

Water footprint assessment: evolution of a new research field

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Supporting material

As a reference base for further research, Tables S.1 to S.5 provide an overview of selected water footprint (WF) and virtual water trade (VWT) studies at different spatial scales: global; continental/regional; country/state/province; municipality; and river basin / catchment / aquifer. Table S.6 lists selected WF studies for specific products; Table S.7 shows WF papers comparing diets; Table S.8 lists WF studies for specific sectors; and Table S.9 shows publicly available WF studies for or by specific companies. The list of references provided is extensive but not exhaustive. The Web of Science database gives 1297 papers when searching for “water footprint” OR “virtual water” published until 31 December 2016. The Scopus database gives 1603 results with the same search.

Table S.1 Global WF and VWT studies

Comprehensive WF-VWT studies	Bottom-up WF assessment	Mekonnen and Hoekstra 2011a; Hoekstra and Mekonnen 2012a
	Top-down WF assessment based on trade statistics	Hoekstra and Hung 2002; Chapagain and Hoekstra 2004; Hoekstra and Chapagain 2007a, 2008; Fader et al. 2011; Ercin and Hoekstra 2014; O'Bannon et al. 2014; Yang and Cui 2014
	Top-down WF assessment based on input-output modelling	Chen and Chen 2013; Tukker et al. 2016; Arto et al. 2016; Wang and Zimmerman 2016
Studies focussed on VWT	Based on trade statistics	Oki and Kanae 2004; Hoekstra and Hung 2005; Chapagain et al. 2006a; Yang et al. 2006; Chapagain and Hoekstra 2008; Hanasaki et al. 2010; Konar et al. 2011, 2012, 2013; Suweis et al. 2011; Dalin et al. 2012a, 2012b; Yang et al. 2012; Carr et al. 2012, 2013; Tamea et al. 2014; Fracasso 2014; Schwarz et al. 2015; Clark et al. 2015; Sartori and Schiavo 2015
	Based on input-output modelling	Lenzen et al. 2013
Blue WF-based water scarcity assessment		Hoekstra et al. 2012; Mekonnen and Hoekstra 2016
Grey WF-based water pollution assessment		Liu et al. 2012; Mekonnen and Hoekstra 2015; Wan et al. 2016

Note: in bottom-up WF assessment, the WF of national consumption is estimated based on consumption data and the WFs of consumed products based on their origin; in top-down WF assessment, the WF of national consumption is estimated as the WF of national production minus the WF of exported products plus the WF of imported products.

Table S.2 Continental/regional WF and VWT studies

Africa	Konar and Caylor 2013
Central Asia	Aldaya et al. 2010b
Europe	Hoekstra 2011; Galli et al. 2012; Steen-Olsen et al. 2012; Vanham 2013b; Vanham and Bidoglio 2013, 2014a; Vanham et al. 2013a, 2013b; Ercin and Hoekstra 2016; Tukker et al. 2016; Serrano et al. 2016; Gobin et al. 2017
Latin America and Caribbean	Mekonnen et al. 2015b
Mediterranean	Antonelli et al. 2012; Fracasso et al. 2016
Middle East and North Africa	Antonelli and Tamea 2015; Gilmont 2015
Nile basin countries	Zeitoun et al. 2010
Roman empire	Dermody et al. 2014

Table S.3 WF and VWT studies for specific countries/states/provinces

Austria	Vanham 2013a
Belgium	Vincent et al. 2011
Brazil	Da Silva et al 2016; Flach et al. 2016
Chile	Osorio-Ulloa 2013; Donoso et al. 2016
China	Ma et al. 2006; Liu et al. 2007b; Hubacek et al. 2009; Zhao et al. 2009, 2014, 2015b; Ge et al. 2011; Zhang et al. 2011a, 2015, 2016a, 2016b; Sun et al. 2013a; Dalin et al. 2014; Dong et al. 2014; Feng et al. 2014; Shi et al. 2014; Zhang and Anadon 2014; Zhao and Chen 2014; Goswami and Nishad 2015; Song et al. 2015; Sun et al. 2015a; Deng et al. 2015, 2016; Zhuo et al. 2016a, 2016b
China, Liaoning	Dong et al. 2013
China, Shandong	Wang et al. 2014
Colombia	Arévalo et al. 2011, 2012
Cyprus	Zoumides et al. 2014
Egypt	El-Sadek 2010
France	WWF-France 2012; Ercin et al. 2013
Germany	Sonnenberg et al. 2009; Flachmann et al. 2012
India	Kumar and Jain 2007, 2011; Kampman et al. 2008; Verma et al. 2009; Goswami and Nishad 2015; Harris et al. 2017
Indonesia	Bulsink et al. 2010
Iran	Faramarzi et al. 2010; Arabi et al. 2012; Ababaei and Etedali 2014, 2017; Karandish et al. 2015
Italy	Tamea et al. 2013; Capone et al. 2013; WWF-Italy 2014; Winter et al. 2014; Hoekstra 2015
Japan	Oki and Kanae 2004
Jordan	Schyns et al. 2015a
Kenya	Mekonnen and Hoekstra 2014b
Mexico	AgroDer 2012; Pérez-Espejo et al. 2016
Morocco	Hoekstra and Chapagain 2007b; Schyns and Hoekstra 2014
Nepal	Shrestha et al. 2013
Netherlands	Hoekstra and Chapagain 2007b; Van Oel et al. 2009
Romania	Ene and Teodosiu 2009; Ene et al. 2012
Singapore	Vanham 2011
South Africa	Hastings and Pegram 2012; Pahlow et al. 2015c; Hassan and Thiam 2015
Spain	Aldaya et al. 2010a; Fundación Mapfre 2011; Cazcarro et al. 2012, 2015; Duarte et al. 2014a, 2014b, 2015
Spain, Andalusia	Dietzenbacher and Velazquez 2007
Switzerland	Sonnenberg et al. 2010; Ercin et al. 2012b; Gnehm 2012
Tunisia	Chahed et al. 2008, 2015; Chouchane et al. 2015
Turkey	WWF-Turkey 2014
UK	Chapagain and Orr 2008; Feng et al. 2011; Yu et al. 2010; Hunt et al. 2014; Hess et al. 2015a, 2015b; Hoekstra and Mekonnen 2016
USA	Mubako and Lant 2013; Marston et al. 2015; Dang et al. 2015; Davis et al. 2017
USA, California	Mubako et al. 2013; Fulton et al. 2014; Marrin 2016
USA, Illinois	Mubako et al. 2013
Uzbekistan	Djanibekov et al. 2013

Table S.4 WF and VWT studies for specific municipalities

Beijing, China	Hubacek et al. 2009; Wang and Wang 2009; Zhang et al. 2011b, 2012; Wang et al. 2013b; Han et al. 2014; Ma et al. 2015; Yang et al. 2015; Sun et al. 2015b, 2016; Jin et al. 2016
Berlin, Germany	Hoff et al. 2014
Dutch cities	Vanham et al. 2016a
Flagstaff, USA	Rushforth and Ruddell 2016
Lagos, Nigeria	Hoff et al. 2014
Latin American cities	SASA and FFLA 2015
Leshan, China	Zhao et al. 2015a
Lijiang, China	Zhao et al. 2011
Mediterranean cities	Vanham et al. 2016b
Milan, Italy	Vanham and Bidoglio 2014b
Nairobi, Kenya	Bosire et al. 2017
New Delhi, India	Hoff et al. 2014
Phoenix, USA	Rushforth and Ruddell 2015
Singapore	Vanham 2011
USA cities	Chini et al. 2017
Vicenza, Italy	Manzardo et al. 2016b
Zhangye, China	Feng et al. 2015
Various other	Van Leeuwen 2013

See Paterson et al. (2015) for a review of the water footprint of cities.

Table S.5 WF and VWT studies for specific river basins, catchments, aquifers, or islands

Baiyangdian basin, China	Mao and Yang 2012
Breede catchment, South Africa	Pegasys 2010
Crete, Greece	Papadopoulou et al. 2016
Duero River basin, Spain	De Miguel et al. 2015
European river basins	Vanham and Bidoglio 2014a
Great Lakes, USA	Mayer et al. 2016
Guadalquivir River basin, Spain	Montesinos et al. 2011; Dumont et al. 2013
Guadiana River basin, Spain	Aldaya and Llamas 2008
Haihe River basin, China	Zhao et al. 2010; Zhi et al. 2014, 2015; White et al. 2015
Heihe River basin, China	Zeng et al. 2012
Hertfordshire - North London catchments, UK	Zhang et al. 2014
Hetao irrigation district, China	Sun et al. 2012, 2013b, 2016; Liu et al. 2015a, 2015b
High Plains (Ogallala) Aquifer	Mekonnen and Hoekstra 2010; Williams and Al-Hmoud 2015; Marston et al. 2015; Multsch et al. 2016
Jordan Valley	Shtull-Trauring et al. 2016
Paranaíba basin	Scarpate et al. 2016b
Segura River basin, Spain	Pellicer-Martínez and Martínez-Paz 2016a, 2016b
Shiyang River basin	Su et al. 2014
Steenkoppies Aquifer	Le Roux et al. 2016
Tapajós River basin	Ayala et al. 2016
Tietê–Jacaré watershed, Brazil	Scarpate et al. 2016a
Yellow River basin, China	Feng et al. 2012; Zhuo et al. 2014, 2016c; Yin et al. 2016

Table S.6 WF studies for specific products

Crops & crop products	Studies considering various crops	Hoekstra and Hung 2002; Hoekstra and Chapagain 2007a, 2008; Siebert and Döll 2010; Hanasaki et al. 2010; Mekonnen and Hoekstra 2011b; Hoekstra 2013; Lovarelli et al. 2016
	Banana	Sikirica 2011
	Beans	Flores-Lopez et al. 2015
	Beer	SABMiller and WWF-UK 2009; SABMiller et al. 2010
	Coffee	Chapagain and Hoekstra 2007
	Lucerne	Scheepers and Jordaan 2016
	Maize	Bocchiola et al. 2013
	Mango	Ridoutt et al. 2010; Domínguez Guzmán et al. 2017
	Margarine	Jefferies et al. 2012
	Melon	Castellanos et al. 2016
	Olives	Salmoral et al. 2011; Pellegrini et al. 2016
	Onions	Larson et al. 2010
	Palm oil	Suttayakul et al. 2016
	Pasta	Aldaya and Hoekstra 2010; Ruini et al. 2013
	Pineapple	Sikirica 2011
	Pizza	Aldaya and Hoekstra 2010
	Rice	Chapagain and Hoekstra 2011; Bocchiola 2015; Davis et al. 2016
	Soap	Francke and Castro 2013
	Soft drink	TCCC and TNC 2010; Coca-Cola Europe 2011; Ercin et al. 2011
	Soybean & products	Ercin et al. 2012a; Lathuilière et al. 2014; Ayala et al. 2016
	Sugar beet	Coca-Cola Europe 2011; Ercin et al. 2011; Gerbens-Leenes and Hoekstra 2012; Thaler et al. 2012
	Sugar cane	Ercin et al. 2011; Gerbens-Leenes and Hoekstra 2012; Scarpore et al. 2016a, 2016b
	Tea	Chapagain and Hoekstra 2007; Jefferies et al. 2012
	Tomatoes	Chapagain and Orr 2009; Evangelou et al. 2016
	Wheat	Liu et al. 2007a; Mekonnen and Hoekstra 2010; Cao et al. 2014; Brueck and Lammel 2016; Denis et al. 2016; Zhuo et al 2016d; Kersebaum et al. 2016
	Wine	Ene et al. 2013; Herath et al. 2013a, 2013b; Lamastra et al. 2014; Bonamente et al. 2015, 2016; Rinaldi et al. 2016
Animal products	Studies considering various products	Chapagain and Hoekstra 2003; Hoekstra and Chapagain 2007a, 2008; Mekonnen and Hoekstra 2012a; Hoekstra 2012, 2013
	Camel meat & milk	Bosire et al. 2015
	Cow meat (beef)	Gerbens-Leenes et al. 2013; Zonderland-Thomassen et al. 2014; Bosire et al. 2015
	Cow milk	Zonderland-Thomassen and Ledgard 2012; Bosire et al. 2015; Cosentino et al. 2015; Palhares et al. 2015; Owusu-Sekyere et al. 2016; Roibas et al. 2016; Murphy et al. 2017
	Cultured meat	Tuomisto and De Mattos 2011
	Fish	Pahlow et al. 2015b
	Goat meat & milk	Bosire et al. 2015
	Mealworms	Miglietta et al. 2015
	Pig meat (pork)	Gerbens-Leenes et al. 2013; De Miguel et al. 2015
	Poultry	Gerbens-Leenes et al. 2013

	Sheep meat & milk	Zonderland-Thomassen et al. 2014; Bosire et al. 2015; Toro-Mujica et al. 2016
Food waste & packaging	Food waste	Lundqvist et al. 2008; Ridoutt et al. 2010; Chapagain and James 2011; FAO 2013; Liu et al. 2013; Song et al. 2015; Vanham et al. 2015
	Food packaging	Li and Nwokoli 2010; Manzardo et al. 2016a
Other agricultural products	Cotton	Chapagain et al. 2006b; Chico et al. 2013; Franke and Mathews 2013a, 2013b; Wang et al. 2013a; Pahlow et al. 2015a; Safaya et al. 2016
	Cut flowers	Mekonnen et al. 2012
Forestry products	Roundwood, timber, pulp, paper	UPM-Kymmene 2011; Van Oel and Hoekstra 2012; Tian and Ke 2012
Energy	Various forms of energy	Mekonnen et al. 2015a, 2016
	Biofuels from crops	Gerbens-Leenes et al. 2009a, 2009b; Dominguez-Faus et al. 2009; Yang et al. 2009; Mekonnen and Hoekstra 2011b; Gerbens-Leenes and Hoekstra 2012; Berger et al. 2015
	Biofuels from crop residue	Wu et al. 2012; Chiu and Wu 2012; Chiu et al. 2015; Wong et al. 2016; Mathioudakis et al. 2017
	Biofuel from wood / wood residue	Chiu and Wu 2013; Wong et al. 2016; Mathioudakis et al. 2017
	Biofuels from algae	Yang et al. 2011; Gerbens-Leenes et al. 2014
	Biofuel from jatropha	Gerbens-Leenes et al. 2009c; Hoekstra et al. 2009; Jongschaap et al. 2009; Maes et al. 2009; Hagman et al. 2013
	Hydroelectricity	Herath et al. 2011; Mekonnen and Hoekstra 2012b; Bakken et al. 2013, 2015; Scherer and Pfister 2016
Minerals and basic materials	Copper	Northey et al. 2013, 2014; Chan et al. 2014; Pena and Huijbregts 2014
	Cement	Bosman et al. 2016
	Glass	Bosman et al. 2016
	Gold	Northey et al. 2014
	Iron, steel	Unger et al. 2013; Gu et al. 2015; Bosman et al. 2016
	Nickel	Northey et al. 2014
	Platinum	Ranchod et al. 2015; Haggard et al. 2015
Manufactured products	Cars	Berger et al. 2012; Unger et al. 2013
	Computers	Alafifi 2010
	Data centres	Ristic et al. 2015
	Various	Chen 2015

Table S.7 WF studies comparing diets

Global	Falkenmark and Rockström 2004; Hoekstra 2010, 2013; Ercin and Hoekstra 2014; Jalava et al. 2014
Europe	Vanham et al. 2013a, 2013b; Ercin and Hoekstra 2016
Specific countries	Liu and Savenije 2008; Capone et al. 2013; Djanibekov et al. 2013; Vanham 2013a; Vanham and Bidoglio 2014a; Hess et al. 2015a; Sun et al. 2015a; Blas et al. 2016; Gephart et al. 2016; Harris et al. 2017
Specific cities	Vanham and Bidoglio 2014b; Vanham et al. 2016a, 2016b
Alternative meal choices	Ercin et al. 2012; Chen et al. 2016

Table S.8 WF studies for specific sectors

Beverage sector	BIER 2011
Electricity sector	Mekonnen et al. 2015a, 2016
Food aid	Jackson et al. 2015
Gaming sector	Li and Chen 2014
Tourism sector	Hadjikakou et al. 2013; Cazcarro et al. 2014
Transport sector	Gerbens-Leenes and Hoekstra 2011; Gerbens-Leenes et al. 2012

Table S.9 Publicly available WF studies for or by specific companies

Company	Sector	References
Barilla	Food & Beverage	Ruini et al. 2013; Antonelli and Ruini 2015
C&A	Apparel	Franke and Mathews 2013a, 2013b; Safaya et al. 2016
Coca Cola	Food & Beverage	TCCC and TNC 2010; Coca-Cola Europe 2011
Dole	Food & Beverage	Sikirica 2011
EDEKA	Retail	Morgan and Wenban-Smith 2015
FMO	Finance	Chico and Zhang 2015
Hewlett-Packard	Information Technology	Alafifi 2010; HP 2013, 2014
Highways Agency	Public sector	Highways Agency 2010
Jain Irrigation Systems	Manufacturing	Larson et al. 2010
Mars	Food & Beverage	Ridoutt et al. 2009
Natura	Cosmetics	Francke and Castro 2013
Nestlé	Food & Beverage	Chapagain and Orr 2010
SABMiller	Food & Beverage	SABMiller and WWF-UK 2009; SABMiller et al. 2010
TATA	Manufacturing	Unger et al. 2013
Tetra Pak	Packaging	Li and Nwokoli 2010
Unilever	Food & Beverage	Jefferies et al. 2012
UPM-Kymmene	Pulp & paper	UPM-Kymmene 2011
Volkswagen	Automobile	Berger et al. 2012

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