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twente WATER centre

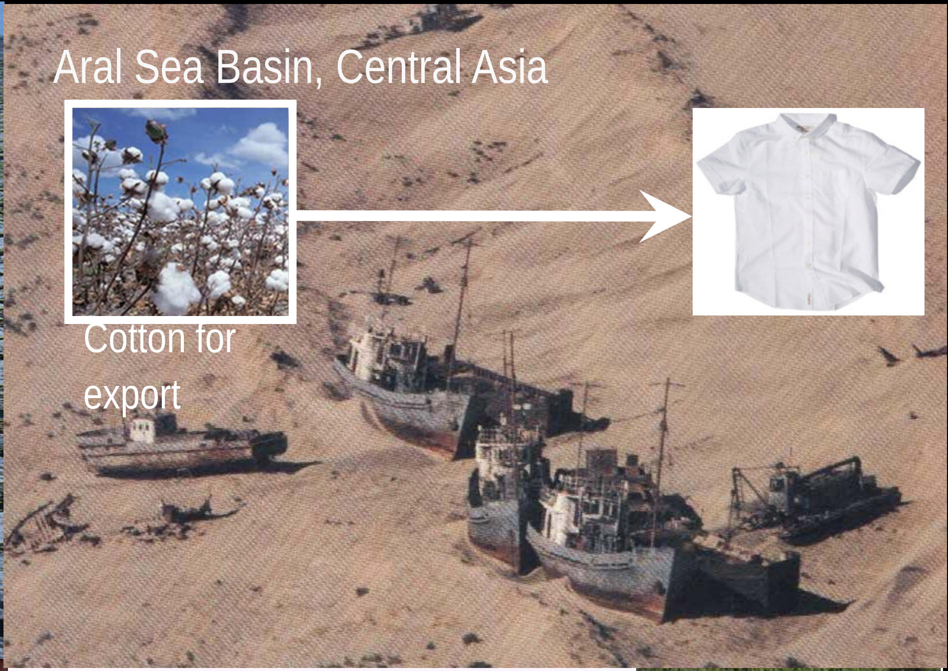
Water Footprint Assessment

Water Footprint Symposium, Leeds, 5.-6. December 2013

Markus Pahlow
University of Twente, The Netherlands

- Freshwater scarcity and pollution
- Globalisation of water
- Water Footprint Assessment
- Case study France
- Summary

Freshwater scarcity and pollution



Globalization of water

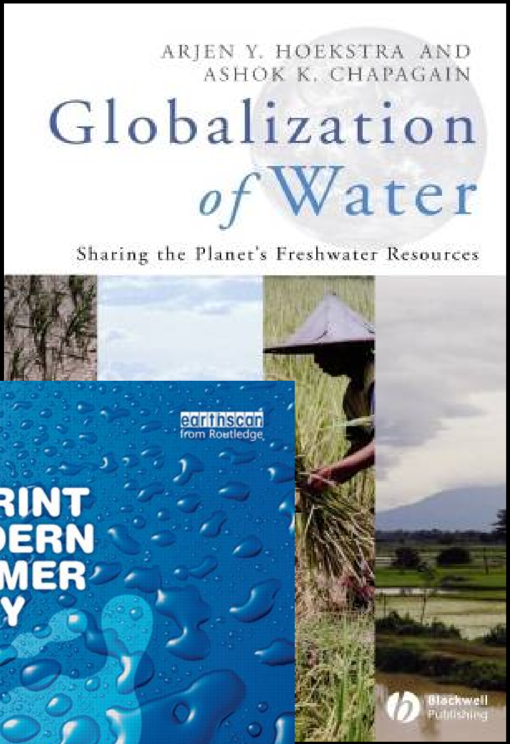
Production

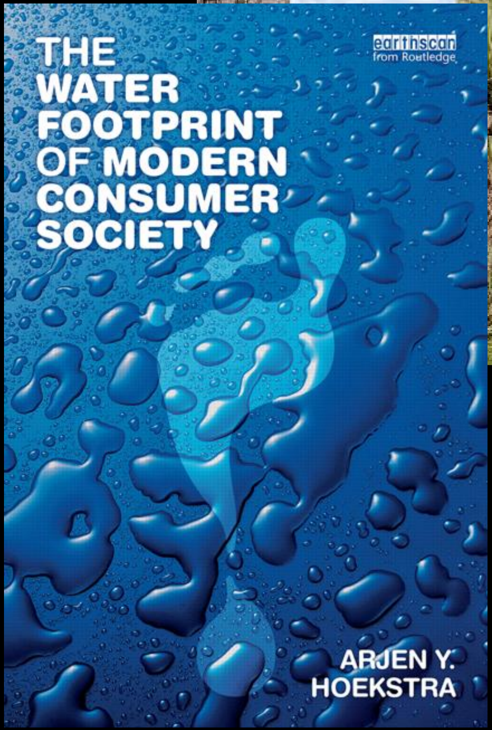
Water consumption and pollution related to production for export

Trade

Water saving, but also water dependency

Consumption





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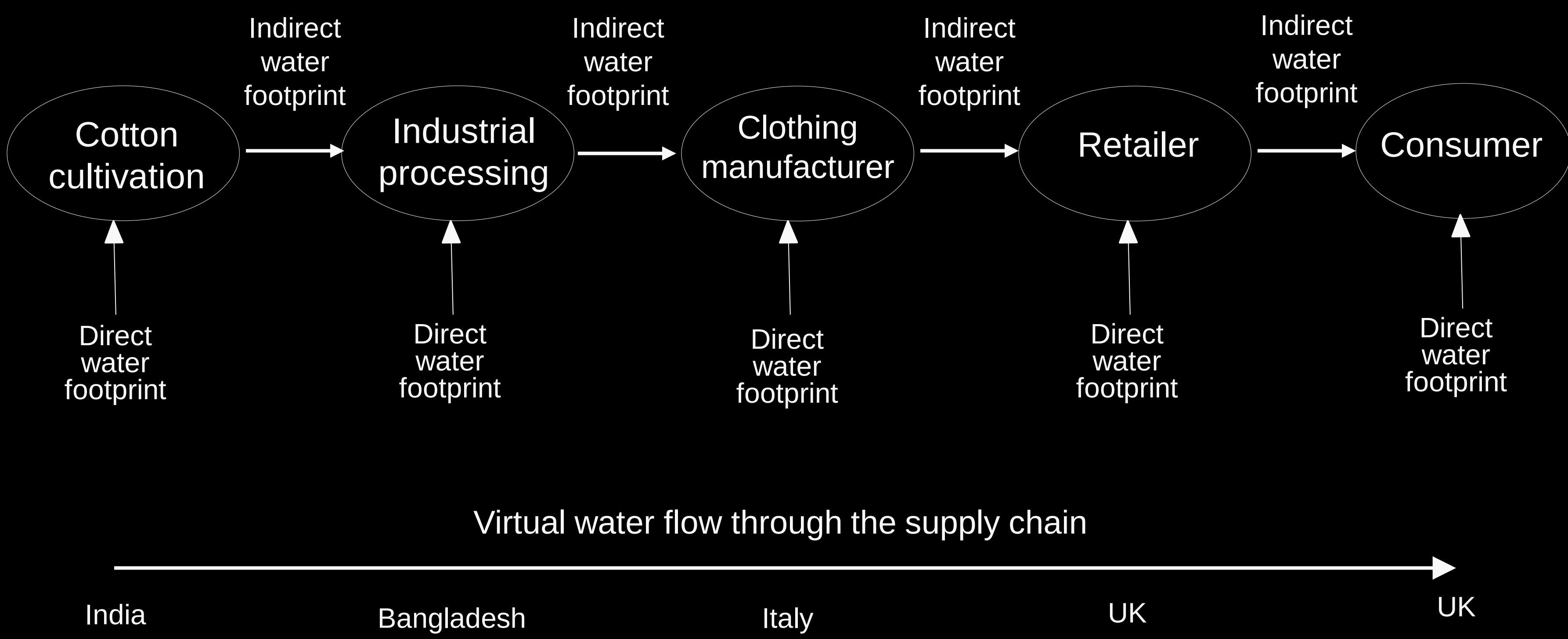
Source: Hoekstra & Chapagain (2008) *Globalization of Water*, Blackwell, Oxford, UK
Hoekstra (2013) The Water Footprint of Modern Consumer Society, Routledge, London, UK

Water footprints along a supply chain – example cotton

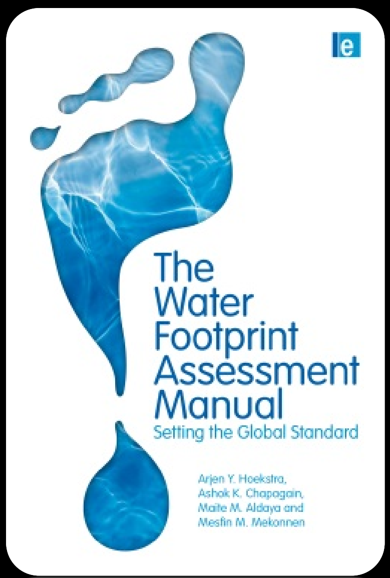


Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Water Footprint Assessment (WFA)

Water Footprint Assessment (WFA)

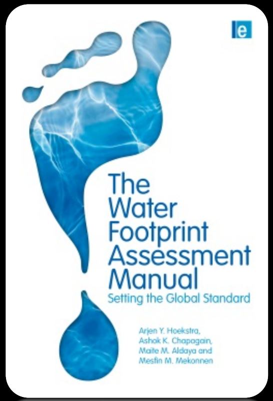
Phase 1	Phase 2	Phase 3	Phase 4
Setting goals and scope →	Water footprint accounting →	Water footprint sustainability assessment →	Water footprint response formulation



→ www.waterfootprint.org

Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

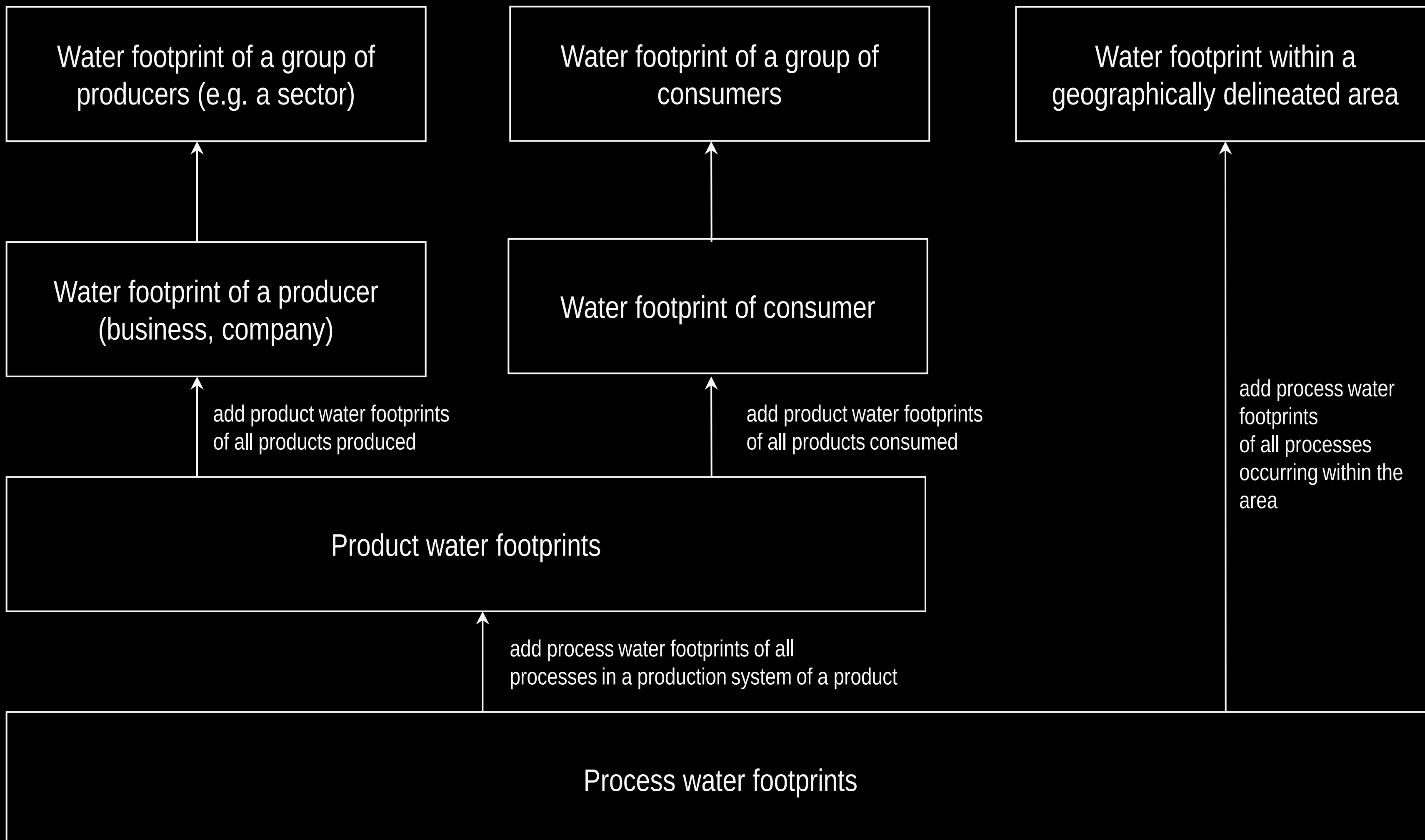
Water Footprint Assessment (WFA)



Phase 1 — Setting goals and scope → **Phase 2** — Water footprint accounting → **Phase 3** — Water footprint sustainability assessment → **Phase 4** — Water footprint response formulation

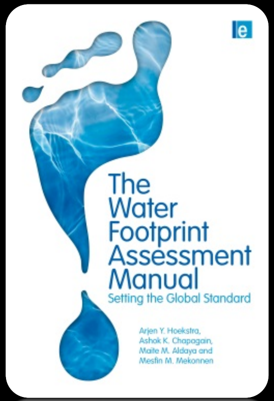
Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Phase 1: Setting goals and scope



Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

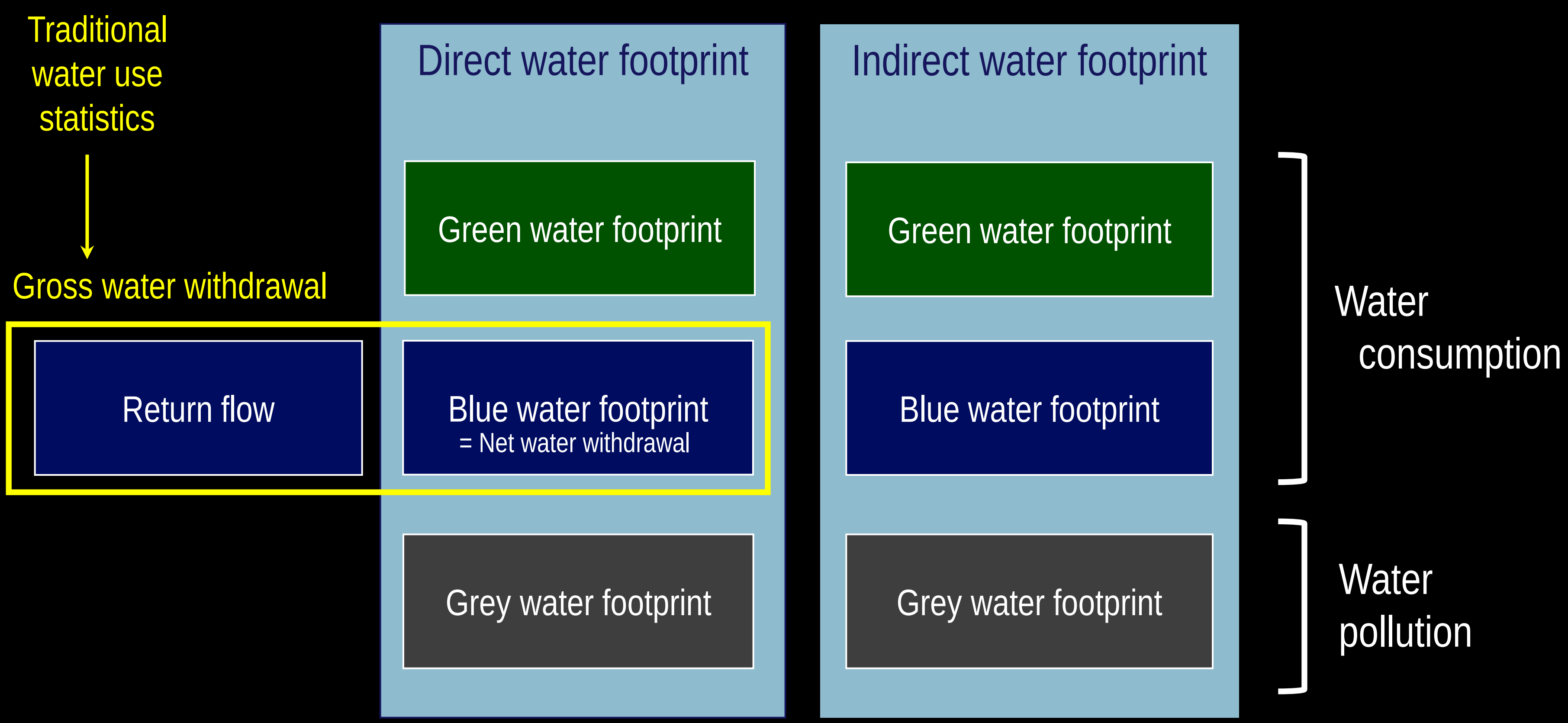
Water Footprint Assessment (WFA)



Phase 1 — Setting goals and scope → Phase 2 — **Water footprint accounting** → Phase 3 — Water footprint sustainability assessment → Phase 4 — Water footprint response formulation

Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Phase 2: Components of a water footprint



Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Phase 2 example: Global water footprint data

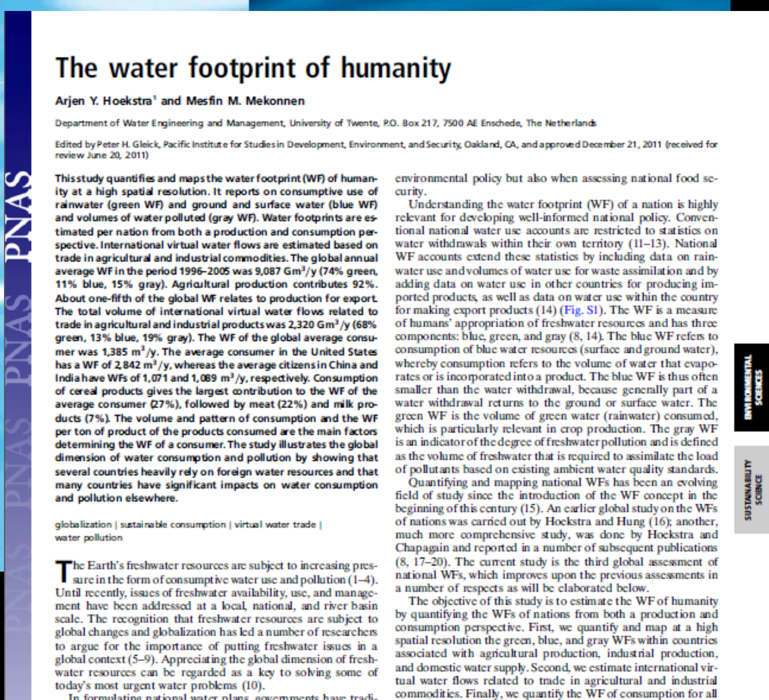
UNESCO-IHE
Institute for Water Education

M.M. MEKONNEN
A.Y. HOEKSTRA

MAY 2011

NATIONAL WATER FOOTPRINT ACCOUNTS:

THE GREEN, BLUE AND GREY WATER FOOTPRINT OF PRODUCTION AND CONSUMPTION



PNAS

The water footprint of humanity

Arjen Y. Hoekstra[1] and Mesfin M. Mekonnen

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Edited by Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, and approved December 21, 2011 (received for review June 20, 2011)

This study quantifies and maps the water footprint (WF) of humanity at a high spatial resolution. It reports on consumptive use of rainwater (green WF) and ground and surface water (blue WF) and volumes of water polluted (gray WF). Water footprints are estimated per nation from both a production and consumption perspective. International virtual water flows are estimated based on trade in agricultural and industrial commodities. The global annual average WF in the period 1996–2005 was 9,087 Gm^3/y (74% green, 11% blue, 15% gray). Agricultural production contributes 92%. About one-fifth of the global WF relates to production for export. The total volume of international virtual water flows related to trade in agricultural and industrial products was 2,320 Gm^3/y (68% green, 13% blue, 19% gray). The WF of the global average consumer was 1,385 m^3/y. The average consumer in the United States has a WF of 2,842 m^3/y, whereas the average citizens in China and India have WFs of 1,071 and 1,089 m^3/y, respectively. Consumption of cereal products gives the largest contribution to the WF of the average consumer (27%), followed by meat (22%) and milk products (7%). The volume and pattern of consumption and the WF per ton of product of the products consumed are the main factors determining the WF of a consumer. The study illustrates the global dimension of water consumption and pollution by showing that several countries heavily rely on foreign water resources and that many countries have significant impacts on water consumption and pollution elsewhere.

globalization | sustainable consumption | virtual water trade | water pollution

The Earth's freshwater resources are subject to increasing pressure in the form of consumptive water use and pollution (1–4). Until recently, issues of freshwater availability, use, and management have been addressed at a local, national, and river basin scale. The recognition that freshwater resources are subject to global changes and globalization has led a number of researchers to argue for the importance of putting freshwater issues in a global context (5–9). Appreciating the global dimension of freshwater resources can be regarded as a key to solving some of today's most urgent water problems (10).

In formulating national water plans, governments have tradi- ... environmental policy but also when assessing national food security.

Understanding the water footprint (WF) of a nation is highly relevant for developing well-informed national policy. Conventional national water use accounts are restricted to statistics on water withdrawals within their own territory (11–13). National WF accounts extend these statistics by including data on rainwater use and volumes of water use for waste assimilation and by adding data on water use in other countries for producing imported products, as well as data on water use within the country for making export products (14) (Fig. S1). The WF is a measure of humans' appropriation of freshwater resources and has three components: blue, green, and gray (8, 14). The blue WF refers to consumption of blue water resources (surface and ground water), whereby consumption refers to the volume of water that evaporates or is incorporated into a product. The blue WF is thus often smaller than the water withdrawal, because generally part of a water withdrawal returns to the ground or surface water. The green WF is the volume of green water (rainwater) consumed, which is particularly relevant in crop production. The gray WF is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

Quantifying and mapping national WFs has been an evolving field of study since the introduction of the WF concept in the beginning of this century (15). An earlier global study on the WFs of nations was carried out by Hoekstra and Hung (16); another, much more comprehensive study, was done by Hoekstra and Chapagain and reported in a number of subsequent publications (8, 17–20). The current study is the third global assessment of national WFs, which improves upon the previous assessments in a number of respects as will be elaborated below.

The objective of this study is to estimate the WF of humanity by quantifying the WFs of nations from both a production and consumption perspective. First, we quantify and map at a high spatial resolution the green, blue, and gray WFs within countries associated with agricultural production, industrial production, and domestic water supply. Second, we estimate international virtual water flows related to trade in agricultural and industrial commodities. Finally, we quantify the WF of consumption for all

ENVIRONMENTAL SCIENCES

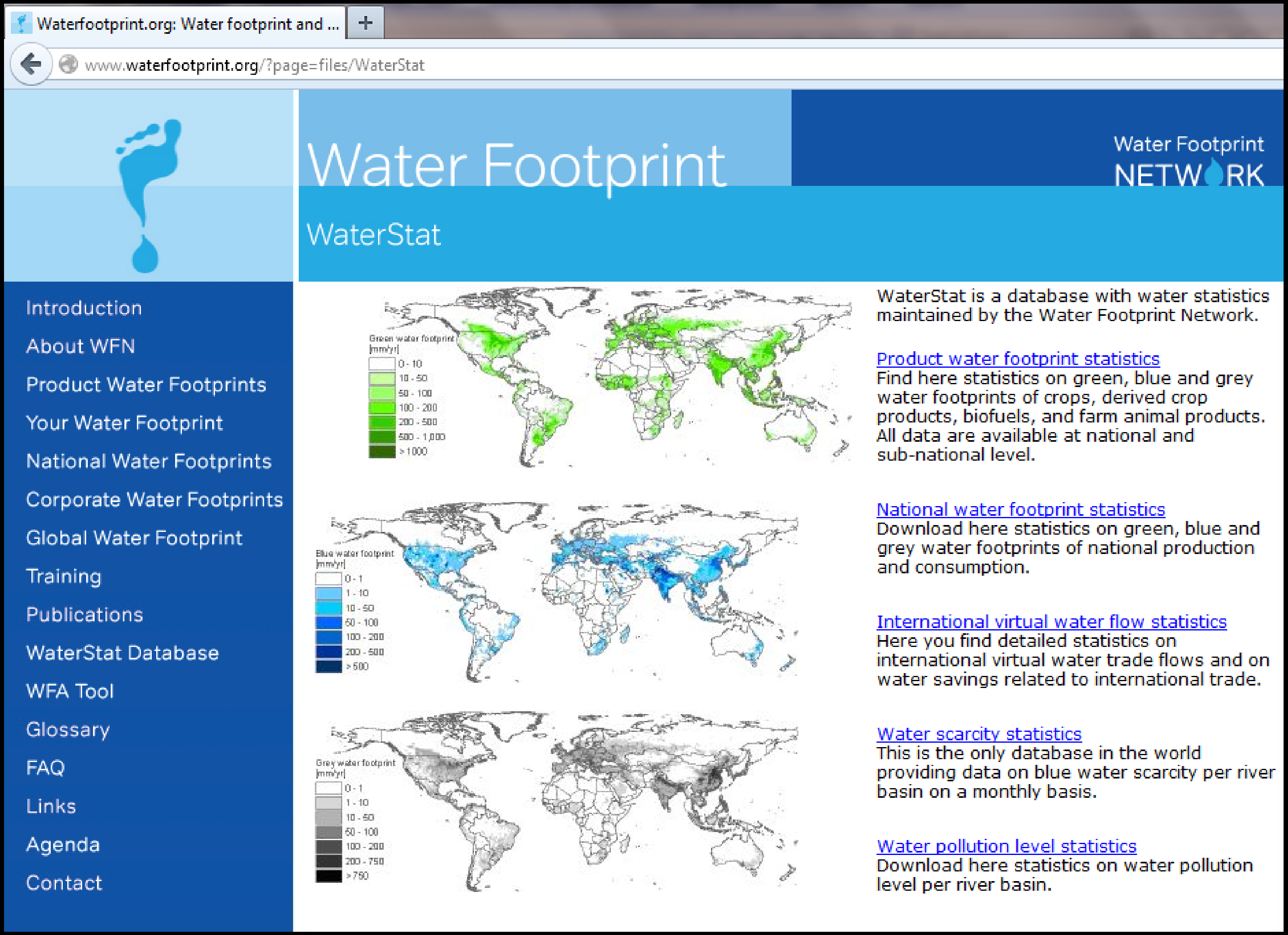
SUSTAINABILITY SCIENCE

National water footprint accounts

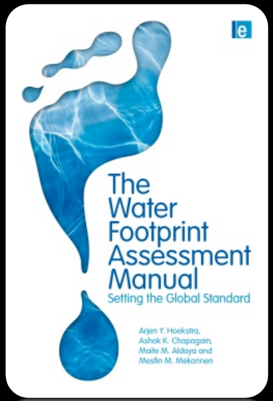
- high spatial resolution
- ten-year period
- specified by consumption category
- both internal and external
- explicit distinction green-blue-grey

Recent: Determination of sensitivity and uncertainty in crop WF accounting (Zhou et al., 2013)

Phase 2: Numerous other studies and data base (www.waterfootprint.org) → freely available



Water Footprint Assessment (WFA)



Phase 1: Setting goals and scope → Phase 2: Water footprint accounting → Phase 3: **Water footprint sustainability assessment** → Phase 4: Water footprint response formulation

Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Phase 3: Assessing the sustainability of the water footprint

Formulation of sustainability criteria → Identification of hotspots → Assessment of primary impacts in the hotspots → Assessment of secondary impacts in the hotspots

Formulation of sustainability criteria

Environmental sustainability:

- Environmental flow requirements
- Environmental green water requirements
- Ambient water quality standards

Social equity:

- Basic human needs: safe drinking water, food security, employment
- Rules of fairness: fair allocation, water user & water polluter principle

Economic efficiency:

- Efficient allocation and use of water resources (benchmarks)

Identification of hotspots

Specific sub-catchments and periods of the year in which sustainability criteria are violated.

Assessment of primary impacts in the hotspots

Identification and quantification of changes to:

- hydrology
- water quality

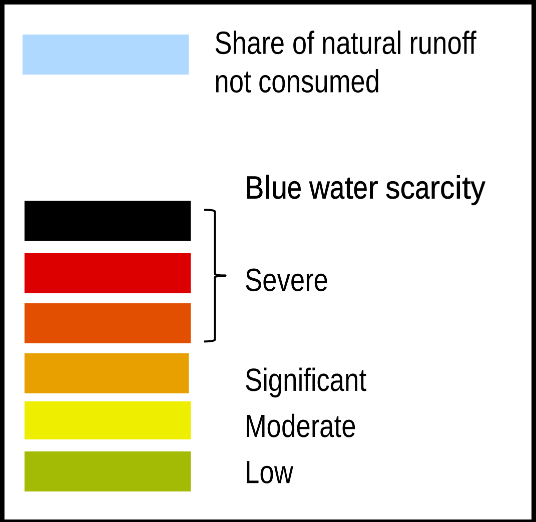
Assessment of secondary impacts in the hotspots

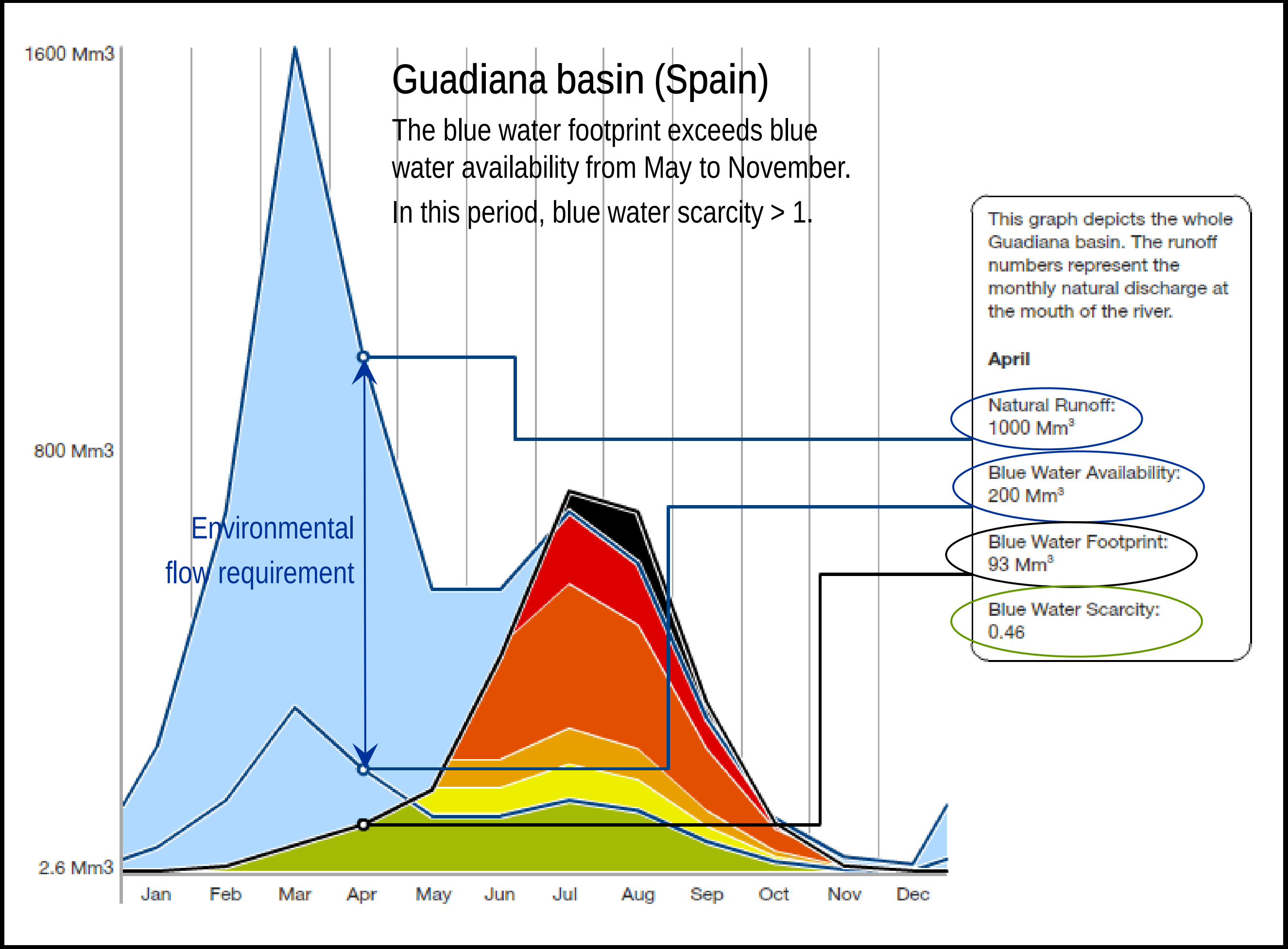
Identification and quantification of effects on:

- abundance of certain species
- biodiversity
- human health
- employment
- distribution of welfare
- income in different sectors of economy

Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Phase 3: Example environmental sustainability: Blue water footprint vs. blue water availability, hotspot identification, primary impacts





Environmental flow requirements

To be established at catchment level, on a monthly basis.

Presumptive standard:
EFR = 80% of natural runoff
(Richter et al., 2011)

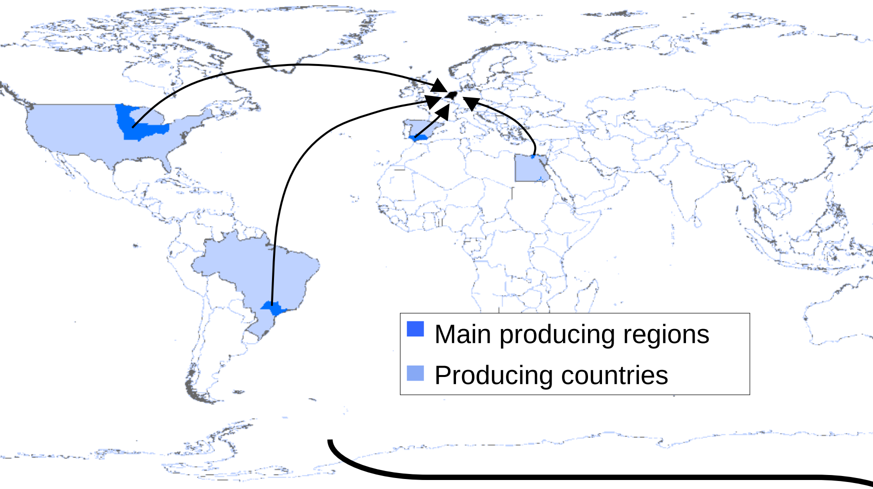
Replace this estimate when better local estimates are available

Blue water availability = Natural runoff – Environmental flow requirement

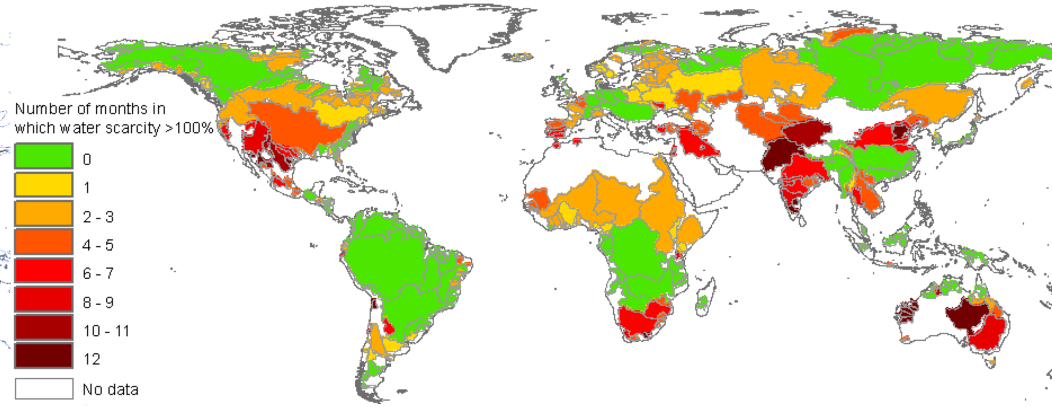
Blue water scarcity = Blue water footprint / Blue water availability

Determined using the Water Footprint Assessment Tool, underlying data from Hoekstra and Mekonnen (2011)

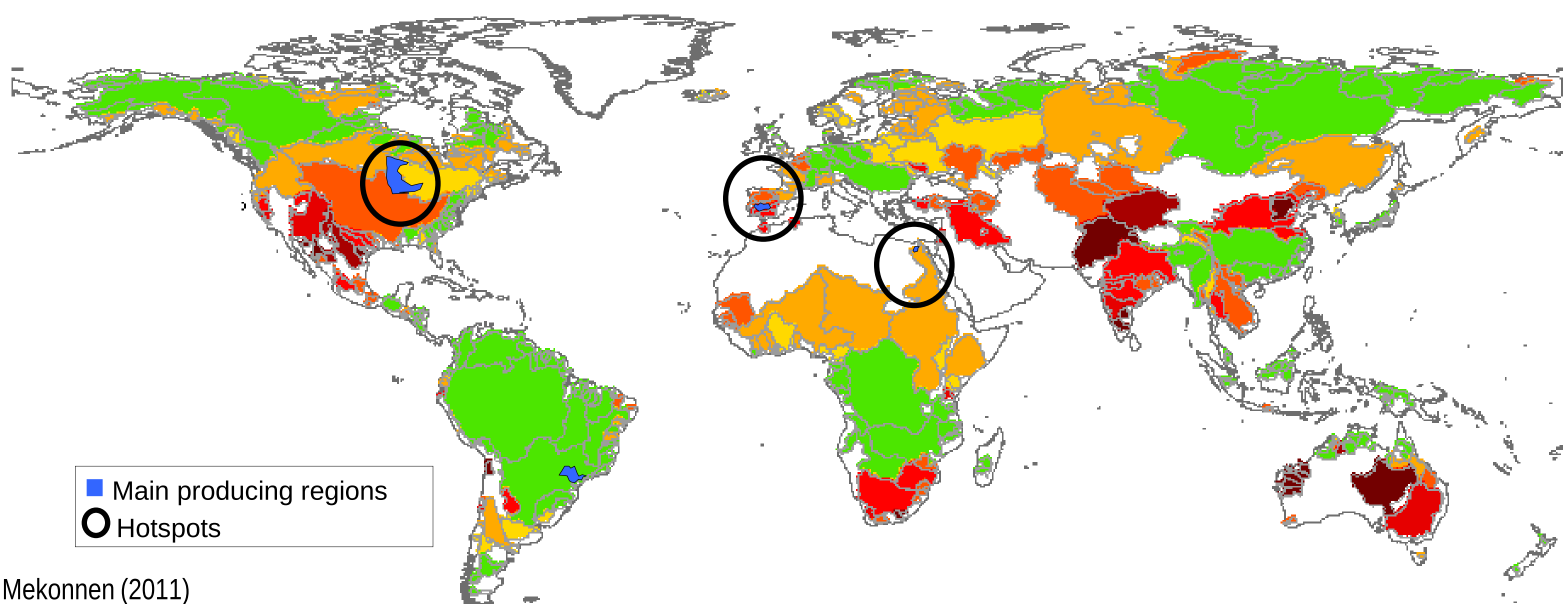
Global blue water footprint of a company located in the Netherlands



River basin hotspot map, showing per river basin the number of months with blue water scarcity > 100%



Unsustainable components of the company's blue water footprint



Hoekstra and Mekonnen (2011)

Phase 3: Examples of other indicators

Green water scarcity

$$WS_{green}[x,t] = \frac{\sum WF_{green}[x,t]}{WA_{green}[x,t]}$$

$$WA_{green}[x,t] = ET_{green}[x,t] - ET_{env}[x,t] - ET_{unprod}[x,t]$$

Blue water scarcity

$$WS_{blue}[x,t] = \frac{\sum WF_{blue}[x,t]}{WA_{blue}[x,t]}$$

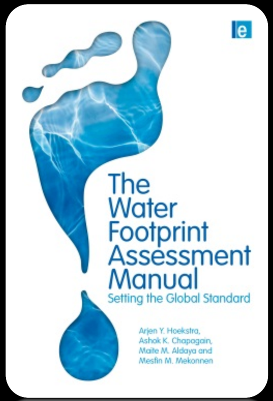
$$WA_{blue}[x,t] = R_{nat}[x,t] - EFR[x,t]$$

Water pollution level

$$WPL[x,t] = \frac{\sum WF_{grey}[x,t]}{R_{act}[x,t]}$$

Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Water Footprint Assessment (WFA)



Phase 1 — Setting goals and scope → Phase 2 — Water footprint accounting → Phase 3 — Water footprint sustainability assessment → **Phase 4 — Water footprint response formulation**

Source: Hoekstra et al. (2011) *The Water Footprint Assessment Manual*, Earthscan, London, UK

Phase 4: Response formulation

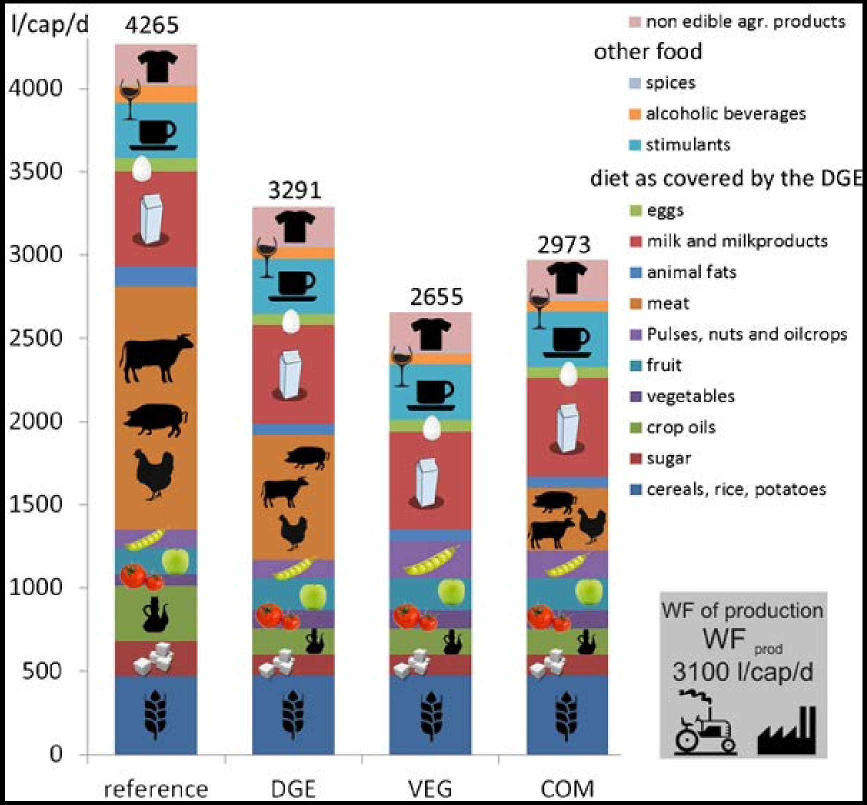
Note on water footprint reduction: a shared responsibility

Consumers and consumer & environmental organizations push businesses and governments to address water use and impacts along supply chains. Own consumption behavior (waste, diet,…water saving shower head).

Source: Hoekstra (2013) *The Water Footprint of Modern Consumer Society*, Routledge, London, UK

Phase 4: Response formulation
Note on water footprint reduction: a shared responsibility

Consumers and consumer & environmental organizations push businesses and governments to address water use and impacts along supply chains. Own consumption behavior (waste, **diet**,…water saving shower head).



Source: Vanham et al. (2013)

Phase 4: Response formulation

Note on water footprint reduction: a shared responsibility

Consumers and consumer & environmental organizations push businesses and governments to address water use and impacts along supply chains. Own consumption behavior (waste, diet,…water saving shower head).

Some businesses act voluntarily in an early stage, driven by consumers or investors. Best management practices.

Governments support frontrunners in businesses and implement regulations.

Governments, companies, consultants and accountants use same standard definitions and calculation methods.

International cooperation.

Source: Hoekstra (2013) *The Water Footprint of Modern Consumer Society*, Routledge, London, UK

Example:
Case study for France

Example: Sustainability of national consumption from a water resources perspective: The case study for France (yrs. 1996-2005)

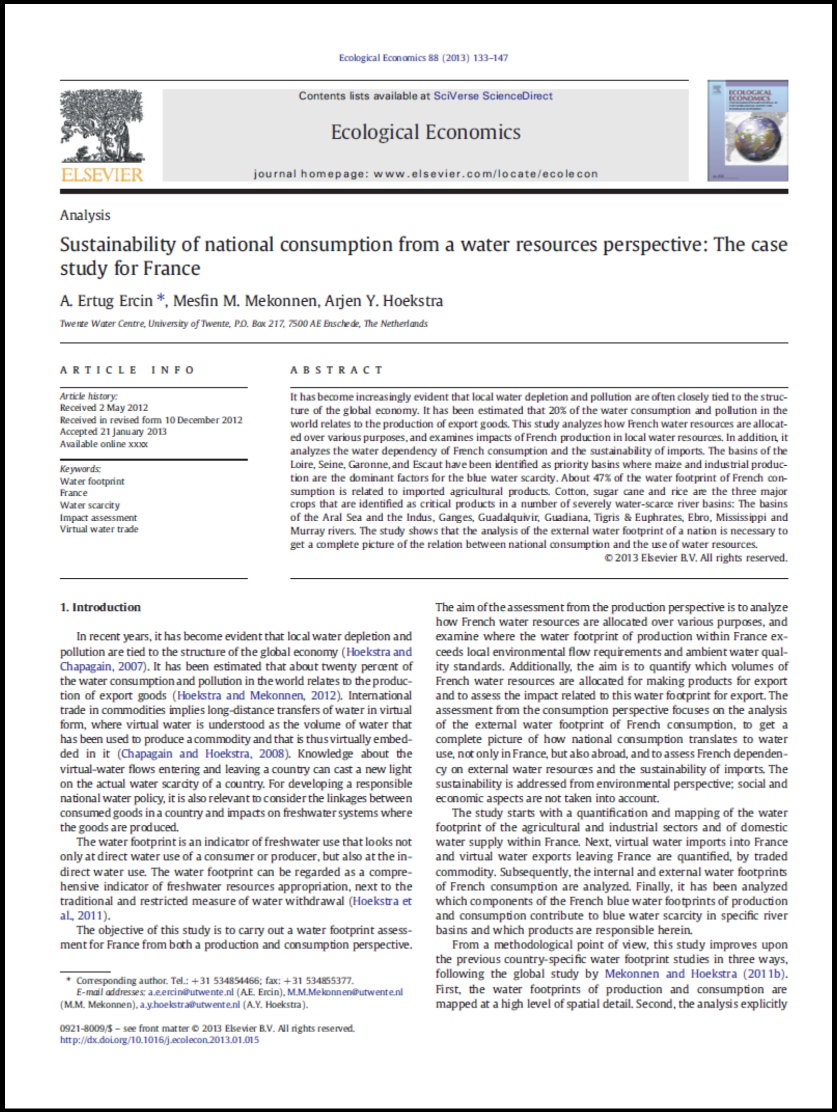
(1) Goals and scope

- ❑ Where and when are the water footprints largest?

- ❑ Where and when do they contribute most to local water scarcity ?
  (critical regions)

- ❑ Which specific products contribute most to the water footprints and to water scarcity?
  (critical products)

- ❑ Policy relevance (potential response options)



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Analysis

Sustainability of national consumption from a water resources perspective: The case study for France

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A B S T R A C T

It has become increasingly evident that local water depletion and pollution are often closely tied to the structure of the global economy. It has been estimated that 20% of the water consumption and pollution in the world relates to the production of export goods. This study analyzes how French water resources are allocated over various purposes, and examines impacts of French production in local water resources. In addition, it analyzes the water dependency of French consumption and the sustainability of imports. The basins of the Loire, Seine, Garonne, and Escaut have been identified as priority basins where maize and industrial production are the dominant factors for the blue water scarcity. About 47% of the water footprint of French consumption is related to imported agricultural products. Cotton, sugar cane and rice are the three major crops that are identified as critical products in a number of severely water-scarce river basins: The basins of the Aral Sea and the Indus, Ganges, Guadalquivir, Guadiana, Tigris & Euphrates, Ebro, Mississippi and Murray rivers. The study shows that the analysis of the external water footprint of a nation is necessary to get a complete picture of the relation between national consumption and the use of water resources.

1. Introduction

In recent years, it has become evident that local water depletion and pollution are tied to the structure of the global economy (Hoekstra and Chapagain, 2007). It has been estimated that about twenty percent of the water consumption and pollution in the world relates to the production of export goods (Hoekstra and Mekonnen, 2012). International trade in commodities implies long-distance transfers of water in virtual form, where virtual water is understood as the volume of water that has been used to produce a commodity and that is thus virtually embedded in it (Chapagain and Hoekstra, 2008). Knowledge about the virtual-water flows entering and leaving a country can cast a new light on the actual water scarcity of a country. For developing a responsible national water policy, it is also relevant to consider the linkages between consumed goods in a country and impacts on freshwater systems where the goods are produced.

The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. The water footprint can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal (Hoekstra et al., 2011).

The objective of this study is to carry out a water footprint assessment for France from both a production and consumption perspective. The aim of the assessment from the production perspective is to analyze how French water resources are allocated over various purposes, and examine where the water footprint of production within France exceeds local environmental flow requirements and ambient water quality standards. Additionally, the aim is to quantify which volumes of French water resources are allocated for making products for export and to assess the impact related to this water footprint for export. The assessment from the consumption perspective focuses on the analysis of the external water footprint of French consumption, to get a complete picture of how national consumption translates to water use, not only in France, but also abroad, and to assess French dependency on external water resources and the sustainability of imports. The sustainability is addressed from environmental perspective; social and economic aspects are not taken into account.

The study starts with a quantification and mapping of the water footprint of the agricultural and industrial sectors and of domestic water supply within France. Next, virtual water imports into France and virtual water exports leaving France are quantified, by traded commodity. Subsequently, the internal and external water footprints of French consumption are analyzed. Finally, it has been analyzed which components of the French blue water footprints of production and consumption contribute to blue water scarcity in specific river basins and which products are responsible herein.

From a methodological point of view, this study improves upon the previous country-specific water footprint studies in three ways, following the global study by Mekonnen and Hoekstra (2011b). First, the water footprints of production and consumption are mapped at a high level of spatial detail. Second, the analysis explicitly

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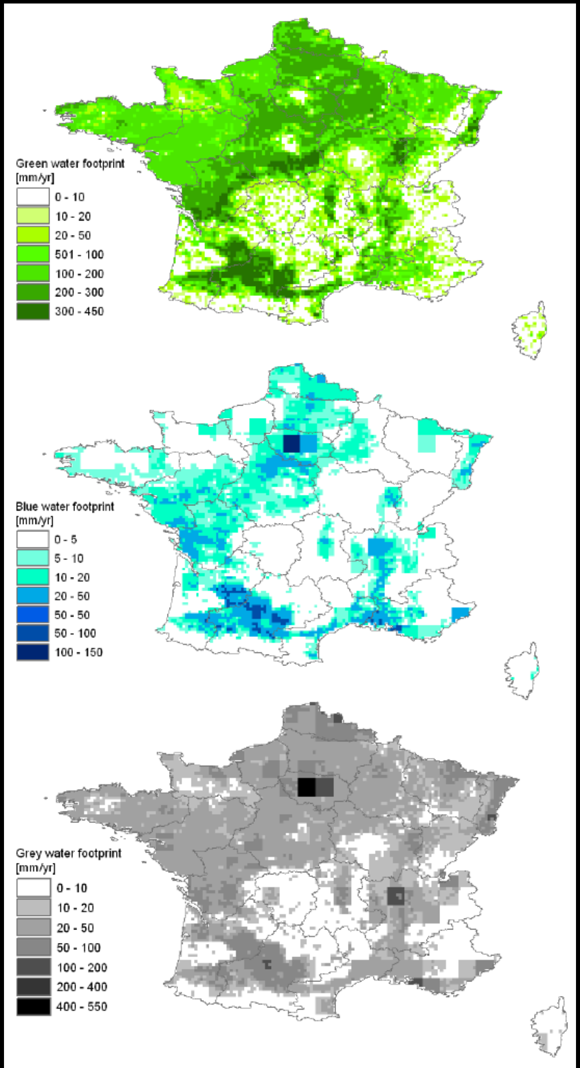
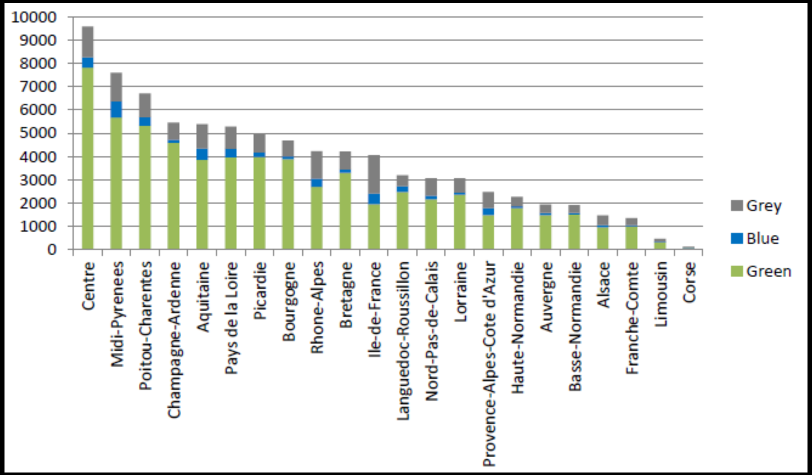
http://dx.doi.org/10.1016/j.ecolecon.2013.01.015

Source: Ercin et al. (2013)

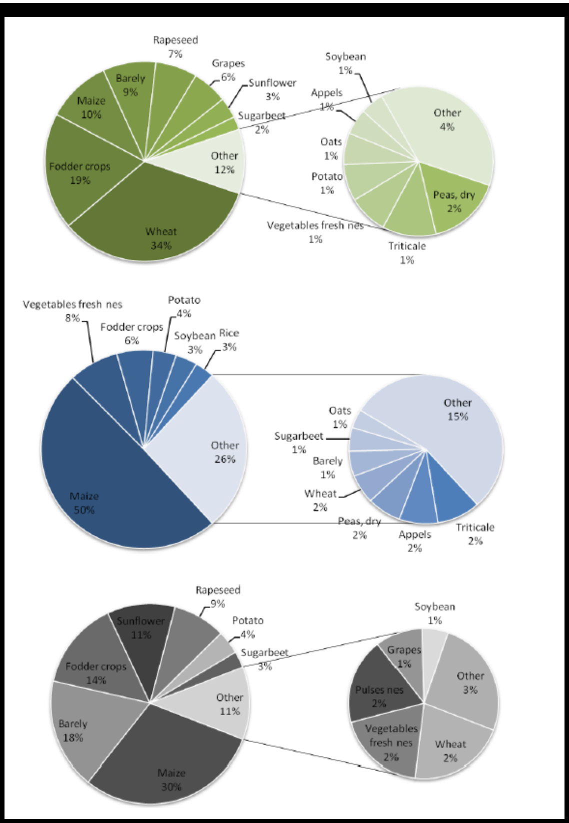
(2) Accounting phase: green, blue and grey water footprint of production





per region

spatially distributed



per crop

e.g. maize 50% of total blue wf and 30% of grey wf

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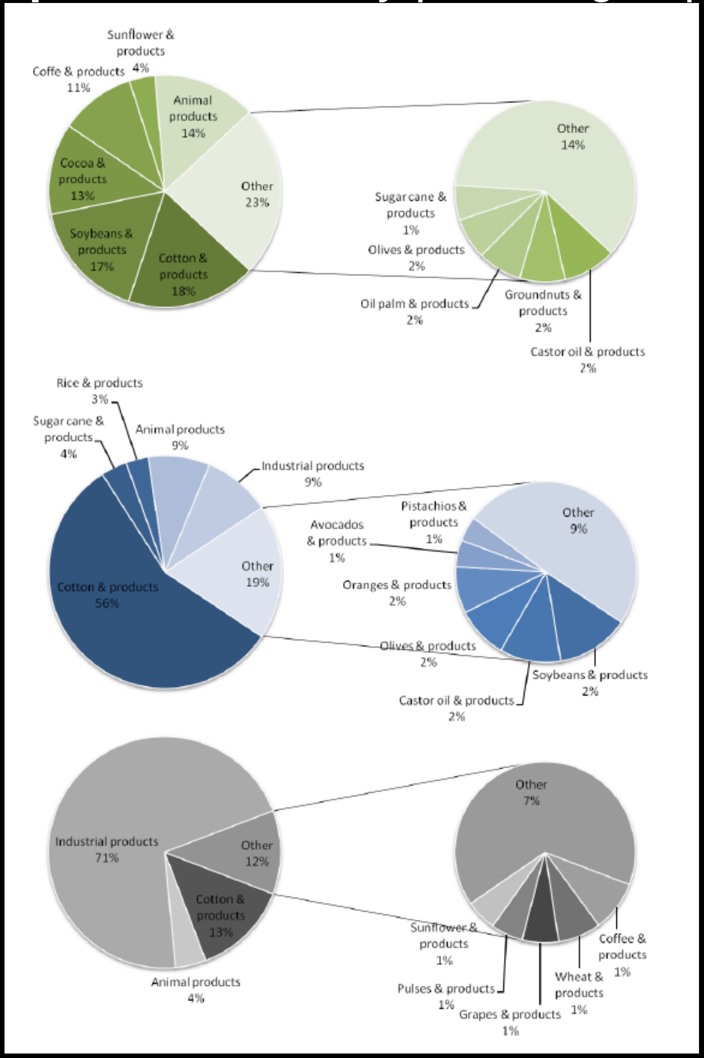
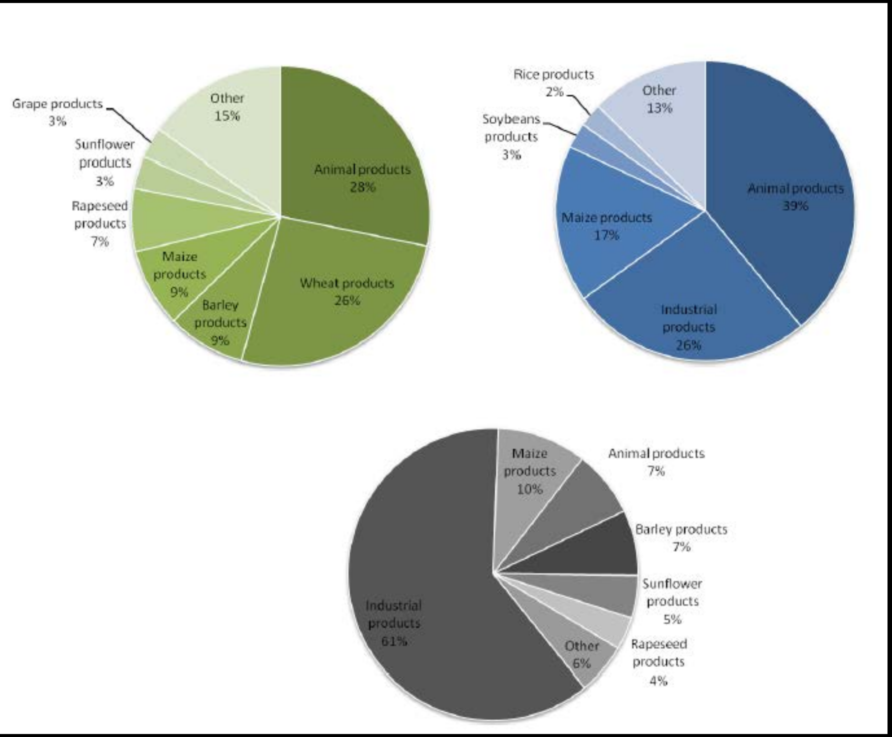
Source: Ercin et al. (2013)

(2) Accounting phase: virtual water import and export

The green, blue and grey virtual water **import** to France by product group



Green, blue and grey virtual water **export** from France by product group

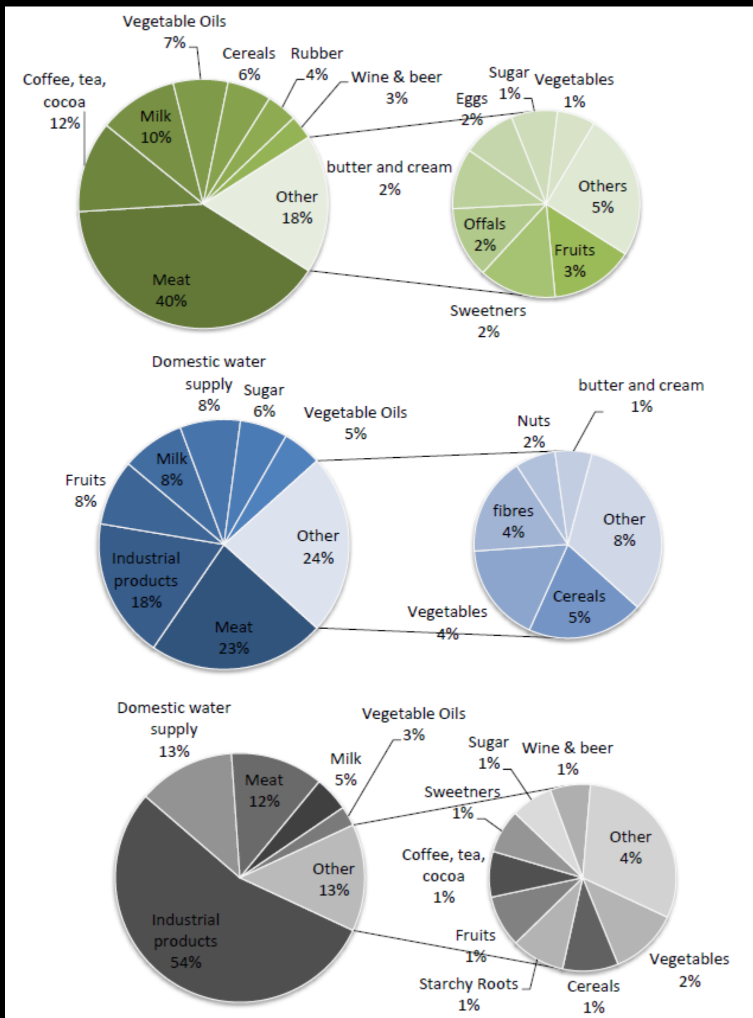


Example: blue water footprint:
~ 45 % of production is for export

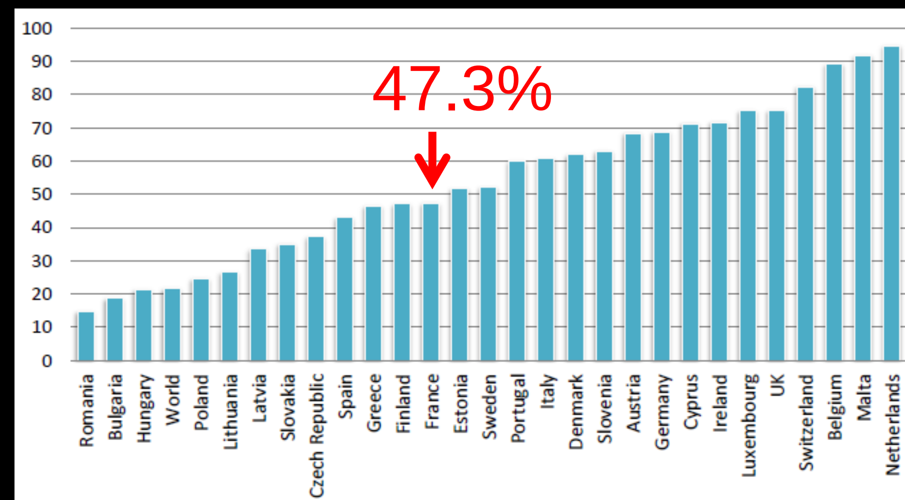
Source: Ercin et al. (2013)

(2) Accounting phase: green, blue and grey water footprint of consumption and external water footprint

The green, blue and grey water footprint of French consumption per consumption category



The ratio of the external to the total water footprint of consumption for the EU countries and the world average (%).

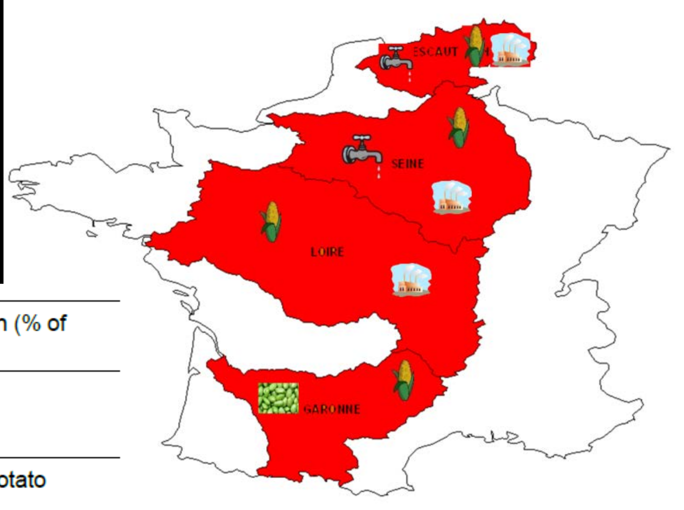


Example: meat consumption contributes 34% to total water footprint of French consumption

Source: Ercin et al. (2013)

(3) Sustainability assessment: Priority basins and products regarding the blue water footprint of production in France

Basin Water scarcity Product

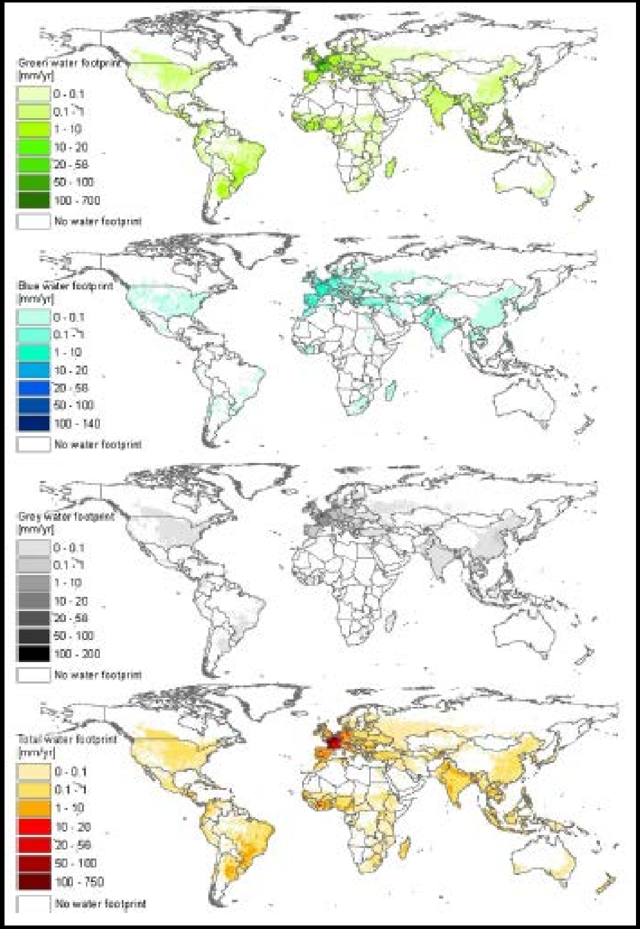


River basin	Month	Level of scarcity	Products with significant contribution to the blue water footprint in the basin (% of contribution)
Loire	August	Significant	Maize (58%), industrial production (6%)
	September	Significant	Maize (45%), industrial production (10%)
Seine	July	Moderate	Industrial production (28%), maize (18%), domestic water supply (12%), potato (11%)
	August	Severe	Maize (38%), industrial production (21%), domestic water supply (9%), potato (%7), sugar beet (%6)
	September	Severe	Industrial production (28%), maize (27%), domestic water supply (12%)
	October	Moderate	Industrial production (5 %), domestic (24%)
Garonne	July	Moderate	Maize (54%), soybean (1 %), fodder (5%)
	August	Significant	Maize (59%), soybean (7%)
	September	Severe	Maize (69%), soybean (8%)
Escaut	July	Significant	Industrial production (61%), domestic water supply (17%), potato (10%)
	August	Severe	Industrial production (57%), domestic water supply (16%), maize (10%), potato (8%)
	September	Severe	Industrial production (70%), domestic water supply (20%)
	October	Severe	Industrial production (77%), domestic water supply (22%)

Source: Ercin et al. (2013)

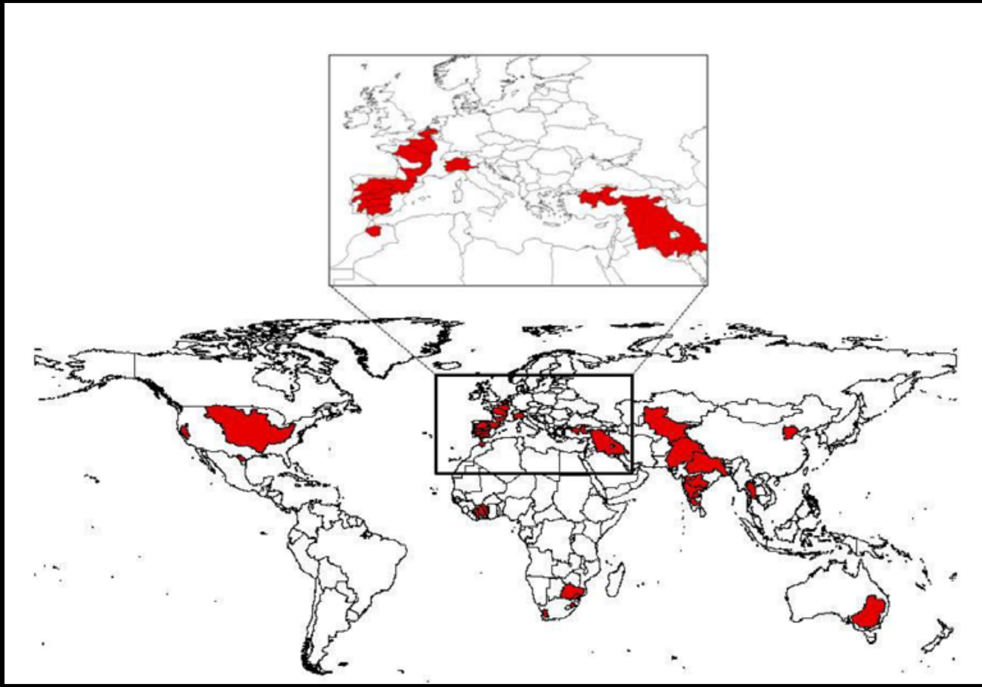
(3) Sustainability assessment: The river basins in the world in which the production of agricultural products for French consumption contributes to moderate, significant or severe blue water scarcity

WF of French consumption



→ contributes to

Basins with water scarcity > 1



Source: Ercin et al. (2013)

(3) Sustainability assessment: Priority basins (top 10) regarding the blue water footprint of French consumption of agricultural products

River basin	Percentage of the blue water footprint of French consumption of agricultural products located in this basin	Number of months per year that a basin faces moderate, significant or severe water scarcity			Major contributing products
		Moderate	Significant	Severe	
Aral Sea basin	6.4	1	0	4	Cotton
Garonne	5.4	1	1	1	Maize, soybean, animal products
Escaut (Schelde)	4.5	0	1	3	Maize, potato
Loire	4.4	0	2	0	Maize
Indus	3.9	1	3	8	Cotton, rice, sugar cane
Guadalquivir	3.0	1	0	6	Cotton, sun flower, rice, sugar beet
Seine	2.2	2	0	2	Maize, potato, sugar beet
Ganges	2.2	0	2	5	Rice, sugar cane
Guadiana	1.8	1	0	6	Grapes, sunflower, citrus
Tigris & Euphrates	1.6	0	1	5	Cotton, rice

Source: Ercin et al. (2013)

Summary

- ❑ WFA improves understanding of linkages between humanity's productive activities and the growing pressure on the world's freshwater resources.

- ❑ Water Footprint Assessment (WFA) can support a broad range of goals and scope.

- ❑ WFA clarifies the environmental sustainability, economic efficiency and social equity of water use and allocation and supports prioritisation of strategic actions in both the public and private sector.

- ❑ WFA studies form a starting point for more in-depth local assessments of environmental, social and economic impacts of water use.

Thank you very much for your attention!

Questions?

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