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Improving intersectorial water use within the seea accounting framework

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ABSTRACT

This document describes the conceptual basis of two methodological approaches which can be used to fully represent the water use of the fishery sector within the SEEA accounting framework. A broader description of this analysis with reference to several water-related SEEA accounts is available as a FAO Fisheries and Aquaculture Technical Paper (FAO, 2016). The fishery sector uses water resources in two different ways. Fishing, vertical raceways cage and pen aquaculture have an *in-stream* water use as they use water on-site. They do not abstract and do not consume water but they are indissolubly dependent to the availability of surface waters as fish habitats. Pond aquaculture, recirculating aquaculture systems, horizontal raceways have an *off-stream* water use as water is initially abstracted from the natural environment to create a culture environment, which according to the aquaculture method used can require different amounts of water additions during the production cycle. The SEEA accounting framework has been mainly developed for monitoring *off-stream* water uses in terms or water volumes abstracted and consumed. The current limited capacity of the SEEA accounting framework to measure *in-stream* water use raises some concerns in the way to which the water requirements and needs of economic activities that have an in-stream water use can be represented in national water accounting. Several economic activities, including the fishery sector, have an *in-stream* water uses. Due to its nature i*n-stream* water uses tend to overlap to each other as well as to *off-stream* water uses. Therefore, in the SEEA water accounting it is important to further develop methodologies able to better account for *in-stream* water use and to compare *in-stream* and *off-stream* water uses. To advance in this direction two different approaches are suggested below.
A first approach is suggested to measure all kind of *in-stream* water use as water areas. Presently SEEA accounting framework measures in-stream water use as the water area clearly delimited for a specific use such as aquaculture cages and areas for conservation purpose (i.e. single purpose water use) while gathers together all *in-stream* water use that tend to overlap in space and time (i.e. multipurpose water use). A second approach is suggested to measure *in-stream* water use as water volumes. In particular, the amount of water needed by in-stream activities of the fishery sector can be measured as the high (flooding) environmental *water flow* required for the maintenance of aquatic ecosystems and reproduction of resident and migratory fish species. These two approaches are undertaken to be able to subsequently compare *in-stream* and *off-stream* water uses amongst different economic units. The SEEA accounting framework contains a matrix to account for origin and destination of water flows within the economy. The proposal is to expand the scope of this matrix to show interactions amongst *in-stream* and *off-stream* water uses. These interactions are assessed in terms of potential rivalry for water abstractions as well as overlapping use of surface waters in time and space.

Keywords: SEEA, water accounting, water use

PAPER

1. Introduction

Water use is a general, non-specific term that describes any action through which water provides a service (Kohli et al., 2010). Water use can be distinguished into off-stream and in-stream:

. *Off-stream water* use takes the water out of the water source, reducing the amount of available water left on-site;
. *In-stream water use on-site water use* does not remove water from its source or water is immediately returned with little or no alteration.
Some activities such as navigation, hydro-electric power generation[1], recreational activities on water, have an in-stream water use as they occur on-site. Other types of activities such as crop production, municipal water use and sanitation, industrial water use, have an off-site water uses, because they require to abstract water and use it in other locations.

. *Off-stream water use* is usually measured in terms of the water volumes abstracted and consumed and returned to the environment.
. *In stream water use* is usually measured in terms of the water area required for a given purpose. By definition in-stream water use has no water withdrawal, no water consumption and no water return;

The fishery sector is comprised of capture fisheries[2] and aquaculture activities[3] and is characterized by both in-stream and off-stream water use (Table 1)

Table 1 - In-stream and off-stream water use within the fishery sector

Characteristics	Fishery sector		
ACTIVITY	Capture fisheries	Aquaculture	
WATER USE	*in-stream*	*in-stream*	*off-stream*
METHOD	Any types of fishing	Cage (including on-bottom and off-bottom)	Pond
		Pen	Indoor tank
			Recirculating systems
		Vertical raceways	Horizontal raceways

Capture fisheries have an in-stream water use as fishing uses water on-site. Fishing does not abstract and do not consume water but is indissolubly dependent to the availability and access to surface waters as fish habitats. Fishing activities are also highly affected by the seasonal variation of inland waters. The contraction of inland waters is usually detrimental for fishing activities, while their enlargement due to the creation of seasonally flooded areas, caused by overflowing of river and lakes, is highly favorable. Seasonally flooded areas are rich in nutrients and are essential for reproduction of many fish species. For these reasons seasonally flooded areas often are fishing areas characterized by high fish catches. Aquaculture can have both *in-stream* and *off-stream* water use according to the aquaculture methods. Cages, pens are considered to have an *in-stream* water use, while pond and recirculating systems have an *off-stream* water use. For pond culture, water is abstracted to fill the pond, to maintain the water level and compensate evaporation and seepage losses, and to maintain suitable values of temperature and other water parameters. Water is used in the same way for indoor tanks but the amount of water needed to replace evaporation will be lower than for outdoor pond. Recirculating systems use indoor tanks in which water circulates into a closed loop so that water is (partially) reused after undergoing treatment. Thus, an initial water withdrawal is needed as well as limited water addition during the production cycle. In raceways, water is flown through artificial tanks. In horizontal raceways water flows in one end of the device and flow out at the other. In vertical raceways water flows in at the top and out at the bottom. Vertical raceways are usually built as flotation frames and therefore they are considered to have an *in-stream* water use. On the contrary horizontal raceways are considered to have an *off-stream* water use since they are constituted by artificial structures, where water is abstracted and diverted from natural surface waters to create a water flow that artificially mimic the river run-off for aquaculture purposes.

2. SEEA accounting framework and water-related accounts

The SEEA-Central framework (United Nations et al., 2014) has two main categories of water-related accounts related to (i) water areas and (ii) water volumes. The SEEA land cover account describes the landscape composition and specifically measure areas occupied by different water resources. The SEEA land use account describes how the landscape is affected by human intervention and management measuring how water areas are used for different purposes. The SEEA water asset account measures the water volumes of surface water, ground water and soil water yearly available in a country. The SEEA supply and use water account compares the water volume available as yearly national water supply to the water volumes requires to meet water demand by different economic units. The development and degree of implementation of these two categories of water-related accounts vary greatly. SEEA accounting framework has been mainly designed for monitoring water volumes.

This is mainly due to the fact that many policy objectives in water management such as improving water supply and sanitation services, developing a rationale for water allocation permits, managing water supply and demand amongst municipal, irrigation and industrial water users, increasing water treatment and reuse, mitigating the risk of flooding, monitoring climate variability require the accounting of available water volumes rather than water areas.

[1] The hydroelectric plant that uses the river rapids to produce electricity has an in-stream water use. However, if the hydroelectric plant requires a dam for the storage of large quantities of water to create the water drop suitable for power generation, water is retained and consumed through evaporation. In this case the hydroelectric plant has an off-stream water use. In the SEEA framework hydropower generation is generally considered as having an off-stream water uses and therefore quantity of abstracted water is explicitly accounted.

[2] Capture fisheries is defined as the extraction of living aquatic organisms from natural or artificial inland waters, but excluding those from aquaculture facilities (FAO, 2010).

[3] Aquaculture is defined as the farming of aquatic organisms involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated (FAO,2010).

3. SEEA accounting framework and water use

Water accounting is a powerful tool for monitoring and evaluating the use of water resources. It provides a measure of the availability of water resources within a country's territory and also a measure of the pressures on these water resources by different economy activities and overlapping or conflicting uses among different water users. This information can then be used to improve resource management and inform decision making processes by identifying whether a country is using its water resources in an efficient, equitable and sustainable way. Accounting for water use requires to take into consideration both in-stream and off-stream water uses. In the SEEA framework the land use account, which measures water area can be used to describe in-stream water uses, while the supply and use, water which measures water volume can be used to describe off-stream water uses. The current limited capacity of the SEEA accounting framework to measure in-stream water use raises some concerns in the way to which the water requirements and needs of economic activities that have an in-stream water use can be represented in national water accounting. Therefore, there is the necessity to further develop methodologies able to better account for in-stream water use and to compare in-stream and off-stream water uses. To advance in this direction two different approaches are suggested below.

3.1 First approach: measuring in-stream water uses as water areas

A first approach is suggested to measure *in-stream* water uses as water area providing information for both *single-purpose* water use and *multi-purpose* water use. The SEEA classification of water use includes four main water categories: *waters used for aquaculture or holding facilities, waters used for maintenance and restoration of environmental functions, other uses of waters* and *waters not in use*. In principle, these four classes are applicable to inland waters, coastal waters and marine waters. The criterion applied to this classification is that areas of water are be considered 'used' only where they have been clearly zoned or delimited for a specific use. Therefore, the SEEA classification of water use distinguishes specific water use such as aquaculture facilities and areas for conservation purpose (i.e. single water use). In this respect other single water uses could be added as a separated classes such as for example *inland waters exclusively used for irrigation* and *inland waters exclusively used for cooling water to a nearby power plant or industrial facility*.

Despite the addition of other classes the bulk of different *in-stream* water use will remain aggregated into the broad class of other uses of water. All *in-stream* water uses take place in existing surface waters. Since *in-stream* water use do not abstract neither consume water often they often don't occur as single use but tend to overlap in space and time with other water use (i.e. multiple water use).

In order to account for multiple water uses a GIS-based approach is suggested. GIS organizes and analyzes information into overlapping layers and therefore is able to deal with multi-dimensionality of different water uses. In the case of the fishery sector, water areas used as fishing grounds could be represented as well as water areas important as reproductive sites or nursery of important fish target species. In the case of aquaculture water areas could directly identify cage and pen used for aquaculture facilities. In addition, other in-stream water uses such as navigation, tourism and recreation could be made spatially explicit so that an area of use is identified.

Using a GIS-based approach the map of surface water to analyze is divided into a grid. Each water use of a given economic unit constitutes a separate layer of information mapping the grid cells where that use take place.

Each water use records the continuity (e.g. yearly, seasonally, monthly, daily etc.) with which the grid cells are used.

Following such GIS-approach also the spatial and temporal overlap between in-stream and off-stream uses can be captured since water areas used for water withdrawal and water discharge can be also mapped.

Within the same surface water:

- *In stream water* are identified by one continuous area or several disjoint areas
- *Off-stream water use* are identified by points where water is abstracted and (eventually) returned, which often correspond only to one or few grid cells.

On the basis of a criterion of continuous use in time each grid cell can have a primary use of a given economic unit and one or few secondary uses of other economic units.

3.2 Second approach: measuring in-stream as water volumes

A second approach is suggested to measure in-stream water uses as water volumes. This approach is undertaken to be able to directly compare in-stream and off-stream uses.

The fishery sector has an *in-stream* water use, which occur on-site and doesn't consume water, however, this does not mean that the fishery sector don't need water. On the contrary fishing, cage and pen aquaculture are highly dependent on the availability and access to surface waters since they are fish habitats. For this reason the volume of water needed to enable the *in-stream* water uses of the fishery sector is the environmental water flows that support the fish life cycle.

The *environmental water flow* is defined by the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on them (The Brisbane Declaration, 2007).

There are several methods to estimate the environmental water flow; hydrology-based methods are the most simple to implement as they primarily use time-series of monthly or daily flow records (Thamer, 2003).

Within river hydrology different water flows enable different ecological processes (Postel and Ritcher, 2003).

. *Base environmental water flow* maintains suitable water temperatures, dissolved oxygen and water chemistry and consequently provide adequate habitat for aquatic organisms. A base water regime can enable fish to move to feeding and spawning areas within the surface water. On the contrary when the base flow decreases below the normal level to the drought level this can hamper fish reproduction as well as fish survival;

. *High (flooding) environmental water flow* enables fish not only to reproduce within to surface water but also trigger fish upstream migration of anadromous fish. The increased run-off causes the overflowing of rivers and lakes with consequent creation of seasonally flooded areas. Seasonally flooded areas are rich in nutrient, shallow and often are used by many fish species as spawning areas and nursery areas for fish juveniles.

In order to estimate environmental water flows (base flow and high flow) a GIS-based approach is suggested. The recommended scale of analysis is the watershed defined at an appropriate spatial scale. The 'environmental water flow' or water regime required to support and maintain aquatic ecosystems differs is specific of each watershed. In fact watersheds differ for: climatic condition and seasonality, amount of precipitations, rate of evaporation or evapotranspiration, land cover, land use and management the water inflows received from neighboring countries and consequent water run-offs.

The volume of water needed to enable the *in-stream* water uses of the fishery sector is identified by the high (flooding) environmental water flow. Since the *in-stream* water use by definition has no water consumption, for accounting purposes, a volume of water equal to the high environmental water flow is 'virtually' abstracted by the fishery sector and the same amount is also returned to the environment.

3.3 A matrix of water-based interactions amongst economic units

The two described methodological approaches are undertaken to be able to subsequently compare in-stream and off-stream water uses amongst different economic units.

The SEEA accounting framework contains a matrix to account for origin and destination of water flows within the economy. In this matrix the economic units (industries by ISIC category, household and rest of the world) constitute both rows and columns. The economic units in the rows are considered as '*water suppliers*', those in columns as '*water users*' (United Nations, 2012; para.3.43).

The proposal is to expand the scope of this matrix to show relationships amongst *in-stream* and *off-stream* water uses. The structure of the account is the same of the original matrix in SEEA-Water with the only difference that some economic units can be further disaggregated to be able to account for the different water use of some sub-units. The *environment* is also added as a '*water supplier*' as many activities including pond aquaculture and recirculating aquaculture systems can abstract water directly from the environment without the intermediation of water supplier industry.

The proposal is to compile this matrix of water-based interactions amongst economic units (Table 2) in twin tables with two units of measurement which account respectively for:

2a. Exchange or competition of water flows between units –water volumes

2b. Overlap or competition in space and time between units – water areas

The compilation of the matrix in water volumes gives the possibility to compare *off-stream* uses with those *in-stream* uses which can be expressed in terms of water volumes. Each cell of the matrix records quantity of water originated from the economic unit in the row (origin) and distributed to the one in the column (*destination*). Consequently the matrix highlights the role of each economic unit as water supplier and/or as water user. Aquaculture can be a 'water supplier' since for example as a water supplier as can supply wastewater to sewerage activities but is also a 'water user' often abstracting water directly from the environment. Fishing is a water user of the environmental water flow that support fish life cycle and consequently allow the reproduction of fish stocks.

With the few adjustments made (i) inserting the environment as unit of origin and destination (ii) measuring the in-steam water use of fishing and cage as environmental water flow, this matrix can account both *in-stream* and *off-stream* water use of the fishery sector. It should be noted that the volume of water used by the fishery sector is 'virtual' since it is usually not secured by the fishery sector but in reality remains available for the potential use of all other sectors. Therefore a comparison between the environmental water flow and the major water volumes used by the economic units can reveal a vulnerability of the sector to water conflicts. In particular the matrix can highlight a large share of the existing environmental water flow used for growing non-perennial crops (ISIC 01-1) or the matrix can show a conflicting use in the water volume required for hydroelectric power generation (ISIC 35-1) and the environmental water flow which support upstream fish migration. Less obviously the water volume used by several industrial activity of agriculture (ISIC 01-03), manufacturing (ISIC 10-16) and the volume of water for household consumption can be compared with volumes of water that are collected and treated (ISIC 36 and 39) to gain an indication of the impact of economic activities on water quality.

Table 2 - Matrix of water-based interactions amongst economic units

ISIC description	ISIC category	01	01-111	02	03-1	03-2	10-16	35-1	36	37	39	50-1	50-2	55	56	ENV	HH	WLD
01 Crop and animal production, hunting and related service activities	01																	
01-111 Growing of rice	01-111																	
02 Forestry and logging	02																	
03-1 Fishing	03-1																	
03-2 Aquaculture	03-2																	
10-16 Manufacturing	10-16																	
35-1 Electric power generation, transmission and distributio	35-1																	
36 Water collection, treatment and supply	36																	
37 Sewarage	37																	
39 Remediation activities and other waste management se	39																	
50-1 Sea and coastal water transport	50-1																	
50-2 Inland water transport	50-2																	
55 Accommodation	55																	
56 Food and beverages service activities	56																	
Environment	ENV																	
Households	HH																	
Rest of the world	WLD																	

In few cases the water requirements of water transport (ISIC 50-1 and 50-2) can also be expressed as water volumes required (i) to maintain a depth of surface water suitable for navigation (ii) to operate waterway locks in inland waters for navigation. In these cases the water of volumes used for water transport can be directly compared with those of other economic units. The compilation of the matrix in water areas shows interactions amongst in-stream water uses and qualitatively can pinpoint also situations of overlap between in-stream and off-stream water use.

In the matrix the area of water reserved or delimited for single water uses can be recorded in the diagonal of the matrix, while any each other cell in the matrix records the area of water shared by two economic units. Therefore, the matrix can show the existing balance between the allocation of surface waters allocated to single water use and the area of surface waters freely accessible available for multiple uses. The matrix can be used to report the outcomes of a previous GIS-based analysis aimed at mapping multiple water use and provide a better understanding on the economic units involved their degree of overlap in space and time.

Each cell of the matrix can be used to record the area of surface waters shared by the economic unit in the row (*dominant user*) and another economic unit in the column (*secondary user*) in respect to their different intensity/continuity of their use in time In this way the overlap in space and time amongst different in-stream water users such as for example fishing (ISIC 03-1) and water transport (ISIC (ISIC 50-1 and 50-2), fishing and hydroelectric power generation (ISIC 35-1), fishing and bottom-cage aquaculture can be compared. Although *off-stream* water uses are described by the water abstracted, consumed and returned to the environment, both withdrawal and disposal of used water can occur in surface waters. Therefore a given area can be affected by both off-stream and in-stream water uses. This situation can also be accounted in the GIS analysis and reflected in the suggested matrix.

4. Conclusions

Accounting for interactions amongst *in-stream* and *off-stream* water uses requires water accounting at multiple-scale composed by three main hierarchical levels: the national scale, the watershed and surface waters within the watershed. Correspondingly the *Matrix of water-based interactions amongst economic units* can be compiled at the level of the single surface water, the watershed and the national level. The assessment of *in-stream* water uses is likely to require an analysis at the level of surface waters but an aggregation of the results at the watershed level and at the national level would be equally important. The watershed is a fundamental spatial scale for water accounting. All water resources within a watershed are interlinked in terms of both quantity and quality and the watershed is often the unit where decisions on water management are taken. The national-level is also fundamental since it is the scale targeted by the SEEA accounting framework. Therefore a GIS-based approach becomes a fundamental tool in SEEA for its analytical capacity of integrating information amongst multiple scales, of analyzing interacting biophysical and climatic factors as well as supporting the assessment of different water uses by different economic units.

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