Illustration of the application of SEEA Experimental Ecosystem Accounting to support policy making: inputs provided to the Netherlands debate on better managing peatlands.

The issue. Peatlands are among the planet's ecosystems most difficult to manage in an economic, environmental and socially sustainable manner. This because most uses of peatlands involve drainage. Peatlands consist of plant remains (about 10% by weight of peat) and water (90%) (Hooijer et al., 2009). Under natural conditions, the water table in peatlands is close to the surface preventing oxidation of organic matter and leading to a slow accumulation of plant materials. The resulting swampy conditions make access to peatlands difficult, and the high water table prevents the cultivation of most crops. Historically, peatlands have been drained to allow cultivation. Whereas this allows agricultural activities, drainage exposes the organic matter in the soil to oxygen in the atmosphere. The oxidation of organic matter leads to CO_2 emissions and soil subsidence. The rate of oxidation and thereby the release of CO_2 and subsidence vary as a function of drainage level, climate and soil management (e.g. use of fertilizers). Soil subsidence from oxidation can exceed 5 cm per year, and CO_2 emissions can reach over 100 ton CO_2 per hectare per year in the most heavily drained areas under tropical conditions. Drained peatlands are also subject to fires. Peat fires can smolder below ground for weeks before they are extinguished, and incomplete burning typical in peatland fires not only results in high CO_2 emissions but also in the emissions of substantial amounts of particulate matter with a diameter below 2.5 micrometer and Polycyclic Aromatic Hydrocarbons. Since peatlands are often located in low-lying areas, there vulnerability to flooding and sea level rise increases as a function of soil subsidence. Given that peatlands cover 100s of millions of hectares globally, that a large proportion of peatlands has been drained, and that drainage of peatlands still continues the resulting CO_2 emissions are of global concern, even though the exact contribution of CO_2 emissions from peat degradation (fire plus oxidation) to the global carbon budget is still unknown. It has been estimated that emissions from peat fires and oxidation in SE Asia alone contribute up to 5% of global CO_2 emissions in years with abundant fires (such as 2014, 2015 and 2019).

Peat in the Netherlands. Peatlands cover around 8% of the land area of the Netherlands. They are mostly located in the West and North, making up the lowest parts of the country. Cities as Amsterdam and Rotterdam are located partly on peatlands. Peatlands drainage started around the 12^{th} - 13^{th} century, with near full drainage of peatlands reached in the late 19^{th} century. Peatlands are mostly used for dairy farming – a substantial part of cheese production in the Netherlands including much of the well-known ' Gouda' cheese is produced on peat. Drainage, at present, varies from 30cm to over 1 meter depending upon the degree of influence of farmers in the local water management boards governing water management. Among farmers, there is a tendency to prefer lower water tables which allows easier access to the meadows and favors the growth of grass. The resulting soil subsidence is around 1 cm pear year in the deepest drained areas, and the resulting national CO_2 emissions are around 6 to 7 million ton CO_2 per year (some 4% of the national total CO_2 emissions). Given that these emissions are considered, in the UNFCCC, as 'natural' they do not need and are, in the case of the Netherlands, not reported to UNFCCC (emissions from fire would have to be reported, but in the Netherlands peat fires are extremely rare). The soil subsidence exacerbates the flooding risks from sea level rise, and with the lowest points in the Netherlands at 8 meter below sea level this is ground for some concern.

The policy context. The issue of better managing peatlands has multiple dimensions. Currently, some 20.9% of all meadows used for dairy production (194,000 ha) are in peatland. For the farmers, a key consideration is that they have been farming on peatlands for centuries, and most farms have been handed over from father to son or daughter for generations. Farmers depend for their income on farming the peatlands, and have often invested large amounts of money in stables, machinery, etc., There is also a substantial food processing industry (cheese, milk powder, other dairy products) dependent upon milk produced in peatlands. Last but not least, locally produced cheeses including from peatland areas are an important element of Netherlands food culture. These make part of the farmers generally reluctant to acknowledge the externalities of peatland drainage. Nevertheless, at present, peat drainage is causing substantial externalities. CO_2 emissions equal to around 4% of national emissions has been mentioned above. On a per hectare basis, the CO_2 emissions are as high as 45 ton CO_2/ha/year on the deepest drained areas. At the CO_2 price currently used in policy analysis of 48 euro per ton CO_2 (Aalbers et al., 2016), in these areas the costs of CO_2 emissions exceed the profits made by farmers, which are typically in the order of 1500-1800 euro/ha/year. However externalities go beyond CO_2 emissions. Pumping out rainwater to maintain the drainage levels in the peat, now that the peat areas are the lowest lying part of the landscape, requires electricity and upkeep of pumping equipment and infrastructure. Soil subsidence due to drainage leads to a need to continuously upgrade and repairs roads and dykes, and repairs to sewage, water and electricity pipes in residential areas in peat areas. In all, these externalities have been estimated to amount to 1000-1500 euro per hectare of drained farmland per year. These values are the highest in the west of the Netherlands with its relatively high population density and somewhat lower in the northern part of the country.

The policy debate. Climate change and adaptation to climate change is high on the political agenda of the Netherlands. Peat areas are an important topic, given that these are densely populated, low lying and subsiding areas that at the same time are important for farming, food processing and are of cultural value. Several approaches have been developed that would reduce soil subsidence and CO_2 emissions, such as increasing water levels in drained areas and various alternative forms of drainage that would lead to better control of water levels. However, increasing water levels is unpopular with farmers since it reduces the use the period they can use their land, and reduces also grass productivity. Alternative drainage systems (such as pressure drains) are relatively expensive and are unproven at large scales. There is no obvious technical solution to the problem: adjusted farm management practices that involve at least some drainage are still inherently unsustainable since they do not stop soil subsidence and CO_2 emissions. Therefore, trade-offs in landscape management are unavoidable. Sustainable peat management involves transition to no-drainage systems. There are some crops that can be grown under undrained conditions (e.g. cats tail and azola for fodder) – however these are considerably less profitable than dairy farming. Hence, any government intervention in peat will affect farmers' income (but may reduce society's costs for dealing with subsidence depending upon the scale and specifics of the intervention).

The Netherlands Carbon account (CBS and WUR, 2017). The carbon account provides a comprehensive overview of all main carbon stocks and flows in the Netherlands and was published in 2017. The carbon account 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 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. The carbon account was developed to provide 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. 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 were combined with new data and with the Ecosystem Extent Account for the Netherlands (EU_NL map, Statistics Netherlands, 2017). 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. For biocarbon and carbon in the atmosphere, a comparison with other reporting frameworks (e.g. LULUCF) was provided. The Carbon account includes detailed information on biocarbon (Table 1) and provides an overview of Carbon stocks and emissions for the country at large (Table 2).

Table 1. Biocarbon. The first three columns report the carbon emission by peat soils resulting from peat oxidation (> 40 cm thick peat layer in soil) and peaty soils (5-40 cm thick peat layer in soil) in the Netherlands in kton C yr-1 per province. For reference, the final column shows the CO_2 equivalent values in kton CO_2 yr-1. From CBS and WUR (2017).

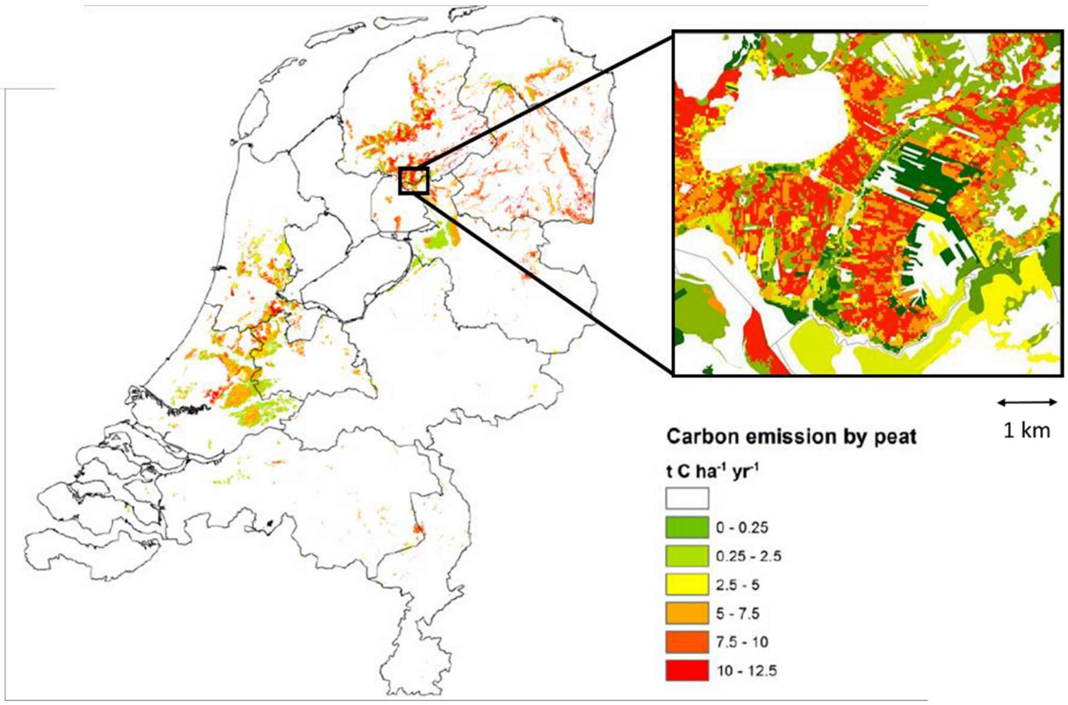
	Peat soils (kton C yr^{-1})	Peaty soils (kton C yr^{-1})	Total carbon emission from org. soils (kton C yr^{-1})	Total CO_2 emission (kton CO_2eq yr^{-1})
Groningen	85	63	148	544
Friesland	375	76	451	1,655
Drenthe	270	139	409	1,501
Overijssel	127	64	192	702
Flevoland	20	4	23	85
Gelderland	14	7	20	75
Utrecht	109	8	116	426
Noord Holland	154	21	175	642
Zuid Holland	247	30	277	1,014
Zeeland	1	0	1	3
Noord Brabant	28	18	46	170
Limburg	16	11	27	98
Netherlands	1,445	441	1,886	6,915

Table 2. Carbon account for the Netherlands (2013). From CBS and WUR (2017).

	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

The role of the Netherlands SEEA ecosystem accounts in the policy debate. Decision making on the use of natural resources usually involves balancing diverging interests and considering social, environmental and economic dimensions of different options. The use of better information does not automatically lead to better decisions. At the same time, accurate and trusted information is often a prerequisite for better decision making. In the case of the Netherlands peatlands, the SEEA EEA accounts provided important information to the public debate. At the time the SEEA EEA accounts were published, a broad stakeholder engagement had been started by the Netherlands government to discuss climate change targets and measures to be taken to reach these sectors. These discussions were organized by sector, with peat management featuring prominently in the discussion on how the agricultural sector could reduce GHG emissions. The Netherlands carbon account was published just prior to the start of these negotiations. The account showed clearly the contribution of peatlands to national CO_2 emissions. The number of 6 million ton of CO_2 emitted form drained peatlands per year was picked up by national newspapers. It also showed that, at a micro-level, profits from farming were smaller than the monetized costs of CO_2 emissions and damages resulting from soil subsidence. A complementary paper published at the same time showed the rates of soil subsidence measured with LIDAR (air-borne radar). These two publications ensured that CO_2 emissions from peat remained part of the discussion in the design of the sectoral climate change mitigation plan. Initially, in a draft form of the national climate change mitigation plan, it was suggested that technical measures (alternative including pressure drainage) could be used to reduce CO_2 emissions. However, subsequent discussions including on social media questioned the effectiveness of such measures. In the final, agreed sectoral climate change mitigation plan, the focus shifted to taking land out of production and increasing water levels to the surface to avoid all CO_2 emissions in these areas, while at the same time further testing technical approaches at pilot scale. An amount of 250 million euro has been reserved for converting drained farmland to undrained land sue including nature areas and no-drainage agriculture (Government of the Netherlands, 2019). Furthermore, in the national parliament an initial law has been proposed to further support and incentivize farmers to stop farming in peatlands (Bromet and De Groot, 2019). Whereas these policy processes would also have been taking place in the absence of the publication of the Carbon accounts, the accounts may have made a difference in the final results of these processes by showing clearly, in a way that was accepted by all stakeholders, both at national and at local scales, the amount of CO_2 being emitted by peat. Furthermore, the accounts facilitated connecting costs of CO_2 emissions to farmers profits. The information being provided by a statistical office ensured the credibility and acceptance of the numbers.

Figure 1 (from Hein et al., 2020): The maps show carbon emissions from peat oxidation in the Netherlands, expressed in tons of carbon (C) emitted per hectare per year (as recorded in the SEEA EEA Carbon account). Emissions are assessed based on soil type, drainage levels and density of drainage canals. National emissions from peat amount to around 2 Mton C per year. In the deepest drained areas, emissions are as high as 12.5 tons of C (or 45 tons of CO_2) per hectare per year (equivalent to emissions from nine Dutch households).



Carbon account map for the Netherlands, showing carbon emissions from peatland drainage (Hein et al., 2020).

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