
Failing Water Management
Alexander J.B. Zehnder
Sustainable Earth Office NTU

Central role of water in religions and beliefs

Examples in alphabetical order

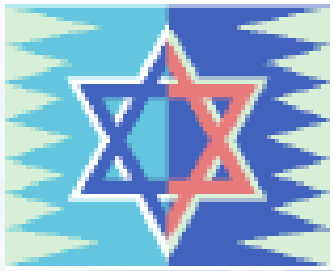
Animism

Buddhism

Christianity

Hinduism

Islam



Judaism

Shinto

Taoism

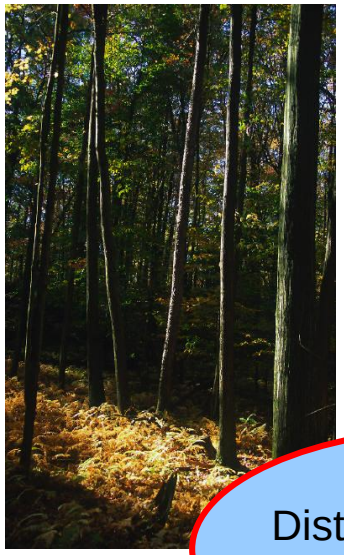
Zoroastrianism

…and many more

6 great challenges in the water area

Good water quality for a growing population

Water infrastructure (distribution & collection)



Water induced disasters
Disaster protection

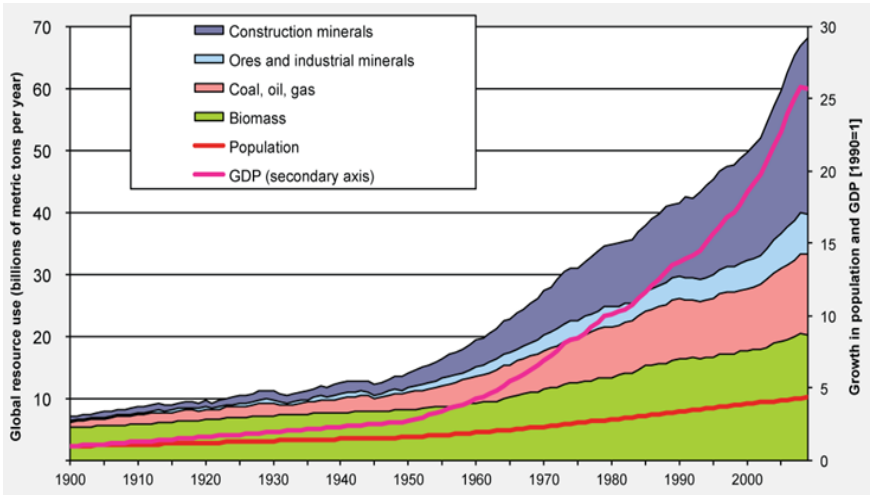
Distribution between humans and ecosystems

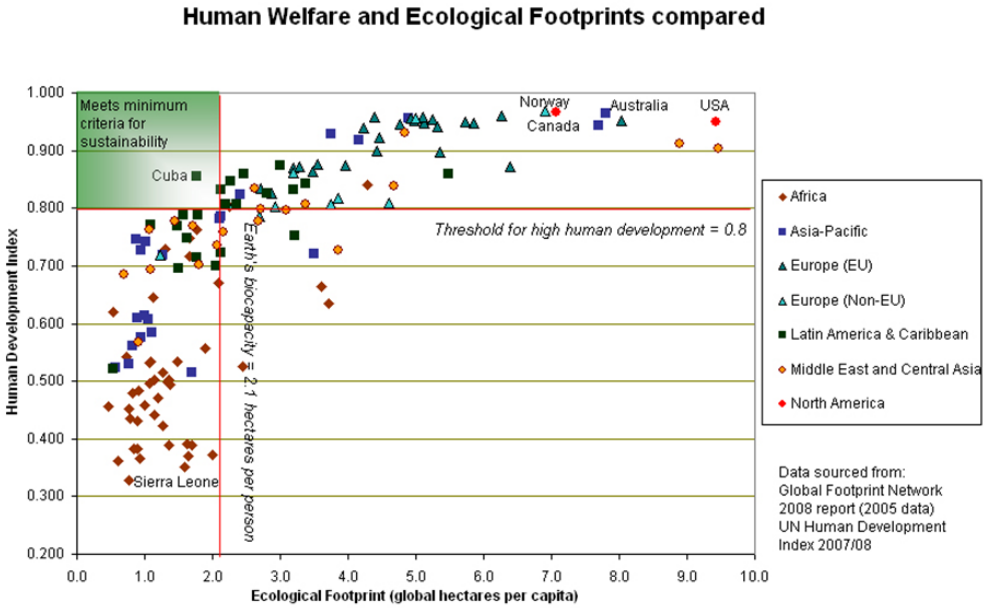
Enough food for all

Solution for water conflicts and fair water share for all

What are the triggers of these challenges (1)?

1. Demographic trajectory





- Increasing number of people are consuming limited resources
- Resource consumption leads to emissions & waste

What are the triggers of these challenges (2)?

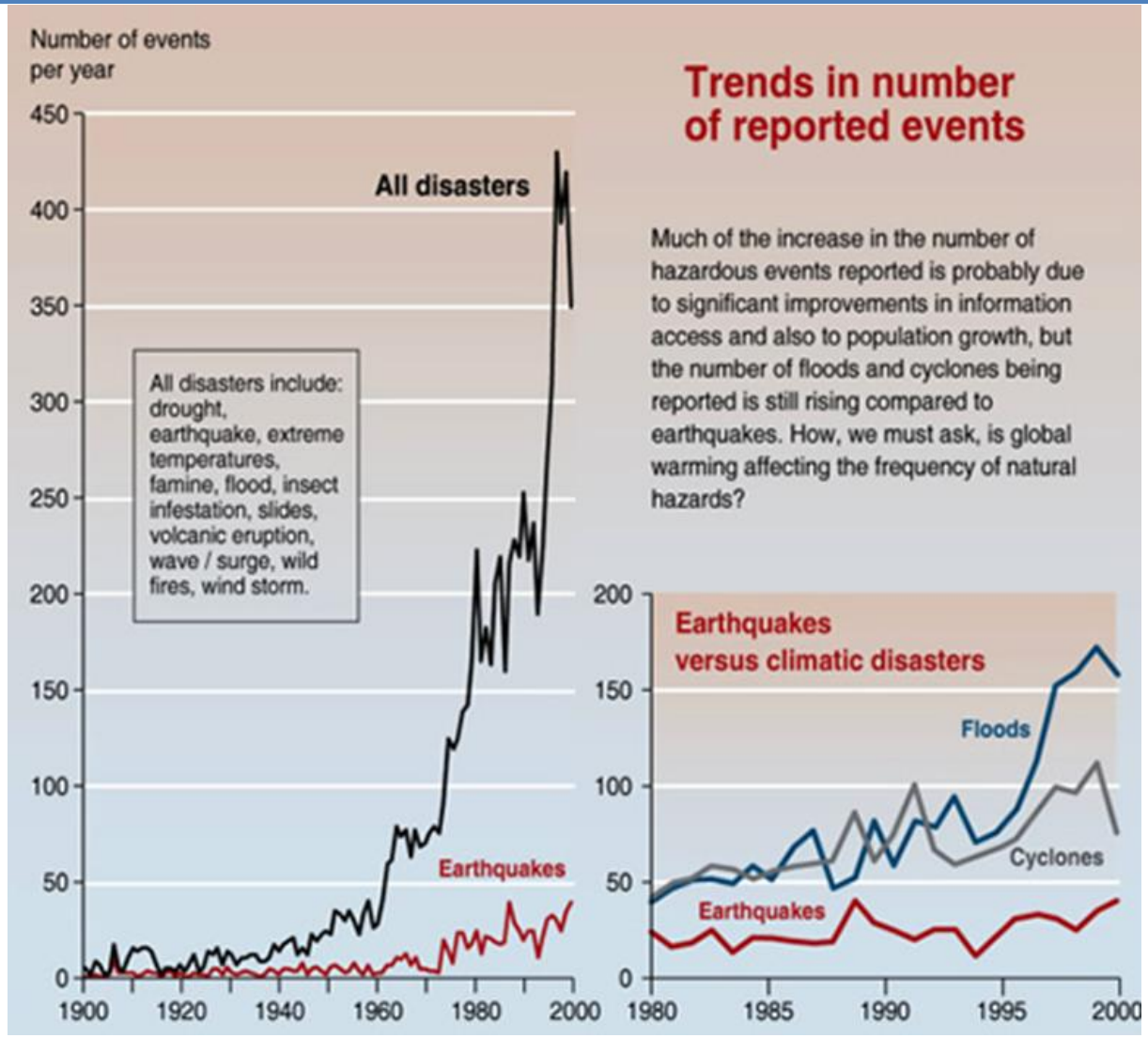
2. Climate Change

Climate change, particularly global warming affects predominantly
the dynamics, quantity and quality of the global, regional & local hydrological cycles, water systems & water bodies

Primarily affected by the alterations of the hydrological cycles are:

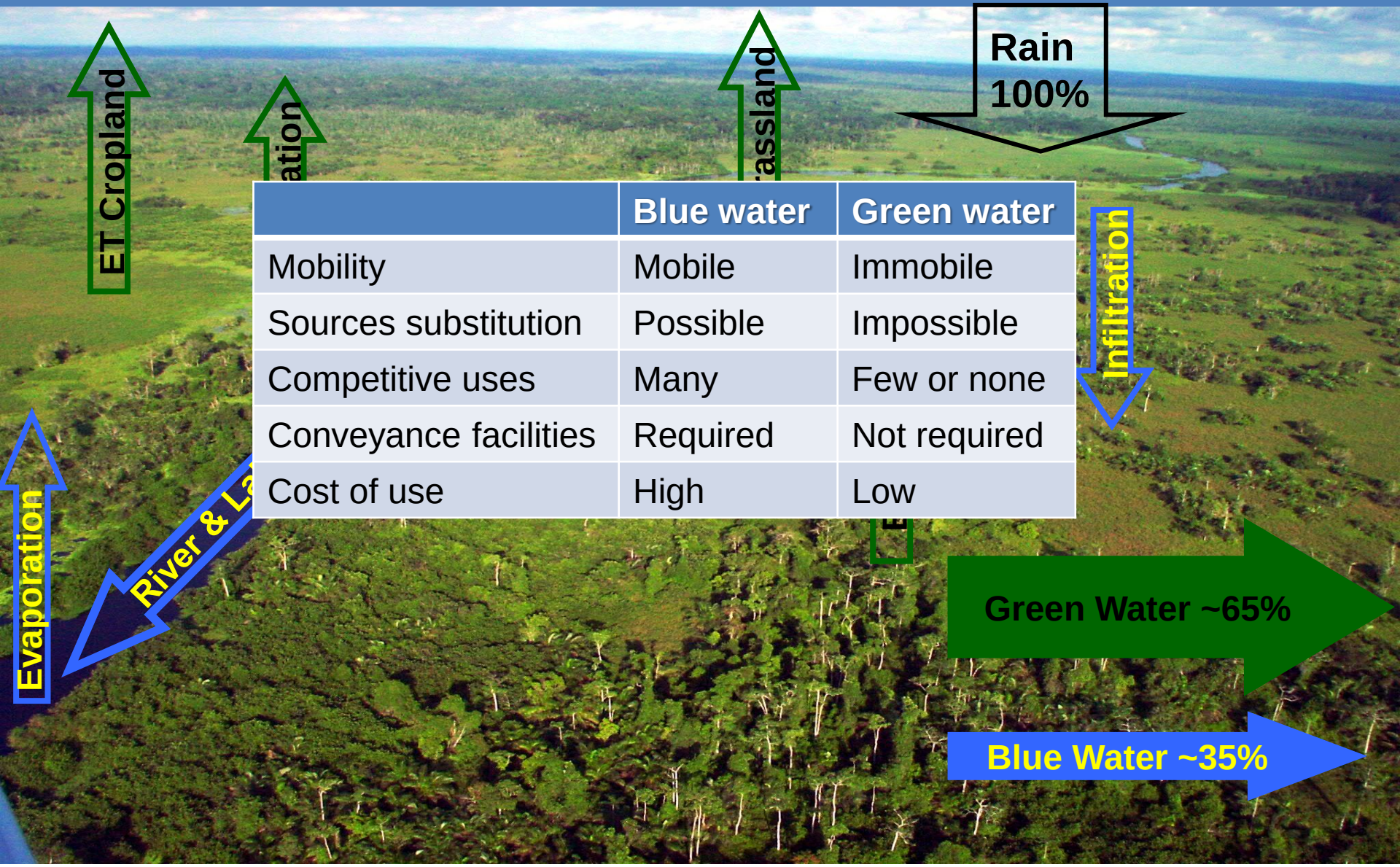
- Agriculture, forestry & fisheries
- Cities & rural areas
- Human health
- Coastal zones
- General infrastructures
- Natural ecosystems
- Tourism & recreation

Climate change related water events



UCAR 2015

Blue and green water



	Blue water	Green water
Mobility	Mobile	Immobile
Sources substitution	Possible	Impossible
Competitive uses	Many	Few or none
Conveyance facilities	Required	Not required
Cost of use	High	Low

Annual water requirement per person

Sufficient	**> 1700 m^3**
Water stress	**1000 - 1700 m^3**
Scarcity	**500 - 1000 m^3**
Extreme scarcity	**< 500 m^3**

From Falkenmark & Widstrand, 1992

Water requirements for people, services, and industry

Purpose	Daily requirements liter/person	Annual requirements m^3/person
Drinking water	**3 - 9**	**1 - 3**
Personal hygiene, sanitation, and cooking	**30 - 50**	**11 - 18**
Other household needs	**80 - 250**	**30 - 90**
Services	**20 - 400**	**8 - 140**
Industries	**20 - 400**	**8 - 140**

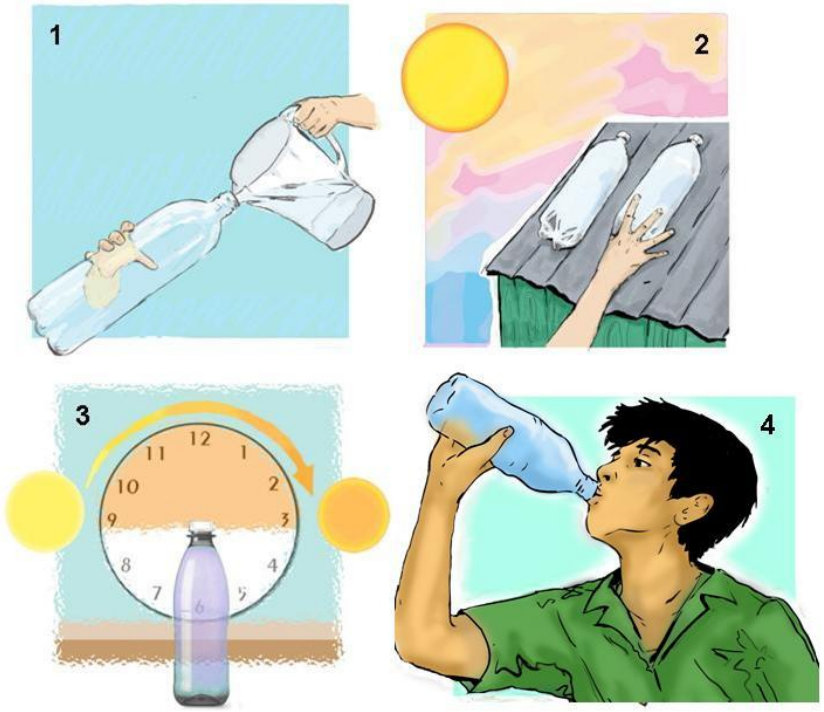
Social good and "human right"

Economic good

From Zehnder *et al.* 2003

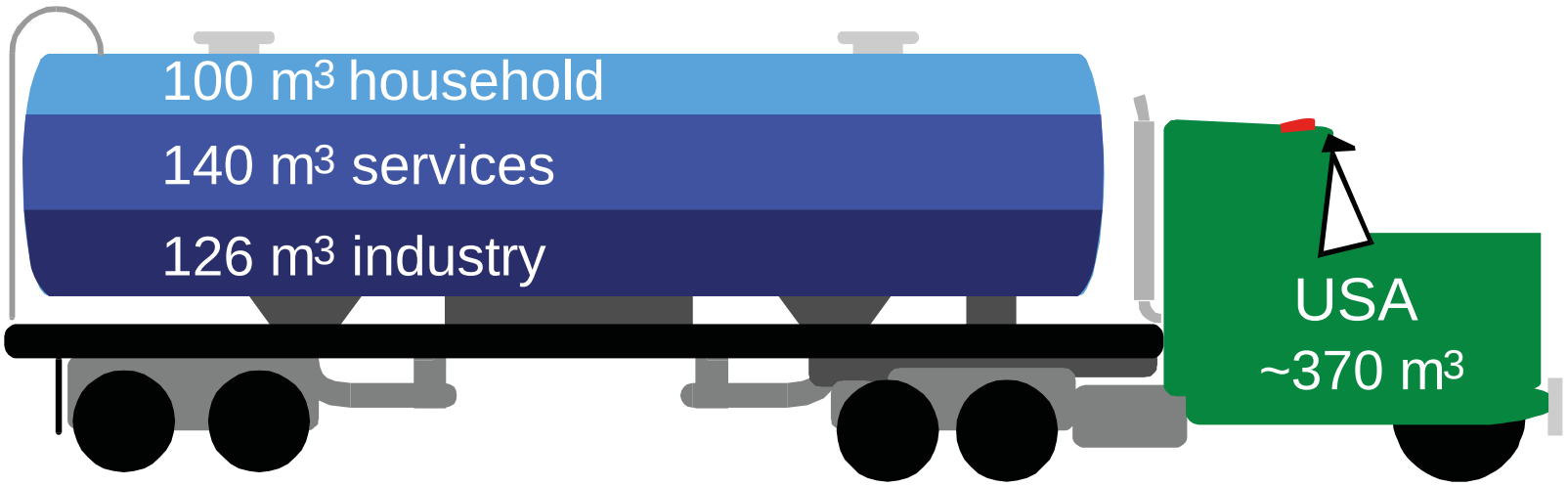
Drinking water treatment

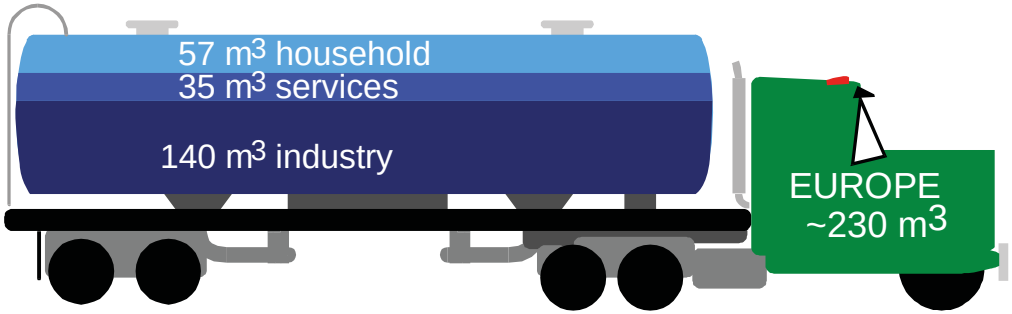
From:
Solar Water Disinfection (SODIS)



To:
sophisticated membrane treatment

Annual water use per capita in different geographical areas





(average 2002–2012)

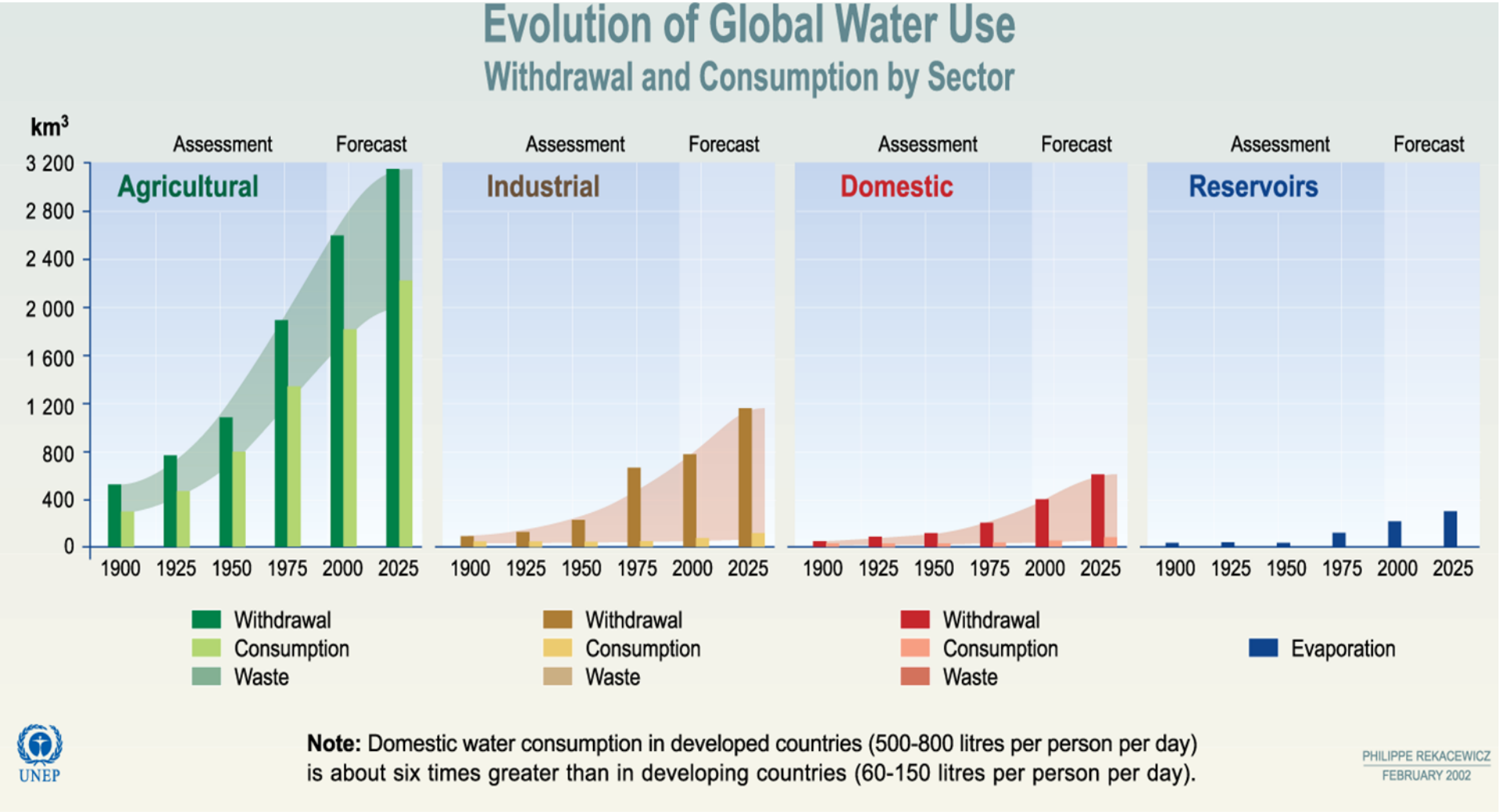
Industry, excl. thermoelectric power

AFRICA

12 m3 household
8 m3 services
7 m3 industry

From Aquastat FAO and USGS, 2014

Estimated annual world water use total and by sector 1900–2025



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999.

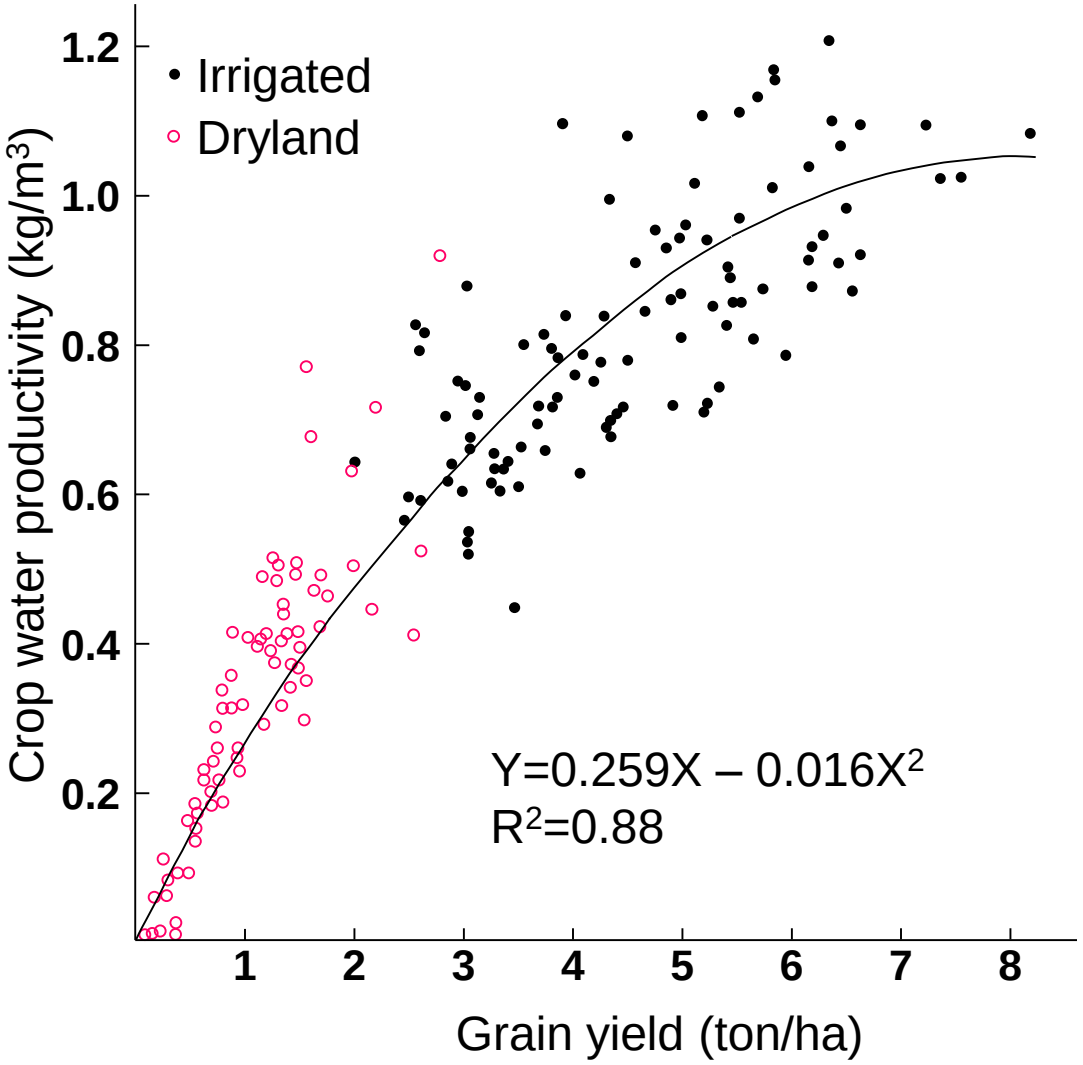
Irrigated crop water productivity

Crop	No. of studies	Median per study kg/m^3	Overall median kg/m^3
Wheat	30	0.58 – 2.23	1.06
Rice	14	0.46 – 1.84	0.89
Maize	29	1.01 – 2.92	1.78

Data are from studies from 1996 to 2011

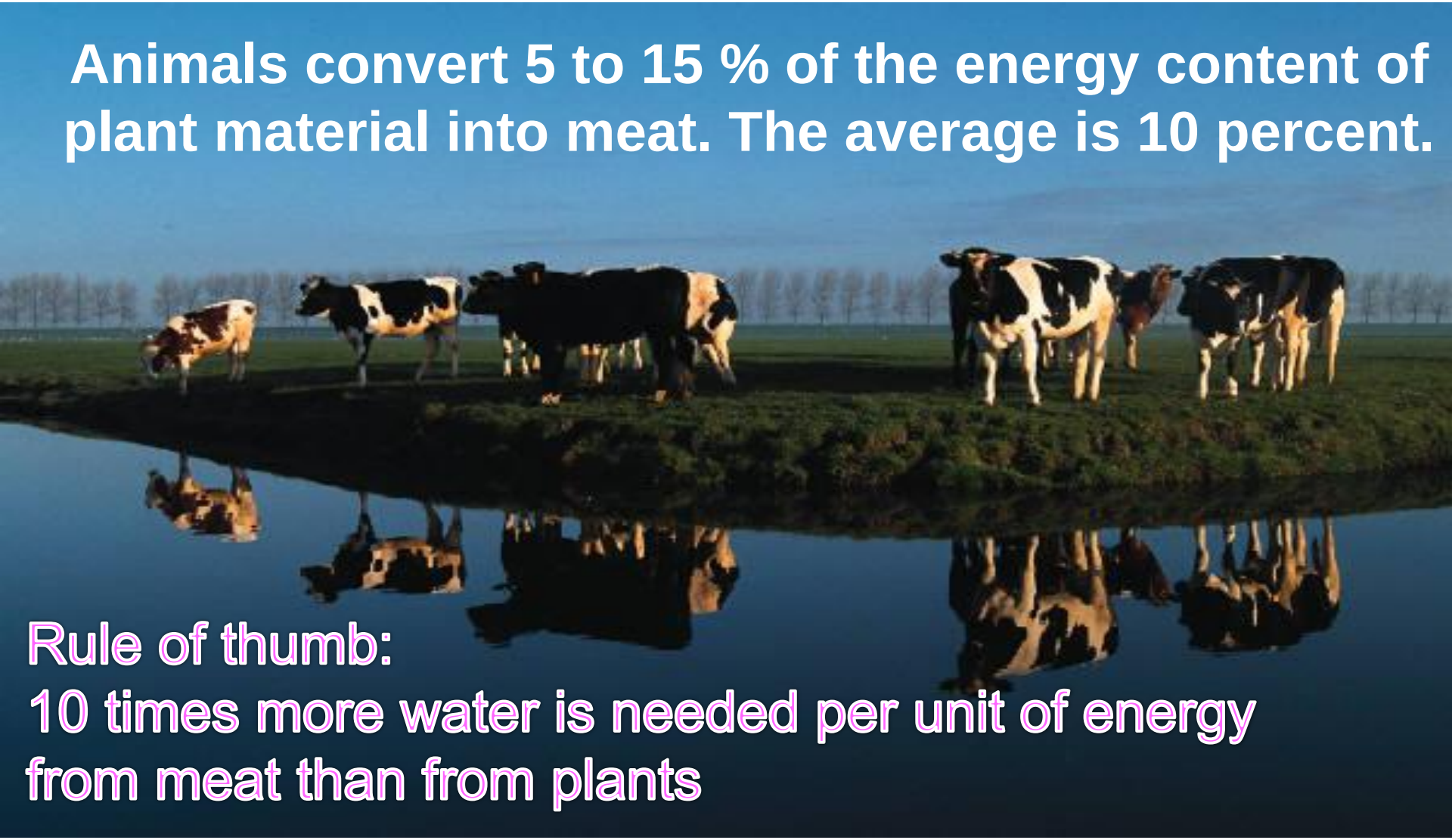
Rule of thumb:
For 1kg of bread 1m^3 water is needed

Relationship of crop water productivity (cwp) to grain yield



From Musick *et al.* 1994

Meat production

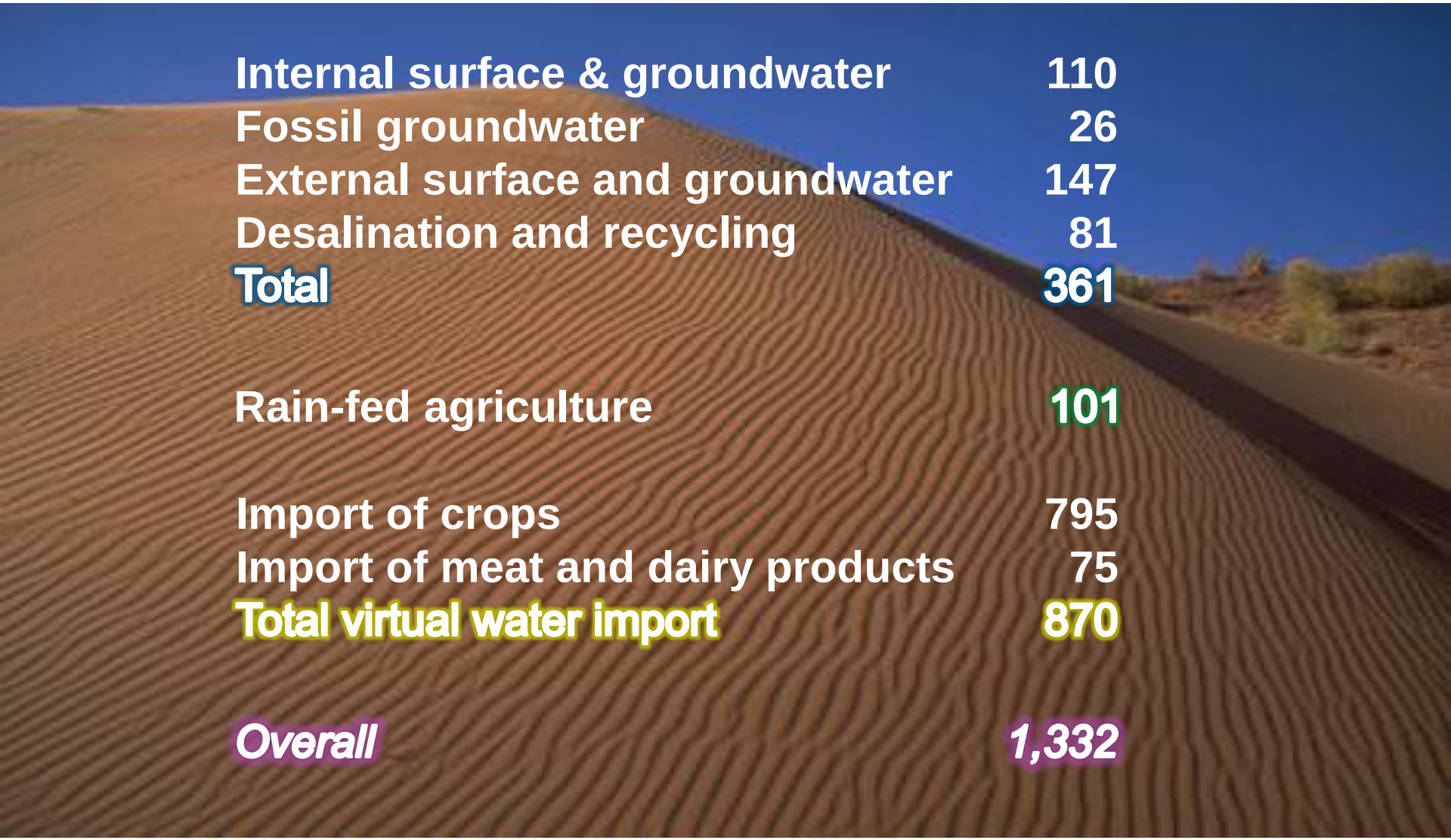


Animals convert 5 to 15 % of the energy content of plant material into meat. The average is 10 percent.

Rule of thumb:
10 times more water is needed per unit of energy from meat than from plants

Annual per capita water needs for food to cover 2500 kcal a day

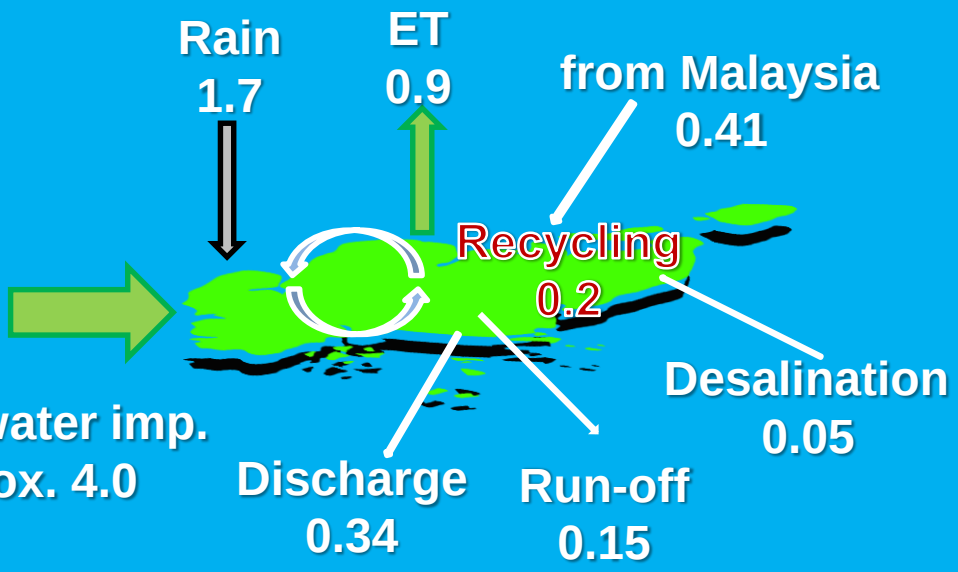
Water availability in Israel in cubic meter per person and year (average 2000–2009)



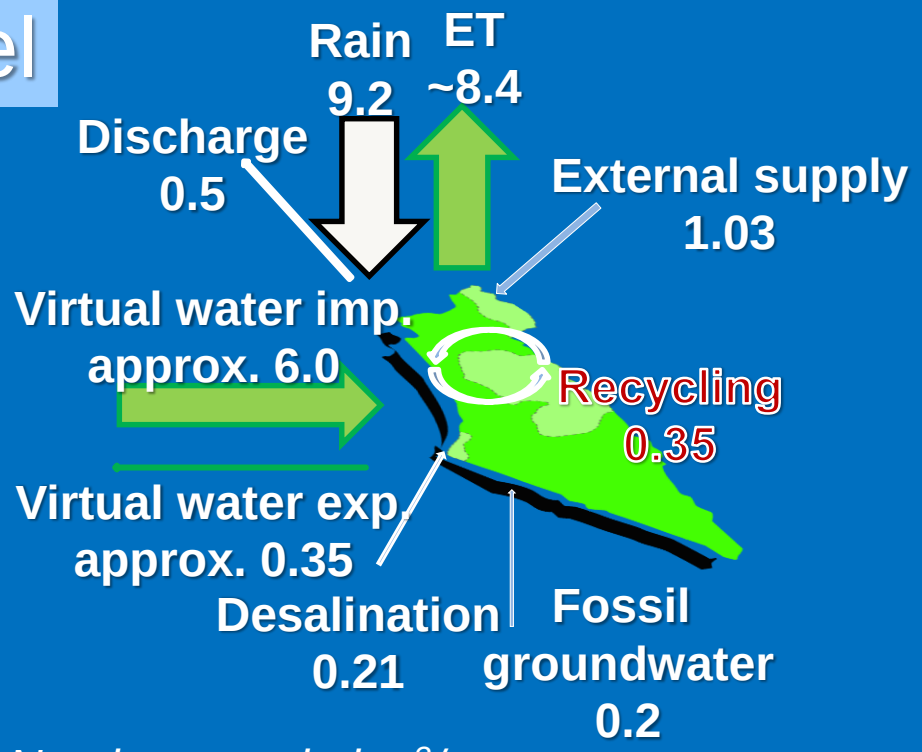
Internal surface & groundwater	110
Fossil groundwater	26
External surface and groundwater	147
Desalination and recycling	81
Total	**361**
Rain-fed agriculture	101
Import of crops	795
Import of meat and dairy products	75
Total virtual water import	**870**
Overall	***1,332***

From: Aquastat FAO, FAOstat WRI, Yang *et al*., 2007 and Liu *et al*., 2009

Singapore

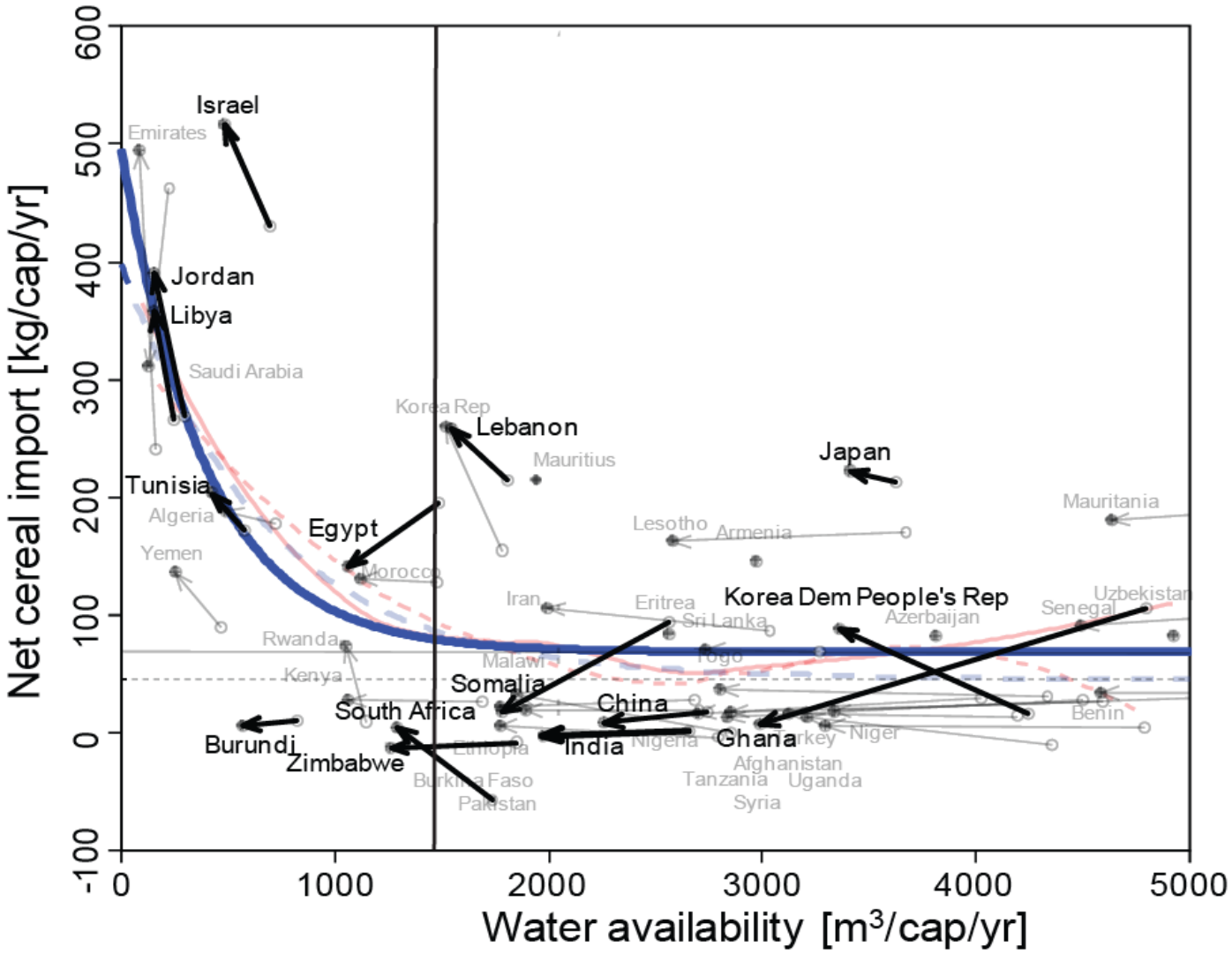


Israel



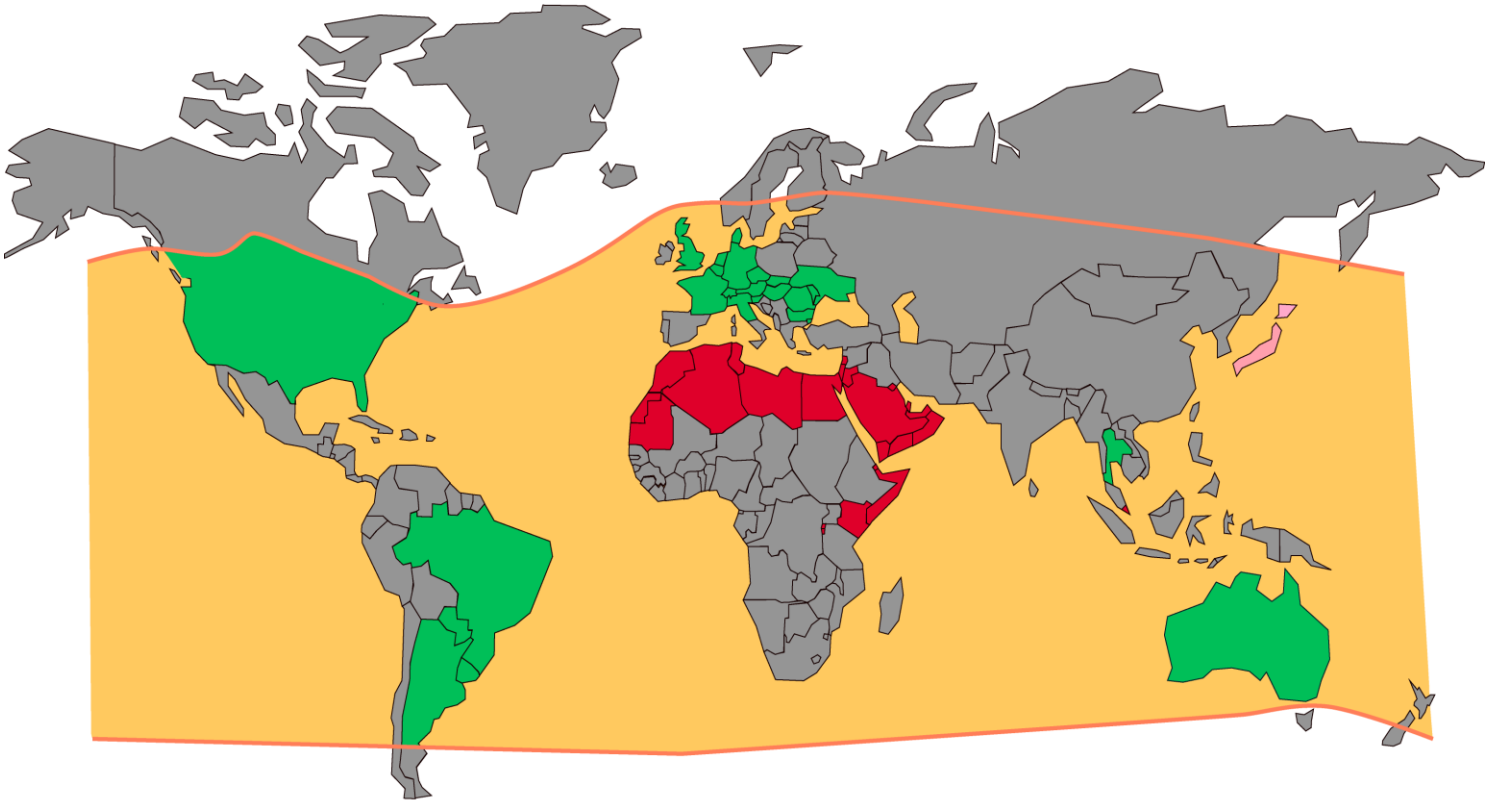
Numbers are in km³/yr

Water availability and cereal import comparison between 1980–84 and 1995–99



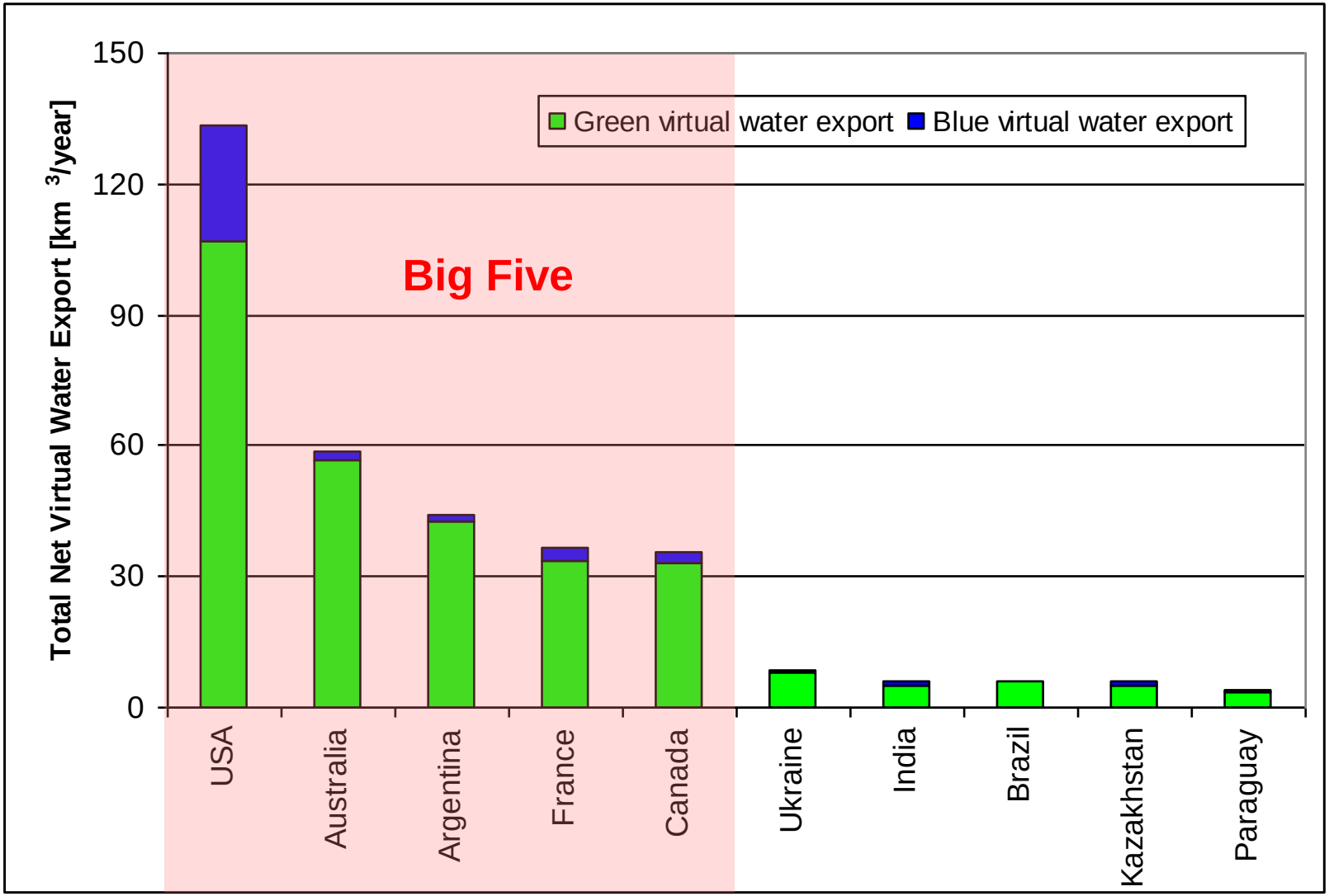
Adapted from Yang *et al.* 2003

Situation 2000



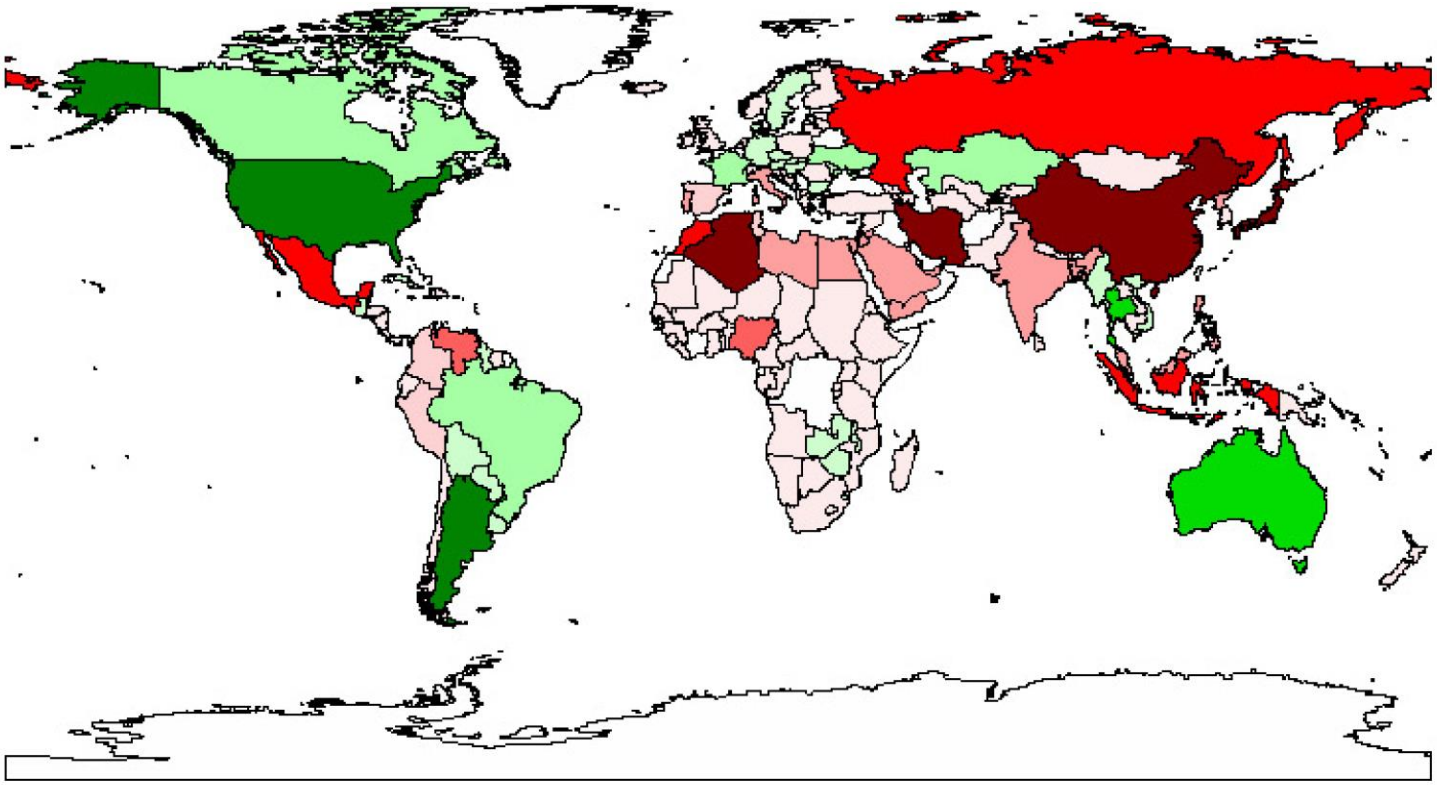
From Zehnder, 2002

Virtual water export



From Liu *et al.* 2009

Net virtual water trade by country (average over the period 2000–2006)

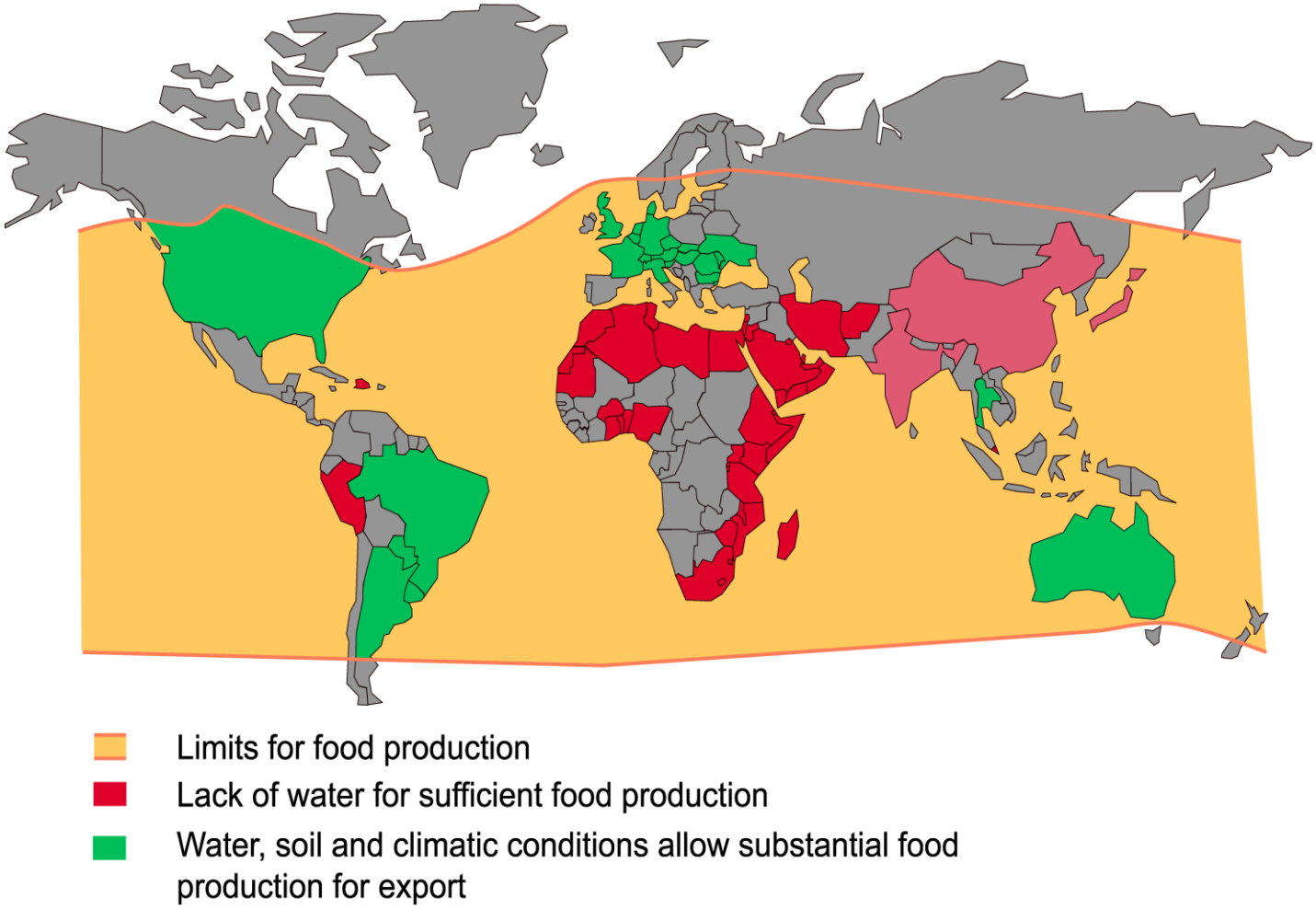


Unit: cubic km

no data	-15 - 0	15 - 20
-100 - -50	0 - 5	20 - 30
-50 - -25	5 - 10	30 - 60
-25 - -15	10 - 15	

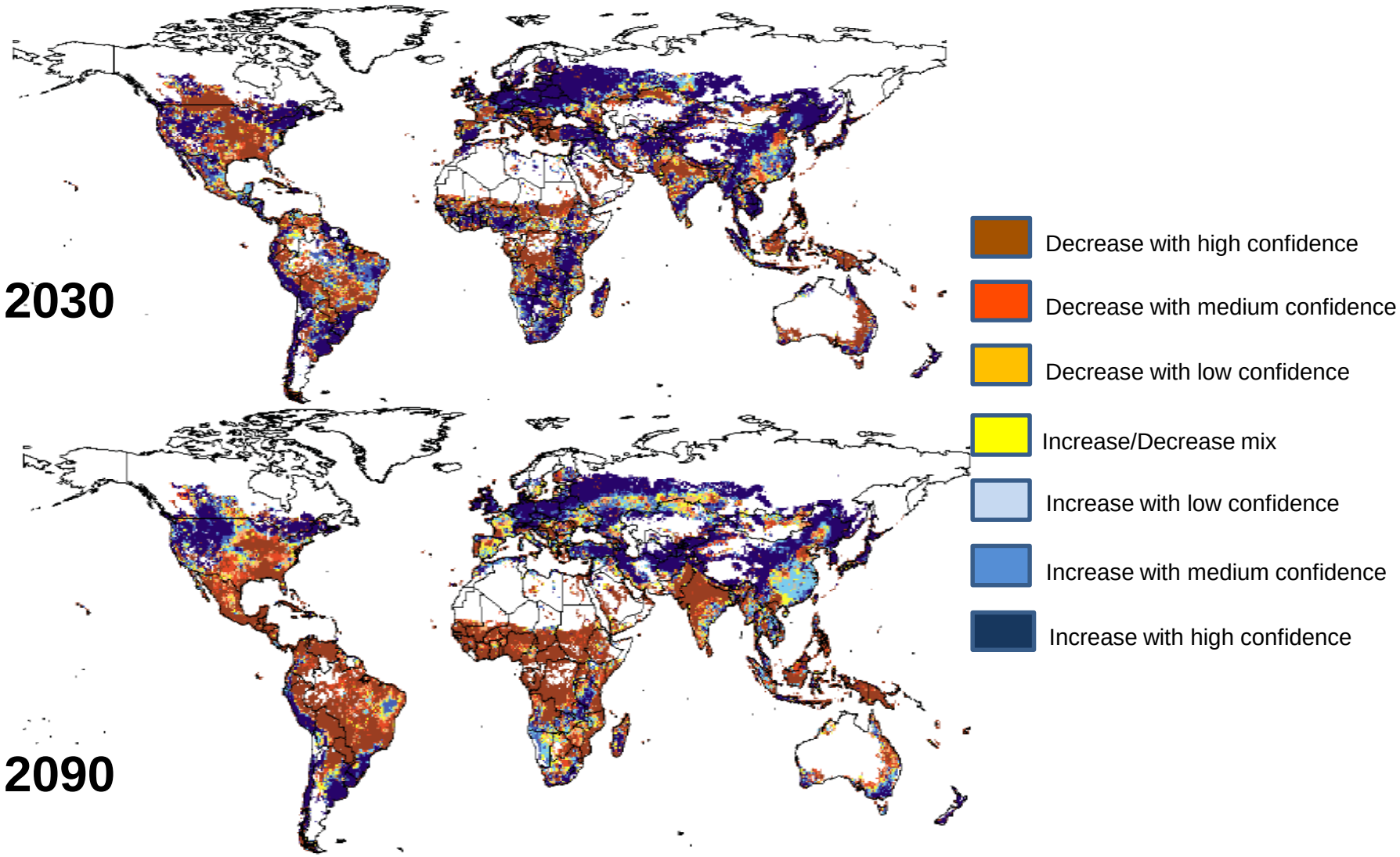
From Yang *et al.* 2007

Situation 2030



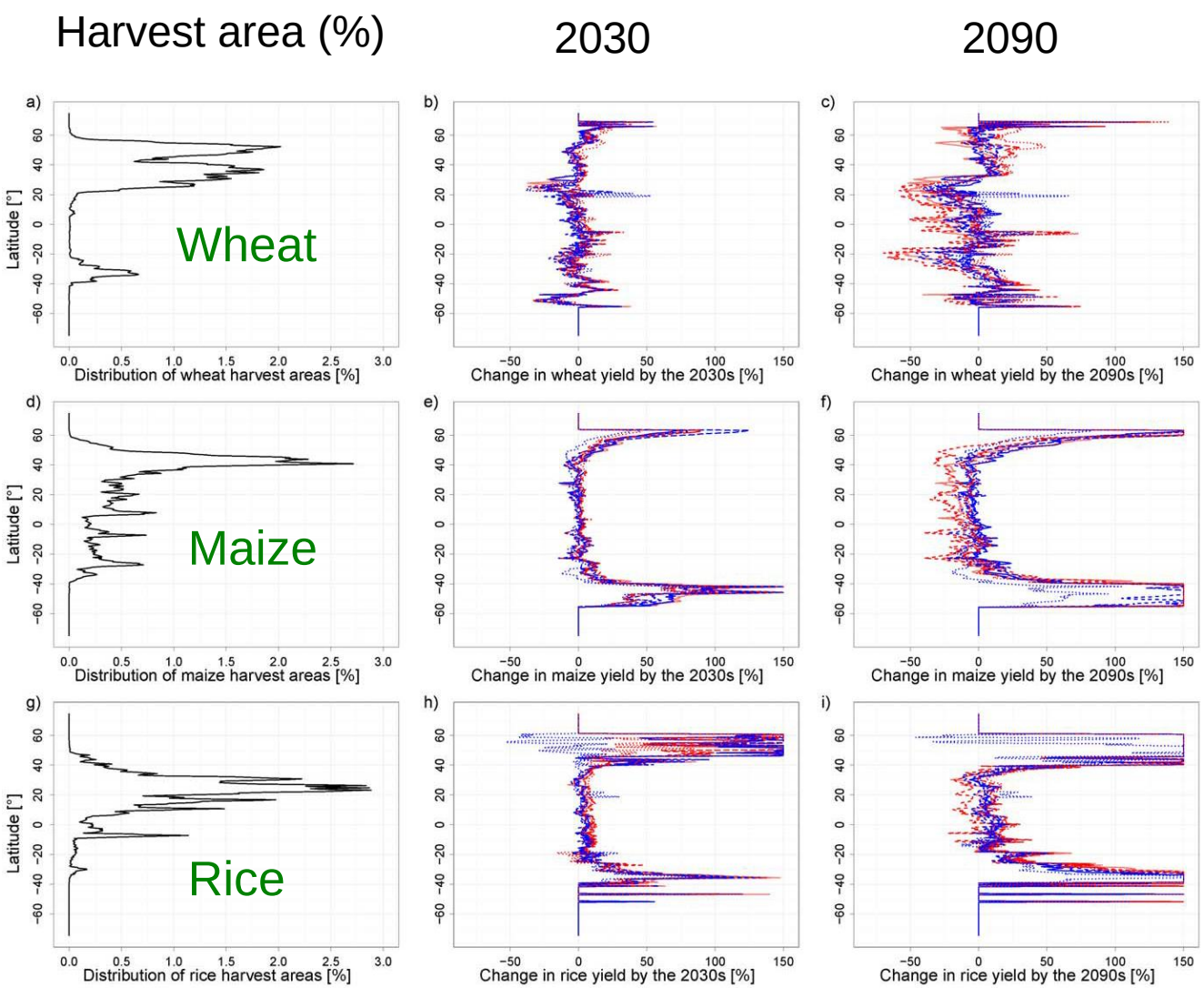
From Zehnder, 2002

Impact of climate change on crop production (wheat, maize & rice)



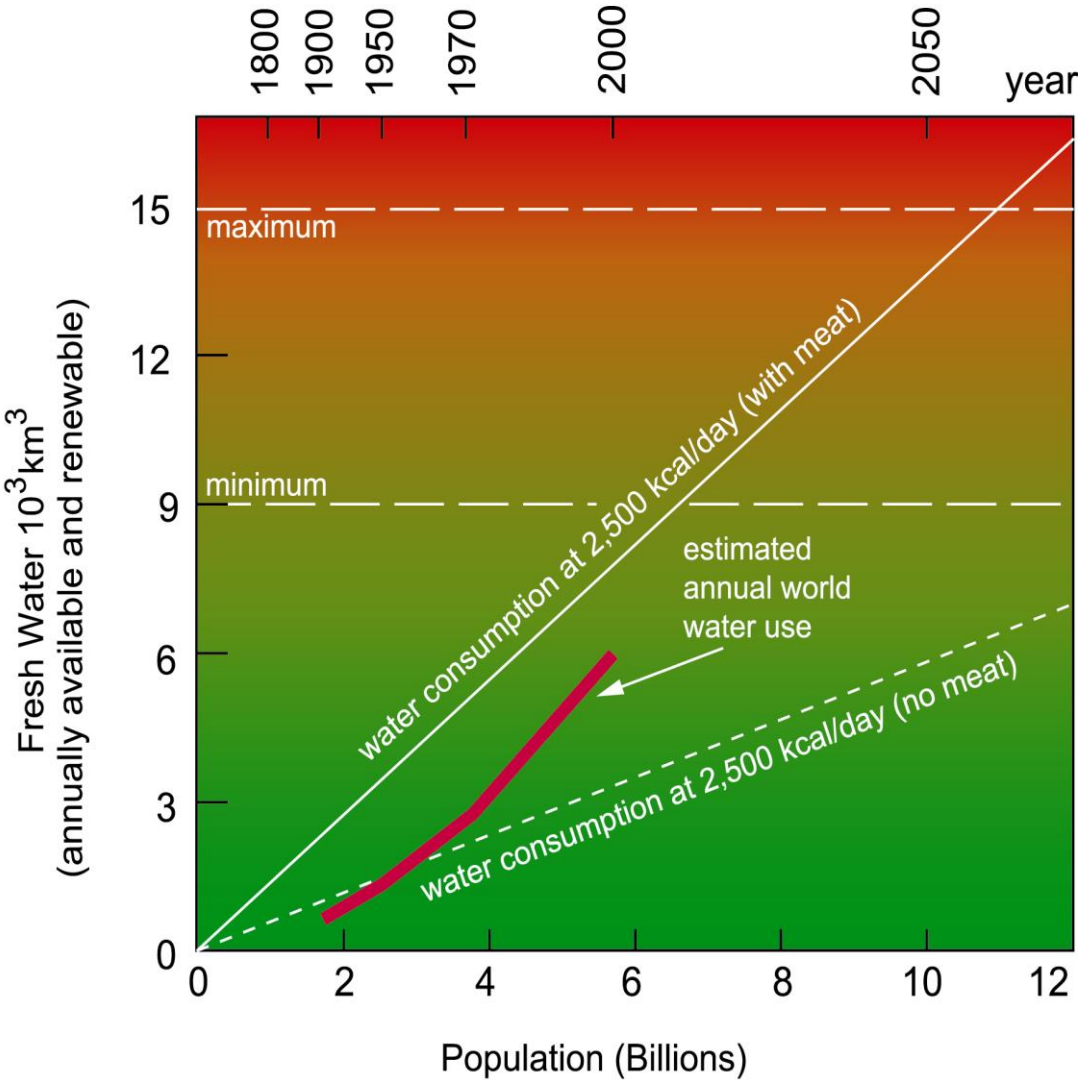
Liu *et al*. 2013

Change in crop yield



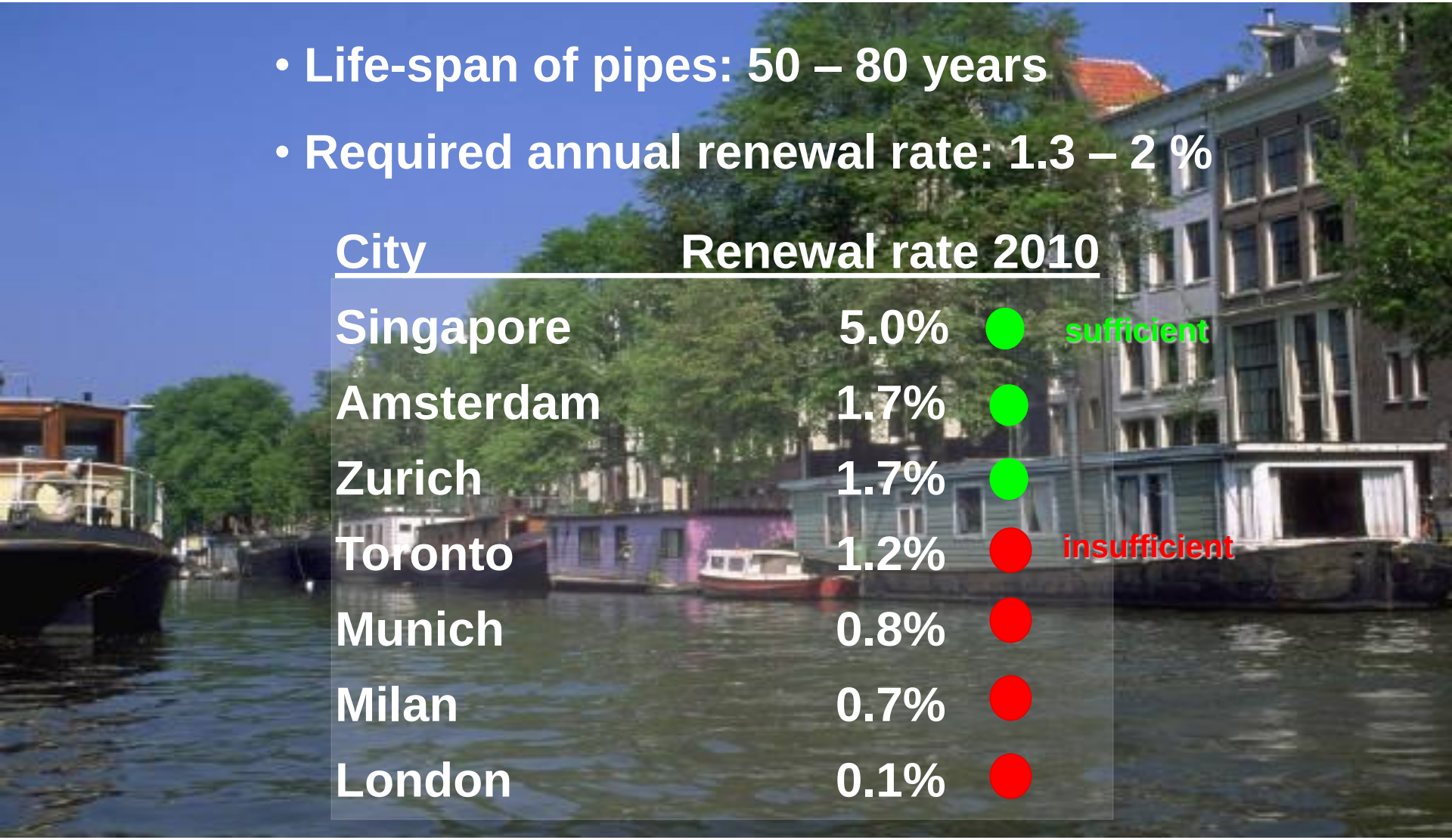
Liu *et al*., 2013

Projection of water availability



From Zehnder, 1999

Ageing of infrastructure



- **Life-span of pipes: 50 – 80 years**
- **Required annual renewal rate: 1.3 – 2 %**

City	Renewal rate 2010	
Singapore	5.0%	sufficient
Amsterdam	1.7%	
Zurich	1.7%	
Toronto	1.2%	insufficient
Munich	0.8%	
Milan	0.7%	
London	0.1%	

Future investments into the water sector

China: 50 Billion US$ in the coming 10 years for wastewater treatment

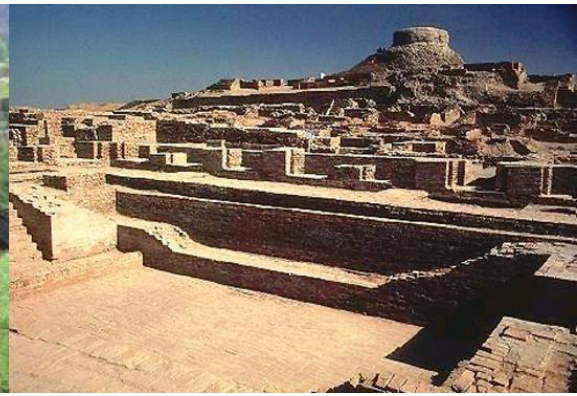
USA: "Water Infrastructure Now": Annually an of addition 30 billion US$ just to keep the water infrastructure running

EU: 200 billion € needed in next 10 years, in order to obey current regulations

CH: 150 billion CHF in the next 20 years for renewal of the water infrastructure

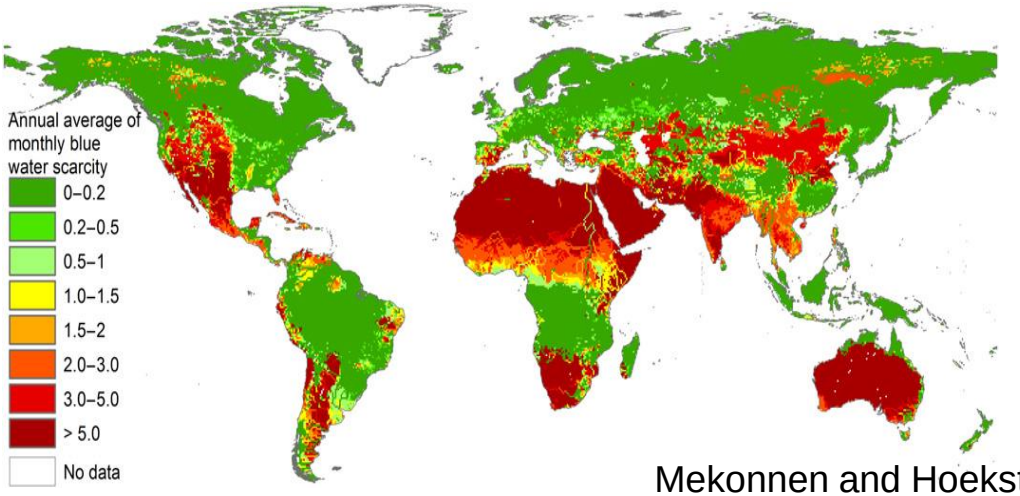
First know water works (approx dates)



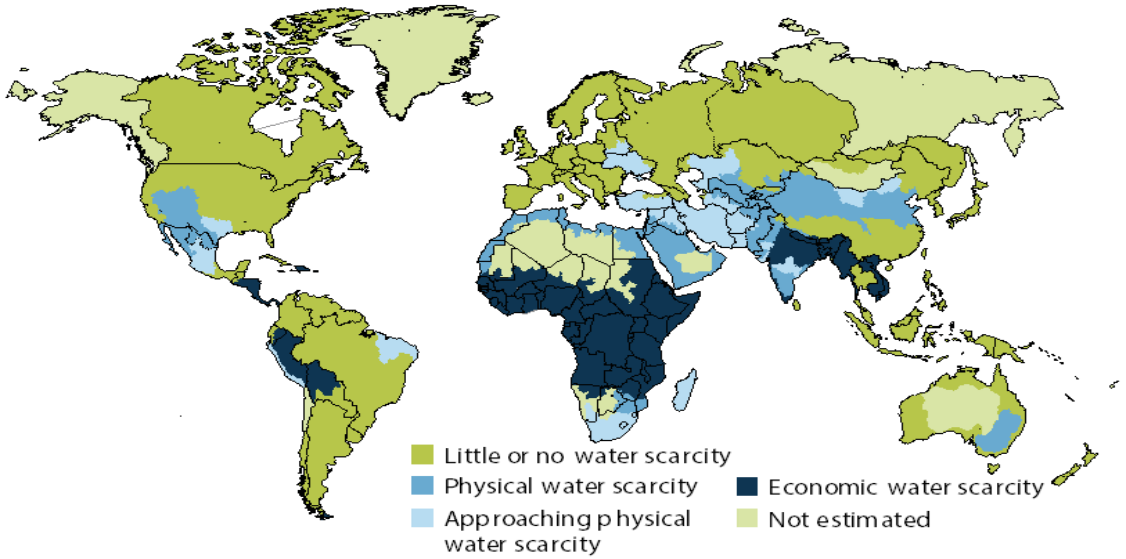



Mesopotamia	8500 BP
River Nile	7000 BP
Andean Cordilleras	6000 BP
Mesoamerica	6000 BP
Indus Valley	5500 BP
China	4000 BP
Persia	3500 BP
Arizona/New Mexico	3000 BP

Physical and economic water scarcity

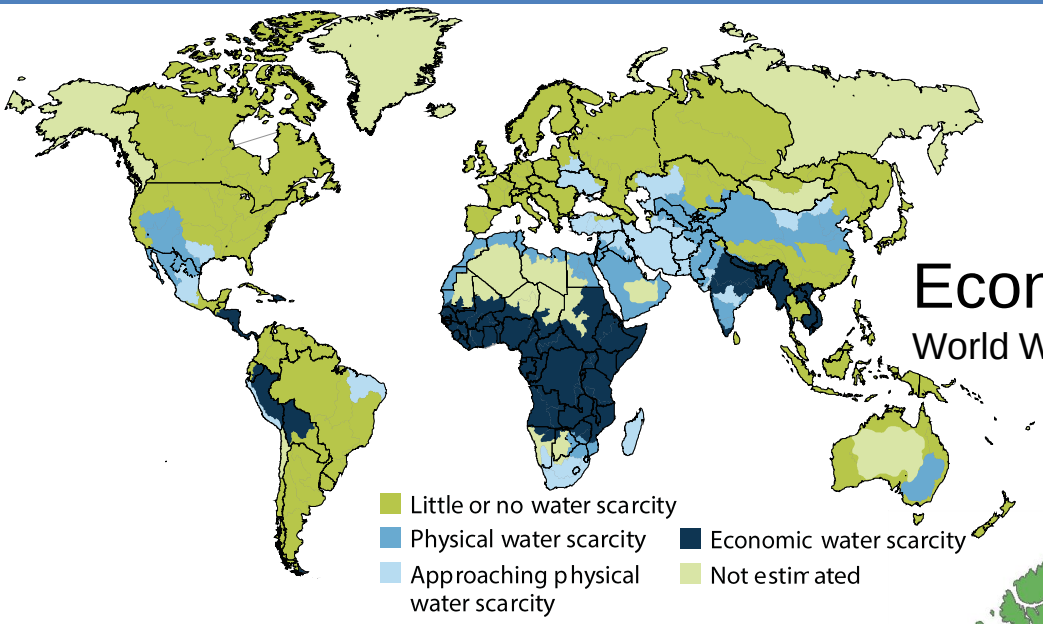


Mekonnen and Hoekstra, 2016



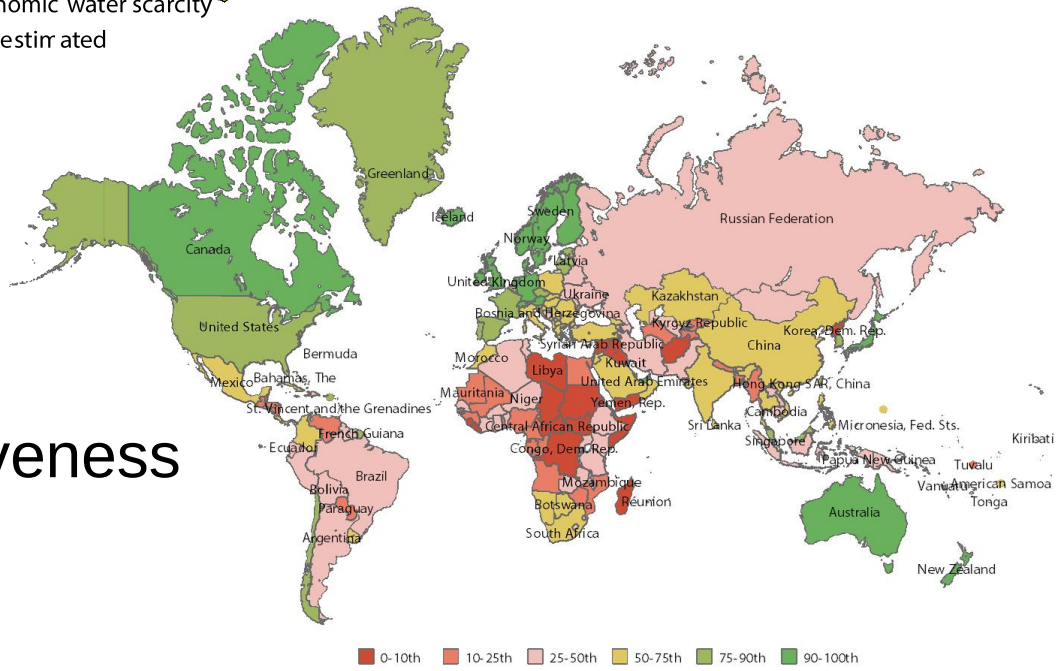
World Water Development Report 4, 2012

Management failure



Economic water scarcity

World Water Development Report 4, 2012



Government effectiveness

Kaufmann and Kraay, 2015

Final thoughts

1. Water is *one* of the great challenges of the 21st century. Its effects go from local to global.
2. Technologies are available to solve water quality issues; the relation between water, food, and climate change is sufficiently clear to allow actions.
3. A lack of local, national, regional and global governance effectiveness makes water challenges to persist or even aggravate.
4. Water issues are emotional; they trigger at first scepticism against new solutions, technologies and those who implement them. Intellectual arguments will rarely change opinions.
5. Water is the prime portfolio of Gods and kings because of the difficulties with the effectiveness and the fact that water issues are emotional.

The Economist

Water

The dry facts

Water is scarce because it is badly managed

Nov 5th 2016