environment. Cultural services are supplied to individuals which makes the application of this approach problematic. For nature-related tourism and recreation we have tried to determine nature-related GVA of some specific industries (accommodation, food and

[19] GVA of horticulture, which in the Netherlands mainly consists of crop production in greenhouses, has been left out here.

drink supply and sports and recreation). However, this figure is very much dependent on the calculated share of the activity that is related to nature.

Figure 6.2.1 Gross value added of economic activities that directly depend on natural capital

million euro	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture	3900	3400	3600	4400	4100	3700	4100	5100
Forestry	100	100	100	100	100	100	100	100
Fisheries	300	300	300	200	200	300	400	400
Water production	1000	1000	1000	1000	1000	1100	1000	1000
Nature related tourism/ recreation	1100	1200	1200	1200	1300	1500	1600	1700
Total	6400	6000	6200	6900	6700	6700	7200	8300

6.3 Extended supply and use accounts

Extended supply and use accounts (SUA) present information on the supply and use of ecosystem services as extensions to the standard SNA SUA. Extended supply and use accounts support the analysis of extended supply chains and the integration of ecosystem services to form extended economic production functions (SEEA EEA TR, 8.4).

There are two key aspects to the extension of the SUA. First, as a result of the extension of the standard production boundary, the set of products within the scope of the SUA is broader than that of the SNA. New rows are added representing the ecosystem services. This extension ensures that ecosystem services are distinguished clearly from the products (i.e. SNA benefits) that are already within the standard SUA. The second key aspect of the extended SUA is that additional columns are required to take into account the production of ecosystem services – i.e. the ecosystem assets are considered additional producing units alongside the current set of establishments classified by industry (agriculture, manufacturing, etcetera). Given that SUA are generally compiled at the national level, it may be sufficient simply to introduce one additional column to cover the production of all ecosystem services by all ecosystem types.

The aggregated SUA of the SNA with data for the Netherlands for 2015 is shown in Table 6.3.1. In the rows the supply and use of SNA products is shown. In the bottom rows gross value added, net operating surplus and GDP (which equals total gross value added plus taxes minus subsidies on products) are presented. The columns represent the aggregated economic activities that supply and use the SNA products.

Table 6.3.1: SUA with SNA data for the Netherlands, 2015

	Industries			taxes/ subsidies	Households	Government	Investments / inventories	Imports/ exports	TOTAL
	A Agriculture	B_E Manufactering	F-Z Services						
Supply									
SNA products	30359	350144	956891	69173				518594	1925161
Use									
SNA products	18461	251053	447045		310816	172354	155079	570353	1925161
Gross value added	11898	99091	509846						620835
Net operating surplus	5556	34336	133317						173209
GDP									690008

Table 6.3.2 shows the extended SUA for the Netherlands (2015). One column for ecosystem assets has been added. This column has not been disaggregated further by ecosystem type for

representational reasons, even though the monetary supply table in section 4.9 does make this possible. In the rows the different ecosystem services have been presented. In short, this table shows in monetary terms the ecosystems services that are supplied and how they are used by industries, households, government and exports (i.e. use by non-residents).

Integration of ecosystem services in the SUA involves more than simply adding the rows for ecosystem services. As discussed is section 2.3 part of the value of the ecosystem services is already incorporated in the standard SNA. To prevent double counting, the following corrections have been made:

- *Provisioning services*: the values of the ecosystem services crop production, grass/fodder production and timber are already included in the net operating surplus of the economic activities that use these services. Accordingly, in the extended SUA these values have to be added to the intermediate consumption and subtracted from net operating surplus for these activities. Overall, the integration of the provisioning services included in the present study does not lead to a change in total gross value added and GDP.
- *Regulating services*: the values of regulating ecosystem services are not already included in the net operating surplus or the final consumption of the economic activities that use these services. For pollination and water filtration – services that are used by production activities – this leads to a net increase of the production of these activities (i.e. agriculture and water producers) and an additional supply of SNA products. To balance supply and use, the use of these SNA products also has to be adjusted (either as additional intermediate consumption, final household consumption or exports). The users of air filtration and carbon sequestration are households and government respectively.[20] Recording these services in an SUA leads to a net increase of final household and final government consumption. Overall, the integration of regulating services included in the present study does lead to a change in total gross value and GDP.
- *Cultural services*: the calculated values for nature recreation, nature tourism and amenity services are already included in the SUA of the SNA, either as household expenditure or as exports. Accordingly, when these values are added in the extended SUA as final household consumption and exports, a correction has to be made for the use of SNA products by households and exports. Also, in order to balance supply and use, a correction has to be made for the production of these SNA products (it is assumed here that these products do not originate from imports). As a result, gross operating surplus of these production activities decreases as well. Overall, the integration of the cultural services included in the present study does not lead to a change in total gross value and GDP.

Table 6.3.3 shows the difference between the SNA SUA and the extended SUA (using the broad scope estimates of tourism and recreation) and makes explicit where the corrections have been made.

[20] In the Netherlands, it is also possible to assign the value of the ecosystem service air filtration to health care insurance companies. The avoided health damage translates into a higher margin between premiums and claims (the amounts payable in settlement of damages). However, in practice premiums might be lowered as well. This is why the value of air filtration has been assigned to households instead. The value of the ecosystem service carbon sequestration has been assigned to government, because the carbon price reflects the prevention costs associated with the government's ambitions with respect to lowering carbon emissions.

Table 6.3.2 Extended SUA for the Netherlands, 2015 (using the broad scope estimates of tourism and recreation)

2015		Ecosystems	Industries			taxes/ subsidies	Households	Government	Investments / inventories	Imports/ exports	TOTAL
			A Agriculture	B_E Manufactering	F-Z Services						
Supply											
SNA products			30718	346930	949540	69173				518594	1914956
ecosystem services		12981									12981
Provisio-ning services	Crop production	415									415
	Fodder production	872									872
	Timber production	44									44
Regulating services	Drinking water	177									177
	Carbon sequestration	171									171
	Pollination	359									359
	Air filtration	86									86
Cultural services	Nature recreation	3873									3873
	Nature tourism	5946									5946
	Amenity service	1037									1037
Use											
SNA products			18461	251168	447045		303646	172354	155079	567203	1914956
ecosystem services			1690	177	0		7601	171		3341	12981
Provisio-ning services	Crop production		415	0	0		0	0		0	415
	Fodder production		872	0	0		0	0		0	872
	Timber production		44	0	0		0	0		0	44
Regulating services	Drinking water		0	177	0		0	0		0	177
	Carbon sequestration		0	0	0		0	171		0	171
	Pollination		359	0	0		0	0		0	359
	Air filtration		0	0	0		86	0		0	86
Cultural services	Nature recreation		0	0	0		3873	0		0	3873
	Nature tourism		0	0	0		2605	0		3341	5946
	Amenity service		0	0	0		1037	0		0	1037
Gross value added		12981	10566	95586	502495						621628
Net operating surplus		12981	4224	30831	125966						174002
GDP											690801

Table 6.3.3 Differences between the SNA SUA and the SEEA EEA extended SUA (using the broad scope estimates of tourism and recreation)

2015		Ecosystems	Industries			taxes/ subsidies	Households	Government	Investments / inventories	Imports/ exports	TOTAL
			A Agriculture	B_E Manufacter	F-Z Services						
Supply											
SNA products			359	-3214	-7351	0				0	-10205
ecosystem services		12981									12981
Provisio-ning services	Crop production	415									415
	Fodder production	872									872
	Timber production	44									44
Regulating services	Drinking water	177									177
	Carbon sequestration	171									171
	Pollination	359									359
	Air filtration	86									86
Cultural services	Nature recreation	3873									3873
	Nature tourism	5946									5946
	Amenity service	1037									1037
Use											
SNA products			0	115	0		-7170	0	0	-3150	-10205
ecosystem services			1690	177	0		7601	171		3341	12981
Provisio-ning services	Crop production		415	0	0		0	0		0	415
	Fodder production		872	0	0		0	0		0	872
	Timber production		44	0	0		0	0		0	44
Regulating services	Drinking water		0	177	0		0	0		0	177
	Carbon sequestration		0	0	0		0	171		0	171
	Pollination		359	0	0		0	0		0	359
	Air filtration		0	0	0		86	0		0	86
Cultural services	Nature recreation		0	0	0		3873	0		0	3873
	Nature tourism		0	0	0		2605	0		3341	5946
	Amenity service		0	0	0		1037	0		0	1037
Gross value added		12981	-1332	-3505	-7351						793
Net operating surplus		12981	-1332	-3505	-7351						793
GDP											793

7. Conclusions and recommendations

In this study we have produced the first experimental monetary ecosystem service supply and use account and ecosystem asset account for the Netherlands based on the SEEA EEA framework. The results do not represent the total or 'true' value of nature. We only estimate the *economic value* of *human benefits* produced by ecosystems. Non-economic values and 'non-human' benefits are not included. Furthermore, we only assign values to *final ecosystem services* (produced by ecosystems and used in production or for consumption) and not to intermediate ecosystem services (produced by one ecosystem for use in another ecosystem). Our focus is on the *actual use* of ecosystem services rather than the capacity of ecosystems. Finally, we calculate exchange values for ecosystem services (consistent with the principles of the System of National Accounting) rather than welfare values, thereby excluding consumer surplus.

We have estimated the value of ten ecosystem services: crop production, fodder production, timber production, air filtration, carbon sequestration in biomass, water filtration, pollination, nature recreation, nature tourism, and amenity services. For each ecosystem service we have selected valuation methods that are conceptually valid and that produce values that are consistent with the SNA. In addition, these methods can be applied using sound statistical data, enhancing their reliability and credibility. Subsequently, the values for the ecosystem services were used to calculate monetary values for the ecosystem assets, using the NPV method.

The general conclusion of this study is that it is feasible to compile monetary accounts for ecosystems on a national scale using several different statistical data sources. However, important challenges remain, particularly with regard to refinement of the assumptions made in applying the different valuation methods, the allocation of the values to ecosystem types, enhancing the scope of the ecosystem services, and communication of the results.

7.1 Main methodological results

In this study, we have distinguished three approaches to valuation: (a) the compilation of exchange values, which is the recommended approach to apply in SEEA ecosystem accounting, (b) the compilation of welfare values, which are often used for cost-benefit analysis, and (c) the Gross or Net Value Added approach, which provides broader insight into the economic significance of ecosystems. In addition, we found that it is important to distinguish between exchange values already incorporated in the GDP of SNA and exchange values that are not.

These approaches lead to different value indicators and the resulting value estimates may not be added up when different approaches have been used. The identification of these three approaches and the distinction between different kinds of exchange values helps (a) to select what valuation method to use for each ecosystem service, (b) to integrate the values into the accounting framework of the SNA, (c) to better understand the scope of the values included in the SEEA EEA, and (d) to better interpret and use the results.

We found that, from conceptual and practical points of view, the best valuation techniques to apply are:

- *Provisioning services*: Rent-based methods (stumpage prices, rent prices for agricultural land)
- *Regulating services*: Replacement costs or avoided damage costs methods

– *Cultural services*: consumer expenditure and hedonic pricing

We also conclude that in practice the resource rent method does not produce reliable results. In the SEEA the resource rent method is considered the method of choice. The general idea is that the value of the contribution of an ecosystem service to production is included in the price or rent and can be calculated by subtracting all human inputs, leaving a residual or rent that represents the value of the ecosystem service. We have estimated resource rents for a number of ecosystem services and compared the results to alternative valuation methods. This revealed two problems.

The first problem is that the resource rent method produces estimates with high margins of uncertainty and, consequently, high annual volatility. This problem relates particularly to assumptions required for estimating components of the resource rent formula. The wages self-employed entrepreneurs pay themselves for their own labour are (to some extent) paid out of the return on capital, which creates the possibility of double counting. Another source of uncertainty is the estimated normal profit, which is equal to the value of the fixed capital stock multiplied by the opportunity costs of the investment.

The second problem is that in many industries, market conditions eliminate rents. A key assumption of the resource rent method is that the economic value of an ecosystem service is fully captured in the price of output. However, this is contingent upon the behaviour of resource owners (entrepreneurs) who determine the price they are willing to accept based on market conditions and the money value of expenses. Rent is inextricably linked to scarcity and market structure (Ricardo, 1821). Rents occur where resources are scarce and markets tend towards monopoly or oligopoly. Oil, gas, and other non-renewable natural resources are essentially free to the resource owner, having been created millions of years ago and needing only to be extracted. Their ownership yields extraordinary profits, i.e. resource rents (Hotelling, 1931). As the number of competitors for rent increases, the proportion of rent each competitor can claim declines (Torvik, 2002). Under perfect competition rents tend to zero. For example, agriculture and tourism are markets with near-perfect competition, while the drinking water industry is highly regulated. Here, estimates of the resource rent are very low, sometimes even negative.

The net present value (NPV) approach was used to convert the estimated flow of ecosystem services into an estimate of the associated asset value. This required assumptions on the future flow of ecosystem services, the discount rate, and the economic lifespan of ecosystem assets.[21] The assumptions are:

1. The future flow of income for each ecosystem services is assumed constant and equal to the flow observed most recently.
2. The discount rate equals 3 percent, unless the ecosystem asset is thought to become scarcer and there are limited substitution possibilities, in which case a discount rate of 2 percent is used.
3. The asset life is 100 years for all ecosystem assets.

[21] The value of amenity services was estimated the other way around. Here, our method produced asset values – a percentage of the current value of houses that was attributed to nearby nature areas – which were converted to the value of ecosystem service flows using the same NPV approach.

7.2 Limitations

The results presented in this report should be handled with care. These are first experimental outcomes that should be improved and verified in the future. There are methodological limitations and ethical considerations, and there is the possibility of irresponsible use.

Valuation inevitably involves assumptions and uncertainties. Valuation according to SNA principles requires exchange values, but most ecosystem services and assets are not traded in markets in the same way as other goods, services, and assets (SEEA EEA, 5.1). It has proven necessary to impute 'missing prices' and to extract from the price of marketed goods and services that part which is attributable to ecosystem services. A critical caveat of the latter approach is that we must assume that the value of an ecosystem service is fully included in the market price.

In this study, we have valued 'only' ten ecosystem services. The scope is not yet comprehensive as we have not included a number of important ecosystem services, such as coastal protection (a regulating service) and marine ecosystem services. In that regard, the aggregated values presented here represent an underestimation. Furthermore, for some ecosystem services we have only included part of the exchange value. For example, for nature tourism and recreation the values now include only the part that is already included in GDP and not the exchange values related to all kinds of (positive) health effects that are not included in GDP.

Assigning an economic value to ecosystems gives rise to a number of ethical and cultural concerns. It can be argued that economic valuation turns nature into a commodity to be used by humans, that efforts to monetize the value of nature detract from its true (intrinsic) value, and that imputed non-market values are misleading (Silvertown 2015).

There is a risk that the statistics presented in this report may be misinterpreted. For example, a particular method may suggest that the economic value of an ecosystem service is zero or negative. It would be irresponsible to conclude that the associated asset truly has no value. This is particularly relevant when the resulting values are used to compare alternatives in policy decision making.[22] The statistics measure value within a narrow focus. The fact that we explain our focus does not relieve us from the obligation to strongly advise our readers to be careful when using the statistics presented in this report.

Valuation is, however, considered essential for communicating the economic value and scarcity of nature. We recognize that monetary values always have to be presented and analysed together with information from the other ecosystem accounts, that is, on extent, condition, and physical output. Monetary accounting must be developed in parallel with physical accounting in order to provide an overall view of the status and trends in ecosystem services.

[22] This involves the Hicks compensation paradigm, in which decisions that involve a particular cost (such as cutting down a forest with a particular monetary value) are considered responsible because there exist potential compensating measures, even when those measures are not actually taken.

7.3 Recommendations for future work

The development of the monetary ecosystem accounts for the Netherlands revealed methodological and conceptual issues for future work, also on an international level.

Develop time series

Although for some ecosystem services it was already possible to provide a short time series, this was not yet possible for all ecosystem services. Furthermore, the allocation of the values to ecosystem types was done only for one year. An important part of the policy applications stem from having the accounts for multiple years. Repeating the work for multiple years, would allow users to track changes in asset and service values and thus allow the evaluation of the change of natural capital in monetary terms over time. In addition, having all data presented in one consistent framework will further improve the strength of the estimates.

Improve the spatial allocation of values

The spatial allocation of the values for ecosystem services and ecosystem assets was primarily based on the maps for the physical supply of ecosystem services. As concluded in our previous study (Statistics Netherlands, 2017) these could be further improved, in particular for nature recreation and nature tourism.

Increase the scope of the ecosystem services

The estimates of total value are highly dependent on the scope of ecosystem services that are included in the calculations. Including more ecosystem services will provide a more comprehensive overview of the contribution of nature to human well-being. Particularly the five ecosystem services that have thus far been excluded from our estimates have to be investigated: two provisioning services (biomass from non-agricultural sources; fishing) and three regulating services (natural pest control; erosion prevention; protection against heavy rainfall). Furthermore, additional ecosystem services related to freshwater ecosystems (e.g. water supply, water filtration by rivers) could be included. In addition, the ecosystem services supplied by the marine environment (e.g. fisheries) could be added.

Test the applicability of the data on a more local level

The focus of this study was on compiling monetary data on the national and regional (provincial) level. However, spatially explicit data make it possible to zoom in to a more local level. It should be investigated whether these results make sense, for example by looking in-depth at specific urban areas, protected areas, or national parks.

Valuing tourism and recreation

The skewed relationship between nature recreation and tourism on the one hand and all other ecosystem services on the other does call for follow-up research. The expenditure approach and the resource rent approach lead to quite different results, as illustrated by comparing the earlier work of Remme et al. (2015) with this account. Further discussions, with national stakeholders as well as other countries working on the SEEA, are required to come to a better understanding of how these services can be valued.

Abbreviations

ACM	Autoriteit Consument en Markt (Authority for Consumers and Markets)
C	carbon
CANA	Nationally Attractive Nature Areas of the Netherlands
CICES	Common International Classification of Ecosystem Services
CO_2	carbon dioxide
CPB	Centraal Planbureau (Netherlands Bureau for Economic Policy Analysis)
GDP	Gross Domestic Product
GVA	gross value added
ha	hectare
ILT	Inspectie voor Leefomgeving en Transport (Human Environment and Transport Inspectorate)
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification of All Economic Activities
LCEU	land cover / ecosystem functional unit
m^2	square metre
m^3	cubic metre
MSR	maximum societal revenue
NPV	net present value
NVA	net value added
OECD	Organisation for Economic Co-operation and Development
ONA	Other Natural Areas
ONS	Office of National Statistics
PBL	Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency)
PIM	perpetual inventory method
PM	particulate matter
SCC	social cost of carbon
SEEA	System of Environmental-Economic Accounting
SEEA CF	System of Environmental-Economic Accounting Central Framework
SEEA EEA	System of Environmental-Economic Accounting 2012–Experimental Ecosystem Accounting
SEEA EEA TR	Technical Recommendations in support of the System of Environmental-Economic Accounting 2012–Experimental Ecosystem Accounting
SNA	System of National Accounts
SUA	supply and use account
SUT	supply and use table
TEEB	The Economics of Ecosystems and Biodiversity
TEV	total economic value
TSA	Tourism Satellite Accounts
VEWIN	Vereniging van Waterbedrijven in Nederland (Association of Water Companies in the Netherlands)
VOLY	value of a statistical life year
WOZ	waardering onroerende zaken (assessed property value)
WTP	willingness-to-pay
WUR	Wageningen University & Research

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