POLITECNICO
MILANO 1863

Rosenberg International Forum on Water Policy

SUSTAINABLE AND EQUITABLE USE OF WATER FOR FOOD PRODUCTION

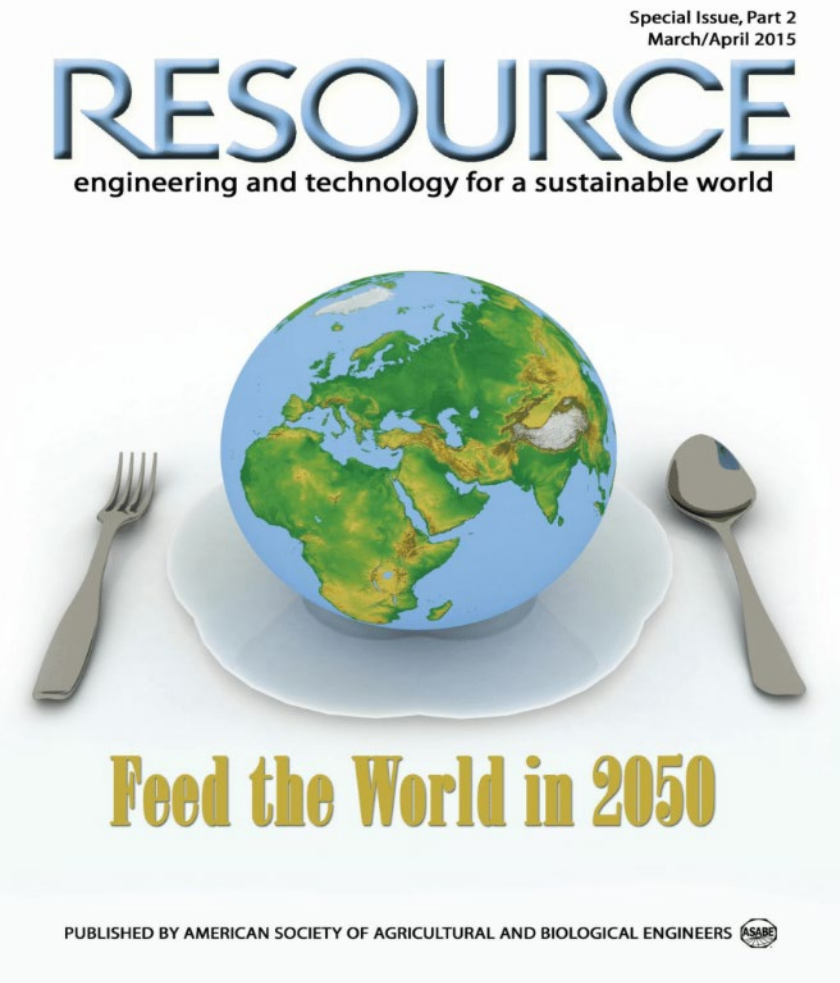
MARIA CRISTINA RULLI

POLITECNICO DI MILANO

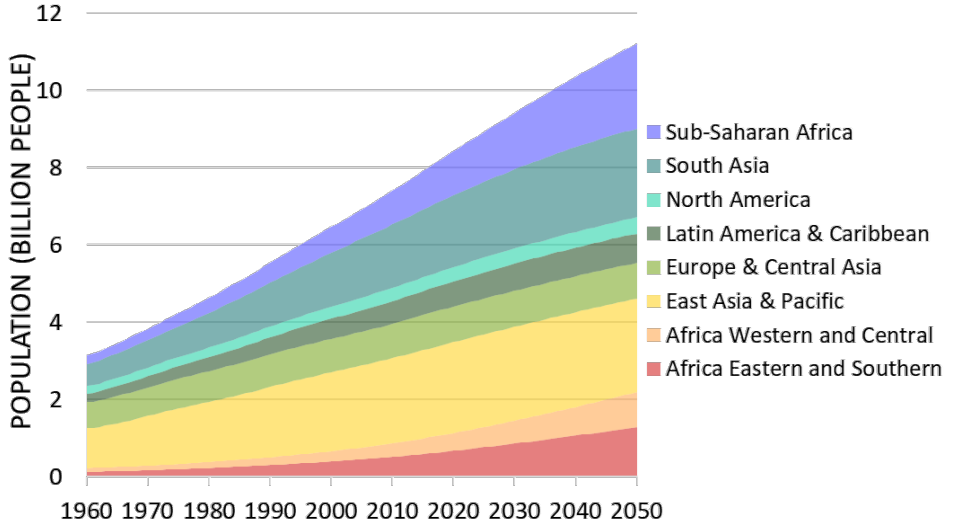
ROSENBERG INTERNATIONAL FORUM ON WATER POLICY

CAPE TOWN, OCTOBER 26TH, 2023

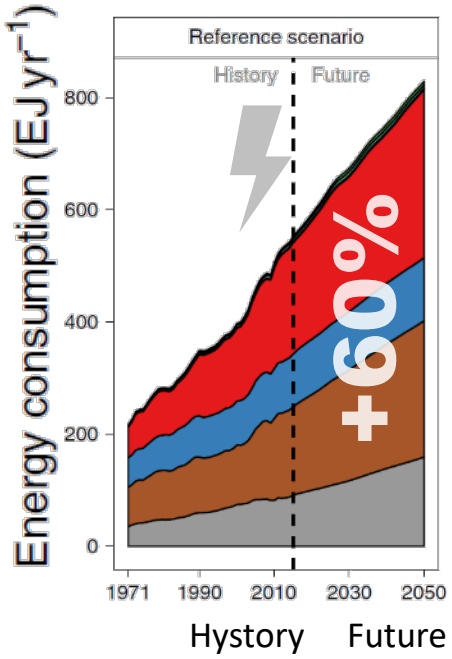
THE CHALLENGE ...

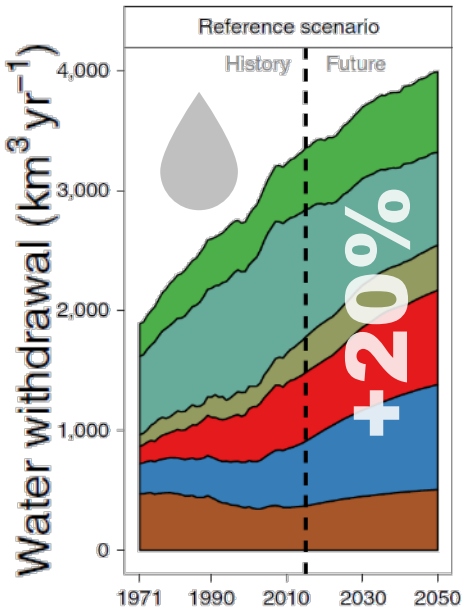


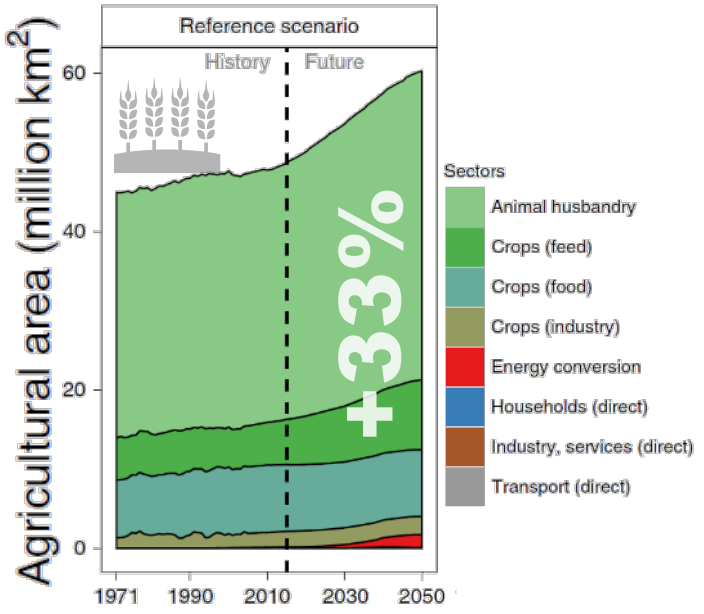
+60% FOOD CONSUMPTION



Data source: World Bank Open Data

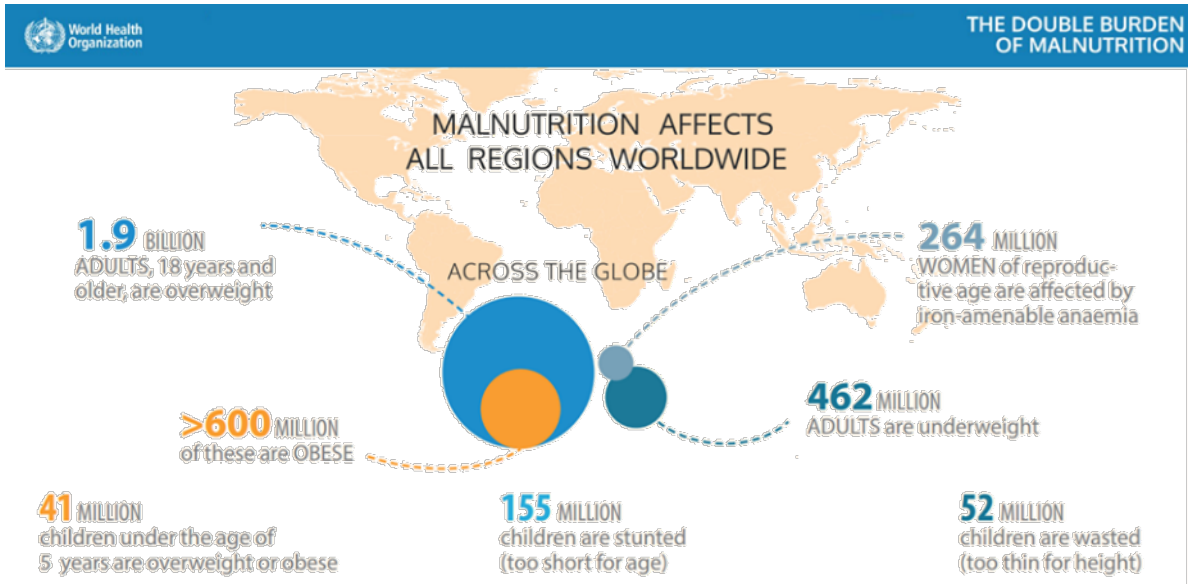


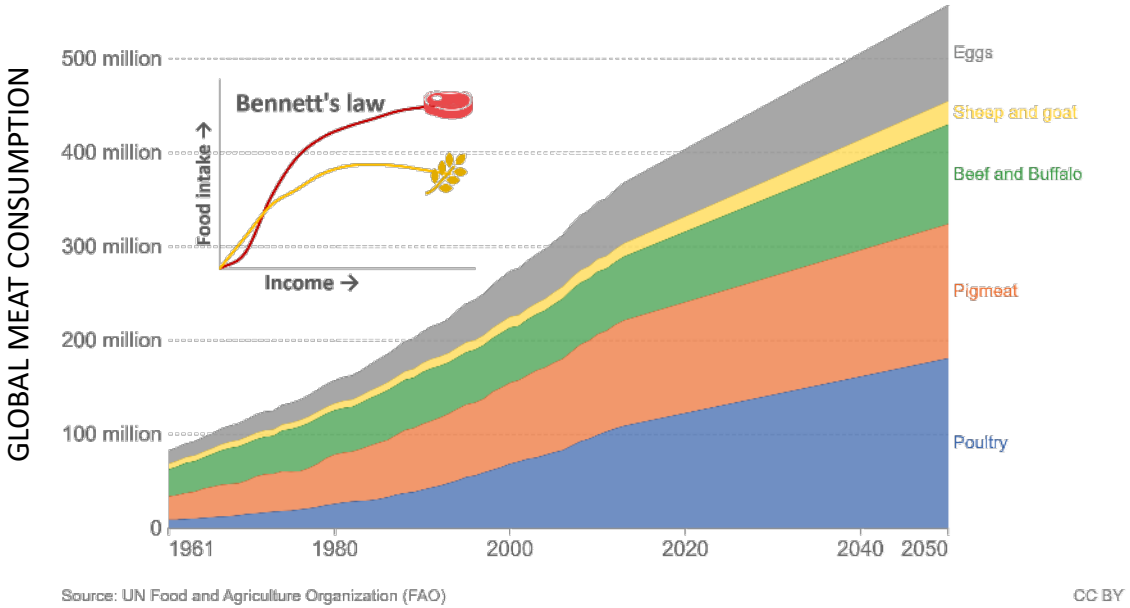




Adapted from: Van Vuuren et al., 2019

THE ADDITIONAL CHALLENGES ...





THE LANCET

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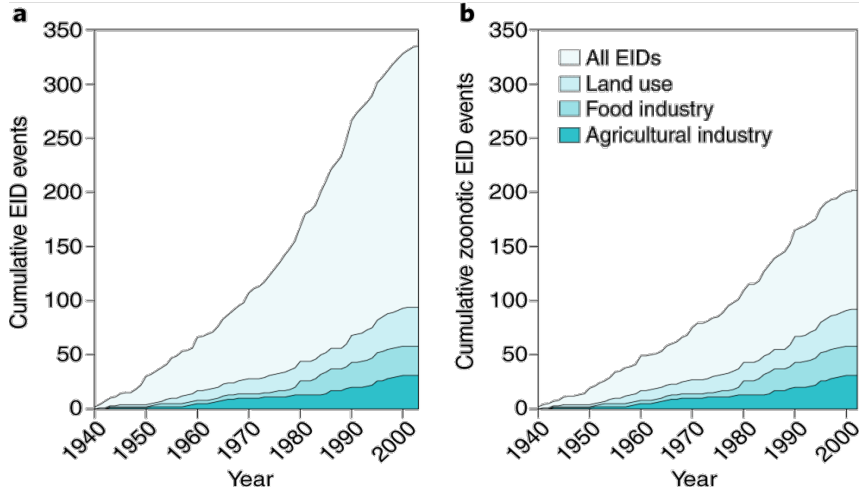
Food in the Anthropocene: the EAT–*Lancet* Commission on healthy diets from sustainable food systems

Published: January 16, 2019

Executive Summary

Food systems have the potential to nurture human health and support environmental sustainability,

EMERGING INFECTIOUS DISEASES



Adapted from: Rohr et al., 2019, *Nature Sustainability*

CAN WE FEED A FUTURE POPULATION OF 10 BILLION PEOPLE A HEALTHY DIET WITHIN PLANETARY BOUNDARIES?

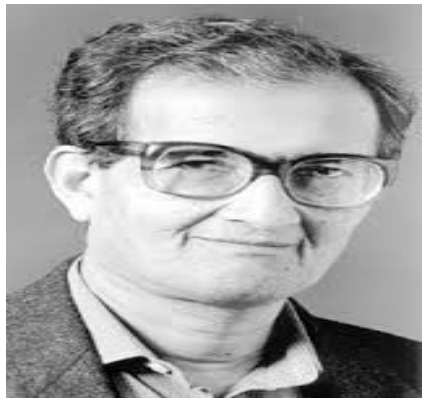
BRIEF HISTORY OF THE FOOD SECURITY DEBATE

Thomas Malthus

Thomas Malthus (1766-1834) Demographic growth is faster than the increase in resources. In the long run not enough resources to feed everybody.

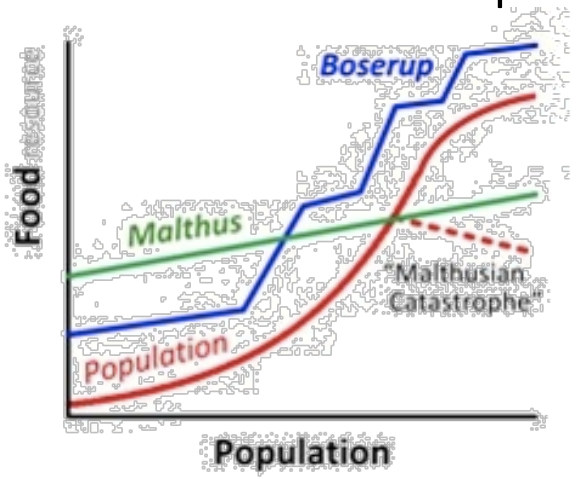
Esther Boserup *(1981)* Technological innovations → increase food production

Esther Boserup



Amartya Sen

Amartya Sen *Poverty and Famines* (1981) Famines caused by lack of access → not a problem of availability



But to what extent is current food production sustainable?

Do we have enough water to feed the humanity sustainably?

The question "*How many people can the planet feed?*" is still relevant

HOW CAN WE MEET THE INCREASING DEMAND FOR FOOD?

Agricultural Intensification

Yield Gap closure on underperforming lands (irrigation, fertilizers,…)

Transition to Commercial Agriculture
Loss of livelihoods
Water resources depletion
Land degradation

Agricultural Extensification

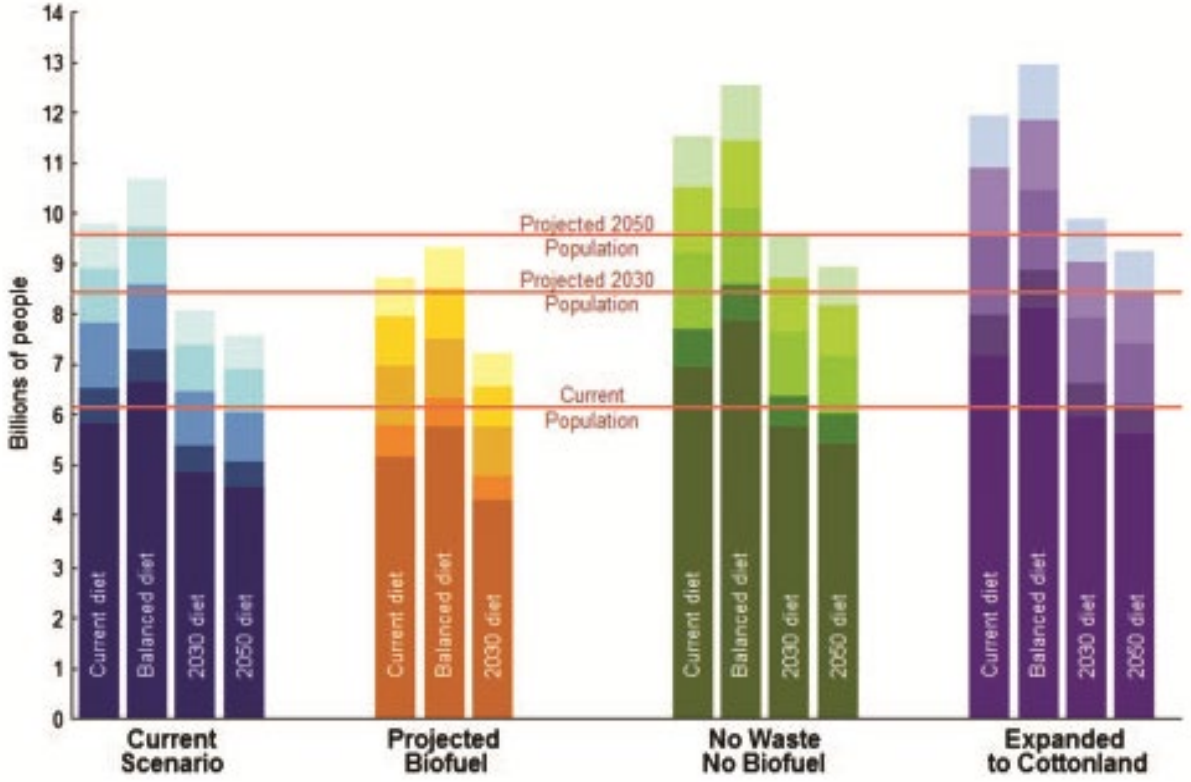
Expansion of the cultivated area

Land Use Change
Deforestation
Biodiversity losses

AGRICULTURAL INTENSIFICATION

Ecologists advocate for Intensification …because it avoids habitat destruction

How many people can we feed if we close the yield gap?



Davis, Rulli, D' Odorico., *Earth's Future*, 2014

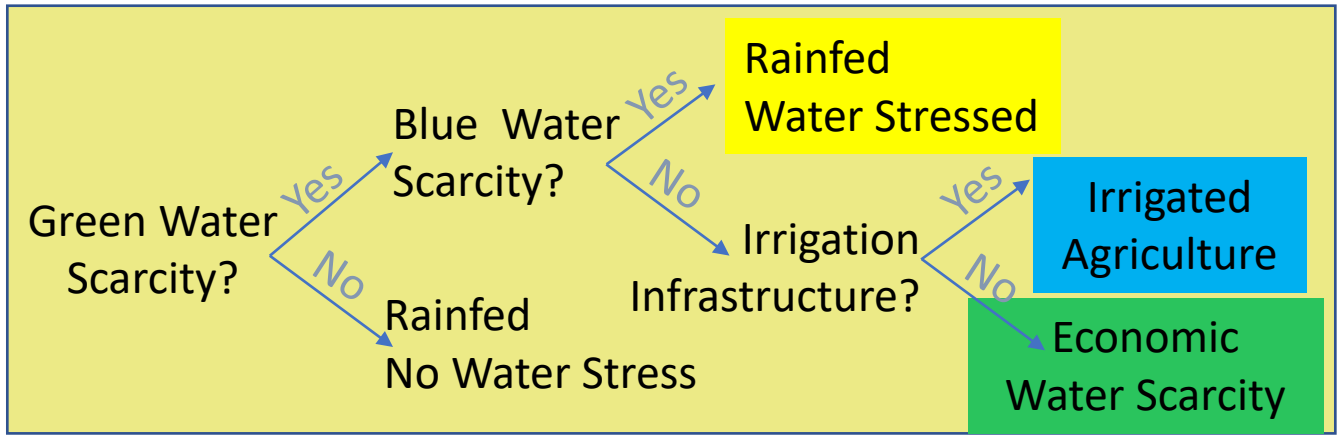
About 4 billions?

Do we have the Natural Resources to sustainably feed humanity?

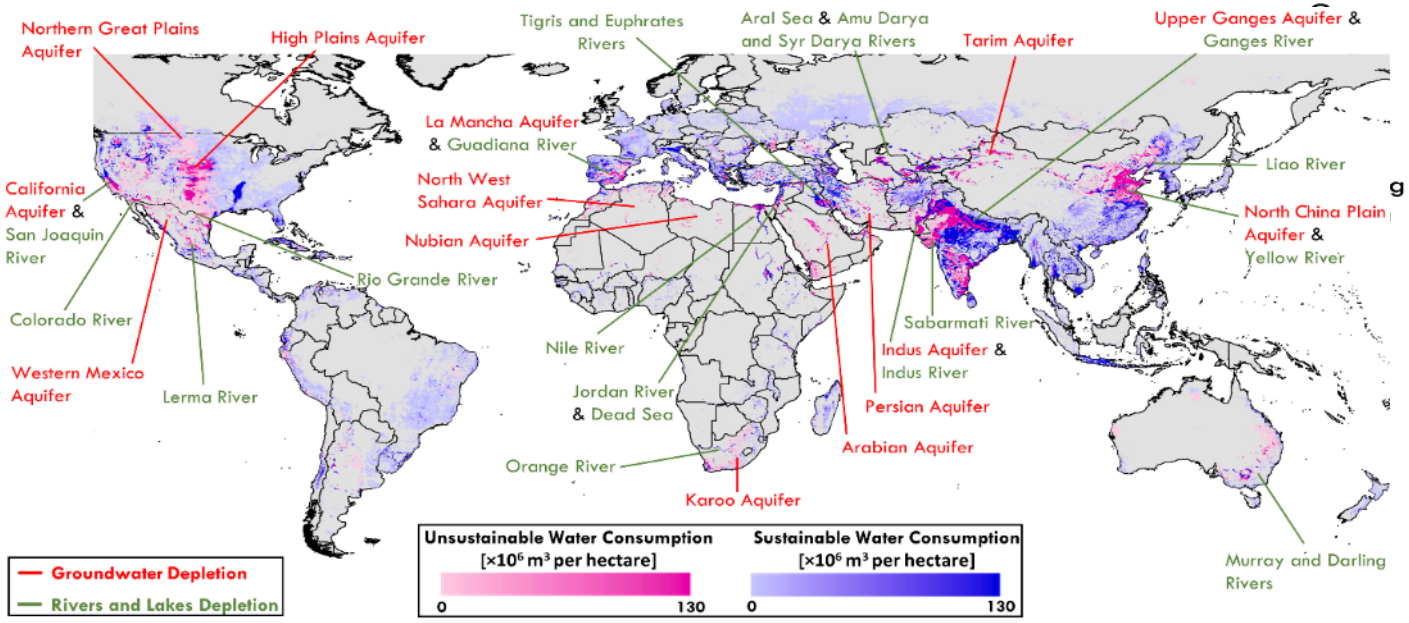
and

Are we running out of Natural Resources to sustainably meet energy and food needs?

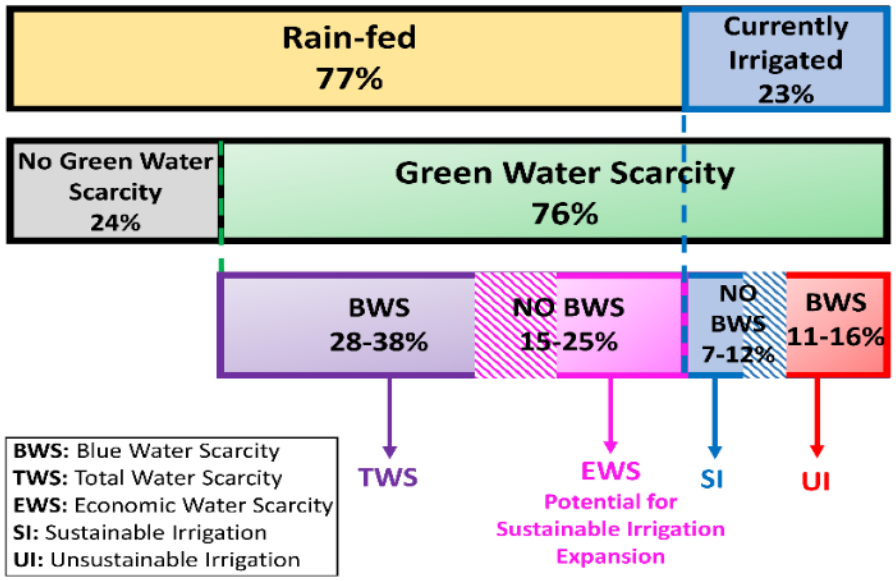
WATER SCARCITY



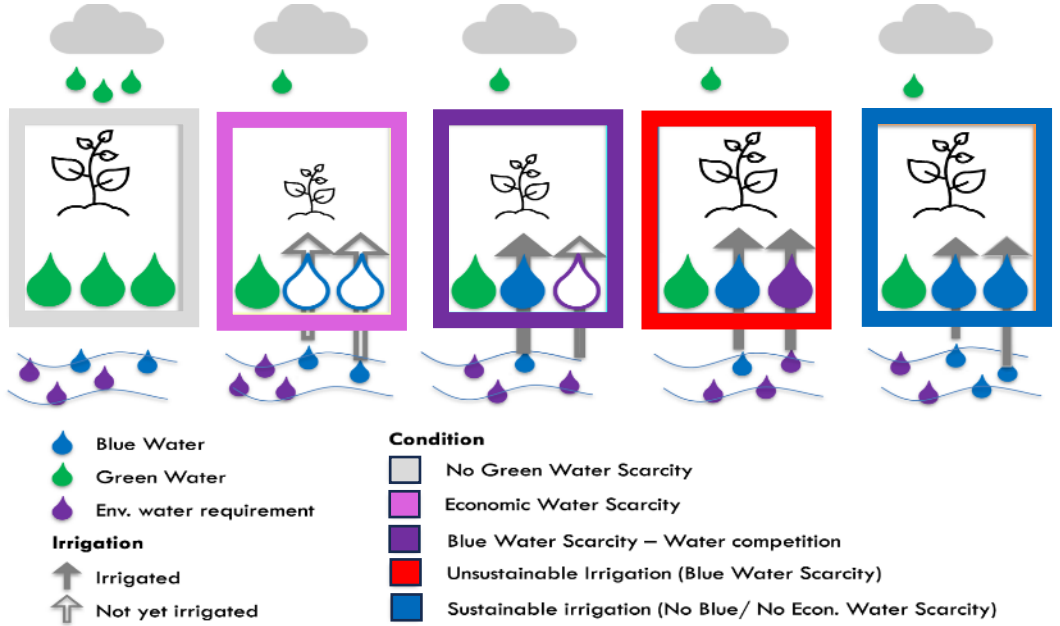
AGRICULTURAL INTENSIFICATION : HOTSPOTS OF UNSUSTAINABLE WATER USE



AGRICULTURAL ECONOMIC WATER SCARCITY OVER GLOBAL CROPLANDS



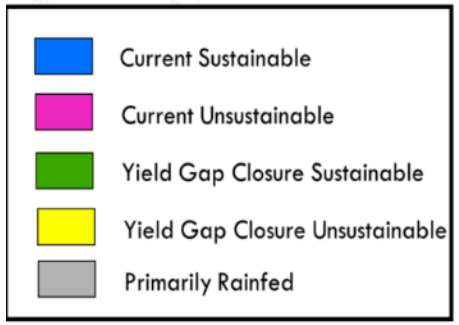
(Rosa et al., Sci Adv., 2020)



AGRICULTURAL INTENSIFICATION: WATER CONSTRAINTS

We can feed 4 Billion people if we close the yield gap

… but is there enough water to do it sustainably while preserving environmental flows and groundwater?

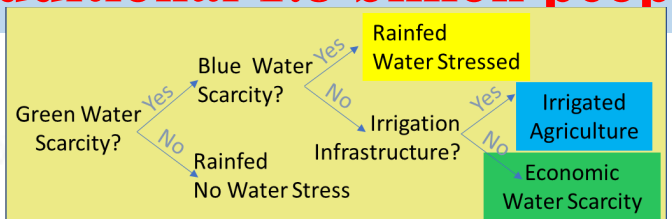


It is possible to sustainably

- increase water consumption for irrigation by 48%
- expand irrigation to 26% of currently rainfed cultivated lands
- increase food production by 37%
- feed an additional 2.8 billion people

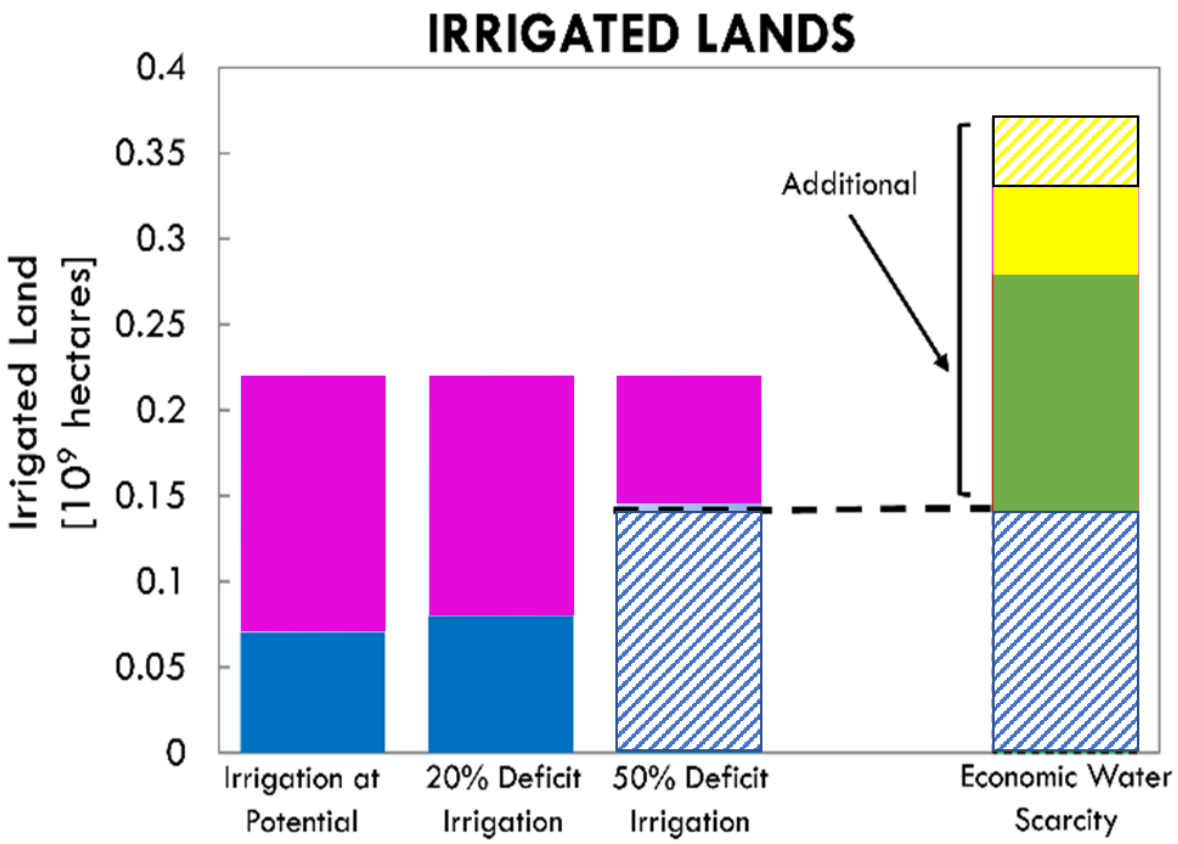
But… if 'we' eliminate unsustainable irrigation

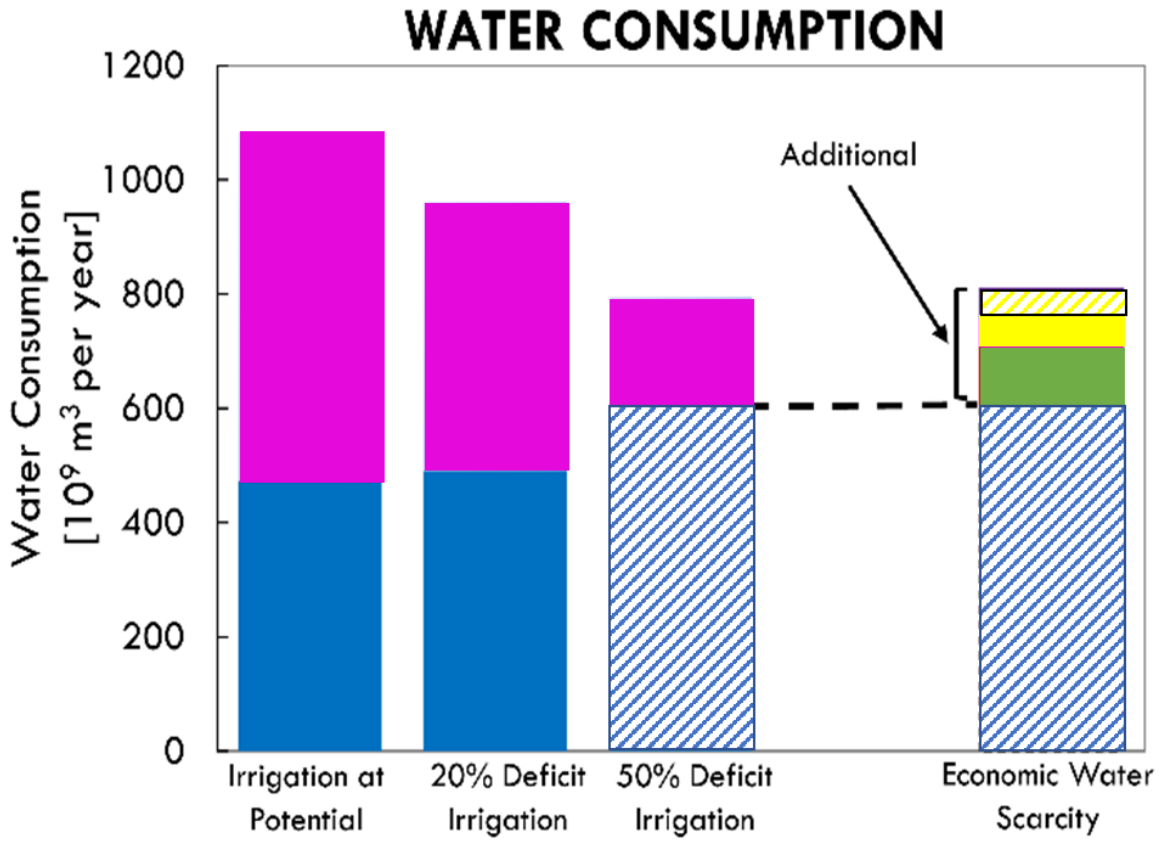
- The increase in food production drops to 24%
- feed an additional 1.8 billion people



Rosa et al., ERL, 2018

SUSTAINABLE IRRIGATION EXPANSION





(Rosa et al., Sci Adv., 2020)

Sustainable irrigation (presently irrigated areas with no Blue Water Scarcity)

Unsustainable irrigation (presently irrigated areas with Blue Water Scarcity)

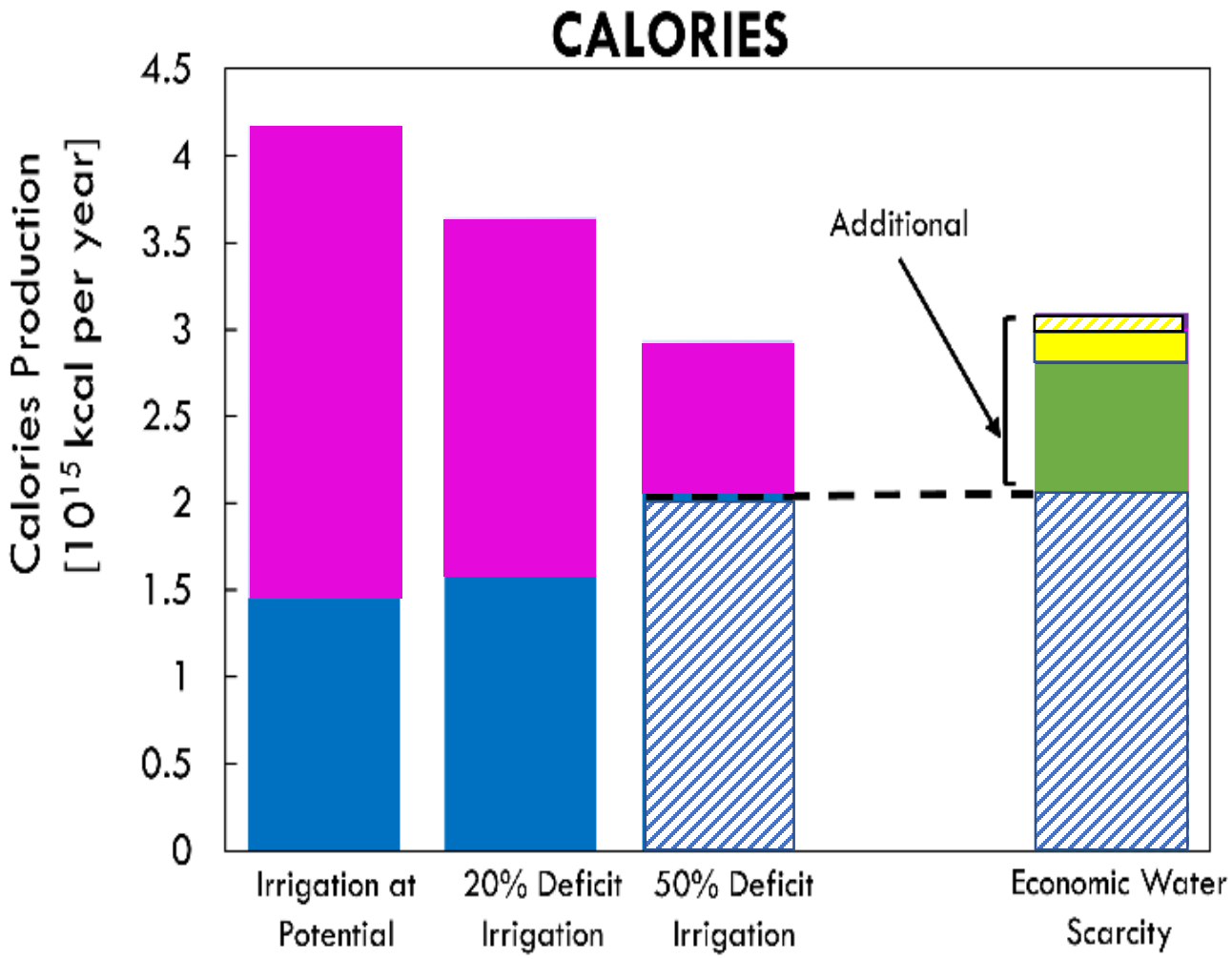
Sustainable irrigation in areas with Economic Water Scarcity and 0% deficit irrigation

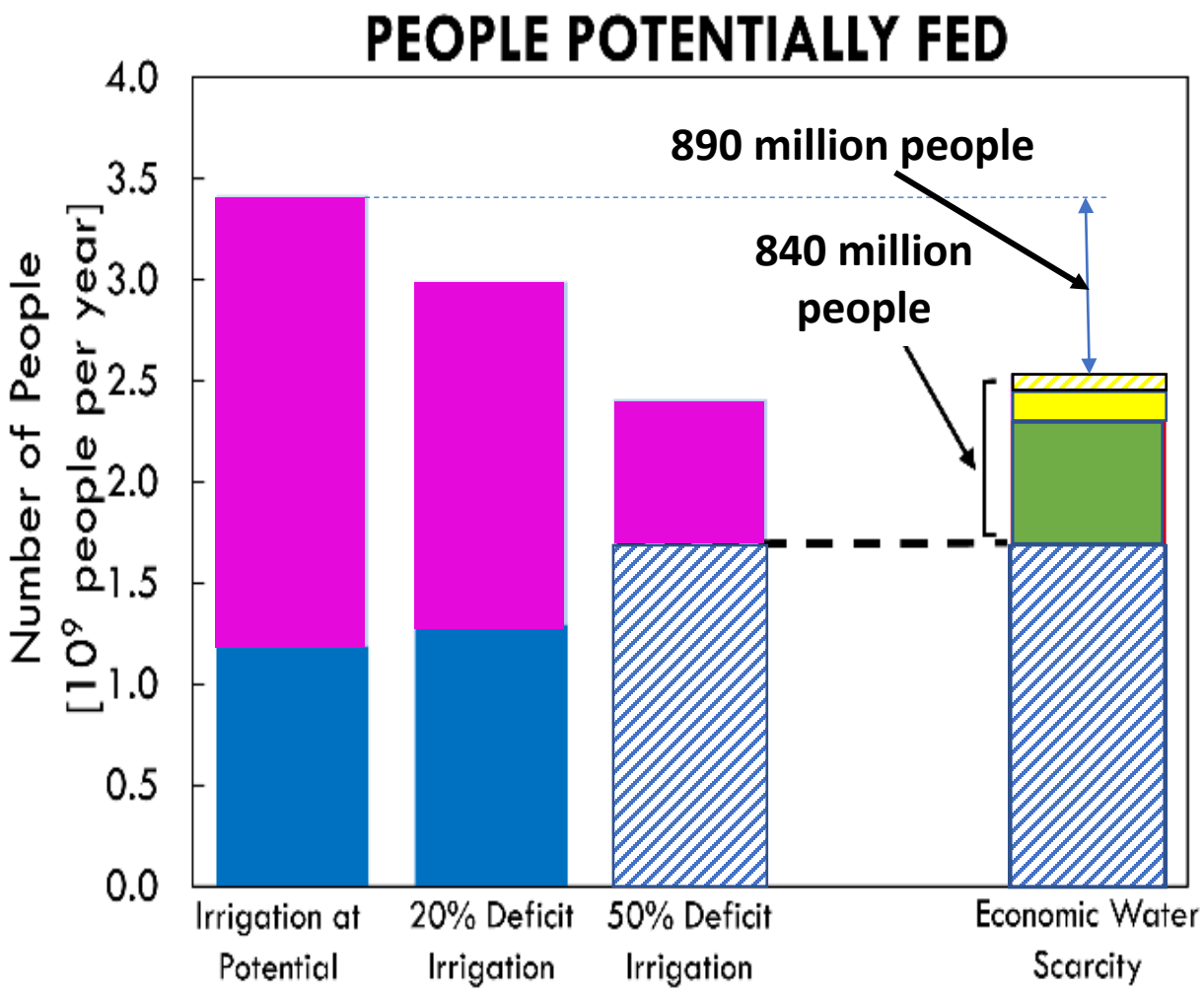
Sustainable irrigation in areas with Economic Water Scarcity and 20% deficit irrigation

Sustainable irrigation in areas with Economic Water Scarcity and 50% deficit irrigation

Maximum sustainable capacity over presently irrigated areas

EFFECT OF SUSTAINABLE IRRIGATION EXPANSION





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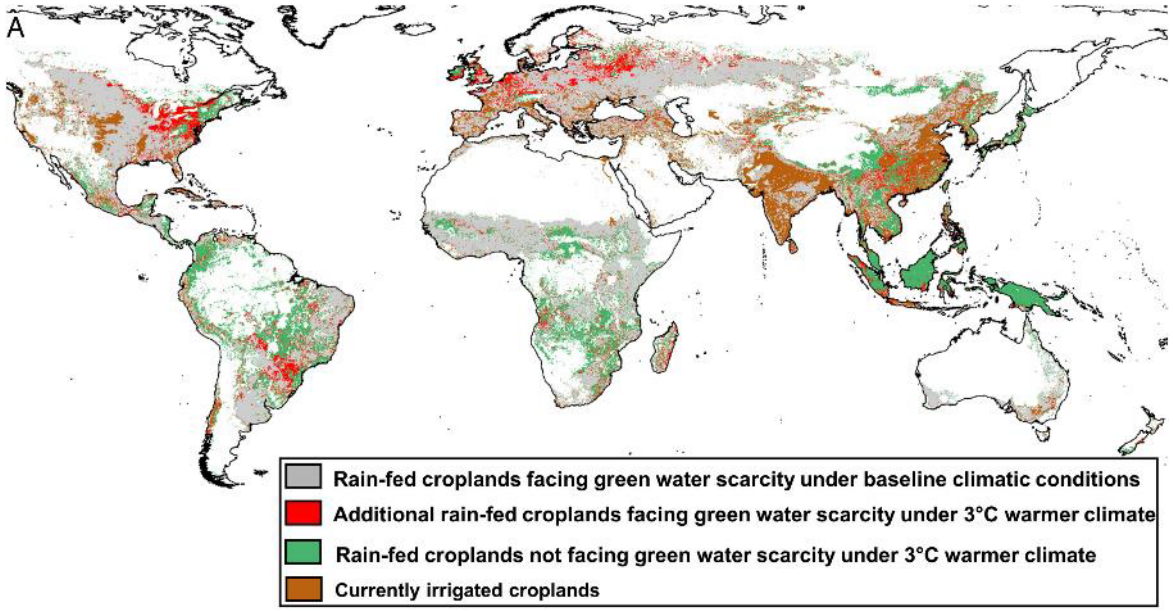
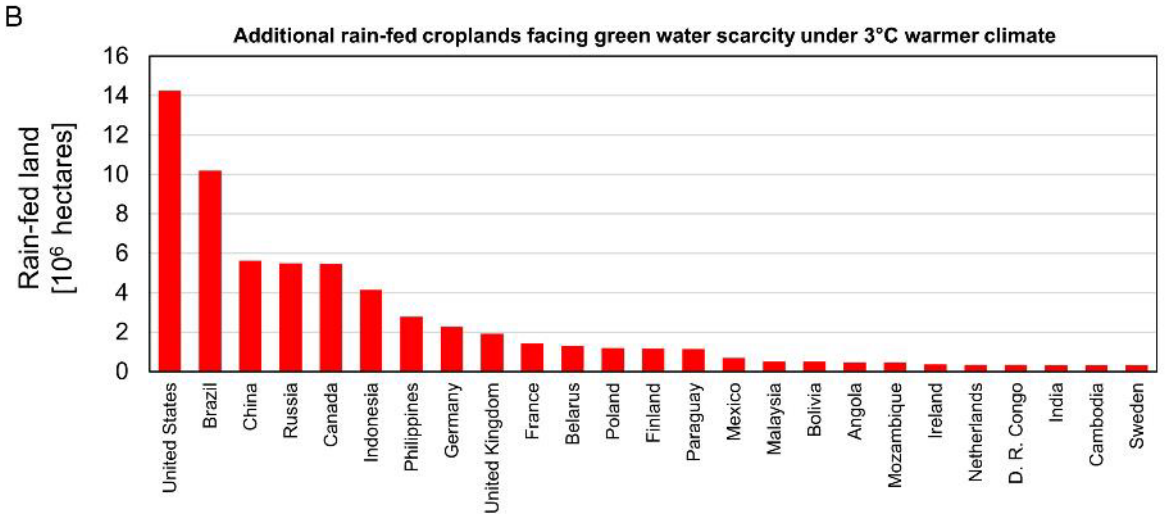
Sustainable irrigation in areas with Economic Water Scarcity and 50% deficit irrigation

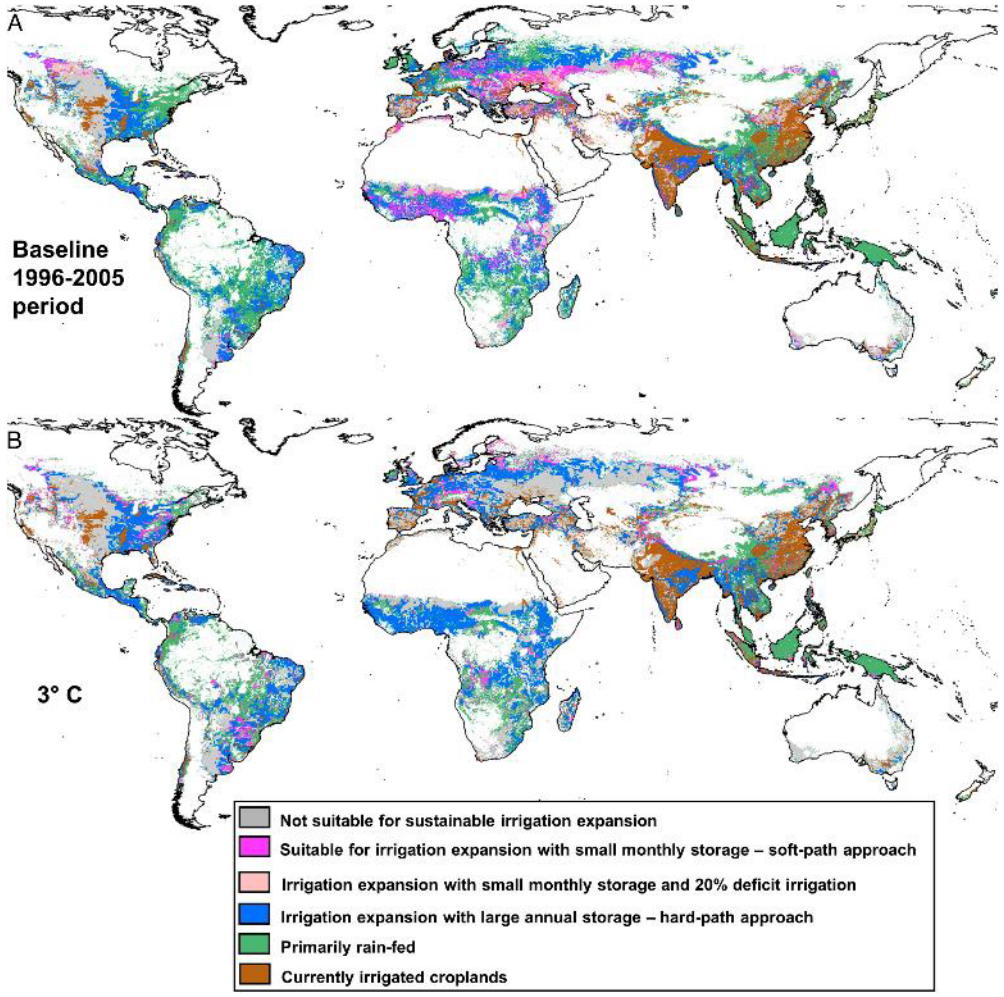
Maximum sustainable capacity over presently irrigated areas

EFFECTS OF CLIMATE CHANGE ON IRRIGATION SUITABILITY

Sustainable irrigation expansion potential under baseline and 3 °C warmer climate conditions with respect to preindustrial era



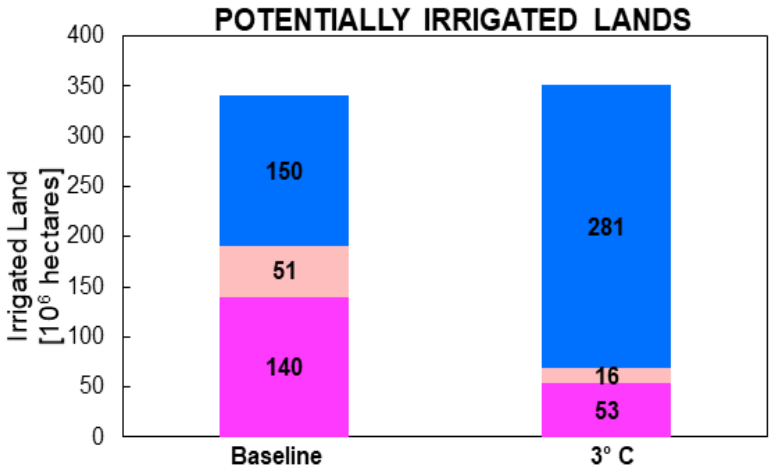


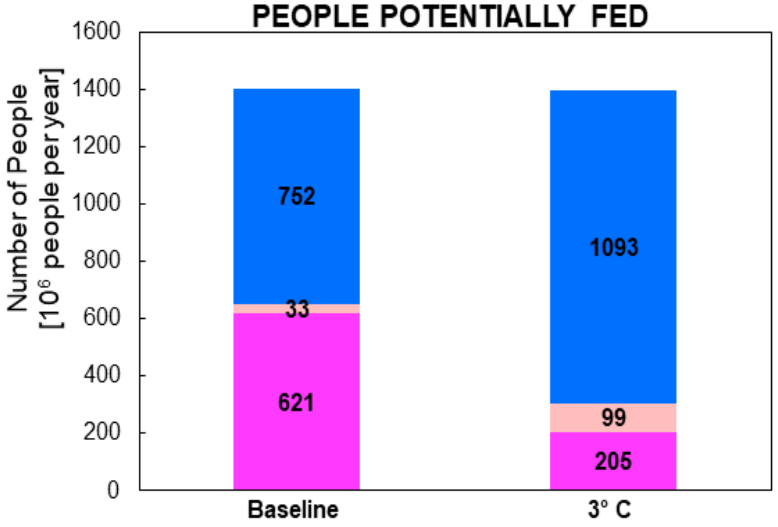


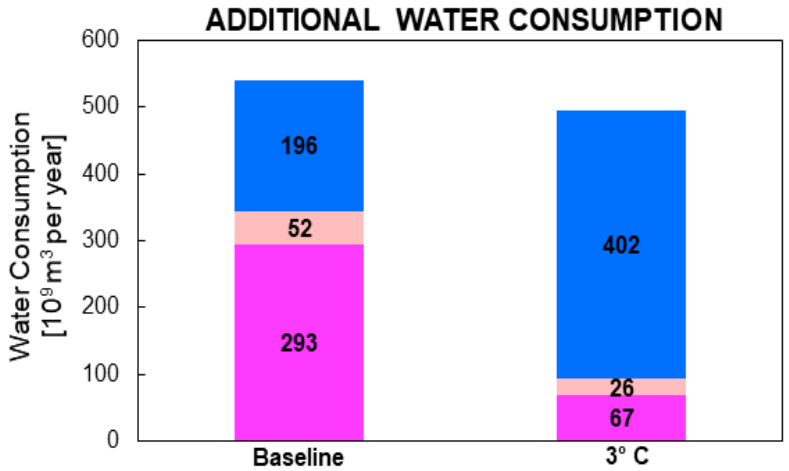
Baseline

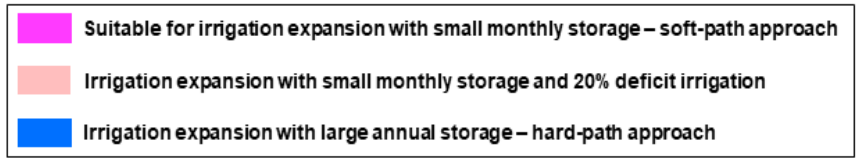
3C Warmer

GLOBAL POTENTIAL FOR "SUSTAINABLE" IRRIGATION EXPANSION









- Increasing needs for water storage
- "soft-path" irrigation expansion: 70 million hectares to feed 300 million more people
- "hard-path"+"soft-path" irrigation expansion with annual water storage: 350 million hectares, to feed 1.4 billion more people

Baseline: 1996 to 2005 period

AGRICULTURAL INTENSIFICATION: SOCIO-ENVIRONMENTAL IMPACTS THE LSLAS

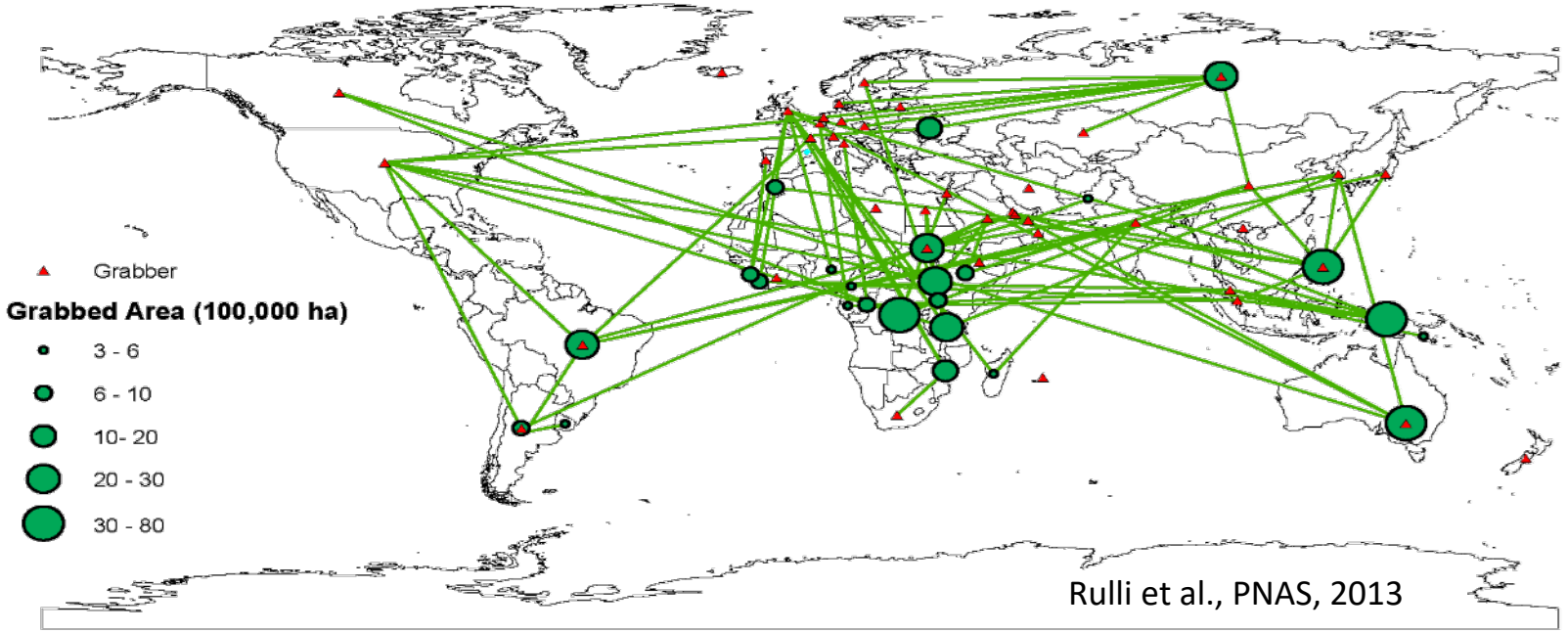
NATURE GEOSCIENCE | VOL 6 | JUNE 2013 | www.nature.com/naturegeoscience

The fourth food revolution

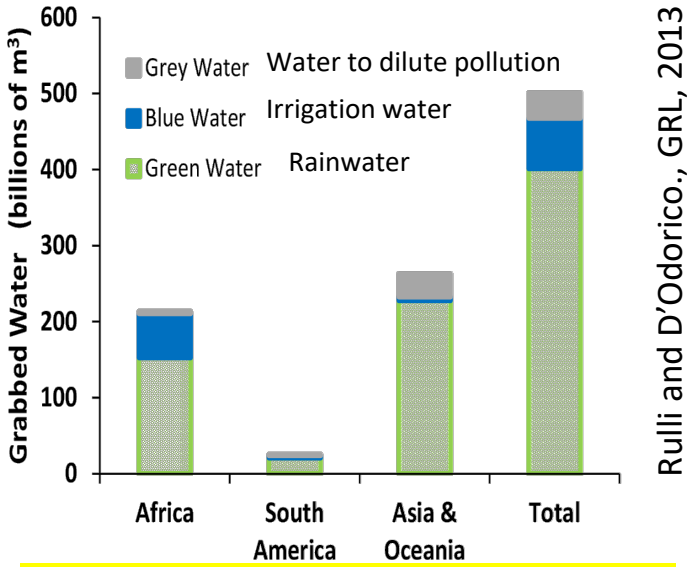
Paolo D'Odorico and Maria Cristina Rulli

In areas of the developing world that have benefited only marginally from the intensification of agriculture, foreign investments can enhance productivity. This could represent a step towards greater food security, but only if we ensure that malnourished people in the host countries benefit.

Yield Gap Closure (big yield gaps often exist in developing world where investments in agriculture have been lacking)

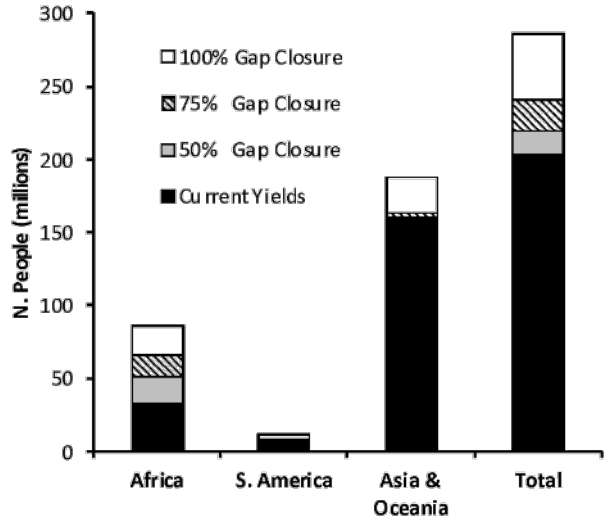


Rulli et al., PNAS, 2013



Rulli and D'Odorico., GRL, 2013

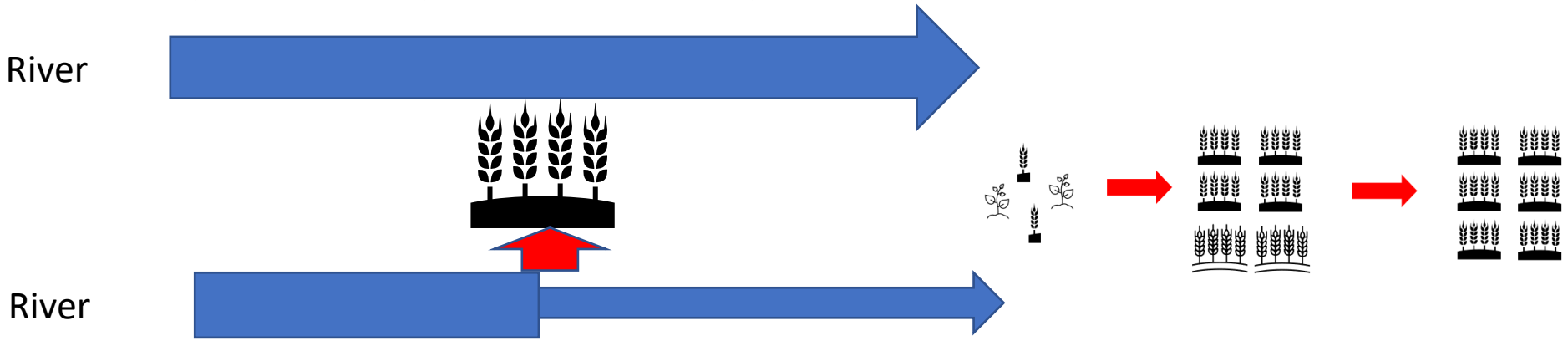
How many people can be fed?

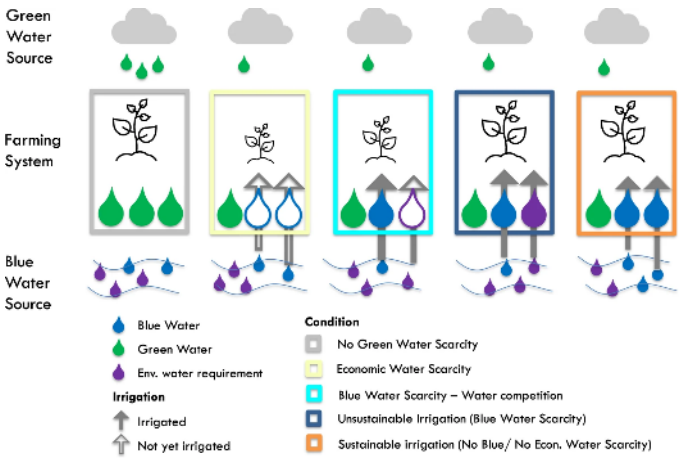


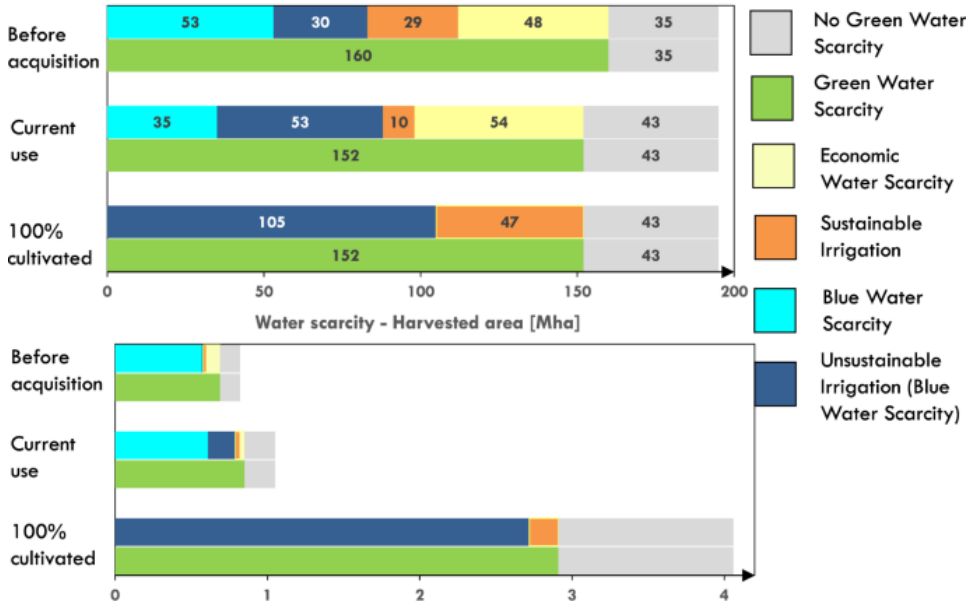
Rulli and D'Odorico., ERL, 2014

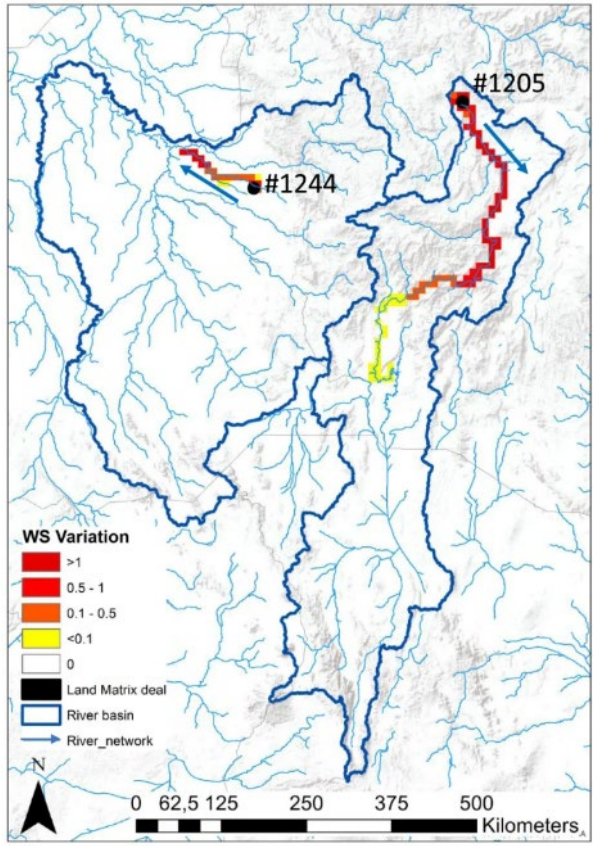
AGRICULTURAL INTENSIFICATION: SOCIO-ENVIRONMENTAL IMPACTS THE LSLAS

Water appropriation associated with LSLAs in Africa accounts for about **210 km^3 year^{-1}** of blue and green water, assuming that all the acquired areas are actively used for agricultural production.









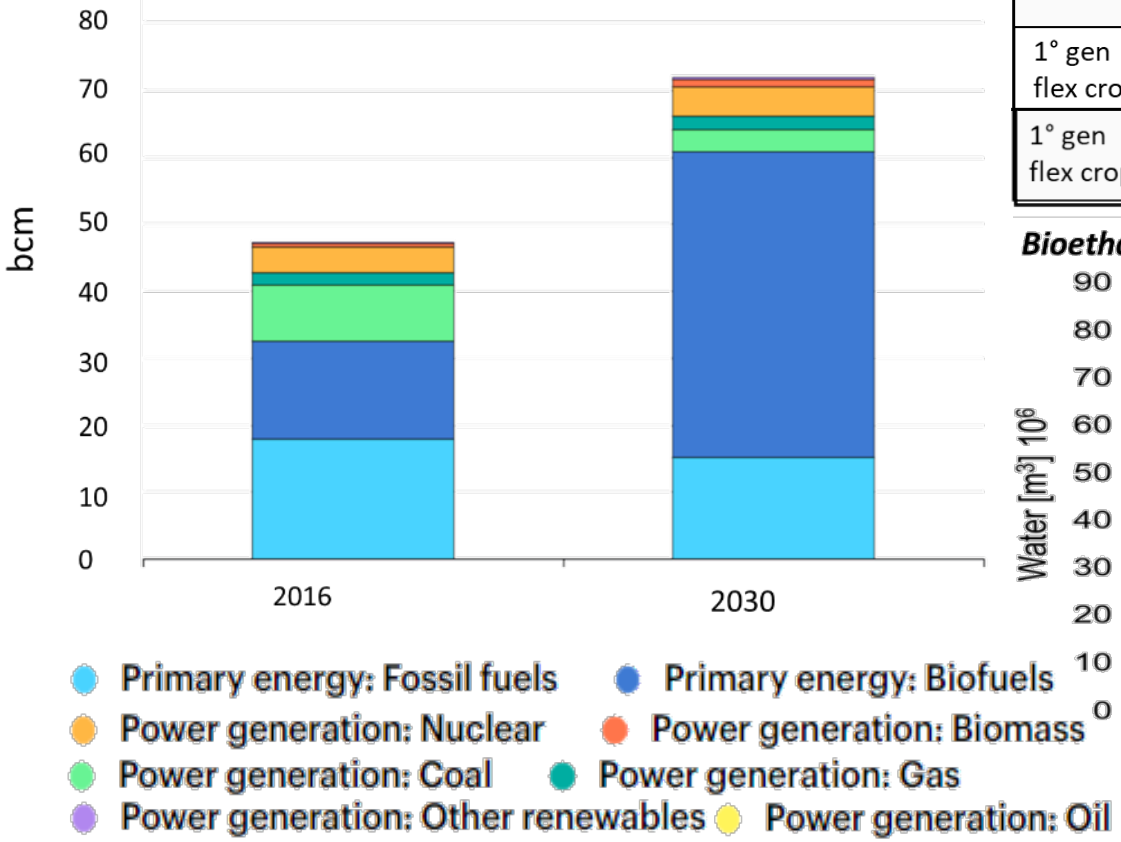
The impact of upstream water appropriations by LSLAs **limits present and future agricultural development opportunities**, while also affecting pastoralist communities in the area

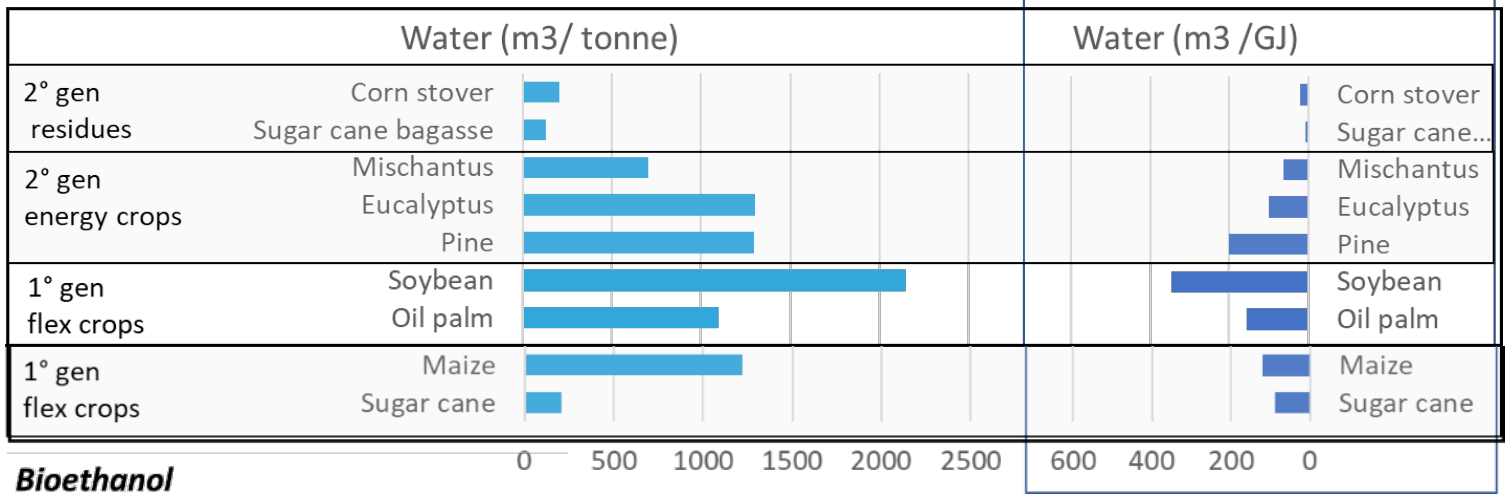
Chiarelli et al., NatComms (2022)

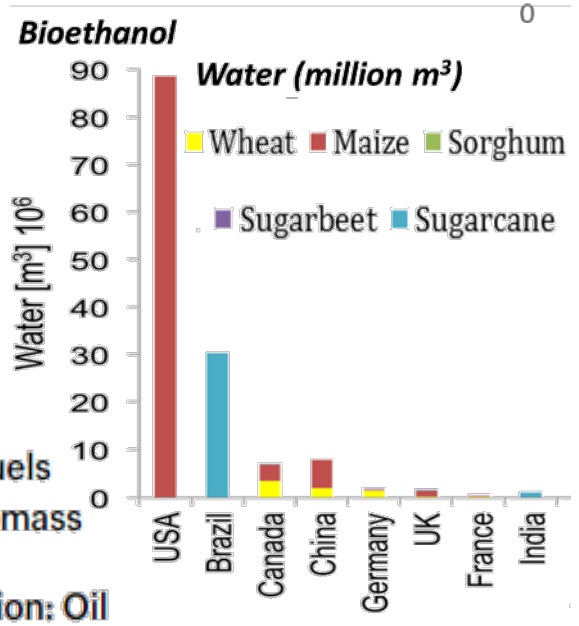
THE ADDITIONAL CHALLENGES …

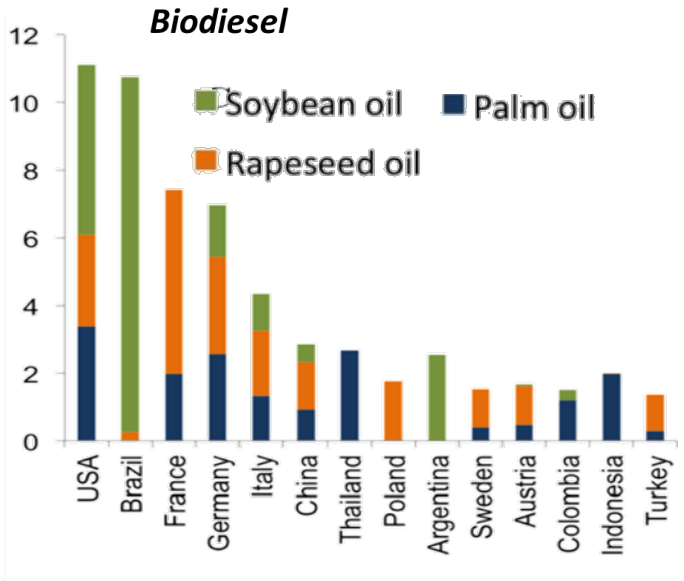
COMPETITION FOR WATER BETWEEN ENERGY AND FOOD SECTORS BIOFUELS, BIOENERGY WITH CARBON CAPTURE &STORAGE, FOSSIL FUELS…

Global water consumption in the energy sector by fuel type in the Sustainable Development Scenario, 2016-2030 (IEA, 2020)









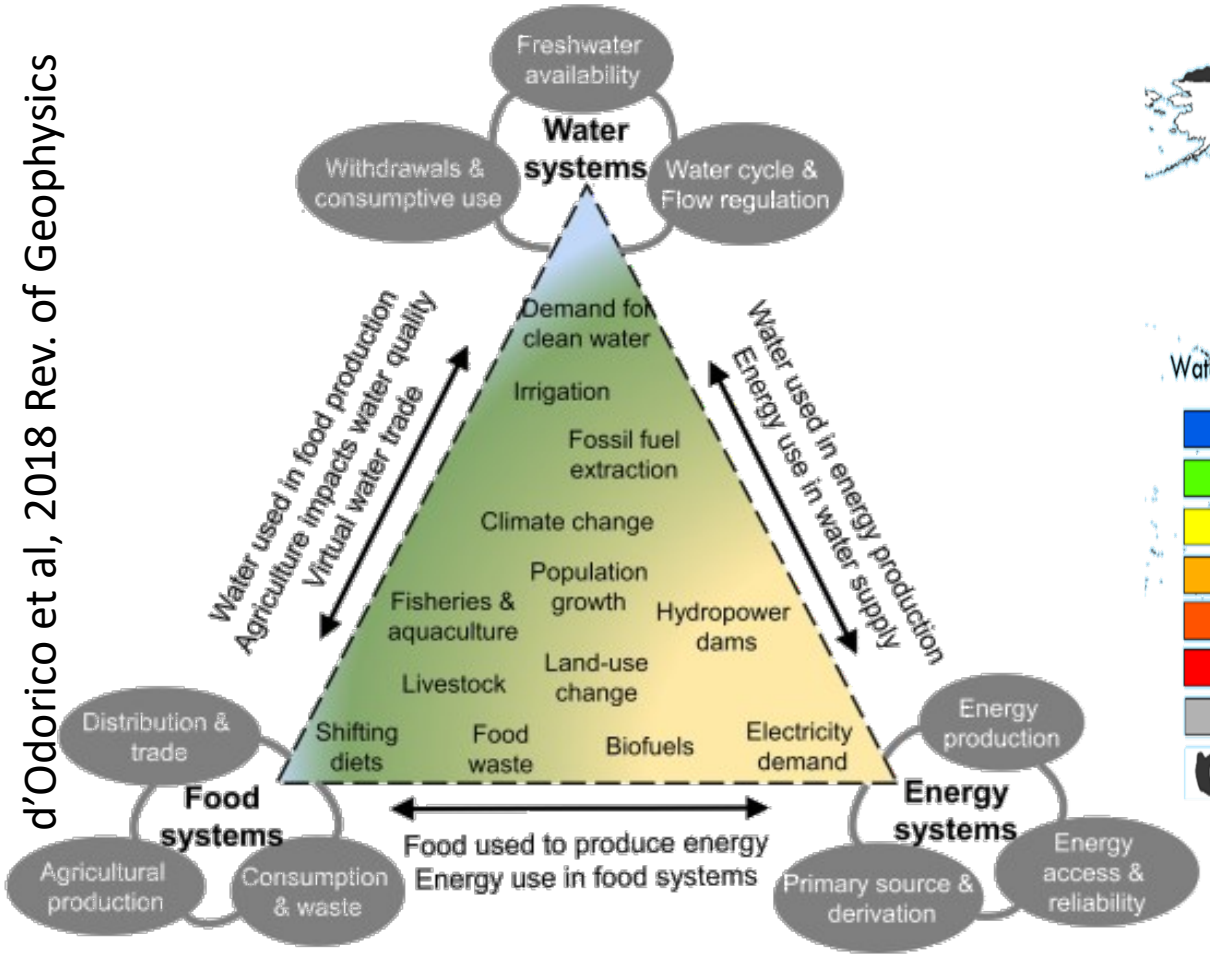
Rulli et al., Sci. Rep., 2016

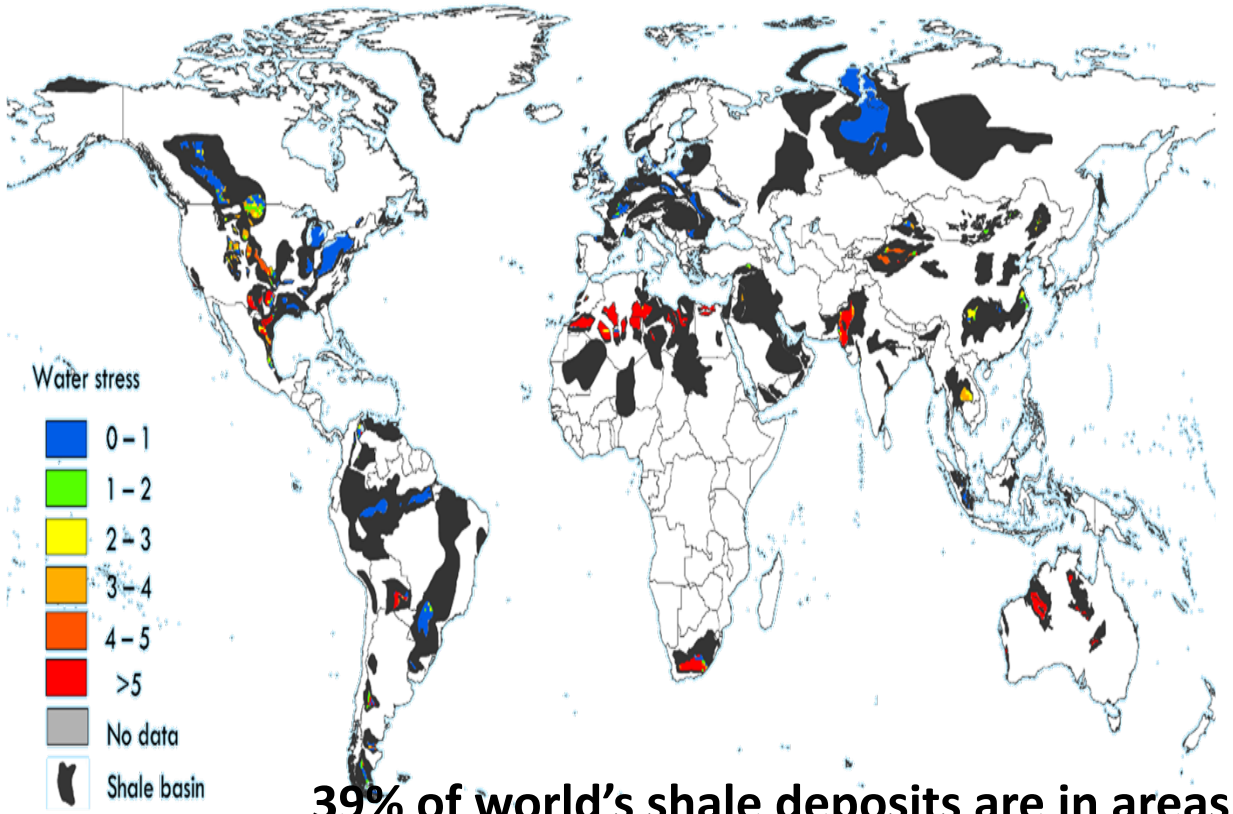
THE ADDITIONAL CHALLENGES …

COMPETITION FOR WATER BETWEEN ENERGY AND FOOD SECTORS

THE FOOD-ENERGY-WATER NEXUS

d'Odorico et al, 2018 Rev. of Geophysics





Rosa, Rulli, d'Odorico, 2018 Earth Future

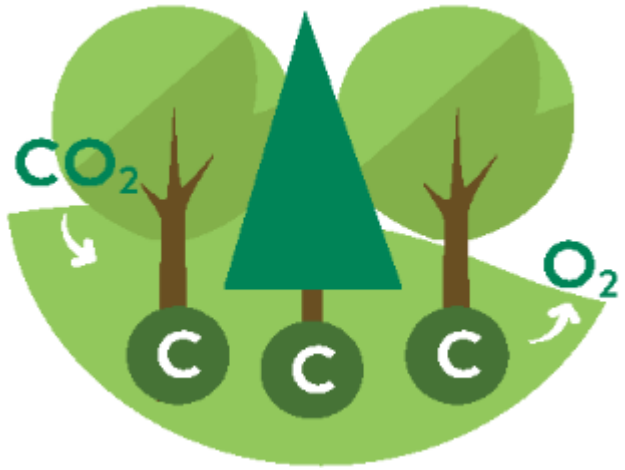
39% of world's shale deposits are in areas affected by water stress
… including major agricultural areas!

CLIMATE CHANGE MITIGATION STRATEGIES …
TREE RESTORATION IN THE TROPICS

Trade-offs between reforestation/afforestation for climate change mitigation strategies and the actual natural resources availability

PROS, a possible measure for:

- help fighting climate change by stocking CO_2
- preventing land degradation
- microclimate improvement
- dryland precipitation enhancement
- desertification reversal



CONS, possible effects on water system:

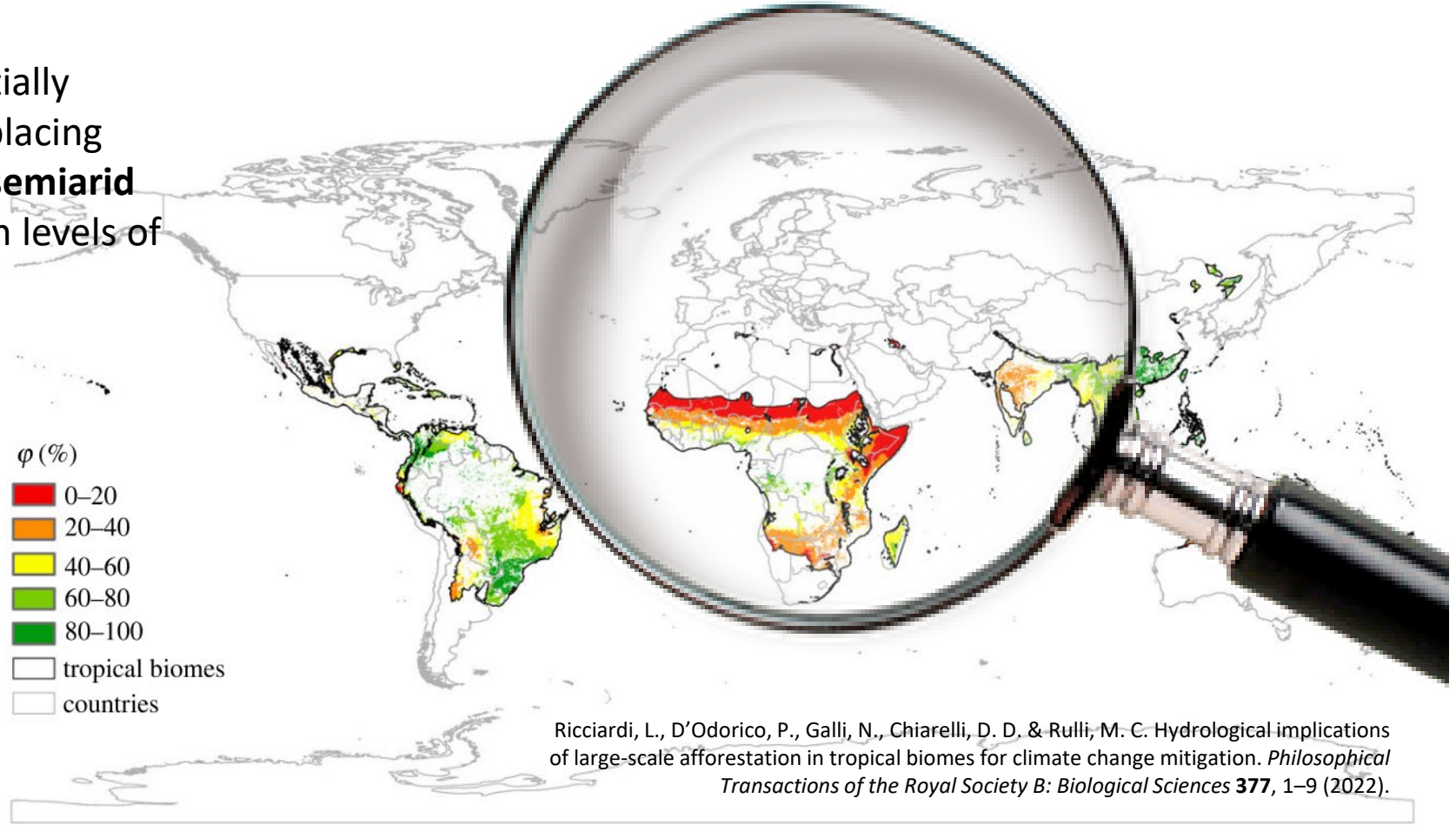
- arid and hyperarid regions as targeting zones
- water scarcity
- competition for resources with present uses among all other sectors (e.g., food system, energy)
- local and downstream effects

CLIMATE CHANGE MITIGATION STRATEGIES ...

FOCUS ON TROPICAL AFFORESTATION / REFORESTATION

- In **Africa** and **Oceania**, the areas potentially available for tree planting (without displacing agriculture or urban areas) are **arid** or **semiarid** and therefore exposed to relatively high levels of **water stress**

- In **South America** and **Asia** (with the exception of India) tree planting projects would take place in relatively more **humid regions**



Ricciardi, L., D'Odorico, P., Galli, N., Chiarelli, D. D. & Rulli, M. C. Hydrological implications of large-scale afforestation in tropical biomes for climate change mitigation. *Philosophical Transactions of the Royal Society B: Biological Sciences* **377**, 1–9 (2022).

Figure 3. Fraction (φ) of plant water requirement (PWR) that is met by precipitation (i.e. green water consumption, GWC) as a percentage, for the feasible net restoration areas (FNRA) in tropical biomes. (Online version in colour.)

CLIMATE CHANGE MITIGATION STRATEGIES ...

FOCUS ON TROPICAL AFFORESTATION / REFORESTATION

WATER SCARCITY

Yearly **water scarcity** induced by tree planting would affect **77%** of the Feasible Net Restoration Area both in **Oceania** and in **South America**, while in **Asia** and **Africa 92%** and **94%** of suitable areas would undergo water scarcity, respectively.

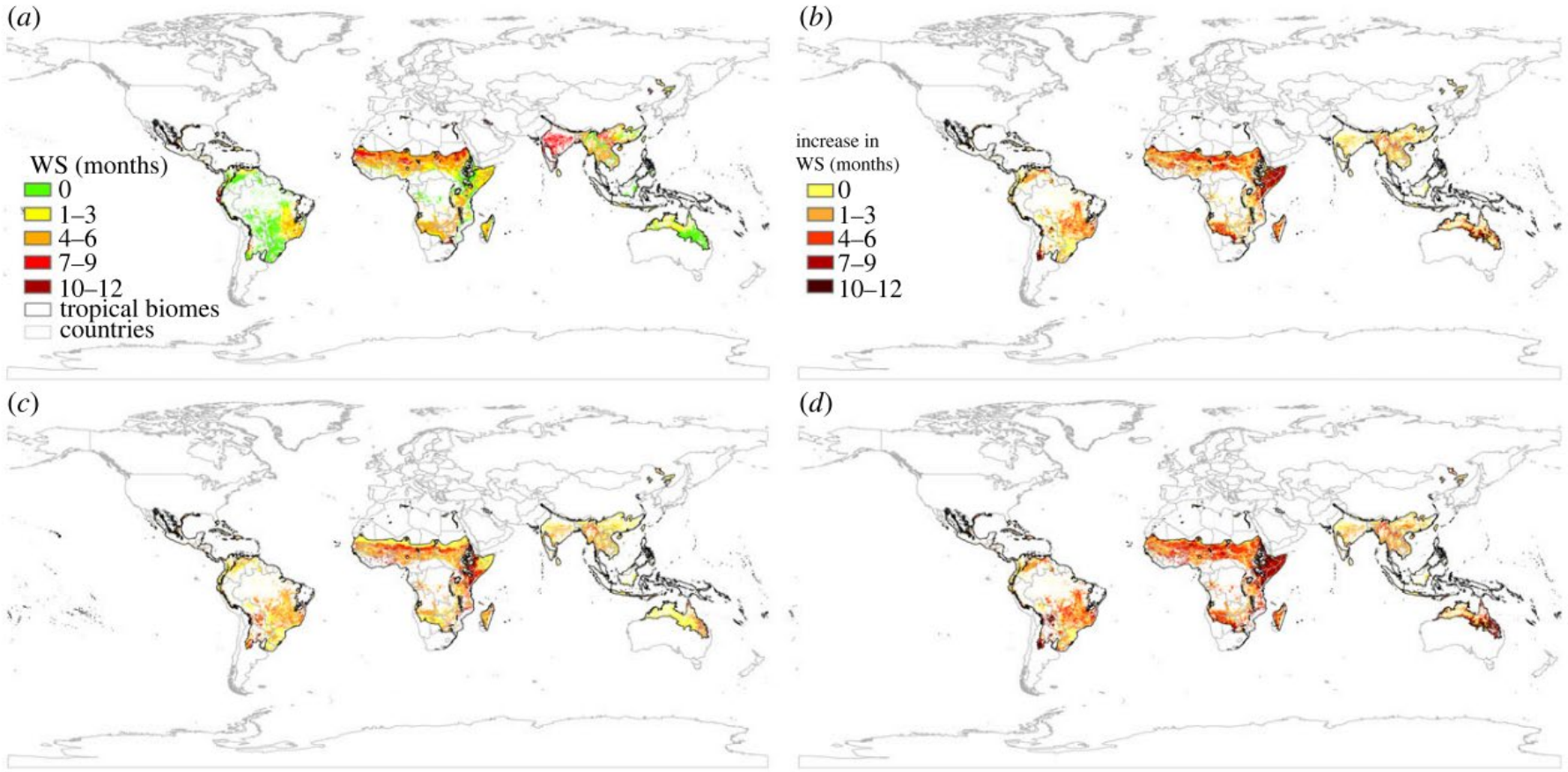


Figure 5. Water scarcity (WS) (in number of WS months), in feasible net restoration areas (FNRA), for scenarios: (*a*) actual land use; and increase in WS duration (in months) with respect to actual land use in FNRA, for scenarios: (*b*) tree restoration scenario, (*c*) yield gap closure without tree restoration, (*d*) yield gap closure with tree restoration. (Online version in colour.)

Thomas R. Maltus 1736-1834

“We still have to prove Malthus wrong, … the challenges of food supply are a major and continuing challenge facing humanity”(J. Sachs)

Even though global agriculture production can feed the planet it does not do so SUSTAINABLY → threats to environment, global health and the future of humanity

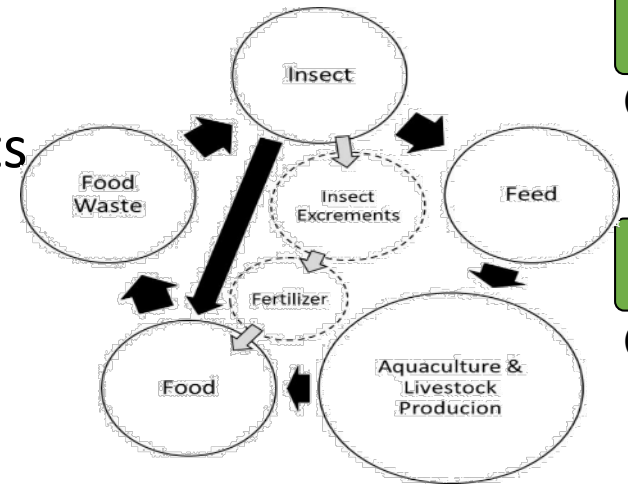
...TOWARDS SUSTAINABLE FOOD SECURITY

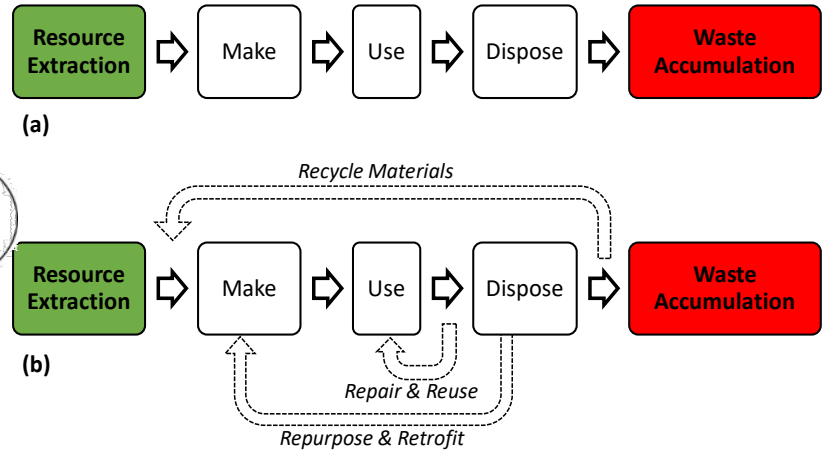
Sustainable Intensification

- Sustainable irrigation expansion on rainfed areas (yield gap closure)
- Use water more efficiently - “more crop per drop”
- Soil water conservation (reduce soil evaporation)
- Crops with better water-use efficiency. Not necessarily transgenic.
- Plant the right crop in the right place

Reduce the Demand

- Reduce waste of food, water, nutrients
- Change diets (less animal products)
- Circular economy of food

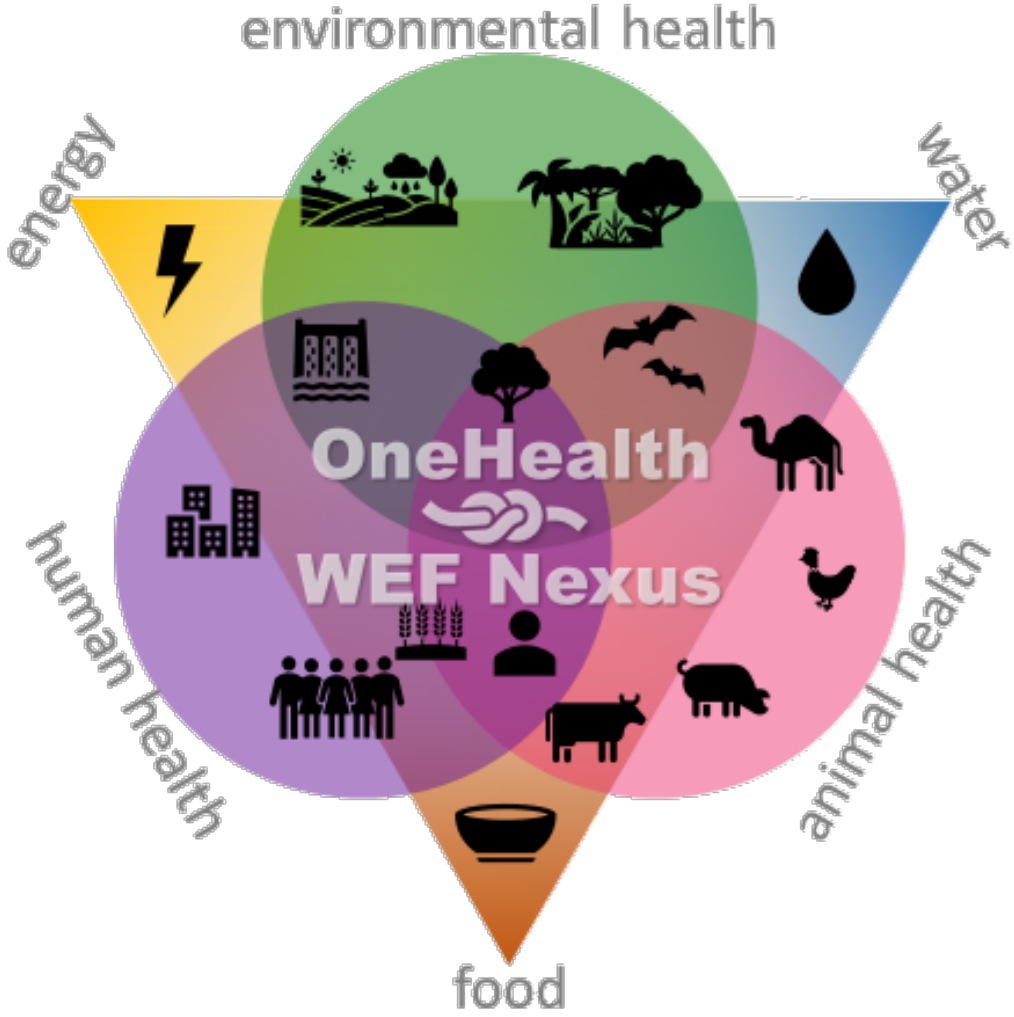




D’Odorico et al., 2018 Rev. of Geophysics

... TO CONCLUDE,

FOOD AND ENERGY PRODUCTION HAVE AN IMPACT BOTH ON ENVIRONMENTAL SUSTAINABILITY (E.G., WATER CONSUMPTION) AND ON HUMAN HEALTH



NEED TO COMBINE THE FOOD-ENERGY-WATER NEXUS WITH THE ONE HEALTH PARADIGM

THANK YOU

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