Last updated: 2024-10-27

Metadata: Water Consumption Footprint

1. Definition, concepts, and classifications

1.a. Definition

Water Consumption Footprint (WF) is the attribution of global blue water consumption to the domestic final demand of a country. Blue water is defined as water stemming from surface water (e.g. rivers or lakes) or groundwater. The total water footprint is the sum of the water footprint for both agricultural and non-agricultural blue water consumption.

1.b. Concepts

Blue water consumption encompasses water withdrawn from surface water or groundwater that is either incorporated into products or evaporated during either the growth period of a crop or the production process of goods. WF reports blue water consumption across the whole supply chain to service final demand.

1.c. Unit of measure

Million m3 H2Oeq

2. Methodological considerations

2.a. Description of the footprint calculation methodology

A Water Consumption Footprint *WF* measures blue water consumption directly and indirectly associated as a result of economic activities of final demanders, that is households, the government and the capital sector. WF includes blue water consumption from the entire upstream supply chains underlying these economic activities. It is derived from input-output data[1] according to:

$$WF = DW + \mathbf{my},$$

where DW are households-associated blue water consumption, $\mathbf{m}$ is a $1{\times}N$ vector of blue water consumption *multipliers* for a range of economic sectors, and $\mathbf{y}$ is an $N{\times}1$ vector of final demand of products made by these sectors.

2.b. Multi-regional input-output (MRIO) framework

The System of National Accounts ([1], §28.37) states the fundamental input-output relationship as:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{y},$$

[1] Representing the economy as *N* intermediate sectors (eg agriculture, forestry, fishing, mining, manufacturing, utilities, construction, trade, transport, services), and *M* final demanders (households, the government and the capital sector).

where $\mathbf{x} = \mathbf{T}\mathbf{1}^{T} + \mathbf{y}\mathbf{1}^{y}$ denotes a vector of sectoral *total output*, $\mathbf{T}$ is an $N\times N$ *intermediate demand* matrix, $\mathbf{y}$ is an $N\times M$ *final demand* matrix, $\mathbf{1}^{T} = \{\underbrace{(1,\dots,1)}_{N}\}$ and $\mathbf{1}^{y} = \{\underbrace{(1,\dots,1)}_{M}\}$ are summation operators, $\mathbf{I}$ is an $N\times N$ identity matrix, and $\mathbf{A} = \mathbf{T}\hat{\mathbf{x}}^{-1}$ holds $N\times N$ intermediate *input coefficients*. The $N\times N$ matrix $\mathbf{L} = (\mathbf{I}-\mathbf{A})^{-1}$ is called the *Leontief inverse* (see §28.38 in [1] and §20.F in [2]), which facilitates the analytical power of input-output analysis for the purpose of enumerating footprints. $\mathbf{T}$, $\mathbf{y}$ and $\mathbf{x}$ are standard components of any official national or global input-output database, and $\mathbf{A}$ and $\mathbf{L}$ are derived from these. The Global Footprint Tool makes use of global, multi-regional input-output (MRIO) data (see [3] and §17 in [2]).

In compliance with the System of Environmental-Economic Accounting (see §29.105 in [1] and §13 in [2]), blue water consumption data distinguishing K blue water consumption types are arranged into a so-called *satellite account* $\mathbf{Q}$, sized $K\times N$. The combination of blue water consumption and monetary input-output data enables the calculation of embodied blue water consumption footprints [4]. Pre-multiplying the fundamental input-output relationship with land use *intensities* $\mathbf{q} = \mathbf{Q}\hat{\mathbf{x}}^{-1}$ yields blue water consumption footprints WF as:

$$\mathbf{q}\mathbf{x} = \mathbf{q}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y} =: \mathbf{m}\mathbf{y} = WF.$$

The blue water consumption *multipliers* are $\mathbf{m} = \mathbf{q}(\mathbf{I}-\mathbf{A})^{-1} = \mathbf{q}\mathbf{L}$, and – as with the Leontief inverse $\mathbf{L} = (\mathbf{I}-\mathbf{A})^{-1}$ – incorporate the entire supply-chain network underpinning the production of goods and services ultimately consumed by final demanders (§20.K in [2]).

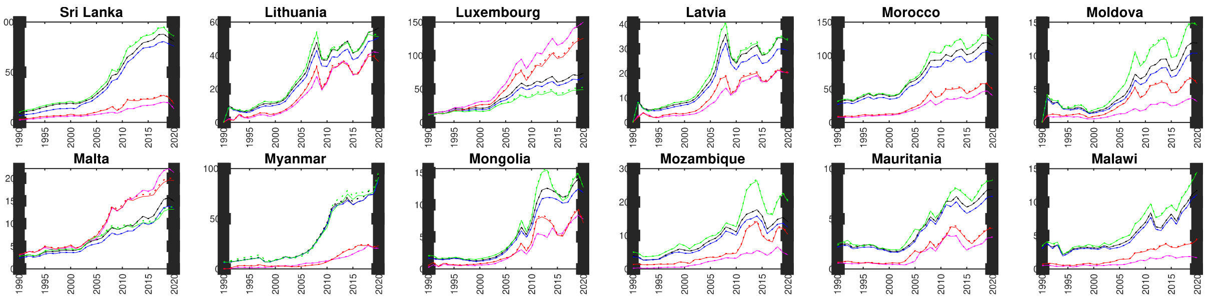
For the attribution of the Water Consumption Footprint of final demand in the Global Footprint Tool, global multi-regional input-output (MRIO) analysis and data are employed (§17 in [2]). The MRIO data are taken from the GLORIA MRIO database [5]. The primary data underlying this database are described in the GLORIA Release Notes. These notes also contain explanations of GLORIA's multi-region Supply-Use structure (see §17.B in [2]), detailed descriptions of compilation procedures, a visualisation of Water Footprint trends for all 164 regions and countries, as well as a plain-English short philosophy of MRIO-building and a plain-English explanation of MRIO-based footprinting.

2.c. Description of the data forecast methodology

Most primary data underlying the GLORIA MRIO database are up-to-date until 2021. The forecast of all monetary tables starting 2022 until 2028 is based on GDP projections by the International Monetary Fund [6] and the World Bank [7]. Satellite entries are forecast by extrapolating a linear fit of the 1990-2021 data.

2.d. Validation

The GLORIA Release Notes contain a number of validation visualisations, for example through a country-by-country comparison of GLORIA aggregates (GDP, value added, imports, exports, labour wages) with corresponding values in the United Nations SNA Main Aggregates database [8] and the ILO labour database [9]. These comparisons illustrate the adherence of GLORIA data and national accounts aggregates.



Excerpt from the GLORIA – UN Main Aggregates comparison.
UN Main Aggregates solid lines, GLORIA dashed lines.

2.e. Quality assurance

The compilation of the GLORIA MRIO database includes a series of Quality Assurance (QA) diagnostics tests. These tests are offered alongside the data download [5] and as excerpts in the Release Notes. These diagnostics tests assure that GLORIA data:

- adhere as much as possible to primary data such as from the United Nations Statistics Division (UNSD), the OECD, the International Labour Organisation (ILO), the United Nations Food and Agriculture organisation (FAO), and the United Nations Industrial Development Organisation (UNIDO);
- yield realistic relationships with physical data; for example (a) dividing GLORIA's monetary wages and salaries data by ILO's employment statistics should yield realistic per-worker wages across various sectors and regions, and (b) dividing GLORIA's monetary household consumption data by FAOSTAT's food balances should yield realistic per-capita energy and macronutrient intakes across various sectors and regions.

3. Data sources

3.a. Data sources

Countries' blue water consumption data are sourced from the data from Pfister and colleagues (2011) [10]. The data from Pfister et al. (2011) representing production patterns in the year 2000 was matched to country and sector resolution in the way described by Lutter et al. [11]. Time series are developed based on a regionalized EXIOBASE 3 version [12].

3.b. Data compilation methods

Constructing a water consumption satellite account (see Section 2.b) for the GLORIA MRIO database requires arranging water consumption data into *activities* (rows) and *emitting industry sectors* (columns).

Water consumption data in their primary form are mapped from their native regional and sectoral classifications to the 164 regions and 120 sectors adapted in the Global Footprint Tool. This mapping is achieved by using a concordance matrix, i.e. a binary matrix that bridges between two classifications, showing values of 1 wherever there is a connection between two regions/sectors from different classifications, and 0 otherwise.

Data available in the regionalized Exiobase 3 version (as used by Cabernard et al., 2019 [12]) covers the period 1995-2015, and was extrapolated using land use for crop products and sectoral output for industrial sectors, for 1990 to 1994 and 2016 to 2018. Estimates are offered at two levels: agriculture (i.e. crops and farming) and non-agriculture blue water consumption.

4. Data availability and disaggregation

4.a. Data availability

The Global Footprint Tool allows to calculate the Water Consumption Footprint indicator for 164 countries (see list of countries in Annex 1).

4.b. Time series

The Water Consumption Footprint indicator can be calculated since 1990.

4.c. Disaggregation

The Water Consumption Footprint indicator is disaggregated into 2 levels: agriculture (i.e. crops and farming) and non-agriculture blue water consumption.

5. Comparability / deviation from international standards

The Water Consumption Footprint is calculated in accordance with international standards, recommendations, and classifications such as the System of National Accounts 2008, the System of Environmental-Economic Accounting – Central Framework 2012, the Balance of Payments and International Investment Position, the International Standard Industrial Classification of All Economic Activities (ISIC), the Central Product Classification (CPC) and the Framework for the Development of Environment Statistics.

5. References

[1] UN, System of National Accounts 2008, United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank, New York, USA, 2009.
[2] UNSD, Handbook on Supply, Use and Input-Output Tables with Extensions and Applications, United Nations Statistics Division, New York, USA, 2018.
[3] W.W. Leontief, A.A. Strout, Multiregional input-output analysis, in: T. Barna (Ed.), Structural Interdependence and Economic Development, Macmillan, London, UK, 1963, pp. 119-149.
[4] W. Leontief, D. Ford, Environmental repercussions and the economic structure: an input-output approach, Review of Economics and Statistics 52(3) (1970) 262-271.
[5] M. Lenzen, M. Li, The GLORIA MRIO database, The University of Sydney, Sydney, Australia, 2023.
[6] IMF, Gross domestic product, current prices, 2020-2028, International Monetary Fund, Washington, D.C., USA, 2023.
[7] World Bank, Global Economic Prospects, World Bank,, Washington DC, USA, 2023.
[8] UNSD, National Accounts Main Aggregates Database, United Nations Statistics Division, New York, USA, 2022.
[9] ILO, ILOSTAT - Statistics on employment, International Labour Organization, Genève, Switzerland, 2022.

[10] Pfister, S., Bayer, P., Koehler, A., Hellweg, S., 2011. Environmental Impacts of Water consumption in Global Crop Production: Hotspots and Trade-Offs with Land Use. Environ. Sci. Technol. 2011, 45, 13, 5761–5768. doi.org/10.1021/es1041755
[11] Lutter, S., Pfister, S., Giljum, S., Wieland, H., Mutel, C., 2016, Spatially explicit assessment of water embodied in European trade: A product-level multi-regional input-output analysis, Global Environmental Change, 38, 171-182. doi.org/10.1016/j.gloenvcha.2016.03.001. .
[12] Cabernard, L., Pfister, S., Hellweg, S., 2019. A new method for analyzing sustainability performance of global supply chains and its application to material resources, Science of The Total Environment, 684, 164-177. doi.org/10.1016/j.scitotenv.2019.04.434.

Annex 1: List of countries for which the Water Footprint indicator can be calculated using the Global Footprint Tool

Region index	Region acronyms	Region full names
1	XAM	Rest of Americas
2	XEU	Rest of Europe
3	XAF	Rest of Africa
4	XAS	Rest of Asia-Pacific
5	AFG	Afghanistan
6	AGO	Angola
7	ALB	Albania
8	ARE	United Arab Emirates
9	ARG	Argentina
10	ARM	Armenia
11	AUS	Australia
12	AUT	Austria
13	AZE	Azerbaijan
14	BDI	Burundi
15	BEL	Belgium
16	BEN	Benin
17	BFA	Burkina Faso
18	BGD	Bangladesh

19	BGR	Bulgaria
20	BHR	Bahrain
21	BHS	Bahamas
22	BIH	Bosnia and Herzegovina
23	BLR	Belarus
24	BLZ	Belize
25	BOL	Bolivia
26	BRA	Brazil
27	BRN	Brunei Darussalam
28	BTN	Bhutan
29	BWA	Botswana
30	CAF	Central African Republic
31	CAN	Canada
32	CHE	Switzerland
33	CHL	Chile
34	CHN	China
35	CIV	Cote d'Ivoire
36	CMR	Cameroon
37	COD	DR Congo
38	COG	Rep Congo
39	COL	Colombia
40	CRI	Costa Rica
41	CUB	Cuba
42	CYP	Cyprus
43	CZE	CSSR/Czech Republic (1990/1991)
44	DEU	Germany
45	DJI	Djibouti

46	DYE	DR Yemen (Aden)
47	DNK	Denmark
48	DOM	Dominican Republic
49	DZA	Algeria
50	ECU	Ecuador
51	EGY	Egypt
52	ERI	Eritrea
53	ESP	Spain
54	EST	Estonia
55	ETH	Ethiopia/DR Ethiopia (1992/1993)
56	FIN	Finland
57	FRA	France
58	GAB	Gabon
59	GBR	United Kingdom
60	GEO	Georgia
61	GHA	Ghana
62	GIN	Guinea
63	GMB	Gambia
64	GNQ	Equatorial Guinea
65	GRC	Greece
66	GTM	Guatemala
67	HND	Honduras
68	HKG	Hong Kong
69	HRV	Croatia
70	HTI	Haiti
71	HUN	Hungary
72	IDN	Indonesia

73	IND	India
74	IRL	Ireland
75	IRN	Iran
76	IRQ	Iraq
77	ISL	Iceland
78	ISR	Israel
79	ITA	Italy
80	JAM	Jamaica
81	JOR	Jordan
82	JPN	Japan
83	KAZ	Kazakhstan
84	KEN	Kenya
85	KGZ	Kyrgyzstan
86	KHM	Cambodia
87	KOR	South Korea
88	KWT	Kuwait
89	LAO	Laos
90	LBN	Lebanon
91	LBR	Liberia
92	LBY	Libya
93	LKA	Sri Lanka
94	LTU	Lithuania
95	LUX	Luxembourg
96	LVA	Latvia
97	MAR	Morocco
98	MDA	Moldova
99	MDG	Madagascar

100	MEX	Mexico
101	MKD	Macedonia
102	MLI	Mali
103	MLT	Malta
104	MMR	Myanmar
105	MNG	Mongolia
106	MOZ	Mozambique
107	MRT	Mauritania
108	MWI	Malawi
109	MYS	Malaysia
110	NAM	Namibia
111	NER	Niger
112	NGA	Nigeria
113	NIC	Nicaragua
114	NLD	Netherlands
115	NOR	Norway
116	NPL	Nepal
117	NZL	New Zealand
118	OMN	Oman
119	PAK	Pakistan
120	PSE	Palestine
121	PAN	Panama
122	PER	Peru
123	PHL	Philippines
124	PNG	Papua New Guinea
125	POL	Poland
126	PRK	North Korea

127	PRT	Portugal
128	PRY	Paraguay
129	QAT	Qatar
130	ROU	Romania
131	RUS	USSR/Russian Federation (1990/1991)
132	RWA	Rwanda
133	SAU	Saudi Arabia
134	SDS	South Sudan
135	SEN	Senegal
136	SGP	Singapore
137	SLE	Sierra Leone
138	SLV	El Salvador
139	SOM	Somalia
140	SRB	Yugoslavia/Serbia (1991/1992)
141	SDN	Sudan/North Sudan (2010/2011)
142	SVK	Slovakia
143	SVN	Slovenia
144	SWE	Sweden
145	SYR	Syria
146	TCD	Chad
147	TGO	Togo
148	THA	Thailand
149	TJK	Tajikistan
150	TKM	Turkmenistan
151	TUN	Tunisia
152	TUR	Turkey
153	TZA	Tanzania

154	UGA	Uganda
155	UKR	Ukraine
156	URY	Uruguay
157	USA	United States of America
158	UZB	Uzbekistan
159	VEN	Venezuela
160	VNM	Viet Nam
161	YEM	Yemen Arab Republic/Yemen (1990/1991)
162	ZAF	South Africa
163	ZMB	Zambia
164	ZWE	Zimbabwe