Public Disclosure Authorized

Indonesia Water Accounts: Feasibility and guidelines for future work[1]

[1] This document was commissioned by Juan Pablo Castañeda (Environmental Economist, GP ENV, World Bank) and written by G.Y. Paula Uyttendaele (Water Resources Consultant). The first water account for the Citarum River Basin in Indonesia was developed by Prof Lars Hein and his team of the University of Wageningen with the use of the SWAT model. The consultancy aimed to assess the feasibility of the SWAT model use for the Citarum Basin and give recommendations and guidelines for future work related to natural capital accounting

1. Introduction

The term water accounting has a different meaning for various water professionals, so it is essential to provide first some definitions for getting more clarification on this issue. Briefly, water accounting differs from water balances and water budgets as follows:

- Water balance is a summary of hydrological flows in a certain spatially discrete domain where inflow and outflow match with the change in storage; users are not described
- Water budget is the desirable water balance based on available water resources for a given domain including water allocations to different disciplines; it is largely a planning result
- Water accounting integrates the users' society with the actual flows, fluxes and stocks and recognizes natural and manmade water pathways. The benefits and services from water (including ecosystem services) are assessed

The most commonly used water accounting frameworks are:

- System of Environmental-Economic Accounting for Water (SEEAW)
- Water Accounting plus or WA+
- Australian Water Accounting system
- Water Footprint Accounting

2. System of Environmental-Economic Accounting for Water

The System of Environmental-Economic Accounting for Water (SEEAW) describes the key hydrological and economic concepts and defines a set of standard tables for presenting the interaction between water and the economy as well as water resources in the environment. The SEEAW provides a direct link from hydrological data to the System of National Accounts (SNA); the macro-economic framework that has been used for more than 50 years and from which the gross domestic product (GDP) is derived. It is widely recognized that the conceptual framework for organizing hydrological and economic information is much in support of integrated water resource management. The SEEAW defines a series of accounting identities to allow consistent comparisons between geographical areas (or countries) and over time.

There are three main accounts for water that capture various aspects: the physical supply and use tables (PSUT), the asset account and the monetary supply and use tables. Stocks are the quantity of a particular product or natural resource at a point in time. Assets are usually associated with stocks that have economic values. Water stocks (or assets) are classified by the SEEAW as surface water, groundwater and soil water. Surface water is further disaggregated and includes artificial reservoirs, lakes, rivers, snow, ice and glaciers. Flows are the quantity that is added or subtracted from a stock during a specific period of time. The flows described in water statistics are (1) flows within the environment (between inland water resources and the atmosphere, between the sea and inland water resources as well as the flows between the different inland water resources such as surface water, groundwater and soil water); (2) flows from the environment to the economy (abstraction); (3) flows within the economy (exchanges of water between economic units); (4) flows from the economy to the environment (returns and waterborne emissions); and (5) flows with other territories (inflows and outflows with neighbouring territories).

The Physical Supply and Use Tables (PSUT) measure, in physical (volume) terms: 1) the flows of water entering the economy, which are either abstracted from the

environment or imported; 2) the flows of water and wastewater between different economic units within the economy, and; 3) the return flows of water from the economy to the environment (directly or via sewerage treatment plants).
The Asset Account describes the inland water resources system in terms of stocks and flows, providing information on the stocks of water resources at the beginning of the accounting period, the corresponding changes in those stocks due to economic activity (e.g. abstractions and returns) and natural processes (e.g. outflows to other territories), and the closing stocks of water at the end of the accounting period. This can be thought of as a hydrological water balance. Asset accounts for water are generally only considered in physical terms, as valuation of water consistent with the SNA valuation principles is still under discussion.

3. Considerations and recommendations for water accounting

A key consideration when designing a system for the production of information is the different audiences for which information is produced. In general, only limited information is used by senior decision-makers and civilians, whereas policy analysis and researchers use greater levels of detail. The accounts draw the data from a wide range of sources (the base of the pyramid in the figure below) and smooth them into a consistent information source that is suitable for analysis and for the construction of indicators.

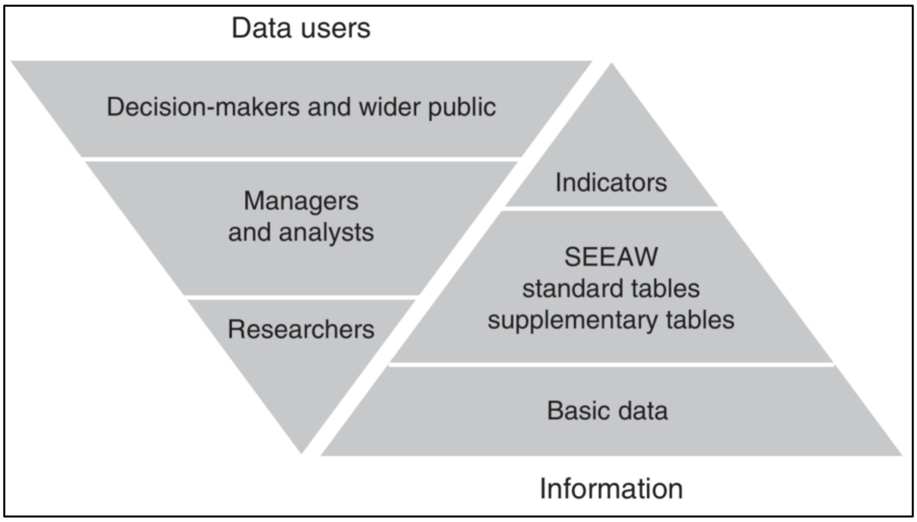

Figure 1 Information and audience pyramids

Accounts are ideally built in close cooperation with all the agencies and institutions that play a role on providing data on stocks and flows between the environment and the economy in current and future exercises. The type of water uses and sectors that should be included in the physical supply and use tables should be defined. Policy relevant aspects or concerns of decision makers and water managers that should be measured or highlighted in the water accounts should also be identified.
The available sources of information and existing know-how on natural hydrological processes and interaction with the economy should be inventoried, as well as the most important flows and stocks to prevent the estimation of data that is less important. Other aspects that should be considered when compiling the water accounts also include:

- The integration of different sources of information including quality assessment and dealing with data inconsistencies, disaggregation and aggregation, format adjustment etc.

- Data availability and degree of uncertainty associated with the values. The SEEAW guidelines recommend the use of officially published information by the national administration, avoiding ‘ad hoc’ estimations.
- Defining the temporal scale including the period of study and time step. It is important that reference periods for the water data align. In water and economic statistics the calendar year is the recommended temporal reference. Practice has shown that the financial year of national accounts and hydrological year of water statics in countries often differ from the calendar year. A complete hydrological year is the minimum required period. In areas where inter-annual variability of hydrological components may be significant, it is preferred to calculate water asset accounts on a series of inter-annual average values than on a single year. As a general rule, a longer period of study presents more representative and reliable results. When several sources of information are used, the period of study may be determined by the avail- ability of datasets with overlapped years. The time step must be carefully selected. Significant intra-annual variability of the key variables of the water balance, can lead to choose a smaller time scale resolution than a year, such as, a month. Yearly water statistics will often hide seasonal variability in data that, in many cases are important to understand for water management purposes. Some water statistics, like precipitation and other meteorological and hydrological data, are compiled more frequently (for example, daily, weekly or monthly) to address these needs.
- Defining the spatial scale: The choice of the spatial reference for the compilation of water accounts ultimately depends on the data needed by users (for example, decision- makers, analysts and researchers) and the resources available to data. In general, four types of spatial boundaries are used in water statistics: (1) physical boundaries (for example, river basins, sub-basins, aquifers); (2) administrative regions; (3) service areas; and (4) accounting catchments. Asset accounts for very large basins, without any disaggregation, may neglect any water resources and water demand variability. On the contrary, a large disaggregation into small areas will not help stakeholders in their water management decisions. The SEEAW recommends the river basin as the spatial unit for which the accounts should be compiled. However, in areas where groundwater is an important source of water, aquifers may also be appropriate for the compilation of water statistics.
- Selection of models to estimate non measured flows or stocks. The information requirements of SEEAW asset accounts are very demanding and frequently no direct data are available to fulfill specific cells of the tables. Most elements or hydrological processes of the SEEAW tables are difficult to fill out based on measured data, especially for large basin case studies. The most important and significant processes should be identified and estimated with the use of adequate models, while processes of low relevance can be disregarded. Attention should be given on inconsistent definitions between the selected model and SEEAW framework. As an example, SEEAW considers the water use in rain-fed agriculture as an ‘abstraction’ from soil water and it should be computed “as the amount of precipitation that falls onto agricultural fields”. Also, the excess of water, which has not been absorbed by the crop, should be recorded “as a return flow into the environment from rain-fed agriculture”.

4. Application of the SWAT model for the Citarum Basin

The Soil & Water Assessment Tool (SWAT) is a small watershed to river basin-scale model, developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in watersheds with varying soil, land use, and management conditions. Water balance components and flow partitioning is presented in the figure below.

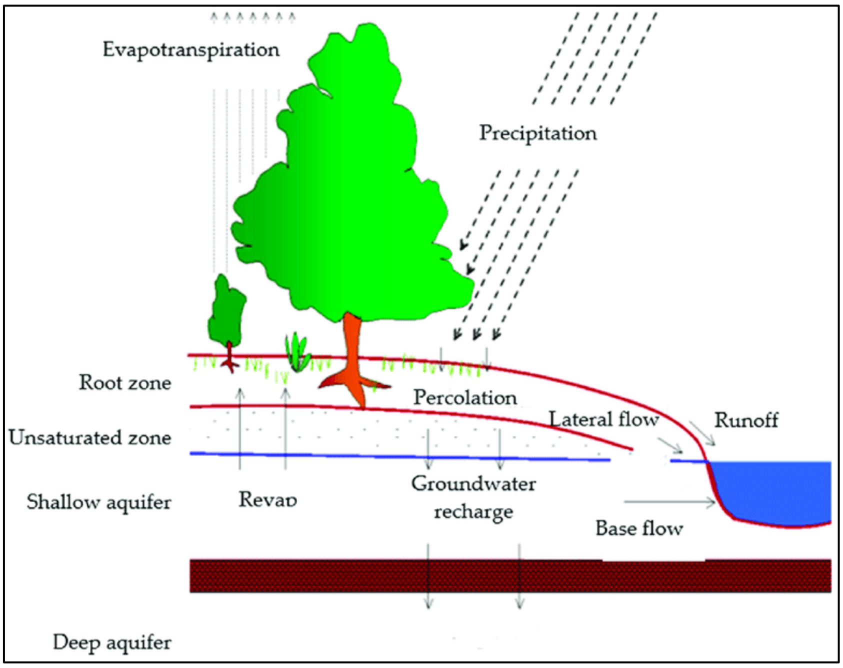

Figure 2 Water balance and flow partitioning in SWAT model

The main advantages of the model comprise the fact that it is an open source tool with detailed online documentation, user groups, video tutorials, and a unique literature database. The tool is computationally efficient and is continuously improved with the support of the core developmental team of SWAT.

Among the disadvantages it is worthwhile to mention that the code is rather difficult with a high number of parameters, requiring expertise to run the model and implementing the calibration process. In addition, the tool is highly data intensive and requires long continuous time series up to 10 or 12 years for the calibration of streamflow. Another limitation is the use of non-interacting Hydrologic Response Units (HRUs). The spatial representation of SWAT consists of spatially explicit sub-basins, further subdivided into lumped, Hydrologic Response Units (HRUs). The HRUs are a unique combination of land use, soil and slope types. The fact that these units do not interact with each other, or in other words are not linked to each other, implies the absence of a routing process of flows. Furthermore, spatially explicit outputs at the HRU level cannot be generated. As a consequence, SWAT does not perform well in highly managed watersheds that involve human made complex infrastructure like cascading reservoirs, water supply abstractions and complex canalizations. The model does include the possibility to include irrigation practices, but when these activities are very intensive the code should be adopted due to management practices and associated hydrologic processes (e.g., canal seepage). Reservoir management is basic and a derivate of SWAT, the Soil and Water Integrated Model (SWIM) is more suitable for simulating reservoir operations as it has an improved reservoir module.

The Citarum River Basin (CRB) is in the province of West Java and covers 13,000 square kilometers (km^2). The upper basin has three hydroelectric dams (Sagulin, Cirata and Jatiluhur) producing a total of 1,400 megawatts. The government of Indonesia considers it the most strategic river basin territory in the country because it provides 80% of the surface water supply to the capital city of Jakarta. This water is diverted from the Citarum river downstream the Jatiluhur dam. The river feeds irrigation covering close to 400,000 hectares (ha) that produce 5% of the country's rice and are dominantly present in the lower part of the basin. Given the agricultural land use upstream the Saguling reservoir and limitations of the SWAT model in terms of reservoir management, the model can only be used to simulate flows and changes in stocks in the upper part of the Basin (that is upstream Saguling). More appropriate models are discussed under Chapter 6. The developed SWAT model did not include water uses such as irrigation, water supply, reservoir management. The city of Bandung withdraws its drinking water from the lower laying Jatiluhur reservoir. Water is deviated from the Citarum river (downstream Jatiluhur) through the West Tarum Canal for irrigation purposes in the lower part of the basin and water supply in Jakarta. The calibration and validation process sourced its data from the same database and the model was not trained over a long and continuous period of time, initiating after a dry period/summer. The developed model can therefore not be used for the water accounts of the basin.

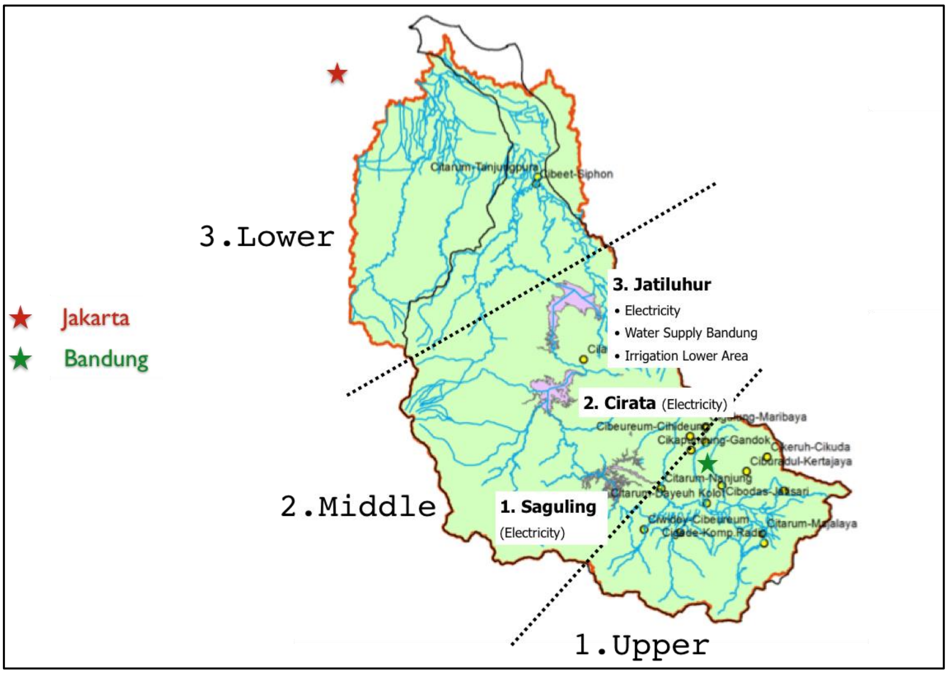

Figure 3. Lower, middle and upper part of the Citarum Watershed with main cities and reservoirs.

5. Sources of information of the Citarum water account

In the following table the sources of information behind the identified values of the water account for the Citarum basin are specified as follows:

- Cells coloured in grey are processes that were not included in the asset account or PSUT due to lack of available data
- Cells coloured in white are not expected to contain any value
- Cells are tagged with reference or model name to clarify sources of information.
- Cells are tagged with "Automatic" when they are automatically calculated as sum of others cells in the table

Asset account	EA. 131. Surface water			EA. 132 Ground water	EA.133 Soil water	Total
	EA. 1311 Artificial reservoir	EA. 1312 Lakes	EA. 1313 Rivers			
1. Opening stocks (2013)	**Citarum Master Plan**		**Citarum Master Plan**			**Automatic**
Increase in stocks	Automatic		Automatic			**Automatic**
2. Returns	Citarum Master Plan + SWAT + Ito et al, 2019 + Kim et al., 2009		Citarum Master Plan + SWAT + Ito et al., 2019 + Kim et al., 2009			**Automatic**
3. Precipitation	SWAT		SWAT			**Automatic**
4. Inflows	SWAT		SWAT			**Automatic**
4.a. From upstream territories						**Automatic**
4.b. From other resources in the territory						**Automatic**
Decrease in stock	Automatic		Automatic			**Automatic**
5. Abstraction			Citarum Master Plan / BPS			**Automatic**
6. Evaporation / Actual evapotranspiration	SWAT		SWAT			**Automatic**
7. Outflows	SWAT		SWAT			**Automatic**
7.a. To downstream territories						**Automatic**
7.b. To the sea						**Automatic**
7.c. To other resources in the territory						**Automatic**
8. Other changes in volume						**Automatic**
9. Closing stocks	**Automatic**		**Automatic**			**Automatic**

A. Physical use table		Industry (by ISIC Category)				Household	Rest of the world	Total
		Div 1-3	Div 10-33	Div 35	Total			
From the Environment	**1. Total Abstraction (= 1a+1b = 1.i+1.ii)**	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic
	1.a. Abstraction for own use	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic
	Irrigation water	Citarum Master Plan			Automatic			Automatic
	Fish pond	Citarum Master Plan			Automatic			Automatic
	Hydroelectric power generation			Citarum Master Plan + Master thesis (Perwitasari, 2013)	Automatic			Automatic
	Manufacture industries		BPS		Automatic			Automatic
	Household				Automatic	BPS		Automatic
	Other				Automatic			Automatic
	1.b. Abstraction for distribution							
	1.i. From inland water resources:	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic
	1.i.1. Surface water	Citarum Master Plan	Citarum Master Plan	Citarum Master Plan + Master thesis (Perwitasari, 2013)	Automatic	BPS		Automatic
	1.i.2. Ground water		Citarum Master Plan		Automatic	BPS		Automatic
	1.i.3. Soil water				Automatic			Automatic
	1.ii. Collection of precipitation				Automatic			Automatic
	1.iii. Abstraction from the sea				Automatic			Automatic
Within the Economy	**2. Use of water received from other economic units**							
	2.a. Reused water				Automatic			Automatic
	2.b. Wastewater or to sewerage				Automatic			Automatic
	2.c. Desalinated water				Automatic			Automatic
	3. Total use of water (= 1+2)	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic

B. Physical supply table		Industry (by ISIC Category)				Household	Rest of the world	Total
		Div 1-3	Div 10- 33	Div 35	Total			
Within the Economy	**4. Supply of water to other economic units**	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic
	4.a. Reused water				Automatic			Automatic
	4.b. Wastewater to sewerage				Automatic			Automatic
	4.c. Desalinated water				Automatic			Automatic
Into the Environment	**5. Total returns (= 5.a+5.b)**	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic
	Irrigation water	Citarum Master Plan + SWAT + Ito et al., 2019 + Kim et al., 2009			Automatic			Automatic
	Fish pond	Citarum Master Plan + SWAT + Ito et al., 2019 + Kim et al., 2009			Automatic			Automatic
	Hydroelectric power generation			Citarum Master Plan+Perwitasari, 2013	Automatic			Automatic
	Other				Automatic			Automatic
	5a. To inland water resources (=5.a1+5.a.2+5.a.3)	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic
	5.a.1. Surface water	Citarum Master Plan + SWAT + Ito et al., 2019 + Kim et al., 2009	Citarum Master Plan + SWAT + Ito et al., 2019 + Kim et al., 2009	Citarum Master Plan + Mater thesis (Perwitasari, 2013)	Automatic	Citarum Master Plan + SWAT + Ito et al., 2019 + Kim et al., 2009		Automatic
	5.a.2. Groundwater		Citarum Master Plan + SWAT + Ito et al., 2019 + Kim et al., 2009		Automatic			Automatic
	5.a.3. Soil water				Automatic			Automatic
	5.b. To other sources (e.g. sea water)				Automatic			Automatic
	6. Total supply of water (= 4+5)	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic
	7. Consumption (= 3-6)	Automatic	Automatic	Automatic	Automatic	Automatic		Automatic

6. Recommendations for a new water account

The following recommendations should be considered when developing the water accounts for the Citarum Basin in the future.

- Accounts should be built in close cooperation with the agencies and institutions that will provide the necessary data for the water accounts. The main stakeholders involved were limited to the Central Bureau of Statics in Indonesia (BPS), the Citarum Watershed Authority and water station authority and did not include important stakeholders such as hydropower, sewerage services, water supply and irrigated agriculture. ISIC 36 and ISIC 37 are very important in water accounts and especially as the basin provides 80% of the surface water supply to the capital city of Jakarta (with 9.6 million inhabitants). A total of three meetings were planned with BPS, and one meeting with the water station authority to obtain a view on the policy applications and existing available data.
- A broad stakeholder engagement might have highlighted early onwards the more actual policy concerns such as water quality and solid waste management in the basin.
- The recollection, integration and quality assessment of data is a time-consuming process that is often underestimated. Very important is to distinguish between the significant and insignificant stocks and flows in the considered geographical area. During a first attempt the water accounts, assets and PSUT tables can be compiled without using any model and based on the measured data/data at hand. Only those processes that are known or suspected to be significant should be considered to be estimated based on a certain model. Research centres can be helpful in the identification of significant hydrological processes.
- The selection of the correct model has shown to be an important step in building the water account. In the case of the Citarum basin, SWAT is not an appropriate model. More appropriate models are Aquatool[2] (University of Valencia, Spain) or WEAP [3] (Stockholm Environment Institute) in combination with a rainfall runoff model. However, it should be noted that when data accuracy remains an issue the quality of modelled data can be as good as the quality of the input data (garbage in means garbage out). A valid option is the use of remote sensing based open source products that provide spatially distributed estimates of precipitation, soil moisture, evapotranspiration, reservoir levels and water quality over large time series. Global or local hydrological models and digital elevation models are used to estimate streamflow and groundwater.
- The geographical area that falls under the mandate of the Citarum Watershed Authority does not fully coincide with the drainage basin of the Citarum River and is actually smaller. The Western and lower part of the basin is not considered by the Water Authority.

[2] https://aquatool.webs.upv.es/aqt/en/home/
[3] https://www.weap21.org

- More attention should be given to the economic dimension of water
- More general and useful tips have been discussed under Chapter 3.

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