“Accounting” for water use in Crop Production

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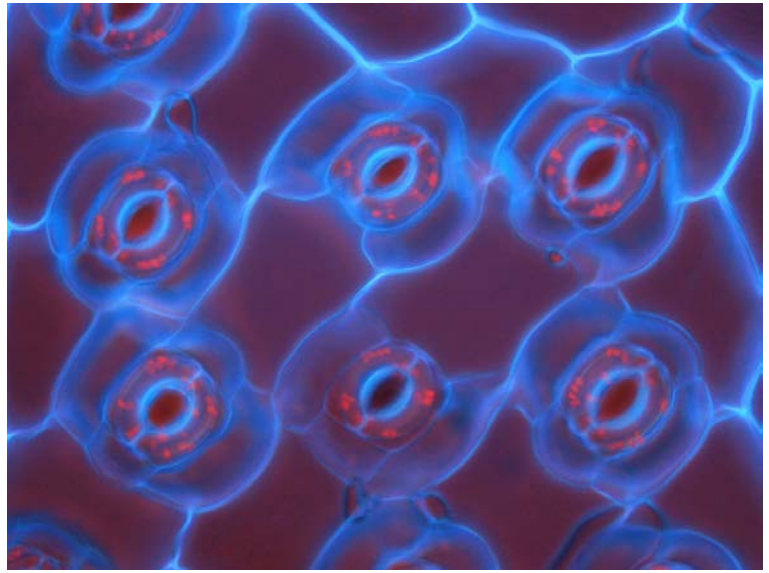
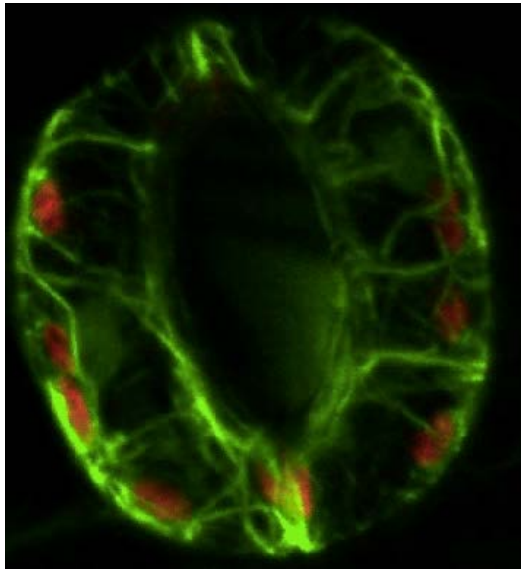
GLOBAL FOOD SECURITY

- “Food security occurs when all people are able to access enough safe and nutritious food to meet their requirements for a healthy life, in ways the planet can sustain into the future”.
- Crop Science and Food security: the productivity, waste and distribution “trilemma” extends from GHG emissions to water use along the food supply chain
- Can we “cost” direct and indirect water use in the same way that carbon emissions can be traded?

- Plants really matter- their CARBON fuelling, feeding and clothing society
- WATER: Between 250 – 1000 water molecules are lost via transpiration through leaf stomatal pores for every CO_2 molecule fixed.



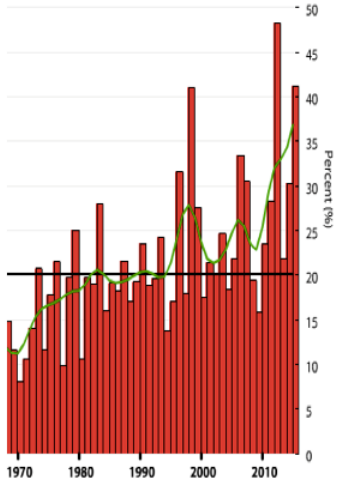


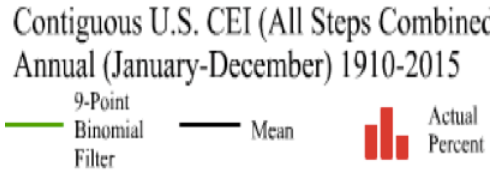
  - Global impact of CO_2 and H_2O gas exchange at leaf surfaces:
    - Carbon: 15% of global atmospheric CO_2 pool (120 x 10^{15} g or 120 Gt (gigatonnes) of carbon as CO_2
    - Water: 32,000 km^3 (= 1.5 times the volume of the Baltic Sea) or x2 atmospheric water vapour content .
    - For every kilo of carbon fixed, more than 1 tonne of water transpired by crops
    - Direct and indirect water use now a major consideration for cropping systems
  -

Costing the earth: threats to water use for food production.

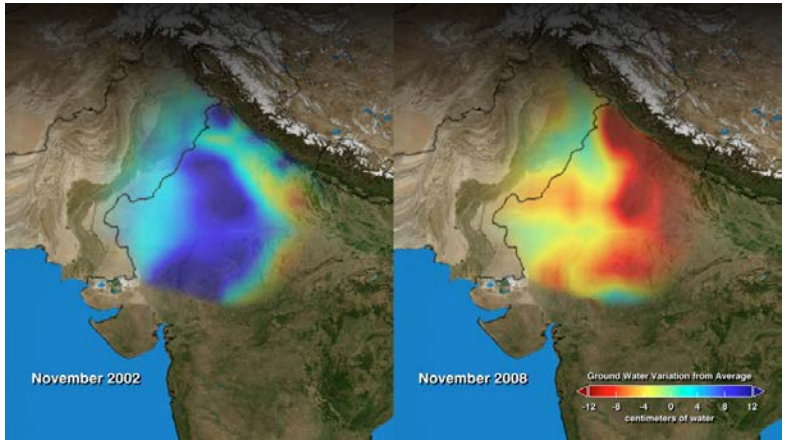
How should we account for the typical “use” of water for common commodities in the developed world and the global south?

Climate extremes index





Climatic drivers



Groundwater depletion in the Punjab

Increasingly frequent extreme drought events

Foodstuff	Quantity	Water consumption, litres
Chocolate	1 kg	17,196
Beef	1 kg	15,415
Sheep Meat	1 kg	10,412
Pork	1 kg	5,988
Butter	1 kg	5,553
Chicken meat	1 kg	4,325
Cheese	1 kg	3,178
Olives	1 kg	3,025
Rice	1 kg	2,497
Cotton	1 @ 250g	2,495
Pasta (dry)	1 kg	1,849
Bread	1 kg	1,608

https://www.nature.com/scitable/blog/eyes-on-environment/water_world

The United Nations World Water Development Reports
http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

- 85% of the world's population resides in the drier half of the Earth. More than 1 billion people living in arid and semi-arid parts of the world have access to little or no renewable water resources.
- More than 60% of the world's population growth between 2008 and 2100 will be in sub-Saharan Africa (32%) and South Asia (30%). Together, these regions are expected to account for half of world population in 2100.
- Agriculture is the largest consumer of freshwater by far – about 70% of all freshwater withdrawals go to irrigated agriculture.

The United Nations World Water Development Reports
http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

- Water scarcity may limit food production and supply, putting pressure on food prices and increasing countries' dependence on food imports.
- Part of the current pressure on water resources comes from growing populations and increasing demands for animal feed. Meat production requires 8-10 times more water than cereal production
- Contemporary global water demand has been estimated at about 4,600 km3 per year and projected to increase by 20%–30% to between 5,500 and 6,000 km3 per year by 2050 (Burek et al., 2016)

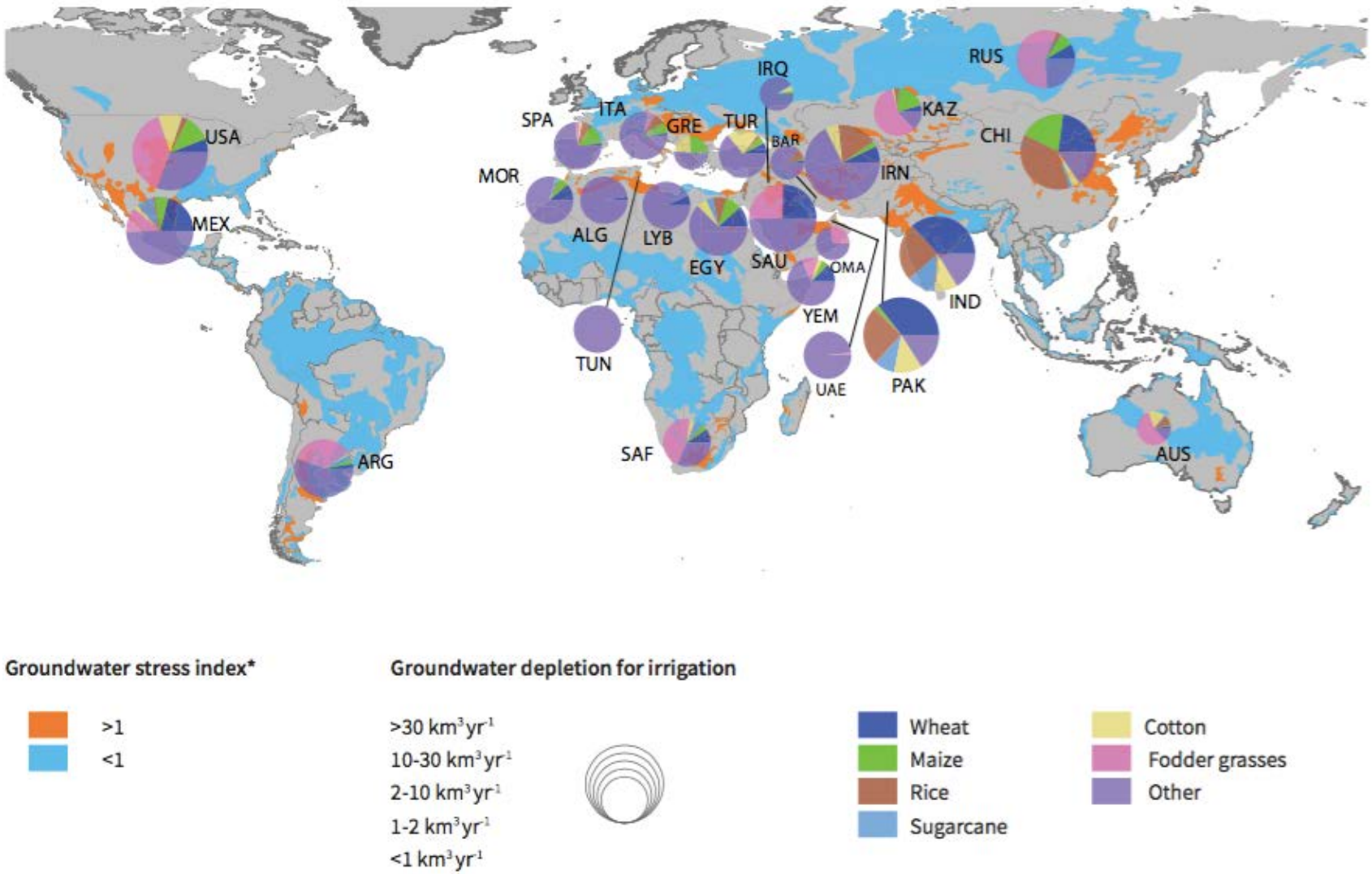
Takeaway messages

- Access to safe, affordable and reliable drinking water and sanitation services are **basic human rights**.
- **Billions are being left behind** in terms of access to water and sanitation.
- The wealthy generally receive high levels of service and often at very low price, while the **poor often pay a much higher price** for a service of similar or lesser quality.
- Ensuring that water is affordable to all requires policy recommendations **tailored to specific target groups**.
- Equitable access to water for agricultural production, particularly for **supplemental irrigation**, can make a difference for farmers' livelihoods.
- **Mass displacement** can strain water-related services for both existing populations and new arrivals, creating inequalities and potential conflicts.
- Investing in water supply and sanitation in general, and for the vulnerable and disadvantaged in particular, makes **good economic sense**.
- **Good governance** overcomes vested interests and exclusionary practices.

http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

The threat to groundwater from water abstraction by agriculture

- More than 2 billion people lack access to safe drinking water and more than double that number lack access to safe sanitation.
- demand for water is expected to increase by nearly one-third by 2050.
- we need new ways to manage competing demands on freshwater resources.



- http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2018-nature-based-solutions/

Water quality is declining, with projected N loading increasing

- For too long, the world has turned first to human-built, or “grey” infrastructure, to improve water management
- they suggest re-examining nature-based solutions (NBS) to help achieve water management objectives.

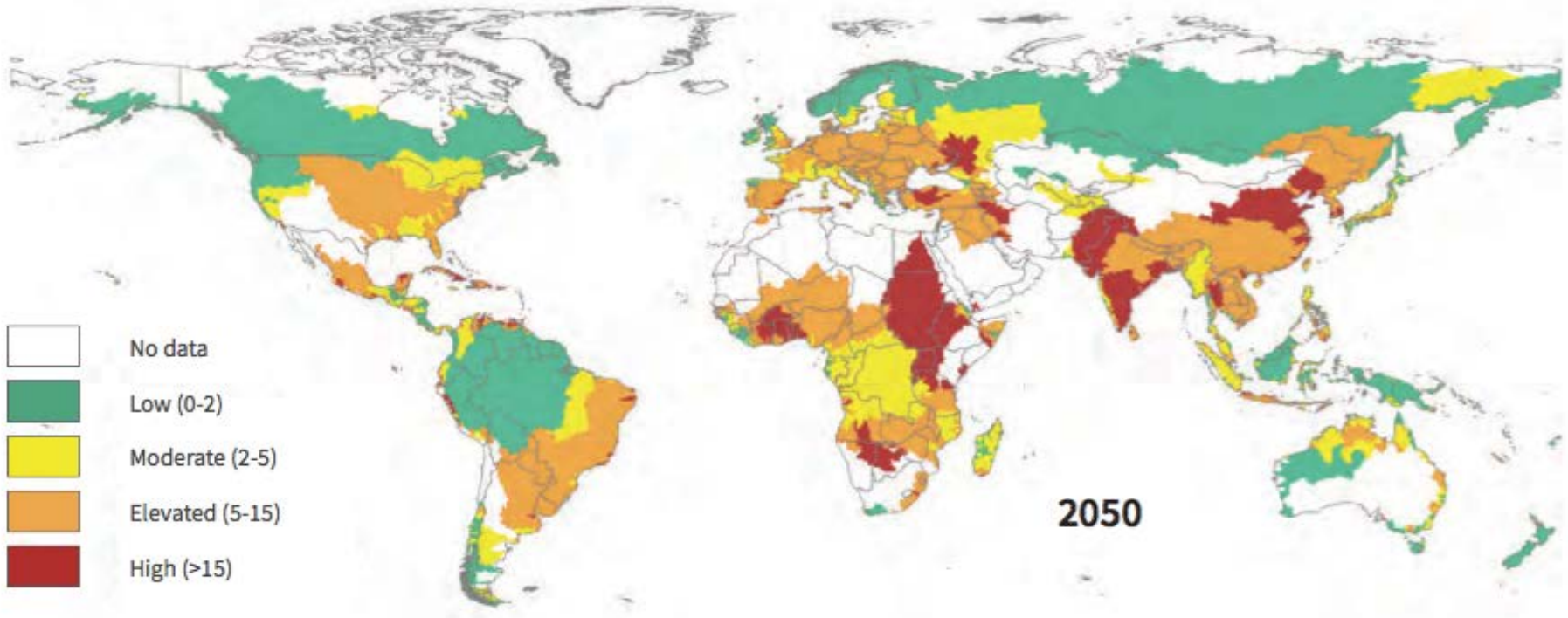
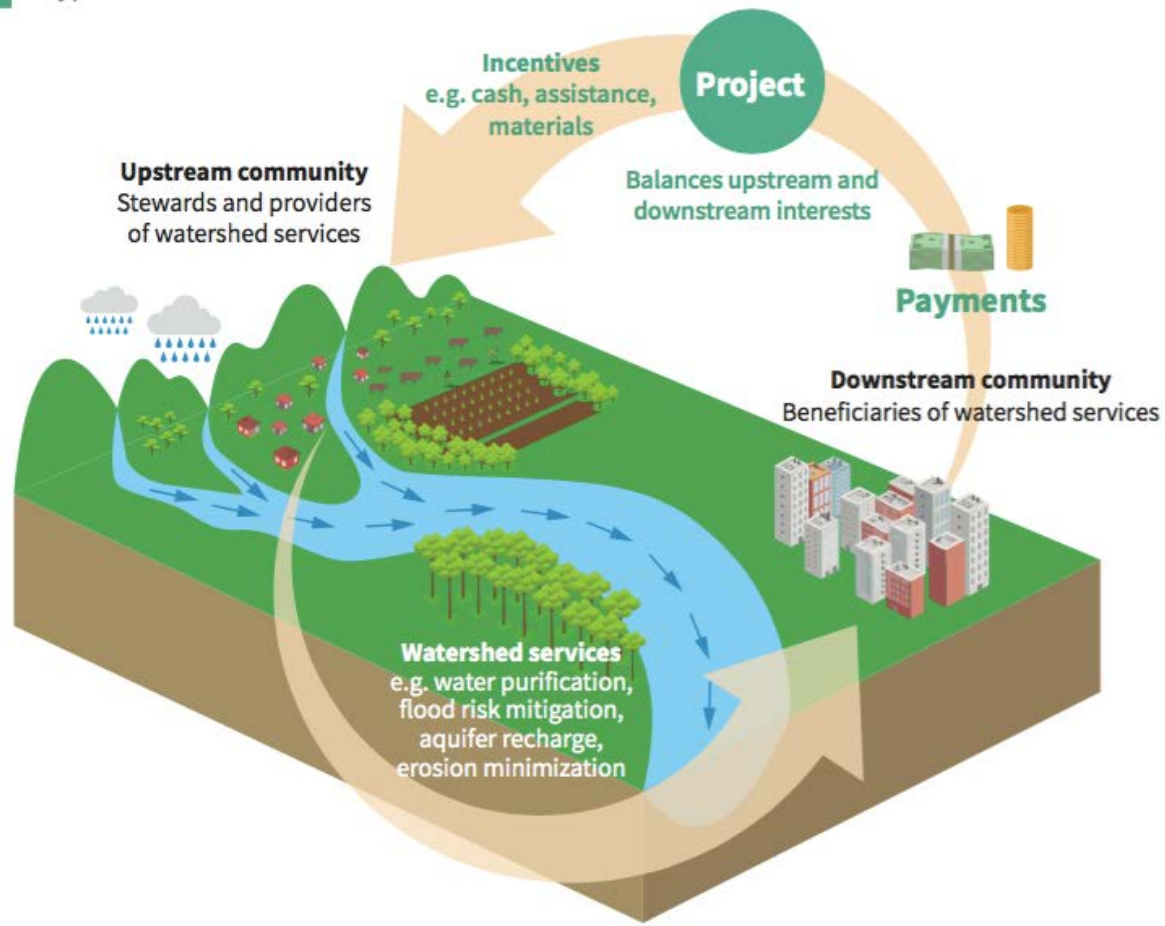


Figure 4 **Water quality risk indices for major river basins during the base period (2000–2005) compared to 2050 (nitrogen index under the CSIRO*-*medium-scenario*****)**

- http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2018-nature-based-solutions/

- The case of maintaining the water supply system for New York City, initiated in 1997, is one of the best known and documented examples of the implementation of NBS for watershed protection.
- This was also one of the first recognized successful payment for environmental services (PES) schemes.
- Today, three protected watersheds provide New York City with the largest unfiltered water supply in the USA, saving the city more than US$300 million per year on water treatment operation and maintenance costs.
- The programme also serves as an alternative to building a water treatment plant which would have cost between an estimated US$8 and 10 billion (Abell et al., 2017).

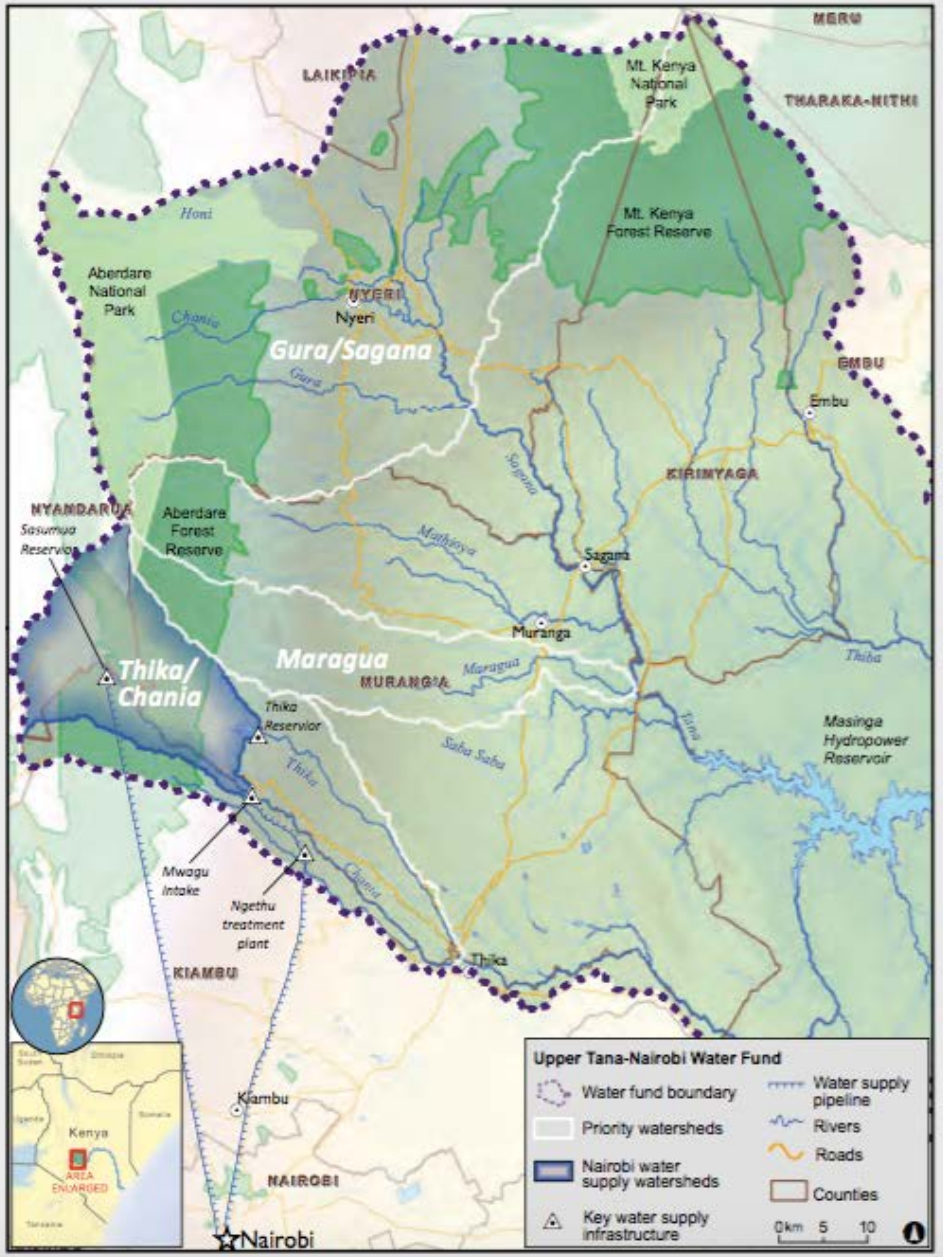
Figure 5.1 A typical watershed PES scheme



Source: Adapted from Bennett et al. (2013, fig. 7, p. 1).

- The Upper Tana-Nairobi Water Fund launched in March 2015 to mitigate the threats associated with watershed degradation.
- aims to secure Nairobi's water supplies while improving agricultural livelihoods, maintaining dry- season flow in selected watersheds, and thus contributing to resilience to droughts.
- working with over 15,000 farmers by collaborating with local partners.
- Estimate a US$10 million investment in Water Fund-led conservation interventions would likely return US$21.5 million in economic benefits over a 30-year timeframe
- Leading to increases in power generation, agricultural crop yields for smallholders and larger producers, and from savings in water and wastewater treatment

Figure | Location of the proposed Upper Tana-Nairobi Water Fund

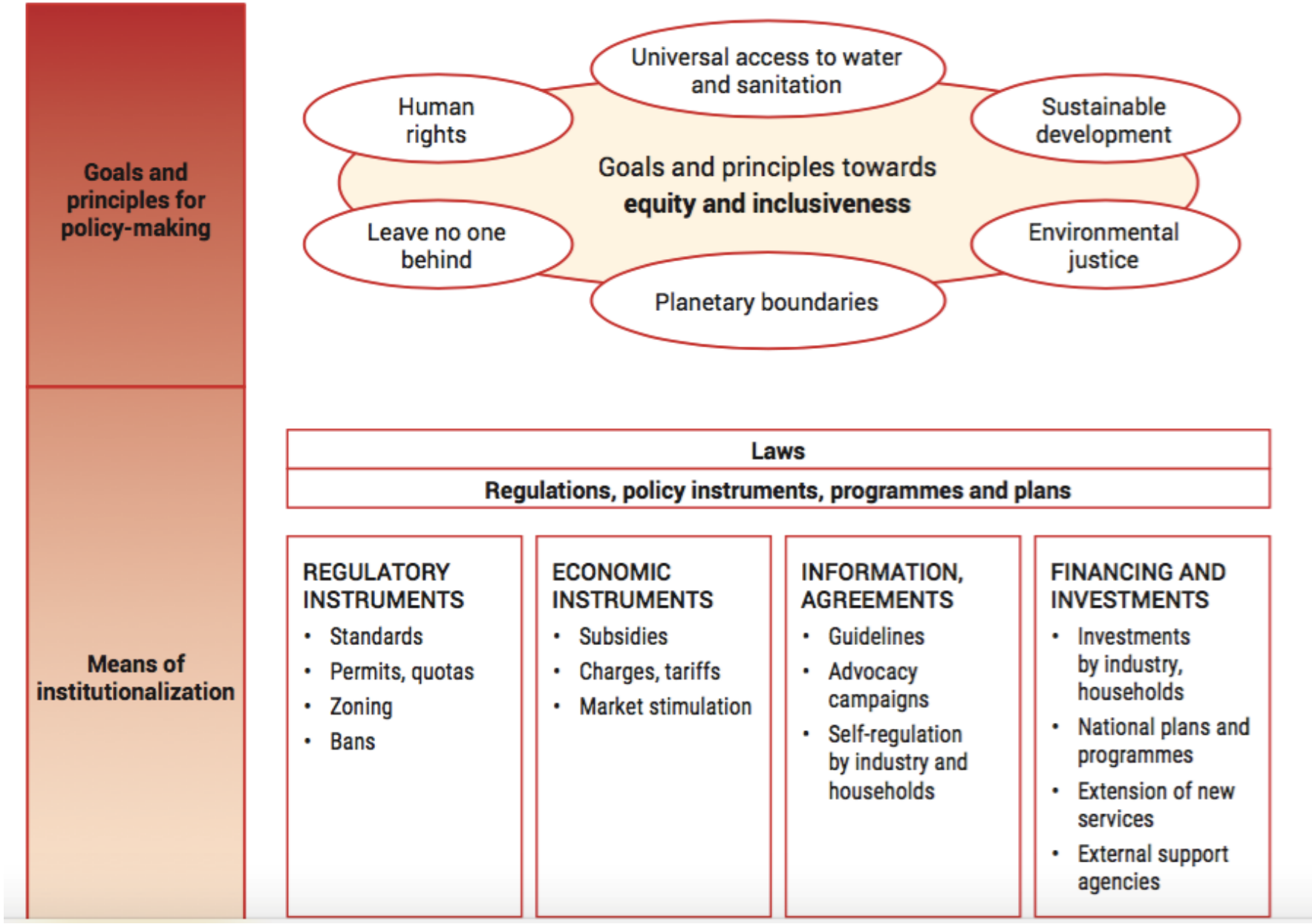


- if women had the same access as men to productive resources – including land and water, they could increase yields on their farms by 20 to 30%, raising total agricultural output in these countries by 2.5 to 4%.
- This could reduce the number of hungry people in the world by around 12 to 17
- The depletion of water and other natural resources is increasingly recognized as a driver of displacement that triggers internal and international migration.

- http://www.unesco.org/new/en/natural sciences/environment/water/wwap/

Women pushing Hippo Water Rollers

Proposed regulatory framework – could this be integrated into the water footprint concept?



- http://www.unesco.org/new/en/naturalsciences/environment/water/wwap/

water footprint network

What is the water footprint?

The **water footprint** maps and measures how, when and where we use freshwater resources.

► Water footprint is a measurement of the **volume of water consumed** (evaporated or otherwise not returned) or **assimilation capacity used.**

► The water footprint is a **geographically** & **temporally** explicit indicator.

► The water footprint is an indicator of water use that looks at both **direct** & **indirect** water use of a consumer or producer.

► A water footprint can be calculated for a **process**, a **product**, a **consumer**, **group of consumers** (e.g. municipality, province, state or nation) or a **producer** (e.g. a private enterprise, public organization).

[Hoekstra et al., 2011]

water footprint network

2 - Water footprint accounting

Integration in the Hydrological cycle: the colors of water

Green water footprint

- volume of rainwater evaporated or incorporated into product


Blue water footprint

- volume of surface or groundwater evaporated or incorporated into product, lost return flow




https://waterfootprint.org/en/water-footprint/

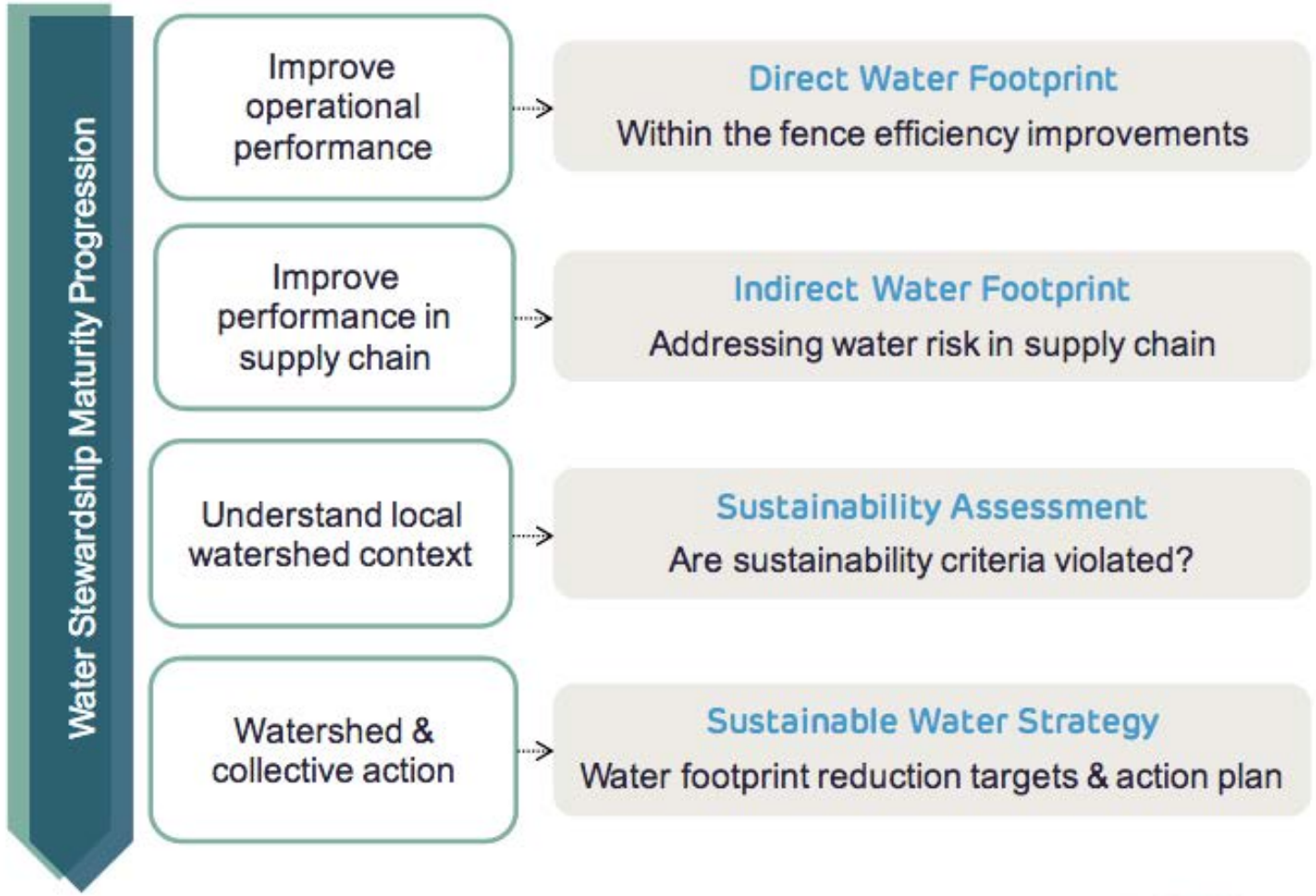
Grey water footprint

- an indicator of assimilation capacity used.

[Hoekstra et al., 2011]

water footprint network

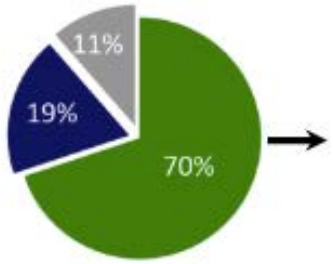
Water Footprint Assessment – Water Stewardship Progression



https://waterfootprint.org/en/water-footprint/

water footprint network

2 - Water footprint accounting

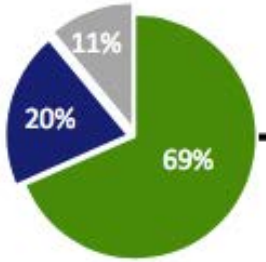


1600 litres water

1 kg wheat bread

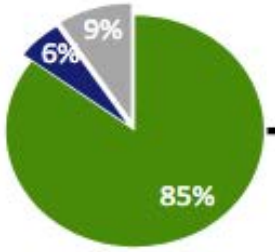
Global average water footprint

https://waterfootprint.org/en/water-footprint/



2500 litres water

1 kg rice

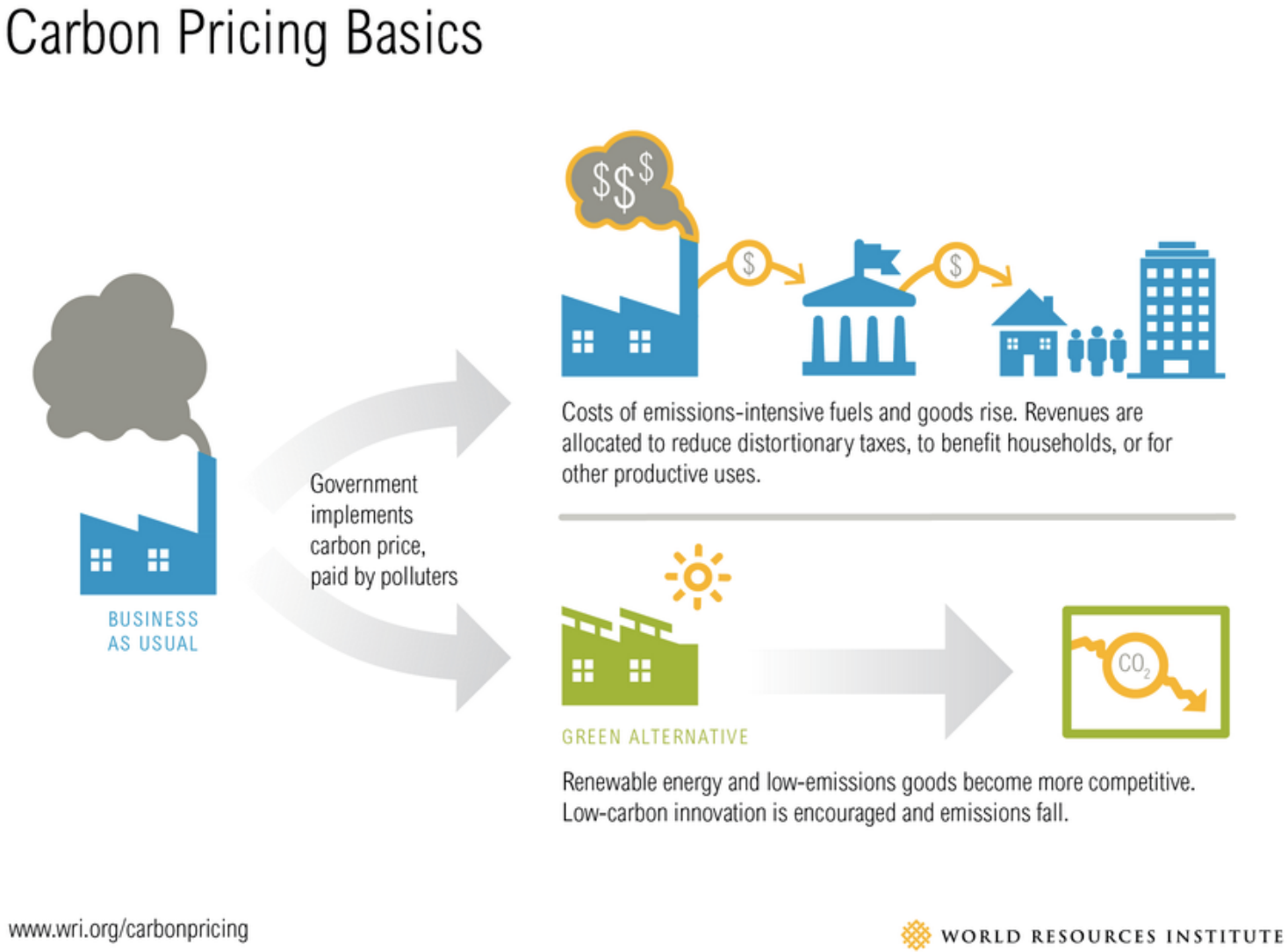


300 litres water

1 litre beer

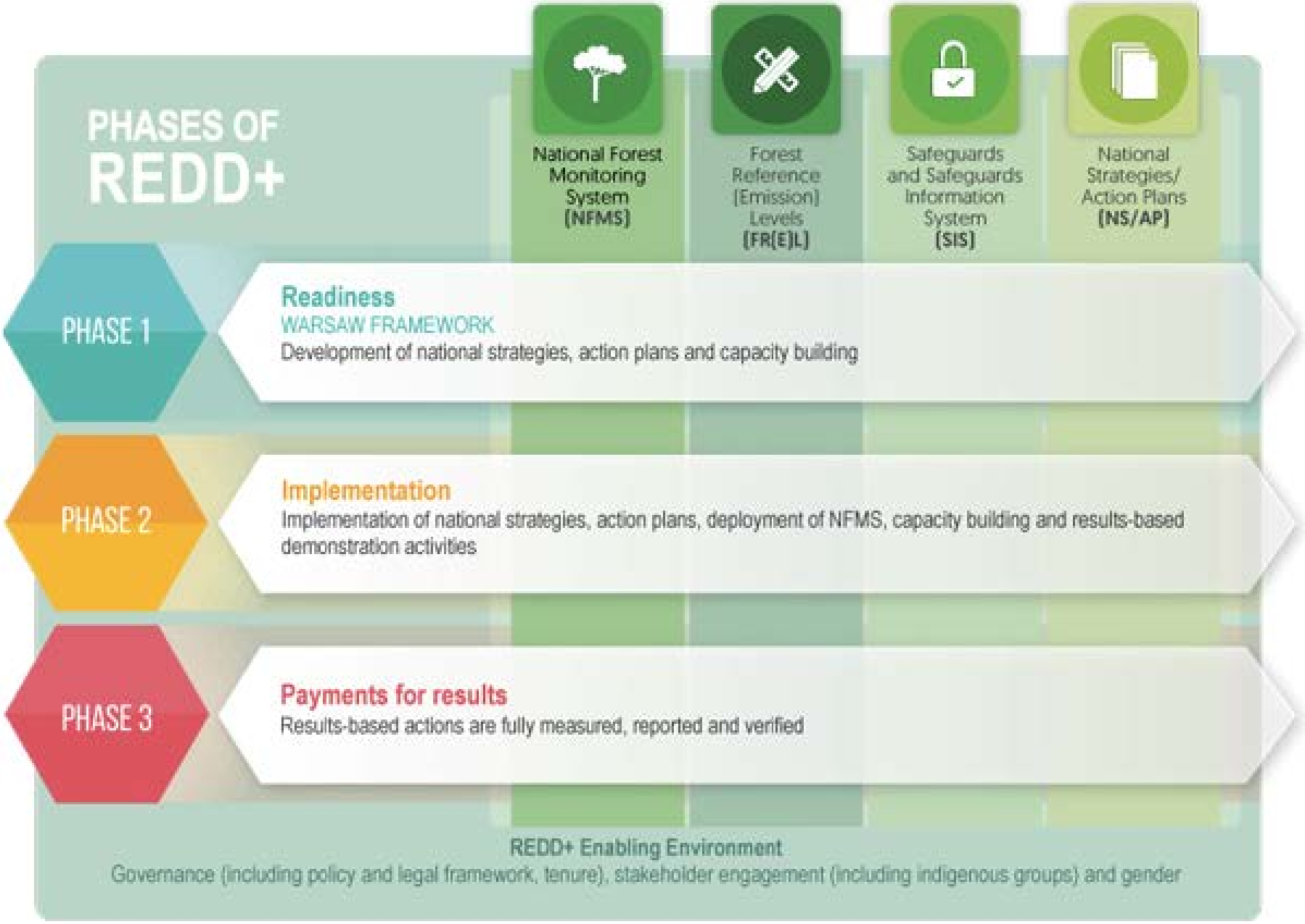
Mekonnen & Hoekstra., 2012

- The EU ETS works on the 'cap and trade' principle.
- A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that **total emissions fall**.
- Within the cap, companies receive or buy **emission allowances** which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world.



- Are there lessons from Carbon accounting?

- http://www.fao.org/redd/overview/en/



But how to "Account" for water use in Crop Production?

- Something analagous to Carbon Pricing? e.g. EU Emissions Trading System "Cap and Trade"
- **The carbon price** is the amount that must be paid for the right to emit one tonne of CO_2 into the atmosphere.
- We can be made aware of our direct and indirect water use:
  - https://www.ccwater.org.uk/households/using-water-wisely/averagewateruse/
  - https://www.epa.gov/watersense/how-we-use-water
- 1 m^3 (1,000 L) water costs around £3.20 in the UK (excluding standing charges)
  - 3,300 cups of tea
  - 28 showers
  - 13 baths
  - flushing the toilet more than a hundred times
- Each day we "use" around 150 L, but each person's virtual or indirect water use in the UK amounts to 4,645 litres a day

*price had around *seven euros* per ton for many years, but has sharply risen over the past year to €20 per ton. Germany's Berenberg Bank has predicted that the carbon price could rise to €100 per ton.

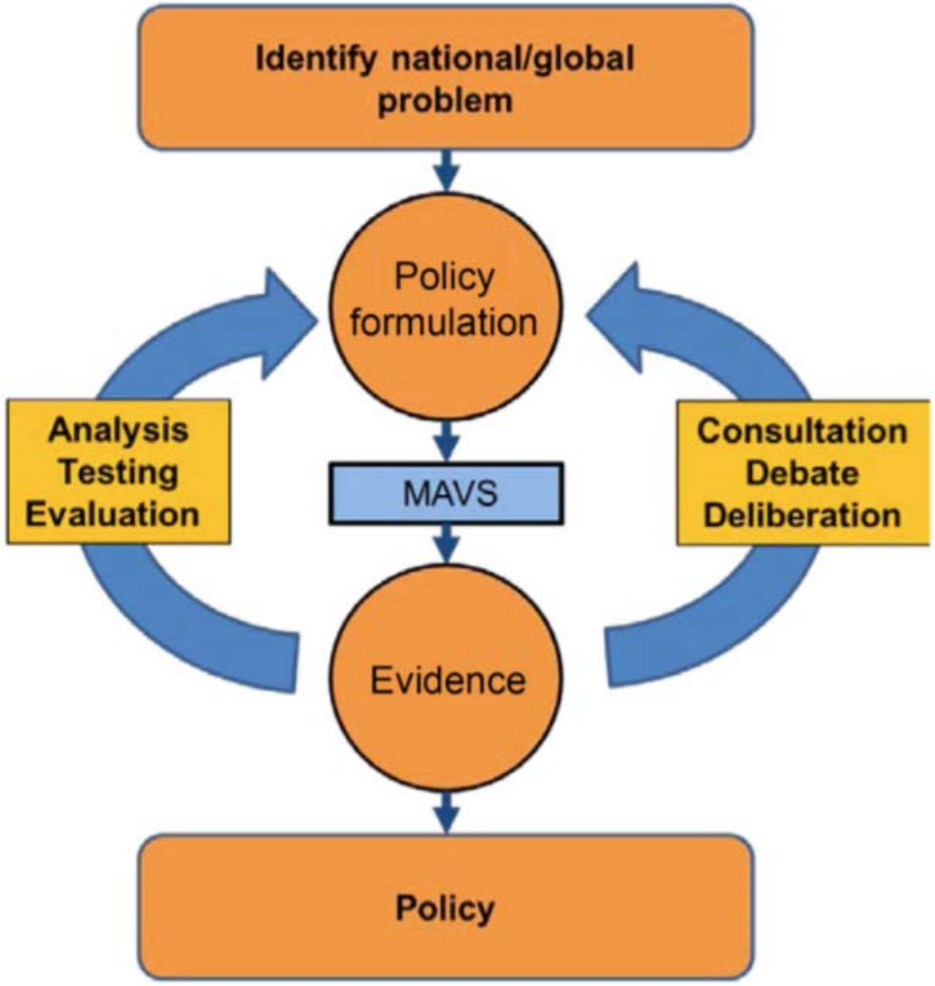
Formulating food and nutrition policy

- MAVS: Map, Analyse, Visualise, Share
- As a pre-requisite for effective policy making, we propose a methodology that fully integrates scientific investigation with political debate and social discourse.
- This would then be followed by transparent evidence evaluation, combining independent assessment to test the validity and completeness of the evidence with deliberation to discover how the evidence is perceived, misunderstood or ignored.

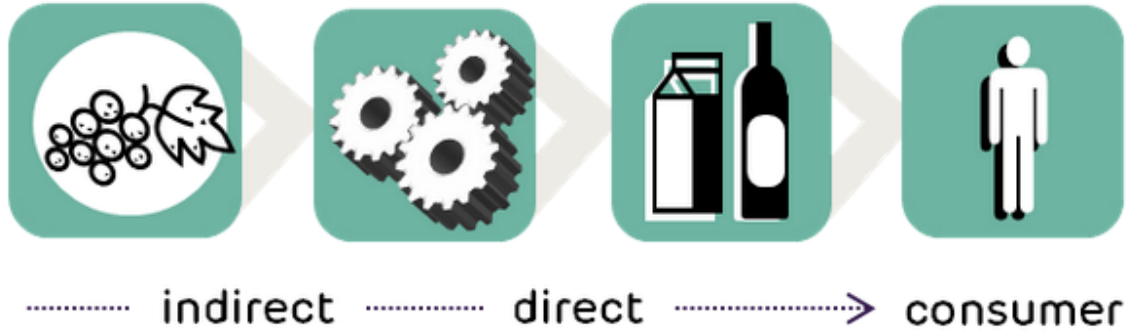
DOI: 10.1057/s41599-018-0099-3 OPEN

Integrating evidence, politics and society: a methodology for the science-policy interface

Peter Horton[1] & Garrett W. Brown[2]



How to introduce such a payment system, even if a cost per tonne of water could be agreed and then levied?



- 1 m^3 (1,000 L) water costs around £3.20 in the UK (excluding standing charges)
- Each day we "use" around 150 L, but virtual or indirect water use in the UK amounts to 4,645 litres a day
- Payment for Ecosystem Services schemes are practicable and financially viable for urban catchments, providing potable water for drinking and sanitation
- A meat and dairy-based diet consumes about 5,000 litres of indirect (virtual) water a day while a vegetarian diet uses about 2,000 litres
- AJ Hoekstra, 2017: "With the transition from a fossil to biobased economy, carbon footprint studies will gradually make place for land and water footprint studies, because biobased essentially means based on scarce land and water resources. Finally, the idea of 'zero WF' as the ultimate target for industrial processes fits within studies on the circular economy"
- **But would society be prepared to pay a realistic contribution on each commodity?**

Hoekstra AJ: Water Footprint Assessment: Evolvement of a New Research Field (2017) Water Resour. Manage. 31:3061–3081 DOI 10.1007/s11269-017-1618-5

The VISION: sustainable, nutritious food to meet needs for a healthy diet for all

- We need all the tools in the technology toolbox (David Baulcombe)
- Fundamental research in crop and soil science
- More sustainable use of water, land and reduced GHG emissions
- Improved supply chain resilience to minimise waste
- how to encourage (nudge?) the consumer to embrace changes in lifestyle
- How to improve equal opportunities, water availability, health and nutrition for all

With thanks to Tim Benton

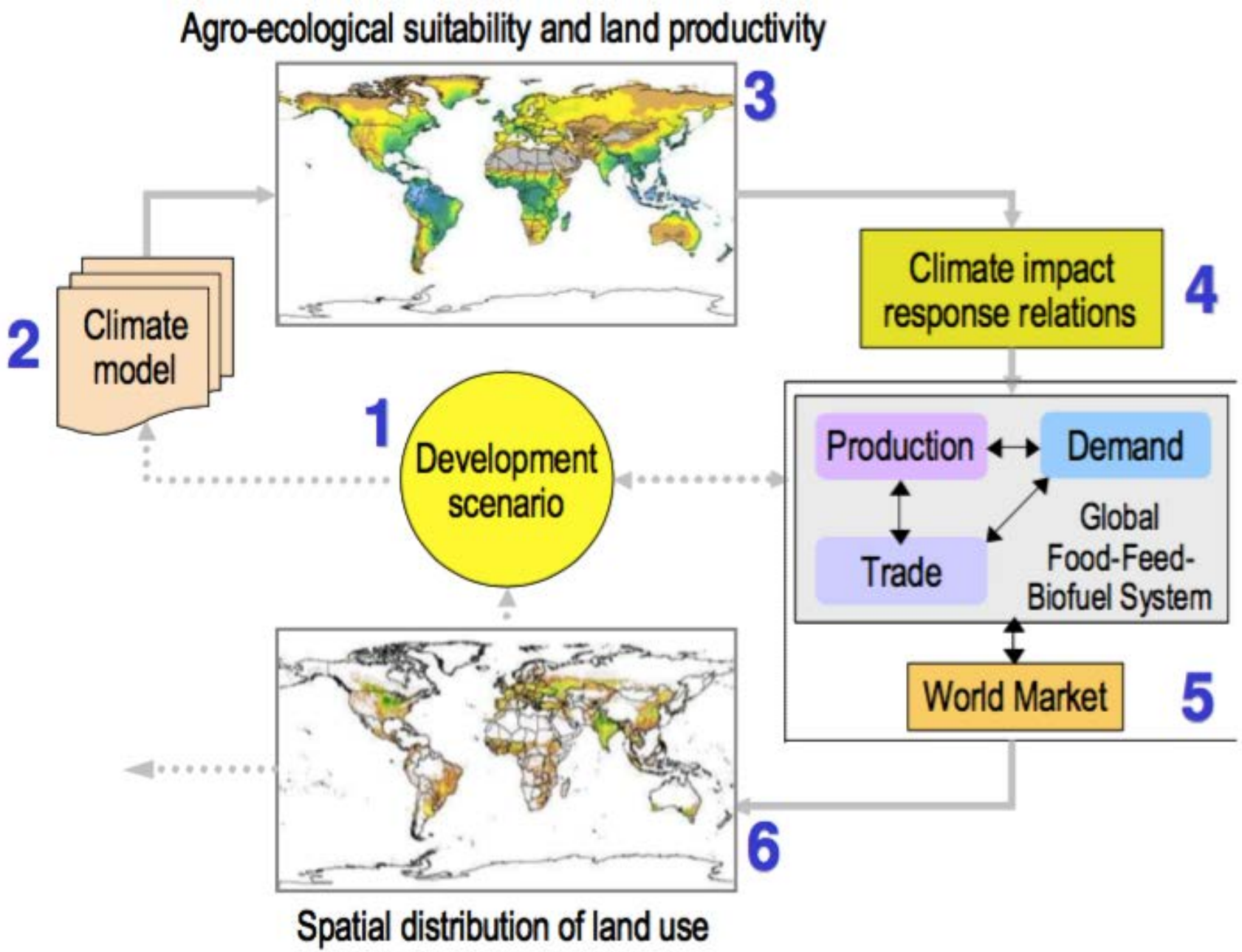
Peter Horton (2017)
We need radical change in how we produce and consume food

- A commitment by governments of all countries to implement agri-food policies that will help deliver the United Nations Sustainable Development Goal, Zero Hunger.
- Recognition by governments that environment, agriculture, food and public health are an integrated system, that has to be considered as a whole.
- Social aspects of the agri-food system, such as equality of access, culture, ethics and justice should not be secondary to free market economics and technology.
- Consumer action and government policy have to work together to bring about change, curtailing and redirecting the motivations of the agri-food businesses and their shareholders.
- Food Security (2017) 9:1323–1327 https://doi.org/10.1007/s12571-017-0740-9

https://ec.europa.eu/clima/policies/ets_en

- The EU emissions trading system (EU ETS) is a key tool for reducing greenhouse gas emissions cost-effectively
- **A 'cap and trade' system**
- The EU ETS works on the 'cap and trade' principle.
- A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that **total emissions fall**.
- Within the cap, companies receive or buy **emission allowances** which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value.

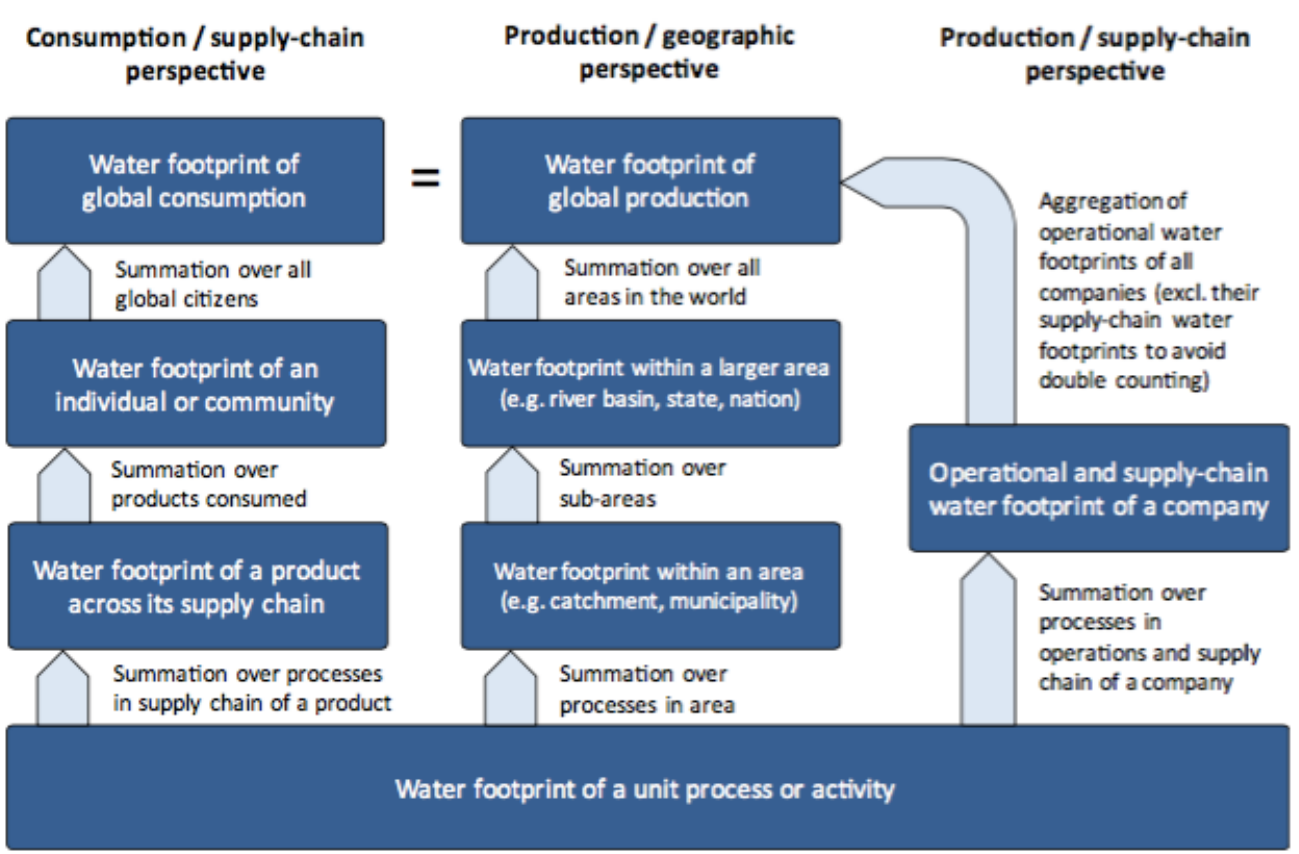
Nature-Based Solutions (NBS) to achieve water management objectives: infographic



water Futures and Solutions
www.iiasa.ac.at/wfas

Figure 3-3: Framework for ecological-economic world food system analysis

- Water Resour Manage (2017) 31
  DOI 10.1007/s11269-017-1618-5
- Water Footprint Assessment: Evo
  a New Research Field
- Arjen Y. Hoekstra1,2



- Improvements in water resources management and access to water supply and sanitation services are essential to addressing various social and economic inequities, such that ‘no one is le behind’ when it comes to enjoying the multiple bene ts and opportunities that water provides.
- Three out of ten people do not have access to safe drinking water. Almost half of people drinking water from unprotected sources live in Sub-Saharan Africa. Six out of ten people do not have access to safely managed sanitation services, and one out of nine practice open defecation.
- Women and girls regularly experience discrimination and inequalities in the enjoyment of their human rights to safe drinking water and sanitation in many parts of the world. Ethnic and other minorities, including indigenous peoples, migrants and refugees, and people of certain ancestries (e.g. castes), o en experience discrimination, as can religious and linguistic minorities. Di erences in property, tenure, residence, and economic and social status can lead to discrimination as well.
- Caution must be taken in order to clearly di erentiate between ‘water rights’ and the human rights to water and sanitation. Water rights, which are normally regulated under national laws, are conferred to an individual or organization through property rights or land rights, or through a negotiated agreement between the state and landowner(s). Such rights are o en temporary and can potentially be withdrawn. The human rights to water and sanitation are neither temporary nor subject to state approval, and they cannot be withdrawn.

4.4 Forests as post Kyoto Protocol saviours: accounting for LULUC (Land use and Land Use Change) and carbon storage potential

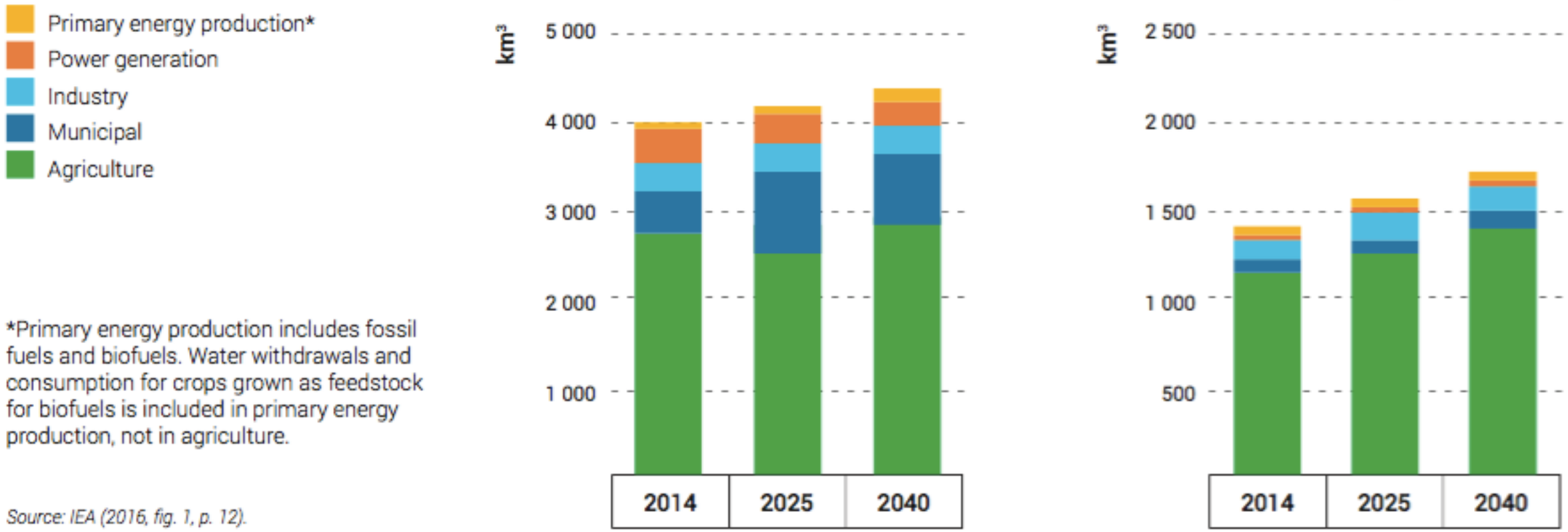
- CO_2 fertilisation (as discussed in previous 3 lectures) – direct effects on carbon gain and indirect effects of water and N use efficiency, forest carbon sink = 2.4Gt yr^{-1}
- Boreal forest show contrasting effects: warming may both stimulate respiration (remember all of those peatlands), but increased decomposition may promote mineralisation and growth- and deforestation/fire an issue in Eastern Siberia
- Temperate forests- could be big sinks- except in drought years (e.g. 2003); issues with eddy flux- often set up on young, developing stands; aging might decrease sink capacity
- But Boreal and Temperate forests are sequestering 1.1 Gt (C) per year
- Tropical forests- in arid and semi arid regions, water limits productivity- tropical forests may become sources in dry / ENSO years; deforestation counters any potential sink
- BUT: Global deforestation (to grasslands) would add 2-4 times more C to the atmosphere than could be taken up by reforestation of cleared areas.. So now you can see why politicians suddenly love forests!!

*UNFCC: COP off or COP out with REDD+?

REDD= Reducing Emissions from Deforestation and forest Degradation

*United Nations Framework for Climate Change: Conference of the Parties

Figure 2 Global water demand by sector to 2040



*Primary energy production includes fossil fuels and biofuels. Water withdrawals and consumption for crops grown as feedstock for biofuels is included in primary energy production, not in agriculture.

Source: IEA (2016, fig. 1, p. 12).

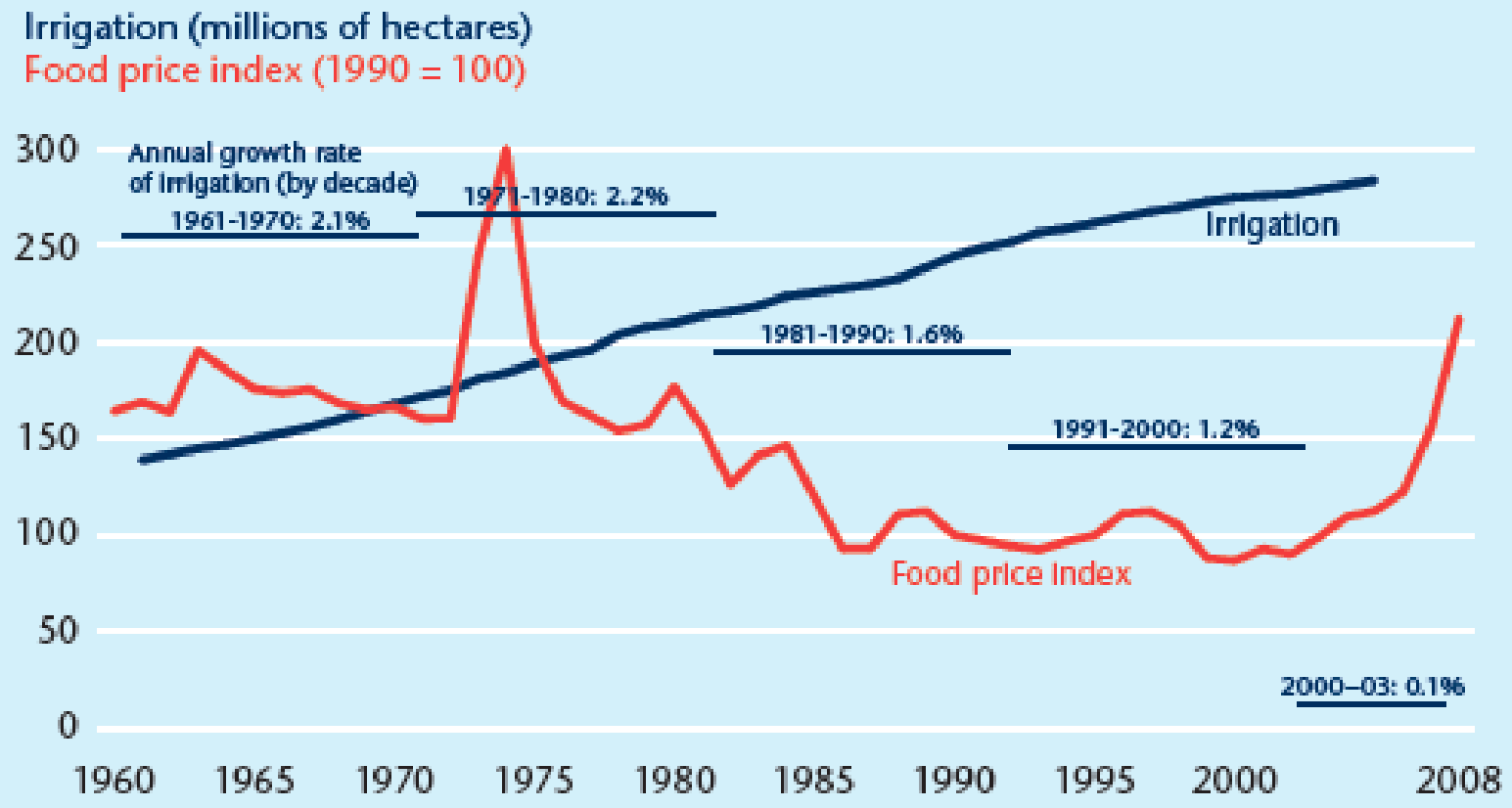
- With the transition from a fossil to biobased economy, carbon footprint studies will gradually make place for land and water footprint studies, because biobased essentially means based on scarce land and water resources. Finally, the idea of ‘zero WF’ as the ultimate target for industrial processes fits within studies on the circular economy.
- WFs of all primary crops (and various derived crop products), WFs of eight types of animal (and animal products like meat, milk, butter, cheese, leather) and WFs of the industrial and municipal sectors. Mekonnen and Hoekstra (2011, 2012a) made improvements and applied a high spatial resolution, thus accounting for spatial variability in climate, soils and other production conditions.
- Another focus of research has become the WF of food waste; it has been estimated that the blue WF for the production of total food wastage is about 250 billion m3, which is 3.6 times the blue WF of total USA consumption (FAO 2013

- The aim of REDD+ is to encourage developing countries to contribute to climate change mitigation efforts by: i) reducing greenhouse gas emissions (GHG) by slowing, halting and reversing forest loss and degradation; and ii) increasing removal of GHGs from the earth's atmosphere through the conservation, management and expansion of forests.
- Countries interested in REDD+ are required to progress through three phases, which are closely linked with one another (UNFCCC Decision 1/CP.16, paragraph 73):
- **readiness phase**, involving the development of national strategies or action plans, REDD+ mitigation actions, and capacity building;
- **implementation of national strategies and results-based demonstration activities**, enacting REDD+ actions and national strategies or plans that could involve further capacity building, technology development and transfer, and results-based demonstration activities;
- **results-based actions** that must be fully measured, reported and verified.

The following five REDD+ activities contribute to mitigation actions in the forest sector and have been globally agreed to:

- reducing emissions from deforestation
- reducing emissions from forest degradation
- conservation of forest-carbon stocks
- enhancement of forest-carbon stocks
- sustainable management of forests
- These five activities are implemented through a package of coordinated REDD+ actions defined by each country and included in national strategies and action plans.
- These activities may also provide important climate change adaptation co-benefits. Adaptation refers to the resilience of ecosystems, as well as resilience of societies.
- Where forests have not been degraded, people have enjoyed greater protection from natural disasters such as flooding and landslides. In coastal areas, mangroves can protect against storms and waves. Healthy forests also reduce vulnerability, offering food, shelter, medicine, and livelihood support to some of the world's poorest people.

Figure 7.6 **As irrigation area expanded, food price fell for 30 years before starting to rise again**



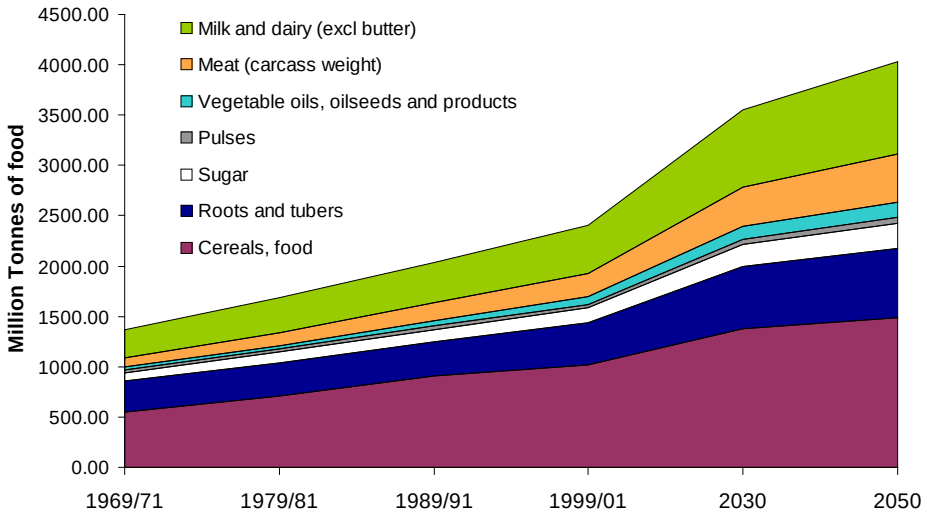
Source: Based on Comprehensive Assessment of Water Management in Agriculture 2007; FAO FAOSTAT.

- success in agricultural production led to a 30-year decline in food prices in most countries a trend that lasted until very recently.

We see an increased demand projected for food (particularly meat) and energy

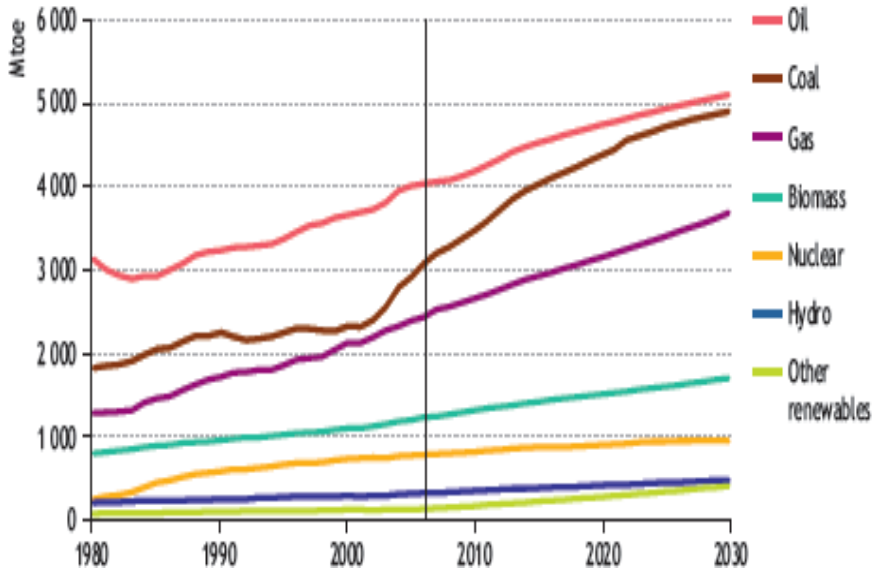
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/288329/11-546-future-of-food-and-farming-report.pdf

World food requirements



World food production must rise by **50 % by 2030** to meet increasing demand (*Source: UN 2008)*

World primary energy demand by fuel



Total world energy demands are predicted to increase by approx. **50% by 2030** (*Source: IEA 2008: Reference Scenario*)

Slide from John Beddington