Supplementary Information for Irrigation-induced precipitation as a water externality of agricultural production

Supplementary Information for Figure 3

Supplementary Table 1 reports the country-scale volumes underlying Fig. 3b for the 24 countries labeled in the figure: imports and exports of blue virtual water (IVW, EVW) and of irrigation-induced atmospheric water (IAW, EAW), together with domestic irrigation recycling (DIR), all averaged over 2008–2017. A country is a net exporter in the atmospheric network when $EAW > IAW$ and in the virtual water network when $EVW > IVW$; together, these define its role. The 24 countries cover all four roles: eight are net exporters in both networks (EVW&EAW), nine are net importers in both (IVW&IAW), three are net importers of virtual water but net exporters of atmospheric water (IVW&EAW), and four show the reverse pattern (EVW&IAW). Together they hold 74% of the global WF_b and account for 65% of cross-border irrigation-induced atmospheric exports and 62% of atmospheric imports, 71% of blue virtual water exports and 42% of blue virtual water imports, and 87% of global domestic irrigation recycling.

Supplementary Table 1 Imports and exports of atmospheric water (AW) and blue virtual water (VW), in cubic meters, for the countries highlighted in Figure 3, and their respective role across the two networks. IAW and EAW exclude domestic irrigation recycling, reported separately as DIR, in cubic meters (Eq. **??**).

Country	**IVW [m^3]**	**EVW [m^3]**	**IAW [m^3]**	**EAW [m^3]**	DIR **[m^3]**	**Role**
CHN	1.34E+10	9.47E+08	1.29E+11	1.98E+10	8.04E+10	IVW&IAW
IND	1.50E+09	2.14E+10	4.81E+10	1.30E+11	9.59E+10	EVW&EAW
PAK	2.15E+09	1.53E+10	1.09E+10	6.27E+10	1.69E+10	EVW&EAW
RUS	3.21E+09	4.25E+08	4.93E+10	2.38E+08	1.26E+09	IVW&IAW
EGY	1.37E+09	2.86E+09	4.87E+07	3.42E+10	1.86E+08	EVW&EAW
USA	5.34E+09	2.37E+10	3.73E+09	1.83E+10	2.47E+10	EVW&EAW
KAZ	8.11E+08	1.63E+09	1.57E+10	4.73E+09	8.52E+08	EVW&IAW
THA	1.09E+09	9.59E+09	3.39E+09	1.00E+10	2.01E+09	EVW&EAW
ESP	1.85E+09	6.36E+09	6.35E+08	6.51E+09	1.21E+09	EVW&EAW
ETH	4.87E+08	1.70E+08	7.40E+09	9.31E+08	6.43E+08	IVW&IAW
JPN	3.31E+09	1.92E+07	3.35E+09	2.11E+08	1.78E+08	IVW&IAW
TUR	4.32E+09	1.68E+09	5.71E+09	9.08E+09	2.52E+09	IVW&EAW
DEU	3.54E+09	3.88E+07	8.46E+08	1.42E+08	2.11E+07	IVW&IAW
IDN	3.29E+09	1.34E+08	2.66E+09	2.04E+09	6.88E+09	IVW&IAW
ARG	7.61E+07	2.88E+09	1.70E+09	7.90E+08	1.89E+09	EVW&IAW
AUS	4.76E+08	3.47E+09	1.97E+08	2.73E+08	1.29E+09	EVW&EAW
FRA	2.83E+09	7.86E+08	2.08E+09	1.10E+09	2.32E+08	IVW&IAW
ITA	3.28E+09	1.28E+09	1.71E+09	2.30E+09	4.32E+08	IVW&EAW
BOL	4.97E+07	6.03E+07	2.05E+09	5.76E+08	3.49E+08	EVW&IAW
NGA	1.23E+09	1.13E+07	2.67E+09	3.04E+09	2.11E+09	IVW&EAW
UKR	3.78E+08	8.30E+08	2.01E+09	1.24E+09	1.54E+08	EVW&IAW
CHL	4.56E+08	8.24E+08	2.55E+07	7.42E+08	1.25E+08	EVW&EAW
SEN	8.72E+08	1.04E+08	2.67E+08	1.81E+08	4.17E+07	IVW&IAW
MOZ	1.01E+09	3.07E+08	4.49E+08	2.39E+08	5.71E+07	IVW&IAW

Supplementary Information for irrigation-evapotranspiration estimate

Supplementary Table 2 places the global blue water footprint of crop production estimated in this study (WF_b = 1,052 km^3 yr^{-1} in 2015) in the context of previous global assessments. For each study, the table reports the reference period, the global WF_b, and the dataset used to locate irrigated harvested areas; it is adapted from Demeke et al. [1], and values are as reported there.

Previous estimates range from 882 to 1,530 km^3 yr^{-1}, with a median of about 1,010 km^3 yr^{-1}. Our estimate falls within this range, about 4% above the median. Most studies, including ours, model crop evapotranspiration on irrigated land assuming that irrigation fully meets crop water requirements, and most of them locate irrigated areas with MIRCA2000 [2], whereas this study uses the more recent MIRCA-OS map for 2015 [3]. The closest benchmark is CWASI v1.4 [4], which follows the same method as this study and differs only in the irrigated area dataset (MIRCA2000 instead of MIRCA-OS 2015): the two estimates differ by 17% (900 versus 1,052 km^3 yr^{-1}), a difference that reflects the updated irrigated area data.

The remaining spread across studies reflects differences in model structure, crop coverage, reference period and irrigated area data; the estimates are therefore comparable in order of magnitude rather than directly. In the table, "around 2000" denotes multi-year averages centred on 2000. Some estimates also differ in definition or period from the values reported in the original studies:

Supplementary Table 2 Comparison of the global blue water footprint of crop production (WF_b) estimated in this study with previous global estimates, reporting the reference period, the total annual volume and the data source for irrigated harvested areas. Adapted from [1]; "around 2000" denotes multi-year averages centred on 2000.

Study	**Reference period**	$\boldsymbol{WF_b}$ **(km^3 yr^{-1})**	**Irrigated harvested area**
Hoekstra & Chapagain (2007) [5]	Around 2000	1,060	National withdrawal statistics
Chiarelli et al. (2020) [6]	Around 2000	1,068	MIRCA2000 [2]
Siebert & Döll (2010) [7]	Around 2000	1,180	MIRCA2000 [2]
Hanasaki et al. (2010) [8]	Around 2000	1,530	MIRCA2000 [2]
Rost et al. (2008) [9]	Around 2000	1,258	Siebert et al. (2007) [10]
Heinke et al. (2020) [11]	Around 2000	882	MIRCA2000 [2]
Fader et al. (2011) [12]	Around 2000	923	MIRCA2000 [2]
Liu & Yang (2010) [13]	Around 2000	951	MIRCA2000 [2]
Huang et al. (2019) [14]	Around 2000	1,121	MIRCA2000 [2]
Mekonnen & Hoekstra (2011) [15]	1996–2005	899	MIRCA2000 [2]
Mialyk et al. (2024) [16]	2018	896	SPAM2010 + HID + HYDE 3.2
Demeke et al. (2026) [1]	2000	960	Monfreda et al. (2008) [17] + LUH2-ISIMIP + FAOSTAT
Demeke et al. (2026) [1]	2018	1,178	Monfreda et al. (2008) [17] + LUH2-ISIMIP + FAOSTAT
CWASI v1.4 [4]	2008–2017 average	900	MIRCA2000 [2]
This study	**2015**	**1,052**	**MIRCA-OS 2015** [3]

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