A Comprehensive Introduction to Water Footprints

Professor in Water Management – University of Twente – the Netherlands

Scientific Director – Water Footprint Network

- **The presentation can be freely used for educational purposes, but not for commercial purposes.**
- **When using this presentation or pieces from it, due credit should be given to the author (Prof. A. Hoekstra ; Prof. W. Gerbens-Leenes).**
- **Useful background publications:**

*** Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2011) The water footprint assessment manual: Setting the global standard, Earthscan, London, UK.**

*** Hoekstra, A.Y. and Chapagain, A.K. (2008) Globalization of water: Sharing the planet's freshwater resources, Blackwell Publishing, Oxford, UK.**

Overview

- Freshwater scarcity & pollution

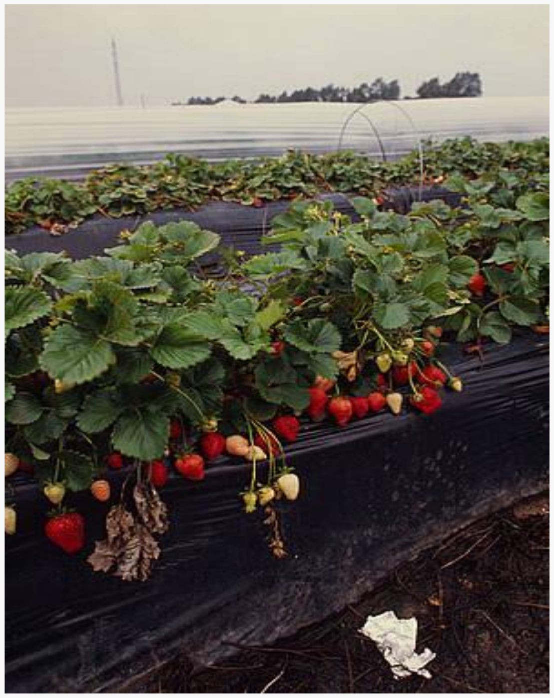
- The water footprint of products
- National water footprint accounting
- The water footprint of a business

- WF sustainability assessment
- Response: reducing water footprints

- Water Footprint Network

Freshwater scarcity
and pollution

Signs of global water scarcity



Strawberries for export

Coto Doñana National Park, southern Spain

Signs of global water scarcity

Cotton for export

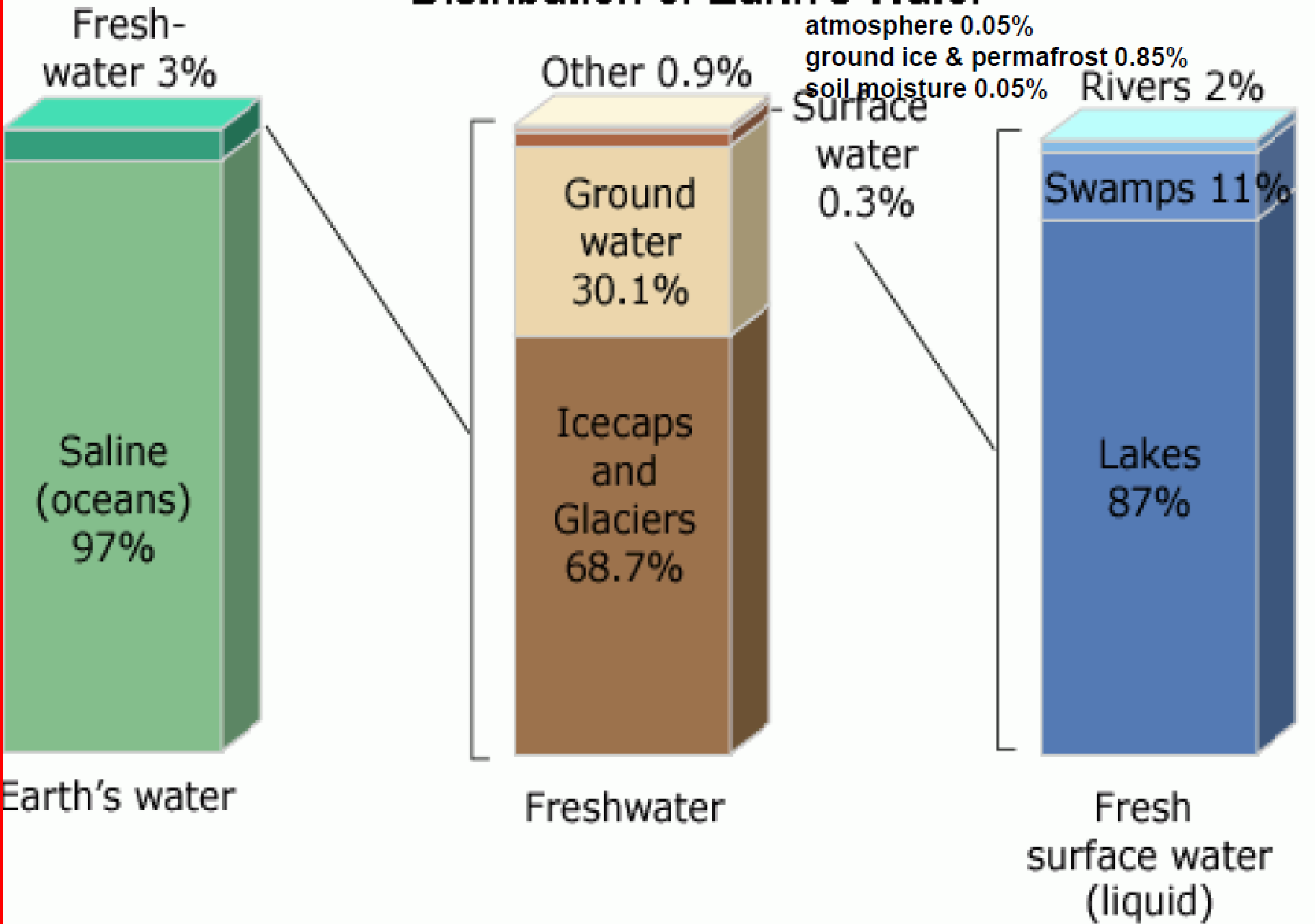
Former Aral Sea, Central Asia

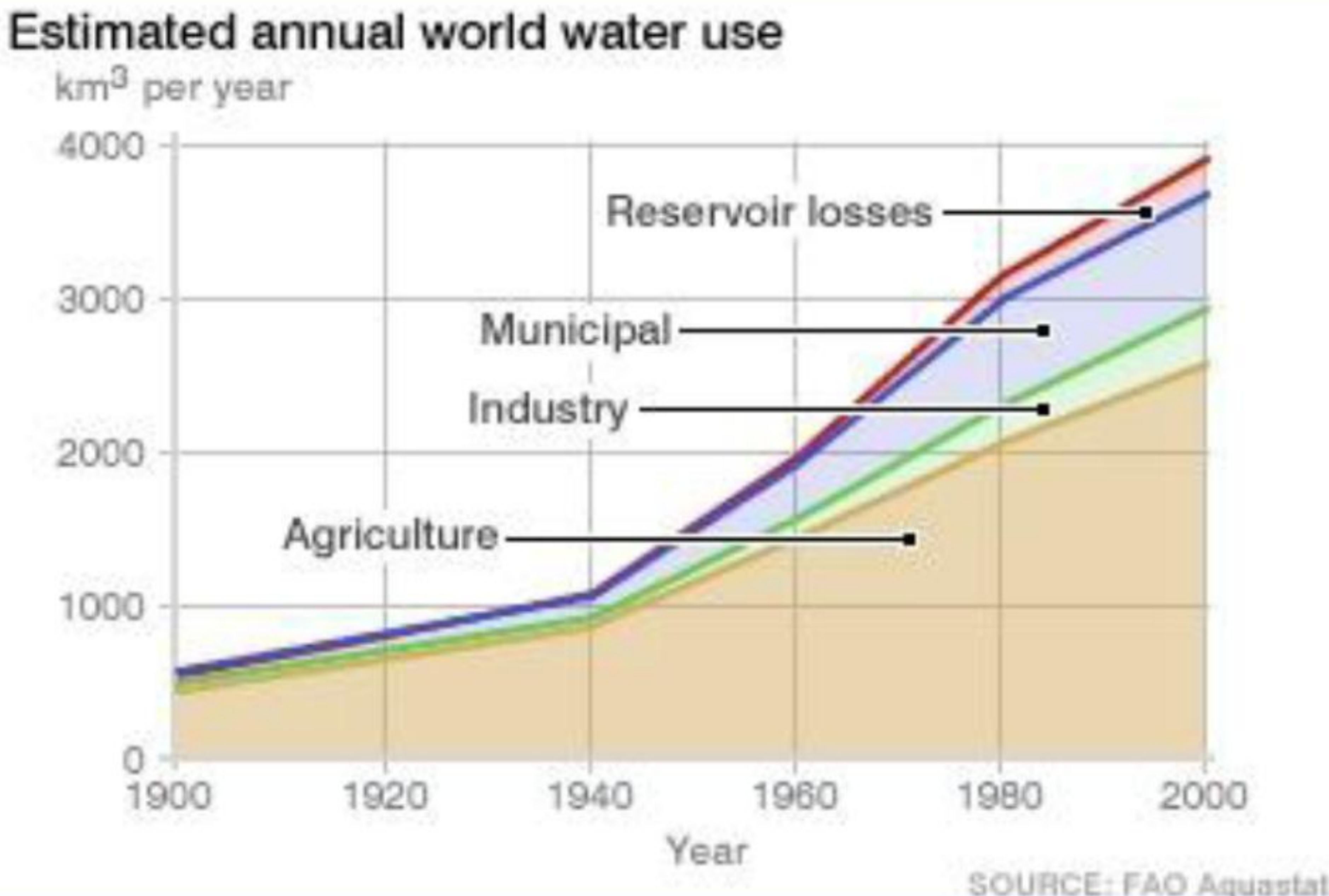
Signs of global water pollution

Devecser, Hungary, Oct. 5, 2010

Signs of global water pollution

Distribution of Earth's Water




Estimated annual world water use
km3 per year
4000
3000
2000
1000
0
1900
1920
1940
1960
1980
2000
Year
Reservoir losses
Municipal
Industry
Agriculture
SOURCE: FAO Aquastat

The water footprint
of a product

The water footprint of a product

► the volume of fresh water used to produce the product, summed over the various steps of the production chain.

► when and where the water was used:
a water footprint includes a temporal and spatial dimension.

The water footprint of a product

Green water footprint

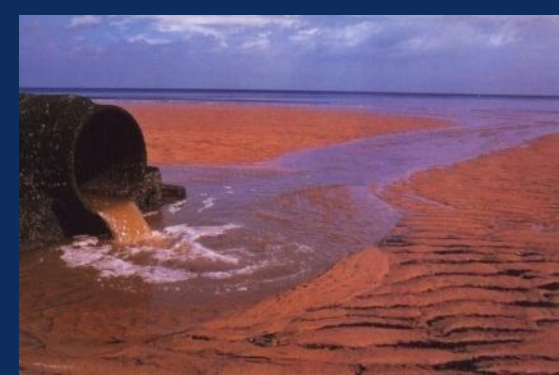
► volume of rainwater evaporated or incorporated into product.

Blue water footprint

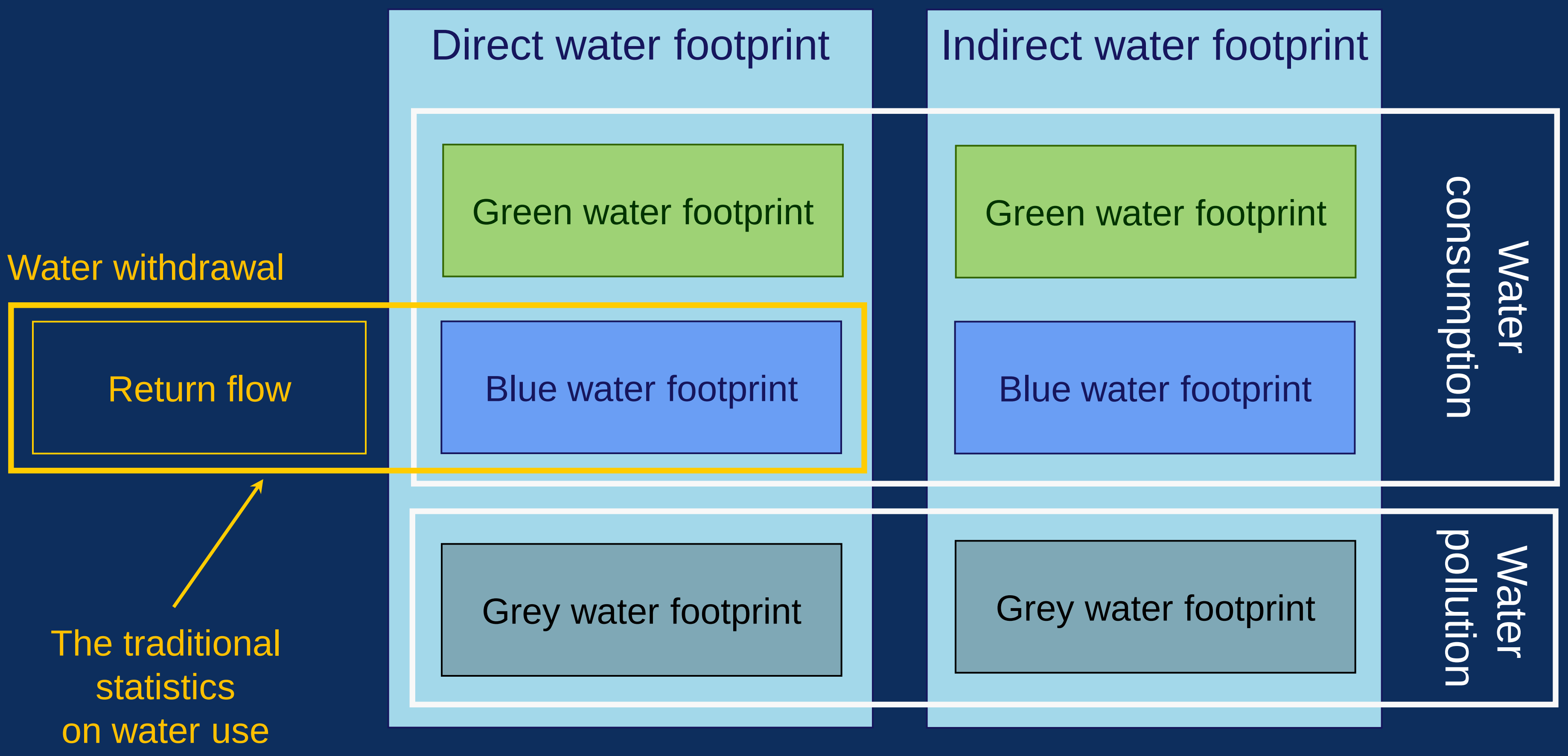
► volume of surface or groundwater evaporated, incorporated into product or returned to other catchment or the sea.

Grey water footprint

► volume of polluted water.

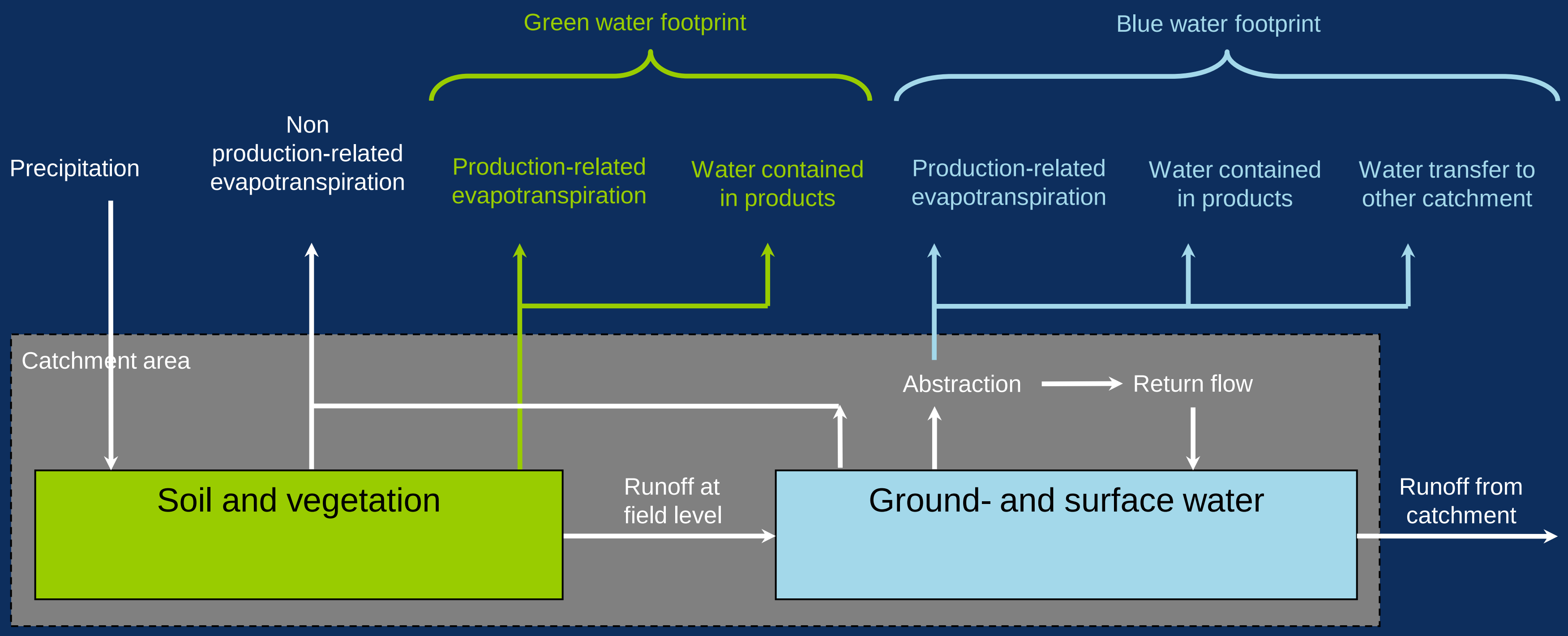


Components of a water footprint



[Hoekstra et al., 2011]

The green and blue water footprint in relation to the water balance of a catchment area



[Hoekstra et al., 2011]

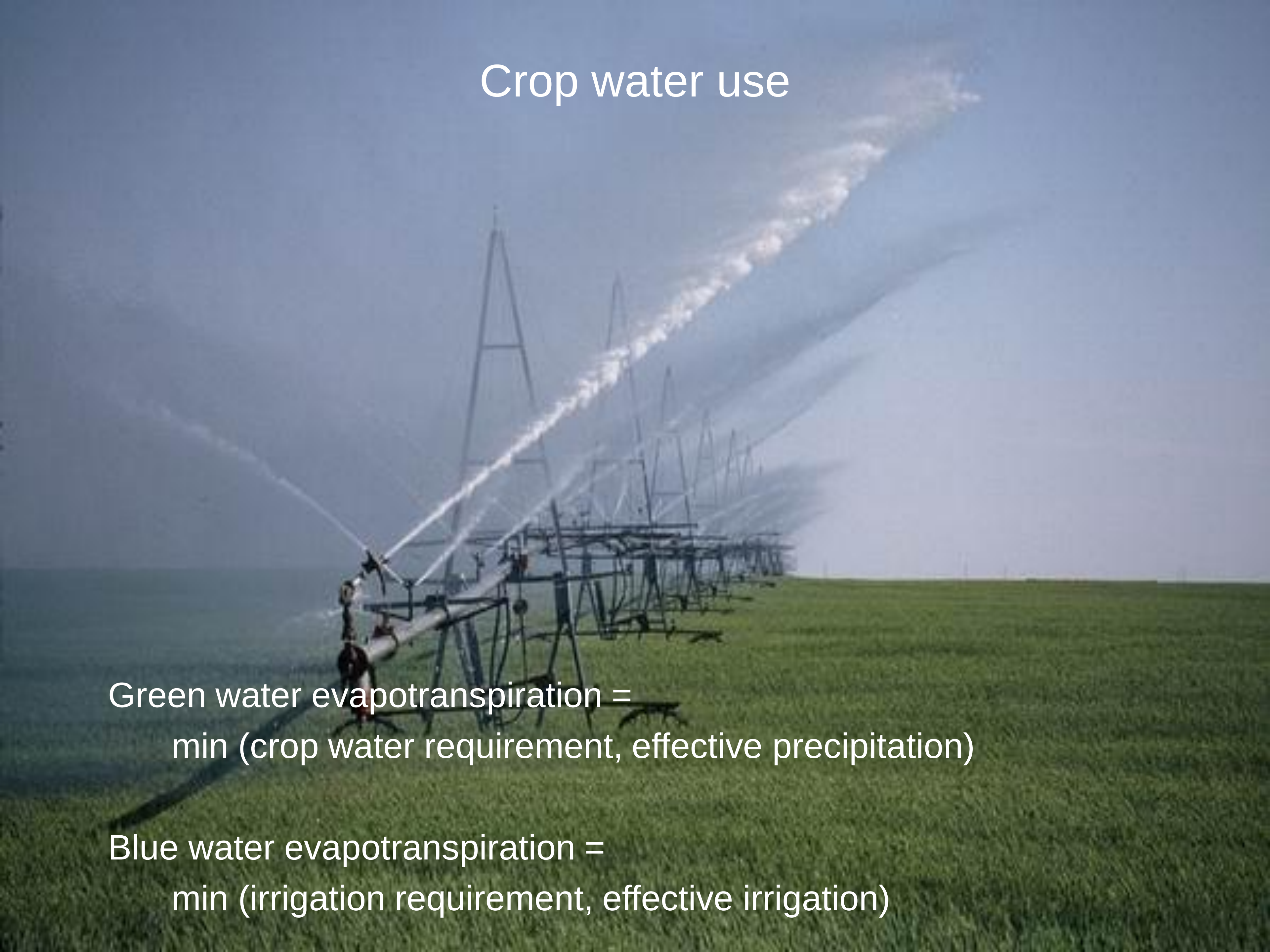
Assessing the blue and green process water footprint of growing a crop

Water footprint of growing a crop

- Crop water use (m^3/ha) / Crop yield (ton/ha)

$$CWU_{green} = 10 \times \sum_{d=1}^{lgp} ET_{green}$$

$$CWU_{blue} = 10 \times \sum_{d=1}^{lgp} ET_{blue}$$



Crop water use

Green water evapotranspiration =
min (crop water requirement, effective precipitation)

Blue water evapotranspiration =
min (irrigation requirement, effective irrigation)

Crop water requirement

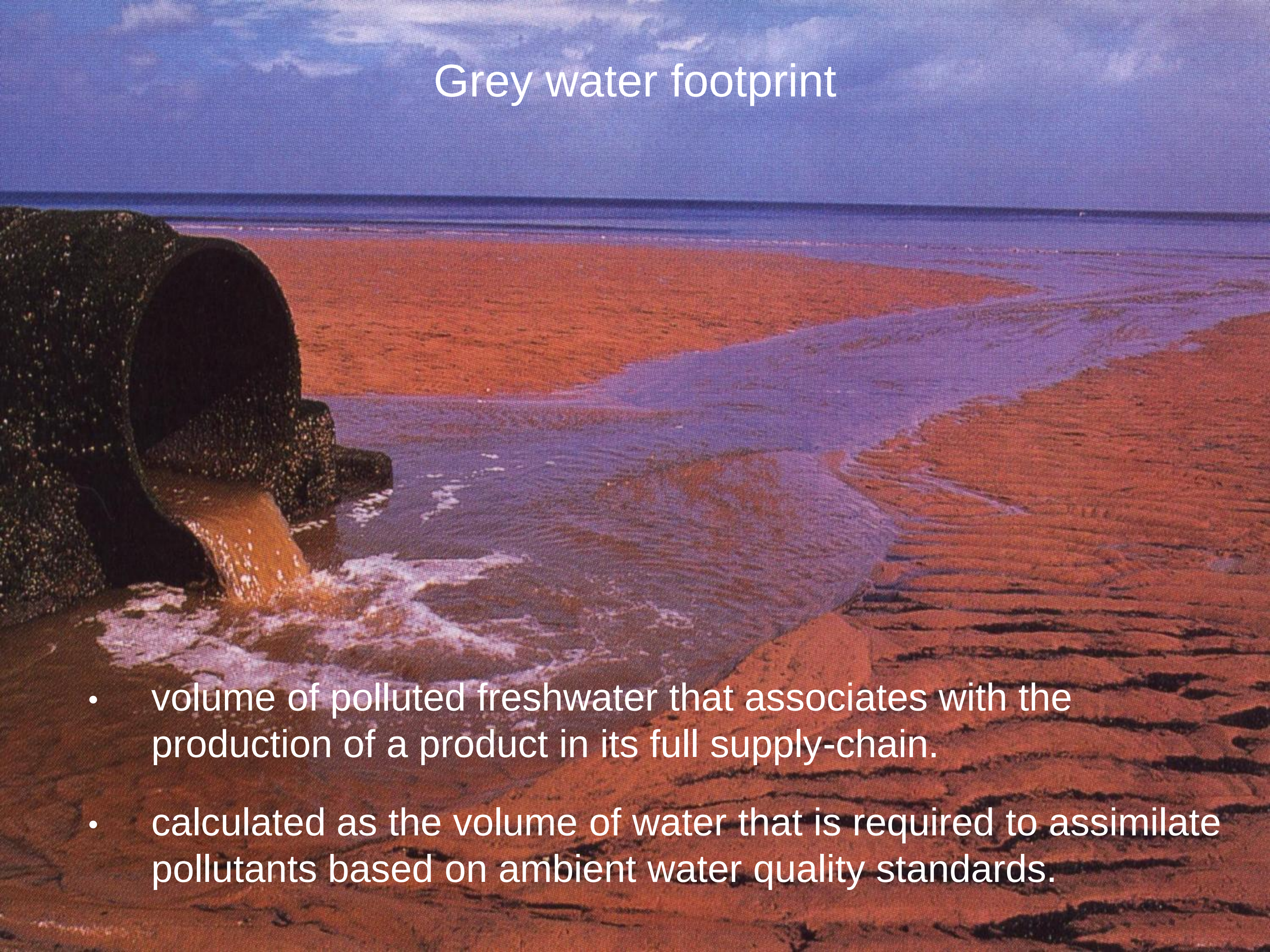
1. **Calculate reference crop evapotranspiration ET_0 (mm/day)**
   e.g. Penman-Monteith equation

2. **Calculate crop evapotranspiration Et_c (mm/day)**
   $Et_c = ET_0 \times K_c$ where K_c = crop coefficient

3. **Calculate crop water requirement CWR (m^3/ha)**
   $CWR = \Sigma\, Et_c$ [accumulate over growing period]

Irrigation requirement

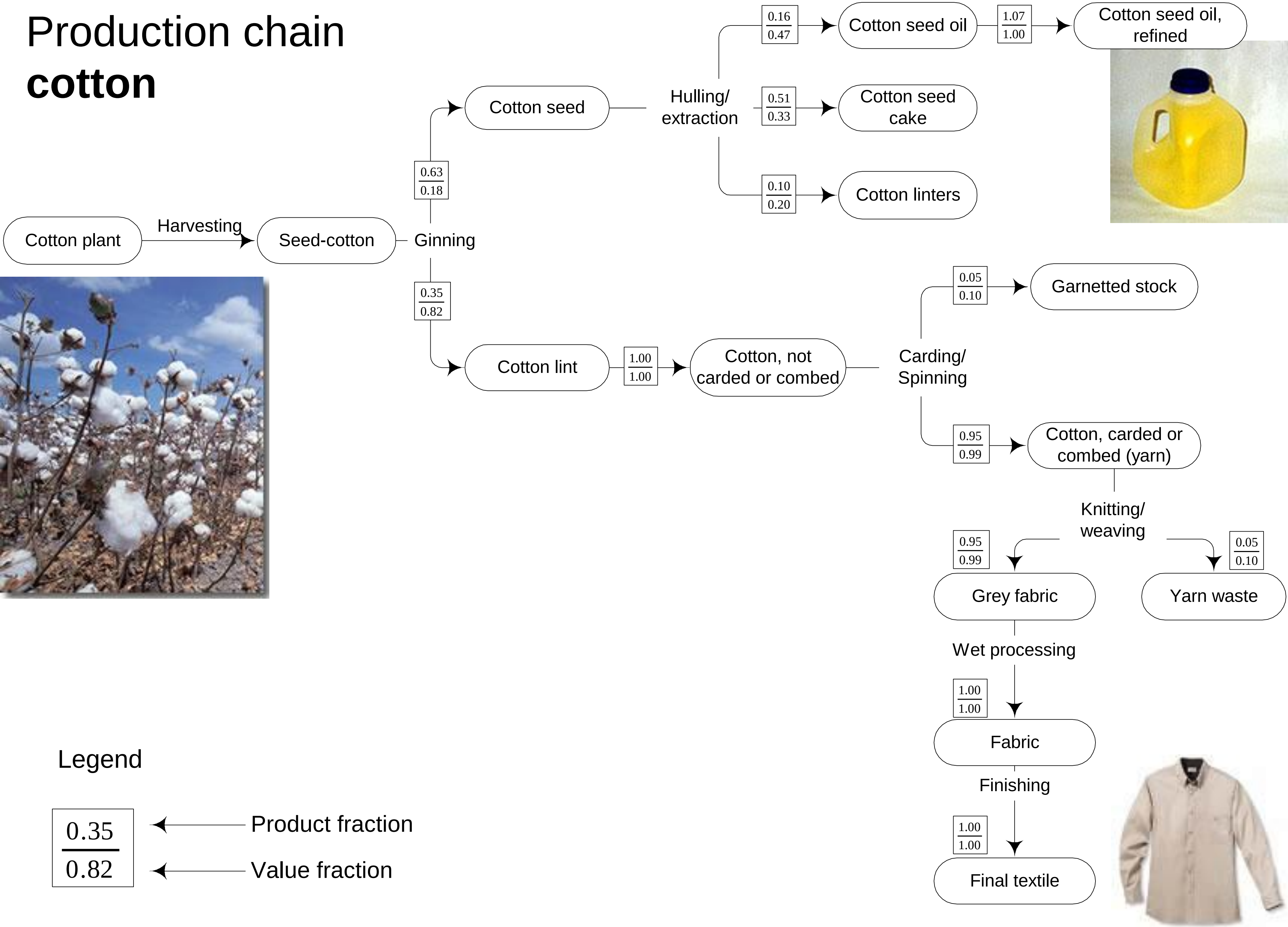
Irrigation requirement = crop water requirement – effective rainfall



Grey water footprint

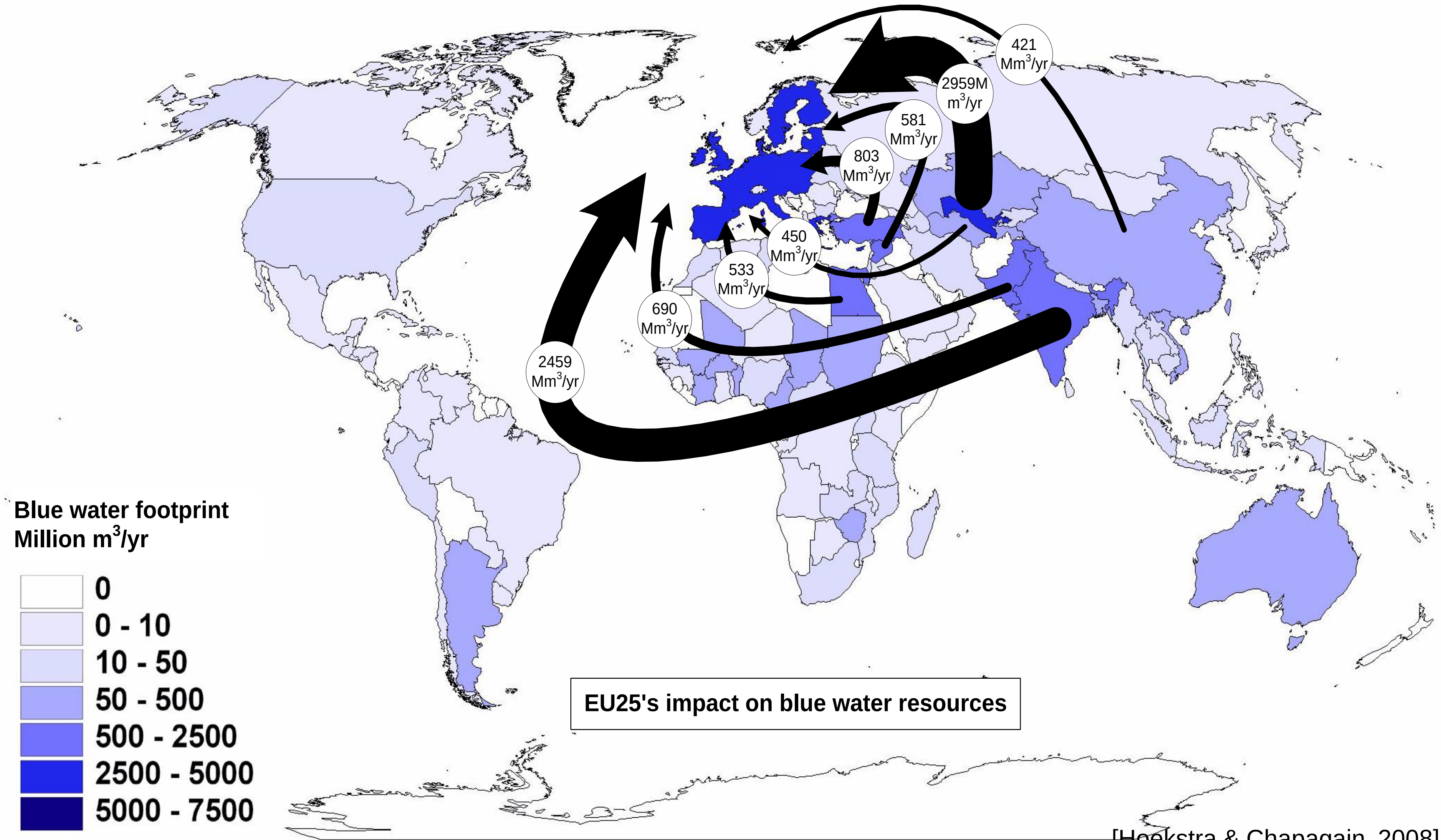
- volume of polluted freshwater that associates with the production of a product in its full supply-chain.
- calculated as the volume of water that is required to assimilate pollutants based on ambient water quality standards.

Production chain **cotton**



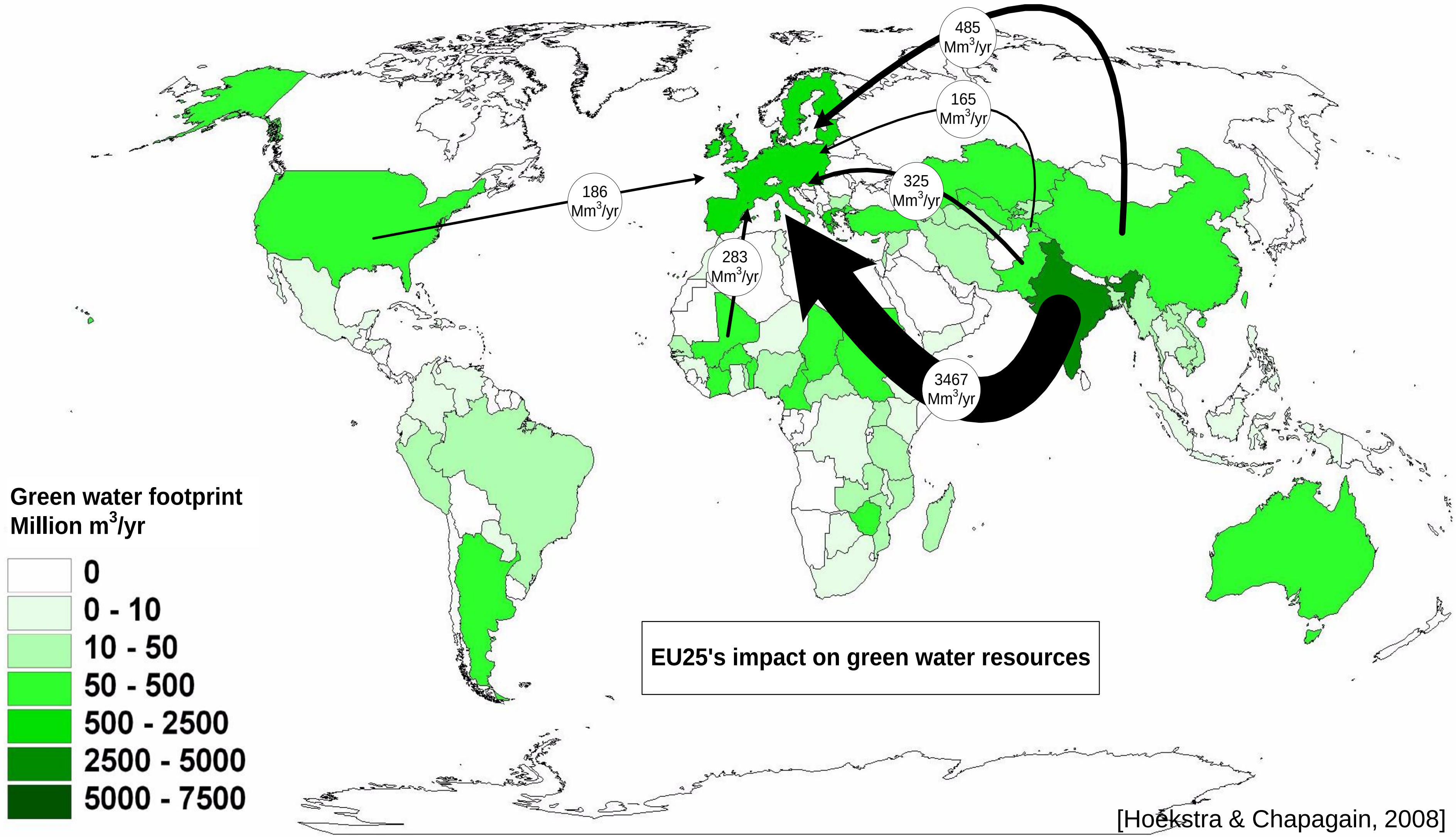
[Hoekstra & Chapagain, 2008]

Water footprint of EU's cotton consumption (blue water)



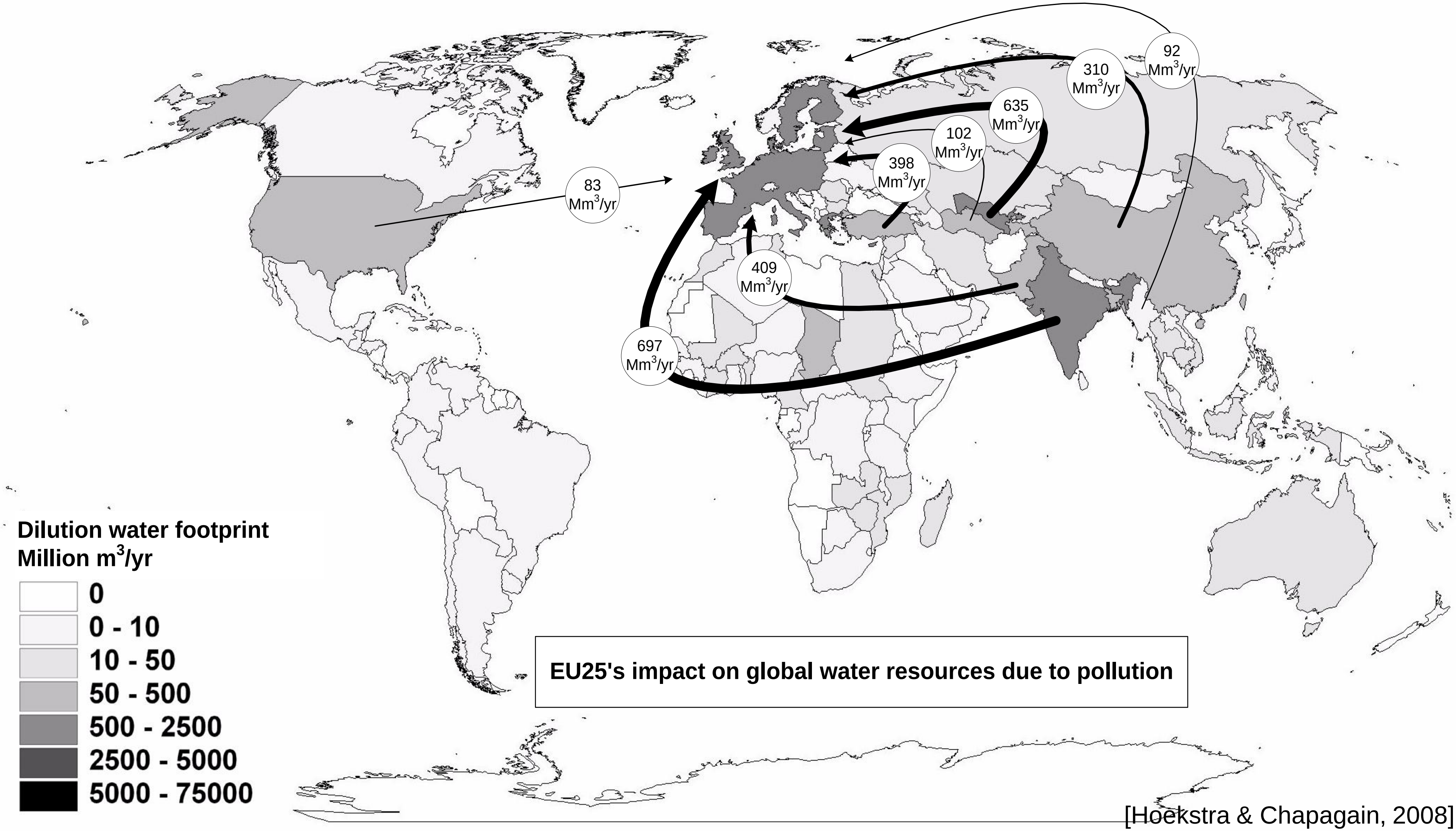
[Hoekstra & Chapagain, 2008]

Water footprint of EU's cotton consumption (green water)



[Hoekstra & Chapagain, 2008]

Water footprint of EU's cotton consumption (grey water)



[Hoekstra & Chapagain, 2008]


The water footprint:
making a link between consumption in one place and
impacts on water systems elsewhere
Shrinking Aral Sea


The water footprint:
making a link between consumption in one place and impacts on water systems elsewhere
Endangered Indus River Dolphin
[Photo: WWF]

This is a **global average** and **aggregate** number. Policy decisions should be taken on the basis of:

1. Actual water footprint of certain coffee at the precise production location.
2. Ratio green/blue/grey water footprint.
3. Local impacts of the water footprint based on local vulnerability and scarcity.

[Hoekstra & Chapagain, 2008]

[Hoekstra & Chapagain, 2008]

[Hoekstra & Chapagain, 2008]

[Hoekstra & Chapagain, 2008]

[Hoekstra & Chapagain, 2008]

The water footprint of a cow

Food

- ► 1300 kg of grains
  (wheat, oats, barley, corn, dry peas, soybean, etc)
- ► 7200 kg of roughages
  (pasture, dry hay, silage, etc)

99%

Water

- ► 24000 litres for drinking
- ► 7000 litres for servicing.

1%

[Hoekstra & Chapagain, 2008]

[Hoekstra & Chapagain, 2008]

[Hoekstra & Chapagain, 2008]

[Hoekstra & Chapagain, 2008]

$\neq$

Water footprint:
- mostly green
- local

Water footprint:
- green & blue
- local

Water footprint:
- green & blue
- partly imported

[Hoekstra & Chapagain, 2008]

The water footprint of energy

UNESCO-IHE
Institute for Water Education

A.R. van Lienden
P.W. Gerbens-Leenes
A.Y. Hoekstra
Th.H. van der Meer

April 2010

Biofuel scenarios in a water perspective: The global blue and green water footprint of road transport in 2030

UNESCO-IHE
Institute for Water Education

P.W. Gerbens-Leenes
A.Y. Hoekstra
Th.H. van der Meer

March 2008

Water footprint of bio-energy and other primary energy carriers

UNESCO-IHE
Institute for Water Education

P.W. Gerbens-Leenes
A.Y. Hoekstra

June 2010

Burning water: The water footprint of biofuel-based transport

T Series

UNESCO-IHE
Institute for Water Education

P.W. Gerbens-Leenes
A.Y. Hoekstra

November 2009

The water footprint of sweeteners and bio-ethanol from sugar cane, sugar beet and maize

ECOLOGICAL ECONOMICS 68 (2009) 1052–1060

available at www.sciencedirect.com

ScienceDirect

ELSEVIER

www.elsevier.com/locate/ecolecon

ANALYSIS

The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply

P.W. Gerbens-Leenes*, A.Y. Hoekstra, Th. van der Meer

University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

PNAS

The water footprint of bioenergy

Winnie Gerbens-Leenes[a,1], Arjen Y. Hoekstra[a], and Theo H. van der Meer[b]

[a]Department of Water Engineering and Management and [b]Laboratory of Thermal Engineering, University of Twente, P.O. Box 217, 7500 AE, Enschede, The Netherlands

Edited by David Pimentel, Cornell University, Ithaca, NY, and accepted by the Editorial Board April 20, 2009 (received for review December 12, 2008)

All energy scenarios show a shift toward an increased percentage of renewable energy sources, including biomass. This study gives an overview of water footprints (WFs) of bioenergy from 12 crops that currently contribute the most to global agricultural production: barley, cassava, maize, potato, rapeseed, rice, rye, sorghum, soybean, sugar beet, sugar cane, and wheat. In addition, this study includes jatropha, a suitable energy crop. Since climate and production circumstances differ among regions, calculations have been performed by country. The WF of bioelectricity is smaller than that of biofuels because it is more efficient to use total biomass (e.g., for electricity or heat) than a fraction of the crop (its sugar, starch, or oil content) for biofuel. The WF of bioethanol appears to be smaller than that of biodiesel. For electricity, sugar beet, maize, and sugar cane are the most favorable crops [50 m^3/gigajoule (GJ)]. Rapeseed and jatropha, typical energy crops, are disadvantageous (400 m^3/GJ). For ethanol, sugar beet, and potato (60 and 100 m^3/GJ) are the most advantageous, followed by sugar cane (110 m^3/GJ); sorghum (400 m^3/GJ) is the most unfavorable. For biodiesel, soybean and rapeseed show to be the most favorable WF (400 m^3/GJ); jatropha has an adverse WF (600 m^3/GJ). When expressed per L, the

scarcely any new land will be available so all production must come from the current natural resource base (15), requiring a process of sustainable intensification by increasing the efficiency of land and water use (16).

Globally, many countries explore options for replacing gasoline with biofuels (11). The European Union and the U.S. even have set targets for this replacement. When agriculture grows bioenergy crops, however, it needs additional water that then cannot be used for food. Large-scale cultivation of biomass for fossil fuel substitution influences future water demand (17). An important question is whether we should apply our freshwater resources to the production of bioenergy or to food crops. The Food and Agriculture Organization (FAO) estimated that in 2007 alone, before the food price crisis struck, 75 million more people were pushed into undernourishment as a result of higher prices, bringing the total number of hungry people in the world to 923 million (18). Moreover, the FAO reports that biofuels increase food insecurity (19). The World Bank recognizes biofuel production as a major factor in driving up food prices. It estimates that 75% of the increase in food prices in the period

Water - energy nexus

- The water sector is becoming more energy-intensive.
  - desalination
  - pumping deeper groundwater
  - large-scale (inter-basin) water transfers

- The energy sector is becoming more water-intensive.
  - biomass

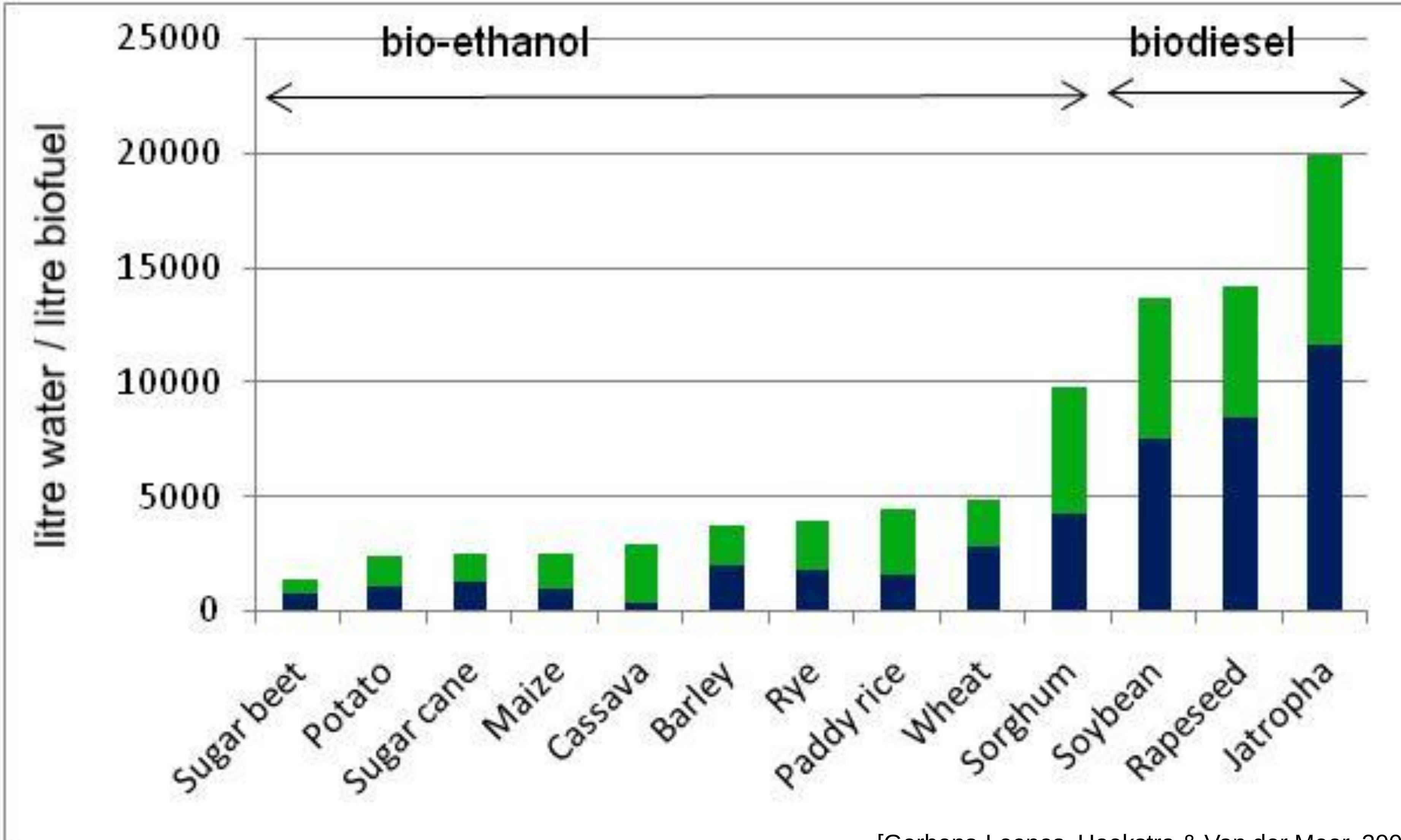
[Hoekstra & Chapagain, 2008

Water footprint of energy

Primary energy carriers		Global average water footprint (m^3/GJ)
Non-renewable	Natural gas	0.11
	Coal	0.16
	Crude oil	1.06
	Uranium	0.09
Renewable	Wind energy	0.00
	Solar thermal energy	0.27
	Hydropower	22
	Biomass energy	70 (range: 10-250)

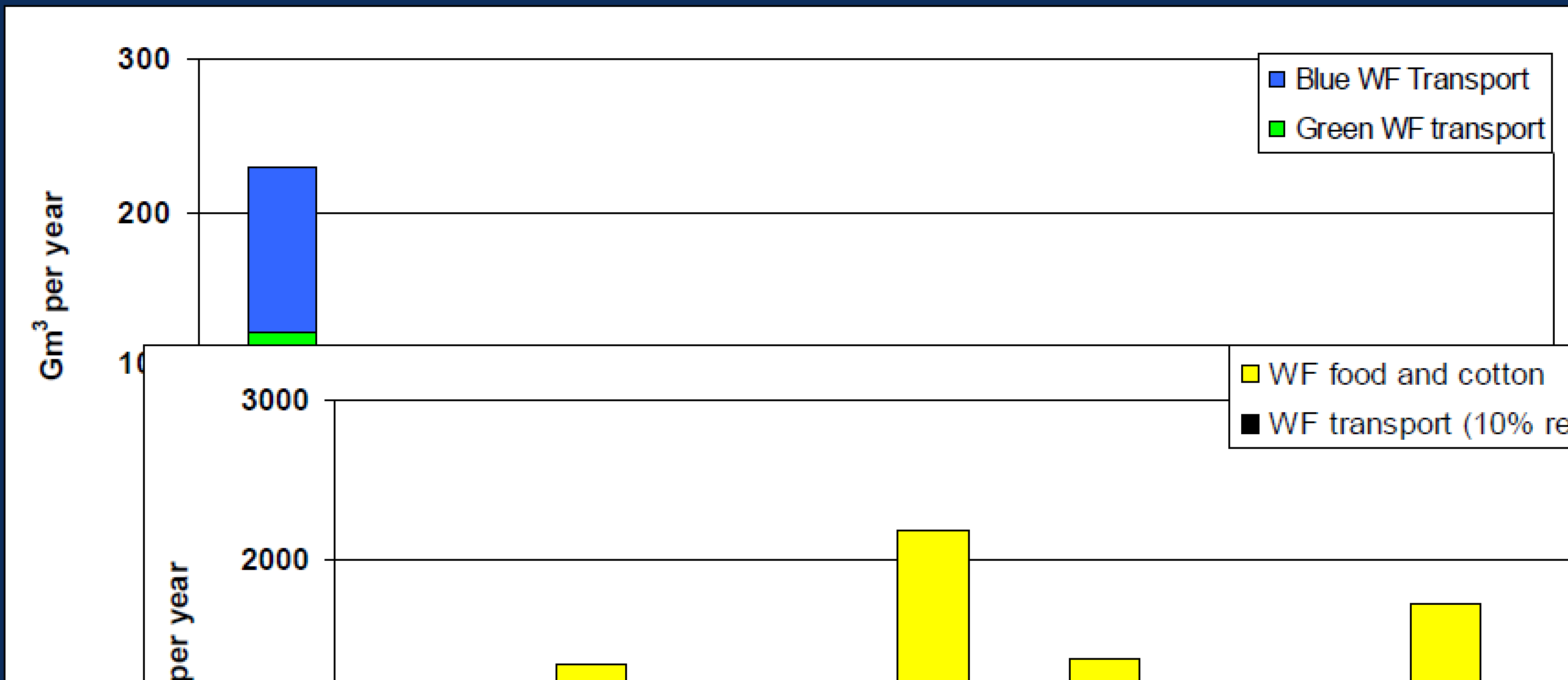
[Gerbens-Leenes, Hoekstra & Van der Meer, 200

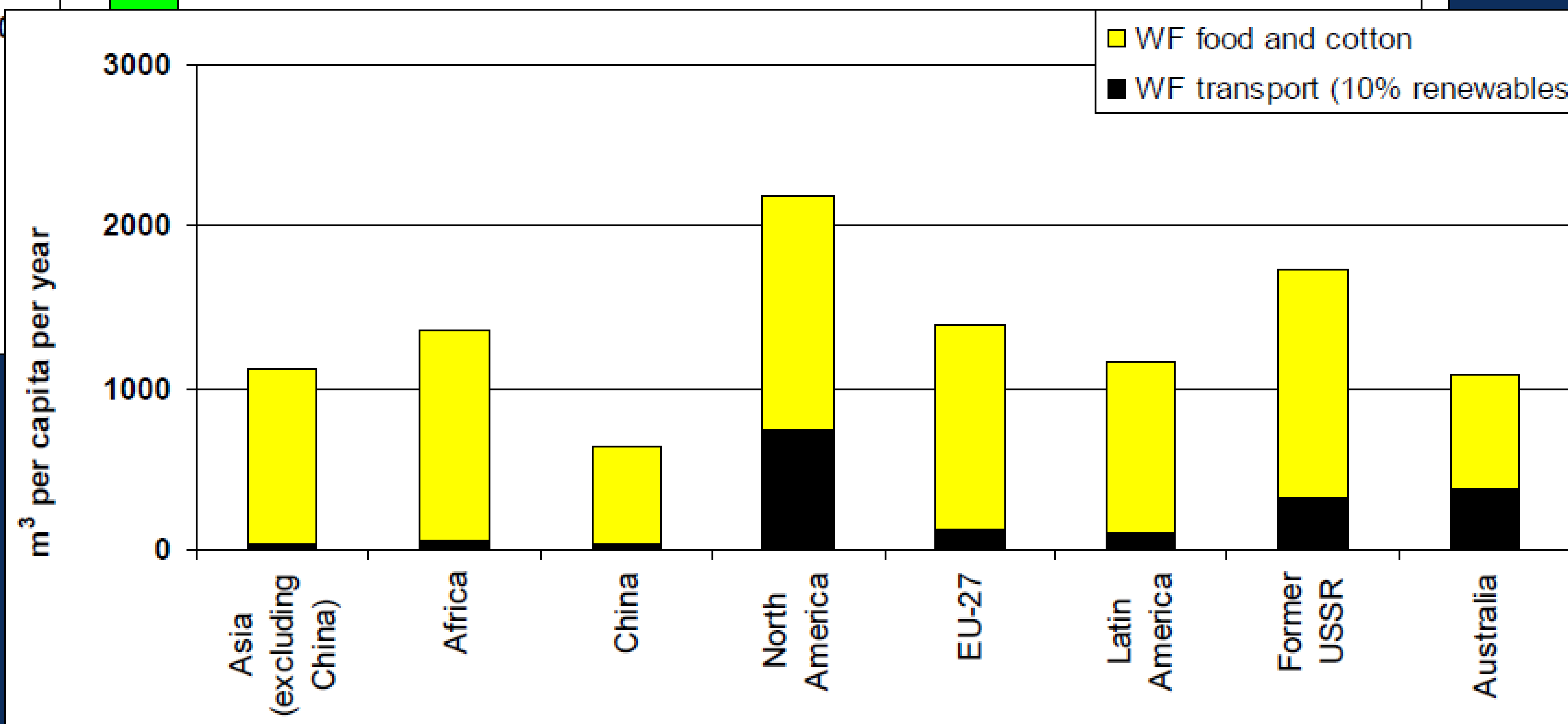
Water footprint of biofuels from different crops [litre/litre]



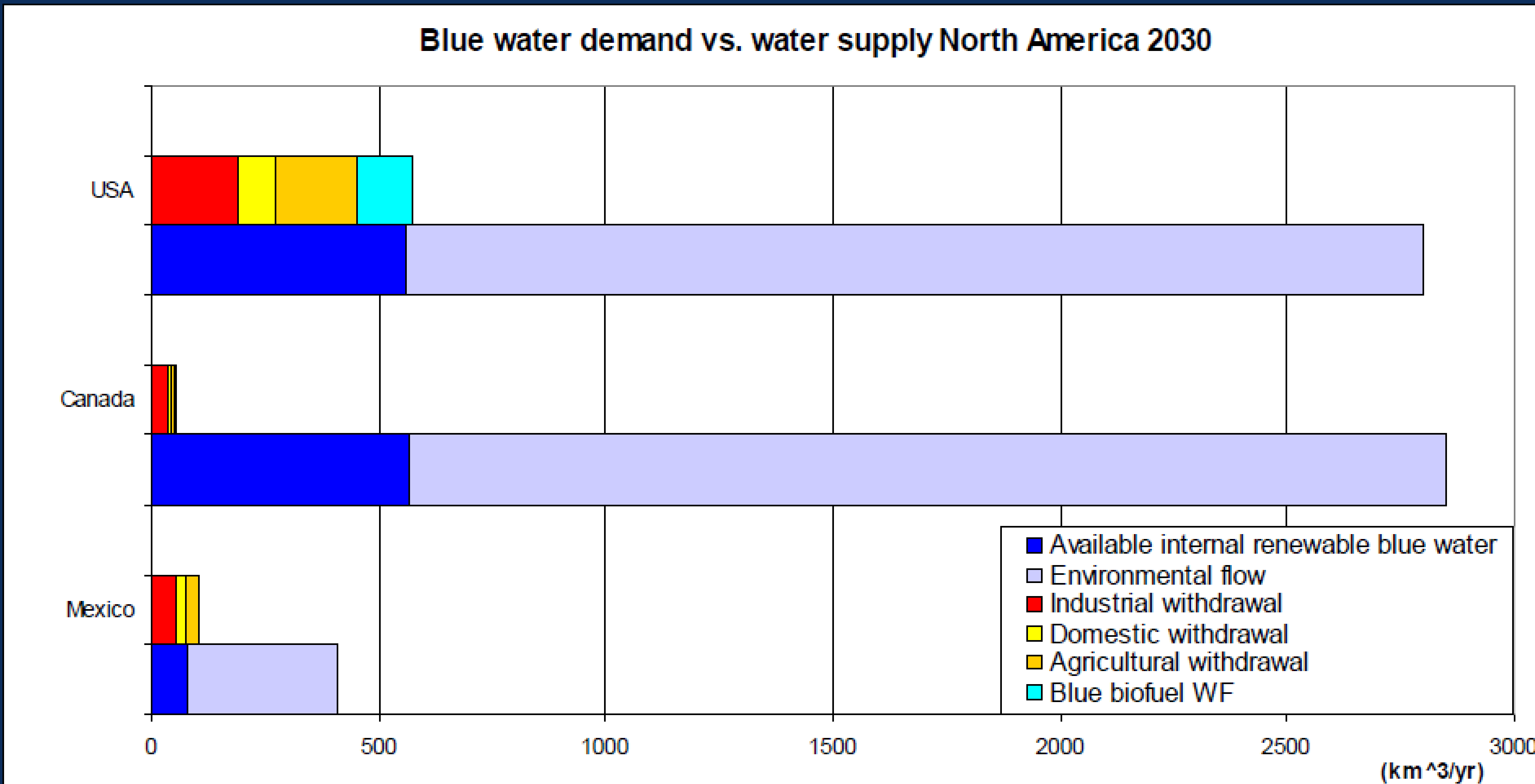
[Gerbens-Leenes, Hoekstra & Van der Meer, 2009]

Water footprint per region when 10% of transport fuels are derived from bio-ethanol





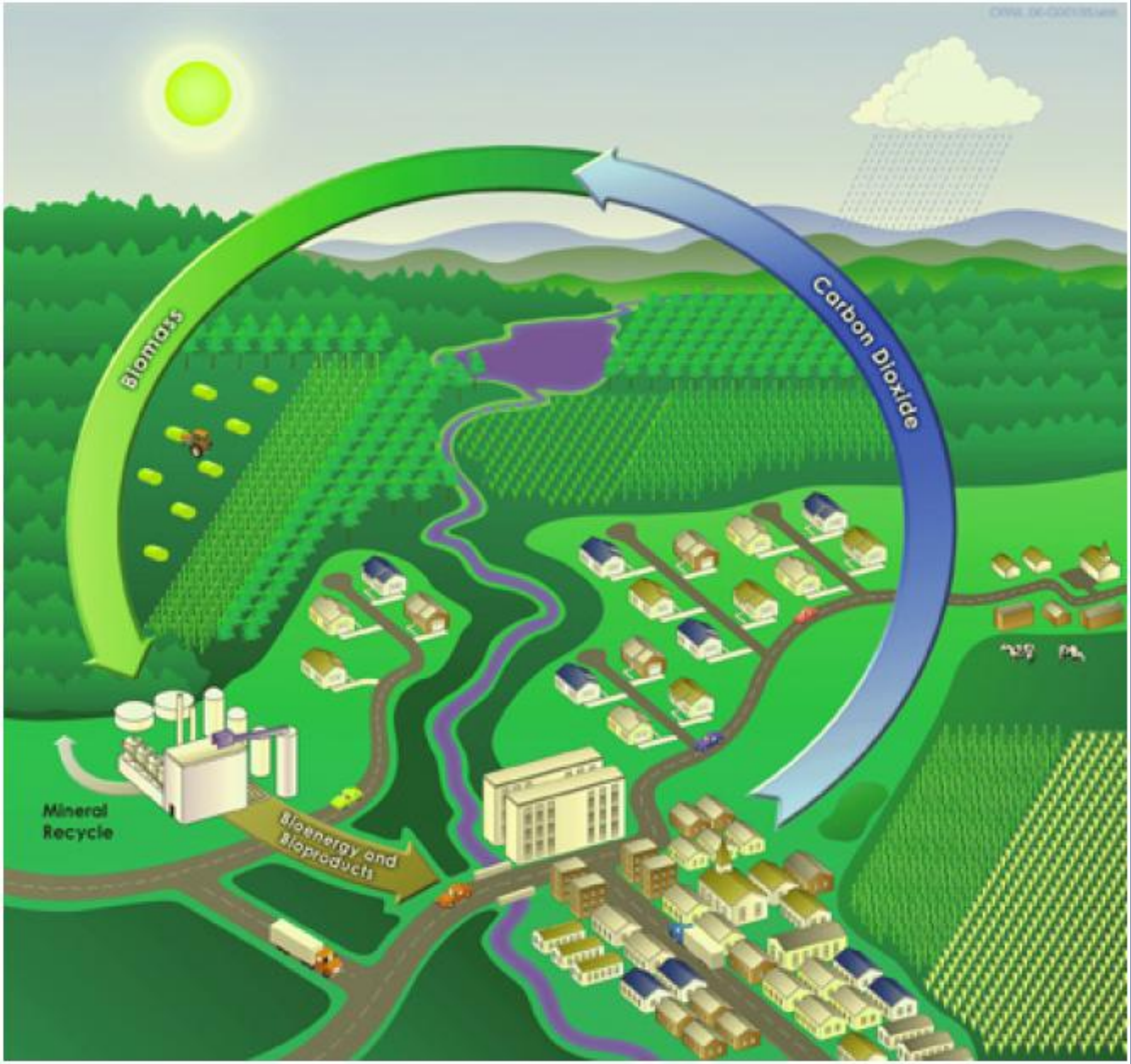
Water footprint of bio-energy in context



Van Lienden et al. (201

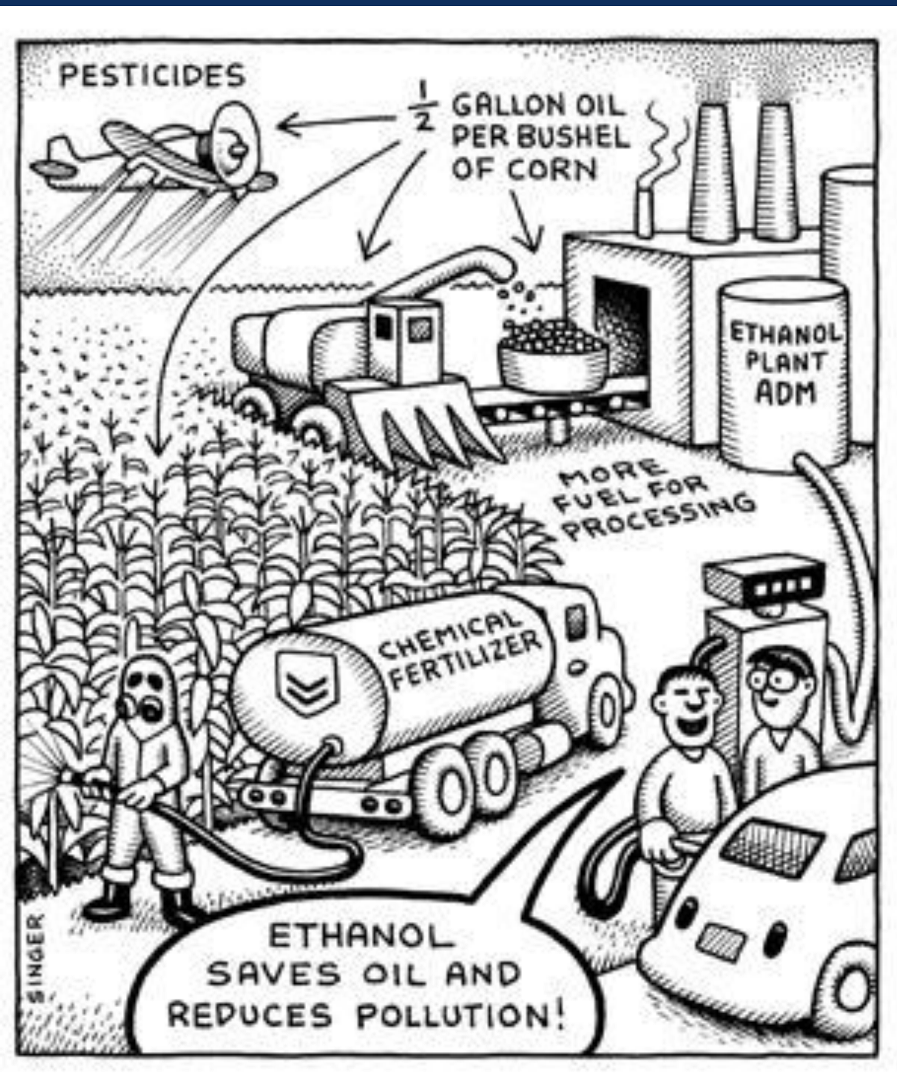
Biofuels: A Solution for Climate Change ?

(source:Shabbir H Gheewala, 2013)



The idea is that the CO_2 production during combustion of the biomass is compensated by CO_2 consumption during growth of the plants (photosynthesis)

(source:Shabbir H Gheewala, 2013)



"We've gathered to give thanks for our bountiful harvest. But it seems all our corn crop went to ethanol production."

Biofuels and rainforests

(source: Shabbir H Gheewala, 2013)

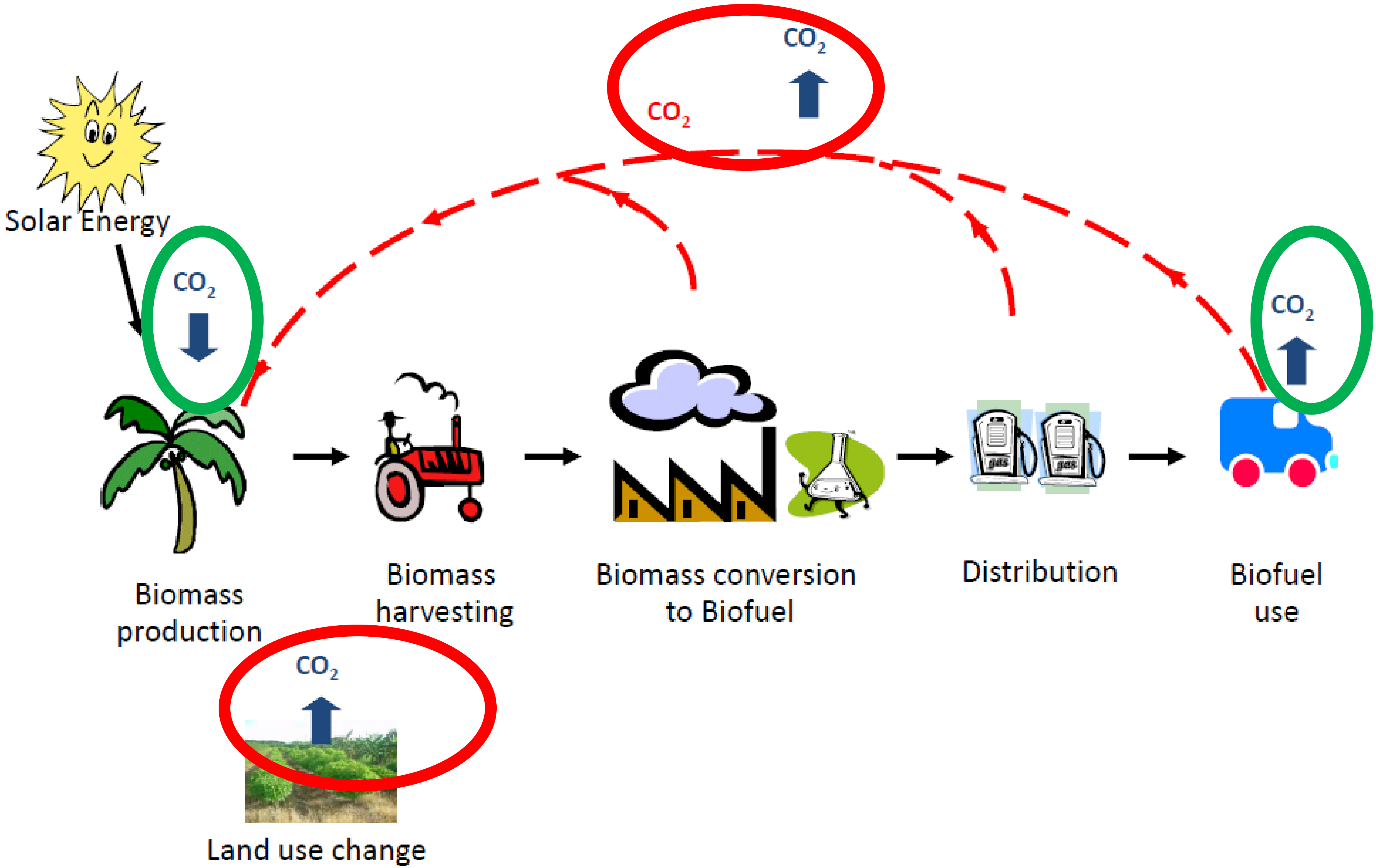
- "Rain Forest for Biodiesel? Ecological effects of using palm oil as a source of energy" *WWF report*
- "Forests paying the price for biofuels" *New Scientist*
- "Europe's move to biofuels threatens rainforest" *MSNBC*
- "Biofuels boom could fuel rainforest destruction, *Stanford researcher warns"*
- "Biofuels menace rainforests" *guardian.co.uk*
- "Biofuels make climate change worse, scientific study concludes" *The Independent*

Biofuels and climate change

(source: Shabbir H Gheewala, 2013)

- “Biofuels make climate change worse, scientific study concludes” *The Independent*
- “Biofuels will speed climate change, chief scientist says” *news.scotsman.com*
- “CLIMATE CHANGE: Biofuels Worse Than Fossil Fuels, Studies Find” *ipsnews.net*
- “Another Inconvenient Truth: How biofuel policies are deepening poverty and accelerating climate change” *Oxfam Briefing Paper*

…. Why are biofuels considered (NOT) to be green? (source: Shabbir H Gheewala, 2013)



Expanding system boundaries of biofuels needed

(source: Shabbir H Gheewala, 2013)

- only in use phase biofuels are carbon neutral.
- from the cultivation to end use – carbon benefits are achievable.
- expand the boundary further to include land use change effects, carbon benefits are questionable
  - sugarcane cultivation on grassland – net benefits feasible
- ripple effects throughout the whole world
  - how does reduced soybean production in the US affect palm oil prices (and probably impacts too) in Thailand?
  - what if biofuel production results in displaced food production at another location where forests are cleared?
  - should these be part of the "environmental baggage" of the biofuel?

Water footprint
of a consumer

Water footprint of a consumer

► the total volume of water appropriated for the production of the goods and services consumed.

► equal to the sum of the water footprints of all goods and services consumed.

► dimensions of a water footprint
- volume
- where and when
- type of water use: green, blue, grey

The total water footprint of a consumer in the UK

► about 3% of your water footprint is at home.

150 litre/day

► about 97% of your water footprint is ‘invisible’, it is related to the products you buy in the supermarket.

3400 litre/day for agricultural products
1100 litre/day for industrial products

► about 60 to 65% of your water footprint lies abroad.

Meat versus vegetarian diet

	Meat diet	kcal/day	litre/kcal	litre/day	Vegetarian diet	kcal/day	litre/kcal	litre/day
Industrial countries	Animal origin	950	2.5	2375	Animal origin	300	2.5	750
	Vegetable origin	2450	0.5	1225	Vegetable origin	3100	0.5	1550
	Total	3400		3600	Total	3400		2300
Developing countries	Animal origin	350	2.5	875	Animal origin	200	2.5	500
	Vegetable origin	2350	0.5	1175	Vegetable origin	2500	0.5	1250
	Total	2700		2050	Total	2700		1750

National water footprint accounting

Water footprint of national consumption

► total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation.

► two components:

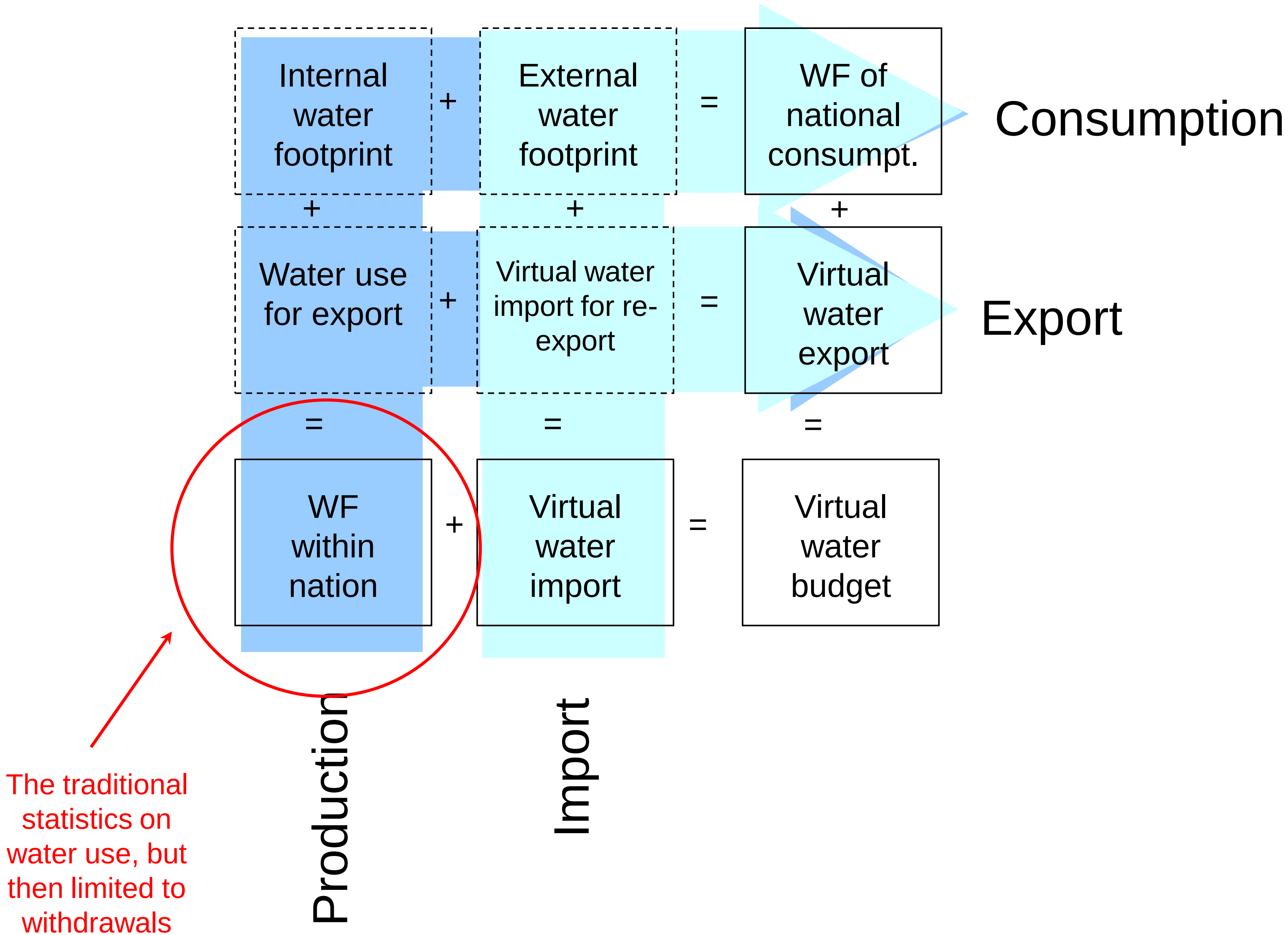
- internal water footprint – inside the country.
- external water footprint – in other countries.

► water footprint of national consumption =

water footprint within the nation + virtual water import

– virtual water export

National water use accounting framework



Country/region	National water footprint (Gm^3/year)	
	from the perspective of production	from the perspective of consumption
Australia	91	27
Canada	123	63
China	893	883
Egypt	59	70
EU25	559	744
India	1013	987
Japan	54	146
Jordan	1.8	6.3
USA	750	696

WF within a nation

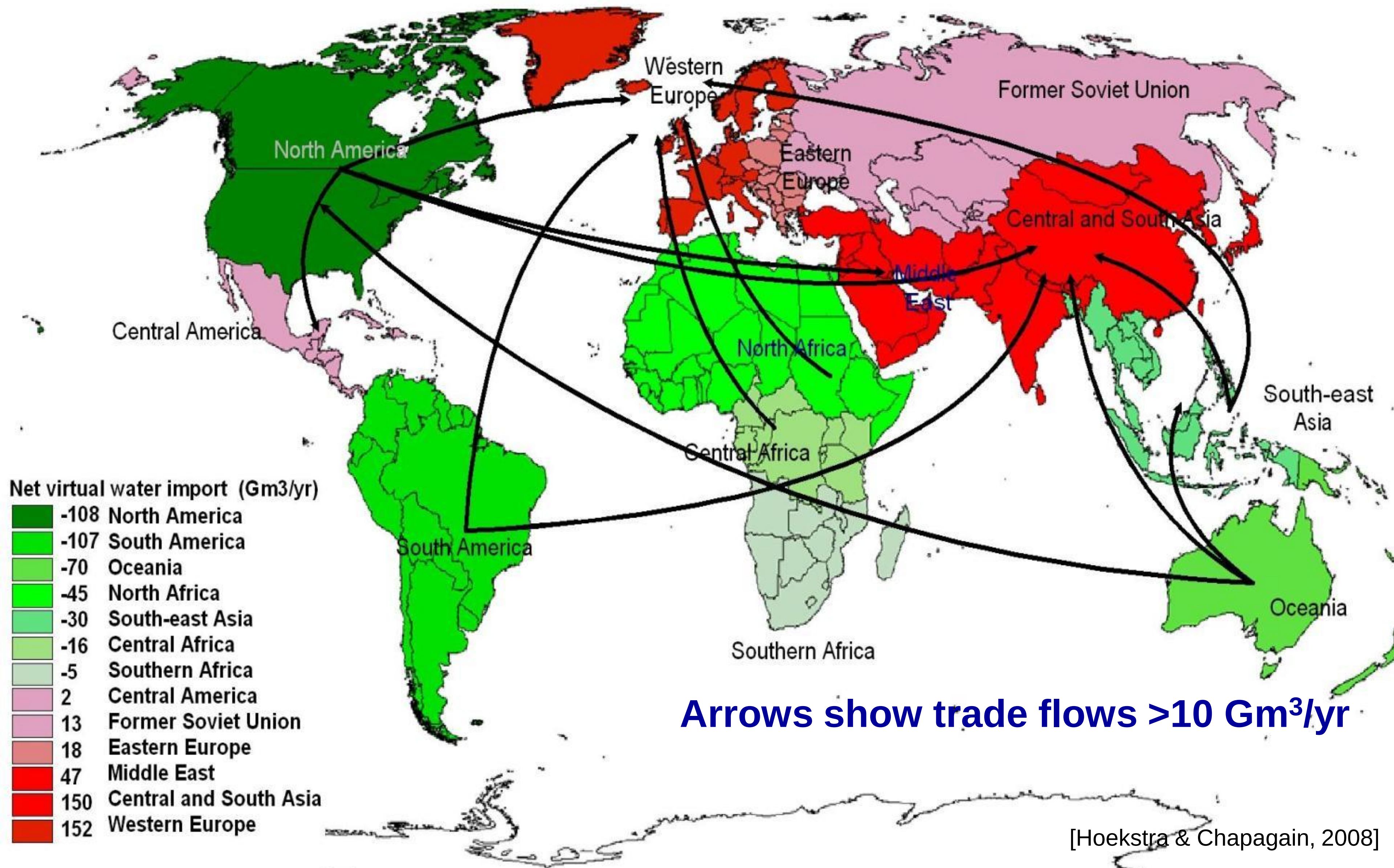
WF of national consumption

Traditional statistics on water use, but then restricted to water withdrawal

[Hoekstra & Chapagain, 2008]

Regional virtual water balances

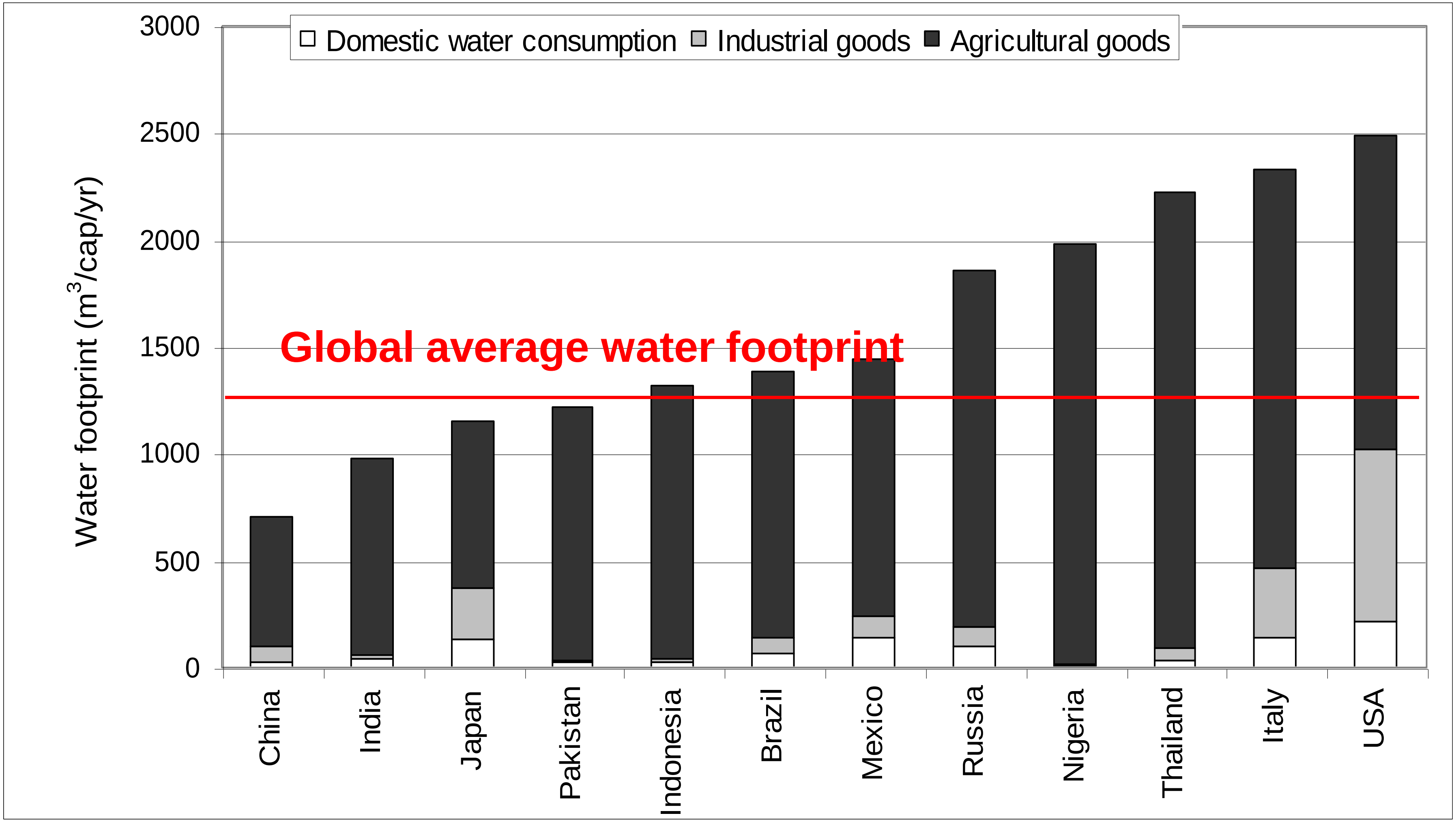
(only agricultural trade)



Arrows show trade flows >10 Gm^3/yr

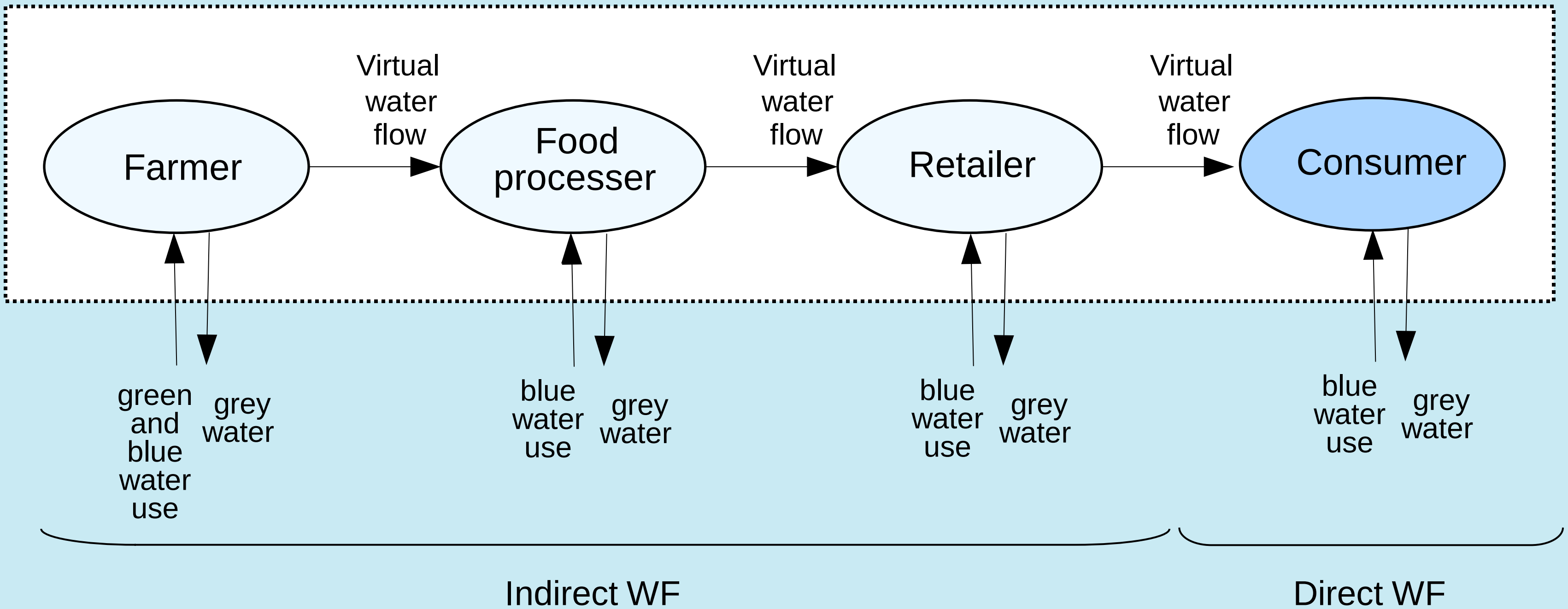
[Hoekstra & Chapagain, 2008]

Water footprint per capita



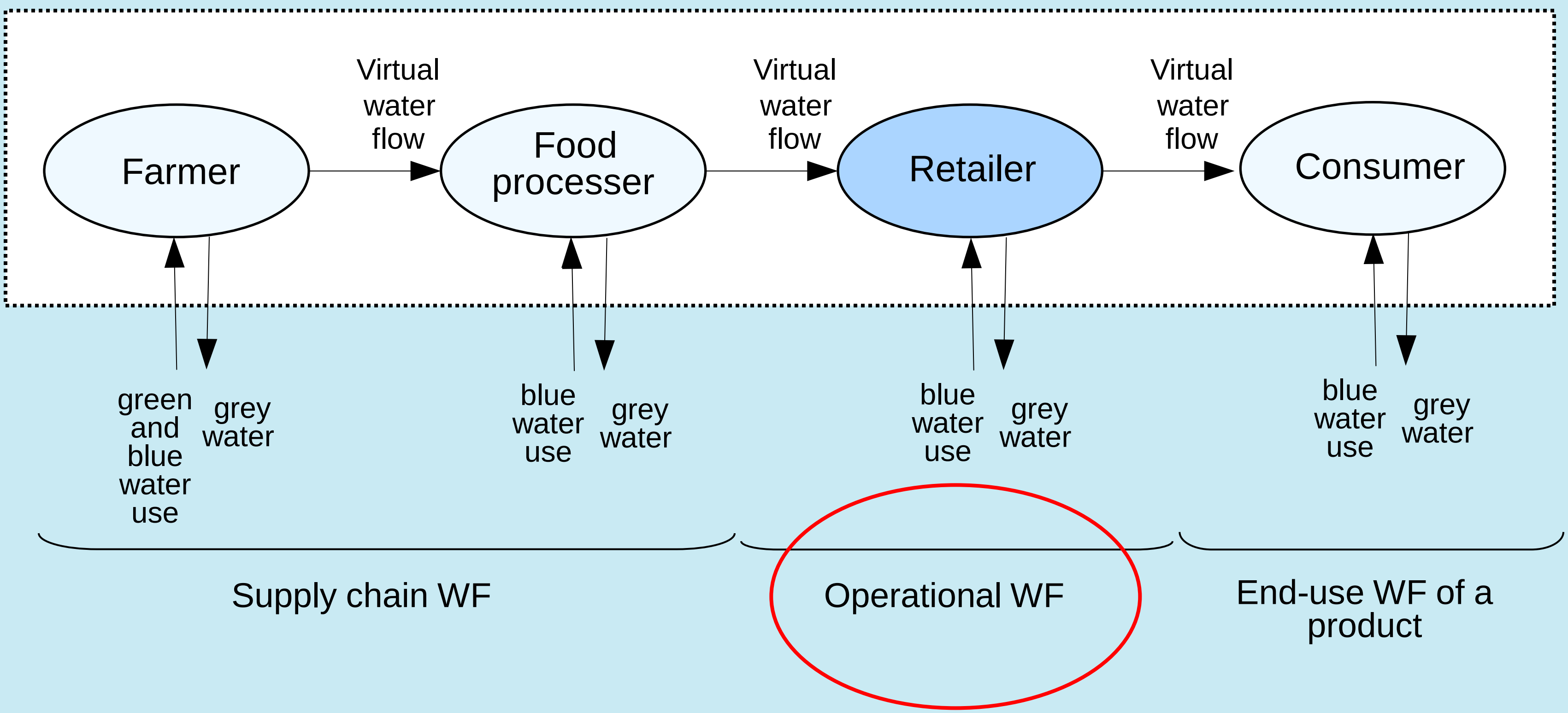
[Hoekstra & Chapagain, 2008]

The water footprint of a consumer



[Hoekstra, 2008]

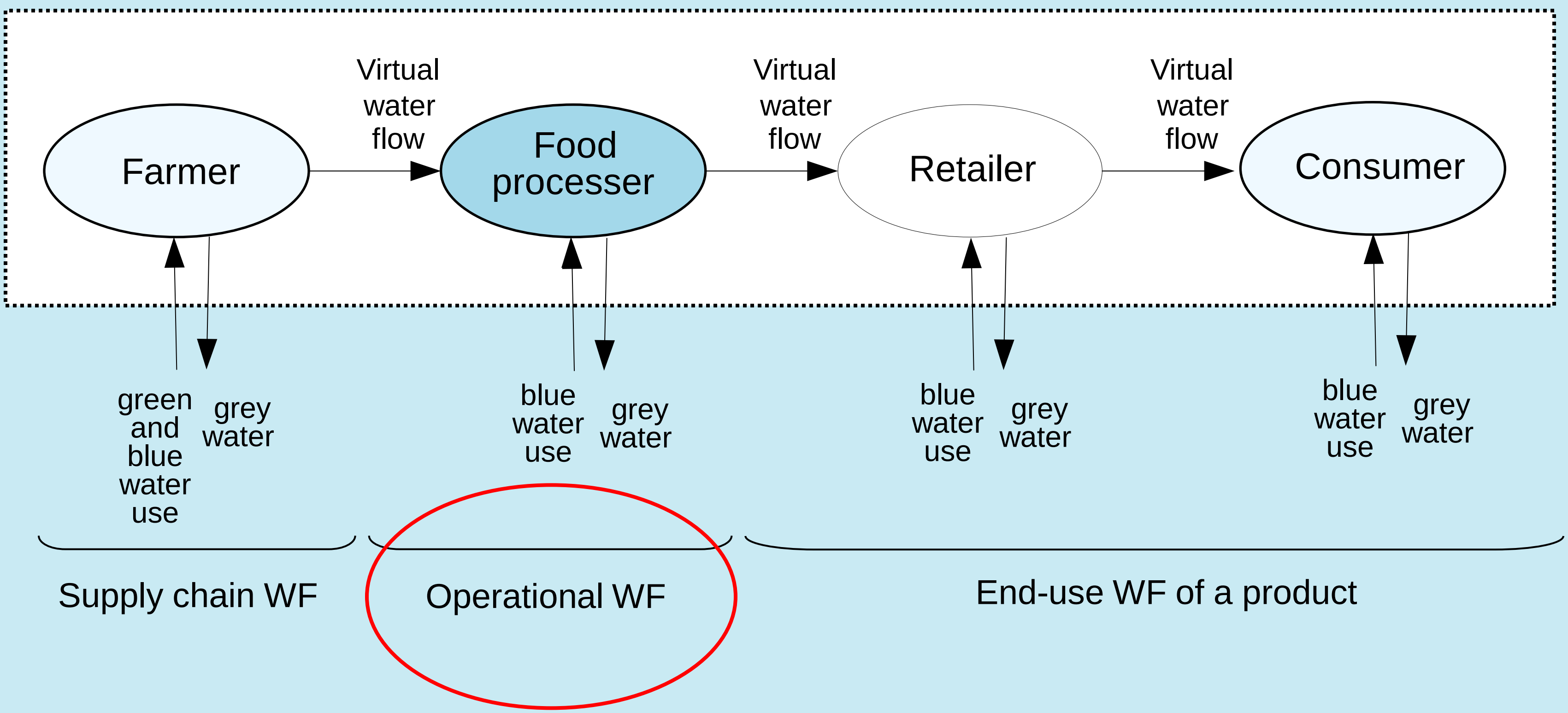
The water footprint of a retailer



The traditional statistics on corporate water use

[Hoekstra, 2008]

The water footprint of a food processor



The traditional statistics on corporate water use

[Hoekstra, 2008]

Water footprint – Carbon footprint

Water footprint

- measures freshwater appropriation
- spatial and temporal dimension
- actual, locally specific values
- always referring to full supply-chain
- focus on reducing own water footprint (water use units are not interchangeable)

Carbon footprint

- measures emission GH-gasses
- no spatial / temporal dimension
- global average values
- supply-chain included only in ‘scope 3 carbon accounting’
- many efforts focused on offsetting (carbon emission units are interchangeable)

Water footprint and carbon footprint are complementary tools.

[Hoekstra et al., 2009]

Water footprint – Life cycle assessment

Water footprint

- measures freshwater appropriation
- multi-dimensional (type of water use, location, timing)
- actual water volumes, no weighing

LCA

- measures overall environmental impact
- no spatial dimension
- weighing water volumes based on impacts

For companies, water footprint assessment and LCA are complementary tools.

- *WF assessment is a tool to support formulation of a sustainable water management strategy in operations and supply chain.*
- *LCA is a tool to compare the overall environmental impact of different products.*

WF is a general indicator of water use; application of WF in inventory phase of LCA is one particular application.

[Hoekstra et al., 2009]

Stop waste of ‘blue water’


Make better use of ‘green water’
Increase water productivity in rain-fed agriculture

Grey water footprint ↓ zero

Reducing humanity's water footprint – Consumers

Reduction of the direct water footprint:

- water saving toilet, shower-head, etc.

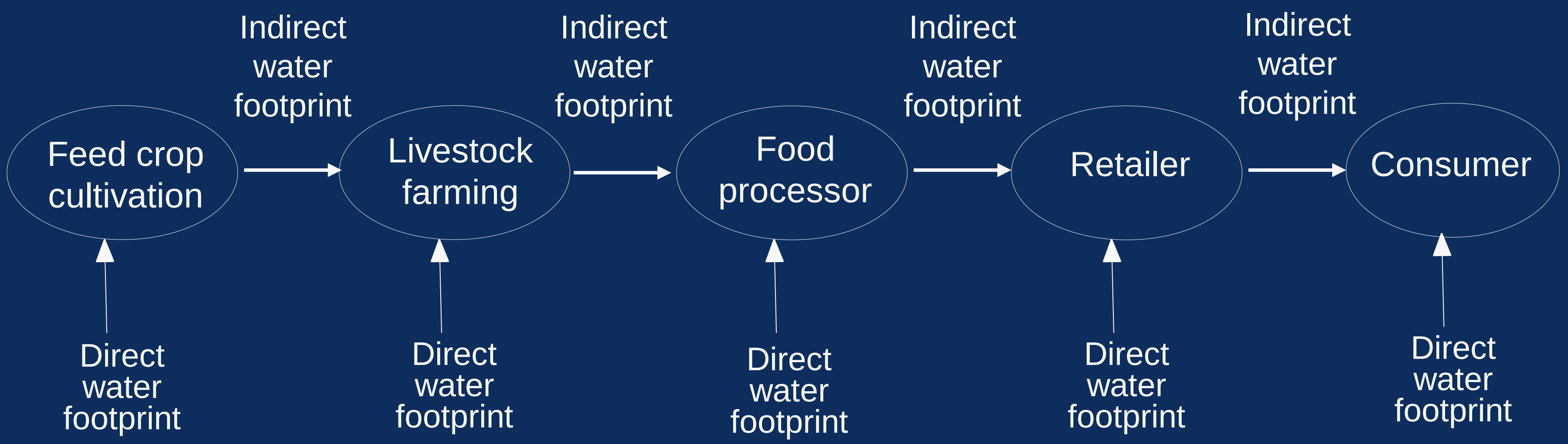
"Save water in the supermarket"

Reduction of the indirect water footprint:

- substitution of a consumer product that has a large water footprint by a different type of product that has a smaller water footprint;
- substitution of a consumer product that has a large water footprint by the same product that is derived from another source with smaller water footprint.

Ask product transparency from businesses and regulation from governments

Transparency along the supply chain



Reducing humanity's water footprint – Government

Embed water footprint assessment in national water policy making.

Promote coherence between water and other governmental policies: environmental, agricultural, energy, trade, foreign policy.

Reduce the own organizational water footprint:

- reduce the water footprint of public services.

Promote product transparency

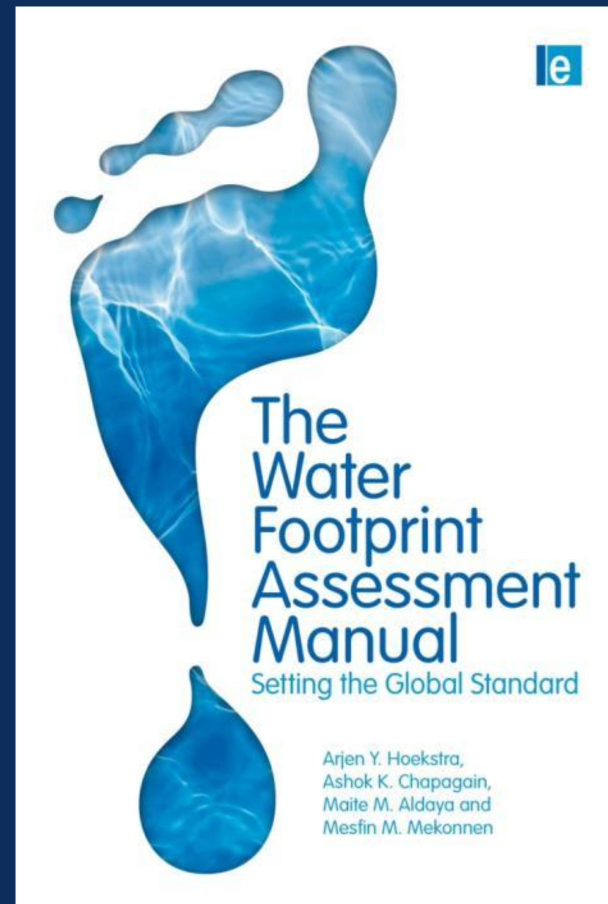
- support or force businesses to make annual water footprint accounts and to implement water footprint reduction measures.
- e.g. through promoting a water label for water-intensive products;
- e.g. through water-certification of businesses.

International cooperation

- international protocol on water pricing
- minimum water rights
- tradable water footprint permits
- water-labelling of water-intensive products
- water-certification of industries and retailers
- international nutrient housekeeping
- shared guidelines on water-neutrality for businesses

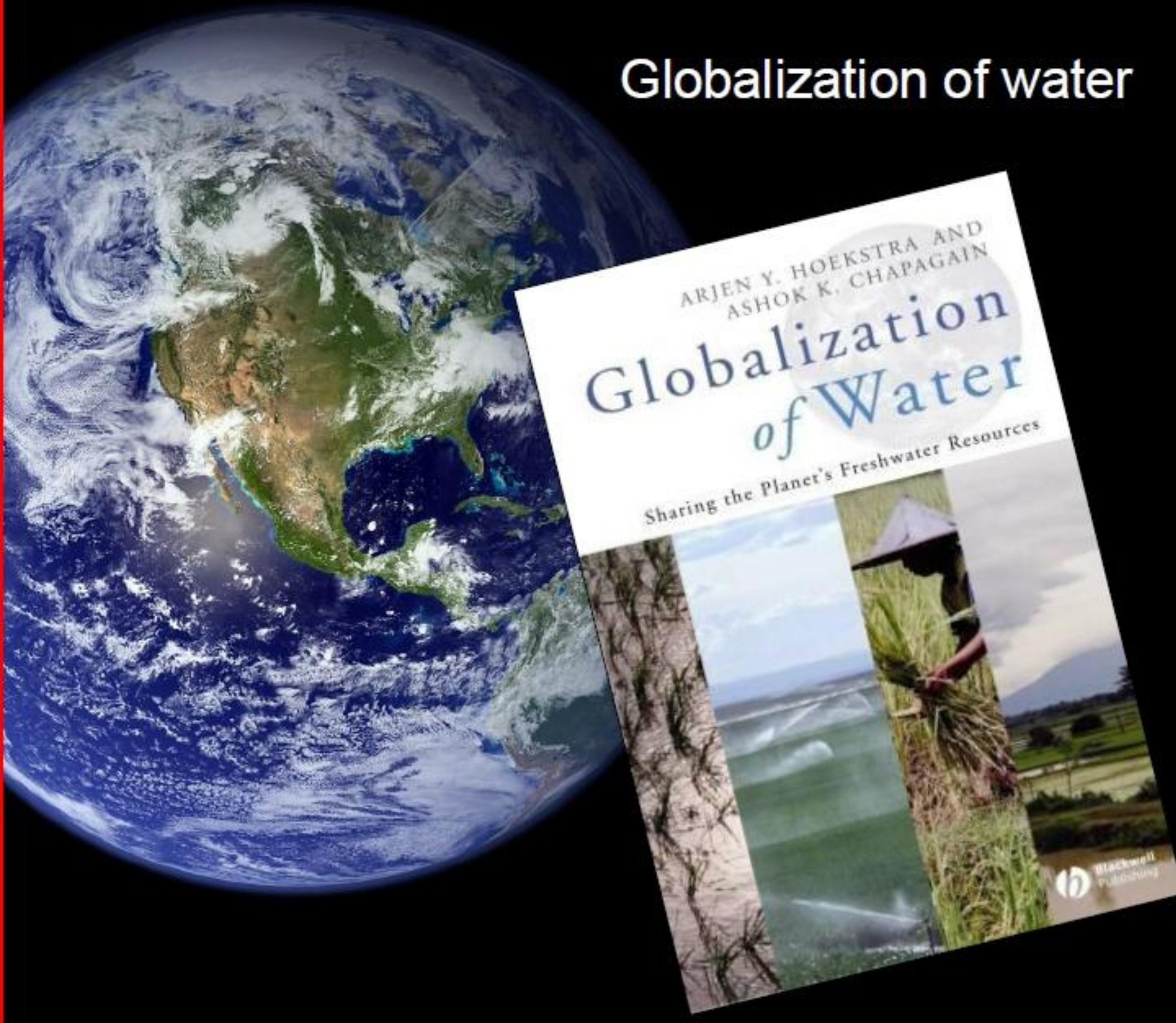
The Water Footprint Assessment Manual

Manual Nov. 2009



Manual Feb. 2011

Globalization of water



Water Footprint

Water Footprint NETWORK

Introduction

Introduction
Agenda
About WFN
Product Water Footprints
Your Water Footprint
National Water Footprints
Corporate Water Footprints
Global Water Footprint
Training Materials
Publications
Glossary
FAQ
Links
Contact

[Chinese] [Dutch] [French] [German] [Italian] [Spanish] [Turkish]

People use lots of water for drinking, cooking and washing, but even more for producing things such as food, paper, cotton clothes, etc. The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

Highlights of the site
Water footprint calculator
Product gallery

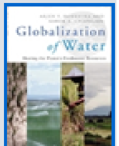
Press release World Water Day

UNEP joins the Water Footprint Network, working towards a globally shared water footprint standard, read more...

The relation between consumption and water use

"The interest in the water footprint is rooted in the recognition that human impacts on freshwater systems can ultimately be linked to human consumption, and that issues like water shortages and pollution can be better understood and addressed by considering production and supply chains as a whole," says Professor Arjen Y. Hoekstra, creator of the water footprint concept and scientific director of the Water Footprint Network. "Water problems are often closely tied to the structure of the global economy. Many countries have significantly externalised their water footprint, importing water-intensive goods from elsewhere. This puts pressure on the water resources in the exporting regions, where too often mechanisms for wise water governance and conservation are lacking. Not only governments, but also consumers, businesses and civil society communities can play a role in achieving a better management of water resources."

Water Footprint Manual
Practical guide on water footprint assessment



Globalisation of Water
Comprehensive book on water footprint and virtual water trade.

Key publications
Water Footprints of Nations
Water Footprint Bioenergy

Download other publications
List of publications

Waterfootprint.org: Water footprint and virtual water - Windows Internet Explorer

http://www.waterfootprint.org/?page=files/productgallery&product=coffee

Bestand Bewerken Beeld Favorieten Extra Help

Microsoft Outlook ... Waterfootprint.o...

Water Footprint

Water Footprint NETWORK

Product Gallery

- Introduction
- Agenda
- About WFN
- Product Water Footprints
- Your Water Footprint
- National Water Footprints
- Corporate Water Footprints
- Global Water Footprint
- Training Materials
- Publications
- Glossary
- FAQ
- Links
- Contact

Apple Barley Beef Beer Bread Cheese Chicken meat Coconuts

Productgallery

Coffee

Water footprint: 140 litres for 1 cup of coffee.

It costs about 21000 litres of water to produce 1 kg of roasted coffee. For a standard cup of coffee we require 7 gram of roasted coffee, so that a cup of coffee costs 140 litres of water. Assuming that a standard cup of coffee is 125 ml, we thus need more than 1100 drops of water for producing one drop of coffee. Drinking tea instead of coffee would save a lot of water. For a standard cup of tea of 250 ml we require 30 litres of water.

The world population requires about 120 billion cubic metres of water per year in order to be able to drink coffee. This is equivalent to 1.5 times the annual Rhine runoff and constitutes 2 % of the global water use for crop production.

Water Footprint

Water Footprint NETWORK

Your Water Footprint » Extended Calculator

Your individual water footprint is equal to the water required to produce the goods and services consumed by you. Please take your time and feel free to use the extended water footprint calculator to assess your own unique water footprint. The calculations are based on the water requirements per unit of product as in your country of residence.

Note: put decimals behind a point, not a comma (e.g. write 1.5 and not 1,5).

Select a Country

Food consumption

Cereal products (wheat, rice, maize, etc.)	kg per week
Meat products	kg per week
Dairy products	kg per week
Eggs	number per week
How do you prefer to take your food?	High fat
How is your sugar and sweets consumption?	High
Vegetables	kg per week
Fruits	kg per week
Starchy roots (potatoes, cassava)	kg per week
How many cups of coffee do you take per day?	cup per day
How many cups of tea do you take per day?	cup per day

Domestic water use