Distinguishing and valuing the water provisioning service, water as a natural resource and the product “natural water” (CPC 1800)

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Summary

Determining when water is treated as an ecosystem service, natural resource or product depends on the perspective taken and in particular what or who are deemed to be suppliers and users of water, with the same flow being recorded in different ways in the System of Environmental-Economic Accounting (SEEA) and the System of National Accounts (SNA). The SNA confines its recording to the supply and use of the product. Understanding the chain of water flows between different water sources or ecosystems and use by economic units is key to the recording of flows as intermediate or final ecosystem services, natural resource and products in both parts of the SEEA. In some cases water can simultaneously be a final ecosystem service, natural resource and product (e.g. water extracted from a lake and used by an economic unit). Water flowing into, and being extracted from artificial reservoirs, is an example where the production boundary between SNA and SEEA Central Framework and SEEA Ecosystem Accounting could differ, if the water is deemed to enter the economy when it enters artificial reservoir rather than leaves the reservoir. Examples of flows and accounting treatments are provided. The recording of water flows to croplands and of the water used in agricultural production requires consideration. Understanding the different perspectives and treatment of water flows, and in particular the supply and use of intermediate water provisioning ecosystem services, should help with valuation of water flows, water assets and inventories of water products as well as when the value of water is embedded in other assets (e.g. land).

Four conclusions for discussion are:

1. The supply of the natural resource water from natural resource water (non-produced) assets to the supply of water provisioning ecosystem service from water ecosystems assets (rivers, lakes, artificial reservoirs, subterranean) **is equivalent**
2. In the case of supply of water from water natural resources and water ecosystem assets these flows **are equivalent to the product flow CPC 1800 "Natural Water"** (with the point is becoming a product changing with the production boundary)
3. The supply and use of the water provisioning ecosystem services from non-water ecosystem assets to industry is open interpretation and conventions need to be established – at least two options
4. Valuation remains contentious
    - Distinguishing the different types of physical water flows and the assets producing and using water provisioning ecosystem services is a useful step. Doing this can help identify actual or potential double counting of ecosystem service flows in asset values
    - Value of some water flows (or assets) will be embedded in assets (e.g. land)

1. Introduction

This paper address two items on the System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting Research Agenda (pp. 348-352). They are:

- Connections to complementary valuations of ecosystem services and ecosystem assets and
- Ongoing alignment with the SNA

For both issues it is necessary to have a common understanding of the scope and treatment of flows in the System of National Accounts (SNA), SEEA Central Framework/SEEA Water and SEEA Ecosystem accounting. A key is that the valuation of ecosystem assets is based on the net present value of flows, hence distinguishing the flows from those already within scope of the SNA and SEEA Central Framework/SEEA Water is necessary as well as understanding with the value of the water is embedded in other assets already included in the national balance sheet.

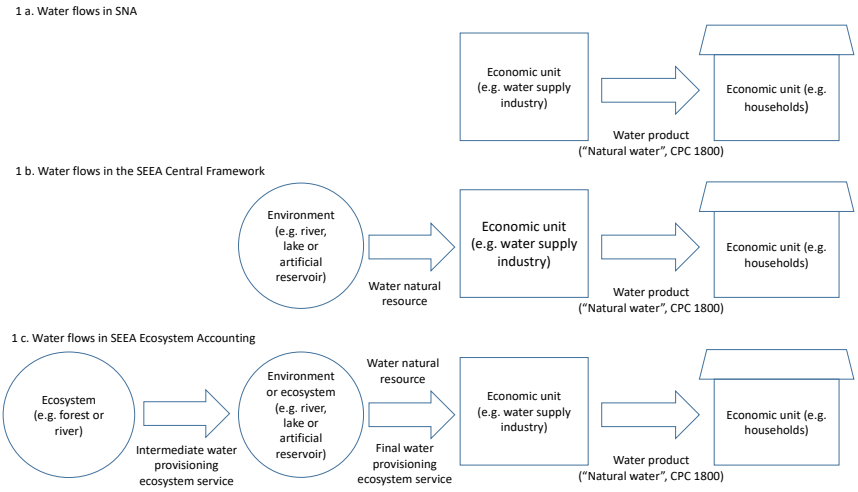
This paper also returns to the issue of determining when water crosses the SNA production boundary. This issue was addressed, mostly in reference mostly to artificial reservoirs, in the development of the SEEA Central Framework (Nagy et al. 2009, Obst 2010, UNSD 2008). Determining where the production lies has implications for both the records of flows.

2. Classification of water flows

The classification of water flows as an ecosystem service, natural resource or product depends on the type of units supplying and using water. Figure 1 illustrates the expanding coverage of the flows in the SNA, SEEA Central Framework, and SEEA Ecosystem Accounting. In SNA the units supplying and using water are economic units classified to industry and sector (Fig. 1a). In the SEEA Central Framework, the "environment", split by categories (e.g. surface water, soil water and groundwater), is added as a unit that supplies water to economic units, but the environment does not use water (Fig 1b). In the SEEA Ecosystem Accounting, ecosystems supplying water to economic units is final use of water, while ecosystem can also supply water to other ecosystems, an intermediate use of water if the water supplied to other ecosystems is ultimately supplied to an economic unit (Fig 1c).

Note that there is no difference between the flows from the environment or ecosystem and the economic unit, except the name of the supplying unit and the name of the flow. As such, there is no difference between the flow of natural resources recorded in the SEEA Central Framework and flow of the water provisioning ecosystem service recorded in the SEEA Ecosystem Accounting. The point is reinforced with the classification of the surface water resources in the SEEA Central Framework and the 'water" ecosystems in the SEEA Ecosystem Accounting are identical. The classification of water ecosystems does not include groundwater, which is, along with soil moister, included in the SEEA Central Framework.

Figure 1. Coverage of flows in the SNA, SEEA Central Framework and SEEA Ecosystem Accounting



An important consideration in the chain of flows in SEEA Ecosystem Accounting (Fig 1c) is that it is only the part of flows supplied to economic units as a final ecosystem service that is counted as an intermediate ecosystem service. For example, if the flows of water from river ecosystem to a lake are 10,000 m^3 but the water extracted from the lake and used by an economic unit (the final water provisioning ecosystem service) is 4,000 m^3, then the intermediate water provisioning service supplied by the river to the lake is 4,000 m^3. The other 6,000 m^3 is not recorded in the ecosystem service supply and use table, although it would be recorded in the water asset account of the SEEA Central Framework.

3. The production boundary and water

In assessing the classification of water flows determining when water enters the economy – the production boundary – is important. When water enters the economy has been a matter of debate, especially in regard to artificial reservoirs.

In the SNA, SEEA Central Framework and SEEA Water the stock of water held in artificial reservoirs is considered a non-produced asset and is included in the asset accounts as a subcategory of "surface water" and water enters the economy only when it is abstracted from the environment.

The changes to the natural hydrological regime due to artificial reservoirs, such as net recharge (inflows minus *all* outflows), are not currently recorded in the physical supply-use tables, but are considered as a part of "natural" interactions between inland water resources (e.g. inflows from rivers, seepage to groundwater) and the atmosphere (e.g. evaporation). The water asset account does record these flows. However, the current recording in supply and use lead to is a significant distortion of the real-world situation in the water accounts and may have implications for decisions on the building or reservoirs, the allocation of water and the calculation of water consumption and productivity for the enterprises operating artificial reservoirs and has implications for the value of water.

A key outflow from artificial reservoirs not recorded in the current supply-use tables is evaporation for the reservoirs. This is significant as several studies show that the increased surface area of reservoirs often leads to high levels of evaporation. For example, the World Commission on Dams estimated that evaporation from reservoirs is in the order of 188km^3 per year, which equates to more than 8% of the total human consumption of freshwater (WCD 2000). If the water in artificial

reservoirs was treated as a produced asset then evaporation from reservoirs would be shown in the supply and use tables as a use by enterprise operating the reservoir (e.g. the water supply industry).

The SNA 2008 defines produced assets as non-financial assets that have come into existence as outputs from production processes that fall within the production boundary of the SNA. (2008 SNA paragraph 10.9a.). In the 2008 SNA the growth and regeneration of crops, trees, livestock or fish which are controlled by, managed by and under the responsibility of an enterprise constitute a process of economic production. Their growth is not construed as a purely natural process that lies outside the production boundary (2008 SNA paragraph 6.136).

The arguments used to delineate the production boundary between cultivated and non-cultivated crops and trees can also be used for water. The flows of water into artificial reservoirs constitutes a process of production. The water contained in dams is not wholly a natural process as the natural course of water is changed. Dam walls are built to contain water and on-going management is needed to regulate the stock of water in the reservoir (see SEEA Water paragraph 6.23). If the production boundary is established when water enters the artificial reservoir, then water changes from being a natural resource in the SEEA Framework and SEEA Water to the product "natural water" CPC 1800. The water in the reservoir would then be an inventory of the produce "natural water" CPC 1800.

The SNA 2008 defines inventories as stocks of outputs that are still held by the units that produced them prior to their being further processed, sold, delivered to other units or used in other ways and stocks of products acquired from other units that are intended to be used for intermediate consumption or for resale without further processing (2008 SNA 10.12). This definition of inventories fits with the water in artificial reservoirs: the water came existence in the current period or in an earlier period and is held for sale, used in production or other use at a later date. Apart from the losses of water in reservoirs due to evaporation and seepage to groundwater there are a number of other ecological effects (e.g. sediment trapping, changes of water quality, changing patterns of stream-flows, stopping of the migration of aquatic organisms etc.) which would also be of interest to water managers, ecologist and policy analysts.

The treatment of water in artificial reservoirs was discussed in in the development process of SEEA Water, SEEA Central Framework and the International Recommendations on Water Statistics (IRWS). The issue was also discussed during the drafting of the SEEA-Water, although records of these discussion were not kept. The Expert Group Meeting (EGM) on the IRWS (New York, USA, 5-7 November 2008) recommended that the matter should be brought to the attention of the London Group on Environmental Accounting as part of the development process of the SEEA Central Framework (UNSD 2008). This became Issue Number 16 in the development of the SEEA Central Framework.

The treatment of water in artificial reservoirs was also discussed at the 14th and 15th Meetings of the London Group (e.g. Nagy et al. 2009; Comisari and Vardon 2010). The group was unable to reach a conclusive position during these discussions or during subsequent discussion among water accounting experts. The ultimate decision in the SEEA Central Framework was to maintain the current treatment, despite the Outcome Paper for Issues 16 (Obst 2010) recommending a change to the production boundary.

So while there was much discussion, the SNA, SEEA-Water and SEEA Central Framework all have the same production boundary. As we will see in subsequent sections, a change to the production

significantly alters how the flows of final and intermediate water provision ecosystem service are recorded.

4. Accounting for water flows

Figure 2 shows a chain of flows beginning with flows from a forest into a river and onto non-irrigated cropland. In this the total run-off from the forest is greater than water provisioning ecosystem service – which based on the reasoning outlined in Section 2 and summerized in Figure 1 and is also the nature resource water – which is only the water ultimately used by people. In Figure 2, the current production boundary is used, with the water produced when it leaves all types of water assets, irrespective of the degree of human management. In this the total supply of final water provisioning services to industry and households is 1090 Mm^3. There is intermediate use of ecosystem services for the contribution to final ecosystem service of water provisioning (Table 1). Own-account production of water (CPC 1800) by agriculture and households has not been reallocated to the water supply industry (but could be). If an account including the food provisioning ecosystem service was produced then a water provisioning service (200 Mm^3) would be recorded as an input to agricultural production along with the agricultural food provisioning service. Accounting for both water and food provisioning services in the one table world is complicated (I tried and gave up!).

In the two examples, artificial reservoirs are both identical asset classes in the SEEA Ecosystem Accounting and the SEEA Central Framework. In this, either the artificial reservoir or river asset supplies a final water provisioning ecosystem service to the water supply industry, which in turn produces and supplies the product “natural water” (CPC 1800). The only question is when the product is produced: when it leaves the reservoir (Figure 2, Table 1) or when it leaves the river and goes into the reservoir (Figure 3, Table 2). The decision affects the volume of final and intermediate use of the ecoservice.

Whatever is chosen, when water is extracted by an economic unit (e.g. a household or agricultural enterprise) from a river, lake or artificial reservoir, then the final water provisioning ecosystem service and the natural resource water are the same, both being used by the economic unit (e.g. a household or agricultural enterprise). In ecosystem accounting, the recording of the supply and use of the final ecosystem service would end with the supply by the river, lake or artificial reservoir and the use would be by the economic unit. To be strictly in accordance with SNA and SNA Central Framework, the water abstracted from a water asset by any economic unit would also be deemed own-account production, hence the use of the final water provision ecosystem service (or the water natural resource) and in theory attributed to the water supply industry which would the supply the water product (CPC 1800) back to the economic unit (e.g. a household or agricultural enterprise). This is not done in either Table 1 or 2 but it could be with and in this the water supply industry would be the sole supplier and supply, 1090 and 1110 respectively. In this case, the water extracted by an economic unit would be simultaneously a final ecosystem service, natural resource and product.

It should be noted that the examples provide are not a complete representation of all water flows. For example, neither shows the use of soil moisture (e.g. by non-irrigated agriculture), although both show the use of water from the forest ecosystem. This is the amount of run-off from the forest ecosystem that is incepted and transpired by crops, downhill from the forest. Use of groundwater or of precipitation captured in rainwater is likewise not shown. Precipitation (rain) and the interactions between groundwater and surface water are not shown in supply and use tables but are shown in the water asset accounts.

Figure 2. Chain of water flows with current production boundary

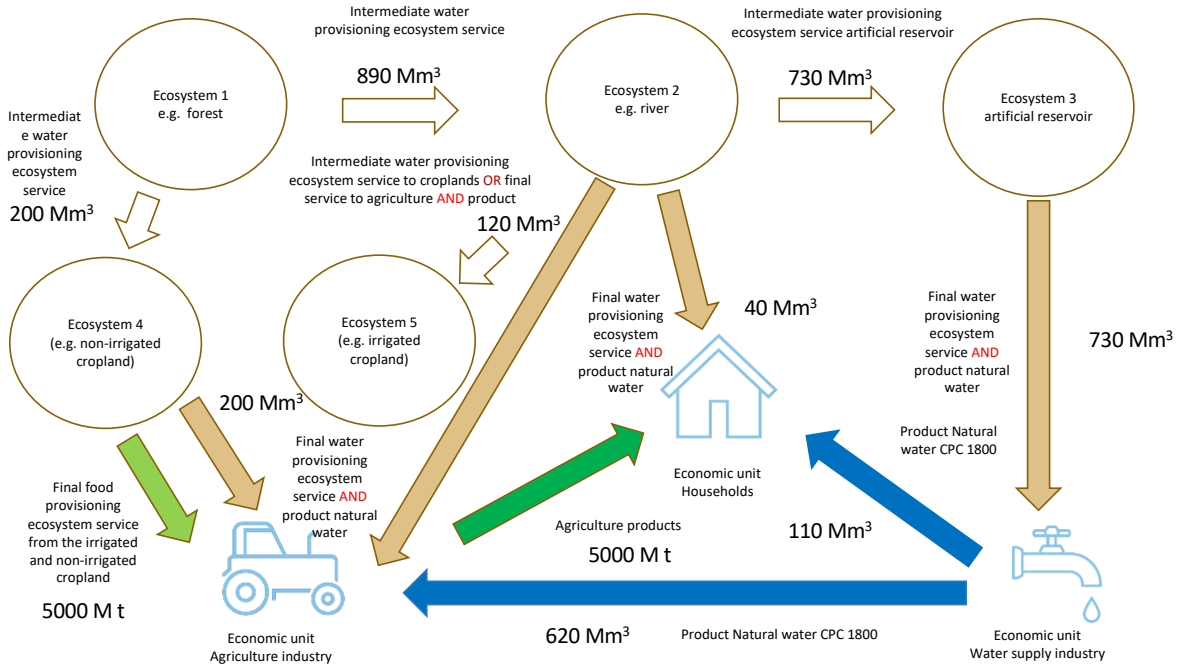


Table 1. Recording of water flows with current production boundary

	Economy				Ecosystem					
Table 1a River supplies agriculture and exisiting productions boundary	Agriculture	Water supply	Inventories	Households	Forest	Non-irrigated cropland cropland	Irrigated cropland	River	Artificial reservoir	Total
SUPPLY	M m3	M m3	M m3	M m3	M m3	M m3	M m3	M m3	M m3	M m3
Ecosystem service										
Water provisioning										
Intermediate					1090			730		1820
Final						200		160	730	1090
Products										
Natural water	320	730		40						1090
USE										
Ecosystem service										
Water provisioning										
Intermediate						200		890	730	1820
Final	320	730		40						1090
Products										
Natural water	940			150						1090

Figure 3 and Table 2 show the accounting if the production boundary is moved so that the water is a final ecosystem service as it enters an artificial reservoir and become a product when it is within the reservoir. Total supply of the intermediate water provisioning ecosystem service from the forest to the river increases by 20 Mm^3 due to extra water that goes to the production of “natural water” (CPC 1800) and recorded as an addition to inventories. No losses due to evaporation are shown to the inventory.

Figure 2. Chain of water flows with changed production boundary for artificial reservoirs

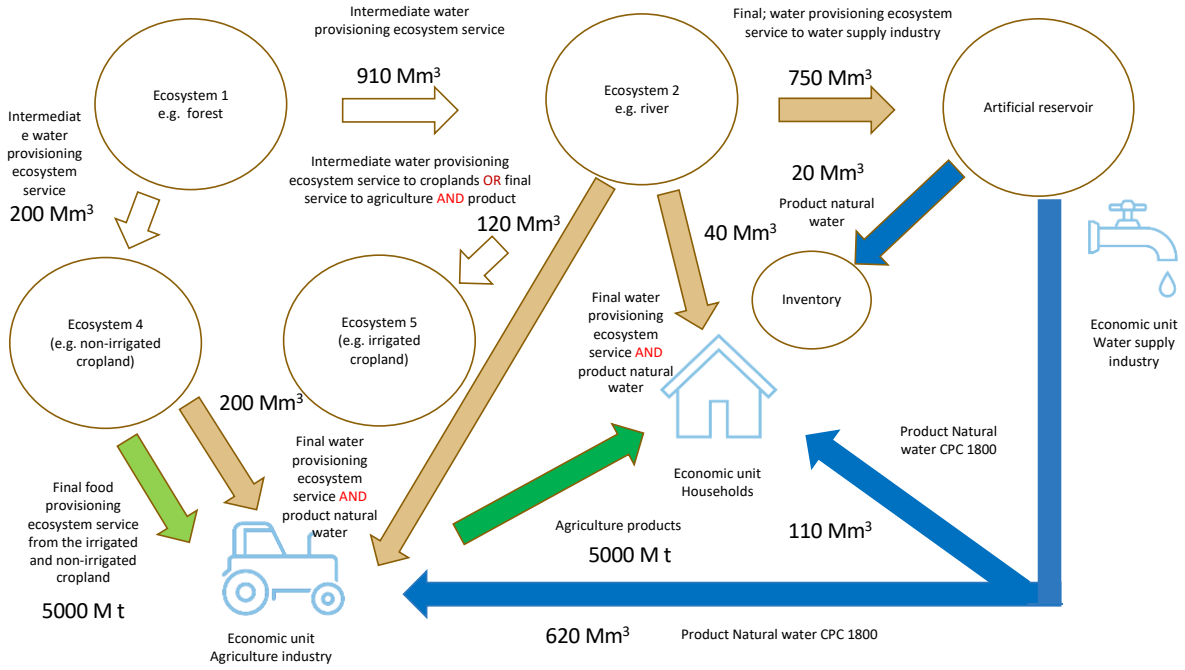


Table 2. Recording of water flows with changed production boundary for artificial reservoirs

	Economy				Ecosystem					
Table 2b River supplies agriculltures and expanded productions boundary	Agriculture	Water supply	Inventores	Households	Forest	Non-irrigated cropland cropland	Irrigated cropland	River	Artificial reservoir	Total
SUPPLY	M m3	M m3	M m3	M m3	M m3	M m3	M m3	M m3	M m3	M m3
Ecosystem service										
Water provisioning										
Intermediate					1110			750		1860
Final						200		160	750	1110
Products										
Natural water	320	750		40						1110
USE										
Ecosystem service										
Water provisioning										
Intermediate						200		910	750	1860
Final	320	750		40						1110
Products										
Natural water	940		20	150						1110

Use of water by agriculture

The recording of water use by agriculture differs between the SEEA Central Framework/SEEA Water and SEEA Ecosystem Accounting (Table 3). The main difference is the source of the water used in agriculture, which is soil moisture, with the source of water for soil moisture being the water provisioning service from other ecosystems, including precipitation from the atmosphere (in this the atmosphere is an ecosystem).

Another difference is the recording of return flows, that is flows from the economy to environment. In the SEEA Central Framework/SEEA Water this recording is explicit. Such flows are not in the SEEA Ecosystem Accounting. The return flows are of interest as these partly determine the amount of water available for use, the hence the potential volume of water provision ecosystem service.

Table 3. Comparison of the use of water by agriculture in the SEEA Central Framework and SEEA Ecosystem Accounting

SEEA Central Framework and SEEA Water	**SEEA Ecosystem Accounting**

Non-irrigated cropland
• Uses soil moisture
  - Source of source moisture is direct precipitation plus run-off
• Use of soil moisture by agriculture
	Non-irrigated cropland
	• Uses intermediate water provisioning service from other ecosystems
	  - Runoff from other ecosystems transpired by crops
	  - Precipitation onto the non-irrigated cropland (atmosphere as an ecosystem) transpired by crops
	• Use of all water by agriculture

Irrigated cropland • Use surface and groundwater from water suppliers (including own-account production), and soil moisture - Source of source moisture is direct precipitation plus run-off • Use of all water by agriculture	Irrigated cropland – options 1 • *Water ecosystems* (e.g. rivers, artificial reservoirs) supply the final water provisioning ecosystem services to agriculture Irrigated cropland – options 2 • *Irrigated croplands* use of intermediate water provisioning ecosystem services from water ecosystems (e.g. rivers, artificial reservoirs) by irrigated cropland • *Irrigated croplands* supply the final water provisioning ecosystem service to agriculture

Valuation

For valuation, water is recognized as a natural resource and its value could be included in the balance sheets of countries according to the practices of the SNA. However, no country has official estimated the value of water assets using the SNA or SEEA Central Framework, even though many countries produce monetary supply and use tables for "natural water" (CPC 1800) and some academic studies have done so (e.g. Edens and Graveland 2014; Fenichel et al. 2016). The ecosystem service of water provisioning has also been valued in several studies (e.g. Keith et al. 2017). Comparing the valuation approaches will be an important step and to do this there needs to be a clear classification and understanding of water flows. With the valuation of flows then the value of assets can be done with net present value.

This begins with agreement on the classification water provisioning ecosystem service, water as a natural resource and the product "natural water" (CPC 1800). It then requires the development of recording conventions, especially for agriculture and the supply and use of the final and intermediate water provisioning ecosystem services. This should aid the valuation of water stocks and the different types of flows

Conclusion

The overlaps between the SNA, SEEA Central Framework and SEEA Ecosystem Accounting are many. The definitions of final ecosystem services in SEEA Ecosystem Accounting and natural resources in the SEEA Central Framework are equivalent (Figure 1). In addition, because of the notion of own-account production in the SNA, water abstracted from any surface water asset by any economic unit can simultaneously be a final ecosystem service, natural resource and product.

Four conclusions for discussion are:

5. The supply of the natural resource water from natural resource water (non-produced) assets to the supply of water provisioning ecosystem service from water ecosystems assets (rivers, lakes, artificial reservoirs, subterranean) **is equivalent**
6. In the case of supply of water from water natural resources and water ecosystem assets these flows **are equivalent to the product flow CPC 1800 "Natural Water"** (with the point is becoming a product changing with the production boundary)
7. The supply and use of the water provisioning ecosystem services from non-water ecosystem assets to industry is open interpretation and conventions need to be established – at least two options
8. Valuation remains an issue
    - Physical water flows and the and the assets producing and using water provisioning ecosystem services needs to identify double counting of flows
    - Value of some flows will be embedded in assets (e.g. land)

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Assets and flows

	Assets				
	SNA	SEEA CF	SEEA EA (SEEA-CF + terrestrial ecosystes)		
Flows		Rivers and streams Lakes Artificial reservoirs Snow, ice and glaciers Soil water Groundwater	F1 Rivers and streams F2 Lakes F3 Artificial reservoirs		
Natural resource of Water					
Product “natural water” CPC 1800					
Product “bottled water” CPC					
Ecosystem service water provisions					