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Water Footprint Estimation in Latin America

Giovanna Ferrazzo Naspolini
Jesse Madden Libra
María Pérez Urdiales

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Authors:
Giovanna Ferrazzo Naspolini
Jesse Libra
María Pérez-Urdiales

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1. Introduction

Latin America and the Caribbean (LAC) is home to approximately one-third of the world's freshwater supply; however, the geographic distribution of this abundance is not aligned with demand, making much of the region vulnerable to water scarcity (Libra et al., 2022). This vulnerability is expected to increase as average global temperatures continue to rise, with the Intergovernmental Panel on Climate Change (IPCC) predicting increases in the frequency and duration of droughts, changes in rainfall patterns, and more intense storms (Castellanos et al., 2022).

Understanding the role of water in LAC economies is vital as climate change poses several severe challenges in the region, including ecosystem disruption, increased risk of food insecurity, amplified costs of natural disasters (both economic and human), and public health risks, all of which have important implications for the agricultural and water and sanitation sectors (Castellanos et al., 2022). Simultaneously, population projections in the region point to increasing demand, both directly for human consumption and indirectly through water needed for economic output (Baeumler et al., 2021).

Considering the projected changes to water supply and demand, it is important to understand how water resources are currently used throughout economies to predict the impact of these changes on existing economic systems. Water footprint analyses produce this understanding by using environmental-extended input-output models, which capture the interdependence of economic activities and generate comprehensive indicators of direct and total water use (Hoekstra et al., 2011). By considering sectoral disaggregation, analysts gain insights into water flow, linkages, and the influence of water on economic output. Overall, water footprint analyses enable the identification of water-related risks and inefficiencies across the economy.

Across LAC, few comprehensive water footprint analyses consider country-generated environmental accounting data and linkages throughout the economy, making it difficult to get an exhaustive view of water use and vulnerability within the region's economies. This technical note describes the methodology used to carry out water footprint analyses for three economies in the region – Costa Rica, Colombia, and Brazil from 2012-2017, following the approach proposed by Naspolini et al. (2020). While the country selection is primarily motivated by data availability, these countries are interesting case studies for two reasons. First, they are diverse regarding the geographic and economic scales, representing three distinct Latin-American regions (Central America, Southern Cone, and Andean regions). Second, these countries have experienced droughts and other adverse climate events during the analysis period, allowing for the observation of changes in water use related to scarcity. In 2014, 27 million people were affected by drought in Brazil (World Bank, 2021), while drought in Colombia's La Guajira province spurred protests (BBC, 2014) and drought in Costa Rica cost the agricultural sector an estimated USD 19.5 million (Echeverría, 2016).

The focus of this note is methodological, describing the data and methods used to carry out the water footprints analyses. The note includes a brief presentation of results, which lays the foundation for an upcoming working paper by the Water and Sanitation Division's Knowledge Team, which will analyze these results with the aim of understanding the effects of water scarcity on these economies and identifying opportunities for improving sustainable water use.

2. Data and Methodology

Water footprint analyses require physical water and economic information, both disaggregated at the same sectoral level. Physical water data is then integrated into the economic input-output model to produce the water footprint estimations.

The study uses economic data from the OECD's input-output database and physical water data from the System of Environmental Accounting for Water published by Brazil, Colombia, and Costa Rica. The physical water data span different periods: 2010-2020 for Colombia, 2012-2017 for Costa Rica, and 2013-2017 for Brazil, whereas the most recent available economic dataset is from 2018. Harmonization strategies were implemented with the environmental-extended input-output modeling to ensure consistency between the economic and physical data.

This section outlines the data inputs used in the analysis for both economic sectoral tables and physical water accounting and the methodology used to produce the final water footprint estimates. It discusses methodological assumptions, data limitations, and how irregularities in the data were addressed.

2.1 Data

2.1.1 Input-Output tables (IOT)

The IO model is an economic tool used to analyze the interdependence of economic sectors within an economy. It provides a systematic framework to track the flow of goods and services among different economic sectors and the corresponding monetary transactions. The model assumes that the output of one sector becomes an input for another sector, creating a circular flow of goods and services thorough the economy (Leontief, 1970).[1]

The Organization for Economic Co-operation and Development (OECD) has been at the forefront of conducting extensive research on IO datasets. These tables are fundamental tools for comprehending the interdependencies between economic sectors and the flow of goods and services within and across countries. In this context, harmonizing the sectoral aggregations of economic data and physical water data becomes essential to establish the relationship between economic activity and water consumption.

The OECD's IO datasets cover various types of IOT, including national and multiregional systems on a global scale. One of the key areas of focus for the OECD's IOT research is national systems. The OECD provided detailed datasets for 66 countries, comprising OECD members and the G20 group, covering 1995 to 2018. These national IOT systems provide a comprehensive overview of the economic structure of individual countries, allowing researchers to identify production and consumption patterns within a nation.

The 2021 edition of OECD'S national IOT is broken down into 45 economic sectors, following the International Standard Industrial Classification (ISIC)[2] Rev 4. This level of detail provides a more granular understanding of the interdependencies between economic sectors and how they contribute to the overall economy and identify the key drivers of economic growth and productivity (OECD, 2021).

Another feature of OECD'S national IOT dataset is the presentation of inputs combined (total table) and split into imports and domestic inputs tables. Discerning domestic and imported inputs is important when estimating the water footprint because accounting for imported products could overestimate the national water footprint.

Finally, OECD'S national IOT dataset is estimated at current prices, e.g., the monetary values correspond to the years of the table's transactions. When working with current prices, there is an implicit price or inflation effect when comparing different years. The values must be estimated in basic prices, e.g., all the series will be expressed in monetary values of a given base year, eliminating the effect of inflation. This study normalizes all prices to USD 2015, using the process explained in Appendix B.

2.1.2 System of Environmental and Economic Accounting for Water

The System of Environmental-Economic Accounting for Water (SEEA-Water) is an international statistical standard for water accounting (UN, 2012). The United Nations Statistical Division developed this framework to monitor interactions between water resources and the economy. SEEA-Water employs the same accounting framework as the System of National Accounts (SNA), resulting in a standardized dataset that can be coupled to input-output tables. This allows for estimating indicators for policy assessment within the integrated water resources management concept, such as the water footprint analysis.

[1] Appendix A provide a brief explanation on input-output model foundations.
[2] International Standard Industrial Classification (ISIC) is a standardized system of codes and names for categorizing economic activities. It was first developed by the United Nations in 1948 and has been revised several times to reflect changes in the global economy. ISIC is currently in its fourth revision (ISIC 4), which the United Nations published in 2008.

The primary SEEA-Water set of tables are physical supply and use tables, hybrid and economic tables, and asset tables:

- **Physical supply and use tables (PSUT):** describe, in physical units, the water flows between the economy and the environment (abstractions and returns) and the water flows within economic sectors (supply and use of water inside the economy). More specifically, the **use table** combines the information on total water use, e.g., the abstraction from the environment (in-stream and off-stream use) and the water demanded from other economic sectors. Analogously, the **supply table** combines the flows that leave an economic sector: the one provided to another economic sector and the one returned to the environment. PSUT is the key dataset for the water footprint assessment since it allows the estimation of the sectoral **direct water requirements.**

- **Hybrid and economic tables (HET):** combine the typical supply and use tables from the System of National Accounts with the corresponding PSUT, making the physical and economic data share the same structure. This feature allows for monitoring national economies' hydrological-economic performance and the interdependence of water use among economic sectors.

- **Asset tables (AT):** establish a connection between the data on total water use and supply and the information on water stocks in the environment, permitting the evaluation of how the economic activity impacts water resources, or, how the availability of water resources can impact the economic activity.

Brazil, Colombia, and Costa Rica use the SEEA-Water approach, which is compatible to the input-output framework. These countries collect standardized information from various data sources and maintain relatively consistent data organization across countries and time, enabling a consistent methodology for calculating the water footprint across countries. The methodology considers water abstraction from the environment by the economy, the water flows within the economy, and the return flows to the environment. However, slight methodological differences exist in how each country constructs its PSUT, which require harmonization. In the following sections, we discuss the primary characteristics and constraints of the datasets of these countries.

Brazil – Environmental-Economic Accounting for Water

The Environmental-Economic Accounting for Water (CEAA for its Portuguese acronym) compiled by the IBGE (the Brazilian Institute for Geography and Statistics) covers the period from 2013 to 2017 and encompasses PSUTs, HETs, and ATs (IBGE, 2020).[3] Additionally, the Brazilian economic system is organized into six economic sectors:

1. Agriculture, Livestock, Forestry, Fishing, and Aquiculture
2. Heavy industries
3. Manufacturing and Construction
4. Electricity and Natural Gas
5. Water and sewage
6. Other activities

The primary data sources for the CEAA are IBGE's structural surveys, including information such as municipalities' gross domestic product, municipal agricultural production, annual industrial products research, and data from the sewage national information system, among others. The Brazilian National Water and Sanitation Agency (ANA) contributes to CEAA estimation by providing data on water-use permissions and their related monitoring activities, e.g., how users abstract water from the environment and estimations of consumptive water demand[4] for all economic activities.

In the last few years, ANA has been promoting a formidable set of studies about water usage by economic activities, such as Water in Industry: use and technical coefficients, Atlas Brazil: urban water supply, Atlas Sewage: Water basins pollution control, Manual of consumptive use of water in Brazil, Use of water in rainfed agriculture, and the Atlas of irrigation in Brazil, besides the annual report: Context of Water Resources in Brazil. These studies provide a comprehensive understand of the role of water resources within the Brazilian economy.

Another feature of CEAA's data is the disaggregation of the electricity supply by the type of power generation. By distinguishing hydro and thermal power, it is possible to identify the water consumption from thermal-power plants and, consequently, the consumptive water use of the electricity sector. Hydropower plants demand on-stream use of water, e.g., the economic activity returns the volume of water required for electricity production to the environment.

The IBGE and ANA produce CEAA with PSUTs in the format indicated by the SEEA-Water framework.[5] Following the SEEA-Water guideline, the Brazilian framework includes the consumptive use of water concept, e.g., the amount of water incorporated into products or consumed by households or livestock. The water consumption estimation is based on the difference between the total water use (abstraction from the environment plus the use of water from other economic activities) and the total water supply (water returned to the environment and supplied to other economic activities).

[3] We used the most recent version available when processing data in 2023.
[4] Consumptive water demand is the water volume abstracted by industries which cannot be reused, either because it has evaporated, transpired, been incorporated into products and crops, or consumed by man or livestock.
[5] Table III.1 – Standard physical supply and use tables for water (UN, 2012).

The IBGE and ANA have published 2 batches of water accounts: CEAA 2013-2015 in 2018 and CEAA 2013-2017 in 2020. The methodological changes between CEAA's first and second publications improved the validity of the data produced in 2020, making the latest version the most appropriate dataset to perform this study.

Despite recent improvements in the methodological estimations in the 2020 CEAA data, there are still certain limitations. Information regarding water losses during abstraction and distribution is not explicit. Water lost due to leaks is recorded as a return flow because it infiltrates an aquifer and is available again for abstraction. In contrast, water lost due to evaporation is recorded as water consumption, together with water consumed in the water treatment process (UN, 2012).

As loss accounting is required to estimate the direct water requirements, the lack of explicit loss accounting requires certain assumptions on CEAA data. By consulting the Sewage National Information System (SNIS for its Portuguese acronym), it is possible to assume that the reported return flows of the water sector to the environment correspond to losses during abstraction and distribution, while water consumption refers to utilities' own consumption and evaporation. To maintain consistency with the water used by agriculture from public perimeters of irrigation (which are reported as supplied to agriculture by another economic sector), the same share of water abstraction per water return is applied to the water supplied to the agricultural sector.

CEAA focuses on reporting its datasets under the SEEA-Water framework, making IBGE/ANA the only custodial agencies to do so. However, no methodological report explains the methodology adopted for each economic sector, which imposes some challenges when comparing it to the datasets from Colombia and Costa Rica.

Colombia – Environmental and Economic Account of Water Flows

The National Administrative Department of Statistics (DANE for its Spanish acronym) publishes Colombia's water accounting data. The Environmental and Economic Account of Water Flows (CAE-FA for its Spanish acronym) data is available from 2010 to 2020 and mainly focuses on estimating PSUTs, while HETs and ATs are not available (DANE, 2022).[6] The data is disaggregated by economic activities, which include the following:

1. Agriculture, livestock, hunting, forestry, and fishing
2. Mining
3. Manufacturing
4. Electricity, steam, and AC supply; Water supply; Evacuation and treatment of residual waters, waste management and environmental sanitation activities
5. Construction
6. Wholesale and retail sale; repair of motor vehicles and motorcycles; Transport and storage activities; Accommodation and food service activities
7. Information and communications
8. Financial and insurance activities
9. Real-state activities
10. Professional, scientific, and technical activities; Administrative and support activities
11. Public administration and defense; compulsory social security; Education; Human health and social work activities
12. Arts, entertainment and recreation, and other service activities; Activities of households as employers; undifferentiated goods-and-services-producing activities of households for own use

DANE'S data offers an impressive level of sectoral granularity. The 12 economic sectors above are further disaggregated into 61 specific economic activities. This level of disaggregation is particularly relevant to this study as sector 4, which looks like a miscellaneous catch-all of diverse activities, is further broken down into four distinct activities:

- 4.1 Electricity generation; Electricity transmission, supply and commercialization
- 4.2 Natural gas supply; gaseous fuels supplied by pipelines; steam and AC supply
- 4.3 Water collection, treatment, and supply
- 4.4 Wastewater drainage and treatment; Waste collection, treatment and disposal and environmental activities and other waste management activities

Disaggregating water usage by economic activities is relevant in accurately estimating the water footprint. Organizing energy, water, and wastewater into distinct economic sectors facilitates a more precise estimation of water requirements for electricity production and provision of water and sanitation services. This level of disaggregation gives a more detailed and comprehensive understanding of water usage and aids in developing effective water management strategies.

DANE publishes a comprehensive methodological report illustrating the assumptions and data used in CAE-FA elaboration. The adaptation of SEEA-Water methodology to the Colombian context is specific for each group of economic activities (DANE, 2022). The methodology for the sectors studied in this note are summarized below:

- **Agriculture, livestock, hunting, forestry, and fishing:** The water consumption estimation for the sector "Agriculture, livestock, hunting, forestry, and fishing" (sector 1 in the abovementioned list)

[6] We used the most recent version available when processing data in 2023.

relies on a detailed bottom-up analysis based on the type of crops, planted area, and local water requirements (for agriculture) and a comprehensive livestock inventory.

- **Water and sewerage sector** (economic activities 4.2, 4.3, and 4.4): the total water abstraction for the water and sewerage sector is based on the volume of water captured by the public water utilities. The estimations also consider water utilities' own water consumption, e.g., the volume of water consumed during the abstraction and treatment process and the water losses during distribution. This information allows for estimating the potable water volumes distributed to households and economic sectors. The difference between the total water abstraction and the utilities' own consumption and losses during distribution is the water distributed to households and economic sectors.

The methodology distinguishes the water consumption by households and services sectors (sectors 5 to 12 mentioned above) based on the time people spend at home and work. The primary water consumption by households is estimated according to regional and demographic requirements. Then, a model of water consumption for human use by economic activity is created to indicate the minimum water usage by employees to fulfill their daily biological needs during working hours, considering an inverse relation between household water consumption and water consumption while at work. Additionally, each economic activity has a specific water usage based on the activities performed, and its estimation relies on the expenditure related to potable water consumption.

The methodological assumptions and data availability mentioned above suggests that CAE-FA focuses on estimating the total water usage of economic sectors as the consumptive use (except for the case of electricity generation, which requires only on-stream use). It represents the overall water requirements for sectoral production. While this approach cannot account for physical water abstraction and returns, it is still noteworthy as it reveals the minimum consumptive use of the economy. Furthermore, the presentation of losses explicitly enables the estimation of direct water requirements by economic activities.

Costa Rica – Water Account

Water accounting data for Costa Rica are published by the Central Bank of Costa Rica (BCCR for its Spanish acronym) and available from 2012-2017 (BCCR, 2021). The data includes PSUTs, HETs, and ATs. The tables are disaggregated by economic sector; however, the categorization does not remain constant over the study period (Table 1). Losses and consumptive water use by economic sectors and households are provided in the PSUT, allowing for the calculation of sectoral direct water requirements.

Table 1-- Costa Rican economic sectors

2012-2016	2017
1. Agriculture, forestry, and fishing 2. Manufacturing and services 3. Water collection, treatment, and supply 4. Sewerage 5. Hydroelectric power generation	1. Agriculture, forestry, and fishing 2. Manufacturing and construction 3. Services 4. Water collection, treatment, and supply 5. Sewerage 6. Hydroelectric power generation

Source: Authors' elaboration based on BCCR (2017; 2019; 2021).

Another noteworthy aspect of Costa Rican data pertains to reporting information within the Agricultural sector. Specifically, the water provided to agriculture through public irrigation systems is classified separately, distinguishing it from water supplied by other economic activities. Furthermore, corresponding losses associated with this specific water supply are reported independently from losses in the overall water sector. This clear distinction obviates the need for any assumptions concerning water losses related to the water supplied to public irrigation perimeters.

The BCCR has published 3 batches of water accounts: Water Account 2012-2015 in 2017 (BCCR, 2017), Water Account 2012 – 2016 in 2019 (BCCR, 2019), Water Account 2012 – 2017 in 2021 (BCCR, 2021). This study relies on the BCCR 2021 accounts with data from 2012-2017. The SEEA-Water process in Costa Rica changed significantly between iterations, improving the methodology over time, particularly with respect to how input values were calculated. These improvements were retroactively applied to previous years; however, in some cases, the improved inputs were not available, resulting in issues of comparability across years in the most recent iteration of the study (BCCR, 2021).

One such example is data on abstractions for industrial sectors ("Agriculture, livestock, forestry and fishing," "Manufacturing and services," and "Electricity generated in hydroelectric plants"). Data on water abstraction for these industries comes from the Water Authority, which provides abstraction estimates based on active water-use permits. However, the 2016 and 2017 data included permits such as pending permits to reflect reality more accurately. This change in methodology caused a loss of comparability in the BCCR 2021 estimates between the estimates for 2012-2015 and the estimates for 2016-2017, specifically concerning self-supply extractions from "Agriculture, livestock, forestry and fishing", "Manufacturing and services", and

"Electricity generated in hydroelectric plants." It is important to note that this change does not affect the temporal comparability of the "Water collection, treatment, and supply" sector.

Another relevant change in methodology is in the measurement of assets. In the 2017 data, "surface water available" refers to water resources available in the four largest reservoirs in Costa Rica: Arenal, Reventazón, Cachí, and Pirrís. For years before 2017, this data has been unavailable and, as a result, is not included in calculations. It is important to consider how this change affects the 2017 asset tables and to keep it in mind when comparing information from 2017 to other years.

Finally, data from 2012 to 2015 on treated wastewater were estimated assuming fixed return coefficients from literature (Ballestero, 2013). The 2016 and 2017 Water Accounts obtained data directly from wastewater operators, resulting in more reliable data for accounts in 2016 and 2017.

The data also poses challenges due to changing sectoral categorizations over time. Years before 2017 categorized mining activities, manufacturing, and services as a unique economic sector called "Manufacturing and Services". In the 2017 revision of the Water Accounts, Services were disaggregated from this sector according to the methodology proposed by FAO for the construction of SDG 6.4.1, now being reported as "Manufacturing and Construction" and "Services" activities. This change made the data for Costa Rica inconsistent with the information from other countries, limiting the sectoral aggregation level of this study to a higher level.

The accounting process also has issues in terms of accuracy. Regarding the electricity sector, Costa Rican data implies that all power generation comes from hydropower plants. Data from 2012-2016 used a water consumption coefficient of 2% for this sector, even though no information on water abstraction was available, while data for 2017 has no information about water consumption for electricity generation, implying that the sector does not require water consumption in its activities. However, geothermal technology dominates the sector providing 61% of the electricity grid in 2012 and 54% in 2017 (SEPSE, 2023). While geothermal energy is considered a renewable and environmentally friendly power source, its operation does involve a consumptive use of water due to evaporation or loss of water during the process. Additionally, there is a need for water for steam and to maintain optimal operating temperatures within the power plant. This water consumption should not be neglected.

Lastly, the sectoral consumptive use of water relies on estimations based on fixed coefficients, as described in the PSUT. Once the consumptive coefficient is fixed over time, capturing potential pattern changes in this variable is not possible.

These methodological challenges and data issues provided some constraints for this study, limiting the sectoral aggregation to "Agriculture", "Water and sewerage" and "the rest of the economy". Nonetheless, the provided information allows the estimation of the direct water requirements and, consequently, the water footprint for Costa Rica's economic system.

2.2 Methodology

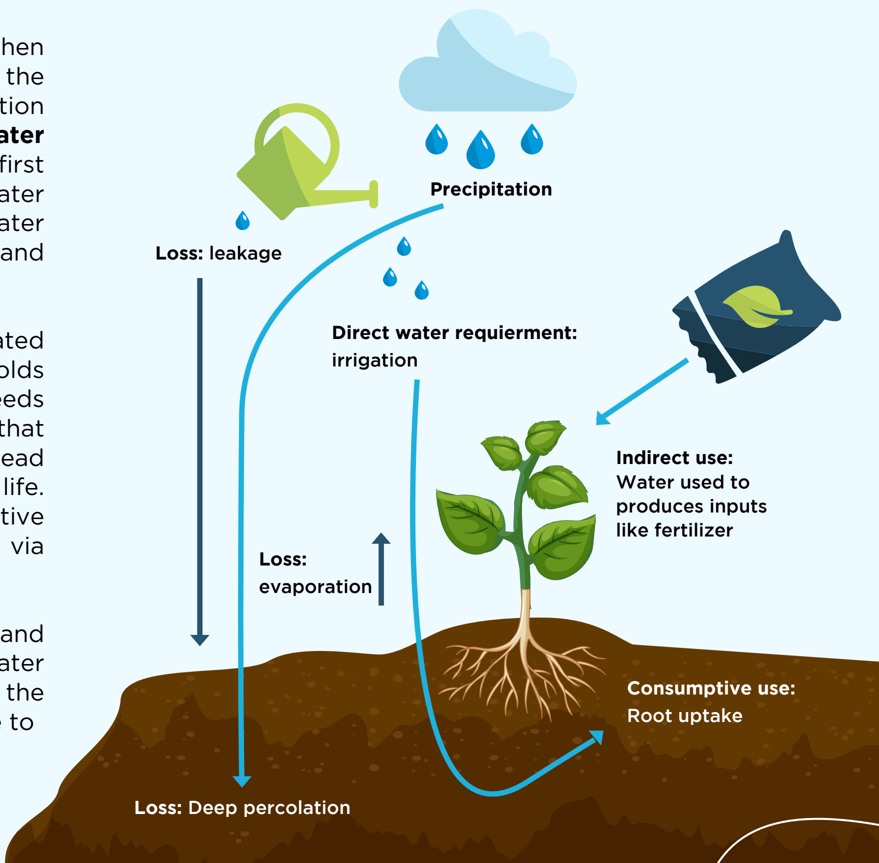
2.2.1 Direct water requirements estimation

Water footprint estimations are more accurate when considering the consumptive use of water and the respective losses of abstraction and distribution networks. This is what is referred to as the **direct water requirement (DWR)**, and its estimation is the first methodological step when estimating a country's water footprint. Figure 1 illustrates key concepts on water accounting, as consumptive use, losses, direct and indirect use.

Consumptive use is the portion of water incorporated into economic production or consumed by households and livestock (root uptake in Figure x). Water needs classified under consumptive use represent water that does not return to the environment after but is instead embodied into economic output or used to sustain life. As a result, changes in water availability for consumptive use can affect multiple sectors of the economy via forward and backward linkages.

Considering **water losses** during abstraction and distribution is also essential when estimating water footprints for the water and sanitation sector and the agricultural sector. In these sectors, water losses due to

Figure 1 - Key concepts on water accounting



leaks and evaporation can represent a significant percentage of water abstracted from the environment. Despite not being consumed as part of consumptive use, this water is not readily available for reuse and as such is classified as loss. When water losses are not included in water footprint estimations, water footprints are underestimated and undermine opportunities for improving sustainable water management. The sum of consumptive use and loss gives an estimate for the direct water requirement.

The direct water requirements are not directly provided by any of the countries' data analyzed. Still, it is possible to estimate it, given that all the countries provide information on water consumption and losses – implicitly or explicitly – in their SEEA-Water datasets. Table 2 summarizes the main features of SEEA-Water data for Brazil, Colombia, and Costa Rica.

Table 2 – Main features of SEEA-Water for Brazil, Colombia, and Costa Rica

	Brazil	Colombia	Costa Rica
Cover period	2013-2017	2010-2020	2012-2017
Water physical unit	Cubic hectometers (hm³)	Cubic hectometers (hm³)	Cubic hectometers (hm³)
Economic sectoral disaggregation	6 sectors	12 sectors also detailed in 61 activities	5 sectors (2012-2016) 6 sectors (2017)
Consumptive use	Explicit and estimated as the difference between water abstraction and return	Bottom-up estimation of off-stream and on-stream water consumption	Estimation based on fixed coefficients
Losses during abstraction and distribution	Implicit. Return flows to the environment include the losses	Explicit	Explicit
Irrigation by public perimeters	The water supply is explicit, but the losses are not.	There is no identification of irrigation in agricultural water demand	Explicit both water supply and losses
Electricity generation	Distinguish hydro and non-hydro water use	100% hydro (non-consumptive use)	100% hydro (non-consumptive use)

Source: Authors' elaboration.

Estimating the direct water requirements calls for identification of the lines in the PSUT representing the volumes of water consumption and losses. As Table 2 mentions, all countries provide such information, but data presentation differs, which implies the need for systematization. Data are not strictly comparable across countries, given the underlying differences in methods. Therefore, caution must be used when interpreting results.

For Brazil, the PSUT indicates the water consumption as the difference between total abstraction and total return. The information is straightforward in the table; however, the losses for water and sewage sector and for water distributed in public perimeters of irrigation are not explicitly presented. By checking the water and sanitation return flows and the reported losses in the SNIS, it is possible to assume that the return flows refer to the losses of the water abstraction and distribution network. As explained previously, the same proportion between the volumes returned and withdrawn by the water sector was applied to the volume of water distributed by the public perimeters of irrigation to the agricultural sector. So, the direct sectoral water requirement for agriculture is given by equation (1), whereas equation 2 presents the estimation for the water and sanitation sector. For the rest of the economy, the direct water requirements are equal to the water consumption since there is no available information for loss estimations.

$$DWR_{\substack{Brazil\\AGRI}} = \text{water consumption} + \left(\begin{array}{c}\text{\% losses from}\\\text{SNIS}\end{array}\right) * \begin{array}{c}\text{water supplied by public}\\\text{perimeters of irrigation}\end{array} \quad (1)$$

$$DWR_{Brazil\ WASA} = \text{water consumption} + \text{water returns} \quad (2)$$

For Colombia, the methodological approach indicates that data described in the water use table is, in fact, the consumptive use of water.[7] In this sense, as losses are explicitly presented in the PSUT, the sectoral direct water requirements are given by equation (3):

$$DWR_{Colombia} = \text{consumptive water use} + \text{water losses} \quad (3)$$

For Costa Rica, the estimation of water consumption relies on the multiplication of water use by the consumption coefficient. Since the losses are explicitly presented in the PSUT, the sectoral direct water requirements are given by equation (4). Water use refers to the total water abstracted by economic sectors, i.e., the consumptive and non-consumptive volumes.

$$DWR_{Costa\ Rica} = (\text{water use} * \text{consumption coefficient}) + \text{water losses} \quad (4)$$

[7] As gently elucidated for us by the National Accounts Division from DANE.

After estimating each country's sectoral direct water requirements, the following step lies in integrating these estimates with the OECD's IOTs tables to determine the water footprints. This methodological step requires coupling the water requirements with the economic data at the same sectoral aggregation level, as discussed in the following section.

2.2.2 Sectoral Aggregation

The OECD IOT tables dataset is reported for 45 economic sectors, whereas the physical water data is presented aggregated for 6 economic sectors in Brazil, 12 in Colombia, and 5 in Costa Rica. Such aggregation level disparities require an aggregation process to harmonize physical and economic data into the same level of sectoral aggregation.

The aggregation process consists of summing up sectoral data connected to each aggregation level, as defined in Table 3. This process is feasible because all the datasets follow the standardized system of codes ISIC 4.

The aggregation level chosen for the study is determined by the dataset with the highest level of aggregation (or most restrictive), which is Costa Rica's physical water data. This dataset provides water usage data for four economic sectors across most of the time series. For example, the OECD IOT presents water and sewerage as a single sector. At the same time, the country data generally report physical data for water and sanitation as two separate sectors, requiring the aggregation of water and sewage physical data to make it compatible with the OECD's IOT. In addition, as observed in Table 2, Colombia and Costa Rica's data do not allow the isolation of the Electricity sector since these datasets do not provide the water consumption from the power grid.

Table 3 – Study aggregation level

Aggregated sectors	Acronym[8]
Agriculture, livestock, forestry, and fishing	AGRI
Water and Sewerage	WASA
Rest of the economy - Heavy industries, manufacturing, construction, electricity and natural gas supply, and services	RoE

Source: Authors' elaboration.

Tables 4 to 6 present how economic and physical data were aggregated according to the study aggregation definition, data availability, and ISIC 4 classification for each country. After harmonizing the sectoral aggregation, the physical and economic data are prepared for coupling with the water model to estimate the water footprints.

Table 4 – Study aggregation level for Brazil

Study aggregation level	Brazil's water data		OECD IOT	
	ISIC 4	Description	ISIC 4	Description
AGRI	01 to 03	Agriculture, Livestock, Forestry, Fishing, and Aquiculture	01, 02	Agriculture, hunting, forestry
			03	Fishing and aquaculture
WASA	36	Water	36, 37, 38, 39[9]	Water supply; sewerage, waste management and remediation activities
	37	Sewage		
RoE	05 to 09	Heavy industries	05, 06	Mining and quarrying, energy producing products
			07, 08	Mining and quarrying, non-energy producing products
			9	Mining support service activities
	10 to 33, 41 to 43	Manufacturing and Construction	10, 11, 12	Food products, beverages and tobacco
			13, 14, 15	Textiles, textile products, leather and footwear
			16	Wood and products of wood and cork
			17, 18	Paper products and printing
			19	Coke and refined petroleum products
			20	Chemical and chemical products

[8] Acronyms defined by the authors for a matter of simplification.
[9] Activities 38 and 39 under ISIC Rev4 are responsible for waste management, treatment, and disposal, as well as soil and water remediation. The original data available (physical and economic) had aggregated these activities differently across economic sectors. Nevertheless, at different levels of aggregation, the size of the sector may not be substantial enough to impact the overall outcome of a water footprint analysis. For instance, if we consider a highly aggregated level of analysis, where there are only four economic activities, the waste management and remediation activities will only constitute a small percentage of each sector's economic activity and water use. Thus, changes in the allocation of activities 38 and 39 may not have a significant impact on the overall results of a water footprint analysis.

Study aggregation level	Brazil's water data		OECD IOT	
	ISIC 4	Description	ISIC 4	Description
RoE	10 to 33, 41 to 43	Manufacturing and Construction	21	Pharmaceuticals, medicinal chemical and botanical products
			22	Rubber and plastics products
			23	Other non-metallic mineral products
			24	Basic metals
			25	Fabricated metal products
			26	Computer, electronic and optical equipment
			27	Electrical equipment
			28	Machinery and equipment, nec
			29	Motor vehicles, trailers and semi-trailers
			30	Other transport equipment
			31, 32, 33	Manufacturing nec; repair and installation of machinery and equipment
			41, 42, 43	Construction
	35	Electricity and Natural Gas	35	Electricity, gas, steam and air conditioning supply
	38 to 39, 45 to 47, 49 to 55 to 56, 58 to 66, 68 to 75, 77 to 82, 84 to 88, 90 to 99	Other activities	45, 46, 47	Wholesale and retail trade; repair of motor vehicles
			49	Land transport and transport via pipelines
			50	Water transport
			51	Air transport
			52	Warehousing and support activities for transportation
			53	Postal and courier activities
			55, 56	Accommodation and food service activities
			58, 59, 60	Publishing, audiovisual and broadcasting activities
			61	Telecommunications
			62, 63	IT and other information services
			64, 65, 66	Financial and insurance activities
			68	Real estate activities
			69 to 75	Professional, scientific and technical activities
			77 to 82	Administrative and support services
			84	Public administration and defence; compulsory social security
			85	Education
			86, 87, 88	Human health and social work activities
			90, 91, 92, 93	Arts, entertainment and recreation
			94, 95, 96	Other service activities
			97, 98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use

Source: Authors' elaboration based on IBGE (2020) and OECD (2021).

Table 5 – Study aggregation level for Colombia

Study aggregation level	Colombia's water data		OECD IOT	
	ISIC 4	Description	ISIC 4	Description
AGRI	01 to 03	Agriculture, Livestock, Forestry, Fishing, and Aquiculture	01, 02	Agriculture, hunting, forestry
			03	Fishing and aquaculture
WASA	36	Water collection, treatment, and supply	36, 37, 38, 39	Water supply; sewerage, waste management and remediation activities
	37 to 39	Wastewater drainage and treatment; Waste collection, treatment and disposal and environmental activities and other waste management activities		
	38	Material recovery (recycling)		
RoE	05 to 09	Mining	05, 06	Mining and quarrying, energy producing products
			07, 08	Mining and quarrying, non-energy producing products
			09	Mining support service activities
	10 to 33	Manufacturing and Construction	10, 11, 12	Food products, beverages and tobacco
			13, 14, 15	Textiles, textile products, leather and footwear
			16	Wood and products of wood and cork
			17, 18	Paper products and printing
			19	Coke and refined petroleum products
			20	Other non-metallic mineral products
			21	Pharmaceuticals, medicinal chemical and botanical products
			22	Rubber and plastics products
			23	Other non-metallic mineral products
			24	Basic metals
			25	Fabricated metal products
			26	Computer, electronic and optical equipment
			27	Electrical equipment
			28	Machinery and equipment, nec
			29	Motor vehicles, trailers and semi-trailers
			30	Other transport equipment
			31, 32, 33	Manufacturing nec; repair and installation of machinery and equipment
	35	Electricity generation; Electricity transmission, supply and commercialization	35	Electricity, gas, steam and air conditioning supply
	35	Natural gas production; gaseous fuels supplied by pipelines; steam and AC supply		
	41 to 43	Construction	41, 42, 43	Construction
	45 to 47, 49 to 53, 55 and 56	Wholesale and retail sale; repair of motor vehicles and motorcycles; Transport and storage activities; Accommodation and food service activities	45, 46, 47	Wholesale and retail trade; repair of motor vehicles
			49	Land transport and transport via pipelines
			50	Water transport
			51	Air transport
			52	Warehousing and support activities for transportation
			53	Postal and courier activities
			55, 56	Accommodation and food service activities

Study aggregation level	Colombia's water data		OECD IOT	
	ISIC 4	Description	ISIC 4	Description
RoE	58 to 63	Information and communications	58, 59, 60	Publishing, audiovisual and broadcasting activities
			61	Telecommunications
			62	IT and other information services
	64 to 66	Financial and insurance activities	64, 65, 66	Financial and insurance activities
	68	Real estate activities	68	Real estate activities
	69 to 75, 77 to 82	Professional, scientific, and technical activities; Administrative and support activities	69 to 75	Professional, scientific and technical activities
			77 to 82	Administrative and support services
	84 to 88	Public administration and defense; compulsory social security; Education; Human health and social work activities	84	Public administration and defense; compulsory social security
			85	Education
			86, 87, 88	Human health and social work activities
	90 to 98	Arts, entertainment and recreation, and other service activities; Activities of households as employers; undifferentiated goods-and-services-producing activities of households for own use	90, 91, 92, 93	Arts, entertainment and recreation
			94, 95, 96	Other service activities
			97, 98	Activities of households as employers; undifferentiated goods- and services-producing activities of

Source: Authors' elaboration based on DANE (2022) and OECD (2021).

Table 6 – Study aggregation level for Costa Rica

Study aggregation level	Costa Rica's water data		OECD IOT	
	ISIC 4	Description	ISIC 4	Description
AGRI	01 to 03 and 3600-2	Agriculture, forestry and fishing Water supply for agriculture	01, 02	Agriculture, hunting, forestry
			03	Fishing and aquaculture
WASA	3600-1	Water collection, treatment and supply	36, 37, 38, 39	Water supply; sewerage, waste management and remediation activities
	3700	Sewerage		
RoE	05 to 33, 38, 39, 41 to 43, 45 to 96	Manufacturing and Construction and Services	05, 06	Mining and quarrying, energy producing products
			07, 08	Mining and quarrying, non-energy producing products
			09	Mining support service activities
			10, 11, 12	Food products, beverages and tobacco
			13, 14, 15	Textiles, textile products, leather and footwear
			16	Wood and products of wood and cork
			17, 18	Paper products and printing
			19	Coke and refined petroleum products
			20	Chemical and chemical products
			21	Pharmaceuticals, medicinal chemical and botanical products
			22	Rubber and plastics products
			23	Other non-metallic mineral products
			24	Basic metals
			25	Fabricated metal products

Study aggregation level	Costa Rica's water data		OECD IOT	
	ISIC 4	Description	ISIC 4	Description
RoE	05 to 33, 38, 39, 41 to 43, 45 to 96	Manufacturing and Construction and Services	26	Computer, electronic and optical equipment
			27	Electrical equipment
			28	Machinery and equipment, nec
			29	Motor vehicles, trailers and semi-trailers
			30	Other transport equipment
			31, 32, 33	Manufacturing nec; repair and installation of machinery and equipment
			41, 42, 43	Construction
			45, 46, 47	Wholesale and retail trade; repair of motor vehicles
			49	Land transport and transport via pipelines
			50	Water transport
			51	Air transport
			52	Warehousing and support activities for transportation
			53	Postal and courier activities
			55, 56	Accommodation and food service activities
			58, 59, 60	Publishing, audiovisual and broadcasting activities
			61	Telecommunications
			62	IT and other information services
			64, 65, 66	Financial and insurance activities
			68	Real estate activities
			69 to 75	Professional, scientific and technical activities
			77 to 82	Administrative and support services
			84	Public administration and defense; compulsory social security
			85	Education
			86, 87, 88	Human health and social work activities
			90, 91, 92, 93	Arts, entertainment and recreation
			94,95, 96	Other service activities
			97, 98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
	3510	Hydroelectric power generation	35	Electricity, gas, steam and air conditioning supply

Source: Authors' elaboration based on BCCR (2021) and OECD (2021).

2.2.3 Water-Economic model: environmental-extended input-output model

The IO model is a valuable tool for assessing water footprints (Hoekstra et al., 2011). The model allows for a comprehensive analysis of water consumption throughout the entire supply chain of a product or sector. Tracing the water inputs and outputs across various economic sectors enables researchers and policymakers to understand the direct and indirect water usage associated with economic activities, and effectively address water consumption and improve water use efficiency by analyzing the water footprint of economic systems.

This analysis not only helps identify sectors with high water consumption where measures can be implemented to reduce water use but also identifies sectors where water plays a crucial role and may be more susceptible in the event of droughts. When applied to a time series, the water footprint analysis also allows for trends identification and serve as a baseline for strategic sustainable development policies.

The IO model establishes a method for assessing the water footprint by connecting water needs to economic activities. This process is realized through the utilization of data on consumptive direct water requirements, which helps in determining the overall water volume essential for various sectors' production activities. By integrating this data with the input-output model, the tracking of water flow becomes possible across the entire economic framework.

The consumptive direct water requirements data is derived from the SEEA-Water dataset, which has been published by Brazil, Colombia, and Costa Rica for their respective economies. Specifically, the direct water requirements are represented as a vector, where which of the elements represent the volume of water that each sector demand (agriculture, water and sewerage, and the rest of the economy) in its production process.

Miller and Blair (2009) explain that the first step in performing the water footprint is to estimate the direct technical coefficient matrix for water, as in the traditional IO model. The multiplication of DWR by the inverse of gross output defines the direct technical coefficient matrix for water, $\breve{A}$, as shows equation (5):

$$\breve{A} = \hat{W}\hat{X}^{-1} \quad (5)$$

Where $\hat{W}$ is a diagonal matrix with the vector of DWR in the main diagonal, and $\hat{X}$ is a diagonal matrix with the vector of gross output in the main diagonal. Each element in $\breve{A}$ represents a linear water coefficient that defines direct water requirements per dollar's output of the economic sector (m^3 per USD). Or, in other words, how much water is embedded on the direct inputs that are required to accomplish the total sectoral output.

Hence, the DWR vector can be expressed by the multiplication of the direct technical coefficient matrix for water ($\breve{A}$) and the Leontief Inverse matrix (L), which expresses the total sectoral requirements to meet a given Final Demand (F), as expresses equation (6):

$$DWR = \breve{A}LF \quad (6)$$

Therefore, the direct water footprints (DWF) vector is estimated by the multiplication of $\breve{A}$ by the direct technical coefficient matrix (A) and summing up its rows (equation 7), representing water requirements directly embedded on each sector's direct inputs (or direct m^3 per USD) (Montoya, 2020).

$$DWF = \sum_{i}^{n} \breve{A}_{i,j} A_{i,j} \quad (7)$$

Analogously, the total water footprints (TWF) matrix is estimated by multiplying $\breve{A}$ by the Leontief inverse matrix (L), representing the total (direct and indirect) water requirements for each sector's production, i.e., total m^3 per USD (equation 8). The indirect water requirements illustrate water interdependency, i.e., water requirements that are triggered through the economic system either when suppling or demanding inputs.

$$TWF = \breve{A}_{i,j} L_{i,j} \quad (8)$$

Analyzing the elements of TWF matrix illustrates the water interdependency within an economy, also called water linkages. In the context of the water footprint, backward and forward linkages can provide valuable insights into the water use patterns within an economy. Backward linkages are derived by analyzing TWF matrix by the lines (inputs) perspectives, identifying the most water-intensive sectors as consumers of inputs. For example, the food processing sector may have significant backward linkages to the water supply sector, indicating that it is a major consumer of water resources (equation 9).

$$BL = \sum_{i}^{n} TWF_{i,j} \quad (9)$$

Similarly, forward linkages are derived by analyzing TWF matrix by the columns (gross outputs) perspective (equation 10), identifying the downstream sectors that depend on water-intensive sectors as suppliers of inputs. For instance, the agriculture sector may have significant forward linkages to the food processing sector, indicating that the second depends heavily on the water resources used in agriculture. By analyzing forward linkages, policymakers can identify the most vulnerable sectors to water scarcity and develop strategies to mitigate the impact of water shortages on those sectors.

$$FL = \sum_{i}^{n} TWF_{i,j} \quad (10)$$

The next section presents the results for sectoral direct water requirements and water footprint estimations. Specifically, it explores DWR and TWF trends and backward and forward linkages impact on economic systems. The analysis primarily focuses on the years 2013-2017, which serve as the common time series for all countries. Appendix B details the results for each country, considering all available data.

3. Results

The results presented in this study should be interpreted with caution due to the differences in the methodology for producing the physical data between countries, which required making certain assumptions for water balance systematization. Despite these limitations, this section aims to present the water footprint analysis results for the water and sewage (WASA) sector and the agricultural (AGRI) sector in Brazil, Colombia, and Costa Rica. The results include direct water requirements, direct water footprint, and total water footprint in the form of backwards and forward linkages, discussing results through a national lens across sectors and a sectoral lens across countries. In doing so, these results provide valuable information that contributes to understanding water footprints in Brazil, Colombia, and Costa Rica.

3.1 Direct water requirement

The direct water requirements (DWR), measured in cubic hectometers (hm^3), account for a given sector's consumptive use and losses (Figure 2). Results show that the DWR varies significantly in magnitude between the three countries; however, there are some common patterns. As shown in Figure 1, the agricultural sector has the largest DWR in each country, followed by the water and sewage sector, and the rest of the economy, respectively.

The agricultural sector consumes the most water in all three countries while representing only 4-6% of overall gross output across countries from 2013-2017. The water and sewage sector represents the second most water-intensive sector across the three economies considered in the analysis, while the percentage of the total economic output of the water and sewage sector hovers around 1%. Interestingly, in terms of percentage of total DWR, Costa Rica's WASA sector makes up approximately 27%. This is significantly larger than the WASA DWR in Brazil (average of 2% of total over the study period) or Colombia (average of 3%).

By contrast, the rest of the economy (RoE) represent proportionally minuscule water consumption but produce the most economic value in all analyzed countries. The rest of the economy encompasses various economic activities, including mining, manufacturing, energy, and services. This sector consistently achieves the highest economic output across all three countries, from 93 to 95% on average, and the lowest water consumption (averaging around 2%) is the case for the three countries analyzed.

The expressive DWR of the AGRI and WASA sectors compared to sectoral gross output indicates that analyzing the drivers of water consumption in these sectors could significantly benefit water conservation while adapting the economic system to a water scarcity context. This is specially the case for Colombian and Costa Rican economies, which have increased DWR overtime.

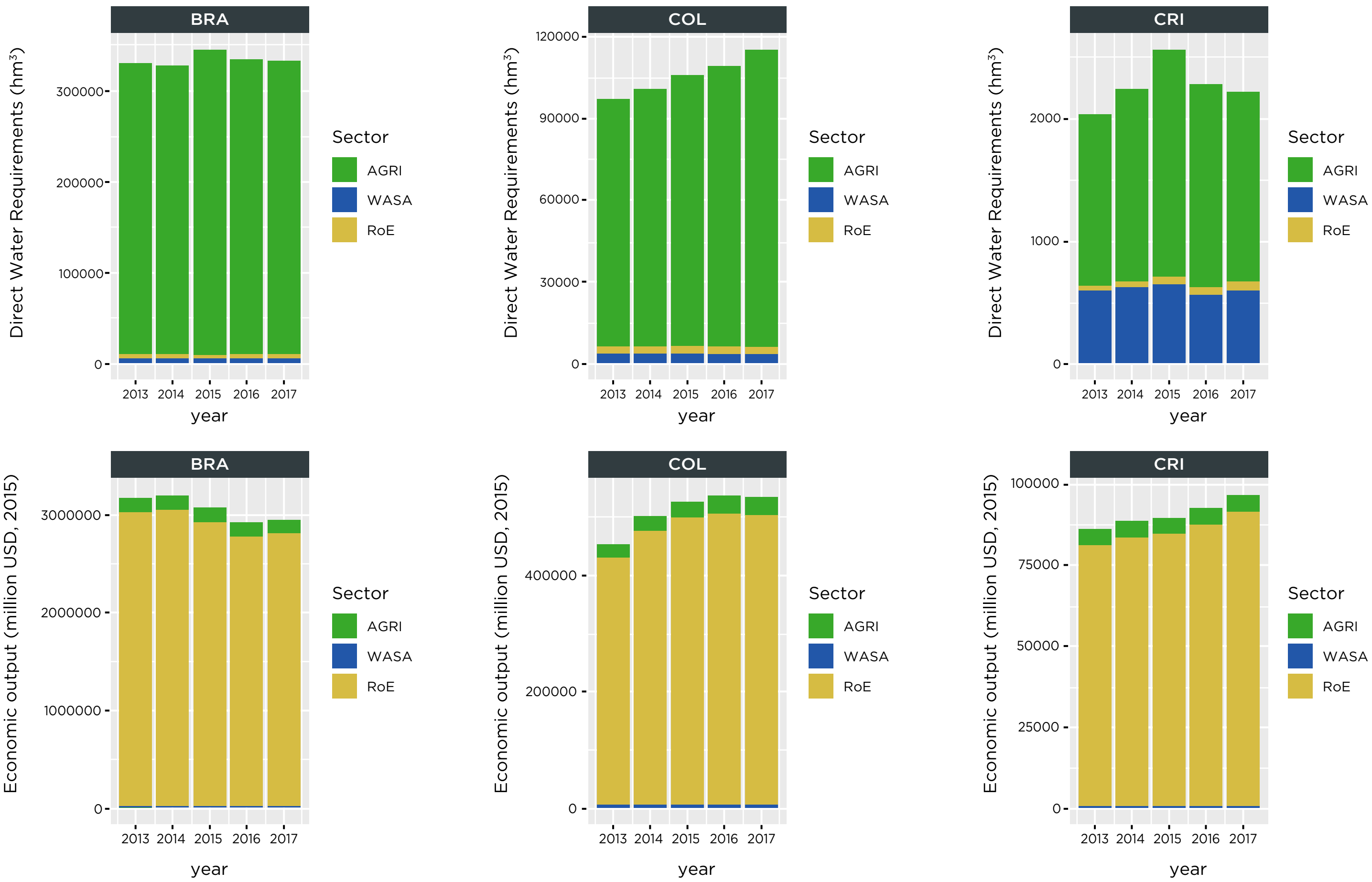


Figure 2: Direct water requirements (hm^3) and Sectoral economic output for each country by year (Millions USD, 2015).

While the economies follow similar macro trends concerning their compositions and water consumption, there are significant differences in the magnitude and efficiency of water use. The agricultural sector in Brazil is a massive consumer of water, reflecting the sector's size in terms of economic output (Figure 1). However, comparing the ratio of its gross output to its DWR, Colombia averages 0.25 USD/m^3 over the study period while Brazil and Costa Rica average 0.45 and 3.31 USD/m^3, respectively.

Results also show intriguing imbalances between water use and economic output in the water and sanitation sector. For example, comparing Brazil and Costa Rica's WASA sectors shows that Brazil's DWR is 11 times higher, while its the gross output is, on average, 27 times higher than Costa Rica's. The same comparison between Colombia and Costa Rica, being DWR and gross output in Colombia's water and sewerage sector about 6 times higher than in Costa Rica.

While Brazil's economy is much larger than Colombia's and Costa Rica's, the fact that the DWR and economic output does not scale proportionally could point to differences in water use efficiency or sectoral policy. For example, at an economy-wide perspective Colombia and Costa Rica presented an output growth by 18% and 16% between 2013 and 2017, respectively, while the induced DWR accounted for 19% and 9.4% growth. Brazil presented a crash of economy-wide output by -6.8%, inducing a stable DWR by 0.78% in the same period.

Nonetheless, some sectors had distinct growth behavior than the national average. For example, AGRI sector grew in all countries (1.8% in Brazil, 36% in Colombia, and 7.4% in Costa Rica), triggering an increase of AGRI DWR by 0.94%, 20%, and 11% respectively. Regarding the WASA sector, Brazil and Colombia presented gross output growth rates by 2.2% and 17%, respectively. While Brazil accounted for an increase of 2.3% in WASA DWR, Colombia presented a reduction by -2.6% in WASA DWR. On the other hand, the water and sewerage sector in Costa Rica presented a reduction by -21% in its output, at the same time the sectoral DWR increased by 0.28%.

To explore the differences in water use across sectors, direct water requirements and gross output analyses provide a partial picture. Nonetheless, water footprints represent the relationship between water input and economic output by giving a better understanding of water consumption patterns within sectors and across countries. By considering total water requirements within the economic structure, direct and total water footprints highlight the water intensity of sectoral output and reveal the interdependent relationship between water consumption and the entire economic system. The following sections explore these relationships in more detail, analyzing the relationship between water consumption and production in each of the three economies and comparing the agricultural and the water and sewage sectors across countries.

3.2 Results by Country

Water footprint indicators represent the water embodied in the economic system expressed in cubic meters per US dollars in 2015 (m^3/USD). Water footprints are essential for illustrating how water consumption is intertwined with the economic structure of each country and their trends over time. Water footprint indicators are expressed as direct and total water footprints. When the demand for a good or service increases by one monetary unit, it triggers two effects on sectoral water requirements. The first is the initial water embodied in the production of direct inputs (direct water footprint). The second is the water embodied in the production of inputs which are used as inputs, i.e., transactions which represent the interdependency of the economic system, accounting for both direct and indirect embodied water (total water footprints). Therefore, backward and forward linkages are derived from the total water footprints to understand how water use, efficiency, or production changes in one sector affect water use and production in other sectors.

Figure 3 shows that the direct water footprints present distinct sectoral and country-level behavior over time. Of the three countries, Colombia has the highest direct water footprint, averaging 0.35 m^3 required per USD output over the study period. This indicates that the Colombian economy is the most water intensive in terms of direct sectoral inputs, and likely the most vulnerable to water scarcity. This is supported by the fact that the sectors that make up the bulk of the economy (RoE and Agriculture) hold the highest shares of this direct water footprint (~90%). Colombia is also the only country which did not see a reduction in direct water footprint from 2013 to 2017, increasing its direct water footprint by 0.02 m^3/USD. By contrast, Brazil, which had a direct water footprint of 0.17 in 2013, reduced its direct water footprint by 0.01 m^3/USD during the same period, while Costa Rica presented a substantial direct water footprint reduction, dropping from 0.11 in 2013 to 0.08 m^3/ USD in 2017.

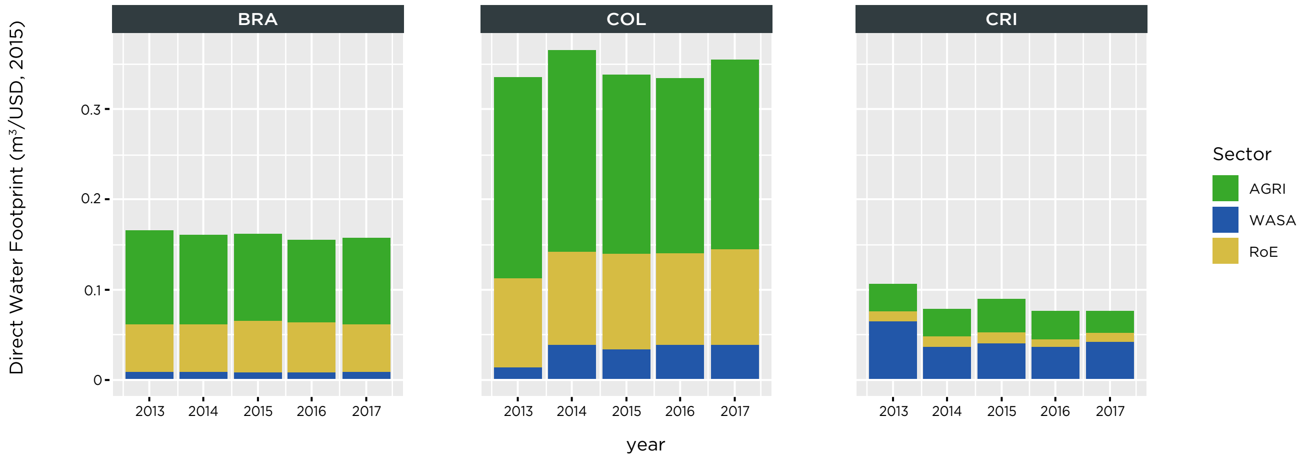


Figure 3: Direct water footprint for each country by year (m^3/USD, 2015).

Total water footprints also vary across countries. These values, which account for water embedded in inputs and water use spurred by sectoral outputs throughout the economy can more accurately communicate the water intensity of these economies. Again, Colombia has the most water-intensive economic system, with an average total water footprint of 4.9 m^3/ USD/year, followed by Brazil (2.9 m^3/ USD/year) and Costa Rica (1.3 m^3/USD/year) (Figure 4). Colombia, therefore, appears to be the most economically vulnerable to scarcity, followed by Brazil, and Costa Rica.

The risk of scarcity, however, is not equal across these countries. While Colombia is the most dependent on water resources for economic output, the country also has generally low risk for water scarcity, especially in the geographic areas with the highest economic productivity. While the discussion of risk is outside the scope of this work, it is important to consider that a high economic vulnerability to scarcity does not necessarily imply high vulnerability.

It is also important to note that differences in total water footprint stem from each country's economic system features, e.g., the participation of water-intensive activities in the economic system composition, sectors' productive technology, and efficiency in water usage across economic sectors. The water intensity within an economy or economic sector is determined by the role that water plays and the efficiency of water use within the sector. In the case of the agricultural sector, which generally makes up the largest proportion of the total water footprint, the role that water plays depends heavily on the crops portfolio within the agricultural sector, specifically the ratio of a given crop's water demand to its economic value-added; an agricultural sector comprised of water-intensive low-value products will have a much higher water footprint than an agricultural sector comprised of drought-resistant high-value products. Additionally, irrigated systems affect the agricultural sector's water productivity. While irrigated fields require more investment, irrigation may be strategic by reducing the dependence of crops on rainfall patterns and allowing for the increase of harvests within a year.

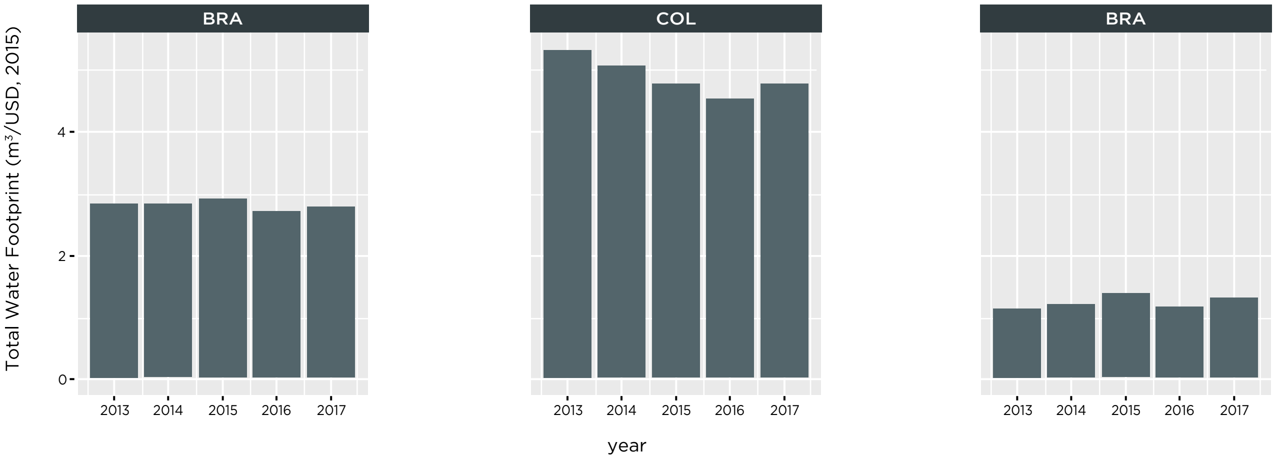


Figure 4: Total water footprint for each country by year (m3/USD, 2015).

Total water footprints also changed over time. From 2013 to 2017, Brazil reduced its total water footprint by 0.027 m^3/USD (from 2.85 m^3/USD in 2013 to 2.82 m3/USD in 2017), while Colombia's indicator decreased by 0.54 m3/ USD (from 5.32 m^3/USD to 4.78 m^3/USD). Costa Rica, on the other hand, increased its total water footprint by 0.18 m^3/ USD, from 1.17 m^3/USD in 2013 to 1.35 m^3/USD in 2017 (Figure 4). Several events can explain such changes. For example, a country can become more water-intensive over time thanks to the greater participation of water-intensive sectors in the GDP composition, potentially also becoming more inefficient. A country also can decrease its total water footprint by becoming more efficient in water usage within economic sectors, for example, by implementing water savings policies or water markets. In Colombia, the fact that direct water footprint increases while total water footprint decreases over the same period is notable and will be addressed in future research.

3.3 Results by Sector

Figure 5 presents an overview of each country's direct and total water footprints (the latter represented as backward and forward linkages) over the years. High values for backward linkages indicate that a sector's required inputs contain more embodied water. Forward linkages elucidate water footprint patterns through the supply side, e.g., how much water is consumed when a new unit of sectoral production is available in the economic system. As expected, Colombia presents the highest backward and forward linkages compared to Brazil and Costa Rica, given the magnitude of its direct and total water footprints.

As expected, AGRI and WASA sectors are relevant in explaining national water footprint trends identified in all countries. In this sense, the following section explores the differences in water footprint intensity of agricultural and water and sewerage sectors across Brazil, Colombia, and Costa Rica, giving insights into the water intensity patterns among these countries by identifying trends that emerged between 2013 and 2017. Identifying trends of increasing water intensity in key sectors sheds light on intervention necessities when designing water-saving policies to adapt to contexts of scarcity.

(m^3/USD)		Direct water footprint				Backward linkages				Forward linkages			
Country	Year	AGRI	WASA	RoE	TOTAL	AGRI	WASA	RoE	TOTAL	AGRI	WASA	RoE	TOTAL
BRA	2013	0.10	0.01	0.05	0.17	2.38	0.38	0.10	2.85	2.49	0.35	0.00	2.85
	2014	0.10	0.01	0.05	0.16	2.39	0.37	0.09	2.85	2.51	0.34	0.00	2.85
	2015	0.10	0.01	0.06	0.16	2.47	0.38	0.10	2.94	2.59	0.35	0.00	2.94
	2016	0.10	0.01	0.06	0.16	2.29	0.38	0.10	2.77	2.42	0.35	0.00	2.77
	2017	0.09	0.01	0.05	0.16	2.35	0.38	0.09	2.82	2.47	0.35	0.00	2.82
COL	2013	0.22	0.01	0.11	0.37	4.03	0.85	0.19	5.07	4.28	0.77	0.02	5.07
	2014	0.22	0.04	0.10	0.34	3.77	0.83	0.18	4.78	4.01	0.75	0.01	4.78
	2015	0.20	0.04	0.10	0.33	3.55	0.82	0.18	4.55	3.79	0.74	0.01	4.55
	2016	0.19	0.04	0.10	0.35	4.07	0.77	0.19	5.03	4.07	0.69	0.01	4.78
	2017	0.21	0.04	0.10	0.35	3.86	0.78	0.18	4.82	4.11	0.70	0.01	4.82
CRI	2013	0.03	0.07	0.009	0.11	0.31	0.84	0.02	1.17	0.31	0.85	0.00	1.17
	2014	0.03	0.04	0.010	0.08	0.33	0.86	0.02	1.21	0.34	0.87	0.00	1.21
	2015	0.04	0.04	0.012	0.09	0.41	0.95	0.02	1.38	0.42	0.96	0.00	1.38
	2016	0.03	0.04	0.010	0.08	0.35	0.82	0.02	1.19	0.36	0.83	0.00	1.19
	2017	0.02	0.04	0.010	0.08	0.31	1.02	0.02	1.35	0.32	1.03	0.00	1.35

Figure 5: Sectoral water footprints for each country by year (m^3/USD, 2015).

3.3.1 The Agricultural Sector – AGRI

Costa Rica has the lowest water footprint indicators for the agricultural sectors among the countries examined. From 2013 to 2017, the direct water footprints for Costa Rica in this sector averaged 0.03 m^3/ USD, followed by Brazil (0.10) and Colombia (0.21) (Figure 6). These estimations indicate that Colombia requires 8 times more water than Costa Rica to generate each monetary unit of agricultural output, while Brazil requires 3.2 times more. These differences are likely due to differences in these countries' agriculture portfolios, water use efficiency variations, or increasing irrigation and diminishing rain-fed agriculture.

From 2013 to 2017, all countries experienced a reduction in direct water footprint. Costa Rica achieved the most significant decrease (20%), followed by Brazil (10%) and Colombia (6%). Water efficiency improvements in the agricultural sector play a crucial role alongside changes in the structure of economic activity. For example, countries can reduce their direct water footprint of agricultural activities by implementing improved irrigation systems, enhancing water governance for integrated water resources management, or adopting production processes that require less water-intense inputs. During the study period, drought in all three countries often spurred these actions, positioning efficient water use as an important political issue and prompting producers to invest in irrigation systems or pivot to less water-intensive or more value-added crops to mitigate the climate risk and increase production efficiency.

Direct water footprints, however, do not tell the whole story. To better understand virtual water flows, it is essential to emphasize how efficiently water is consumed within different sectors and consider water consumption efficiency by material and resources that go into supply chains. By analyzing total water footprint indicators, like backward and forward linkages, we can encompass these factors in our analysis and work towards effective water conservation.

The relevance of considering both backward and forward linkages become evident through a practical example. In Colombia, the agricultural sector initially exhibits a water intensity of 0.21 hectometers of water per 1 USD of gross output. However, when one accounts for the water embedded in the direct and indirect inputs required to generate 1 USD of agricultural output, this figure escalates to 3.89 cubic meters. Looking from a forward linkage perspective, downstream product generation results in 4.11 cubic meters of embodied water for every USD increase in the sector's supply. This comparative analysis underscores the importance of evaluating both backward and forward linkages alongside direct water footprints when assessing sectoral water usage.

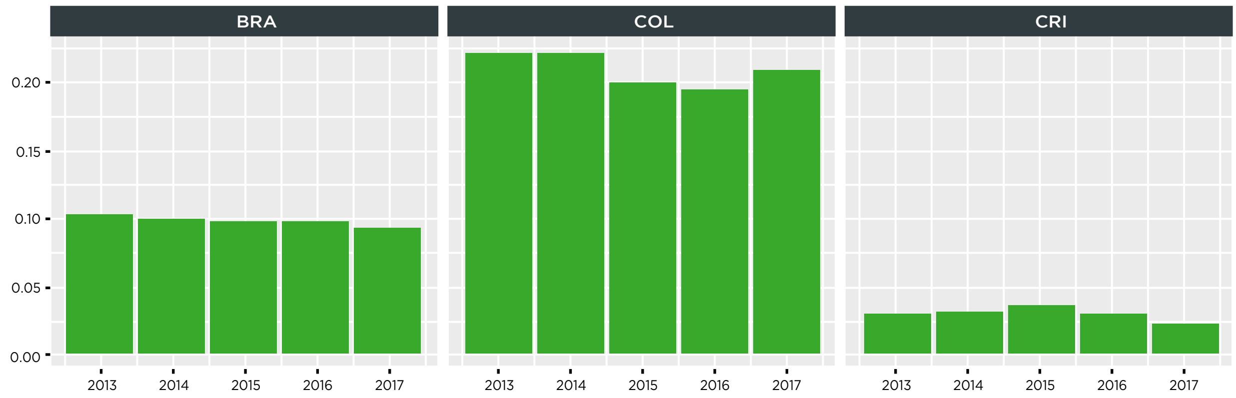
Between 2013 and 2017, forward and backward linkages for agriculture showed some variation in each country, but estimations for the beginning and end of the period were relatively similar, except for Colombia. Colombia experienced a 5% reduction in backward and a 9% reduction in forward linkages. In comparison, Costa Rica and Brazil maintained relatively stable indicators, with a slight increase of 0.1% and 1% for Costa Rica, respectively, and a decrease of 1% for Brazil for both indicators. The decrease in Colombia's backward and forward linkages might point to potential increases in efficiency both upstream and downstream of the agricultural sector.[10] These variations emphasize the importance of comprehensively assessing water consumption efficiency throughout supply chains to understand conservation efforts.

Total water footprint estimations reveal that each unit increase of economic output in Colombia's agricultural sector requires 13 times more water flow within the economic system than Costa Rica's. In contrast, each unit increase in Brazil's agricultural sector requires 7 times more than Costa Rica's. Comparing direct water footprint estimations to backward and forward linkages for each sector, we see that linkage estimations are generally 10 to 25 times larger than their corresponding direct water footprint (~10 for Costa Rica, ~20 for Colombia, and ~25 for Brazil). Such relationships mean that the incorporation of water consumption embodied in inputs from other sectors or water use in other sectors that use agricultural outputs vastly changes the water footprint estimations of the agricultural sector, indicating that the agricultural sector demands not only large direct water requirements but also triggers significant virtual water flows within economic systems.

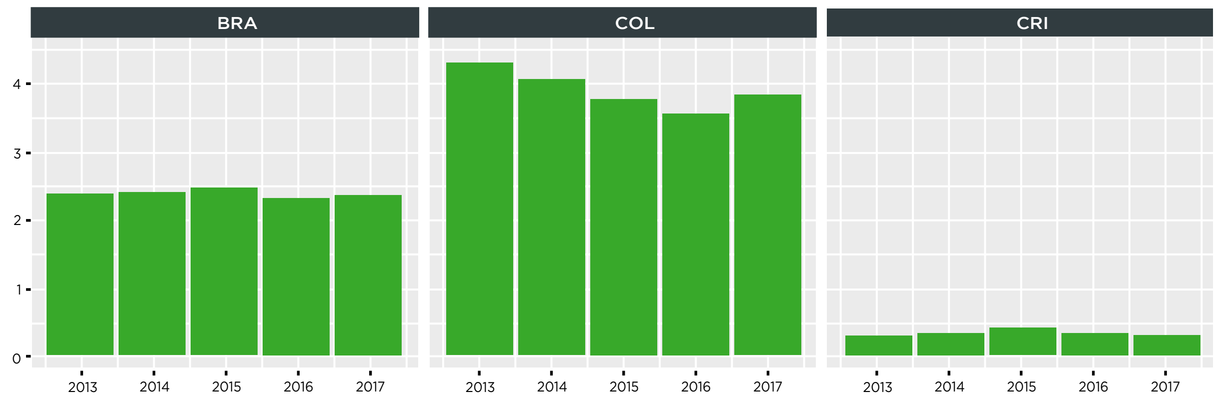
[10] In fact, a sectoral backward linkage reduction can also occur due to industrial de-densification, meaning the loss or weakening of links in a production chain. For example, an increase in the import penetration in the supply chain of the agriculture sector would drop its backward linkage, and thus its water footprint. In any case, the pressure on water resources diminishes. Changes in imports penetration is not part of the scope of this study, although opens a complementary and important research avenue when designing development policies.

m³/ USD year		Direct Water Footprint			Backward Linkages			Forward Linkages		
		BRA	COL	CRI	BRA	COL	CRI	BRA	COL	CRI
AGRI	**2013**	0.10	0.22	0.03	2.38	4.29	0.31	2.49	4.50	0.31
	2014	0.10	0.22	0.03	2.39	4.03	0.33	2.51	4.28	0.34
	2015	0.10	0.20	0.04	2.47	3.77	0.41	2.59	4.01	0.42
	2016	0.10	0.19	0.03	2.29	3.55	0.35	2.42	3.79	0.36
	2017	0.09	0.21	0.02	2.35	4.07	0.31	2.47	4.07	0.32

AGRI Direct Water Footprint (m^3/ USD)



AGRI Backward Linkages (m^3/ USD)



AGRI Forward Linkages (m^3/USD)

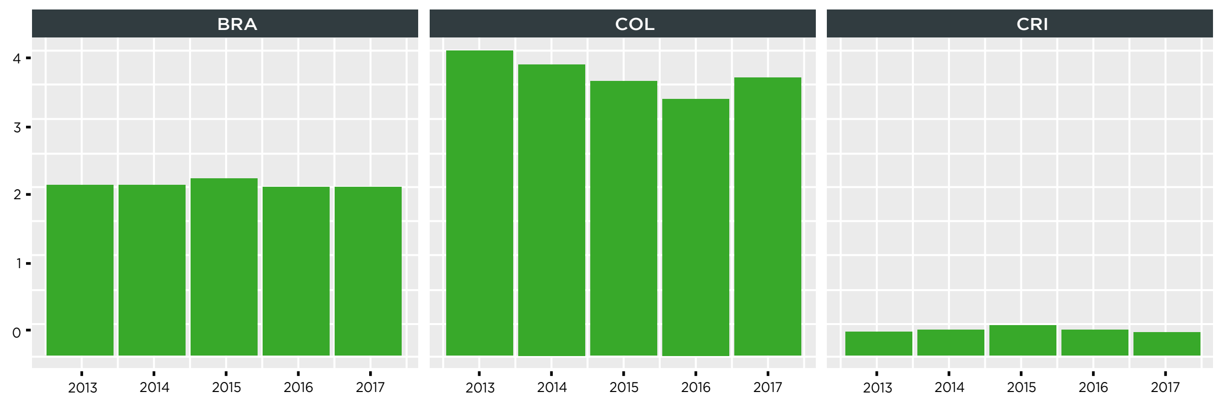


Figure 6: National water footprints for AGRI by year (m^3/USD, 2015).

3.3.2 The Water and Sanitation sector - WASA

Among the countries examined, Brazil has the lowest water footprint indicators for the water and sewerage sector. From 2013 to 2017, the direct water requirements for Brazil averaged 0.01 m^3/USD, followed by Colombia (0.03) and Costa Rica (0.05) (Figure 13). These results exhibit consistent trends in direct water requirements per capita across the three countries: Brazil, with 33 m^3; Colombia, with 79 m^3; and Costa Rica, with 126 m3. In simpler terms, Colombia requires 3 times and Costa Rica 5 times more water to meet the water and sanitation sector's output, directly related to their respective populations' water supply. Costa Rica experiences the highest percentage of losses per direct water abstraction from the environment, averaging 40% yearly, which may explain the highest direct water footprint among countries. Brazil recorded 33% losses and Colombia 27% on average, suggesting that losses are not the only driver behind direct water footprint indicators. The estimations highlight the complex interplay among population, water supply, losses, and other factors[11] influencing direct water footprint indicators.

From 2013 to 2017, the variations observed in the direct water footprint indicators are expressive. Brazil shows a slight increase of 3% , while notable changes occurred in the water and sewerage sector indicators for Costa Rica and Colombia. **Costa Rica achieved a 35% reduction in its direct water footprint between 2013-2014,** potentially due to water-saving policies and investments in sectoral infrastructure. In contrast, **Colombia faced a substantial increase of 179% in its direct water footprint during the same period.** Interestingly, the most relevant growth also took place in 2013-2014. The reasons for this sharp increase in Colombia remain unclear. The physical data relies on information on water abstracted by public companies, which may have changed methodology throughout the process. A deeper assessment of the water and sewerage sector and the economic system in Colombia may provide further insights into the factors influencing these changes during the analyzed period, while Costa Rica's expressive direct water footprint reduction might provide insights for other economies in the region when designing water saving policies for this sector in a context of adapting for a more water scarcity context.

Comparing the total water footprint estimations among the countries analyzed, Costa Rica emerged with the highest values, although the indicators' behavior differs among countries (Figure 7). The average backward and forward linkages for Costa Rica are 0.90 and 0.91 m^3/USD, while for Colombia, these values are 0.83 and 0.75, and for Brazil, they are 0.38 and 0.35, respectively. These estimations provide insights into the amount of embodied water in each country's economic system per water and sewerage output unit, showing that economic output in the water and sewage sector of Colombia and Costa Rica triggers nearly 2.4 times more embodied water than in that of Brazil. These differences are likely due to differences in the sectoral water productivity, e.g., how much water produces an equivalent monetary output.

Interestingly, between 2013 and 2017, Colombia's WASA sectors backward and forward linkage estimations decreased by 11% and 15% respectively, while simultaneously increasing its direct water footprint by 179%. This means that while the sector became more water-intensive in its activities, the entire economic system of Colombia became less intensive, diminishing the water content of the sector's supply chain. For example, the agricultural sector, Colombia's most water-intensive sector, experienced a reduction in its direct water requirements between 2013 and 2017 while growing its share of the Colombian economy, possibly compensating for the increased water and sewerage direct water footprint.

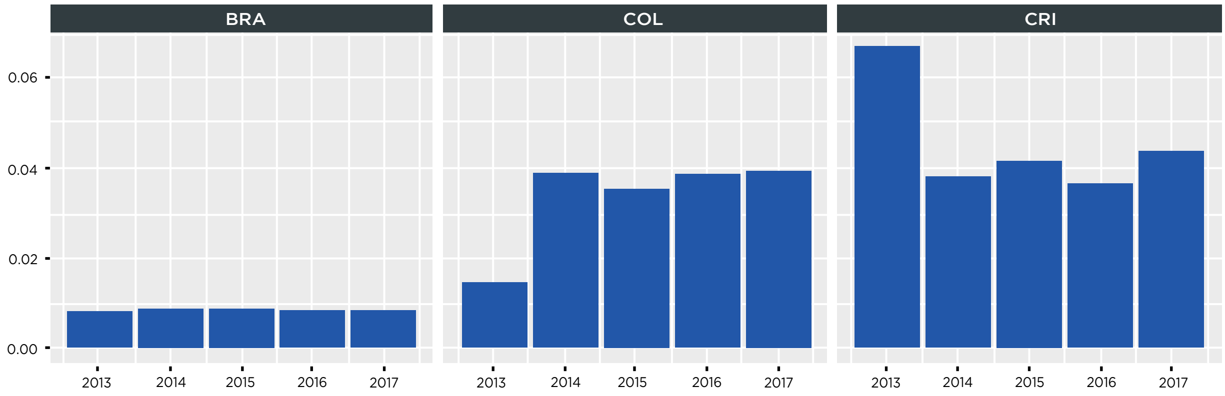
In contrast, Costa Rica's WASA sector experienced an increase of 22% and 21% in backward and forward linkages estimations between 2013 and 2017, despite a decrease in the direct water footprint for the water and sewerage sector. This implies that the sector became more efficient, but its supply chain became more dependent on embodied water. However, this decrease is a result of 2013 having an exceptionally high direct water footprint. When analyzing direct water footprint between 2014-2017, there was 14% increase, aligning with the overall trend of the total water footprint.

Meanwhile, the WASA sector in Brazil only experienced a slight variation from 2013-2017, registering an increase of 1% in the backward linkage estimation and a 0.2% in the forward linkage estimation. This indicates relatively stable water usage patterns during the analyzed period, the same tendency observed in direct water footprint for the sector. Estimations show that not only did the water and sanitation sector become more water-intensive, but the supply also chain had an increase in water requirements even though the differences are not large in magnitude, even in a period of water scarcity faced by the country during the period.

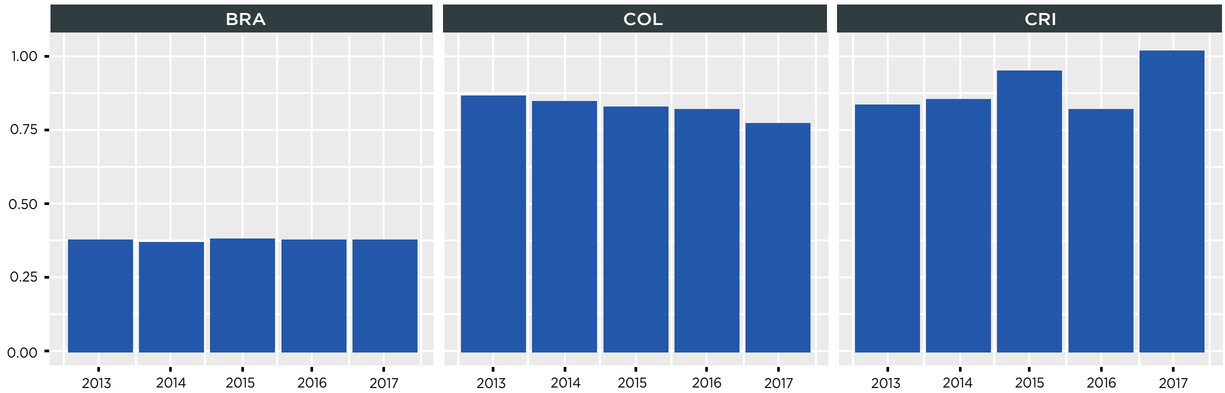
[11] For example: investment in either modernization of water treatment equipment, expanding of sanitation services, revenue recovered by tariffs, among other factors.

(m³/ USD) year		Direct Water Footprint			Backward linkages			Forward Linkages		
		BRA	COL	CRI	BRA	COL	CRI	BRA	COL	CRI
WASA	2013	0.01	0.01	0.07	0.38	0.87	0.84	0.35	0.81	0.85
	2014	0.01	0.04	0.04	0.37	0.85	0.86	0.34	0.77	0.87
	2015	0.01	0.04	0.04	0.38	0.83	0.95	0.35	0.75	0.96
	2016	0.01	0.04	0.04	0.38	0.82	0.82	0.35	0.74	0.83
	2017	0.01	0.04	0.04	0.38	0.77	1.02	0.35	0.69	1.03

WASA Direct Water Footprint (m³/USD)



WASA Backward Linkages (m³/USD)



WASA Forward Linkages (m³/USD)

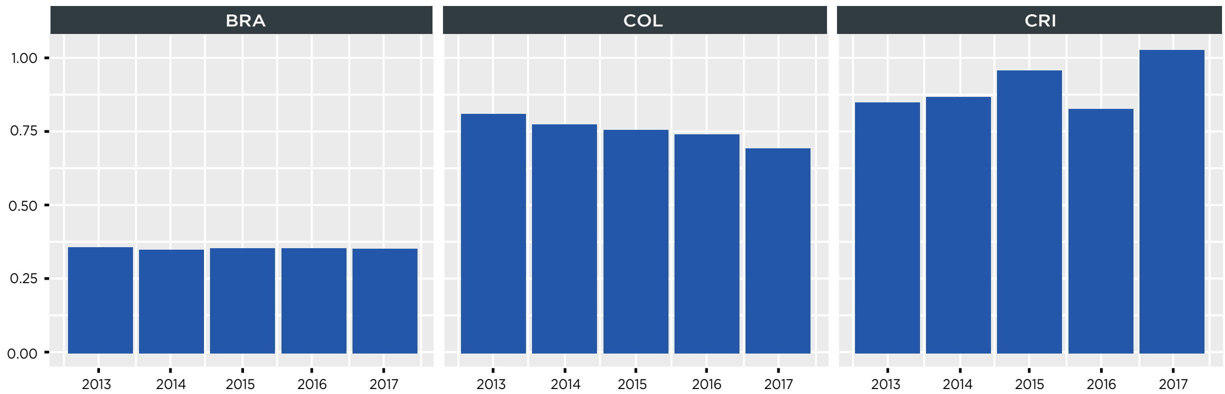


Figure 7: National water footprints for WASA by year (m³/USD 2015).

4. Conclusion

This study estimated direct and total water footprints for three economies in the LAC region – Brazil, Colombia, and Costa Rica – with a focus on the agriculture and water and sewerage sectors due to their relevance on water requirements relative to other sectors. The findings offer valuable insights into water consumption patterns across these economies.

I. **Brazil, Colombia, and Costa Rica show many common trends with respect to water consumption throughout sectors; however, direct water footprint information shows that the embodied water per unit of gross output vary significantly between countries and sectors.** Colombia experienced an increase of 179% in the direct water requirement for the water and sewerage sector between 2013 and 2017. This surge warrants further investigation to determine the primary factors exerting pressure on Colombia's direct water requirement. Conversely, Brazil has the lowest water footprint for the water and sewage sector; however, it exhibited a different pattern than the sector's economic output from 2013 to 2017. The underlying causes for these trends require further research. Additionally, the water and sewerage sector does not appear to have been substantially affected despite facing droughts during this period, highlighting the need for an in-depth analysis of the factors at play.

II. **The incorporation of backward and forward linkages in water footprint analysis drastically raises water footprints in both the agricultural and water and sewerage sectors, making their incorporation vital when performing similar analyses.** Colombia has the most water-intensive economic system among the countries analyzed, translated by the highest values of backward and forward linkages. In Costa Rica, the water and sewerage sector demonstrated both higher direct and total water footprints than the agricultural sector, which is unique compared to other countries. Determining if it is necessary to prioritize efficiency in water usage within the water and sewerage sector requires deeper investigation to understand better why the sector has a higher water footprint in Costa Rica than in other countries analyzed. Brazilian direct water requirements in the agricultural sector decreased over time. This might indicate improved efficiency in water usage or potential impacts from the country's droughts. However, agriculture's total water footprint indicators did not follow the same downward trend, suggesting that despite agricultural activities becoming less water-intensive, the increasing proportion of the agricultural sector in GDP composition offset the decrease in the direct water footprint, leading to an overall more water-intensive economic system. In line with this, Naspolini et al. (2020) emphasize the importance of considering total water footprints when formulating policies, particularly considering the role played by the economic structure in triggering embodied water in supply chains.

III. **It is crucial to have physical water data at the most granular sectoral level to facilitate future water footprint analyses and subsequent areas for future research.** The analyzed countries could pursue improvements on the available data to strengthen the water accounting in the region. For example, Colombia could work on providing asset tables to estimate the economic system's impact on water resources, while Brazil could offer more detailed methodological reports, facilitating data comparison across countries. In terms of sectoral information, Colombia and Costa Rica could consider estimating thermal-power water consumption to allow for an accurate disaggregation of the electricity sector, thus gaining a deeper understanding of its water consumption patterns. Meanwhile, Costa Rica could aim to disaggregate service sectors for 2016-2012, as this information is currently unavailable. Including this data would allow for water footprint analyses with higher levels of granularity, which would have direct benefits for policymakers.

Promoting and implementing the System of Environmental and Economic Accounting for Water can contribute to a better understanding of water-economic dynamics in the LAC region. Additionally, it is important to focus on exploring possibilities of data disaggregation. By implementing these improvements, researchers can enhance their understanding of water consumption patterns, enabling policymakers to make well-informed decisions and ensure the sustainable use of water resources in the Latin America and Caribbean region.

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6. Appendix

A. The Input-output Model

The IO model relies on a set of n linear equations with n unknowns. The equations describe how each sector's outputs are related to other sectors' inputs. For example, suppose an economy has two economic sectors, A and B. The output of sector A can be used as an input in sector B, and the output of sector B can be used as an input in sector A. We can set up a system of two linear equations with two unknowns to model this interdependence using the IO model. The unknown variables would represent the amount of output produced by each sector. The solution to the system of equations provides information about sectoral production and the quantities of goods and services flowing between the two sectors or the total sectoral output.

In addition to interindustry transactions, goods and services are demanded by the final users, such as households, government, and exports, representing the amount of goods and services consumed or used up by these final users. In other worlds, each industry output can be demanded as an input to other industries' production or as final goods and services. For example, households can directly demand water and sanitation services, or water and sanitation services serve as input for economic activities. The model formalization is given by equation A.1:

$$x = Z_i + f \qquad \text{(A.1)}$$

The vector x represents the sectoral output, the matrix Z represents the interindustry transactions (the summation vector "i = [1, 1, ..., 1]" represents the rows sum of matrix Z to accomplish with matrix notation), and the vector f represents the final demand (goods that are directly demanded by internal and external markets, e.g., households, government, or exports)[12]. All variables are recorded in monetary units, specifically for this study, in millions of US dollars (million USD 2015). The IO datasets commonly follow equation (A.1) for data organization, which serves as the starting point for the IO model. The Organization for Economic Cooperation and Development (OECD) 's IO dataset is an example of this approach and forms the basis of the IO model in this study.

Following the IO model construction, the interindustry transactions can also be represented as a direct coefficients matrix by relating the interindustry inputs to the total output, as shown in equation A.2. A is the direct technical coefficients matrix, representing the direct sectoral requirements of a given sector output.

$$A = Z\hat{X}^{-1} \qquad \text{(A.2)}$$

By substituting equation 2 in 1 and doing some elementary algebra, it is possible to express the total sectoral output (x) as shown in equation (3). The matrix L, defined as (I – A)-1, is known as the Leontief inverse matrix or total requirements matrix. L displays each industry total (direct and indirect) input technical requirements to produce one unit of its output. Equation A.3 also shows the direct relation of the total output (x) and the final demand (*f*) through matrix L. This is the IO model elementary equation.

$$x = (I - A)^{-1} f = Lf \qquad \text{(A.3)}$$

The IO model can be used to analyze the economic impact of changes in production or consumption, making it a valuable tool for policymakers and researchers. The total requirements matrix (L) is useful for analyzing the interdependencies among economic sectors. A higher element of L indicates a greater dependency on the output of other sectors to produce its output. More specifically, the (i, j) element of L, denoted as Lij, represents the proportion of output from sector j required to produce one unit of output from sector i. This element captures the linkages between sector i and sector j.

Another key feature of the IO model is its versatility. The model can be coupled to variables external to the economic system extending the analysis to (number of) employment, natural resources requirements (such as energy, water, or land), emissions embodied in the economy, and many others. The following section describes the IO model extension to estimate water footprints.

B. The Deflation Process

The deflation process involves isolating the effects of domestic prices (inflation) and change in exchange rates when comparing economic data across countries and time periods, which is the case of OECD IOT datasets. To achieve this, it is necessary to perform the following steps.

The first step in the deflation process is selecting a base year, which serves as a reference point for converting current prices into fixed prices. In this study, the base year chosen is 2015 since it is applicable to all data series.

After determining the base year, the next step is to choose a deflator for the domestic price effect. In this case, we adopted the Gross Domestic Product deflator (IMF 2023), which reflects changes in the overall price level of the economy over time. Additionally, it is necessary to account for the

[12] In fact, the final demand can be represented as a vector or matrix depending on whether its components are presented summed up in a single column or disaggregated into a matrix.

variation in exchange rates used by OECD to convert the national currency units into dollars when estimating the IOT dataset (OECD 2021) This step ensures that the effects of exchange rate fluctuations are considered.

To perform the deflation process, we multiply each value in the input-output table for a given year by the deflators and exchange rate ratios calculated (Equation B.1). The first ratio term adjusts the inflation in domestic prices, while the second one adjusts the dollar data to account for changes in exchange rates for the period.

$$IOT_{\text{value (base year)}} = IOT_{\text{value (n)}} \left(\frac{Deflator_{\text{(base year)}}}{Deflator_{(n)}} \right) \left(\frac{Exchang\ rate_{(n)}}{Exchang\ rate_{\text{(base year)}}} \right) \quad \text{(B.1)}$$

By applying the deflation process, we can effectively adjust the IOT values for inflation and exchange rate effects. This adjustment allows for the accurate analysis of cross-country economic data over time.

C. Detailed results

Brazil

	Brazil	A.AGRI	A.RoE	A.WASA	L.AGRI	L.RoE	L.WASA	FD_AGG. Households	FD_AGG. OtherIn	FD_AGG. Exports	X_diag. AGRI	X_diag.RoE	X_diag. WASA	A_water. AGRI	A_water. RoE
1	AGRI	0.046	0.023	0.001	1.060	0.040	0.013	32056.871	7193.108	25995.089	142426.425	0	0	2.240	0
2	RoE	0.273	0.385	0.294	0.472	1.647	0.492	881592.041	733936.766	193180.701	0	3012702.200	0	0	0.001
3	WASA	0	0.004	0.016	0.002	0.007	1.018	6503.095	265.765	12.255	0	0	19733.476	0	0
4	AGRI	0.044	0.023	0.001	1.057	0.039	0.013	32246.323	8087.123	24900.866	140329.462	0	0	2.258	0
5	RoE	0.287	0.385	0.301	0.495	1.648	0.506	912673.810	722473.615	185872.071	0	3036985.874	0	0	0.001
6	WASA	0	0.004	0.017	0.002	0.007	1.020	6500.935	296.925	6.086	0	0	19566.102	0	0
7	AGRI	0.042	0.023	0.001	1.057	0.040	0.014	32766.500	5196.000	31998.600	143551.700	0	0	2.332	0
8	RoE	0.313	0.379	0.316	0.534	1.634	0.526	893617.900	657146.000	205973.100	0	2911593.400	0	0	0.001
9	WASA	0	0.004	0.017	0.002	0.007	1.019	6093.200	385.100	5.900	0	0	18844.700	0	0
10	AGRI	0.044	0.025	0.001	1.060	0.043	0.015	35580.007	9909.438	27660.805	149685.706	0	0	2.164	0
11	RoE	0.295	0.375	0.311	0.501	1.623	0.513	874795.215	612237.831	189454.314	0	2761650.287	0	0	0.001
12	WASA	0	0.005	0.016	0.002	0.008	1.019	6665.378	245.794	7.572	0	0	19863.142	0	0
13	AGRI	0.042	0.024	0.001	1.056	0.040	0.014	34135.342	8481.966	29807.054	145031.036	0	0	2.220	0
14	RoE	0.303	0.376	0.315	0.515	1.627	0.522	899232.430	600302.366	192579.809	0	2793750.228	0	0	0.001
15	WASA	0	0.004	0.016	0.002	0.007	1.018	7701.867	217.493	9.158	0	0	20162.558	0	0

	A_water. WASA	L_water. AGRI	L_water. RoE	L_water. WASA	X_water. Households	X_water. OtherIn	X_water. Exports	BL_ water	FL_ water	DWR. AGRI	DWR. RoE	DWR. WASA	direct _WF	year
1	0	2.374	0.091	0.030	156183.180	83592.954	79217.046	2.375	2.494	318992.919	0	0	0.104	2013
2	0	0.001	0.002	0.001	2193.642	1808.738	493.000	0.095	0.004	0	4495.382	0	0.054	2013
3	0.340	0.001	0.002	0.346	4378.033	1849.168	483.524	0.377	0.349	0	0	6710.726	0.008	2013
4	0	2.388	0.088	0.030	157826.017	83152.468	75877.606	2.389	2.506	316856.377	0	0	0.099	2014
5	0	0.001	0.002	0.001	2170.465	1702.344	454.015	0.093	0.004	0	4326.827	0	0.053	2014
6	0.335	0.001	0.002	0.342	4344.723	1768.865	447.021	0.372	0.345	0	0	6560.508	0.009	2014
7	0	2.464	0.092	0.033	163420.639	73476.070	97853.778	2.465	2.589	334751.805	0	0	0.098	2015
8	0	0.001	0.002	0.001	2093.264	1522.021	499.903	0.097	0.004	0	4115.190	0	0.056	2015
9	0.339	0.001	0.002	0.345	4212.057	1667.949	506.561	0.379	0.349	0	0	6386.605	0.009	2015
10	0	2.293	0.093	0.032	163162.554	79673.093	81047.761	2.295	2.418	323884.011	0	0	0.097	2016
11	0	0.001	0.002	0.001	2043.347	1416.210	455.645	0.098	0.004	0	3915.200	0	0.057	2016
12	0.339	0.001	0.003	0.345	4563.283	1656.413	508.583	0.378	0.349	0	0	6728.445	0.009	2016
13	0	2.345	0.090	0.032	161020.698	73786.915	87192.800	2.347	2.467	322000.972	0	0	0.093	2017
14	0	0.001	0.002	0.001	2077.191	1372.776	459.857	0.094	0.004	0	3909.828	0	0.055	2017
15	0.340	0.001	0.002	0.347	4853.858	1522.182	488.204	0.379	0.350	0	0	6864.279	0.008	2017

Colombia

	Colombia	A. AGRI	A. RoE	A. WASA	L. AGRI	L. RoE	L. WASA	FD_AGG. Households	FD_AGG. OtherIn	FD_AGG. Exports	X_diag. AGRI	X_diag. RoE	X_diag .WASA	A_water .AGRI	A_water. RoE	A_water. WASA
1	AGRI	0.062	0.029	0.003	1.078	0.048	0.019	7343.567	1259.735	1681.195	22183.462	0	0	3.518	0	0
2	RoE	0.213	0.362	0.341	0.362	1.589	0.547	122717.938	69818.267	35871.900	0	368088.471	0	0	0.007	0
3	WASA	0.002	0.005	0.007	0.003	0.008	1.010	1921.866	784.992	2.281	0	0	4518.899	0	0	0.737
4	AGRI	0.059	0.029	0.002	1.073	0.048	0.019	7619.666	1059.248	1574.298	22840.808	0	0	3.492	0	0
5	RoE	0.211	0.355	0.339	0.353	1.569	0.536	126128.906	75236.260	46239.604	0	393632.088	0	0	0.007	0
6	WASA	0.002	0.004	0.006	0.003	0.007	1.008	1972.084	801.089	2.386	0	0	4498.877	0	0	0.757
7	AGRI	0.056	0.025	0.002	1.069	0.041	0.016	7859.601	1443.505	1651.119	22213.294	0	0	3.709	0	0
8	RoE	0.222	0.353	0.339	0.369	1.562	0.534	132125.157	78032.069	46753.641	0	406914.048	0	0	0.006	0
9	WASA	0.002	0.004	0.006	0.003	0.006	1.008	2030.532	801.007	3.078	0	0	4415.504	0	0	0.788
10	AGRI	0.054	0.023	0.002	1.067	0.038	0.016	8241.474	1359.647	1839.371	22565.235	0	0	4.016	0	0
11	RoE	0.224	0.351	0.351	0.370	1.557	0.550	137722.214	85015.958	47127.322	0	426139.323	0	0	0.006	0
12	WASA	0.002	0.004	0.005	0.003	0.006	1.007	2118.781	878.352	3.284	0	0	4583.507	0	0	0.795
13	AGRI	0.058	0.026	0.005	1.074	0.046	0.022	8319.310	1175.640	1728.456	25188.976	0	0	3.746	0	0
14	RoE	0.253	0.376	0.363	0.438	1.624	0.607	146920.009	94308.207	45260.200	0	471899.307	0	0	0.006	0
15	WASA	0.003	0.004	0.025	0.005	0.007	1.028	2265.415	602.779	1.795	0	0	4940.261	0	0	0.745
16	AGRI	0.056	0.028	0.005	1.072	0.048	0.023	9234.200	1452.400	2334.500	28323.400	0	0	3.509	0	0
17	RoE	0.248	0.382	0.371	0.433	1.640	0.625	154727.000	97988.000	43206.400	0	492930.300	0	0	0.005	0
18	WASA	0.002	0.004	0.023	0.005	0.007	1.027	2308.100	675.900	1.800	0	0	5191.600	0	0	0.723
19	AGRI	0.058	0.029	0.006	1.075	0.051	0.025	10494.563	1726.089	2552.374	31200.740	0	0	3.295	0	0
20	RoE	0.239	0.382	0.360	0.417	1.642	0.609	159669.546	99040.342	41151.014	0	500248.724	0	0	0.005	0
21	WASA	0.002	0.004	0.025	0.004	0.006	1.028	2394.426	541.217	1.695	0	0	5013.220	0	0	0.713
22	AGRI	0.058	0.029	0.006	1.075	0.050	0.024	10416.525	1521.501	2667.251	30740.817	0	0	3.547	0	0
23	RoE	0.243	0.377	0.353	0.420	1.628	0.593	161190.655	97367.861	42617.499	0	498315.020	0	0	0.005	0
24	WASA	0.002	0.004	0.027	0.004	0.007	1.030	2590.913	602.622	1.850	0	0	5351.932	0	0	0.663
25	AGRI	0.057	0.027	0.005	1.073	0.047	0.023	10750.268	1543.834	2894.747	30774.446	0	0	3.595	0	0
26	RoE	0.242	0.376	0.349	0.419	1.624	0.585	162745.107	100141.114	45853.974	0	509803.425	0	0	0.005	0
27	WASA	0.002	0.004	0.026	0.004	0.007	1.029	2691.202	669.445	2.050	0	0	5571.597	0	0	0.674

	L_water. AGRI	L_water. RoE	L_water. WASA	X_water. Households	X_water. OtherIn	X_water. Exports	BL_ water	FL_ water	DWR. AGRI	DWR. RoE	DWR. WASA	direct_ WF	year
1	3.790	0.170	0.068	48847.541	16708.539	12476.302	3.796	4.029	78031.481	0	0	0.222	2010
2	0.003	0.011	0.004	1406.158	791.342	407.678	0.187	0.018	0	2605.179	0	0.106	2010
3	0.003	0.006	0.744	2140.130	980.635	208.154	0.816	0.752	0	0	3329.040	0.017	2010
4	3.748	0.166	0.065	49651.190	16527.249	13586.028	3.753	3.980	79764.334	0	0	0.208	2011
5	0.002	0.010	0.004	1317.943	776.804	477.831	0.182	0.016	0	2572.570	0	0.105	2011
6	0	0.005	0.764	2167.093	997.856	241.363	0.832	0.771	0	0	3406.195	0.015	2011
7	3.965	0.151	0.060	51229.962	17550.164	13604.194	3.970	4.176	82384.028	0	0	0.211	2012
8	0.002	0.010	0.003	1329.696	776.506	465.475	0.165	0.016	0	2571.677	0	0.096	2012
9	0.002	0.005	0.794	2249.757	1004.599	225.169	0.858	0.801	0	0	3479.470	0.015	2012
10	4.284	0.153	0.062	56578.783	18929.273	15113.992	4.289	4.500	90621.859	0	0	0.222	2013
11	0.002	0.010	0.004	1420.231	866.205	481.051	0.168	0.016	0	2767.494	0	0.098	2013
12	0.002	0.004	0.801	2335.558	1088.593	218.929	0.867	0.808	0	0	3643.026	0.014	2013
13	4.025	0.171	0.084	58776.769	20895.945	14690.306	4.031	4.279	94362.764	0	0	0.222	2014
14	0.003	0.009	0.003	1395.461	882.329	425.369	0.185	0.015	0	2703.178	0	0.104	2014
15	0.003	0.005	0.766	2503.705	940.473	235.214	0.853	0.774	0	0	3679.172	0.039	2014
16	3.763	0.169	0.082	61153.734	22123.210	16105.422	3.769	4.015	99383.161	0	0	0.201	2015
17	0.002	0.009	0.003	1424.916	889.233	395.107	0.184	0.015	0	2709.259	0	0.102	2015
18	0.003	0.005	0.743	2525.775	1001.732	227.265	0.828	0.751	0	0	3754.700	0.035	2015
19	3.542	0.168	0.083	64121.169	22752.698	15935.314	3.547	3.792	102809.807	0	0	0.195	2016
20	0.002	0.009	0.003	1432.890	875.052	366.948	0.181	0.014	0	2674.884	0	0.101	2016
21	0.003	0.005	0.733	2517.327	857.358	197.502	0.818	0.740	0	0	3572.339	0.038	2016
22	3.811	0.176	0.086	68334.165	23014.537	17677.546	3.816	4.073	109026.057	0	0	0.209	2017
23	0.002	0.009	0.003	1411.559	839.102	370.881	0.189	0.014	0	2621.550	0	0.106	2017
24	0.003	0.004	0.683	2506.138	844.428	196.036	0.772	0.690	0	0	3546.805	0.040	2017
25	3.857	0.168	0.082	68980.585	22803.933	18856.101	3.862	4.107	110640.252	0	0	0.209	2018
26	0.002	0.009	0.003	1428.778	864.890	399.930	0.181	0.014	0	2693.598	0	0.102	2018
27	0.003	0.004	0.694	2623.907	916.661	214.479	0.778	0.701	0	0	3754.852	0.039	2018

Costa Rica

	Costa Rica	A.AGRI	A.RoE	A. WASA	L. AGRI	L.RoE	L. WASA	FD_AGG. Households	FD_AGG. OtherIn	FD_AGG. Exports	X_diag. AGRI	X_diag. RoE	X_diag. WASA	A_water. AGRI	A_water. RoE
1	AGRI	0.078	0.026	0.005	1.097	0.042	0.016	736.223	91.362	1961.849	5314.885	0.000	0.000	0.255	0.000
2	RoE	0.259	0.302	0.196	0.410	1.449	0.318	23523.938	16810.045	13850.596	0.000	79784.107	0.000	0.000	0.000
3	WASA	0.009	0.003	0.098	0.012	0.005	1.110	345.244	3.150	0.326	0.000	0.000	704.610	0.000	0.000
4	AGRI	0.083	0.024	0.004	1.101	0.038	0.013	722.336	140.380	1895.332	5117.459	0.000	0.000	0.273	0.000
5	RoE	0.265	0.302	0.190	0.422	1.449	0.304	24059.222	16746.575	13731.405	0.000	80324.952	0.000	0.000	0.000
6	WASA	0.010	0.003	0.086	0.014	0.006	1.095	399.153	2.890	0.206	0.000	0.000	780.243	0.000	0.000
7	AGRI	0.079	0.023	0.002	1.096	0.037	0.012	771.527	136.404	2028.686	5274.541	0.000	0.000	0.295	0.000
8	RoE	0.259	0.302	0.232	0.411	1.447	0.353	24496.230	17033.045	14540.502	0.000	82505.815	0.000	0.000	0.001
9	WASA	0.010	0.003	0.046	0.013	0.006	1.049	401.466	7.119	0.209	0.000	0.000	776.028	0.000	0.000
10	AGRI	0.079	0.023	0.003	1.096	0.036	0.014	782.800	161.000	1773.000	5063.400	0.000	0.000	0.366	0.000
11	RoE	0.258	0.299	0.285	0.408	1.442	0.431	25106.300	17501.400	14634.300	0.000	83827.000	0.000	0.000	0.001
12	WASA	0.009	0.003	0.045	0.012	0.005	1.048	380.300	2.200	0.100	0.000	0.000	721.600	0.000	0.000
13	AGRI	0.078	0.023	0.003	1.095	0.036	0.014	784.572	132.927	1977.721	5317.898	0.000	0.000	0.312	0.000
14	RoE	0.250	0.295	0.297	0.393	1.433	0.446	25692.079	17917.821	15818.567	0.000	86505.890	0.000	0.000	0.001
15	WASA	0.008	0.003	0.045	0.011	0.005	1.048	391.986	2.399	0.100	0.000	0.000	717.508	0.000	0.000
16	AGRI	0.067	0.024	0.001	1.082	0.036	0.012	779.166	205.901	2013.359	5498.701	0.000	0.000	0.281	0.000
17	RoE	0.270	0.296	0.282	0.417	1.436	0.423	26542.149	18573.947	16867.314	0.000	90364.195	0.000	0.000	0.001
18	WASA	0.005	0.003	0.044	0.007	0.004	1.047	307.334	3.341	0.101	0.000	0.000	613.453	0.000	0.000

	A_water. WASA	L_water. AGRI	L_water. RoE	L_water. WASA	X_water. Households	X_water. OtherIn	X_water. Exports	BL_ water	FL_ water	DWR. AGRI	DWR. RoE	DWR. WASA	direct_ WF	year
1	0.000	0.280	0.011	0.004	456.510	203.596	695.664	0.290	0.294	1355.83	0.000	0.000	0.027	2012
2	0.000	0.000	0.000	0.000	11.720	8.288	7.092	0.015	0.001	0.000	27.103	0.000	0.009	2012
3	0.822	0.010	0.004	0.912	423.598	76.368	79.020	0.916	0.926	0.000	0.000	579.012	0.082	2012
4	0.000	0.300	0.010	0.004	468.120	215.987	711.965	0.311	0.314	1396.07	0.000	0.000	0.030	2013
5	0.000	0.000	0.001	0.000	16.625	11.460	9.751	0.015	0.001	0.000	37.838	0.000	0.009	2013
6	0.763	0.010	0.004	0.836	442.710	74.516	77.923	0.840	0.851	0.000	0.000	595.419	0.067	2013
7	0.000	0.324	0.011	0.003	515.913	228.199	814.286	0.335	0.338	1558.49	0.000	0.000	0.031	2014
8	0.000	0.000	0.001	0.000	19.565	13.463	11.920	0.016	0.001	0.000	44.950	0.000	0.010	2014
9	0.814	0.010	0.005	0.854	461.090	84.186	86.598	0.858	0.869	0.000	0.000	631.532	0.038	2014
10	0.000	0.401	0.013	0.005	649.753	297.271	905.879	0.412	0.420	1852.98	0.000	0.000	0.037	2015
11	0.000	0.000	0.001	0.000	25.579	17.643	15.218	0.019	0.002	0.000	58.443	0.000	0.012	2015
12	0.902	0.011	0.005	0.946	481.939	83.318	85.263	0.951	0.961	0.000	0.000	650.913	0.041	2015
13	0.000	0.341	0.011	0.004	558.268	246.766	852.758	0.350	0.357	1657.90	0.000	0.000	0.031	2016
14	0.000	0.000	0.001	0.000	26.355	18.180	16.565	0.016	0.002	0.000	61.104	0.000	0.010	2016
15	0.780	0.008	0.004	0.818	419.348	67.388	73.151	0.823	0.830	0.000	0.000	559.903	0.036	2016
16	0.000	0.304	0.010	0.003	508.420	251.937	783.981	0.312	0.317	1544.30	0.000	0.000	0.024	2017
17	0.000	0.000	0.001	0.000	33.469	23.220	21.748	0.016	0.002	0.000	78.440	0.000	0.010	2017
18	0.973	0.007	0.004	1.019	429.602	82.356	84.913	1.023	1.031	0.000	0.000	597.085	0.043	2017

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