Water and Agriculture

From Waste towards Sustainable Food Supply

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Water and Agriculture – the point of Departure

- Life sciences are about nature, nature takes place under the open sky.
- Together with clean air, clean water and healthy food are the most basic human and ecosystems needs.
- How to ensure availability of and grant equitable use to today's and future's global citizens and ecosystems?
- Sustainable development demands to use renewable natural resources, like water, globally with the highest possible sustainable efficiency.
- 96% of today's water use is through food and energy production in agriculture. Water use efficiency links food and energy production to water consumption (water-food-energy nexus).
- today's (mostly agricultural) water use is wasteful and/or not sustainable:
  - through inefficient use of water
  - through over-exploitation of scarce water resources
- How urgent is the problem? Where to start best? How to proceed further? How to develop a strategy?

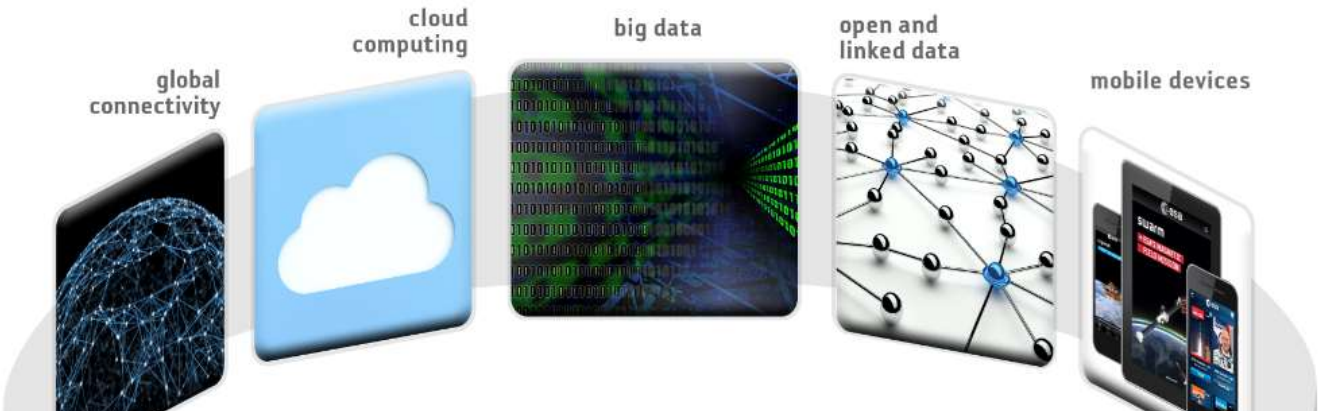
Large global challenges not only for the Life Scientists.

The world is changing at a rapid pace

Current Discussion:

- industry 4.0,
- personalized medicine,
- overcoming aging
- democracy endangered by social media
- artificial intelligence

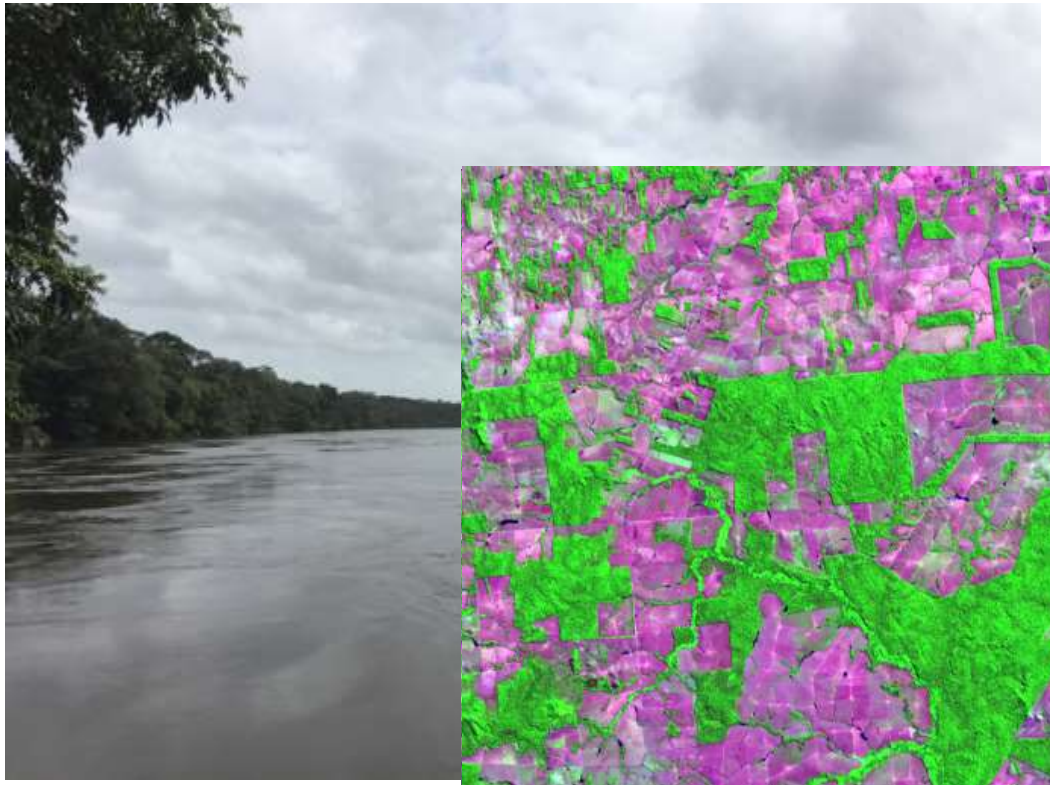
is largely vioceless on environment and sustainability.



----------Global Megatrends---------

Personal fears increase:

- climate change
- loss of biodiversity
- migration



…still we cherish the illusion that untouched nature exists!

Humans‘ Basic Needs rely on Natural Resources:

- Food Supply:

  >5 000 billion $ sales volume/a; demand to increase by 70% (total biomass by 100%) by 2050 (FAO); largest human activity under the open sky; food security, food equity and food sustainability triangle; imperative for sustainable intensification

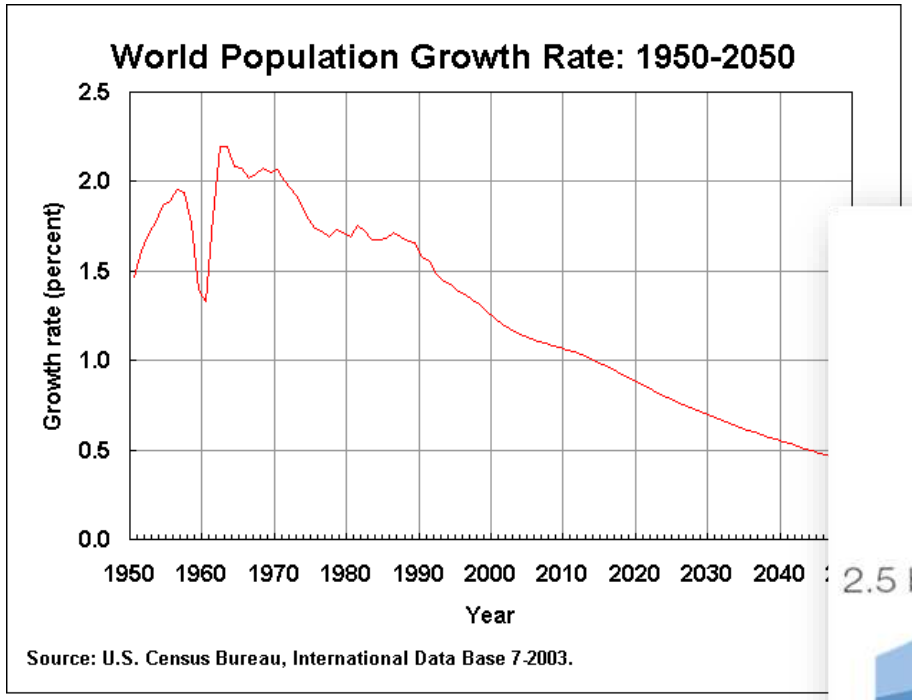
- Energy Supply:

  >6 000 billion $ sales volume/a; demand to double by 2040 (IEA); energy security, energy equity and energy sustainability triangle; imperative for renewables

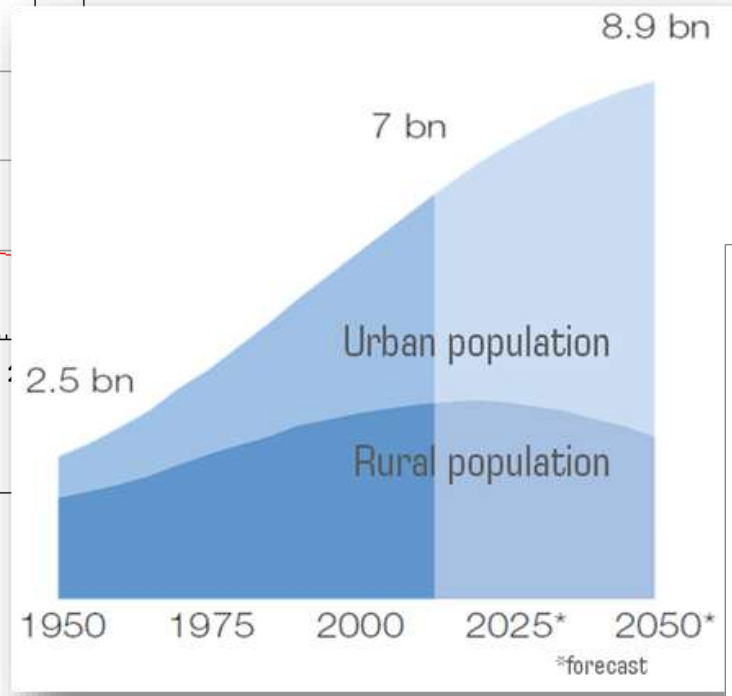
- Water Supply:

  >2 500 billion $ sales volume/a; demand to increase by 55% until 2050 (OECD); green vs. blue water, competition agriculture vs. natural ecosystems, water quality and sanitation; imperative for re-use and use efficiency

Water and Food – some trends

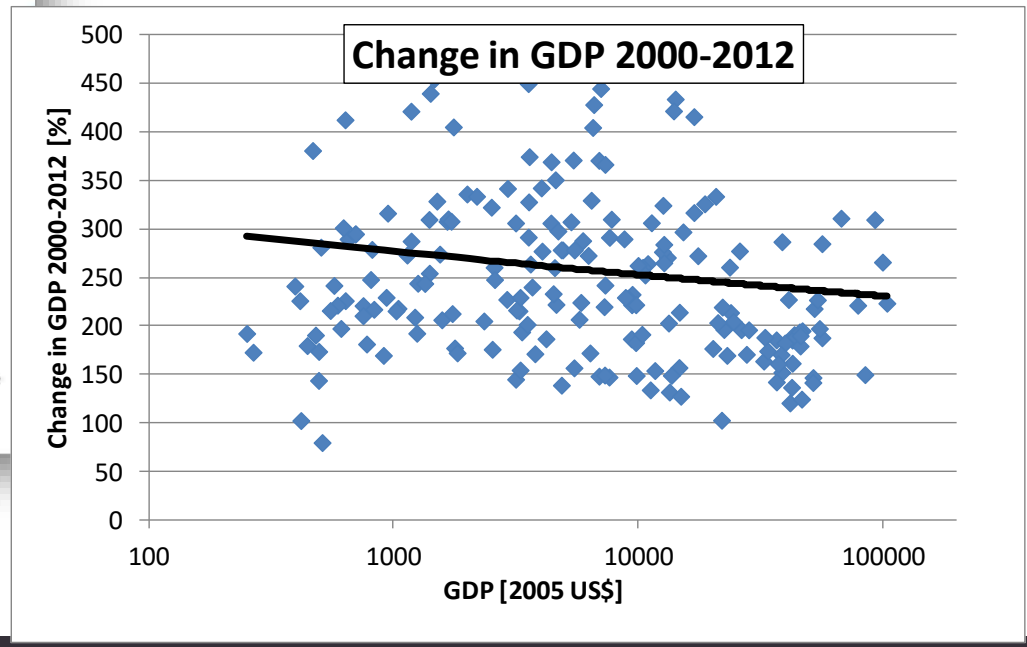


Declining population growth rates



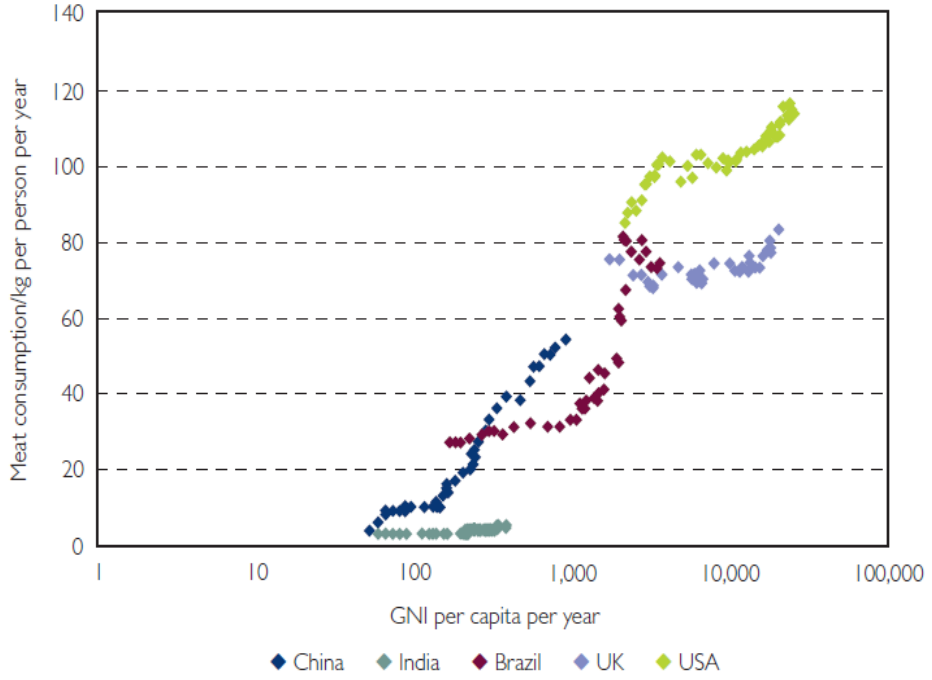
We will live in a more populated, wealthier and more urban world.
Peak population will be reached at ca. 9.5 billion around 2050.

Rapid Urbanisation



Increasing material wealth especially among the poor countries

Water and Food – some trends

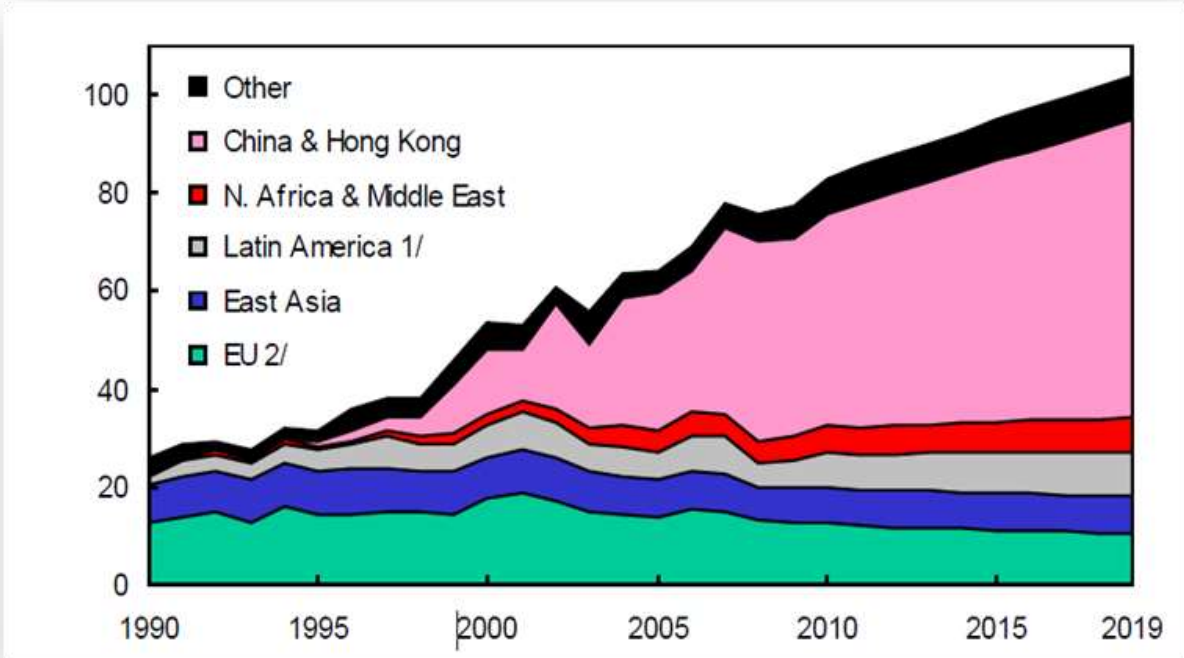


Source: FAOSTAT; World Bank

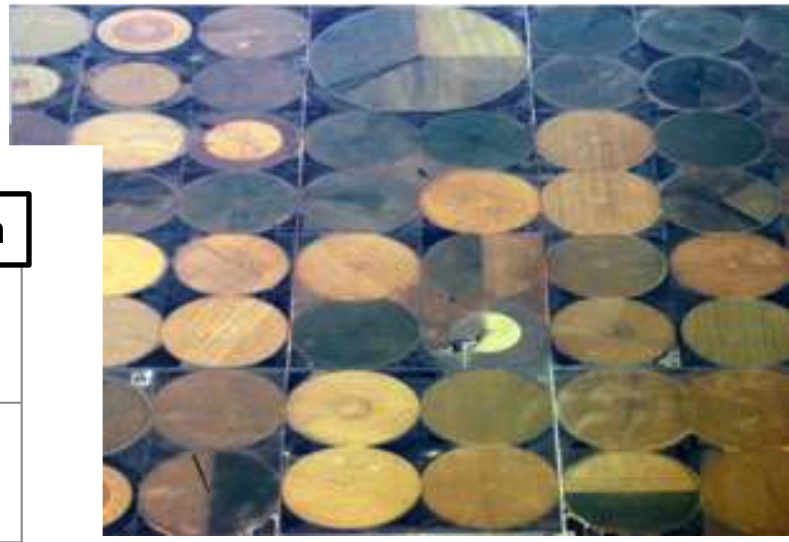
Change in meat consumption related to gross domestic income per person in China, India, Brasil, GB and USA (1951-2007)

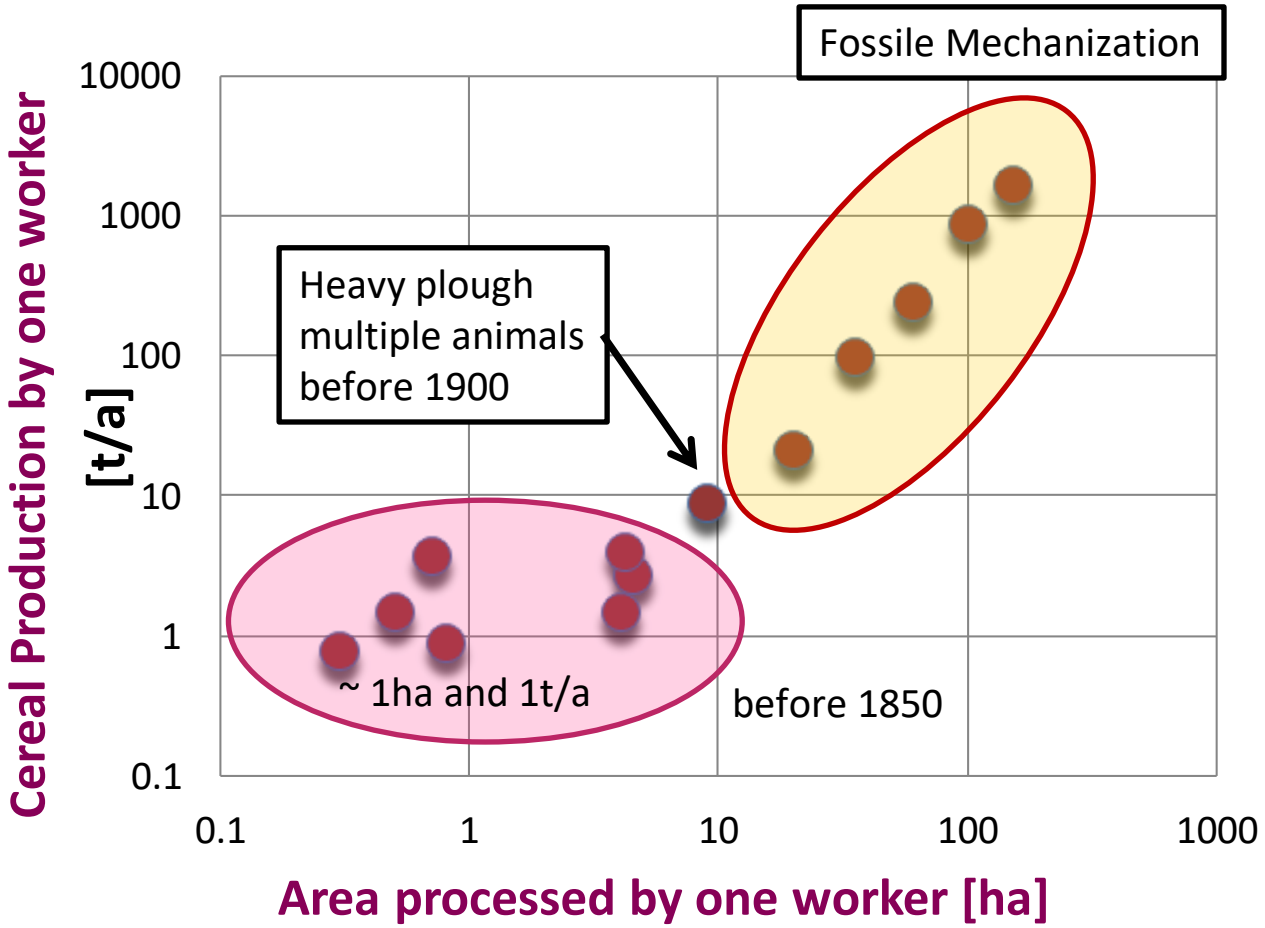
Increasing trade:
Soybean import of selected global regions.

Source: USDA (2009)



Water and Food – some trends





Efficiency of subsistance vs. mechanized farming: factor 1:2000

Water and Food – closely linked!

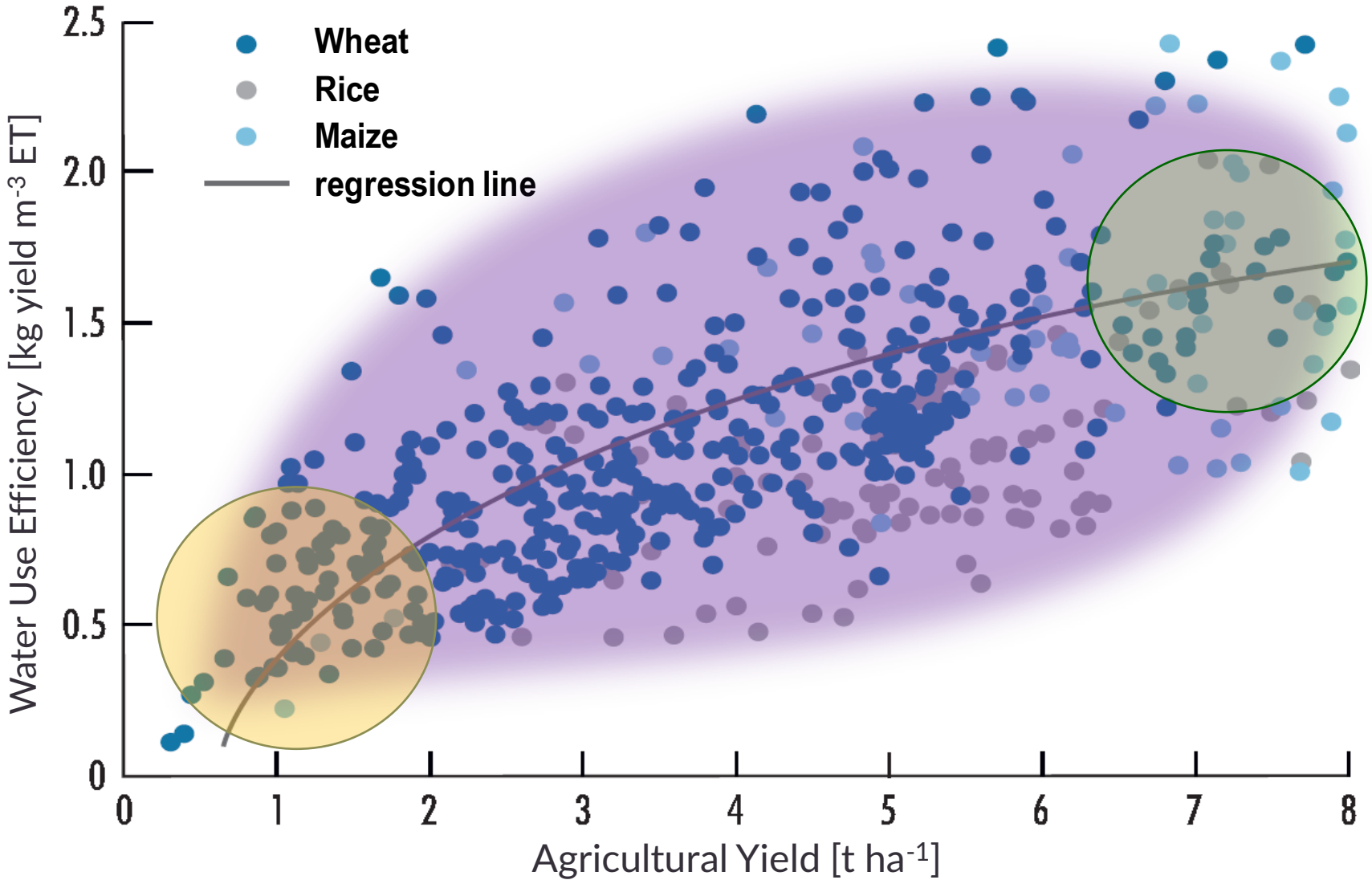
need for drinking water, sanitation and industry

50 liters per day

need for food production!

1200 liters vegetarian **2300 liters meat**

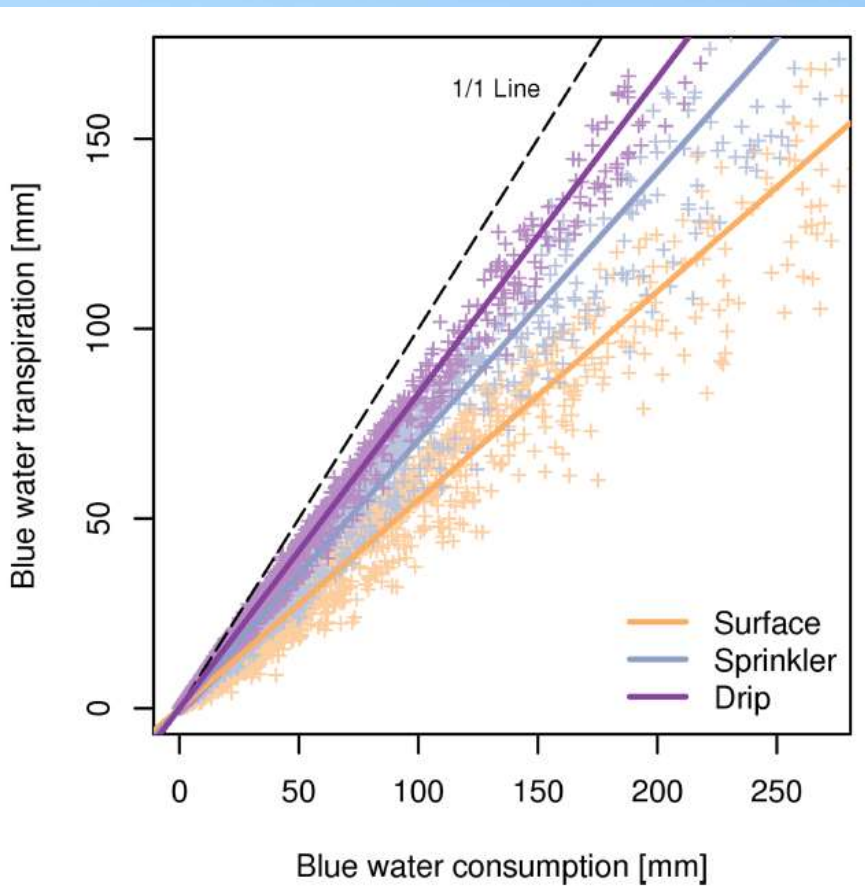
Water and Food – a mostly wasteful relation



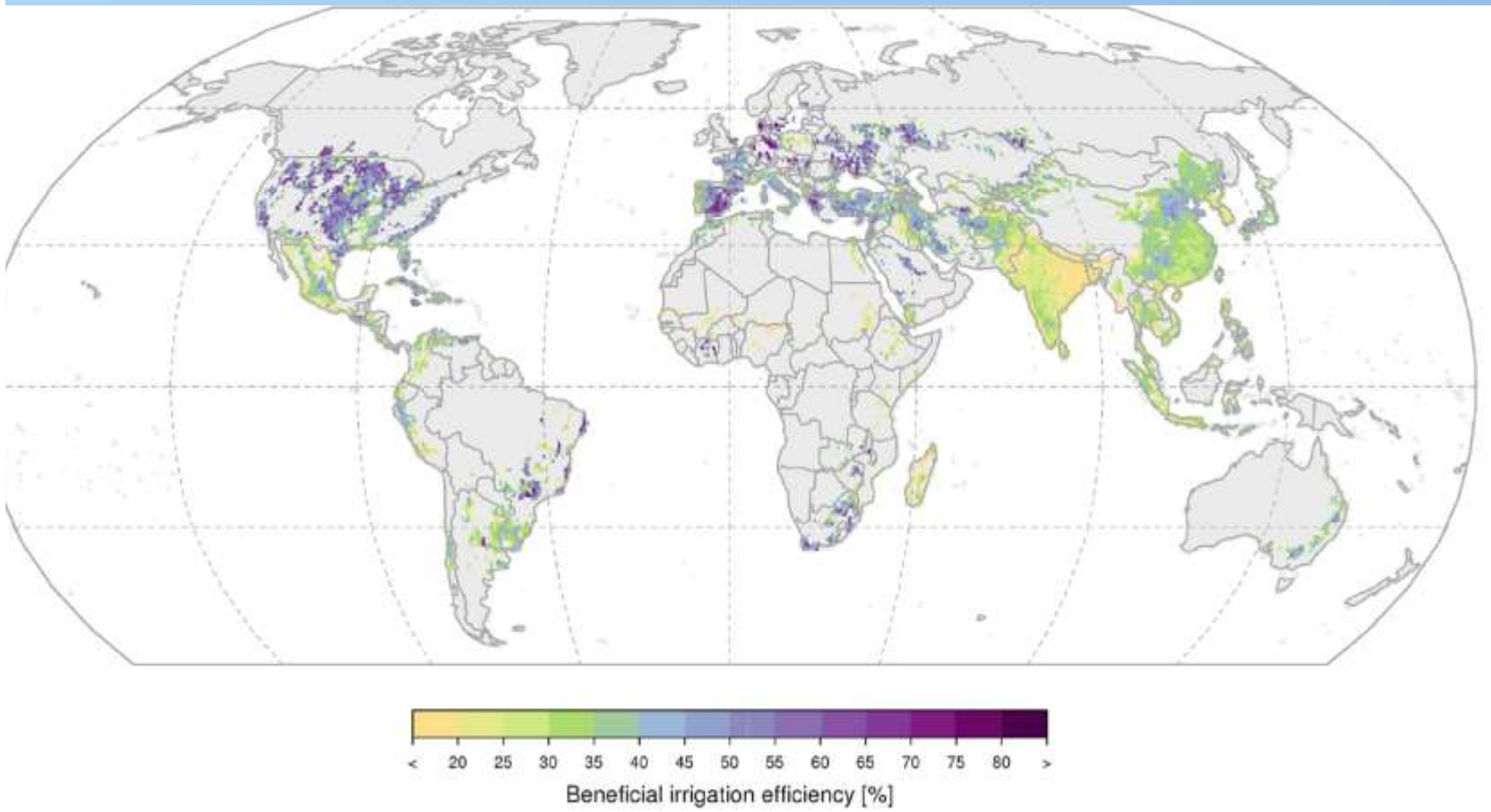
Low yields use water unprodcutively and therefore occupy more land

Large yields use water more productively and counteract agricultural expansion and thereby save land for biodiversity and other ecosystem services.

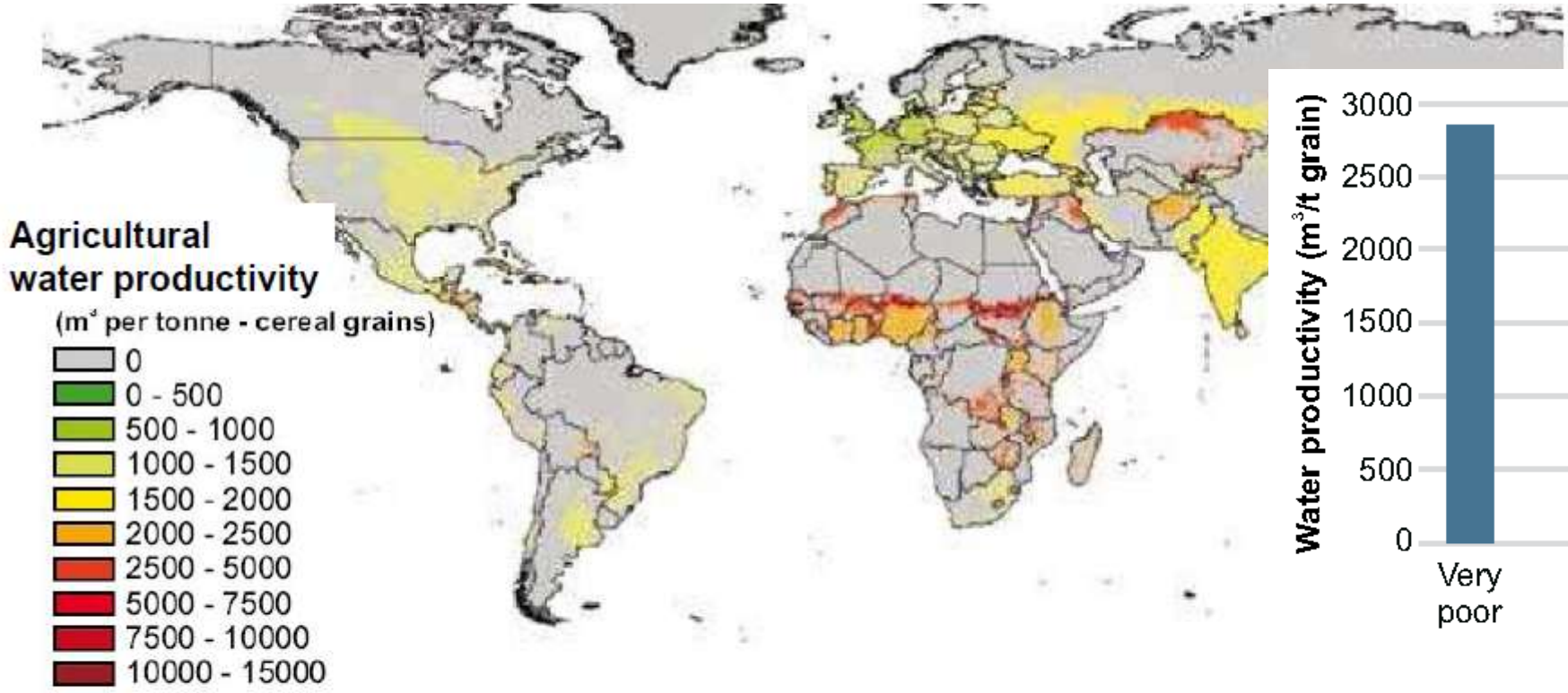
Water Waste in Irrigation

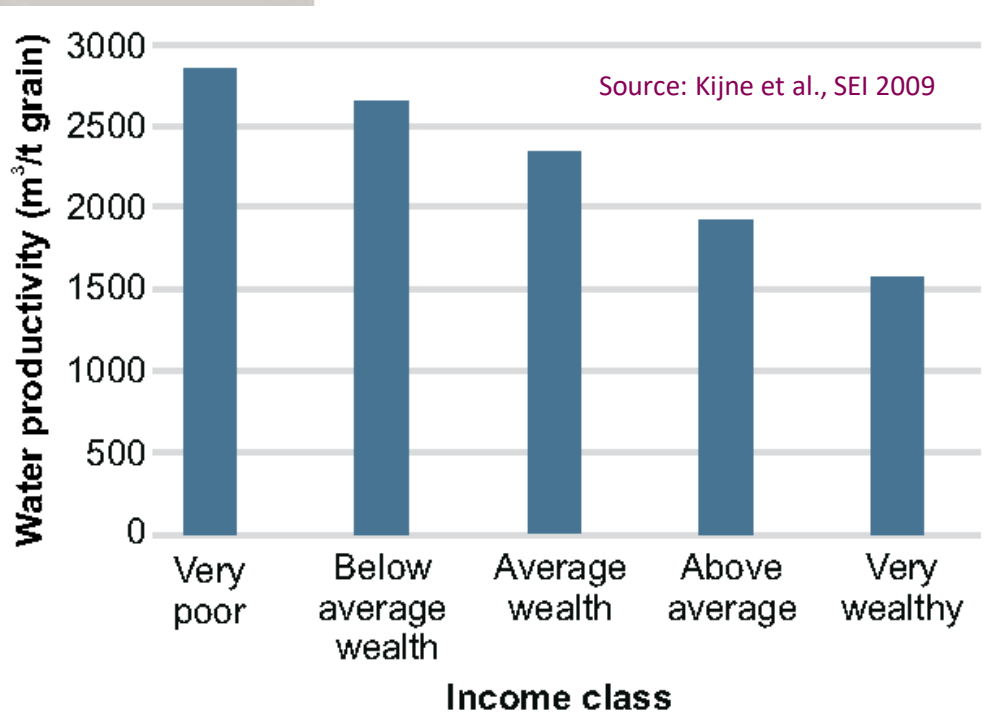


Large Potentials to increase water use efficiency through knowledge and information!



Water and Food – is it environmentally expensive to be poor?





Source: Kijne et al., SEI 2009

Bottom line: large parts of the Globe waste substantial amounts of wate
produce food (e.g. sub-Sahara Africa, Middle East, Central Asia, Australia)

Kijne et al 2009

Quelle: Kijne et al., SEI 2009

Water and Food – Production and Sustainability is the Dilemma!

Different farming systems coexist to ensure global food supply

Not sustainable because of low productivity, waste of water erosion and population pressure

Not sustainable because of high inputs, pollution, environmental degradation and energy consumption

Today's Global Farm is:

- not sustainable:
  - environmental degradation
  - rural poverty
- not efficient through waste of water, energy, labor
- expanding and destroying natural ecosystems

-> **Sustainable Intensification**

HOW?

The Water-Food-Energy Nexus and the Information Age:

The Information Age is the turning point of the Anthropocene:

- **Internet of Things:**

  after consumer goods and human desires have entered the internet, all material things will follow. If a thing is not part of the internet it will not exist. What does that mean for the environment?

- **Earth Observation from Space, Social Media and Big Data:**

  all points on the land surface are monitored at high resolution at least once a week. This creates the largest stream of data on the environmental ever. Humans by living leave strong informational traces. How can this be turned into meaningful information on the water-food-energy nexus?

- **High Performace Computing and Human-Environment-Relation Simulation:**

  exponentially growing computer power opens new perspectives. Will we be able to create a virtual world, which contrary to reality can be accessed through experiments on human-environment relations to identify sustainable futures at the very small and the very large?

Election of Popes Benedict and Francis
& the birth of smartphones and tablets!

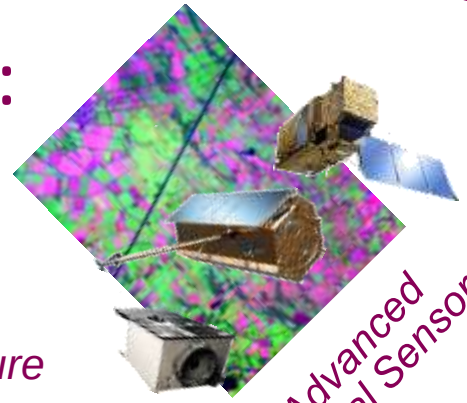
Border between the US and Mexico

Increasing global connectedness

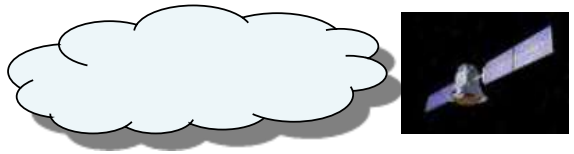

Understanding
Monitoring
Planetary Boundaries
Early Warning
Attribution
In the Anthropocene the Environment needs a Planetary Management System!
Citizen Observatory
Prediction

How does this relate to Water and Agriculture?

The Global Smart Farm:

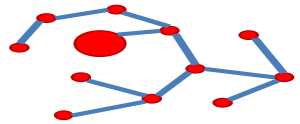


Cyber-Infrastructure

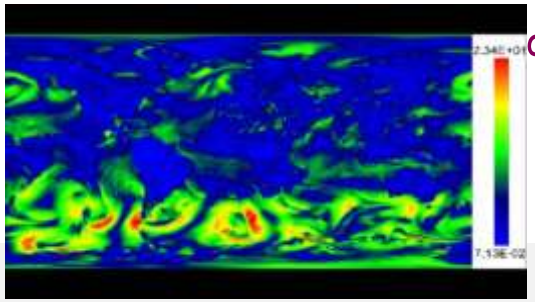


Smart Communication

Simulation and Data Assimilation



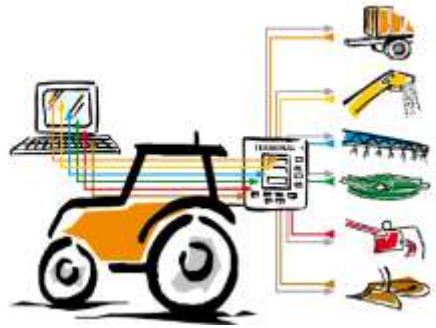
Local Sensor Networks



Smart Weather Services

Farmers: sustainable intensi-fication of production, better and healthier food,optimized resource use

Farming Devices Smart

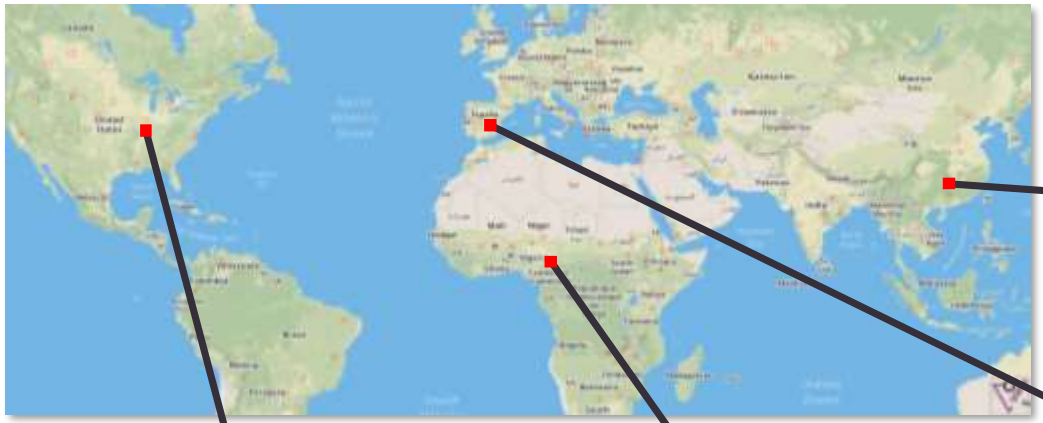


Smart Economic Information

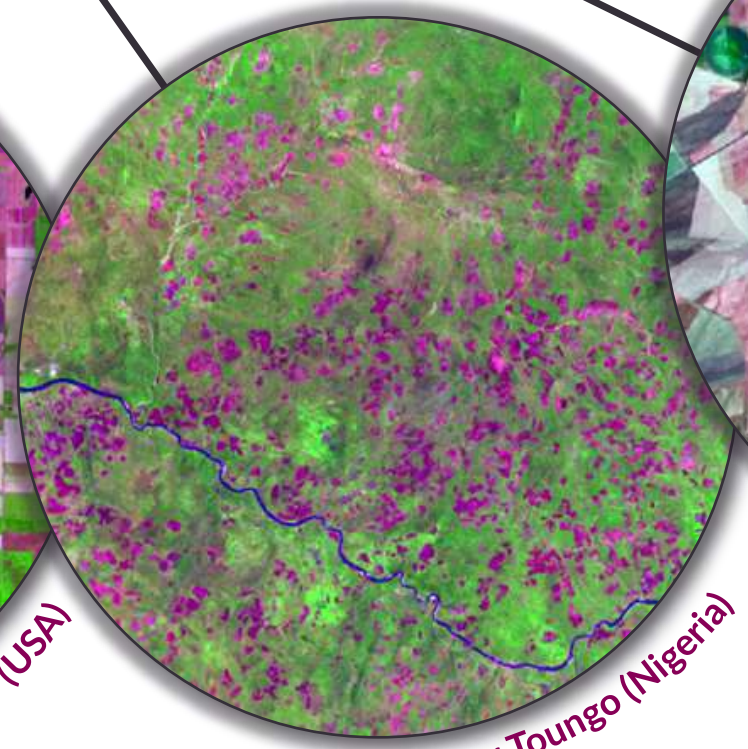
The Global Smart Farm:

Each farmer on the Globe will be embedded in an open cyber-environment which enables him/her to ensure food security through sustainable agriculture

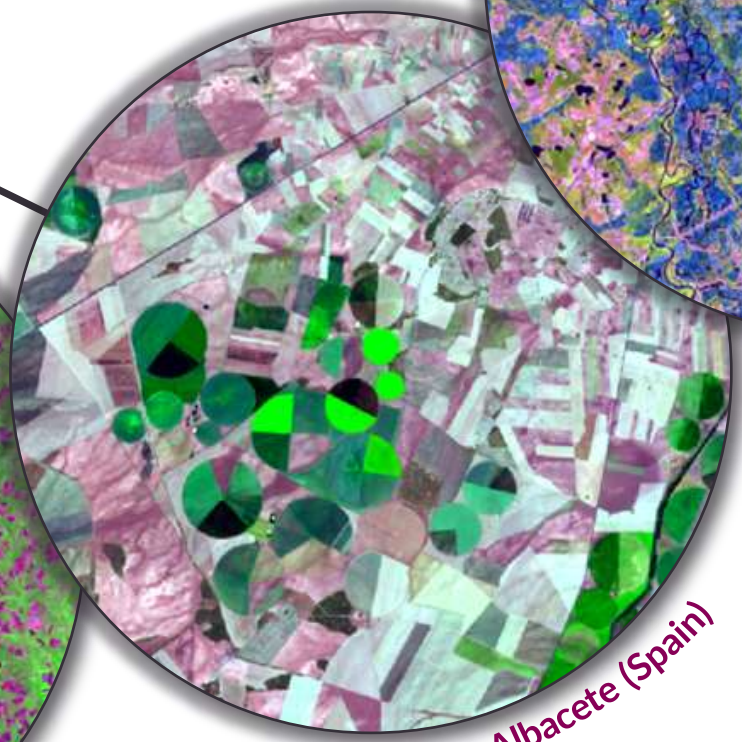
Agriculture is diverse:



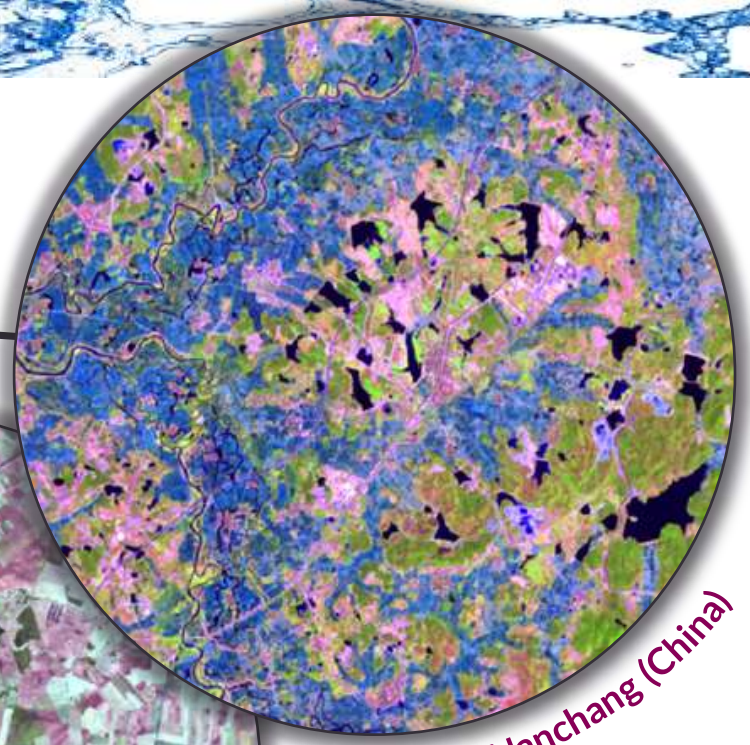
Near St. Louis (USA)



Near Toungo (Nigeria)

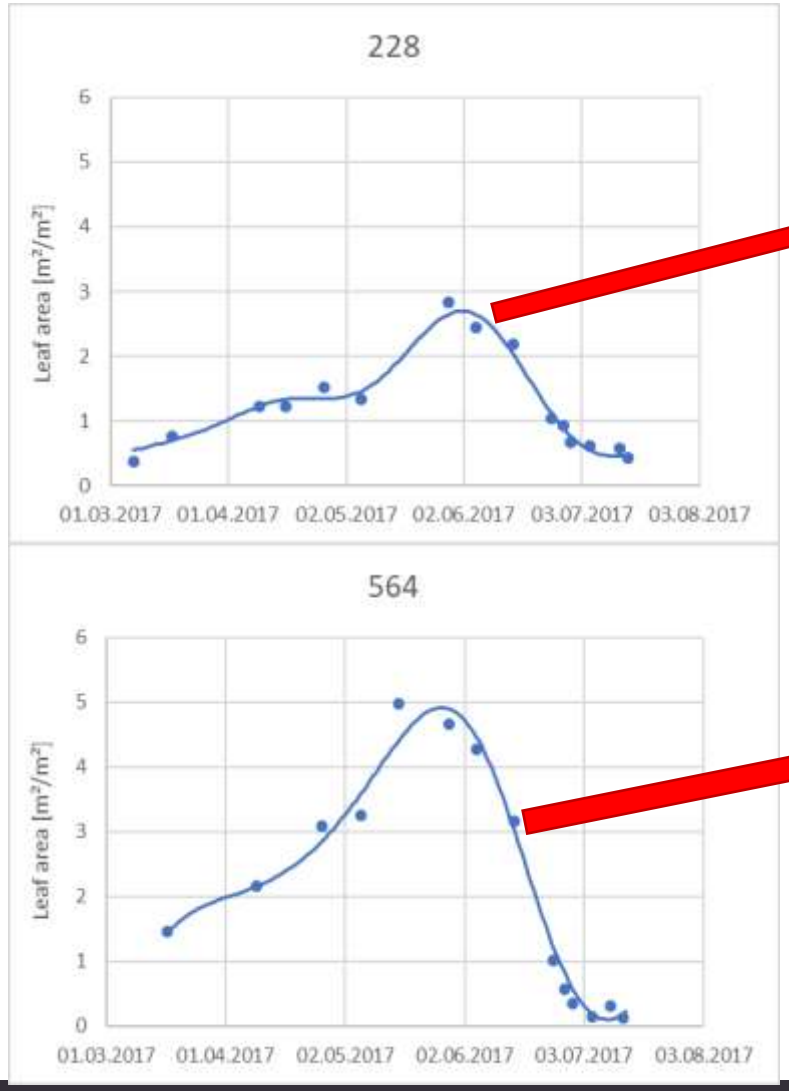


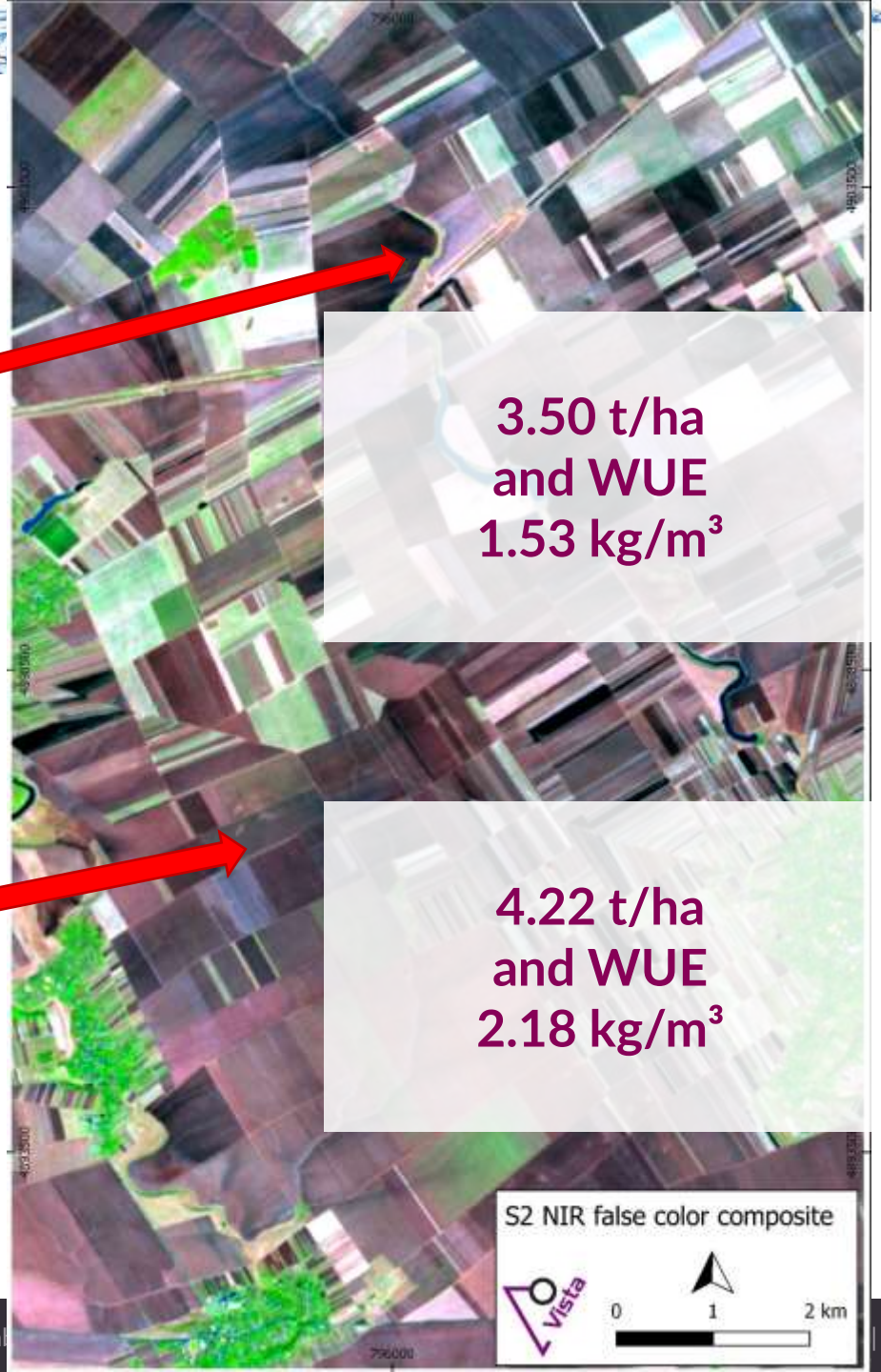
Near Albacete (Spain)



Near Nanchang (China)

Information and Simulation save Natural Resources

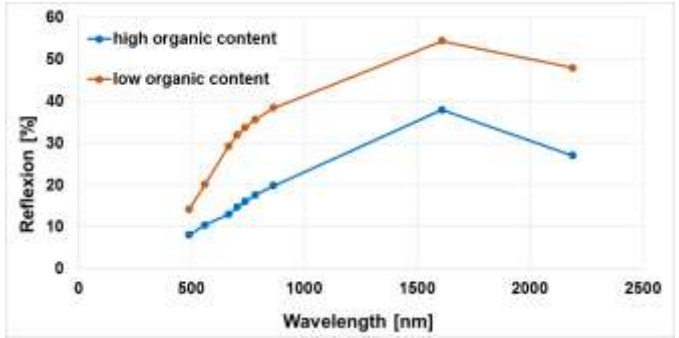


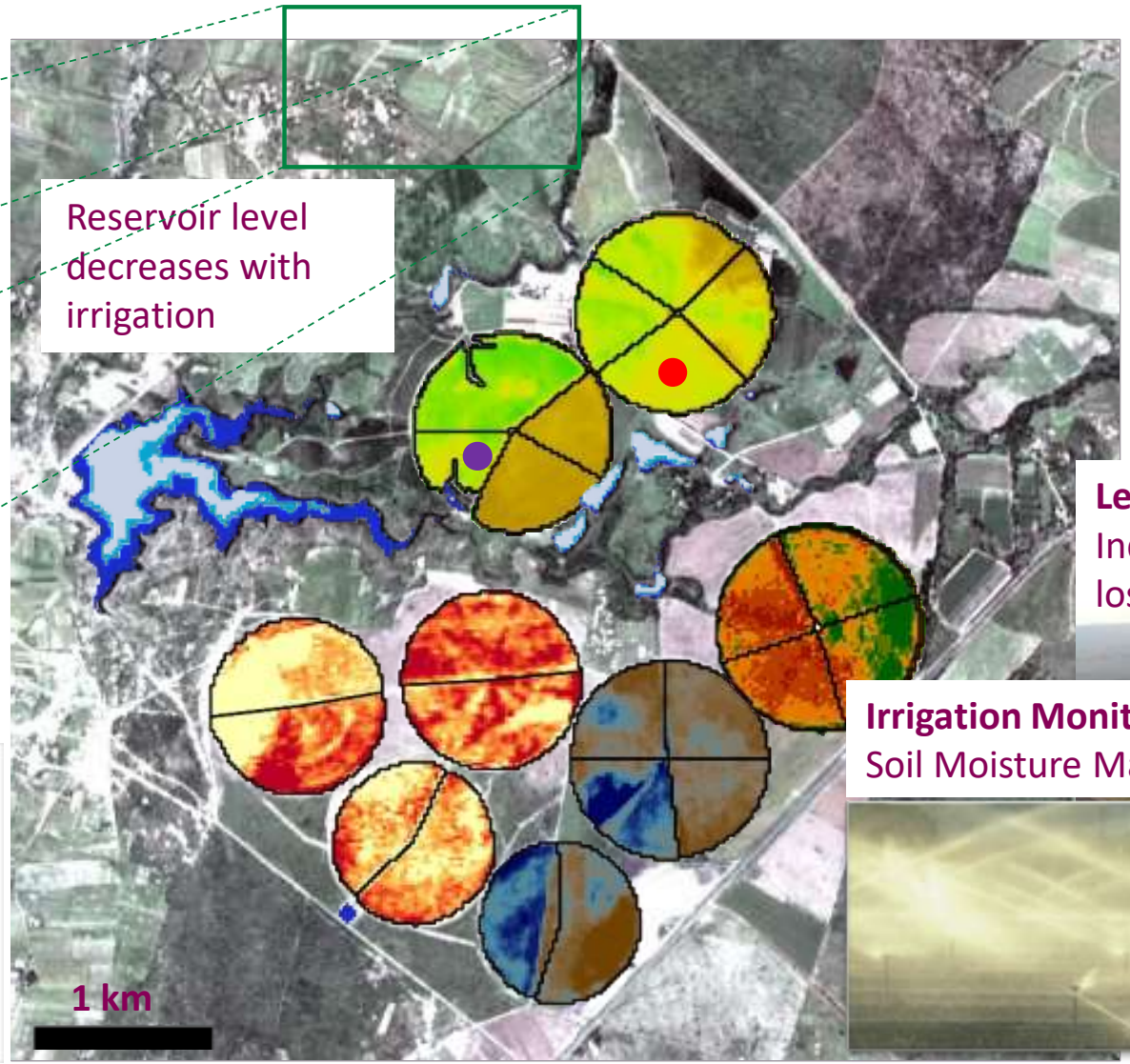


SENTINEL-2 – global data stream and a farm in Africa

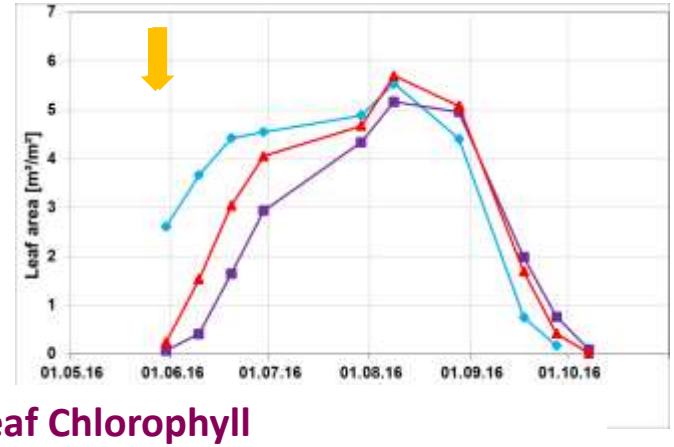
Food Security
Suport of smallholder farms.

Soil Quality / Degradation
Mapping of organic content based on spectral features





Crop Growth Monitoring



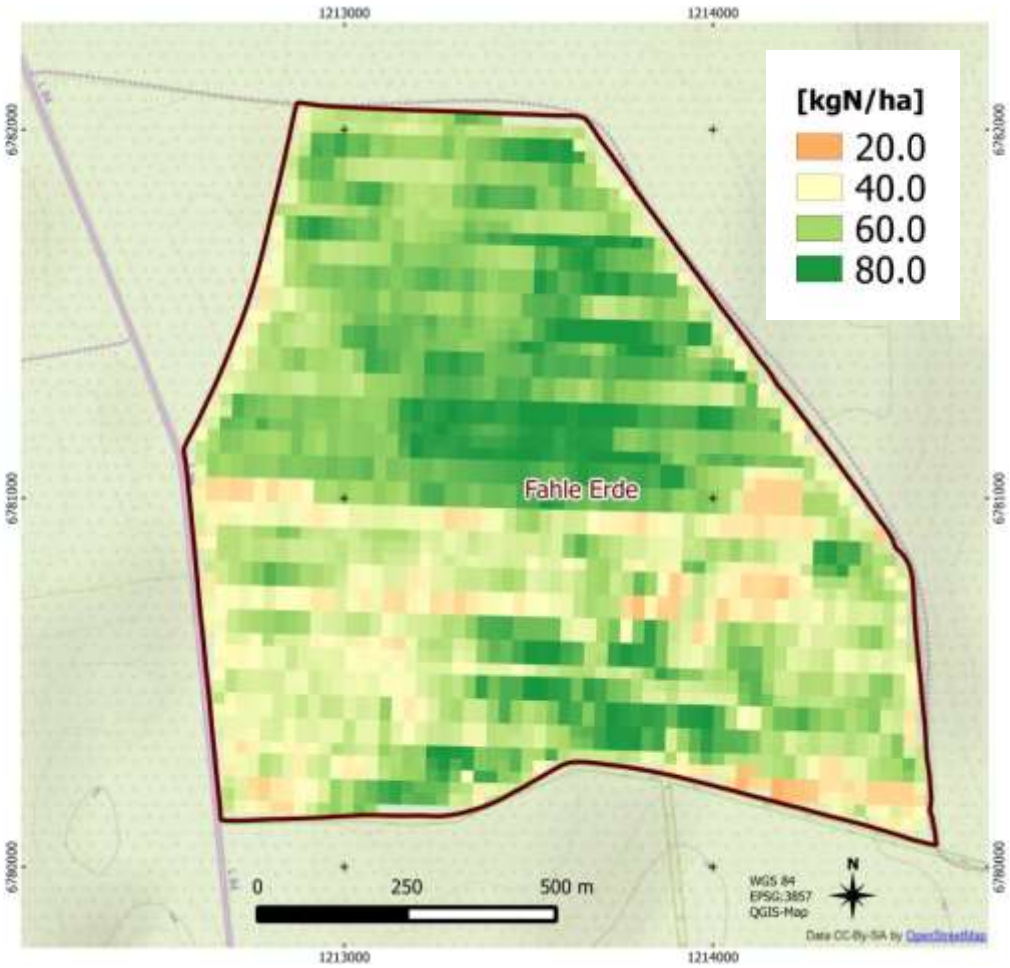
Leaf Chlorophyll
Indicating nitrogen stress and yield losses

Irrigation Monitoring
Soil Moisture Mapping

Space Observations and Simulations allow reducing Irrigation Water use by 35 % and still maintain Yields

SENTINEL-2 – global data stream and a farm in Germany

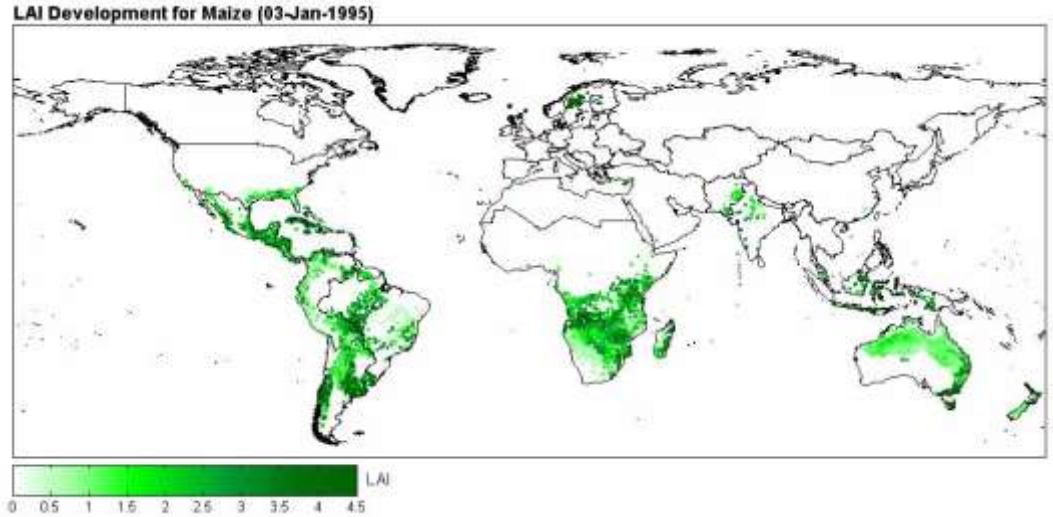
Adjusted nitrogen application for each point in the field through information that was determined from an ensemble of alternative simulation runs and transferred from the model to the tractor.



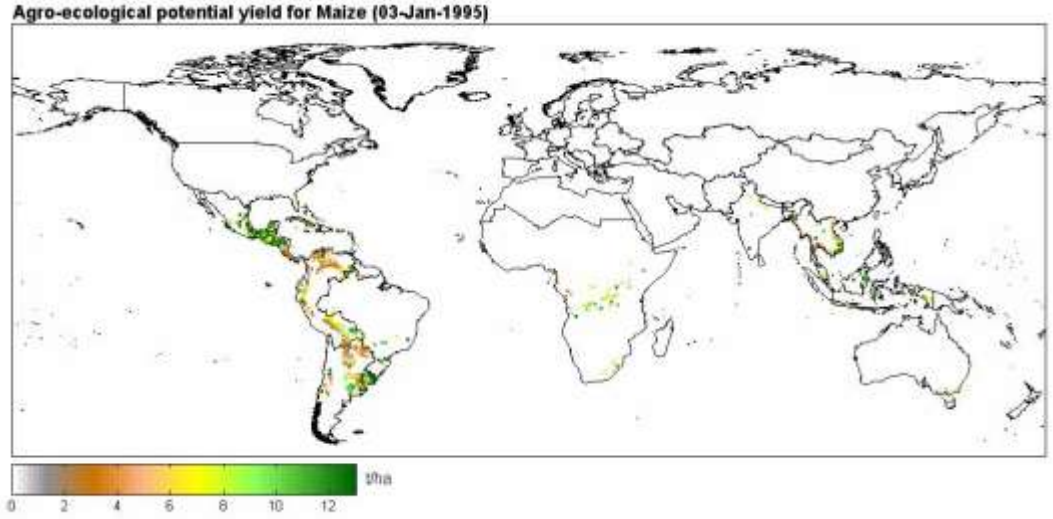
Space Observations and Simulations reduce fertilizer loads by 25%, maintain yields and protect groundwater from nitrogen leaching

Simulations create new global pictures where experiments are impossible:

A



B

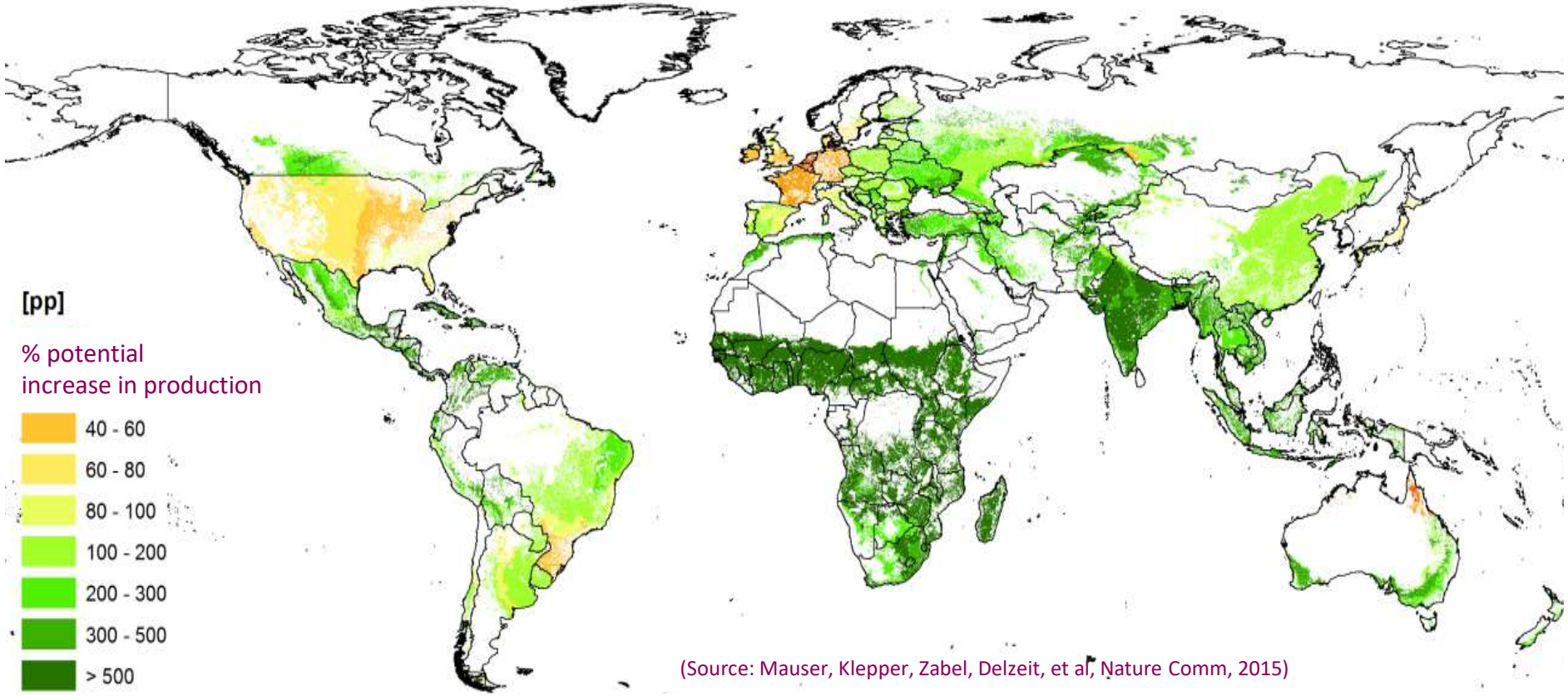


(A) Simulated Global pattern leaf area index (LAI) development of maize under current climate conditions in the year 1995.

(B) Resulting simulated potential maize yields limited by climate, soil and water availability.

Water and Food – some facts

Earth Observation, a high-resolution Earth System model and a macro-economic global trade model combined inform on where biomass production potentials are situated:

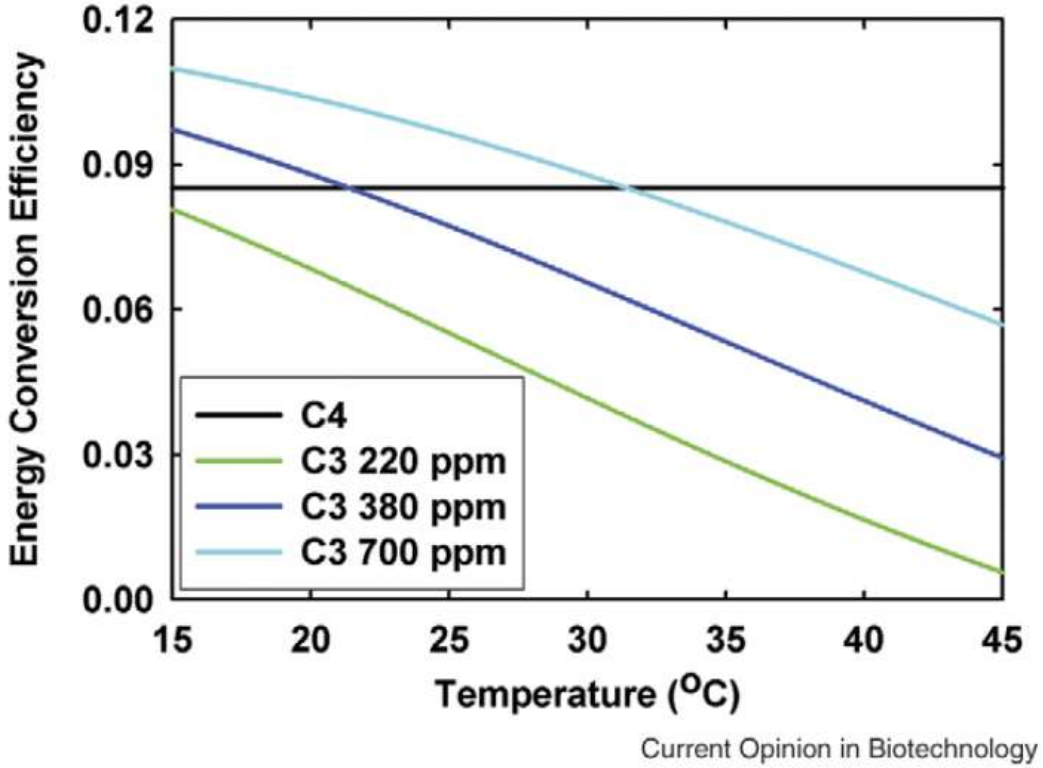


(Source: Mauser, Klepper, Zabel, Delzeit, et al, Nature Comm, 2015)

Bottom-line: world-biomass production can sufficiently be increased to meet demand without expansion of cropping area (factor 2.5)

Water and Food – what about climate change?

CO2-Fertilization may be a game changer (at least for C3-plants!):



Current Opinion in Biotechnology

What does this mean?

1. Energy Conversion Efficiency decreased through rising temperatures!
2. Energy Conversion Efficieny increased by rising CO2 concentration
3. Water Use Effiency increased by rising CO2 concentrations

New model results show that whenever CO_2 fertilization is taken into account in the simulations, climate change results in more food that can be produced with less water.

Some final thoughts

Largest Global Challenge for Life Sciences is finding sustainable solution for the Water-Food-Enegy Multilemma:

- Societal Development,
- Food Security,
- Sustainable Energy Supply,
- Biodiversity Conservation

all need their necessary share of water and land resources and ask for a Management of the Earth System!

The information age offers new nstruments, which are timely because:

- sufficiency and sacrifice is not enough on a hungry planet with 10 billion people
- knowledge and information are what humankind can offer to make the anthropocene different from all predceeding geological ages (which ended with the extinction of index fossil)

Some final thoughts

The biggest challenges for society are beyond technology and digitization!

They address our responsibility and connenct to who we want to be, how we want to share and how we want to live in the future:

- What perception of nature and environment will 8 billion megacity people have?
- We need active participation of all societal stakeholders in the emerging new value systems. There also have to be a seats reserved for nature and future at the negotioation table.
- Will the algorithms make the decisions? Will companies monopolize information?
- Which part of nature should be left over? How natural shouls it be?
- If ist true that humans, trees, a lion or an orchid can only survive as part of the internet how will we ensure that their husbandry is species-appropriate?
- Whom will we hold reponsible?