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Ecosystem Accounting Table

Valuing ecosystem services and ecosystem assets for The Netherlands

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Abstract

Ecosystems contribute to economic activities and provide economic value. There is an increasing interest in measuring these monetary values. This helps making comparisons with other macro-economic variables, such as GDP and the stock of non-financial assets. The System of Environmental Economic Accounting – Ecosystem Accounting (SEEA EA), adopted by the UN Statistical Commission in March 2021, provides internationally recognised statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is consistent with the concepts of the System of National Accounts. Although these guidelines provide a sound statistical basis, there is still a lack of practical experience in applying these principles and recommendations in ecosystem accounts.

Statistics Netherlands and Wageningen University & Research have been implementing the guidelines of SEEA EA since 2014. Ecosystem accounts for The Netherlands, including the monetary supply and use tables for ecosystem services and the ecosystem asset account, are now being compiled on a regular basis. This paper provides an overview of the valuation techniques applied for the different ecosystem services and the practical issues that were encountered. We found that it is important to distinguish between techniques that provide exchange values that are already incorporated in GDP and

exchange values that are not. In addition, we found that, from a conceptual and practical point of view, the best valuation techniques depend upon the type of service, as follows:

- 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 monetary values for the asset account depend upon the valuation of individual ecosystem services, as well as a number of assumptions including the choice of the most appropriate discount rate.

Introduction

Ecosystems contribute to economic activities and provide economic value. Valuation plays a role in signalling the scarcity and quality of ecosystem services and assets. Without such a signal, it is difficult/nearly impossible for people to perceive the economic value of ecosystem services and assets. Nijkamp et al. (2008) 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. There is an increasing interest to provide insight in the monetary values and their changes over time of ecosystems and the ecosystem services they provide, in order to make comparisons with other macro-economic variables like GDP and the stock of non-financial assets (e.g. Obst et al. (2016); Office of National Statistics (2018)).

The SEEA EA, adopted by the UN Statistical Commission in March 2021, provides internationally recognised statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is coherent with the concepts of the System of National Accounts (Hein et al. 2020b; UN 2021a). The main purpose of these guidelines is to support those countries and institutions that want to test and implement valuation of ecosystem services and ecosystems. However, within the statistical community, there is still an ongoing discussion on the use of monetary values of environmental stocks and flows in the measurement and assessment of the environment, also because, internationally, the experience to value ecosystems on a national scale is scarce (e.g. Brown et al. 2021). For this reason, the chapters of SEEA EA on monetary valuation are not yet part on the international statistical standard.

In SEEA, a key purpose of valuing ecosystem services in monetary terms is the integration of information on ecosystem condition and ecosystem services with information in the standard national accounts. This enables comparison of the supply and use of ecosystem services with the production and consumption of other goods and services. Additionally, it supports the use of ecosystem information in standard economic modelling and productivity analysis.

In 2016, Statistics Netherlands and Wageningen University started the implementation of SEEA Ecosystem Accounting for The Netherlands, on behalf of the Ministry of Economic Affairs and the Ministry of Infrastructure and the Environment (Remme et al. 2018; Hein et al. 2020a; Statistics Netherlands and Wageningen University 2021b). The project's aim is to test and implement SEEA EA ecosystem accounting on a national scale, including the monetary ecosystem accounts. This paper provides an overview of the methodology and valuation techniques applied for valuing the different ecosystems services and ecosystem assets. The lessons learned from this study may support the ongoing discussion in this area and the global implementation of the SEEA EA framework.

Data and methods

The ecosystem accounts of The Netherlands have been compiled for 11 different ecosystem services (Table 1). Based the guidelines provided by the SEEA EA (chapters 8-9; UN 2021a), we have applied to following key principles for the valuation of ecosystem services:

Table 1.
Overview of the methods and data sources used to value ecosystem services in The Netherlands.

	Ecosystem service	**Valuation method applied**	**Data sources used**
Provisioning ecosystem services	crop production	Rent prices	Agricultural statistics (harvesting data), Registry on agricultural parcels, Rent prices
	fodder production	Rent prices	Agricultural statistics (harvesting data), Registry on agricultural parcels, Rent prices
	timber production	Stumpage prices	Statistics on wood harvested, stumpage prices for timber
Regulating ecosystem services	air filtration (PM2.5)	Avoided damage	Ecosystem type map Netherlands, Yearly average PM2.5 concentrations, PM10 capture parameters, Age-dependent mortality data, Life expectancy data, Neighbourhood statistics.
	carbon sequestration	Efficient carbon prices (replacement cost)	Ecosystem type map Netherlands, Look-up table sequestration rates, Efficient carbon price for The Netherlands (PBL)
	water filtration	replacement cost	water statistics, expenditure data water companies
	coastal protection	replacement cost	Length of coastal dunes, Expenditure data coastal dykes

	Ecosystem service	Valuation method applied	Data sources used
	pollination	Avoided damage	Ecosystem type map Netherlands, Registry on agricultural parcels, Pollination requirements, Habitat suitability for pollinators, Standard yield by crop type
Cultural ecosystem services	nature recreation	Consumer expenditure	Recreation statistics, Expenditure data (based on survey)
	nature tourism	Consumer expenditure	Tourism statistics, Expenditure data (based on survey)
	amenity services	Hedonic pricing	Housing stock registry, Ecosystem type map

- 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 not taken into account.
- 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).
- The focus is on the actual use of ecosystem services rather than the capacity of ecosystems to deliver ecosystem services. This is consistent with the concept of actual transactions as recorded in the System of National Accounts (SNA).
- We focus on the calculation of exchange values for ecosystem services (consistent with the principles of the System of National Accounting) rather than welfare values. In the discussion section, we will elaborate on this.
- All monetary data for ecosystem services were made spatially explicit, i.e. maps were produced in order to allocate all values to ecosystem types.

Basically, the monetary accounts for ecosystem services were compiled by applying the following steps. Starting point is the data from the extent account and physical data for ecosystem services, as recorded in the physical supply and use tables. The compilation of these data is described in detail in the technical background report (Statistics Netherlands and Wageningen University 2021a). Next, for each ecosystem service, the most appropriate valuation method was chosen (Table 1; for a more detailed description see Statistics Netherlands and Wageningen University 2020). In general, valuation methods were chosen that concur with the general guidlines provided in the SEEA EA and that could be applied taking into account practical considerations (e.g. data availability). The underlying motivation for choosing these methods is discussed in more detail in the Discussion section. Spatially-explicit maps were made for the monetary values of each ecosystem service, which allows the allocation of the values to ecosystem types. For some ecosystem services, such as pollination and air filtration, spatially-explicit monetary values are directly obtained by the models used. For other ecosystem services, such as carbon

sequestration and timber production, the total values calculated for national or regional scale were made spatially explicit using the physical maps of these ecosystem services.

The final step is the recording of the values in monetary supply and use tables for ecosystem services. In the supply table, the value of ecosystems services is allocated to different ecosystem types, i.e. the producers of the ecosystem services. In the 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. Supply and use tables have been compiled for 2013, 2015 and 2018. Extended supply and use tables (as discussed and presented in section 4) are available for 2015.

Valuation of ecosystem assets

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 (UN 2021a). This approach requires assumptions that are described here in more detail.

The first assumption relates to the future flow of income for each ecosystem service. We assumed 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. For example, there is, at present, no overharvesting (where harvest exceeds mean annual increment) of wood in Dutch forests, but potentially water or air pollution may affect future flows of services from these ecosystems. We anticipate that these effects are, for now, modest for most services given that there are no clear indications that ecosystem degradation is reaching the point where the selected ecosystem services cannot be provided any longer or where their supply would be jeopardised. This, however, does not mean that biodiversity in The Netherlands is not under increasing pressure from sustained eutrophication and climate change. Even though biodiversity and, in particular, species richness and abundance may be affected, there are no indications that this would lead to a loss of ecosystem services, which depend mostly upon the structure and functioning of ecosystems and not as much on the presence of threatened species. We note also ongoing efforts to rehabilitate ecosystems. Furthermore, it may be assumed that, for some ecosystem services, demand will increase in the future. For example, 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. In addition, the predicted population growth for The Netherlands will also lead to a higher demand for recreation services. As of yet, this has not yet been incorporated in the asset calculations, but may be considered in a future update of the account.

The second assumption relates to the choice of the discount rate. The value that is chosen is an important determinant of the asset value. Over the years, there have been various interdepartmental working groups in The Netherlands to determine the discount rate to be used by the Dutch government in public cost-benefit analyses. The ‘Werkgroep

Discontovoet' (2015) advised adjusting the discount rate for public investments to 3 percent. For nature, the advice is to take into account increases in the relative prices, due to increased scarcity and limited substitution possibilities, resulting in an effective discount rate of 2 percent. 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 are harder to replace, they recommend a discount rate of 2 percent. In line with these recommendations, we have applied the 3 percent discount rate for provisioning services and 2 percent for regulating and cultural services, which are scarcer and harder to substitute.

The third assumption is related to the asset life, which is the expected period of time over which the ecosystem services are to be delivered. We applied an asset life of 100 years for all ecosystem assets, which is in line with asset account calculations as done in Great Britain (Office of National Statistics 2018). This period is somewhat arbitrary, but values provided after 100 years do not contribute much to the Net Present Value because of the discount rate applied.

Accounting tables and results

The monetary value of the annual contribution of ecosystem services to the Dutch economy was 16.6 billion euros in 2018 (Table 2). This is equivalent to 2.1 percent of GDP. Cultural services account for by far the largest share with 14.4 billion (87 percent). Provisioning and regulating services account for 7 percent and 6 percent, respectively, at 1.2 and 1.1 billion euro. Provisioning services are produced almost exclusively by agricultural ecosystem types (94%). Most of the value of regulating services is produced by forest (32%), grassland (17%) and fresh water ecosystems (17%). Cultural services are produced mostly by forests (32%), dunes and beaches (20%) and open nature ecosystem types (14%). Public green space produces 7 percent of cultural ecosystem services through recreation and amenity services. Water ecosystem types account for 33 percent of the value of amenity services.

Table 2.

Supply table for ecosystem services in The Netherlands, 2018 (Statistics Netherlands and Wageningen University 2021b).

million euro	**Forest**	**Open nature**	**Wet-lands**	**Dunes and bea-ches**	**Water**	**Crop-land**	**Grass-land**	**Horti-culture**	**Other agri-culture**	**Urban and infra-sucture**	**Public green space**	**TOTAL**
Producing services												
Crop production	0.4	2.4	0.0	0.0	0.1	498.1	13.5	0.1	0.3	2.0	0.1	517.0

million euro	**Forest**	**Open nature**	**Wet-lands**	**Dunes and bea-ches**	**Water**	**Crop-land**	**Grass-land**	**Horti-culture**	**Other agri-culture**	**Urban and infra-sucture**	**Public green space**	**TOTAL**
Fodder production	1.3	12.8	0.2	0.3	0.3	132.2	512.0	0.0	0.0	5.0	1.7	665.9
Timber production	43.7		0.5									44.3
Regulating services												
Water filtration												181.4
Air filtration	85.5	2.7	2.3	0.4	0.0	10.2	13.5	0.0	0.0	11.5	45.8	172.0
Carbon seque-stration	83.0	6.7	6.7	4.0	0.0	8.7	34.8	0.0	0.1	7.3	10.1	161.3
Pollination	95.2	81.1	9.6	2.6	0.0	8.4	133.0	0.0	3.1	25.2	16.4	374.5
Coastal protection	45	0		116	0	0				0	0	161
Cultural services												
Nature recreation	1954	396	136	321	464	525	727	2	3	524	774	5826
Nature tourism	2351	1545	543	2430	184	0	0	0	0	0	0	7053
Amenity services	345.2	90.2	7.1	90.6	488.2	30.4	68.3	0.1	0.1	95.2	259.9	1475.3
TOTAL	5004.7	2137.2	705.0	2966.0	1137.2	1212.9	1501.6	1.9	6.8	670.2	1107.8	16632.6

Producing services are used almost entirely by the agricultural and forestry sector (Table 3). Regulating services are used by businesses (water filtration, pollination), households (air filtration) and the government (climate regulation and coastal protection). Cultural services are consumed by households or non-residents. Nature recreation and amenity services are only used by Dutch households, while nature-related tourism is partly used for foreign tourists (non-residents). As cultural services make up the bulk of all services in terms of monetary value, households are the main users of ecosystem services at 64 percent, followed by non-residents (24 percent) and the agricultural sector (9 percent).

Table 3.

Use table of ecosystem services for The Netherlands, 2018 (Statistics Netherlands and Wageningen University 2021b).

million euro	Agri-culture	forestry and fisheries	Manufac-turing and mining	Energy supply	Water supply and environ-mental services	Services	House-holds	Govern-ment	Export	Total
Producing services										
Crop production	517									517
Fodder production	666									666
Timber production		44								44
Regulating services										
Water filtration					181					181
Air filtration							172			172
Carbon sequestration								161		161
Pollination	375									375
Coastal protection								161		161
Cultural services										
Nature recreation							5826			5826
Nature tourism							2910		4143	7053
Amenity services							1475			1475
TOTAL	1557	44	0	0	181	0	10384	322	4143	16633

Forests, open nature, wetland, dunes and beaches represent about 60 percent of the value of the ecosystem capital, increasing from 59 percent in 2013 to 64 percent in 2018 (Table 4). The share of agricultural ecosystem types in the total value decreased from 18

percent in 2013 and 2015 to 15 percent in 2018. The average value of ecosystem capital per hectare increased from 116400 euros in 2013 to 156900 euros in 2018. In 2018, dunes and beaches had the highest average value per hectare (2.3 million euros). The average value per hectare of forest, open nature, wet areas, dunes and beaches was 643800 euros, of agricultural ecosystem types 53336 euros and of public green space in cities 384300 euros.

Table 4.
Monetary asset account for The Netherlands.

million euro	**Forest**	**Open nature**	**Wet-lands**	**Dunes and beaches**	**Water**	**Crop-land**	**Grass-land**	**Horti-culture**	**Other agri-culture**	**Urban and infra-sucture**	**Public green space**	**TOTAL**
2013	182645	82679	25001	108230	46838	47501	65154	80	299	20206	50730	634828
2015	194719	91687	29177	127676	45415	49997	66548	74	254	19212	47361	678631
2018	267805	114434	37819	159165	61020	54468	71728	99	358	35845	59419	868836

Discussion

A key purpose of monetary valuation in the SEEA EA is the integration of information on ecosystem services and ecosystem assets with information in the SNA (UN 2021a). In SEEA EA, the production boundary, which defines production and GDP in the SNA (UN 2010), is extended to include the production of ecosystem services. Accordinlgy, in some cases, ecosystem services provide additional value added to GDP, i.e. when compared to the standardised compilation of GDP following the guidelines of the SNA. A key issue for integration in the SNA is, therefore, to determine what value provided by ecosystem services is already included in GDP and what value is not.

Here, we will look into this issue by looking in more detail at the different approaches and methods that are used to value ecosystem services. The focus will be on exchange values, but we will also briefly address welfare values. Fig. 1 provides a schematic overview of the monetary and non-monetary values provided by ecosystems. The identification and evaluation of the different approaches to valuation 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 EA and (d) to better interpret and use the results.

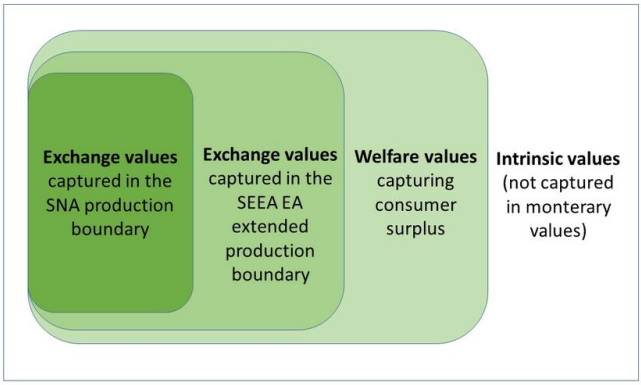

Figure 1.

Overview of values provided by ecosystems

Exchange values already included in GDP

Exchange values are the values at which goods, services, labour or assets are in fact exchanged or else could be exchanged for cash (2008 SNA, para. 3.118). In an ecosystem accounting context, 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 (UN 2021a). Since the ecosystem assets themselves are not actual market participants, the challenge in valuation lies in establishing the assumptions about the institutional arrangements that would apply if there was an actual market involving ecosystem assets. Exchange values are of interest because they allow direct comparison of values of ecosystem services and assets with existing national accounting values. Therefore, this is the recommended approach to apply in SEEA EA (UN 2021a).

Exchange values provided by ecosystem services may or may not already be included in GDP. To address this issue, we first have to look at how ecosystem services are used in economic activities and how they are recorded in the accounts of the SNA. The use of ecosystem services can be categorised according to four main groups of users, which correspond to an input to different economic activities as recorded in the SNA:

1. *Use by businesses (input for production activities)*. These are ecosystem services that are used as inputs for SNA production activities. Examples include biomass provisioning services (crops, timber) used by agricultural and forestry activities. In an SNA/SEEA context, they are recorded as ‘intermediate consumption’ in the use table. These ecosystem services contribute to the production of goods and services currently included in the economic production boundary of the SNA (SNA benefits). The value of these ecosystem services *may* already be included in GDP as will be discussed below.

2. *Use by households (input for consumption activities)*. These are ecosystem services that are directly used by individuals. In an SNA/SEEA context, they are registered as 'final household consumption' in the use table. Examples are air filtration and nature recreation services. They may contribute to either 'SNA benefits' or 'non-SNA benefits'. SNA benefits in this context are the (extra) consumption of SNA products that will occur as a direct consequence of the use of the ecosystem service, for example, expenditure related to nature recreation. These expenses are already included in GDP (as final household consumption). Non-SNA benefits for households are, for example, related to improved health conditions. These benefits are not produced by economic units and consequently not included in GDP. The value of the ecosystem services used by households is, therefore, partially included in GDP.
3. *Use by government (input for consumption activities)*. These are the ecosystem services that accrue to society as a whole. In an SNA/SEEA context, they are registered as 'final government consumption' in the use table. An example is carbon sequestration, as society as a whole benefits from less CO_2 in the atmosphere and CO_2 sequestration can reduce the efforts that need to be taken by governments to implement climate mitigation policies. These are 'non-SNA benefits' in a sense that these benefits are not produced by economic units, except where this concerns commercial carbon projects (e.g. projects that sell carbon credits or offsets on the voluntary or regulated market). Hence, the value of these ecosystem services is not included in GDP.
4. *Use by non-residents (exports)*. These are services that are supplied to and used by non-residents. An example is nature tourism, when non-residents come on holiday and enjoy the benefits of nature. Use by non-residents are recorded under 'exports' in the use table. Similar to services supplied to households, these may be partially included in GDP. Vice versa, the use of nature by residents in other countries may be classified as imports.

The next step is to determine how the value provided by ecosystems services is recorded in the production/generation of income account of the SNA. Natural resources, which include ecosystem assets, provide benefits either from being used in production or simply from being held over a period of time. These economic benefits accrue to and are thus included in net operating surplus or mixed income in the generation of income accounts, which is part of gross value added (GVA). When the legal owner of the asset is not the same as the economic owner (i.e. the user of the asset), an actual payment takes place for the use of the asset. This is a situation that is common for most ecosytsem services. For example, farmers can rent the land for which they annually have to pay a rent price. These rent payments are recorded in the allocation of primary income account and the entrepreneurial income account (SNA 7.13). When the legal owner is also the economic owner, an imputed rent can be calculated, based on the price of the land and an assumed rate of return.

Now we come back to the question in which cases the value ecosystem services is already included in gross value added of production activities. SNA production activities (i.e.

businesses) may use many different ecosystem services, including provisioning and regulating services. Although all these services provide some kind of benefits, not all provide direct *positive* economic benefits in a sense that they directly contribute to the value added of the production activity. This is, for example, clear from resource rent calculations that show that some ecosystem services, including open access fisheries and water supply, provide zero or negative resource rents. In order to determine whether an ecosystem service directly contributes to GVA of a production activity, we can apply the following general criteria:

- If the legal owner of the asset supplying the ecosystem service is not the same as the economic owner, usually an explicit rent payment occurs. If this is not the case, the ecosystem service is provided 'for free' and does not contribute to GVA as recorded in the SNA.
- If the economic owner is the legal owner of the asset, the owner/user must have bought the asset on the market. If this is not the case, the ecosystem service does not contribute to GVA as recorded in the SNA.
- If the government is the owner/user, the value of the ecosystem service does not contribute to GVA as recorded in the SNA. This is because net operating surplus (to which the value of the ecosystem service accrues) of government is zero by definition.

The application of these criteria is illustrated below by describing some examples.

- *Crop provisioning services*. The inputs provided by agricultural land to crop production (nutrients, soil water etc.) is an example where the value of the ecosystem service is included in the GVA of agricultural production. When the farmer (the economic owner) is not the legal owner, the land is rented and the farmer has to pay a rent price. As rent payments are part of net operating surplus of the agricultural production, they directly contribute to GDP. When the farmer owns the land, the land has a market price for which an imputed rent can be calculated. Generally, sometime in the past, the farmer (or his ancestors) has acquired the land on the market.
- *Harvest of marine fish*. In general, the government assumes legal ownership of marine fish stocks that occur within the national EEZ and are subject to international agreements. The government may collect the associated rents by selling fishing licences or quotas to certain designated enterprises. The value of these quotas and licences, which reflect the value of the ecosystem service, is included in the net operating surplus and thus gross value added. Often these fishing licences and quotas are assigned to fishing companies for free. In that case, the value of the associated resource rent and, thus, the value for the ecosystem service, is zero. This is in line with resource rent calculations for fisheries that often show a zero or near zero resource rent.
- *Pollination*. Pollination of cropland usually occurs by pollinators coming from adjacent areas. In most cases, the 'ownership' of these pollinators will not be clear. Even if the ownership could be established (i.e. the legal owner of the land where the pollinators originate), it is highly unlikely that this owner will receive actual rent

payments from the farmers. Thus, the value of pollination services will not accrue to the value added produced by the farmer. Here, it may be argued that the value of pollination may (partly) be incorporated in the value of the agricultural land: a location close to areas with pollinators may increase the land value. However, it is questionable whether the presence or absence of pollinators actually is a real consideration for the fixation of land prices. The presence of pollinators is usually a prerequisite for starting to grow a certain crop. The provision of this ecosystem service is, thus, taken 'for granted'. The contribution of pollination to the actual land value, thus, will probably be zero or near zero.

- *Coastal protection*. Coastal protection is an example of an ecosystem service that may provide benefits to all of society, including households and businesses. This is the case for The Netherlands, where the dunes protect the rest of the country. Accordingly, government acts as the economic owner on behalf of the country. The use of the service is recorded as final government consumption, but is not recorded in the value of GDP.

Exchange values for ecosystem services not included in GDP

As discussed in the previous section, the value of many non-marketed services is not incorporated in the gross value added of the SNA. These services are provided to the users 'for free' in a sense that they do not have to pay for them. However, it can be argued that these services do have an implicit exchange value and (indirectly) contribute to GDP. Although this value is not included in the GDP, as calculated according to the definitions in the SNA, it can be made explicit and incorporated in the SEEA EA as a result of the extension of the production boundary. As there is no market price for the benefit from which the value of the ecosystem service can be derived, alternative valuation strategies for these services must be pursued.

One strategy is to 'construct' transactions and then estimate a value for them. These imputed transactions are recorded when there are flows that are considered analytically useful to treat as transactions. Imputed transactions are also used in the SNA, for example the consumption of fixed capital (depreciation) or imputing 'rents' to owners of houses to value the housing service they receive. In order to determine exchange values of non-marketed ecosystem services, we have to consider the following question: What would happen to GDP if the ecosystem service ceases, i.e. the ecosystem stops to supply the ecosystem service and its contribution to the economic benefits ends? There are two main approaches to answer this question:

1. *Replacement cost approach*. If (for whatever reason) the supply of the ecosystem service ceases, it could be (and it can reasonably be expected that it will be) replaced by an economic production activity that provides a similar service. This must be the most cost effective alternative. For example, the water purification service may be replaced by a water purification plant. Replacing the production of an ecosystem service (not included in GVA of the SNA) with a production activity

(which would be included in the GVA of the SNA) results in an increase in GDP. This increase would then be equal to the imputed value of the ecosystem service.

2. *Damage costs approach*. If (for whatever reason) the supply of the ecosystem service ceases, it may cause damage to the economy. To amend these damages, costs must be made which will lead to an increase of economic production activities and, thus, an increase in GDP. For example, if the supply of air filtration by trees would stop, this would incur more health problems by individuals. This will lead to more health-related expenditure which, in turn, would lead to an increase in GDP. This increase would then be equal to the imputed value of the ecosystem service.

The replacement and damage cost approach work well to determine exchange values for most regulating services, but much less so for provisioning and cultural services.

Welfare values

Welfare economic values entail obtaining valuations that measure the change in the overall costs and benefits associated with ecosystem services and assets (UN 2021a). Welfare values are often related to changes in the sum of the producer and the consumer surplus. It includes the 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. For example, when a consumer buys a loaf of bread or a litre of gasoline, the SNA records the transaction at the purchase price, not the added value to the consumer given that they would be willing to pay more (e.g. a consumer is willing to spend 3 euros on a loaf of bread and get it for 2.5 euros, the 2.5 euros is recorded, not the 0.5 euro consumer surplus). 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 EA does recognise 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. However, for reasons explained above, the current focus of the SEEA EA 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.

Linking valuation approaches and methods to different ecosystem services

Summarising, in the above sections, we found that, besides the distinction between exchange and welfare values, it is important to differentiate between exchange values already included in GDP or not. In addition, it is important to distinguish between the input into SNA production and consumption activities. The suitability of applying these different approaches differs for the main categories of ecosystem services (see Table 5).

Table 5.

Indicators of value most relevant for the three main classes of ecosystem services.

	Exchange values			**Welfare 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		
Provisioning ecosystem services	X			x
Regulating ecosystem services			X	X
Cultural ecosystem services		X	X	X

- **Provisioning services** are always related to a contribution to SNA production activities. Note that when households are using provisioning services (timber, water etc.), according to the SNA, they should be treated as production activities, as households, by definition, cannot produce goods. The exchange value of ecosystem services that is 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 these production activities. 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 problematic, as businesses will pass on any extra cost when an ecosystem service becomes scarcer to the consumers of their products.
- **Regulating services** are used as input for both SNA production activities and consumption activities. A key characteristic of these services is that they are provided as 'free services' and their exchange values are, as a general rule, not included in GDP. These values thus have to be imputed using alternative valuation methods. The only exception is when government has implemented Payments for Ecosystem services (PES) schemes, which may be monitored using data from the SEEA CF monetary activity accounts (UN 2014). Welfare values, which are excluded from SEEA EA, may be determined, based on information on the willingness-to-pay of its users.
- **Cultural services** are usually provided to individuals and, thus, related to a contribution to consumption activities by households or non-residents. An exception concerns the amenity services, as the production of housing services by owner-occupiers is included in the production boundary of the SNA. Exchange values may already be included in GDP, for example, as expenditure for nature-related tourism or may not be included in GDP, for example, as avoided health costs due to recreation in nature. Welfare values may be determined using information on the willingness-to-pay of its users.

Now we can address a key question in monetary valuation, namely what methods should be used to measure the monetary value of each ecosystem service. In literature, a wide scope of different valuation techniques is described to value ecosystem services (for an overview, see UN 2021a and UN 2021b). The nature of the value that is derived from each technique can be related to the valuation approaches that have been identified. This is a fairly straightforward exercise, the results being shown in Table 6. When we now combine Tables 5 and 6, we can select the most appropriate method(s) for the individual ecosystem services (Table 7). Table 7 provides the basis for the selection of valuation techniques for valuing ecosystem services in The Netherlands. Furthermore, we have selected methods that can be based on existing statistical economic data, such as national accounts statistics, production statistics, price statistics, tourism statistics etc. Finally, is some cases, a choice had to be made between two methods, for example, between rent prices and resource rent for provisioning services. This is explained in more detail in the technical background report (Statistics Netherlands and Wageningen University 2021a).

Table 6.
Valuation approaches linked to different valuation techniques.

		Valuation techniques	**Exchange values**			**Welfare 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		
1	Directly observable values	Rent prices	X			
2	Prices from similar markets	Proxy markets			X	
3	Embodied in market transactions	Resource rent	X			
		Hedonic Price	X			
		Productivity Change	X			
4	Related goods and services	Defensive Expenditure			X	
		Travel Cost		X		
		Consumer expenditure approach		X		
5	Expected expenditure or markets	Replacement Cost			X	
		Damage Cost Avoided			X	

		Valuation techniques	Exchange values			Welfare 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		
		Simulated Exchange Value			X	
	Other methods	Contingent Valuation				X
		Choice Modelling				X

Table 7.
Most appropriate methods for estimating the value of ecosystem services.

	Ecosystem service	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	
Provisioning ecosystem services	crop production	rent prices / resource rent		
	fodder production	rent prices / resource rent		
	timber production	rent prices (stumpage prices) / resource rent		
Regulating ecosystem services	air filtration			avoided damage
	carbon sequestration			avoided damage/ social cost of carbon
	water filtration			replacement costs
	coastal protection			replacement costs
	pollination			avoided damage
Cultural ecosystem services	nature recreation		consumer expenditure / travel cost	

	Ecosystem service	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	
	nature tourism		consumer expenditure / travel cost	
	amenity services	hedonic pricing		

Extended supply and use accounts

Extended supply and use accounts (SUA) present the data on the supply and use of ecosystem services as extensions to the standard SUA compiled following the SNA (UN, 2021a). The starting point for compiling the extended SUA is the (aggregated) SUA of the SNA with data for The Netherlands (Table 8). The supply and use of SNA products is shown in the rows. 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.

Table 8.
Supply use account with SNA data for The Netherlands, 2015

	Industries			taxes/ subsidies	House-holds	Govern-ment	Investments/ inventories	Imports/ exports	TOTAL
million euro	**A Agriculture**	**B_E Manufac-tering**	**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

	Industries			taxes/ subsidies	House-holds	Govern-ment	Investments/ inventories	Imports/ exports	TOTAL
Net operating surplus	5556	34336	133317						173209
GDP									690008

The extended SUA for The Netherlands 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) (Table 9). One column for ecosystem assets has been added to the SNA SUA, which here has not been disaggregated by ecosystem type for representational reasons. In the rows, the different ecosystem services have been presented. Integration of ecosystem services in the SUA involves more than simply adding rows for ecosystem services. As discussed above, 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:

Table 9.

Extended supply and use tables for The Netherlands, 2015.

million euro	**Eco-sys-tems**	**A Agri-culture**	**B_E Manufa-ctering**	**F-Z Ser-vices**	**taxes/ sub-sidies**	**House-holds**	**Govern-ment**	**Invest-ments/ inventories**	**Imports/ exports**	**TOTAL**
Supply										
SNA products		30718	346930	949540	69173				518594	1914956
Ecosystem services	12981									12981
Crop production	415									415
Fodder production	872									872
Timber production	44									44
Drinking water	177									177
Carbon sequestration	171									171
Pollination	359									359
Air filtration	86									86

million euro	Eco-sys-tems	A Agri-culture	B_E Manufa-ctering	F-Z Ser-vices	taxes/ sub-sidies	House-holds	Govern-ment	Invest-ments/ inventories	Imports/ exports	TOTAL
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
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
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
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

- The values of the *provisioning 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 does not lead to a change in total GVA and GDP.
- 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. Recording these services in an SUA leads to a net increase in final household and final government consumption. Overall, the integration of regulating services does lead to a change in total GVA and GDP.
- The values for the *cultural services* 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. Additionally, 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 does not lead to a change in total gross value and GDP. This is because the contribution of cultural services to non-SNA benefits has not yet been taken into account.

Contribution to GDP

Well-functioning and diverse ecosystems are critical for sustaining human life and a key element of well-being. However, the extended SUA for The Netherlands shows that the contribution of ecosystems services to GDP is 'only' around 2%. Similar results have been reported for other countries (e.g. Office of National Statistics 2018).

There are several reasons why our estimates seem to be low. First, in our study, only eleven ecosystem services were valued for The Netherlands. Notable omissions are marine and freshwater services, flood control and carbon retention. Second, not all relevant economic values may have been captured. The scope of value applied in SEEA EA is limited to the economic value of human benefits produced by ecosystems. All other notions of value – that may or may not be expressed in monetary terms – have been ignored. Additionally, we assume that all relevant aspects of value are captured in the explicit prices that we have used to estimate the value of ecosystem services. This assumption may be incorrect, considering that ecosystem services are, for all intents and

purposes, provided for free. Third, ecosystems contribute to specific parts of the economy and to specific spatial areas. In each of these sectors (such as agriculture, forestry, and tourism) and spatial areas (such as dunes and beaches), the contribution of ecosystems may be considerable. Fourth, an unknown, but potentially sizable proportion of the ecosystem services that contribute to the economy of The Netherlands is produced in other countries. The Netherlands is a very open economy. Yet, we do not measure the ecosystem content of imported products into The Netherlands. Finally, monetary values for ecosystem services may not well express the actual economic dependency. For example, cropland provides a significant, but still relatively modest contribution to the value added of farming, but without land, farming would not be possible at all.

We argue that, for the reasons outlined above, one has to be careful with the direct comparison of SEEA EA monetary values for ecosystem services with GDP, as this may lead to misinterpretation of the results. Instead, it is better to focus on other comparisons and uses for SEEA EA monetary values, including the comparison of the ecosystem contributions to different economic sectors, monitoring of changes in value over time, identification of ecosystem hotspots (which ecosystems in which regions supply most value) and their use as an input for scenario analysis etc. (UN 2021b).

Conclusion

In this study, we have presented the experimental monetary ecosystem service supply and use account and ecosystem asset account for The Netherlands, based on the guidelines provided by the SEEA EA 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, nor are reciprocal relationships with nature (UN 2021a;Normyle et al. 2022). 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. The focus is on the *actual use* of ecosystem services rather than the capacity of ecosystems to generate ecosystem services. Finally, we calculate exchange values for ecosystem services rather than welfare values, thereby excluding consumer surplus.

We have estimated the value of eleven ecosystem services: crop production, fodder production, timber production, air filtration, carbon sequestration in biomass, water filtration, pollination, coastal protection, 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, the selected methods can be applied using sound statistical data, enhancing their reliability and credibility. We found that it is important to distinguish between exchange values already included in GDP or not. This is important because this 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 EA and (d) to better interpret and use the results.

The results of this study show 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. Clearly, more testing by other countries of the concepts and methods is needed to help advance the implementation of the monetary accounts of the SEEA EA.

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