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How the System of Environmental-Economic Accounting can improve environmental information systems and data quality for decision making

Michael Vardon[a,*], Juan-Pablo Castaneda[b], Michael Nagy[c], Sjoerd Schenau[d]

[a] *Fenner School of Environment and Society, Australian National University, Canberra, Australia*
[b] *World Bank, Washington D.C., U.S.A.*
[c] *United Nations Economic Commission for Europe, Geneva, Switzerland*
[d] *Statistics Netherlands, The Hague, The Netherlands*

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ABSTRACT

The System of Environmental-Economic Accounting (SEEA) is a framework integrating information from different sources with the aim of enabling better decision making by governments, business and others. Accounting allows a wide variety of data to be synthesised so that regular information and indicators are produced and can feed into decision-making processes. The accounting recognises that while there may be discrepancies between different data sources as well as data gaps, government and business must continually make decisions. Over time both the accounts and underlying data improves across the six dimensions of data quality – relevance, accuracy, timeliness, accessibility, interpretability and coherence. In individual data sources the focus is mostly on accuracy (i.e. closeness of estimate to the real number) but accounting addresses all of the six dimensions and has particular strengths in timeliness, accessibility, interpretability and coherence providing data when it is needed in a consistent format. Using examples from high and low-income countries we describe how SEEA can improve information systems and data quality for decision making and distil lessons for the development of the European Shared Environmental Information System.

1. Introduction

The objective of this paper is to outline how better decisions aimed at balancing human and environmental needs can be enabled by having more regular, consistent and integrated environmental and economic information via accounting. In doing this the basic aspects of data quality are described, along with international accounting frameworks for organising information and how these have been applied in three case studies.

The collection, arrangement and availability of data is key to evidenced-based public policy (e.g. Banks, 2008; Head, 2010). Describing and understanding the quality of data being used in decision making is important in science (e.g. Manning et al., 2004; Regan et al., 2005), government (e.g. Vardon, 2013) and business (e.g. Samitsch, 2015). Accepting there is always uncertainty in decision making due to the quality of the data and imperfect understanding of the system(s) that the data describes is an important first step for data providers. Governments, business and others make decisions using the information available and also make assumptions about both future human behaviour (e.g. response to new taxes or subsidies) and the environmental factors (e.g. the weather). Uncertainty in data and imperfect understanding of systems can be reduced through a combination of theoretical and practical measures., which in turn enables better decisions to be made.

National economic policy is underpinned by macroeconomic theory (e.g., Keynes, 1936; Kuznets, 1949; Clarke et al., 1949) and a range of statistics to support this are collected and arranged using the System of National Accounts (SNA) (UN, 1953). The SNA covers all economic activity – production, consumption and accumulation – and all industries (e.g. agriculture, mining, manufacturing, electricity and water supply, health, education, etc.). A key indicator from the SNA is Gross Domestic Product (GDP). The basic theoretical underpinning of the SNA has not changed since 1953 but the detail has continued to evolve with technological, economic and social change (see EC et al., 2009). The SNA is a tried and tested information source, providing both a framework for understanding as well as a place for the data describing the system. For more than 50 years governments and business have used the information from the SNA in economic analysis and policy (e.g. Stuvel, 1955; Ruggles and Ruggles, 1999). However, it has been long recognised that SNA does not adequately account for the environment

* Corresponding author.
E-mail address: michael.vardon@anu.edu.au (M. Vardon).

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(e.g. Nordhaus and Tobin, 1972) and that economic activity is the key driver of environmental degradation (Rockström et al., 2009).

The System of Environmental-Economic Accounting (SEEA) aims to address this deficiency of the SNA by accounting for the environment and linking it to environmental information through common concepts, definitions and classifications. Environmental information in the SEEA does not rely on one overarching theory of the environment but uses the key theoretical constructs of each discipline (e.g. hydrology, geology, forestry, ecology, etc.). The SEEA has several components: the SEEA Central Framework (UN et al., 2014a); the SEEA Experimental Ecosystem Accounting (UN et al., 2014b); the SEEA Applications and Extensions (EC et al., 2014); and SEEA Water (UN, 2012). Compared to the SNA, the SEEA is not yet widely used in decision making, which is at least partly due to the fact that it has only recently be adopted as an international standard, whereas the SNA has been in place for more than 60 years. However, examples of use are emerging (Smith, 2014; Vardon et al., 2017; Ruijs and Vardon, 2018) and examples related to Guatemala, Netherlands and water management are presented in Sections 2–4 of this paper.

The SEEA helps to improve data quality (Vardon, 2013), and hence reduce uncertainty in decision making by: (1) providing a framework for systematically linking economic and environmental data; (2) identifying and correcting anomalies apparent in different data sources; (3) identifying data gaps; (4) consistently presenting information in accounts from which indicators can be derived; and (5) describing data quality (e.g. providing the mean and standard deviation for estimates derived from surveys). In addition, overtime data quality improves through regular production of accounts, encouraging improvements to existing data and the filling of data gaps.

Government information agencies and scientific researchers usually provide information on data sources and methods, providing a means for those using the data to make assessments of uncertainty and "fitness-for-purpose" of the information for specific decisions or processes. Uncertainty in data sources can be described many ways. For climate change, rightly or wrong an area of contention, the Intergovernmental Panel on Climate Change (IPCC) defines uncertainty as:

> "An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts (see Moss and Schneider, 2000; Manning et al., 2004, cited in IPCC, 2007)."

The uncertainty of estimates is sometimes portrayed as a target, with the true value at its centre and the estimates made of the true value represented by arrows hitting the target. In this how close you get to the target is the accuracy of measure, while how closely grouped are the arrows is a measure of the precision. While this is a good representation of the theory, the key issue is that we usually do not know the true value, so accuracy is usually less well known than precision (the ability to repeat the measurement with the same or similar result).

A key aspect of accounting is that as an integrated system it forces many checks and balances in the process of compilation. For example, supply must equal use and all changes between opening and closing stocks must be accounted for, even if this is through the inclusion of balancing items. The use of multiple data sources or estimation procedures forces differences in data to be reconciled.

The internal consistency of the accounting system sets it apart from measures of uncertainty of individual components. The aim is to maximise the usefulness of the data provided by the system (i.e. an overview of the interactions of the environment – land, water, energy, pollution – with the economy), which is not necessarily achieved by maximising the accuracy of every component of the system.

There is difficulty in providing quantitative metrics of uncertainty or data quality in environmental-economic accounting and a range of factors need to be considered when managing and describing data quality (Vardon, 2013). A key point is that in the assessment of data quality, while accuracy is important, it is only one of the dimensions of data quality.

1.1. The six dimensions of data quality

Data quality frameworks are available from a range of international or national statistical agencies. For example, the Australian Bureau of Statistics (ABS, 2009), Eurostat (2005), IMF (2012), OECD (2012) and Statistics Canada (2002). These are all similar and in general describe six dimensions of data quality:

1. Relevance – how well the statistics meets the needs of users in terms of the concept(s) measured, and the population(s) represented;
2. Accuracy – refers to the degree to which the data correctly describe the phenomenon they were designed to measure;
3. Timeliness – which is the delay between the reference period (the time to which the data pertain) and the date at which the data become available; and the delay between the advertised date and the date at which the data become available (i.e., the actual release date);
4. Accessibility – the ease of access to data by users, including the ease with which the existence of information can be ascertained, as well as the suitability of the form or medium through which information can be accessed;
5. Interpretability –the availability of information to help provide insight into the data;
6. Coherence – is the internal consistency of a statistical collection, product or release, as well as its comparability with other sources of information, within a broad analytical framework and over time.

These dimensions also reflect academic notions of data quality (e.g. Clarke et al., 2011).

It is important to recognise that for decision making, data need to be more than accurate and there are often trade-offs between the various aspects of quality. Making information available when it is needed may require, for example, that timeliness be prioritised at the expense of accuracy. For example, the relevance of flood warning is greatly increased by a focus on timeliness rather than accuracy: is it is better to get a flood warning four hours before the flood, with an estimated peak of 4–8 m in height, than a warning 30 min before saying the peak will be 5.6 ± 0.3 m.

While some aspects of data quality can be assessed objectively (these are quantifiable errors mentioned in the IPCC definition of uncertainty), an assessment of the wider concept of fitness-for-purpose is largely qualitative as it also brings to account other factors including user views, the soundness of methodologic practices and corporate culture within the agency compiling data.

A key issue in the production of accounts is availability of data. Repeated production of accounts helps to build trust between different data providers and the producers of accounts. This comes about because of the repeated requests for data usually lead to the development of both administrative and technical mechanisms of data exchange as well as data providers seeing how data are used to create a new product (i.e. the accounts) and how it may be used in decision making. Repeated production of accounts also helps to build trust between account producers and account users.

Underlying the six dimensions of data quality is the notion of integrity – that information policies and practices are guided by ethical standards and professional principles which are transparent. The integrity of data producing agencies may be aided by the laws under which the agency operates and its willingness to subject its operations and performance to both internal and external scrutiny.

A key feature contributing to the integrity of national and environmental accounts is that they are usually released according to a predetermined schedule and the results are released to the public at virtually the same time as they released to the elected officials and government agencies (e.g. the Ministers for Finance or the Environment). This helps to ensure that the results are not altered or delayed by political or bureaucratic imperatives.

1.2. THE SEEA and SEIS

In 2008 the European Commission proposed the establishment of a "Shared Environmental Information System (SEIS)" (Commission of European Communities, 2008). The purpose of SEIS is to improve the collection, exchange and use of environmental data and information across Europe. SEIS aims to create an integrated, web-enabled, European wide environmental information system by simplifying and modernising existing information systems and processes. To achieve this, SEIS has become a collaborative initiative of the European Commission (EC) together with the European Environment Agency (EEA) and the 39 countries of the European environment information and observation network, Eionet (www.eionet.europa.eu).

The Eighth Environment for Europe Ministerial Conference held 8–10 June 2016 in Batumi, Georgia (EEMC, 2016), gave a major boost to the development of SEIS. At this conference the Ministers of the UNECE region invited countries to continue their development of national information systems and to have SEIS in place in the countries of Europe and Central Asia by 2021.

SEIS is a shift in approach, from individual countries or regions reporting data to specific international organisations, to countries creating online systems with services that make information available to multiple users — both people and machines. This is a stepwise shift, ensuring that SEIS remains a driver for access to environmental information and its integration in the knowledge-based economy.

SEIS is based on seven 'principles' (EEA, 2016), namely that information should be:

1 Managed as close as possible to its source.
2 Collected once and shared with others for many purposes.
3 Readily available to easily fulfil reporting obligations.
4 Easily accessible to all users.
5 Accessible to enable comparisons at the appropriate geographical scale and the participation of citizens.
6 Fully available to the general public and at national level in the relevant national language(s).
7 Supported through common, free, open software standards.

The seven principles of SEIS information align mainly with three of the general notions of data quality used in data collection agencies: accessibility, interpretability and coherence. The seven principles of SEIS are also applicable to the development of national and international SEEA-databases. This can be seen from two perspectives:

a) SEEA is designed for multiple purposes, which include policy making, research and analysis, but also to provide information to the general public (e.g. through indicators). Users of SEEA (both national and international) would benefit from easy access to the accounts, if SEIS principles were applied.
b) SEEA integrates information from multiple sources (and in particular environment statistics and the economic information contained in the System of National Accounts), therefore compilers of SEEA accounts can benefit when the underlying data sources conform with the SEIS principles.

At the international level, in 2015 the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA) initiated the establishment of globally consistent SEEA databases (UNSD, 2015). The purpose of this was to provide coherent data supporting integrated policy making at national and international levels, including the implementation of the Sustainable Development Goals (SDGs). This is to be done in a way that is cost-efficient for countries compiling the data as well as international organizations collecting and further processing the relevant data, including the use of SDMX-standards for the exchange of data between countries and international organizations. The work is carried out by OECD in cooperation with Eurostat, FAO and UNSD (UNSD, 2017). The application of the seven principles of SEIS to this global project could assist the harvesting of SEEA accounting data for international databases and would avoid an additional reporting burden for countries.

1.3. Relating SEEA, basic data and analysis to decision-making

Understanding where SEEA fits in an information system used for decision-making is important. Accounting can be seen as one of three parts of an information system: (1) basic data, (2) accounts and; (3) interpretation and analysis. The information system would ideally be at the heart of the decision-making and typical policy cycle (Fig. 1). Decision-making, can occur at any stage in the policy cycle, for example informing agenda setting, when the data identifies an issue, or in policy evaluation, when the data measures success.

Environmental accounts can inform decisions at all stages of the policy cycle and a range of examples are available. For example, Bass et al. (2017) draw on range of material and show that the use of accounts spans the monitoring of sector-based policies, like water, energy, and forests, to more complex areas of implementing or analyzing cross-sectoral policies for green growth and climate change. In addition, Ruijs et al. (2018) examines the application of accounts to the SDGs. Countries which have had accounting programs for many years, like the Netherlands, Sweden, and the United Kingdom, have developed the relationships between the users and producers of accounts to enable more effective use of the accounts in policy processes. Bass et al. (2017) also note that while it takes time to produce accounts with the full range of functions, countries with relatively new programs have been able to apply accounts to decision-making, for example, in setting prices for water and energy, as well as in enriching national, sectoral, and regional planning. However, several challenges to introducing environmental accounting to policy processes are evident including: the prevailing policy focus on the short term (limited policy readiness for change); acceptance of the information (its perceived credibility and trustworthiness); communication of complex information; alignment of accounting supply with demand; ensuring collaboration and understanding among diverse professions and institutions; and maintaining high-level support. To address the challenges Bass et al. (2017) proposed 10 “living principles” for ensuring that environmental accounting is policy-ready. The principles are grouped under four headings—comprehensive, purposeful, trustworthy, and mainstreamed—and can be tested and revised. A first assessment of the principles shows encouraging results (Ruijs and Vardon, 2018).

2. Guatemala case study

2.1. Implementation of SEEA in Guatemala

Guatemala started implementing SEEA in 2006 to organize information so that the relationship between the economy and the environment was described as completely as possible. Guatemala’s interest in developing SEEA was triggered by a report reviewing the potential to compile and use these accounts in the country (Castaneda, 2006) and the rebasing of the SNA, which included a substantial upgrade of economic statistics. Discussions around these led to the inception and preparation of an environmental statistics strengthening

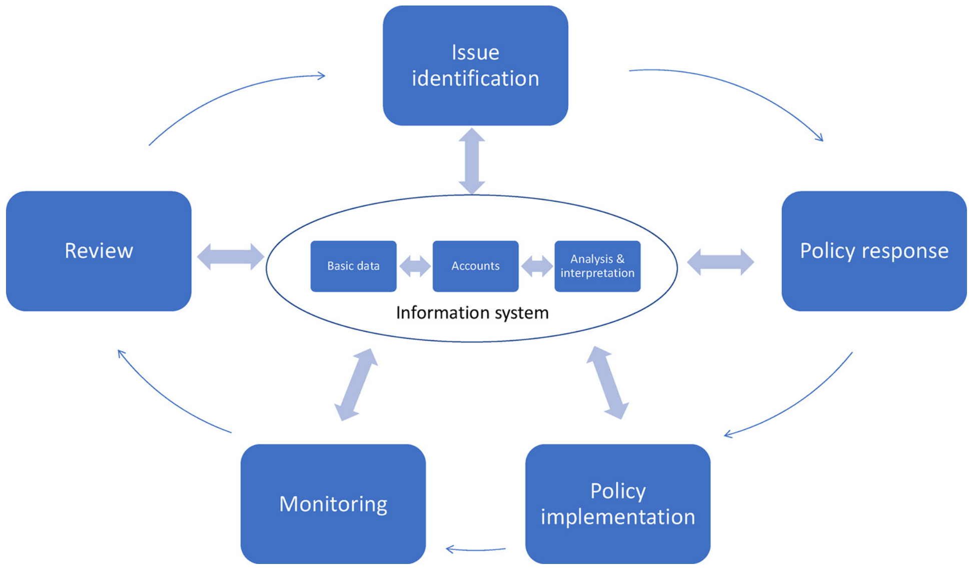

Fig. 1. The place of accounts in the information system and its relationship to the policy cycle.
(Source: after Vardon et al., 2016).

program (including environmental accounting), that was later funded by the Government of The Netherlands.

Two sets of accounts have been produced so far: a first iteration covering the years 2001–2006 (BANGUAT and IARNA, 2009) and then a second edition for the years 2001–2010 (INE et al., 2013). The detailed reports of the accounts were accompanied by briefings, policy notes and other materials, helping to raise the *relevance* of environmental information to the government (Castaneda et al., 2017) as well as facilitating the *accessibility* and *interpretability* of information to the public.

In brief, the Guatemalan accounts provided information about natural assets as well as other interactions including the supply and use of different natural resources by more than 130 industries, government and households. The scope of the accounts is presented in Table 1 according to account type and theme. Both physical and monetary accounts where produced. It should be noted that the environmental expenditures and other transactions accounts cover the national, state, and municipal governments. *Coherence* is a key feature of the accounts and the suite of accounts produced for Guatemala is one of the most comprehensive and integrated ever produced in the world.

2.2. Benefits of SEEA for the information system, data quality and policy use

The Guatemalan accounts were developed with an explicit policy focus and have progressively increased their usefulness, reaching more key decision makers and affecting more decisions about the natural environment (Table 2; Castaneda et al., 2017). This increased the *relevance* of environmental statistics produced by different agencies by integrating and consolidating information into a single system, compatible with other information systems and in particular the SNA.

The integration of all environmental data (e.g. forests, water, fisheries, etc.) in accounts also provided an increased opportunity for different users to access information that otherwise would be disparate and poorly harmonized. This has enabled the accounts to be used to inform the dialogue around environmental sustainability by providing key indicators to better understand and manage the relationships between the economy and the environment, especially the condition of

Table 1
Scope of the Guatemalan Natural Capital Accounts.

	Thematic							
	Forest	Water	Subsoil assets	Energy and emissions	Land and ecosystems	Fisheries and aquaculture	Waste	Expenditures and other transactions
Asset accounts								
Natural resources	P + M	P	P + M			P + M		M
Ecosystems					P			M
Land and surface water	P	P			P			M
Flow accounts								
Natural resources	P	P	P			P		M
Ecosystem inputs				P	P			M
Products	P + M	P + M	P + M	P + M		P + M	P	M
Wastes and emissions	P	P	P	P		P	P	M
Expenditure and other transactions								
Environmental protection expenditure	M	M	M	M	M	M	M	
Natural resource management expenditures	M	M	M	M	M	M		
Aggregate indicators								
Depletion	M		M					
Intensity Indicators	P + M	P + M	P + M	P + M	P + M	P + M	P + M	

P = Physical measures, M = Monetary measures, P + M = Physical and monetary measures.

Table 2
Linking environmental—economic accounting to policy and decision making in Guatemala.

Account type	Main findings	Uses of the account	Stage of policy cycle where account was used
Forest	The stock of forest is reducing at a rate higher than 1.5% per year, higher than that of countries such as Brazil and Mexico. This is equivalent to about 1% of GDP. The real contribution of the forest to the economy is 2.5 times greater than that registered in the national accounts.	The results are a fundamental input for the new forestry strategy which is under discussion. This policy will sustain the financing processes of the forest incentive program, the main instrument of public policy in the forest sector (PINFOR).	Issue identification, Policy response, Monitoring
Water	There are non-agricultural sectors uses of water that are higher than typical world rates.	The results were an input to the "Water Discussion Table" that addresses the main problems associated with water resources and their management.	Issue identification, Policy response, Monitoring
Energy, Forest and CO_2	The country has become a net CO_2 emitter. Including the consumption of firewood in the energy accounts made visible the high dependence of households, especially rural ones, on forests for energy.	The results have been decisive in opening the discussion on the need to include controls for the emission of greenhouse gases in climate change policies. In addition, the intimate relationship between forest and energy was made explicit in the statistics, expanding the discussion and the actors.	Issue identification, Policy response, Monitoring
Environmental Expenditure	Investment is lower than the rate of depreciation of natural capital and environmental revenues are not necessarily reinvested in environmental protection	Input for the negotiation of MARN's budget in 2009 and useful for current negotiations especially in the forestry sector in view of the need to renew the main instrument of forest management (PINFOR)	Issue identification, Policy response

natural assets in the context of the total wealth of the country (IARNA and SEGEPLAN, 2009; IARNA, 2012; Castaneda et al., 2017).

At the thematic level the accounts helped integrate and harmonize information, increasing the ability of policy makers to make strategic decisions that take into account the cross sectoral effects of their decisions. Two examples of applications at sectoral level were:

- **Forest policy and strategies.** Forest accounts measured the extent of deforestation and identified its main drivers as agricultural expansion, urban development, uncontrolled timber harvesting and the harvest of fuelwood. By making explicit the links between forests and the economy, the accounts have informed the debates that led the government to strengthen the regulatory capacity of the public agencies responsible for forests (after World Bank, 2014).
- **Water policy instruments.** The information provided by the water accounts helped foster dialogue across sectors and informed research. For example, a study led by a local municipality looked at the intensity of water use in the metropolitan area of Guatemala City and this study contributed to the design of proposals for policy instruments, including a water fund. Other municipalities have seen the potential of the water accounts to help define their long-term goals for water security (after World Bank, 2016).

In recent years, and in particular the efforts to compile the third iteration of the accounts with assistance from the World Bank (2017), four policy priorities to which the accounts can contribute were identified: (1) inclusive green growth and poverty reduction, (2) food security, (3) climate change, risk and economic growth, and, (4) economic and environmental sustainability. In this, the repeated compilation of the accounts makes the system more *coherent* and ensures more consistency between information sources over time.

The production of accounts also adds *relevance* to the traditional environmental statistics by directly linking them with economic statistics. This allows additional policy applications which include modeling the future and doing policy analysis in more systematic and credible ways. In the case of Guatemala, data from the accounts have been used to model the relations between deforestation, fuelwood and energy security in the long term and some modelling efforts have informed the policy debate in the country (e.g. Banerjee et al., 2017).

3. Netherlands case study

3.1. Implementation of SEEA in the Netherlands

Statistics Netherlands began implementing SEEA more than 20 years ago. In 1991 the first National Accounting Matrix including Environmental Accounts (NAMEA) was presented (De Boo et al., 1993), according to the conceptual design by Keuning (1993). This initial work was driven by the short comings identified in the SNA and the international recognition of the importance of including the environment in the national accounts (e.g. The Rio Declaration, UN, 1992; De Haan, 2004). Statistics Netherlands published detailed NAMEAs for the years 1990–2005. In these NAMEAs, the following themes were considered: the greenhouse effect, ozone layer depletion, acidification, eutrophication, solid waste, wastewater and the exploration of crude oil and natural gas.

Since the initial work in the 1990s, Statistics Netherlands has gradually extended the system of environmental accounts. Table 3 gives an overview of the environmental accounts developed at Statistics Netherlands. Some of these modules already exist, while others are still being developed. Between 2004 and 2010 energy accounts,

Table 3
Overview of the different environmental accounts in the Netherlands, implemented and under development.

	Implemented	Work in progress
Flow accounts		
Energy flow accounts	P	
Water flow accounts	P	
Material flow accounts	P	
Air emission accounts	P	
Water emission flow accounts	P	
Waste accounts	P	
Asset accounts		
Subsoil accounts for oil and gas	P + M	
Water asset accounts		P + M
Environmental activity accounts		
Environmental goods and services sector	M	
Environmental expenditure accounts	M	
Resource management expenditure accounts		M
Environmental tax accounts	M	
Environmental transfers accounts		M
Ecosystem accounts		
Extent account		P
Condition account		P
Ecosystem services (supply and use)		P + M
Asset account		M
Carbon account		P
Biodiversity account		P

P = Physical measures, M = Monetary measures, P + M = Physical and monetary measures.

environmental tax accounts, subsoil accounts for oil and gas, physical water accounts and waste accounts were developed and published, while the air emission accounts and the water emission accounts were further extended.

More recent drivers of SEEA implementation in The Netherlands were: (1) the legal base in Europe for the compilation of certain accounting modules (EU, 2011) and; (2) the increased demand of national users for more data on the environmental. In addition to this, work has started on the testing and implementation of the ecosystem accounts with support of the Dutch ministries of Economic Affairs and Infrastructure and the Environment (De Jong et al., 2015; Lof et al., 2017).

3.2. Benefits of SEEA for the information system, data quality and policy use

Statistics Netherlands complies SEEA accounts within the unit that also compiles the national accounts. As much as possible both the national accounts and environmental accounts are compiled using the same concepts, definitions and classifications as well as the same methodology and data sources. This facilitates the compilation of consistent and *coherent* data. In addition, the different SEEA accounts are compiled in integrated processes further promoting *coherence*. For example, data from the energy accounts is directly used as an input to the air emission accounts and material flows accounts.

Timeliness of the data is a key aspect of data quality and especially relevant for policy making. The Netherlands has progressively made the environmental accounts timelier and most accounts are available within one year of the reference period. That is, if the data are for 2015, the account is produced before the end of 2016. One key indicator from the air emission accounts – total greenhouses emissions by economic activities – is now available three months after the end of the reference period.

The Dutch environmental accounts are *accessible* in many different ways. Firstly, all data are published on Statline, an electronic database of Statistics Netherlands (2018). Previously environmental accounts were published annually in a specific publication (see Statistics Netherlands, 2014 for the last version). More recently, these annual publications were replaced by more in-depth articles that are published on the website of Statistics Netherlands. This helps increase both the *interpretation* and *relevance* of the accounts. The advantage of these online articles is that they are more focussed, can be published throughout the year and can respond directly to issues that are of current interest. Finally, within the website of Statistics Netherlands a special webpage was created where all relevant information of the environmental accounts (data, articles, and methodology) can be found.

The *relevance* of data and indicators from the SEEA is demonstrated by many different users in the Netherlands, including the ministries of Infrastructure and Environment and Economic Affairs, local governments, several research institutes and universities, business associations and the general public. SEEA data is used to inform different environmental-economic policies, including policies with regard to climate change, energy transition, circular economy and natural capital (biodiversity) (e.g. Energiecentrum Nederland (ECN et al., 2017; Planbureau voor de Leefomgeving (PBL et al., 2018). Table 4 summarises a selection of the issues and shows how they are linked to the accounts as well as the stage of the policy cycle that the accounts inform. As a detailed example, we here discuss how SEEA data is used to inform green growth policies in the Netherlands.

In the Netherlands green growth is high on the political agenda. The government sees green growth as an essential part of maintaining the ability to grow the economy into the future, while reducing environmental impact and dependency on scarce resources (Tweede Kamer, 2013). The SEEA provides a consistent, coherent and comprehensive measurement framework for green growth, as it integrates economic and environmental statistics (UN et al., 2014a). Both the United Nations Environment Programme (UNEP, 2011) and the Organisation for Economic Co-operation and Development (OECD) (OECD, 2011) advocate environmental accounting as the underlying framework for deriving the indicators for green growth. The OECD explicitly advocates that measurement efforts should, where possible, be directly obtained from the SEEA.

A large number of the indicators from the OECD green growth monitoring framework (OECD, 2011) can be derived from the accounts of the SEEA Central Framework and the SNA. Indicators for environmental efficiency and resource efficiency can be derived from the physical flow accounts and the production account (e.g. volume of water or energy used per value of output produced). Combining physical information with monetary indicators from the SNA provides information on the interaction between environmental pressure and economic growth. The asset accounts provide the basis for indicators related to the natural resource base. Environmental activity accounts offer useful information on the application and efficiency of various policy instruments, such as environmental taxes and subsidies. Data from the environmental goods and service sector (EGSS) provides indicators for evaluation of economic opportunities that may be initiated by green growth. Finally, ecosystem accounts provide information on both natural capital (asset base) and flows on ecosystem services.

The Dutch government asked Statistics Netherlands to monitor green growth on a regular basis and to develop consistent monitoring frameworks for sustainability and green growth, in order to monitor and review government policies. In response, Statistics Netherlands compiled the *Sustainability monitor*, which also features a chapter on green growth (Statistics Netherlands, 2015a) while the publication *Green growth in the Netherlands* (Statistics Netherlands, 2015b) provides an update of the green growth indicators in the Netherlands, the international context and more detailed thematic aspects. A large number of the indicators needed for the monitoring of green growth come directly from the accounts of the SEEA.

Statistics Netherlands has also developed an interactive infographic to inform policymakers and the general public on the status of green growth in the Netherlands (Fig. 2). The infographic is an interactive tool that enables users to find detailed information on green growth. Data for most indicators can also be directly obtained from Statline.

4. Water case study

4.1. Implementation of water accounting

Water accounting is perhaps the most advanced thematic area of the SEEA accounts, with the SEEA Water (UN, 2012) accepted by the international statistical community in 2007, five years before the SEEA Central Framework (UN et al., 2014a, 2014b). Australia, Austria, Botswana, Canada, China, Costa Rica, Guatemala, Mexico, The Netherlands and others have all produced water accounts (e.g. Castaneda et al., 2017; Nagy et al., 2017; Statistics Netherlands, 2014; Vardon et al., 2012), so there is much experience with water accounting.

The two most common factors impeding the compilation of water accounts are data availability and data quality (Vardon et al., 2012). Countries often have some of the data needed for the water accounts, but no country has access to all of the data needed to produce the full suite of water accounts: physical and monetary supply-use tables, asset accounts, environmental protection expenditure related to water, water quality and emissions to water. As such, those producing accounts rely on a range of estimation methods to populate particular cells in the water accounting tables selected for production. In some cases, data may exist but the agency or agencies producing the accounts may not be able to access the data for legal, administrative or technical reasons. Recent water accounts developed for Finland directly addressed data quality issues including coverage of administrative data; confidentiality; and allocation of water use by industry to correct source (e.g. water from water mains or from groundwater) (Salminen et al., in press).

Table 4
Linking environmental—economic accounting to policy and decision making in The Netherlands.

Name of policy or decision-making process	Account used	Stage of policy cycle where account was used	Notes of use of accounts
Energy transition / Climate policy	Energy flow accounts, Air emission accounts, EGSS	Monitoring, Review	Annually, data from the accounts are used as input to produce the National Energy Outlook publication
Circular economy/ resource efficiency	Material flow accounts, emission accounts, EGSS	Monitoring	The material flow accounts are the basis for monitoring key policy indicators
Green growth	Physical flow accounts, Asset accounts, Monetary activity accounts	Monitoring	Annually data from the accounts are used as input for the green growth publication that is used for policy
Water quality/ water resources	Water flow accounts, Water emission accounts	Monitoring	Data is used among others for reporting to the water framework directive
Nature / agricultural policies	Ecosystem accounts	Issue identification, Monitoring	Still under development

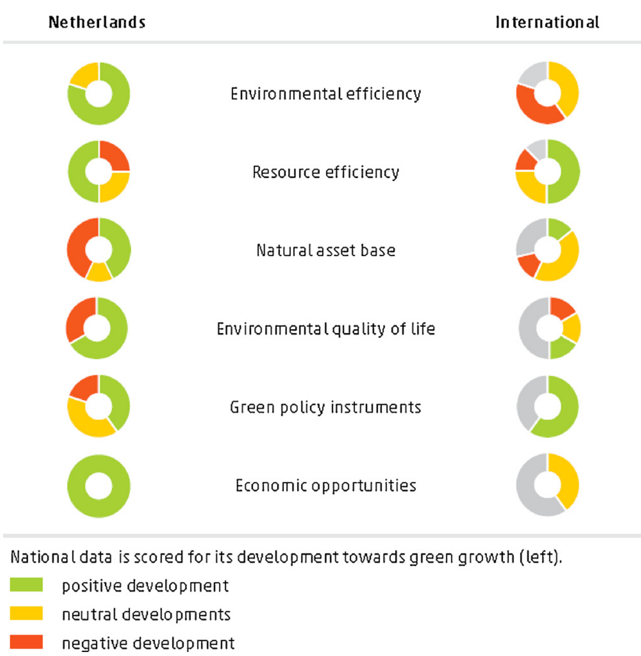

Fig. 2. Summary of the trends for the Netherlands' green growth indicators (left column) and an international comparison of the Netherlands with EU/OECD countries (right column). Note: Gray cells indicate missing data (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).
Source: Statistics Netherlands, 2015b. https://www.cbs.nl/en-gb/visualisaties/green-growth#/.

In the European Union, the Water Framework Directive provides the framework for water policy reporting (EC, 2010) and to support this the Water Information System for Europe (WISE) was developed. The WISE links to water accounting information held by Eurostat. However, the water accounts are not yet one of the accounts required by the European Union.

4.2. Benefits of water accounting for data quality and policy use

Different types of data are held by different organisations. For example: water suppliers have data on dam levels, amount abstracted, amount supplied in physical and monetary terms and losses in distribution; hydrological agencies have data on rainfall, runoff, evaporation; and statistical agencies have data on the area irrigated, value of agricultural production and the amount of water used by different industries. When accounts bring this information together anomalies may be identified, investigated and corrected. Over time those with data become accustomed to supplying the data and less time is usually needed to work through data issues. In addition, data gaps can be identified and again, over time, suitable methods to fill this can be found.

There are four main areas of water policy: (1) improving drinking water and sanitation; (2) managing water supply and demand; (3) mitigating water resource degradation; and (4) adapting to extreme hydrological events (UNSD and WWAP, 2011). Each of these policy areas can be addressed by environmental accounting, with examples from many countries (Table 5). While it is clear that water accounts can inform a range of water policy issues, in most cases accounts have lacked full information and, in particular, information on the economic aspects of the value of water supply infrastructure and estimates of the damage caused to the environment from pollution, thus limiting their ability to fully inform full cost recovery for mitigating water resource degradation (Nagy et al., 2017), which would assist with the *implementation* and *monitoring* of current policy. However, the broad range of experience, spanning low- to high-income countries with high and low water availability (for example, Botswana to the Netherlands), demonstrates that water accounts can be prepared, and Table 5 indicates where they could be useful for decision makers.

5. Conclusions

The systematic integration of economic information and environmental information is essential for better decision making. While the focus of the SEIS is on physical environmental information, it must also consider how this information can be integrated with economic data and hence enable a greater range of uses by government and business. The SEEA provides the concepts and structures enabling such integration and international agencies and countries are already using it both as an information platform and in decision making as we have presented for Guatemala, The Netherlands and for water.

The SEEA as an established information system has advantages beyond the linking of economic and environmental data. Use of it can increase data quality, providing a *coherent* and comprehensive framework resulting in a suite of information on the environment and the economy *relevant* to government and others. An important part of this is that the accounting forces a systematic approach meaning that areas of imperfect understanding or conceptual disagreement can be identified clearly and separated from issues of poor quality data. An example of this is seen in water accounting (Salminen et al., in press) and the discussion on definition and measurement of ecosystem condition in the development of ecosystem accounting (Saner and Bordt, 2016; Vardon and Harris, 2017).

The production of accounts also has practical benefits for information systems and decision making. For information systems, the regular production of accounts means that data from multiple sources is systematically compiled, meaning that *accuracy* is assessed, and information presented in consistent forms aiding *accessibility* and *interpretability*.

Table 5
Links between natural capital accounts and key water policy areas and concepts.
Source: Nagy et al. (2017).

Policy area	Key concept		Country examples
	Full cost recovery	Integrated water resource management	
1. Improving drinking water and sanitation services	Physical and monetary water supply and use tables SNA accounts (with the emphasis of the water supply and sewerage industries) Environment protection expenditure accounts Water asset account	Physical and monetary water supply and use tables Land cover and land use accounts	Colombia, Costa Rica
2. Managing water supply and demand	Physical and monetary water supply and use tables Water asset account Land cover and land use accounts SNA accounts (with the emphasis of the water supply and sewerage industries)	Land cover and land use accounts Physical and monetary water supply and use tables Water asset account	Australia, Botswana, Colombia, Costa Rica, Madagascar, Netherlands, Philippines
3. Mitigating water resource degradation	Physical and monetary water supply and use tables (emphasis on return flows and operation on sewerage collection and treatment) Land cover and land use accounts Water quality accounts Environment protection expenditure accounts	Land cover and land use accounts Physical and monetary water supply and use tables Water asset account	Netherlands, Philippines
4. Adapting to extreme hydro-meteorological events	Land cover accounts Water asset accounts Environment protection expenditure accounts Ecosystem service accounts (for flood protection and regulation of water flows)	Land cover accounts Water asset accounts Environment protection expenditure accounts Ecosystem service accounts (for flood protection and regulation of water flows)	Philippines

For decision-making processes, regular accounts mean that regular governments tasks, such as budgeting, can use the information from accounts. It also means that information is *timely* and can be used to address issues or support decisions which had not been anticipated.

Wherever it has occurred, the regular production of accounts has required practical mechanisms for data exchange to be established. This covers legal, administrative and technical issues. Within and outside Europe the agencies compiling accounts benefit from national laws giving them the authority to collect and use information as well as security of funding for the on-going production of accounts.

In addition to the sharing and collecting of data, the repeated publication of accounts also shows how the accounting adds value to existing information and analysis of policy issues, for example, green growth (Schenau, 2017), forest management (Banerjee et al., 2017) and water management (Vardon et al., 2012; Nagy et al., 2017). A sophisticated understanding of how accounts and the data that underpin them (e.g. from the SEIS) can be used in public policy is just beginning but is promising, with recent attention focusing on attaining the Sustainable Development Goals (e.g. Banerjee, 2017; Ruijs et al., 2018).

The SEIS and SEEA are potentially complimentary and reinforcing. In the short term, those producing accounts in Europe would be able to draw on the information in the SEIS, and those populating the SEIS would see how information and analytical products are using their information. In the longer term this should lead to both improvements in the information system and enable it to more effectively influence decision making. That said, it is recognised that good information and analysis does not automatically lead to better decision making (Head, 2010).

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