The SEEA EEA carbon account

for the Netherlands

Paper for the London group meeting 2017 in Costa Rica

This paper for the London Group is an abbreviated version of the report that will be published in October 2017. Here we focus on some conceptual issues and the results and for a detailed description of the data sources and methodology we refer the more extensive report.

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1. Introduction

Carbon is an important central theme in the SEEA EEA because it is, in a number of ways, related to the core accounts of ecosystem accounting; it plays a role in the supply and use accounts of ecosystem services (e.g. supply of wood and other biomass, and carbon sequestration) and in the condition account (e.g. soil carbon content influences crop productivity). In addition, the carbon account takes into account the registered emissions of carbon to the atmosphere (air emission accounts of the SEEA-CF) and includes some of the carbon in materials, as reported in the physical supply and use tables and more specifically the economy wide material flow accounts (MFA in the SEEA-CF). Hence, the stocks and flows of carbon are an important theme in a number of the environmental accounts in general, and in the ecosystem accounts in particular. Moreover, the carbon account presents a number of important additional policy applications compared to present monitoring systems, related to both the integrated approach where carbon in the economy and in the ecosystems are analysed in an integrated manner, and related to the mapping of carbon flows in the ecosystems.

The SEEA EEA carbon account can be used to answer a range of questions such as; 1) where and how much carbon is currently 'in stock' in a country and in what form, 2) how large are natural and man-made emissions of carbon, 3) where and how strong are the natural sinks for carbon (i.e. carbon sequestration), 4) what is the impact of recycling (in the economy) on emissions of C, and 5) which economic sectors contribute most to emissions of these gasses? The carbon account is unique in that it provides a fully comprehensive and fully consistent overview of C in its different forms and uses.

This study aims to compile a comprehensive carbon account for the Netherlands for one year (2013). All currently available information on carbon stocks and flows were combined in a consistent manner and new models for a number of carbon stocks and flows were developed for which no information was available. Where relevant and possible, data were made spatially explicit. The carbon account for the Netherlands was developed within the scope of the 'System of Environmental Economic Accounts – Experimental Ecosystem Accounting' (SEEA EEA) project for the Netherlands (Natuurlijk Kapitaalrekeningen Nederland: NKR_NL), which is currently carried out jointly by Statistics Netherlands and Wageningen University. Funding and support was provided by the Ministries of Economic Affairs and Infrastructure and the Environment.

2. Scope and methods

The carbon account was developed to allow for a consistent and quantitative comparison of carbon stocks and flows in the reservoirs 'biocarbon' (organic carbon in soils and biomass), 'geocarbon' (carbon in the lithosphere), atmospheric carbon and carbon in the economy[1]. Hence, the account provides a comprehensive overview of stocks of carbon in its many different forms and the ways in which carbon flows through these different reservoirs. The carbon account was based on the combination of datasets from numerous sources, combined with new modelling efforts to capture aspects of the carbon account that were not yet known. For biocarbon, the inputs to the account were modelled in a spatially explicit manner. For the development of these maps, existing models and data describing biocarbon (kindly provided by, among others, PBL and Wageningen Environmental Research) were combined with new data and with the Ecosystem Unit map for the

[1] For this study, we have excluded marine and lacustrine carbon.

Netherlands (EU_NL map, Statistics Netherlands, 2017). This resulted in an up-to-date overview of major stocks and flows of biocarbon for the ecosystem units recognized in this map (these ecosystem units are also the basic spatial unit throughout the NKR_NL project, to develop ecosystem accounts for the Netherlands). For geocarbon, data were derived from existing asset accounts for fossil fuels. These data were complemented with additional data on other types of geocarbon. Data on atmospheric carbon were derived from the national air emissions inventory and air emission accounts, whereas the information on carbon in the economy was primarily derived from the Energy accounts, the economy wide Material Flow accounts, the physical supply and use tables (Material Monitor) and the Waste accounts. Carbon in the oceans was not included in this carbon account due to a lack of data.

The purpose of the carbon account was to integrate existing information on carbon as reported through various mechanisms including the national air emissions inventory, the reports on forests and LULUCF to the UNFCCC, the air emission accounts, and to extend these data by adding spatially explicit data on emissions and sequestrations in the biosphere, including emissions from peat oxidation. The scope of the carbon account as described in this report thus builds upon, but goes beyond current carbon reporting systems. The structure of the account follows the SEEA EEA, leading to a fully comprehensive carbon account. Because all values are reported in units of C they can be compared quantitatively. Hence, the applications of the carbon account are broader in scope than other reporting efforts.

3. Results

3.1Biocarbon

Biocarbon includes all carbon in the biosphere, i.e. carbon in living biomass (plants and animals) and soil organic matter (SEEA EEA, 2014)[2]. Following the concepts of the SNA, cultivated biological resources are, however, part of the economy. Consequently, biomass in crops, grass in meadows and livestock are part of 'carbon in the economy' and not of biocarbon. This only applies to the living biomass of crops and livestock; soil carbon underlying cropland and meadows and dead crop residues left on the field are part of biocarbon. Although forests in the Netherlands are to a large degree managed, it was decided to allocate carbon in forests to biocarbon and not to the economy.

The carbon account records the total stocks for biocarbon and the changes in these stocks. In principle all relevant stock changes for biocarbon can be accounted for, i.e. net primary production, degradation of biomass, soil respiration, harvesting of biomass etc. Particularly relevant here are the different processes related to the formation and storage of carbon in the biocarbon cycle. The biocarbon cycle is known as a short carbon cycle because storage of the carbon is, in principle, relatively short lived; if trees or wood are burned, carbon is released again into the atmosphere. Similarly, surficial soil carbon can be released by e.g. ploughing or erosion, and carbon stored in peatlands may be released when water levels change, be it by natural or man-made causes.

[2] For biocarbon in soils, for practical reasons only the top 30 cm were included in this study. In particular for peat and peaty soils, this results in a strong underestimation of the total stock of biocarbon in soils. This shortcoming in the current models also potentially influences C flows in the case of water figure changes exceeding this depth.

Therefore, the duration of carbon storage in the form of biocarbon is relatively instable in the long geological perspective. Nevertheless, biocarbon stocks can be substantial and are highly relevant because of their sensitivity to land use and hence to policy measures.

For this study total carbon sequestration (i.e. the net amount of carbon that is annually stored in vegetation and soils) was modelled in a spatially explicit manner. Carbon sequestration will be accounted for as an addition of stock by natural expansion. In addition, some biocarbon stocks acts as a net emission source. In the Netherlands, biocarbon is oxidised in peat lands as a result of lowering water tables, resulting in a net emission of CO_2 (and CH_4) to the atmosphere. These emission will be accounted for as a reduction in stock by managed contraction.

Finally, manure produced by livestock is -currently- considered to be a waste residual but is increasingly considered as a resource in the circular economy. Manure is as such part of the economy. It is assumed that all carbon contained in manure will on the short term be returned as CH_4 or CO_2 to the atmosphere[3]. Emissions from manure (CH_4, CO_2) are considered as direct flows from the economy to the atmosphere. This is in line with the recording by the IPCC guidelines and the SEEA air emission accounts.

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[3] In principle, some of the carbon in manure may be mixed into the soil and stored there (in which case it would become biocarbon). However, these amounts will probably be small and eventually also this carbon will be oxidized and returned to the atmosphere.

Table 1 Summary table of biocarbon stocks (Mton C) and flows (kton C) in the Netherlands; totals per ecosystem unit. Data based on all maps presented in this section. Carbon stocks for ecosystem units that are attributed to C in the economy (see text) are indicated with an asterisk (*). These stock values are not included in the totals for biocarbon stock in the Netherlands.

	Area	Biocarbon stocks (in Mton C)				Biocarbon flows (in kton C)		
Ecosystem unit	(1000 ha)	in biomass	mineral soils	peat(y) soils	totals	Sequestration	Emission from peat soils	Emission from peaty soils
Non-perennial plants	781	1.6*	65.7	10.3	77.5	0	156	121
Perennial plants*	79	1.3*	6.9	0.8	9.0	30	15	6
Greenhouses	12	0.0	1.1	0.2	1.3	0	5	1
Meadow*	927	1.9*	74.6	36.9	113.4	167	737	173
Buffer strips	36	0.1	2.6	1.9	4.	6	38	8
Farmyards and barns	35	0.0	3.1	0.7	3.8	0	14	3
Dunes with perm. veg.	16	1.3	0.5	0.0	1.9	30	0	0
Active coastal dunes	34	0.0	0.4	0.0	0.4	0	0	1
Beaches	0	0.0	0.0	0.0	0.0	0	0	0
Deciduous forest	109	9.4	9.6	2.5	21.5	206	43	16
Coniferous forest	82	6.6	6.5	0.2	13.4	155	2	2
Mixed forest	119	10.0	9.9	0.5	20.3	224	6	4
Heath land	41	0.3	3.8	0.8	4.9	8	20	4
Inland dunes	2	0.0	0.0	0.0	0.0	0	0	0
Fresh water wetlands	34	0.0	3.3	1.6	4.9	8	31	7
Natural grassland	54	0.1	4.2	2.4	6.7	10	51	8
Public green space	68	0.4	6.0	0.9	7.3	18	23	4
Other unpaved terrain	295	0.6	25.4	5.3	31.3	53	108	34
River flood basin	73	0.2	6.8	0.0	7.1	15	1	0
Tidal salt marshes	11	0.1	1.0	0.0	1.2	45	0	1
Paved surfaces	540	0.0	45.5	6.1	51.6	0	133	36
Sea	382	0.0	0.0	0.0	0.0	0	0	0
Lakes and ponds	123	0.0	3.5	2.2	5.7	0	60	11
Rivers and streams	298	0.0	0.4	0.0	0.4	0	0	0
Total	4,151	29.1	281.1	73.4	388.3	975	1,443	440

Figures 1 and 2 represent the modelled C stocks and sequestration respectively, in biomass. Table 1 provides an overview of all biocarbon stocks and flows included in this study, represented per Ecosystem Unit.

Biocarbon stocks assessed were stocks of C in aboveground vegetation (29 Mton C) and stocks of C in the top 30 cm of soils (353 Mton C, of which 73 Mton C in peat and peaty soils).

In 2013, ecosystems (in particular forests) sequestered approximately 1.0 Mton C, or 3.6 Mton CO_2. Peat ecosystems emitted in total 1.9 Mton C, or 7.0 Mton CO_2. For comparison, the total Dutch CO_2

emissions in 2013 were 166 Mton CO_2 (IPCC definition) and the total greenhouse gas emissions in the NLs in the same year were 195 Mton CO_2 equivalent.

Given that drainage of peatlands is general deeper in Drenthe and Friesland compared to the peat areas in the west of the Netherlands, the per hectare CO_2 emission is highest in these provinces, up to 12.5 ton C (45 ton CO_2) per hectare per year. In total, 44% of the Netherlands' peat CO_2 emissions originate in these two provinces.

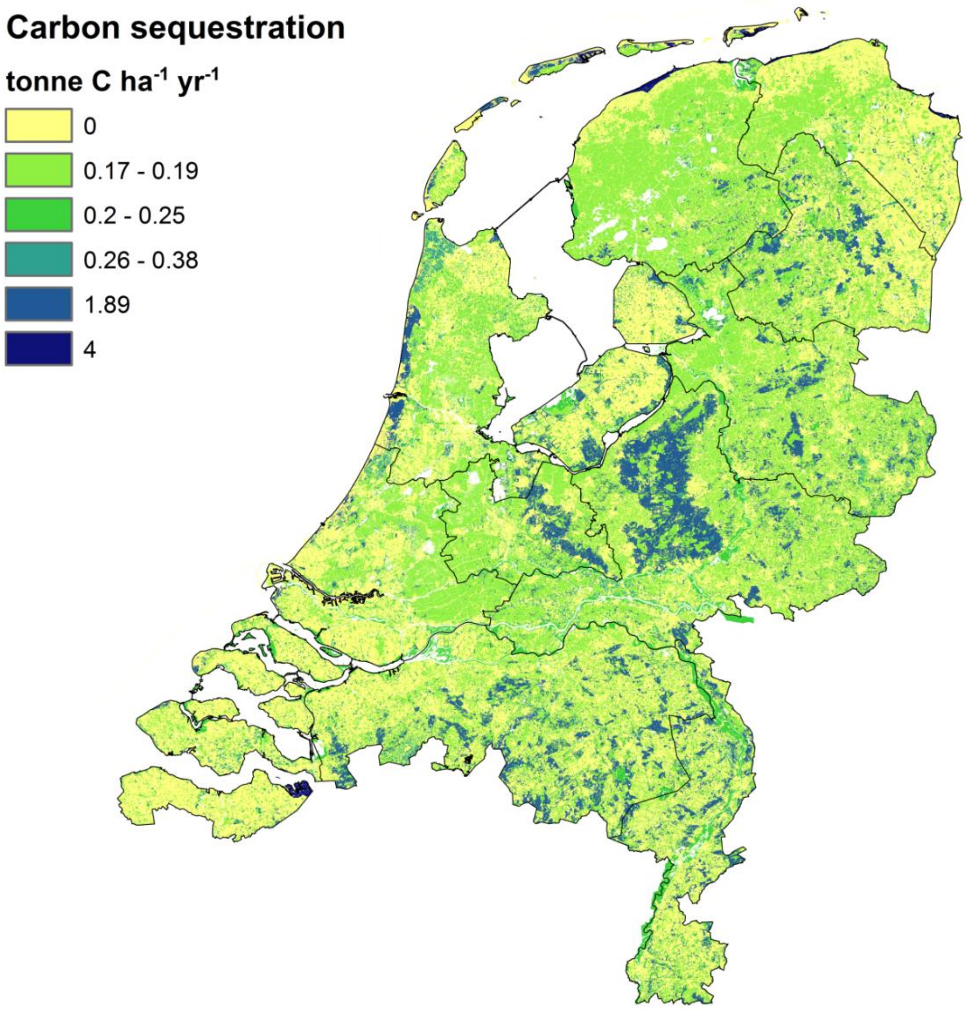

Figure 1 Carbon sequestration in above and below ground biomass.

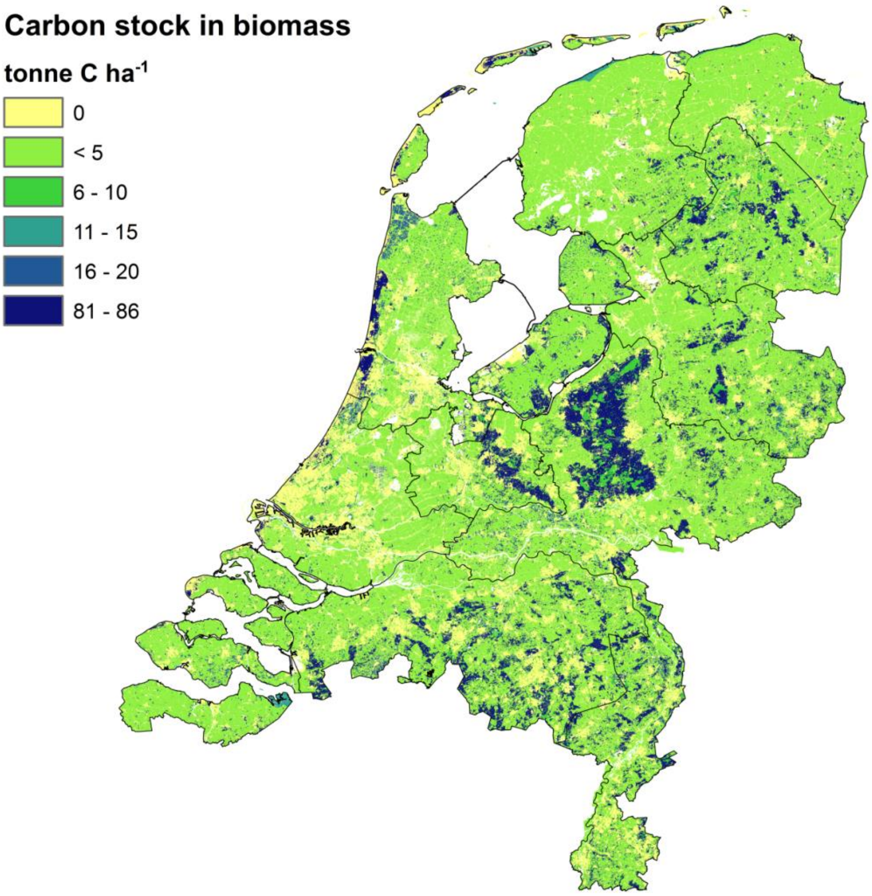

Figure 2 Carbon stock in above ground biomass.

The biocarbon account is aligned with existing reporting methods, in particular the UNFCCC LULUCF reporting, but has a spatial approach which allows estimating emissions for administrative units such as provinces as well as analysing how emissions are spread over the landscape.

3.2 Geocarbon

Geocarbon includes all carbon stored in the lithosphere. It can be disaggregated into oil, gas, coal resources, rocks (primarily limestone), and minerals, e.g. carbonate rocks used in cement production, methane clathrates and marine sediments (UN et al., 2014). Basically, carbon that is part of the Earth's lithosphere is considered as geocarbon (or geological carbon: carbon present in the Earth's bedrock and sediments, primarily from marine sediment deposits: inorganic geocarbon), as well as carbon formed originally in the Earth's biosphere millions of years ago, that, after geological metamorphosis due to high pressure and temperatures in the Earth's crust, was turned into e.g. oil and gas (organic geocarbon)). Organic carbon in soils and in peat deposits is included in biocarbon[4].

[4] Soil is the layer of fine material covering the Earth's land surface influenced by and influencing plants and soil organisms.

Following this definition of geocarbon, all inorganic and organic carbon present in the lithosphere could be accounted for in the carbon account. Underlying the Netherlands are several kilometres of sedimentary rocks, including limestone, shale and sandstone, but also rocks containing oil, gas and coal resources. Most of these sedimentary rocks contain high amounts of carbon, however, only for a few of these data are available. In addition, as the information generated from the accounts is policy-focussed, the priority should be given to those stocks that are impacted by human activity. Therefore, only the subsoil energy resources i.e. oil, gas, coal resources, which could potentially be extracted, will be included in the carbon account. Following the guidelines of the SEEA CF not only the commercially recoverable energy resource will be taken into account, but all known deposits. For limestone, only the extraction (reduction in stock) was accounted for.

Table 2 shows the details of the carbon account for geocarbon. Total stocks of carbon in subsoil energy resources amount to around 13,400 Mton C. Coal represents by far the largest stock of carbon, followed by natural gas and shale gas. It should be noted that the values for coal and shale gas have a high degree of uncertainty and the numbers presented here show the conservative estimates.

Table 2 Geocarbon account for the Netherlands in 2013.

Mton C	oil	gas	shale gas	coal	limestone	TOTAL
Opening stock	54.2	533.0	94.3	12716.5		13398.1
Additions to stock						
Natural expansion						
Managed expansion						
Discoveries		0.1				0.1
Upwards reappraisals	0.3					0.3
Reclassifications						
Imports						
Reductions in stock						
Natural contraction						
Managed contraction	1.5	39.7			0.1	41.3
Downwards reappraisals		1.1				1.1
Reclassifications						0.0
Exports						
Net carbon balance	-1.1	-40.7	0.0	0.0		-41.9
Closing stock	53.1	492.4	94.3	12716.5		13356.4

3.3 Carbon in the economy

The SEEA EEA carbon account includes C in products accumulated in the economy (SEEA EEA, 2014). Examples include petroleum products in storage, C stored in building materials (wood, concrete, etc.), bitumen in roads and C stored in waste dumps. Also carbon in biomass related to agricultural activities are part of carbon in the economy: perennial and non-perennial plants and meadows. The flows of carbon that occur within the economy are very significant and essential for understanding the interaction between economy and environment. The level at which geocarbon and biocarbon stock changes can be linked to the economy will determine the policy usefulness of the carbon stock account. This is particularly relevant in cases where raw materials can be extracted from more than one ecosystem type (e.g. biomass fuel from natural ecosystems or agricultural ecosystems; meat from agricultural ecosystems or semi-natural ecosystems) or from geocarbon reservoirs with different carbon contents and emissions profiles.

Structure of the stock account for carbon in the economy

In the columns the different reservoirs (assets) where carbon can be stored in the economy are recorded. Carbon assets in the economy can be further disaggregated into the following SNA components (SEEA EEA A4.7):

- **Inventories** are produced assets that consist of goods and services, which came into existence in the current period or in an earlier period, and that are held for sale, use in production or other use at a later date. Examples include petroleum products in storage, gas reinjections, food products in storage, etc.
- **Fixed assets** are produced assets that are used repeatedly or continuously in production processes for more than one year. Examples include wood and concrete in buildings, bitumen in roads, etc.
- **Consumer durables:** These are goods that may be used for purposes of consumption repeatedly or continuously over a period of a year or more. Examples include wood and plastic products (furniture, toys etc.).
- **Solid waste** covers discarded materials that are no longer required by the owner or user. Accounting for waste follows the conventions of the SEEA CF, where waste products (e.g., disposed plastic and wood and paper products) stored in controlled landfill sites are treated as part of the economy.

In the carbon stock account for the economy presented in Table 3 fixed assets and consumer durables were put together as one category.

In turn, these main asset categories can be further disaggregated based on the nature of the asset. In this study we have distinguished between 'biobased products' and 'other products' (i.e. mineral (inorganic) products and synthetic materials (plastics)). 'Biobased products' are materials which consist of carbon compounds derived from plants or animals. The carbon in these materials has been sequestered from the atmosphere by plants through the process of photosynthesis. This removal and capture of carbon from the atmosphere is natural CO_2 storage. The carbon is stored in the biobased material until it is released again by decomposition or combustion. In addition, under inventories also 'fossil fuels' have been identified separately.

Cultivated biological resources are a type of produced asset in the SNA and also a type of environmental asset in the SEEA. They may be either fixed assets (e.g., sheep for wool, breeding stocks of fish, and orchards) or inventories (e.g., livestock for slaughter and certain trees for timber) (SEEA CF 5.35). All environmental assets that are classified as cultivated must be recorded as either fixed assets or inventories (SEEA CF 5.38). With respect to the carbon account, the carbon stored in crops should was therefore recorded as carbon accumulation in the economy and not as biocarbon. In this respect, the distinction between cultivated and non-cultivated biological resources is important. Cultivated biological resources cover animal resources yielding repeat products and tree, crop and plant resources yielding repeat products whose natural growth and regeneration are under the direct control, responsibility and management of an institutional unit. Non cultivated biological resources thus yield products that are not under the direct control, responsibility and management of an institutional unit. In this study all carbon in crops (perennial and-non perennial plants), meadows and livestock was allocated to fixed assets. For practical purposes, all carbon in forests and other biomass was allocated to biocarbon.

The row entries in principle should follow the standard layout of the carbon account. However, some row entries are not applicable for carbon in the economy (natural expansion / contraction, discoveries). In addition, some items could be further broken down to provide additional detail and information. Accordingly, we here propose to include the following row entries:

<u>Additions to stock:</u>

Managed expansion

- Extraction of geocarbon: this is the extraction of carbon the form of fossil fuels and mineral deposits (mainly carbonate minerals).
- Extraction of biocarbon: this is the harvesting of non-cultivated assets, i.e. wood extraction, fisheries and extraction of other biological products from the environment
- Capture from the atmosphere: this is all carbon captured from the atmosphere by cultivated biological resources. It is equal to the net carbon sequestered in crops that is subsequently harvested.

Reclassifications

- Incorporation of products: This applies mainly to the production of synthetic materials (plastics) from fossil fuels. For 'other products' (inventories) it is an addition to stock, for fossil fuels it is a reduction in stock.
- Recycled materials: These are waste products that are recycled: for inventories it is an addition to stock, for waste it is a reduction in stock.
- Gross fixed capital formation. This is the incorporation of carbon in fixed assets (for example the use of wood and concrete for buildings etc.), it is an addition to stock for fixed assets/consumer durables, for inventories it is a reduction in stock.
- Waste production: these are products that become waste, it is an addition to stock for waste, for inventories it is a reduction in stock.

<u>Reductions in stock</u>

Managed contraction

- Emissions to the atmosphere: These are all carbon emissions (CO_2, CH_4) by economic activities to the atmosphere by economic activities. These include emissions caused by combustion of fossil fuels and biomass, but also emissions from industrial processes. These emissions are consistent with the emissions reported in the SEEA CF air emission accounts (UN et al., 2014).

- Emissions to the atmosphere by humans / livestock: these are CO_2 emissions caused by respiration.
- Emissions to water: this is total carbon (organic and inorganic) discharged to the surface waters. Carbon here can be both dissolved or as suspended material. These emissions concur to the emissions reported in the SEEA water emission accounts (UN et al., 2014).
- Emissions to soil: this is all carbon that is directly emitted to the soil. This is mainly manure by livestock transmitted to agricultural soils.

Reclassifications

- These are the same entries as under reclassifications for additions to stock (see above).

The net carbon balance is equal to total carbon additions to stock minus total carbon reductions in stock.

Table 3 shows the results for carbon accumulation in the economy (2013). The yellow marked cells indicate where data are still missing or incomplete. Most flows of carbon related to products (including imports and exports) are relatively well known and were derived from the physical supply and use tables, the economy wide material flow accounts, and the energy, water and air emissions accounts. The stocks of carbon in the economy are often not well known, as well as the amount of carbon in fixed assets and the flow of carbon associated with fixed capital formation: carbon in e.g. building materials and in waste dumps, bitumen in roads, etc.

For inventories the net carbon balance is quite significant. For biobased products the calculated net carbon balance is 1.6 Mton. We would expect this figure to be lower, as no significant stock build up (or reduction) of biobased products is expected. This issue needs further investigation and improvement: the difference may be related to inconsistencies in the source data or the carbon conversion factors. Also, for 'other products' the carbon balance is quite high (2.9 Mton). Here, a significant amount of carbon may go to gross fixed capital formation, which is currently largely missing from the data.

Table 3 Carbon in the economy for the Netherlands (2013). Grey cells are null by definition. Yellow cells represent incomplete or missing data.

Mton C	Carbon in the economy: Inventories			Fixed assets and consumer durables		Waste		**TOTAL**
	fossil fuels	biobased	other	biobased	other	biobased	other	
Opening stock	24.4							
Additions to stock								
Managed expansion								
Extraction from geocarbon	41.1		0.1					41.2
Extraction from biocarbon		0.5						0.5
Capture from the atmosphere		8.5						8.5
Upwards reappraisals								
Reclassifications								
incorporation in products			10.0					10.0
Gross fixed capital formation				1.6	0.5			2.2
recycled products		4.4	0.6					4.9
Waste production						5.1	1.3	6.4
Imports	147.2	17.0	21.9			3.2	0.5	189.8
Reductions in stock								
Managed contraction								
Emissions to the atmosphere	49.6	2.7	0.5			1.9	0.9	55.6
Respiration of humans		1.5						1.5
Respiration of livestock		4.7						4.7
Emissions to water		0.0	0.0			0.0	0.0	0.0
Emissions to soil		0.6	0.0			0.0	0.0	0.6
Downwards reappraisals								
Reclassifications								
incorporation in products	10.0							10.0
Gross fixed capital formation	0.2	1.6	0.4					2.2
Recycled products						4.4	0.6	4.9
Waste production		5.1	1.3					6.4
Exports	127.7	12.5	27.5			2.2	0.3	170.3
Net carbon balance	0.6	1.6	2.9	1.6	0.5	-0.2	0.0	7.2
Closing stock	25.0							

3.4 Carbon in the atmosphere

The atmosphere contains carbon mainly in the form of CO_2 and methane. The atmosphere is a receiving environment with regard to carbon from the primary reservoirs geocarbon and biocarbon but also from emissions from carbon used in the economy. On the other hand, carbon uptake from the atmosphere may take place by carbon sequestration in biocarbon. As CO_2 and methane act as greenhouse gasses in the atmosphere, accounting for these flows is highly policy relevant.

In the context of a 'national' carbon account it is difficult to define the carbon stock for the atmosphere. For this study we have taken the cumulative CO_2 emissions from fossil fuels by Dutch economic activities since 1900 as the stock for carbon in the atmosphere. Although we realise this is an assumption, we have included this figure the provide an indication of the total stock of carbon in the atmosphere that was added due to Dutch economic activities.

Table 4 shows the carbon account for the atmosphere for the Netherlands (2013). The emissions of carbon to the atmosphere are larger than the net sequestration of carbon, resulting in a net carbon balance of 55 Mton C. This is of course mainly due to the burning of fossil fuels. This gives an indication of the amount of carbon added to the atmosphere by Dutch economic activities.

Table 4 Carbon account for the atmosphere (2013) in Mton C. The opening and closing stock (yellow cells) comprises of cumulative Dutch carbon emissions resulting from fossil fuel combustion since 1900.

Opening stock	3193.2
Additions to stock	
Short cyclic emissions diue to economic activities	5.1
Other emissions due to economic activities	51.0
Respiration of humans and livestock	6.3
Emissions from biocarbon (natural ecosystems)	1.8
Reductions in stock	
carbon sequestration in cultivated plants	8.5
carbon sequestration in biocarbon (natural ecosystems)	1.0
Net carbon balance	54.8
Closing stock	3248.0

3.5 The Netherlands carbon balance

Table 5 provides an overview of the overall carbon account for the Netherlands. All data presented in the preceding sections are included, allowing for a full overview of all known major stocks and flows of carbon in the four different 'storage' types included in this study; geocarbon, biocarbon, carbon in the economy and carbon in the atmosphere.

Table 5: Carbon account for the Netherlands (2013) in Mton C. Grey cells are null by definition.

	Geocarbon					Biocarbon				Carbon in the economy				Carbon in the atmosphere	Total
Mton C	oil	gas and shalegas	coal	limestone and marl	total geocarbon	Forests	Cropland / meadows	Other ecosystems	Total biocarbon	Inventories	fixed assets, cosumer durables	Waste	Total	Total	
Opening stock	54	627	12717		13398	48	206	123	377	24			24	3193	16993
Additions to stock	0	0	0	0	0	0.6	0.2	0.2	1.0	251	2	10	263	64.2	329
Natural expansion						0.6	0.2	0.2	1.0					1.8	3
Managed expansion										50			50	62.4	113
Discoveries	0	0	0		0										0
Upwards reappraisals	0	0	0		0										0
Reclassifications										15	2	6	23		23
Imports										186		4	190		190
Reductions in stock	1	41	0	0	42	0.6	1.3	0.6	2.4	246	0	10	256	9.4	310
Natural contraction						0.1	1.3	0.5	1.9					1.0	3
Managed contraction	1	40	0	0	41	0.5	0.0	0.0	0.5	60		3	62	8.5	113
Downwards reappraisals	0	1	0		1										1
Reclassifications										19	0	5	23		23
Exports										168		3	170		170
Net carbon balance	-1	-41	0	0	-42	0.0	-1.1	-0.4	-1.4	5	2	0	7	54.8	19
Closing stock	53	587	12717		13356	48	205	122	376	30			32	3248	17012

4. Policy applications and indicators

For the Netherlands, this is the first time that a carbon account was compiled following the SEEA EEA guidelines. The account provides several important policy applications related to facilitating the implementation of climate change policies and actions, and providing a monitoring and planning tool for moving towards a circular economy. Chapter 6 presents detailed indicators, with the main policy applications outlined below:

1. Because of its extended scope, the carbon account is an ideal format to be used for the more detailed requirements on carbon emissions reporting to the EU as of 2020 required as part of the Effort Sharing Regulation (ESR) (European Commission, 2016). This because the account includes both the carbon flows in the economy and the carbon flows in the ecosystems. Both are considered in an integrated way and double counting of carbon emissions or sequestration is avoided. The ESR is currently being designed as the EU response to the Paris Agreement, and is likely to involve compulsory emission reduction targets for member states plus the possibility to use a specific amount of carbon credits from the LULUCF sector to comply with the ESR.
2. The ecosystem part of the carbon account (i.e. biocarbon) is spatially explicit. Maps depict where carbon emissions take place and which areas are most important for carbon sequestration. This facilitates climate action by provincial and local stakeholders. For

instance, provinces or water boards can identify which areas are most important for carbon emissions (e.g. drained peat areas with a low water table) and use the information to plan interventions in the landscape. The reliability of the accounts will be tested in the next project phase. It may well be that the accounts are sufficiently reliable to also support climate actions by local stakeholders such as an estate owner or municipality. For example, the carbon account shows where emissions from organic soils are currently highest. Such areas could be targeted with priority with measures such as increasing ground water levels, or adapting land use practices. The carbon account can therefore also be used to support interventions by local stakeholders, and to monitor the effectiveness of their actions. Hence, the account would allow the government to transition from a climate change policy implemented at national scale to facilitate actions by local stakeholders by allowing them to plan and monitor their interventions. In addition, the carbon account allows analysing the national level impacts of the local interventions over time (which requires updating the carbon account around once every two years).

3. The carbon account is integrated in the SEEA environmental economic accounting approach. This natural capital accounting approach is also gaining traction in the EU where it is currently being tested. The carbon account is an integral and important element of the overall natural capital accounting approach of the SEEA, and allow a better monitoring and planning of natural capital use. This includes information required for a transition to circular economy, which requires closing the flows of matter and energy within the economy. Since the carbon account integrates biocarbon and carbon in the economy it provides a very detailed picture of progress towards closing the carbon cycle.

5. Future improvements

The next carbon account could be improved and enhanced significantly compared to the previous version. In the biocarbon account, the main enhancement possible is that more detailed, spatially explicit information on forests, crops and grasses could be added. New maps, based on remote sensing information, are being developed that can contribute to such improvements (e.g. vegetation and Net Primary Productivity maps in the Atlas of Natural Capital). This will increase the accuracy of both the final figures and in particular also the maps. Vice versa, maps and information developed for the carbon account can be incorporated in public locations such as the Atlas of Natural Capital, to support multilevel decision making. In the account on carbon flows in the economy carbon stocks (urban mine) could be calculated to show how much carbon is accumulated in the economy and also hove much is stored by gross fixed capital formation every year. In addition, the different carbon assets in the economy could be shown on a more detailed level and also by industry. Further discussion is needed on how to account for carbon in the atmosphere and national responsibility for (accumulated) atmospheric carbon stocks Finally, by providing carbon accounts for different years the changes in stocks and flows can analysed in detail for the different policy areas described in the previous section.

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