LINKING WATER RESOURCES TO FOOD SECURITY THROUGH VIRTUAL WATER

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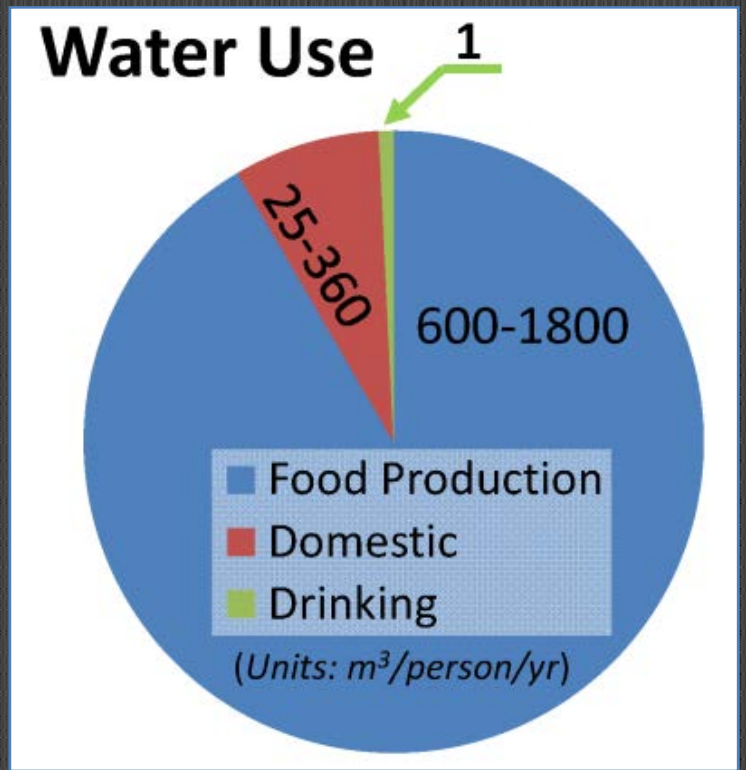
Societal use of water

Water is used for two major purposes:

- Meeting hygienic, health and economic requirements
- Producing food and other biomass



Freshwater used in 2010 for food production exceeded **10'000 km³** with an increase of 50% in 25 years (6'600 km³ in 1986)

… but NO awareness!

(Falkenmark,& Rockstrom 2004)

Overview

- (Use of water)
- Introduction to virtual water
- Food security framework
- Virtual water trade
- Open questions and way forward

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MILESTONES

The **VIRTUAL WATER CONTENT** of a good is the amount of freshwater necessary for its production

(AKA *embedded water* or *hidden water*)

THE IDEA (J.A. Allan, 1993): "Middle Eastern states survive through large quantities of food imports, thus the region does not depend on its own scarce water resources but purchases water embedded in agricultural products."

THE REALIZATION (A.Y. Hoekstra, 2002): "Clean fresh water is a scarce good with high economic value and thus should be treated economically. There is an urgent need to develop appropriate concepts and tools to do so."

The **WATER FOOTPRINT** is a geographically-explicit indicator of the direct and indirect water use associated to the production/consumption of a good

Examples –VW–

=
70 litres

=
120 litres

=
140 litres

=
2000 litres

- Very different from physical water content
- Not only food , but all agricultural products (textiles, biofuels)
- Animal products have large contents because of high forage volumes and low product fraction

On average, each person consumes (eating)
4000 litres per day of virtual water

Components of the water footprint

- GREEN WATER:
soil water coming from rainfall

- BLUE WATER:
water from surface/groundwater

- GREY WATER:
indicator of freshwater pollution

EXAMPLES –WF–

Product	Country	Green (m^3/t)	Blue (m^3/t)	Grey (m^3/t)	TOTAL (m^3/t)
Rice	Cina	549	246	215	1010
	India	1394	452	224	2070
Wheat	USA	522	63	176	762
	Cina	791	74	295	1160
Soy	USA	1560	92	10	1662
	Brasil	2181	1	15	2197

(data from Mekonnen and Hoekstra, 2010)

Factors influencing the water footprint:

- climatic conditions (ET rate, rainfall) - Rice
- agricultural practices and technologies - Soy
- sustainable use of water resources (irrigation, pollution) - Wheat

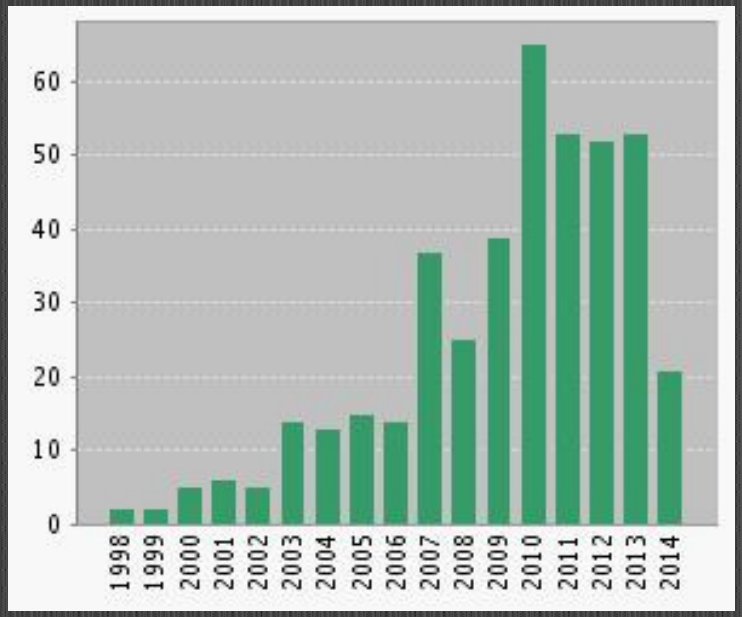
VIRTUAL WATER and WATER FOOTPRINT allow to assess THE IMPACT of FOOD/GOODS on WATER RESOURCES

GROWING INTEREST

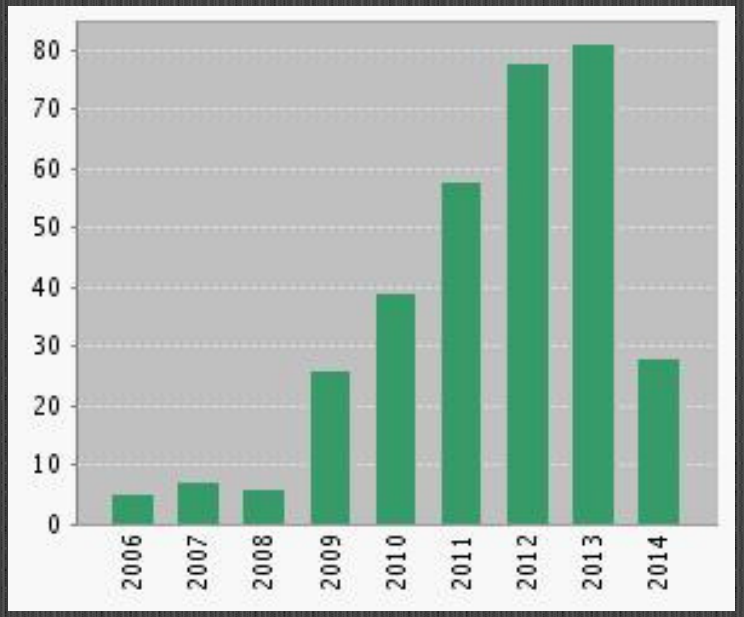
Models for *virtual water* quantification and *water footprint* assessments are growing across the scientific literature

- Number of papers published (WoS) having keywords:

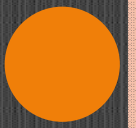
"Virtual Water"



"Water Footprint"



FOOD SECURITY



Food security

UN – FAO's definition (*World Food Summit*, 1996):

1) AVAILABILITY of sufficient quantities of food of appropriate quality.

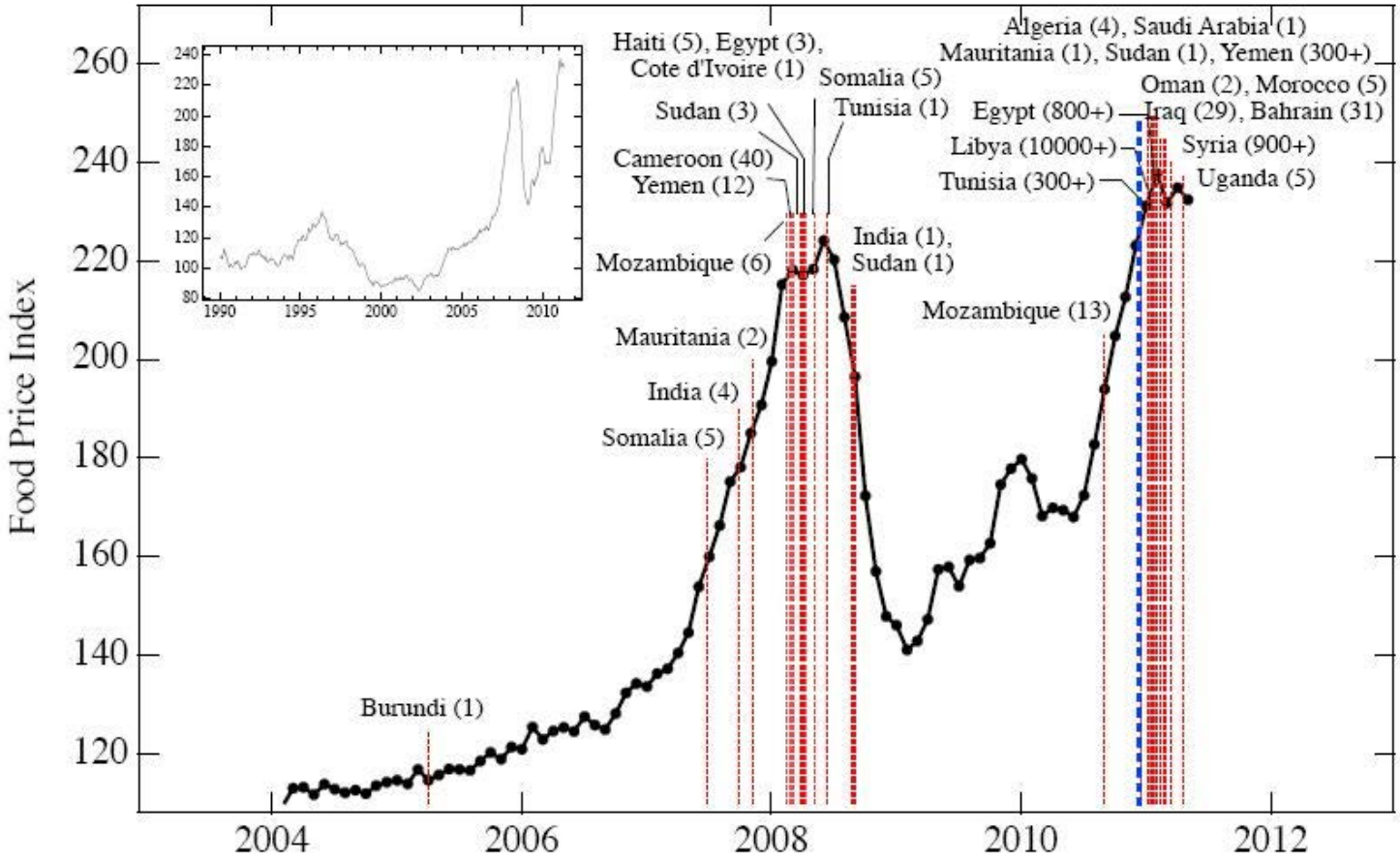
2) ACCESS to adequate resources for acquiring food for a nutritious diet.

3) ADEQUACY of food use to meet all physiological needs (clean water, sanitation and healthcare)

4) STABILITY

Food security (2)

When food availability and food access decrease…



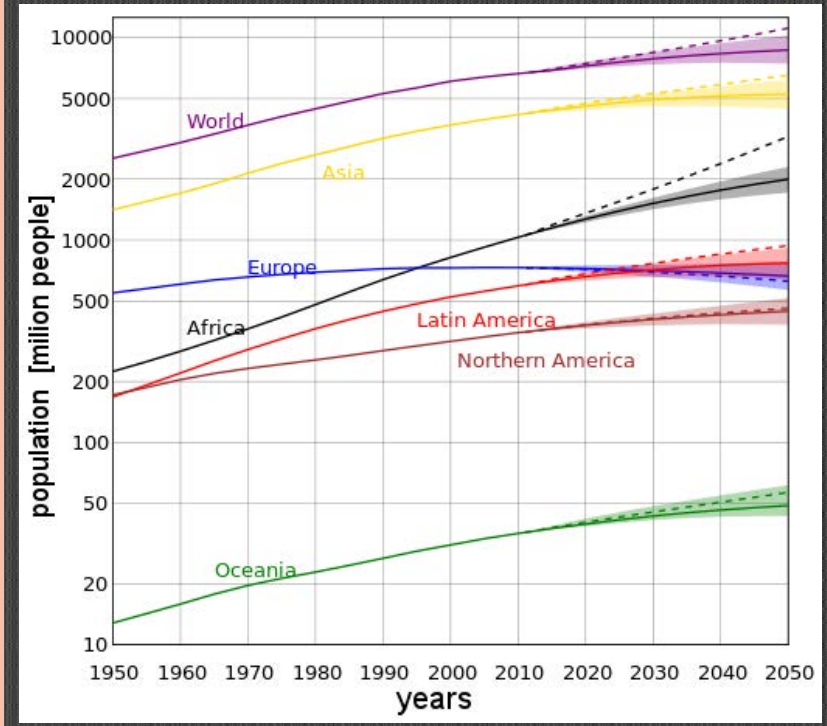
(Lagi et al., arXiv:1108.2455v1, 2011)

CHALLENGES

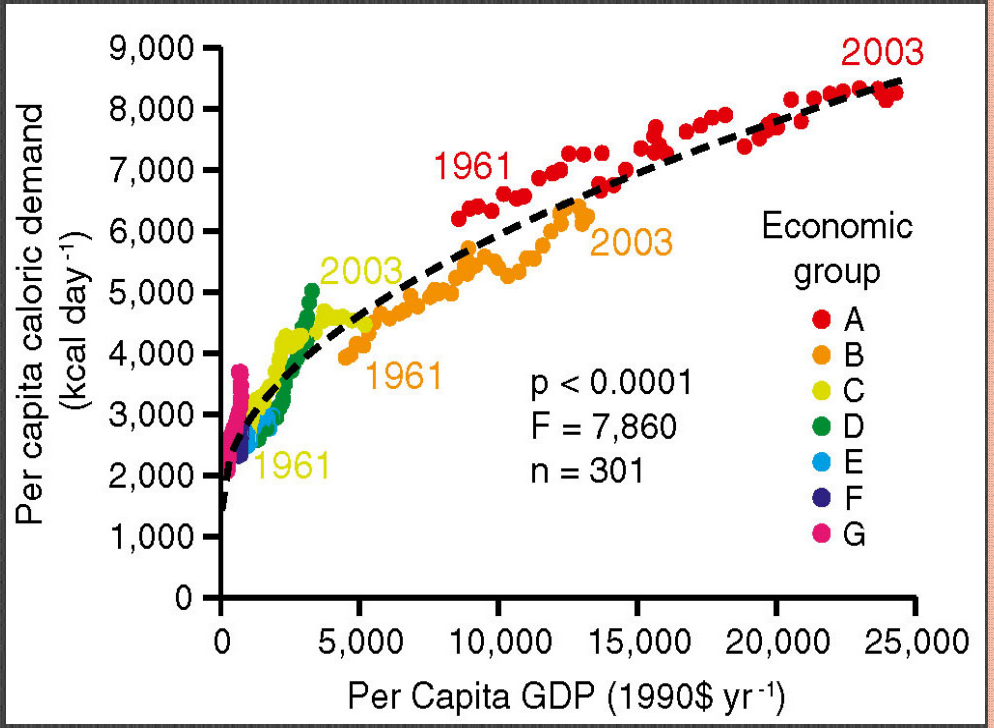
FOOD SECURITY ↔ FOOD AVAILABILITY ↔ FOOD DEMAND

Current challenges of food demand are:

- INCREASING POPULATION
- RISING LIVING STANDARDS
- CHANGING DIETS



(UN, World Pop. Prosp., 2010)



(Tilman et al., PNAS, 2011)

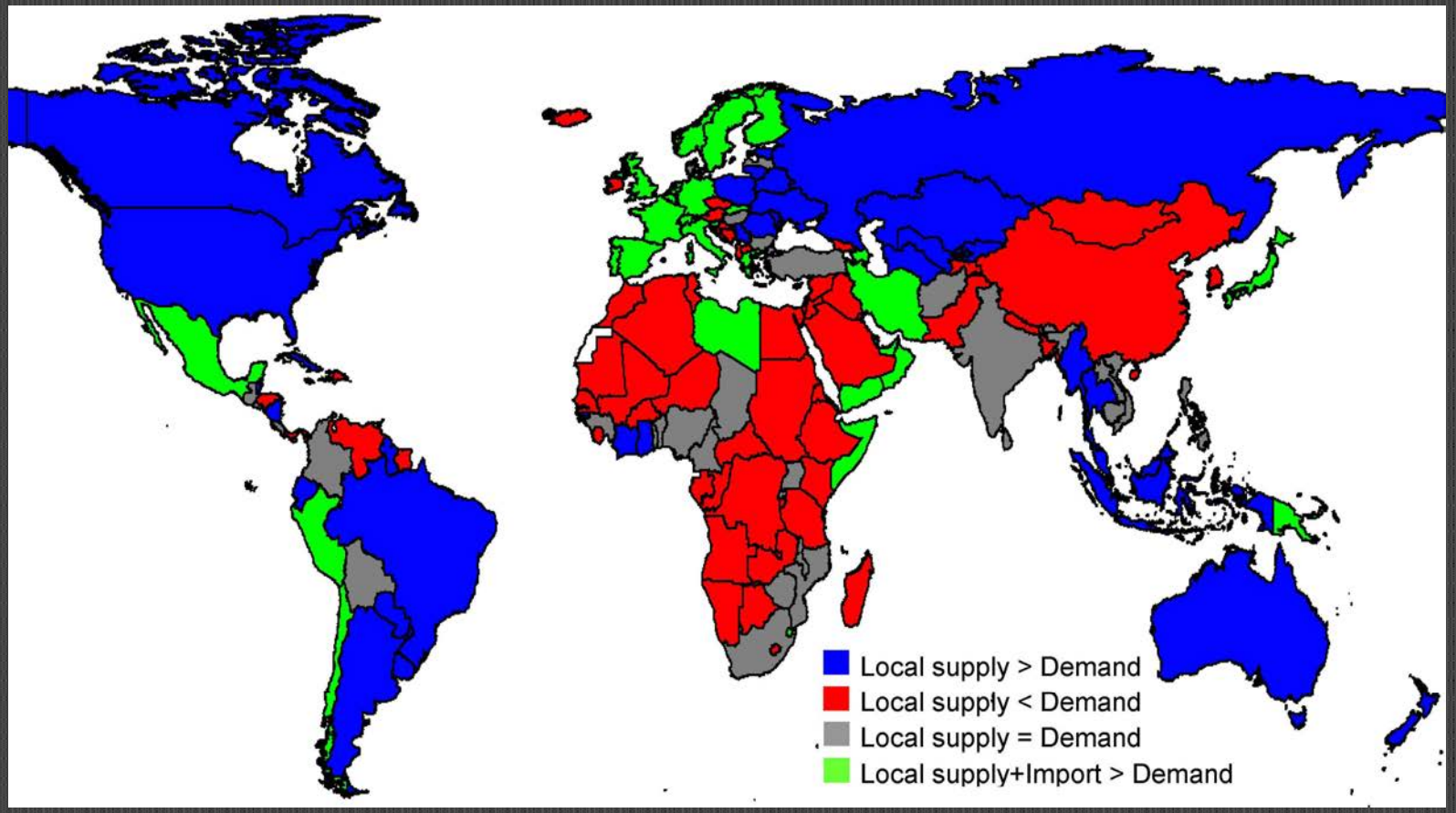
FOOD PRODUCTION

Food demand has hystorically been met thanks to PRODUCTION BURSTS due to technological innovations, scientific breakthroughs and socio-economical changes (*D'Odorico and Rulli, Nature Geoscience, 2013*)

- INDUSTRIAL REVOLUTION: farming machinery and food processing improvement increased the production and distribution of food.
- GREEN REVOLUTION: use of fertilizers, high-yield cultivars and irrigation techniques enhanced the agricultural production.
- **TRADE INTENSIFICATION**: global trade allowed coutries to rely on food imported from other countries and virtually use water resources available abroad.
- (NEW INVESTMENTS in agriculture)

VIRTUAL WATER TRADE

THE NEED FOR TRADE



(elaboration with data from Mekonnen and Hoekstra, 2011)

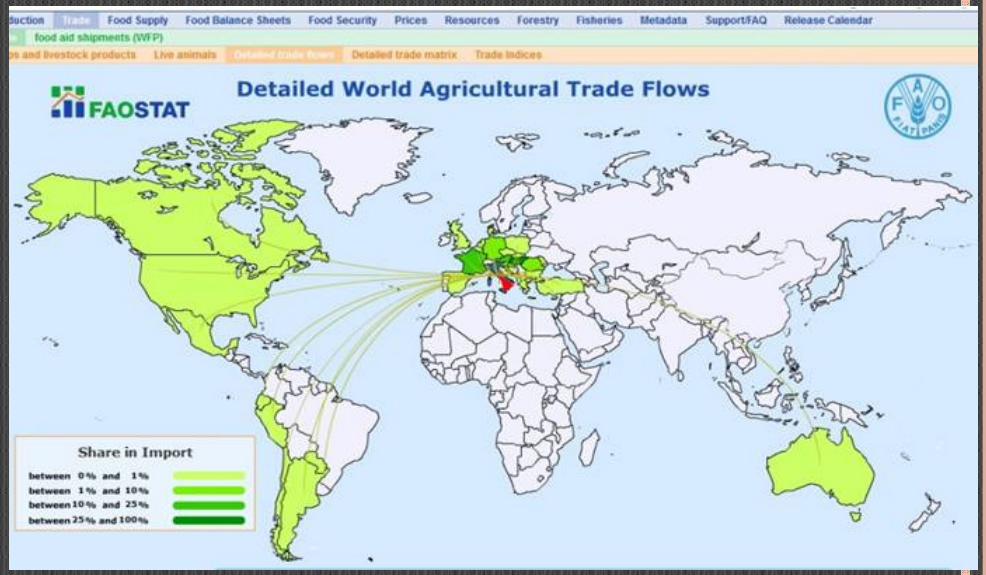
TRADE IS VITAL FOR EUROPE AND MANY OTHER COUNTRIES !!

HINT OF METHODS

⇒ Databases of production, trade and food-balance by product and by country (e.g.. FAOSTAT, ComTrade)

⇒ Virtual water contents taken from *WaterFootprint.org* database or estimated via coupled "hydro-agro" models (CropWat+ClimWat, H8, GCWM)

⇒ Virtual water volumes/fluxes obtained by multiplication, then different summations



Appendix V. Water footprint of animal products (m^3/ton). Period 1996-2005

HS (PC-TAS) code	SITC Rev 3 (SITA) code	Product discription (HS)	Product description (SITC)	Rootproduct (HS)	Rootproduct (SITC)	Product fraction	Value fraction	Country	World Average			
								Production system >>	Grazing	Mixed	Industrial	Weighted average
021019	01619	Swine meat cured, nes	Oth.pigmeat,dry,salt,smk	020311	01221	0.70	1.00	Green	7989	5433	4223	5117
								Blue	443	447	501	472
								Grey	659	606	717	649
021020	01681	Bovine meat cured	Bov.meat,dried,smkd,salt	020110	01111	0.46	1.00	Green	32600	22848	13658	22247
								Blue	724	791	1061	856
								Grey	375	620	1099	696
040110	02211	Milk not concentrated and unsweetened not exceeding 1% fat	Milk,fat cont.1% or less	FAO882	FAO882	0.93	1.00	Green	1087	790	1027	863
								Blue	56	90	98	86
								Grey	49	76	82	72
040120	02212	Milk not concentrated & unsweetened exceeding 1% not exceeding 6% fat	Milk,cream fat cont.1-6%	FAO882	FAO882	0.90	1.00	Green	1123	816	1061	891
								Blue	58	93	101	88
								Grey	50	79	85	75
040130	02213	Milk and cream not concentrated and unsweetened exceeding 6% fat	Cream,fat content 6%+	FAO882	FAO882	0.50	1.00	Green	2021	1469	1911	1605
								Blue	104	168	182	159
								Grey	91	142	153	134
040210	02221	Milk powder not exceeding 1.5% fat	Milk,solid, to 1.5% fat	FAO882	FAO882	0.20	1.00	Green	5052	3671	4777	4011
								Blue	261	421	455	398
								Grey	227	354	382	336

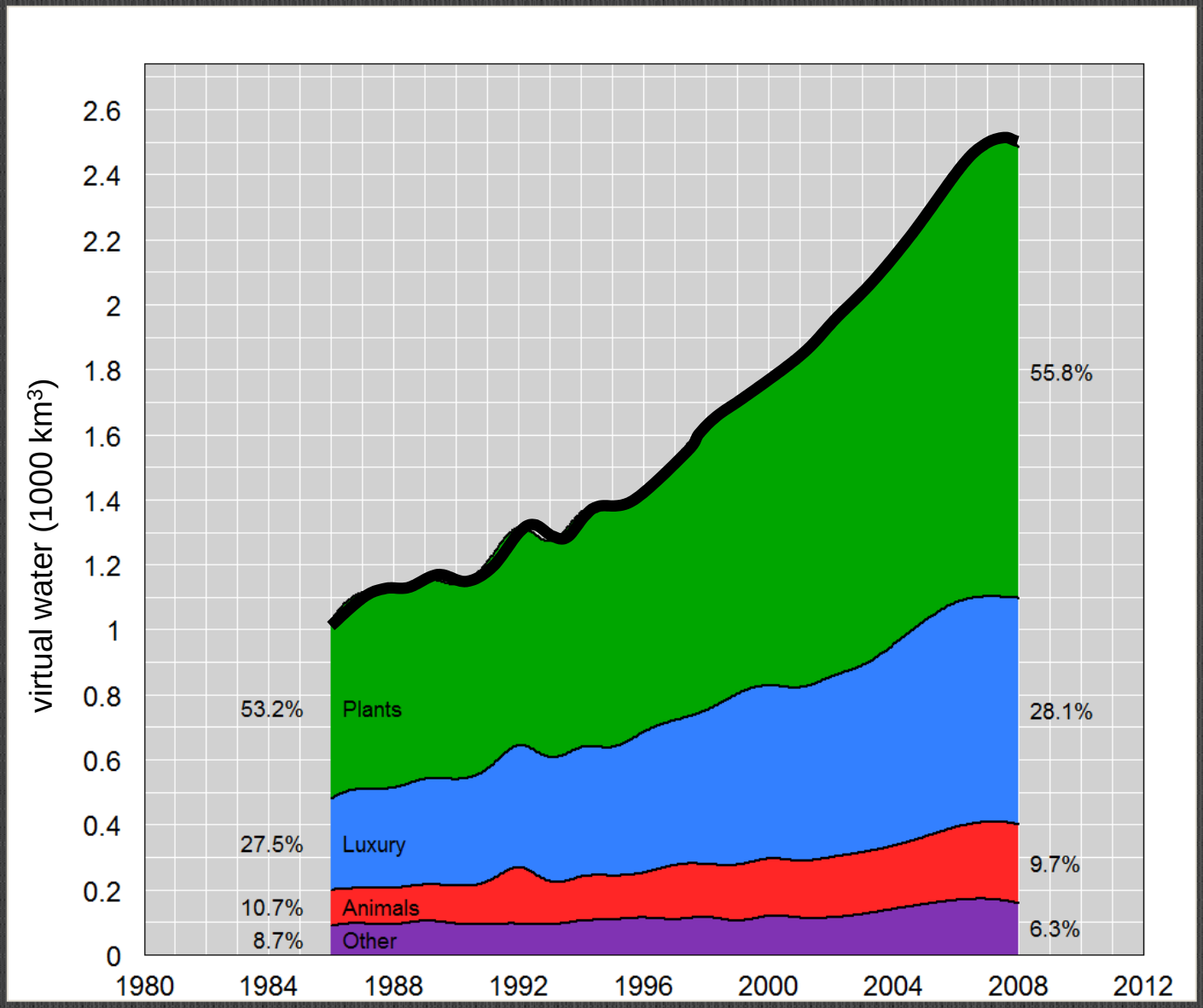
Typical **BOTTOM-UP approach** (TOP-DOWN approaches are based on I/O matrices and on economical values)

TRADE NETWORK

(Konar et al., WRR, 2011)

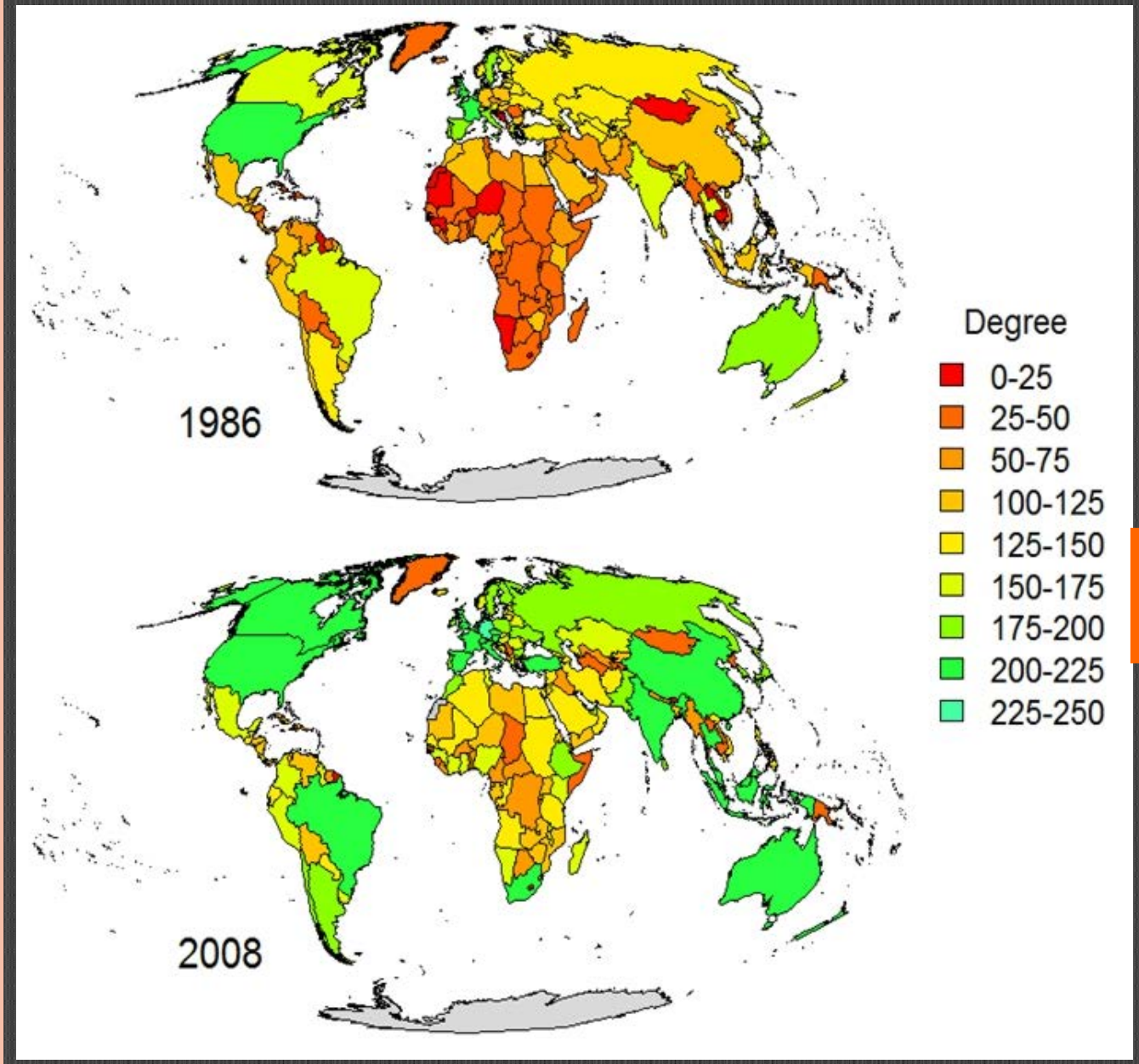
Weighted and directed network
253 nodes (220 active) • 7000 links
about 2000 km^3 of total fluxes

VW TRADE VOLUMES



(Carr et al., Plos-One, 2013)

VW TRADE CONNECTIONS



This is GLOBALIZATION

(Carr et al., Plos-One, 2013)

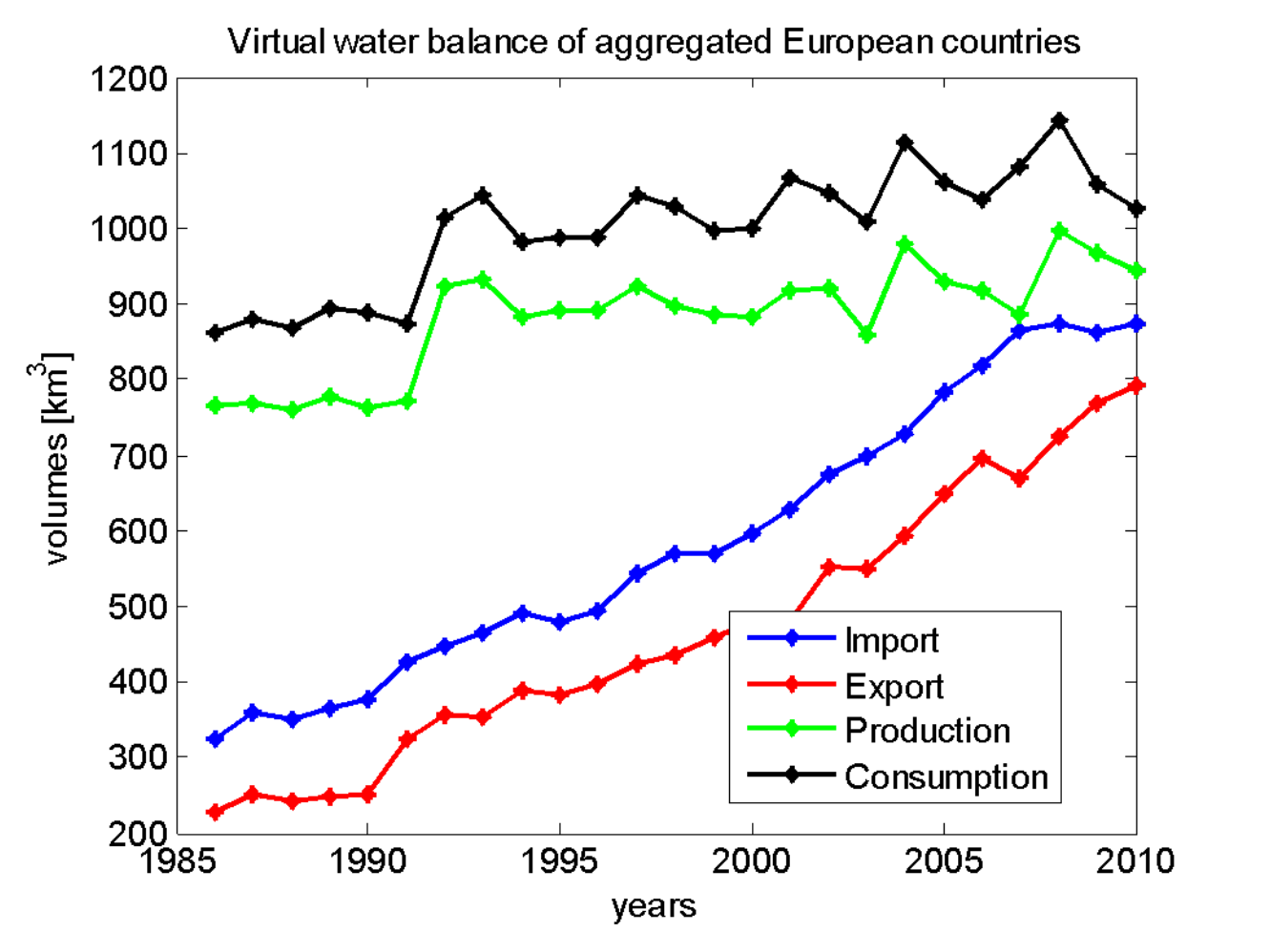
CONSIDERATIONS

1) 50% of virtual water fluxes is exchanged on 1% of the links

2) 6-8% of world population controls the net export flux

- Few countries are net exporter and many countries import virtual water
- Network is structured with “hubs” and “rich clubs”
- Presence of inefficiencies (swaps)
- Socio-economical risks and ethical issues

Virtual water balance of Europe



(author's elaborations)

Import + Production = Export + Consumption

Positive aspects

- Meeting water demand through import
- Water-scarce countries use water resources available abroad
- Global water savings

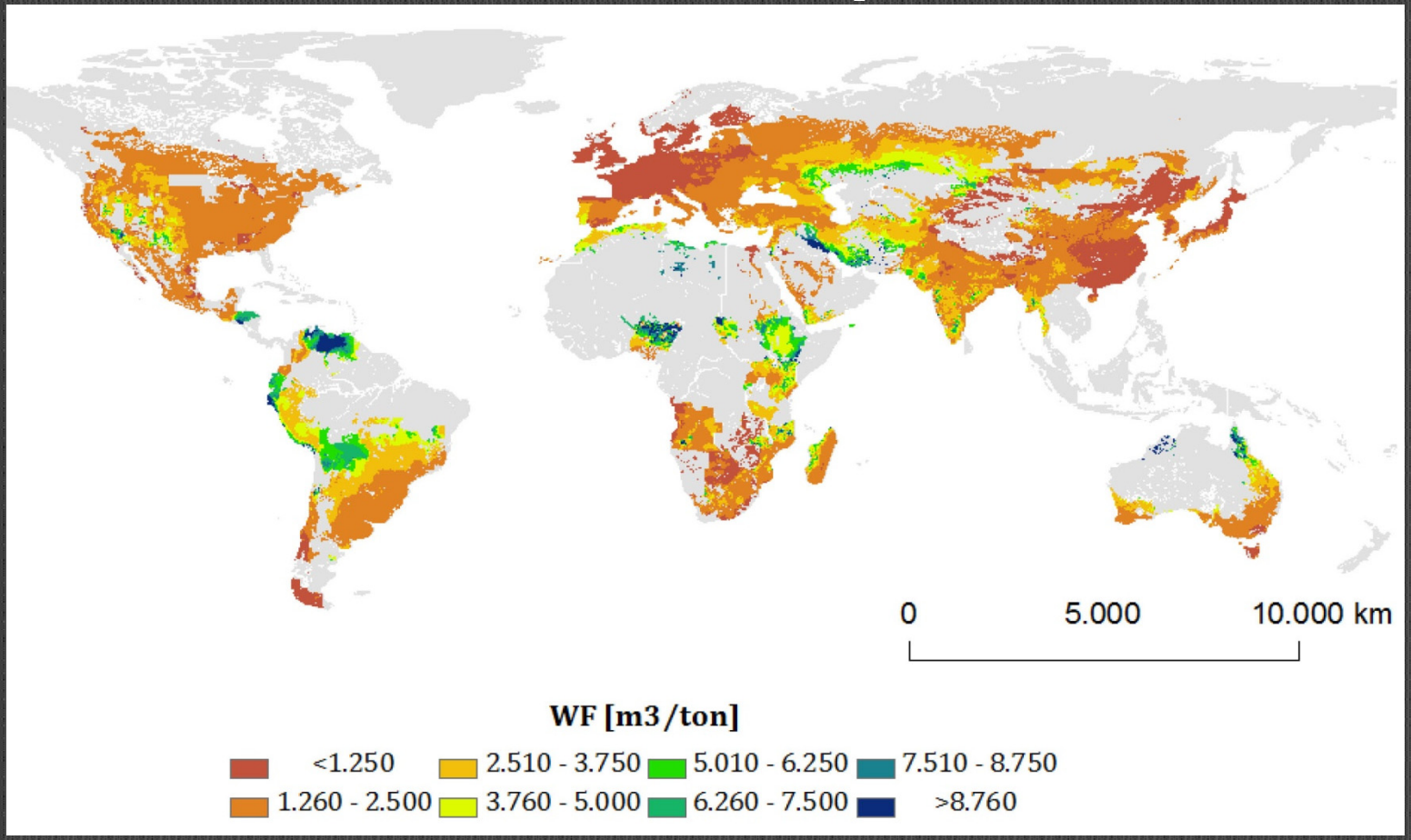
Negative aspects

- Externalization of resources (dependency)
- Decrease of societal resilience to drought
- Vulnerability to water crises
- Externaliz. of pollution without stewardship
- Equity issues

OPEN QUESTIONS AND WAY FORWARD

Data uncertainty and variability

Water footprint of wheat in the world



(author's elaborations)

- Comparison between datasets and between different approaches (I/O)
- Sound assessment of blue water volumes

INVESTIGATING FUTURE SCENARIOS

- Evolution of trade network
- Projection of drivers (e.g., socio-economic variables) of the virtual water trade
- Impact of climate change
- Definition of future water demand accounting for the challenges of:
  - INCREASING POPULATION
  - RISING LIVING STANDARDS
  - CHANGING DIETS

Other open questions

- What is the *system vulnerability* to water crises?
- *Not all water is the same* (differentiating virtual water from water-scarse and water-rich countries)
- Relationship between *food prices and water footprint*
- *Also water comes to a price* (database building, analysis and integration)

CONCLUDING…

Virtual water provides a framework to quantify the link between food production and water resources

- There are several interests (scientific, economic, socio-political, policy implications, standards to set)
- There is a lot to do
- There are many actions that can be taken (research theme of Panta Rhei)
- There is a session here at EGU on Thursday afternoon…

HS5.6
Water and food security: integrating perspectives from geophysics and social sciences

Convener: Stefania Tamea
Co-Conveners: Marta Antonelli, Holger Hoff
Convener Login

Orals / **Thu, 01 May, 13:30–17:00 / Room R8**
Posters / **Attendance Thu, 01 May, 17:30–19:00 / Red Posters**

THANKS FOR YOUR ATTENTION!

"Whatever you do will be insignificant, but it is very important that you do it."
Mahatma Gandhi

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