Mitigating Droughts:

Global Potential to Raise Rainfed Crop Production

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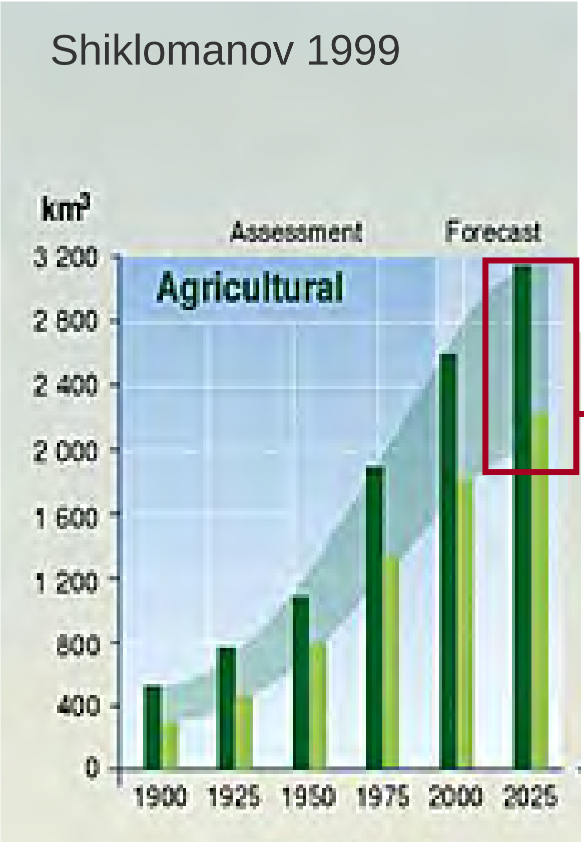
Water for food: The global challenge



Where to get this additional water from?

Expansion, and efficiency improvement of, irrigation?

Groundwater exploitation, large dams, river diversions?

Expansion of rainfed cropland (←→ other land uses)?

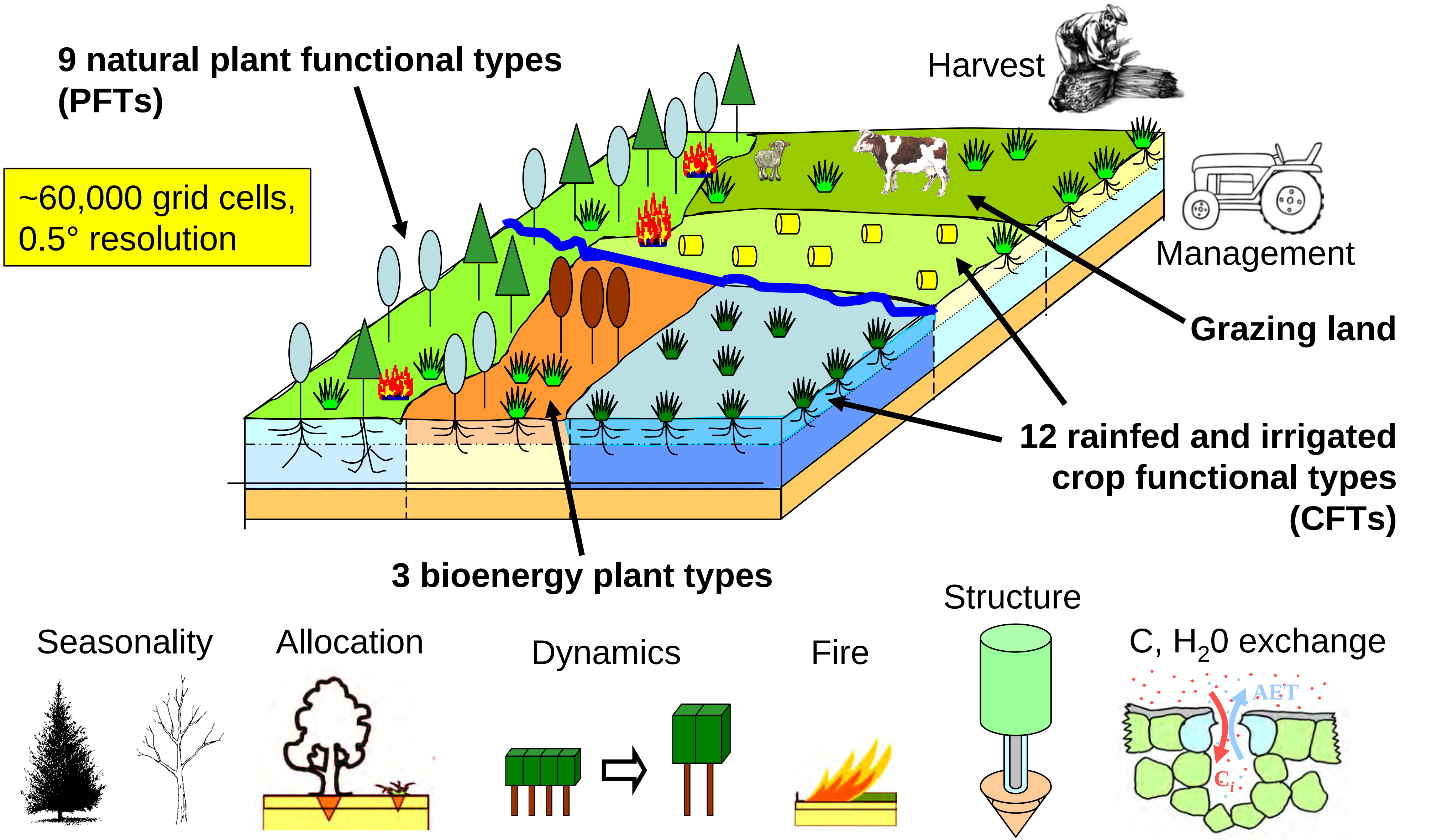
Mitigation of drought spells in rainfed agriculture? ★

etc.

Questions addressed here

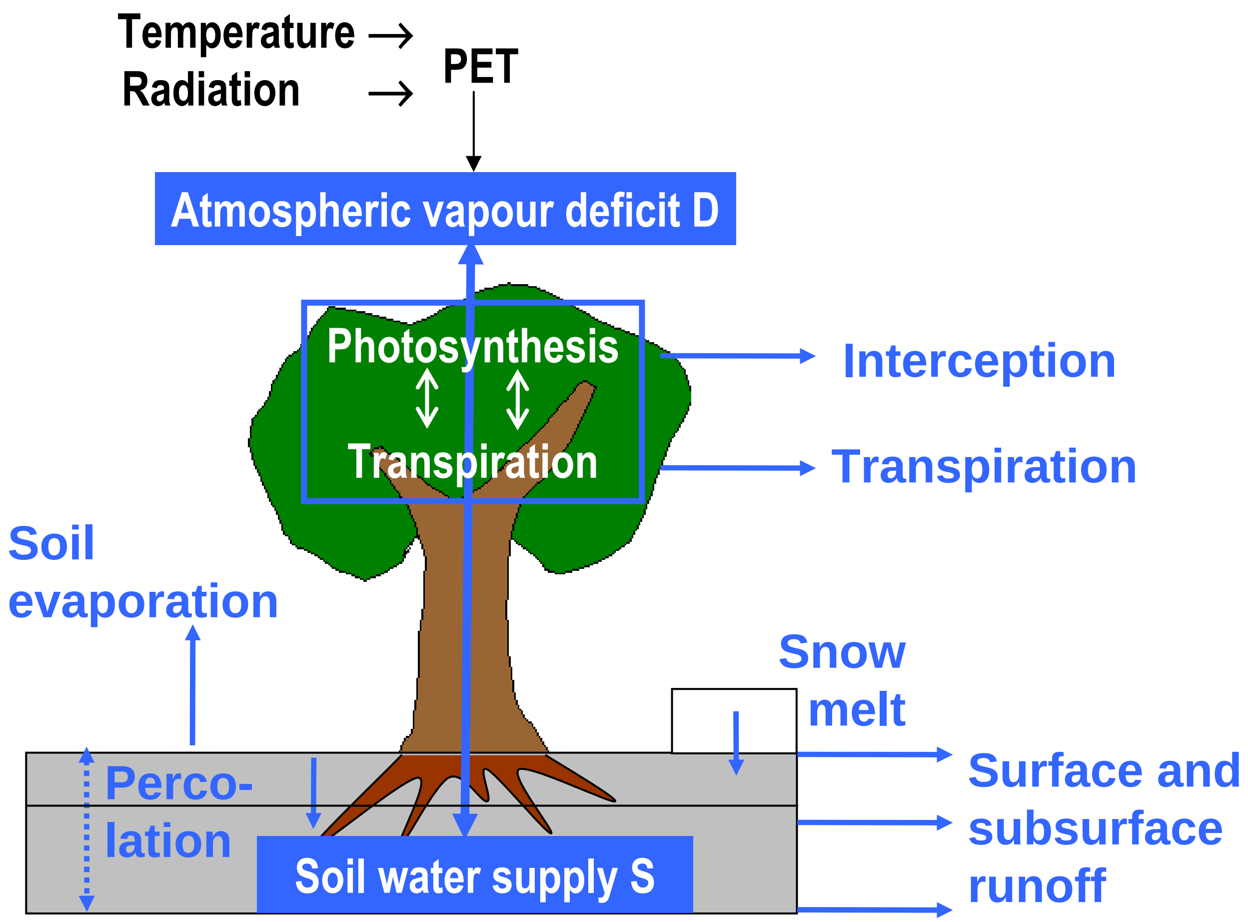
- How strongly water-limited is global crop production?
- What is the potential of water management in rainfed agriculture ("water harvesting", "vapour shift") to increase crop production?
- How will climate change and CO_2 rise modify this potential?
- Will optimising water use efficiency on present cropland suffice to sustain food production for a growing world population?

The LPJmL global vegetation and hydrology model



Sitch et al 2003; Gerten et al. 2004; Bondeau et al. 2007; Rost et al. 2008 ...

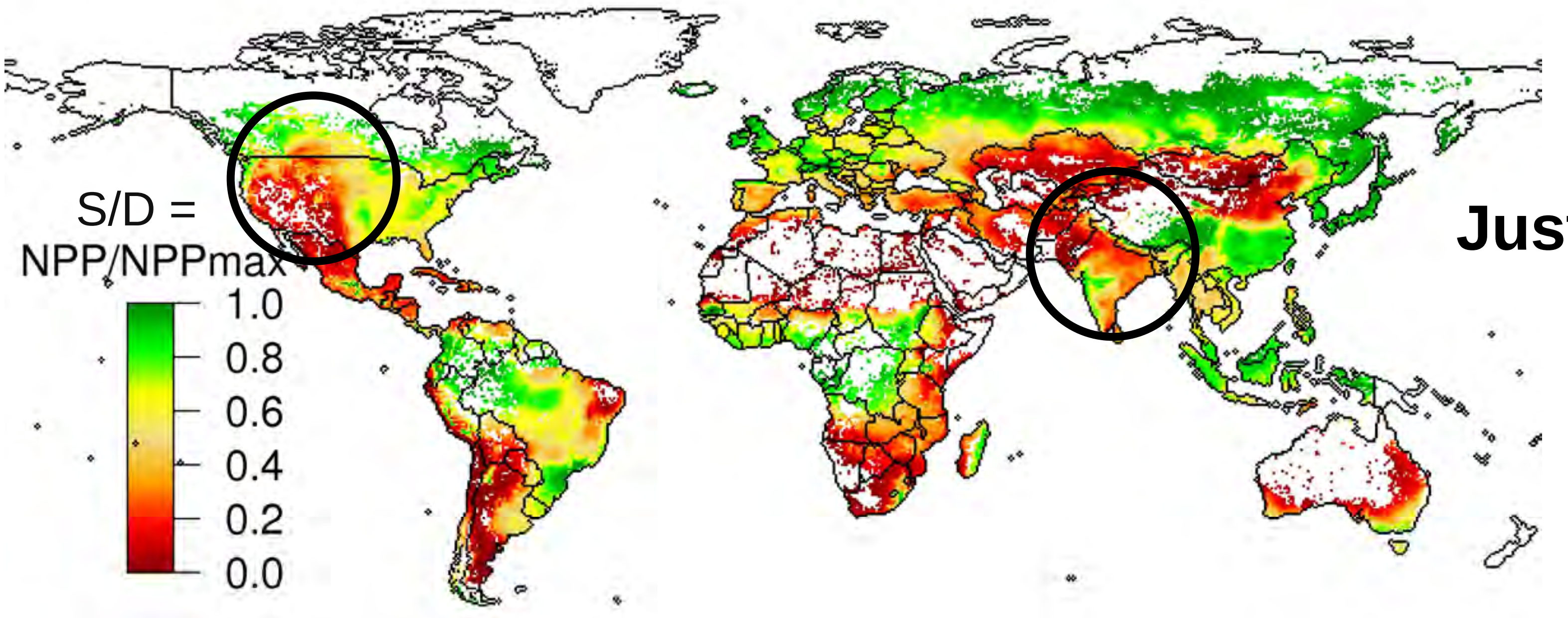
Modelling of plant water limitation in LPJmL



If D>S, photosynthesis and thus net primary production (NPP) is water-limited.
The S/D ratio indicates the degree of water limitation.

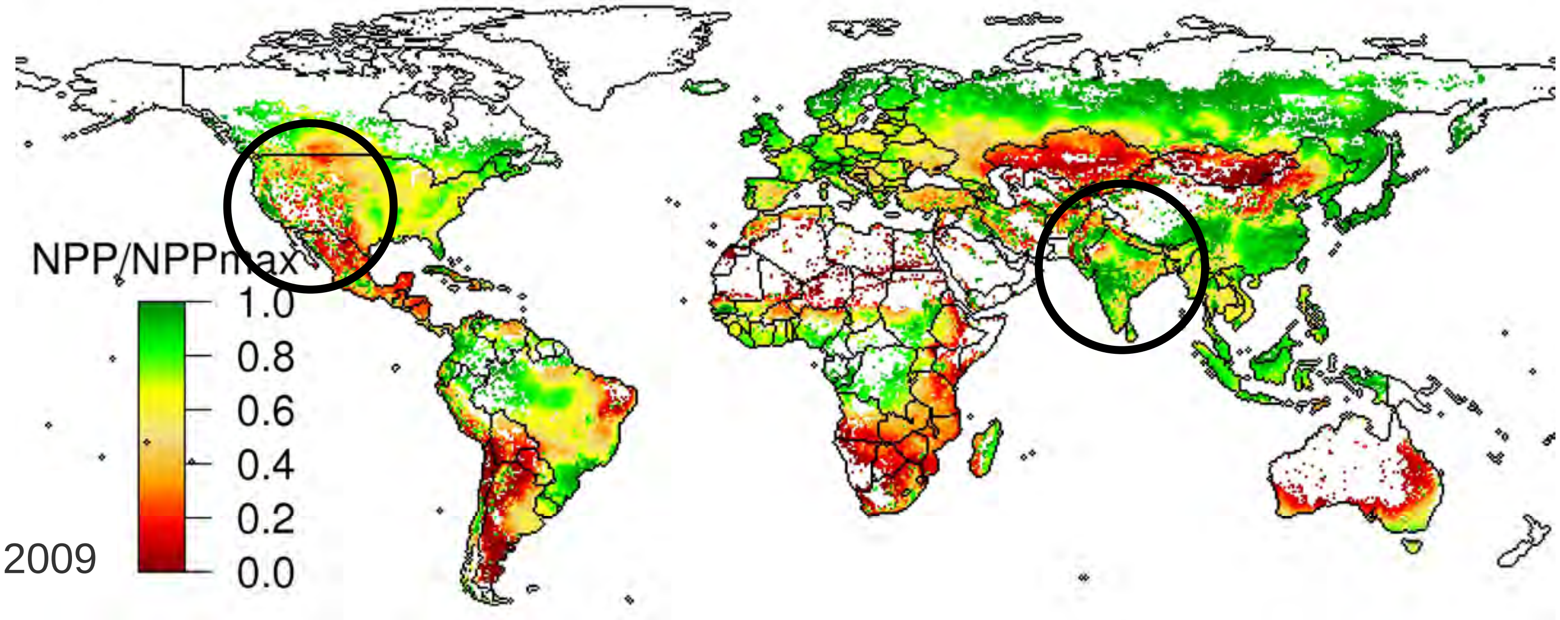
Gerten et al., *Clim. Change* 2007

Water limitation of crop production (NPP)



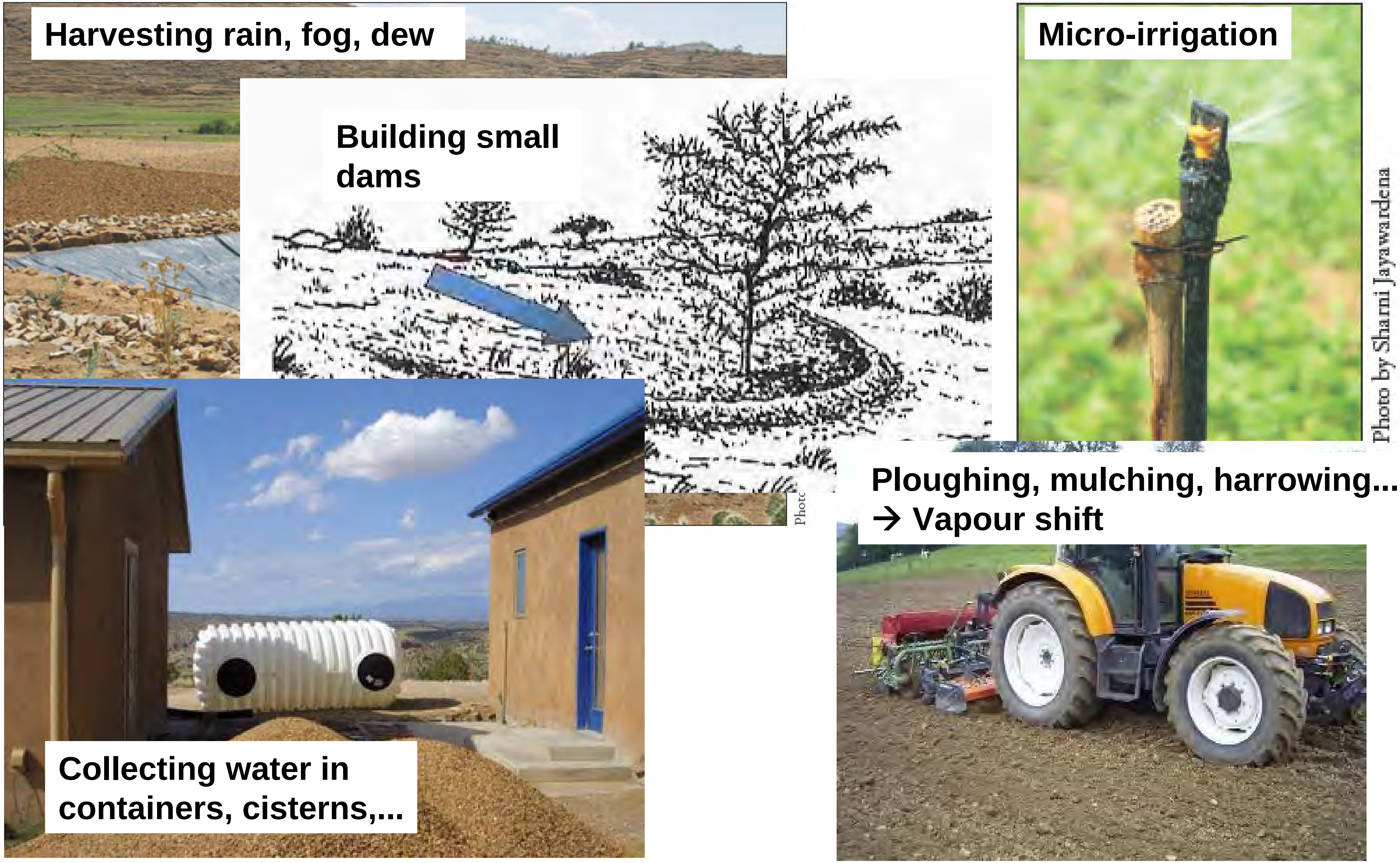
Just rainfed

Irrigated



Rost, Gerten, Rockström
et al., *Environ. Res. Lett.* 2009

Many options of water management in rainfed agriculture



Scenario protocol

1. Baseline (no management; present climate, CRU 1971–2000)

2. Water management scenarios for baseline:

a) Irrigation

b) Water harvesting WH (collect runoff from cropland, use it in dry-spells)

c) Vapour shift VS (reduce soil evaporation, thus increase transpiration)

d) Combination of WH and VS

b–d) for four levels of management intensity each (10, 25, 50, 85%)

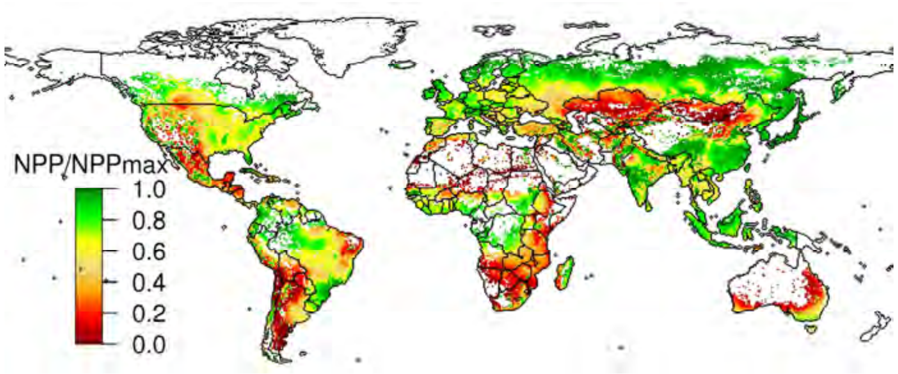
3. Same, under climate and CO_2 change:

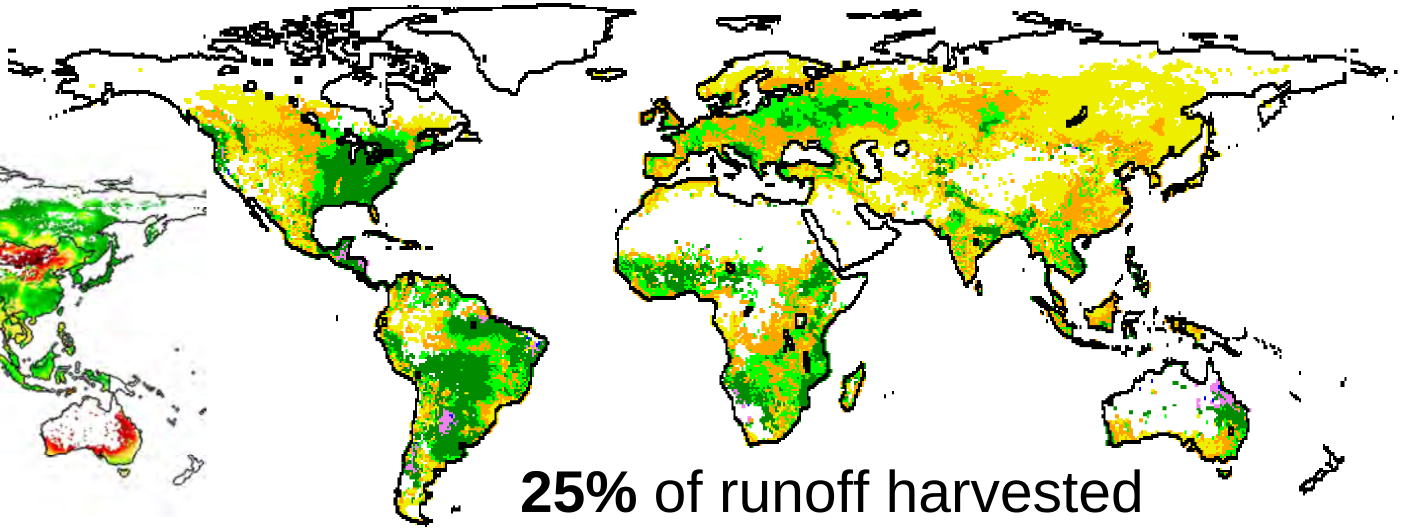
a) WH and VS under 3 climate change scenarios (HadCM3, ECHAM5, CCSM3; SRES-A2)

b) Same, including direct CO_2 effects on plants

Effects of water harvesting & vapour shift **a moderate scenario**

present limitation
(with irrigation)

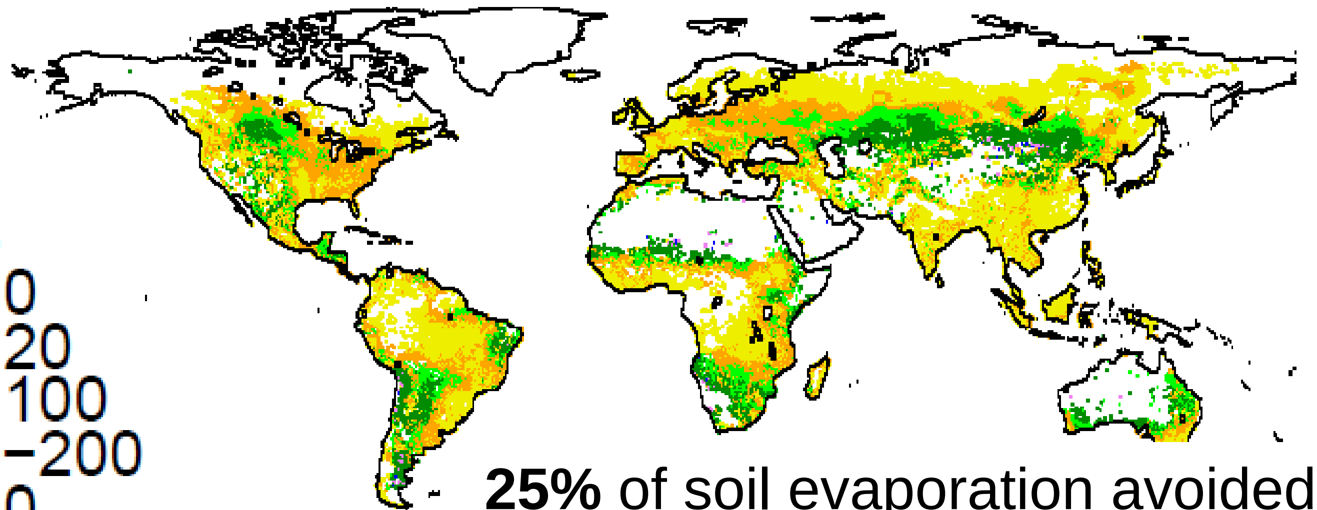




25% of runoff harvested

% increase
in crop NPP

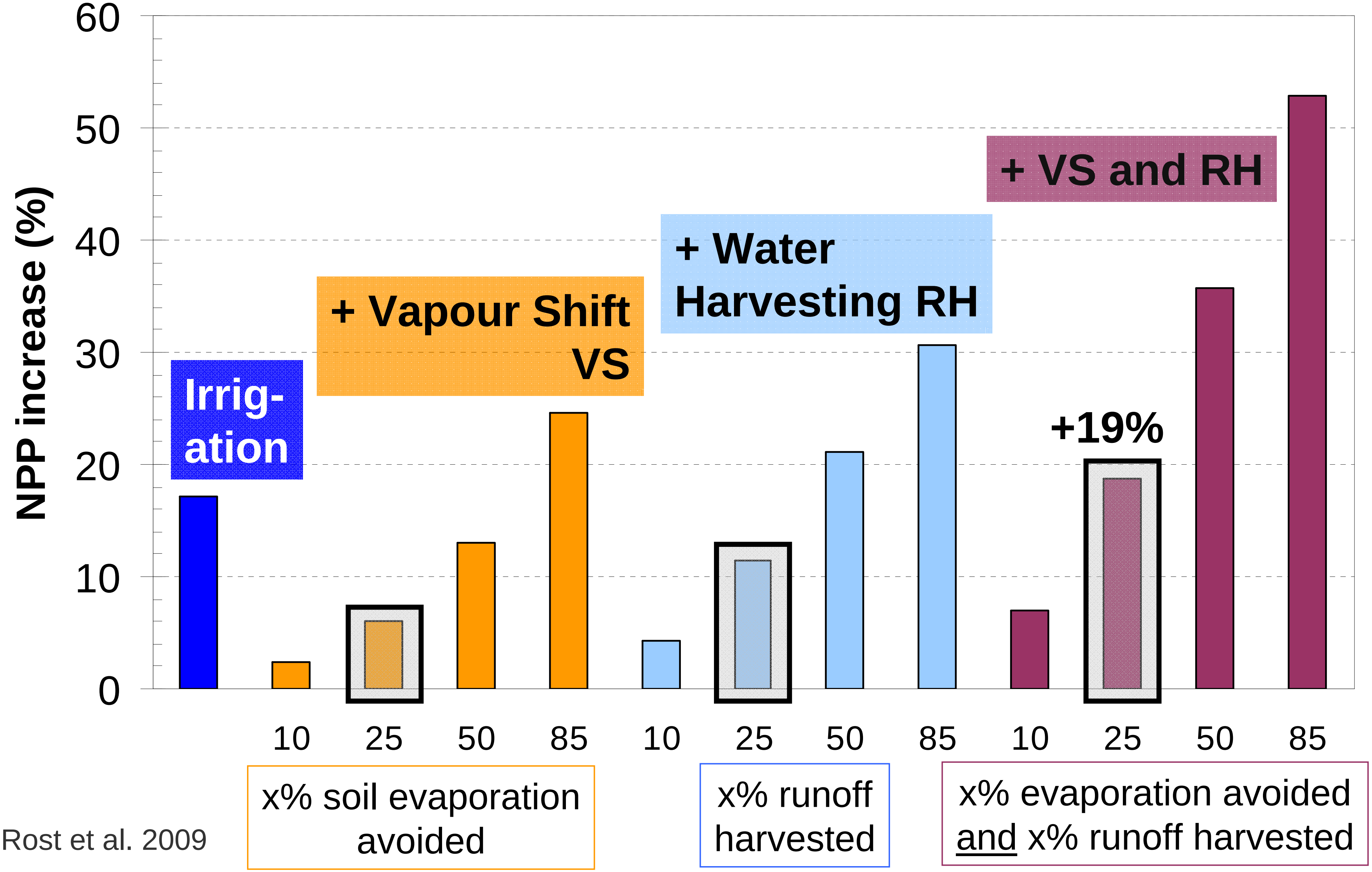
- 1−5
- 5−10
- 10−20
- 20−100
- 100−200
- >200



25% of soil evaporation avoided

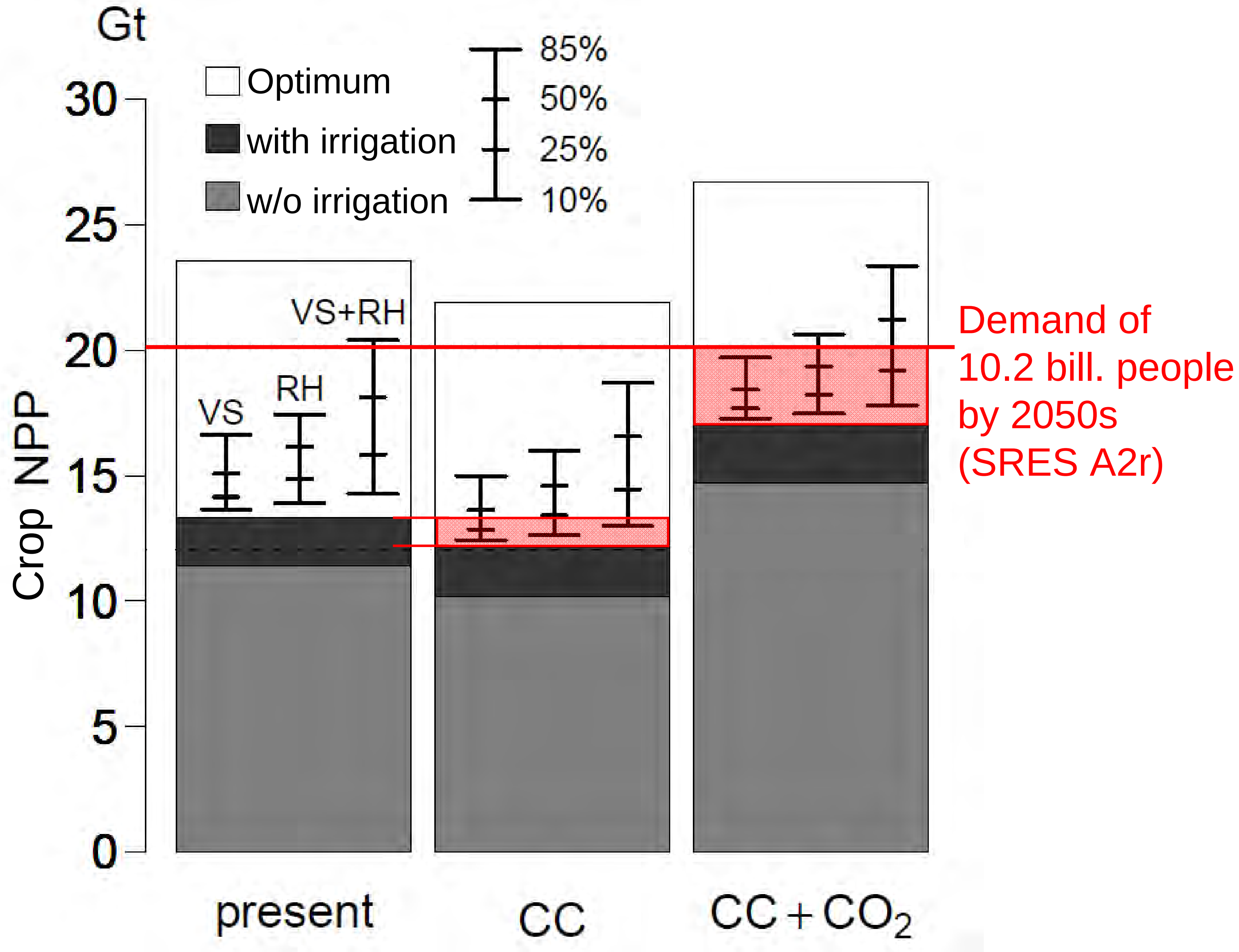
Rost et al. 2009

Increase in global crop NPP in the different scenarios



Rost et al. 2009

Effects of climate, CO_2, and demographic change



Rost et al. 2009

In the future, there will be a substantial water gap

Water currently consumed on cropland: **8500** km^3/yr (Rost et al. 2008)

Further need in the future (10 billion people): **+4000**

- ☑ Increased irrigation areas and efficiency: **–800** (Falkenmark & Rockström 2004)
- ☑ Saving through VS25+RH25 management: **–600** (Rost et al. 2009)
- ☑ Saving through doubled virtual water trade: **–400** (cf. Oki et al. 2004)

→ Missing **~2200** km^3/yr

= ~20% more freshwater (and thus crop area) required than today!

Summary and conclusions

- Water management in rainfed agriculture can contribute significantly to increase regional and global crop production (by up to ~20%).
- This requires investments and implementation strategies.
- Climate change tends to decrease crop NPP, while direct CO_2 effects increase it. The magnitude of the latter effect is highly uncertain.
- Even if most effectively used, water resources on present cropland will not suffice to produce the food for ~10 billion people.
- This suggests the need for a global cropland expansion by ~20%.
- The potential of other options (virtual water trade; breeding; etc.) will have to be quantified systematically.

Thank you for your attention!