Potsdam Institute for Climate Impact Research
RD2 Climate Impacts & Vulnerability

Mitigating Droughts: Global Potential to Raise Rainfed Crop Production

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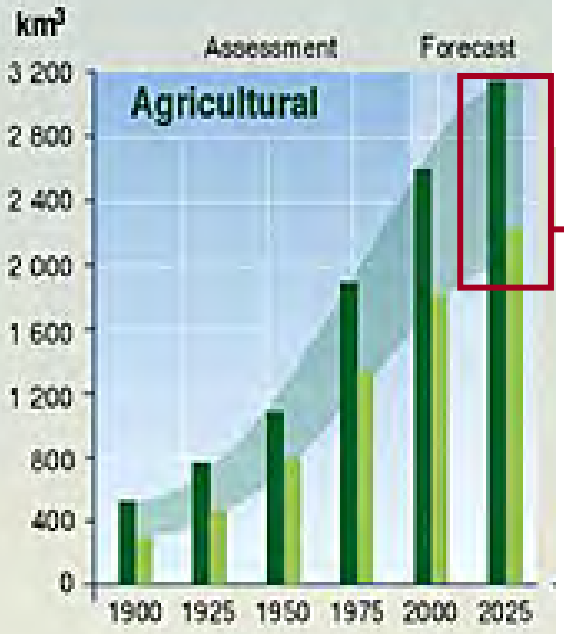
Water for food: The global challenge

Shiklomanov 1999



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)?

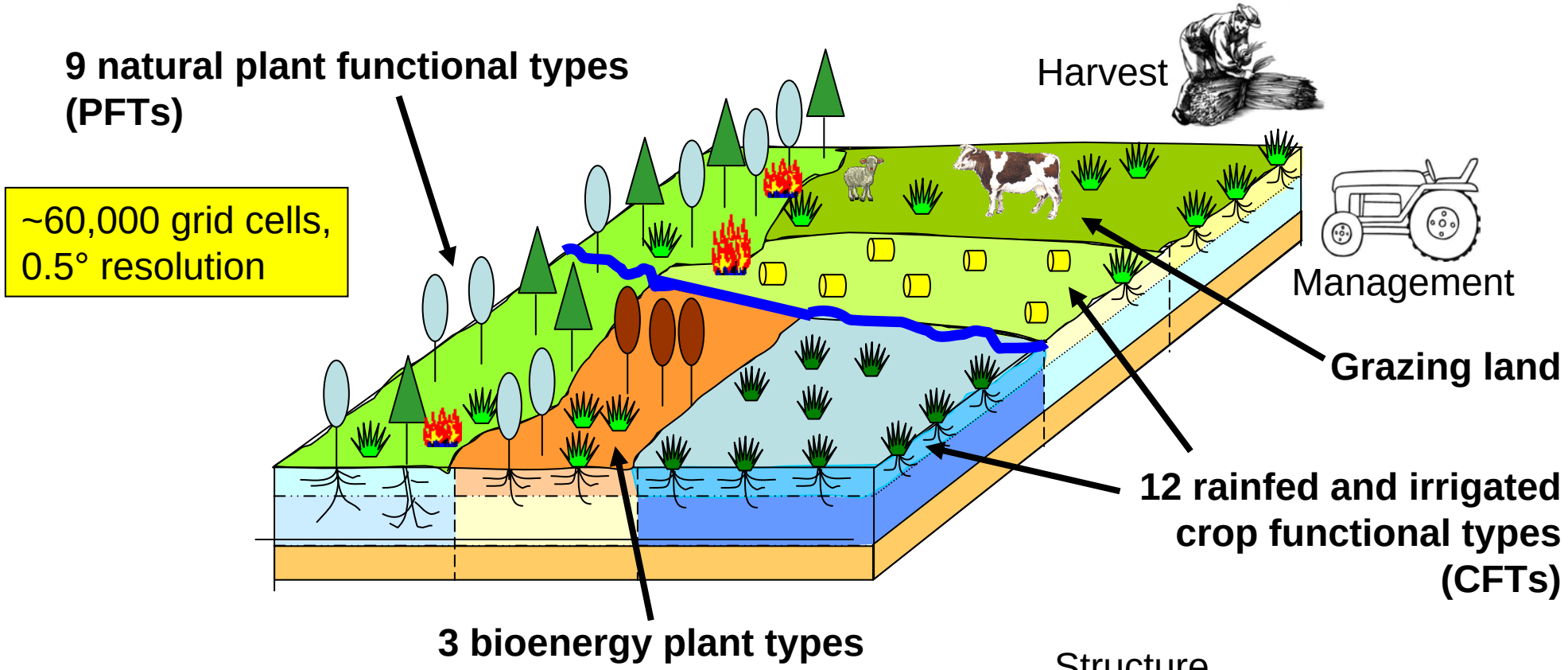
Mitigation of drought spells in rainfed agriculture? ★

etc.

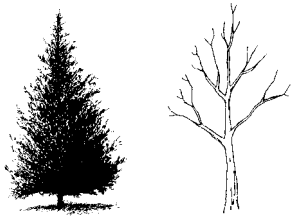
Questions addressed here

- 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?

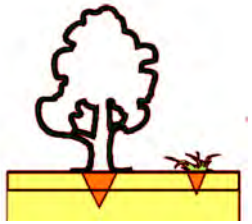
The LPJmL global vegetation and hydrology model



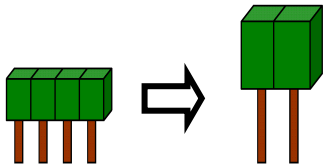
Seasonality



Allocation

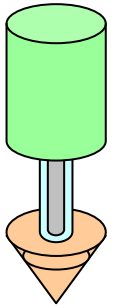


Dynamics

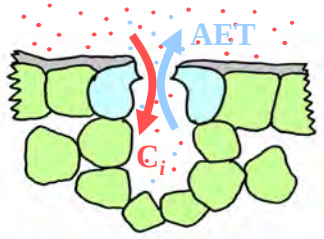


Fire

Structure

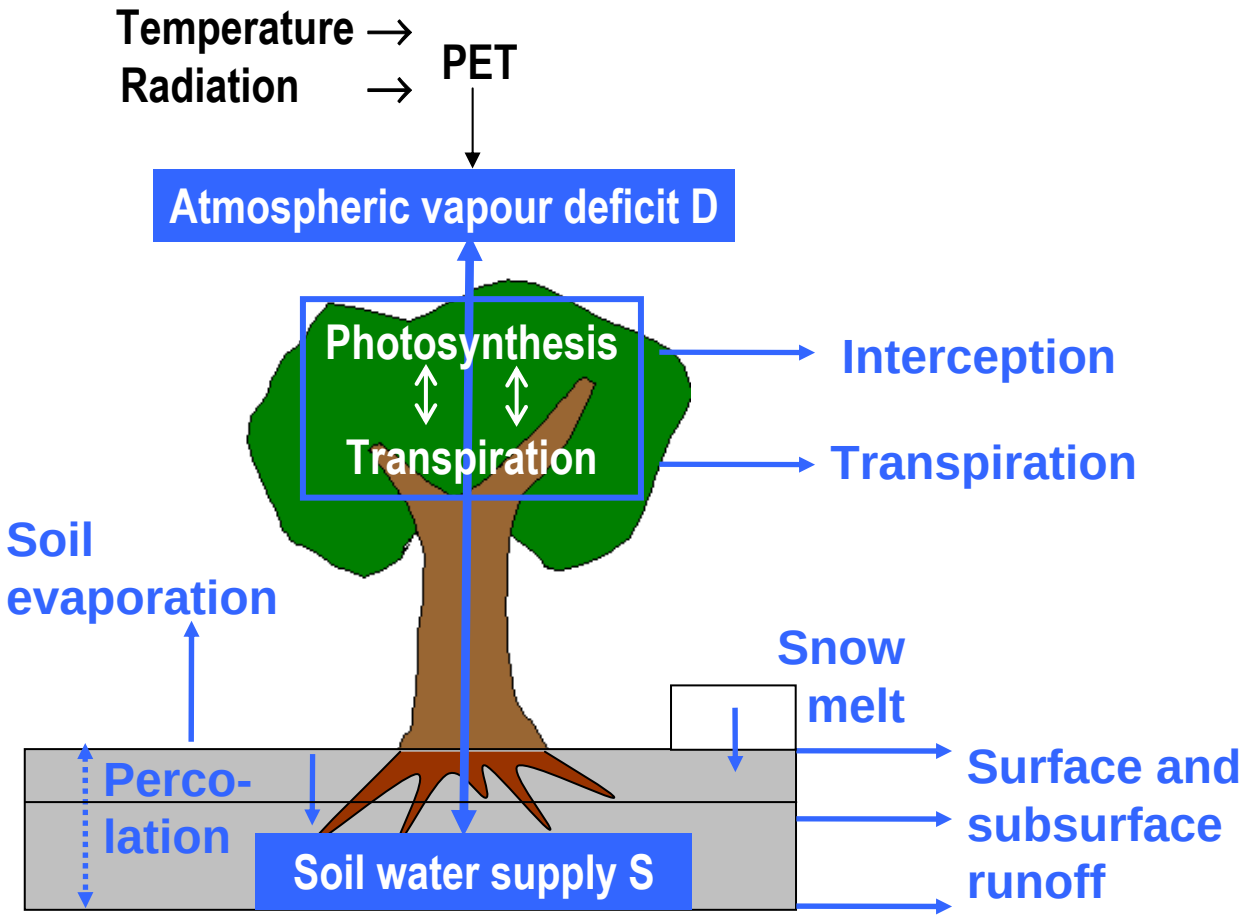


C, H_20 exchange



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

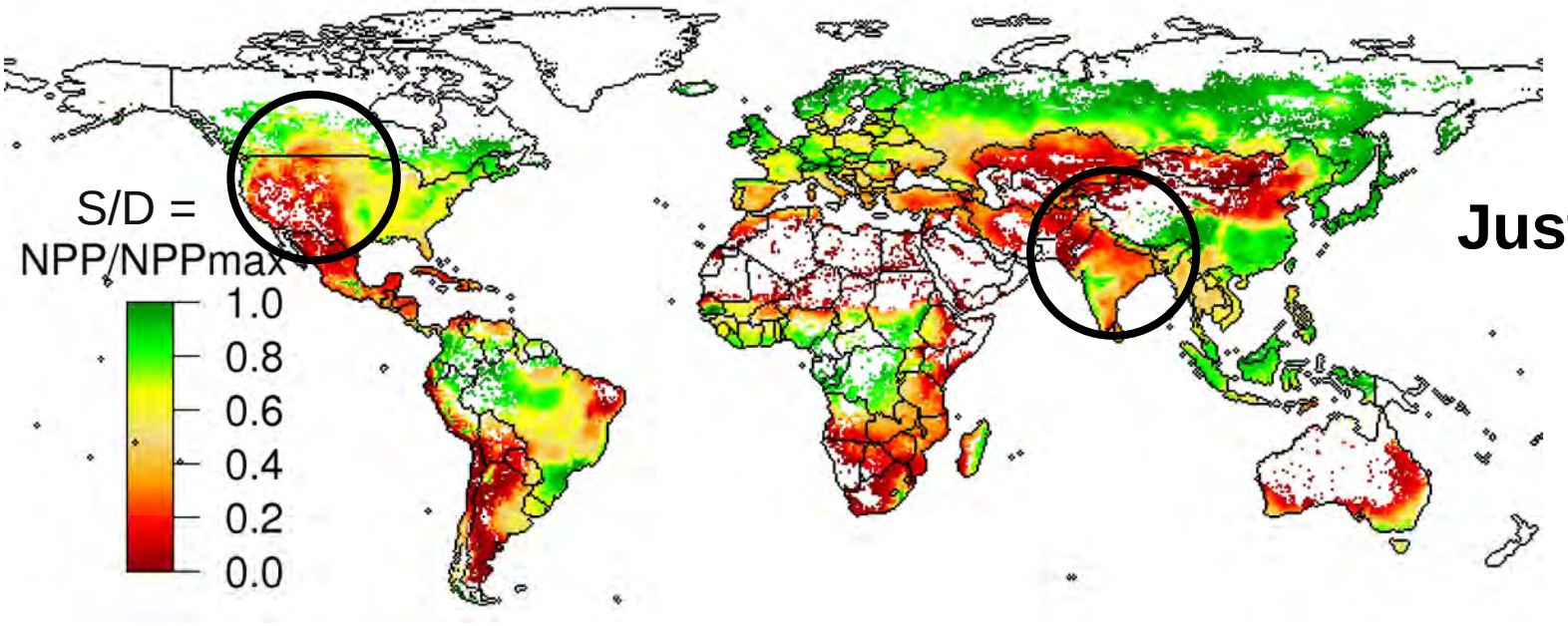
Modelling of plant water limitation in LPJmL



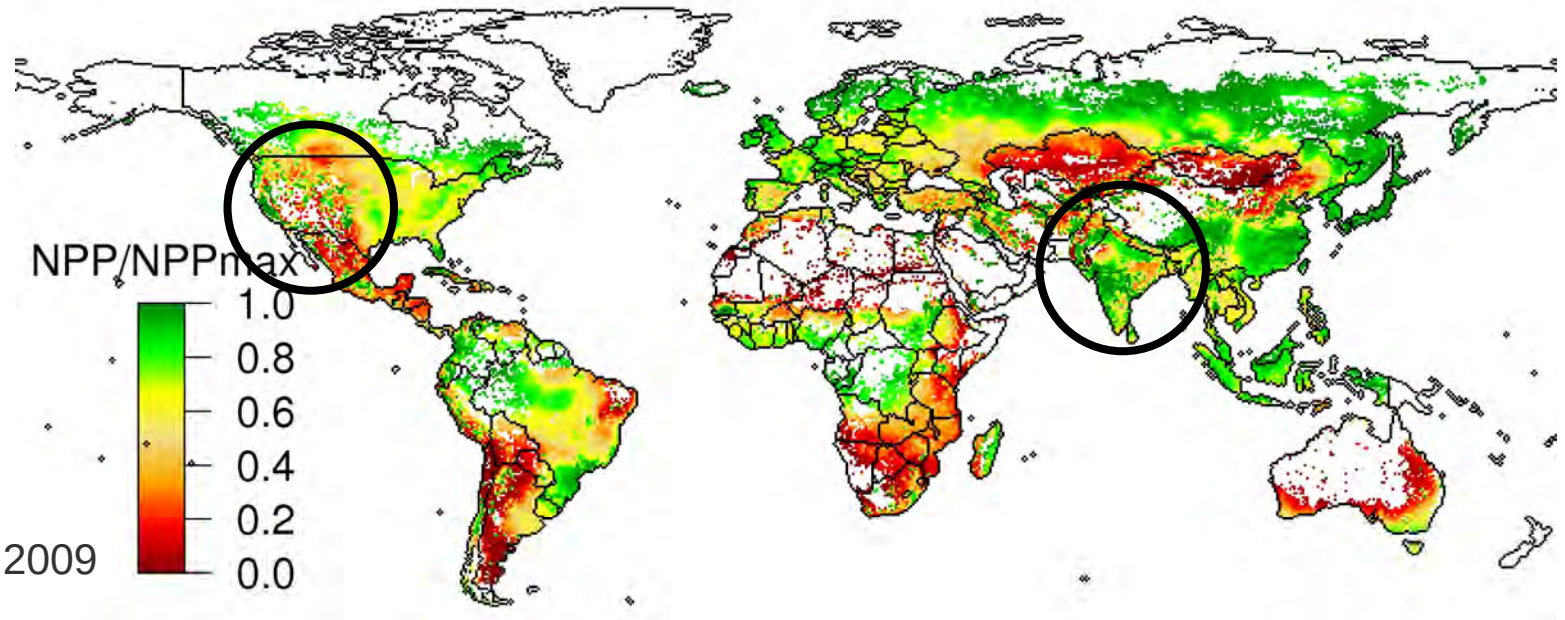
If D>S, photosynthesis and thus net primary production (NPP) is water-limited.
The S/D ratio indicates the degree of water limitation.

Gerten et al., *Clim. Change* 2007

Water limitation of crop production (NPP)



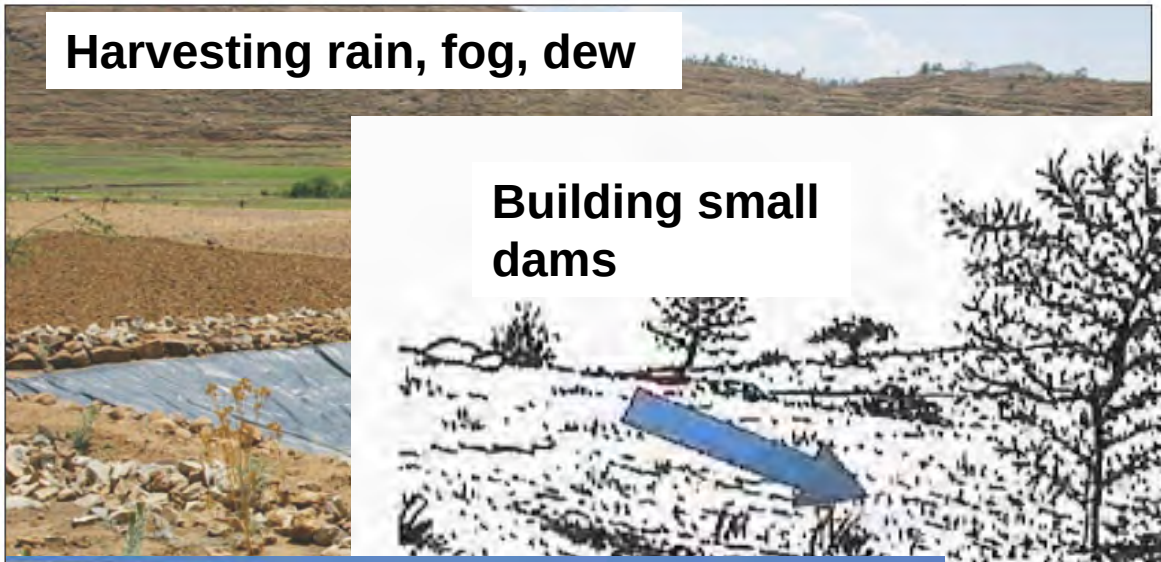
Just rainfed



Irrigated

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

Many options of water management in rainfed agriculture



Harvesting rain, fog, dew

Building small dams

Collecting water in containers, cisterns,...

Micro-irrigation

Photo by Sharmi Jayawardena

Ploughing, mulching, harrowing...
→ Vapour shift

Scenario protocol

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

2. Water management scenarios for baseline:

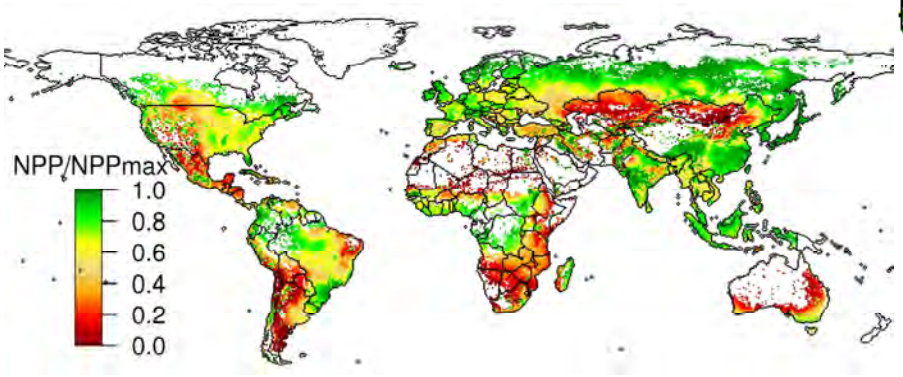
a) Irrigation
b) Water harvesting WH (collect runoff from cropland, use it in dry-spells)
c) Vapour shift VS (reduce soil evaporation, thus increase transpiration)
d) Combination of WH and VS
b–d) for four levels of management intensity each (10, 25, 50, 85%)

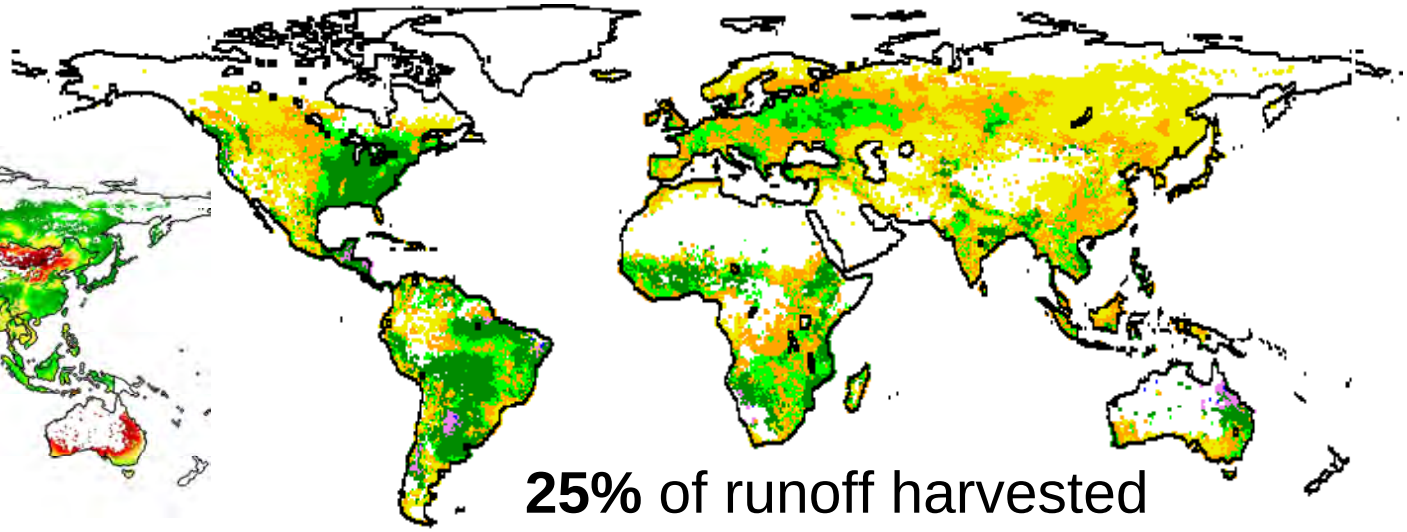
3. Same, under climate and CO_2 change:

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)

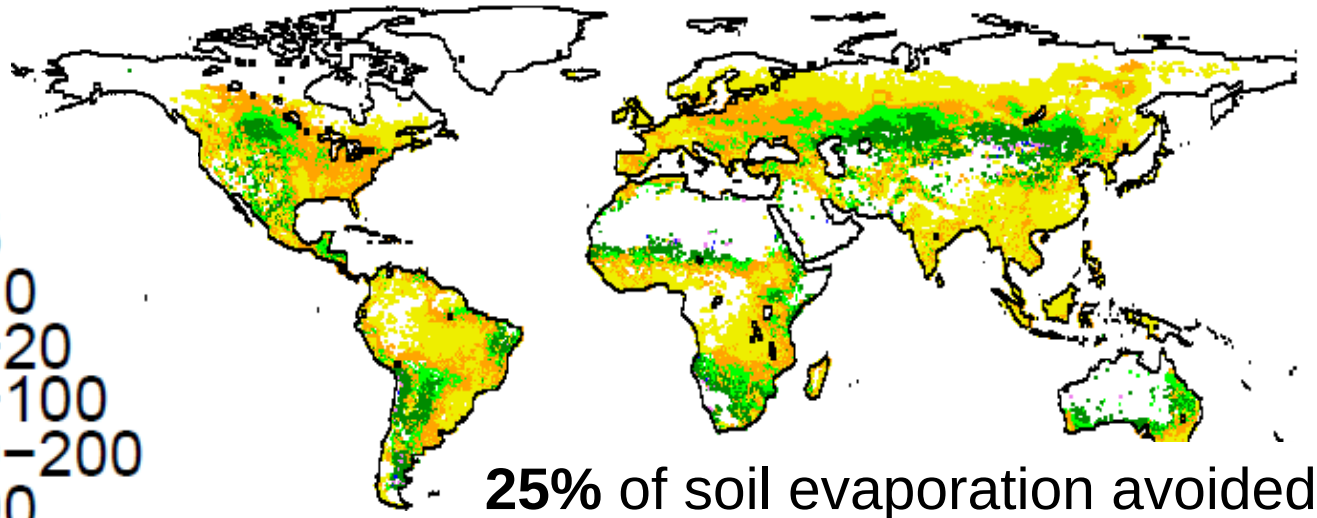




25% of runoff harvested

% increase
in crop NPP

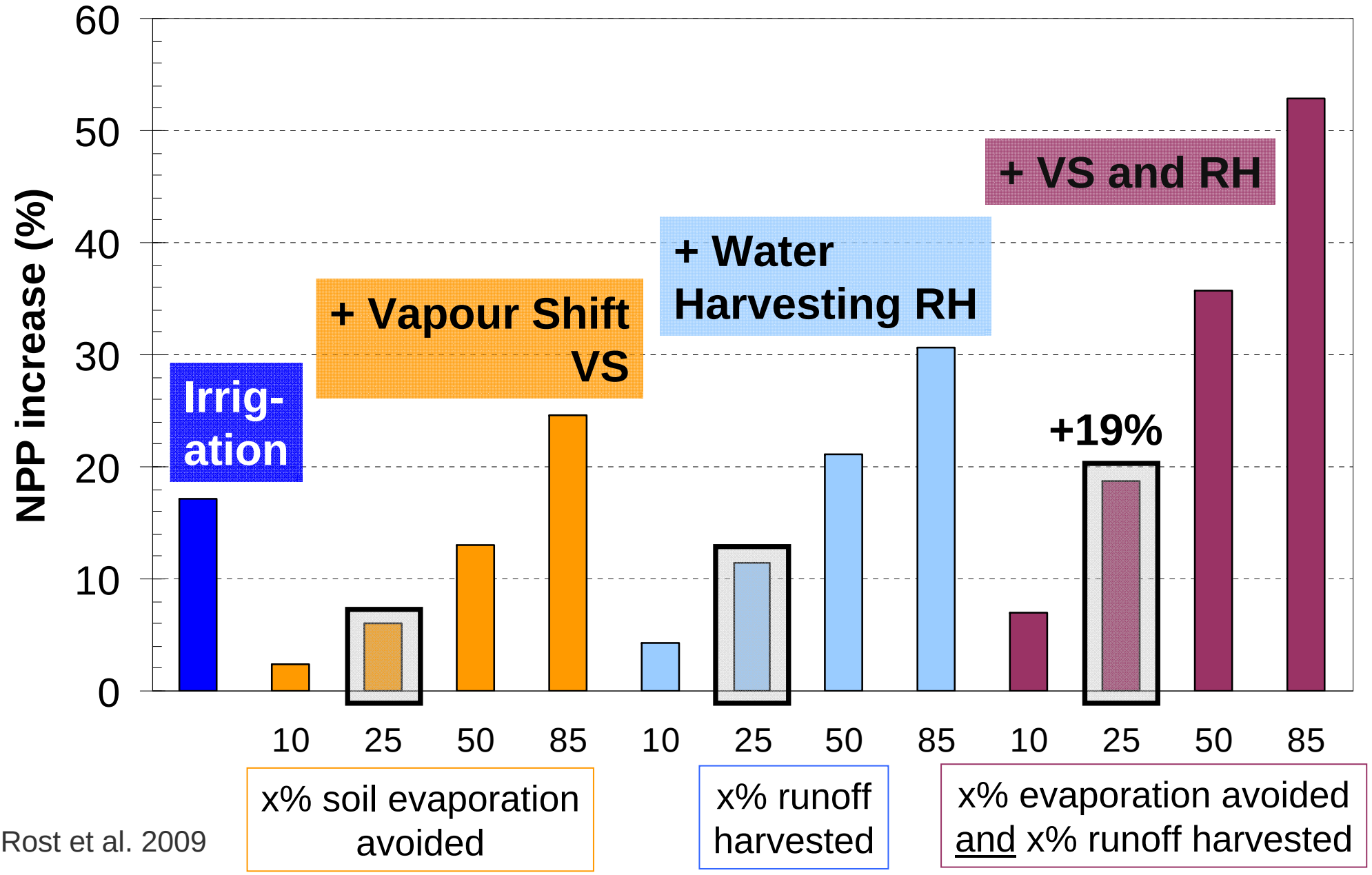
- 1–5
- 5–10
- 10–20
- 20–100
- 100–200
- >200



25% of soil evaporation avoided

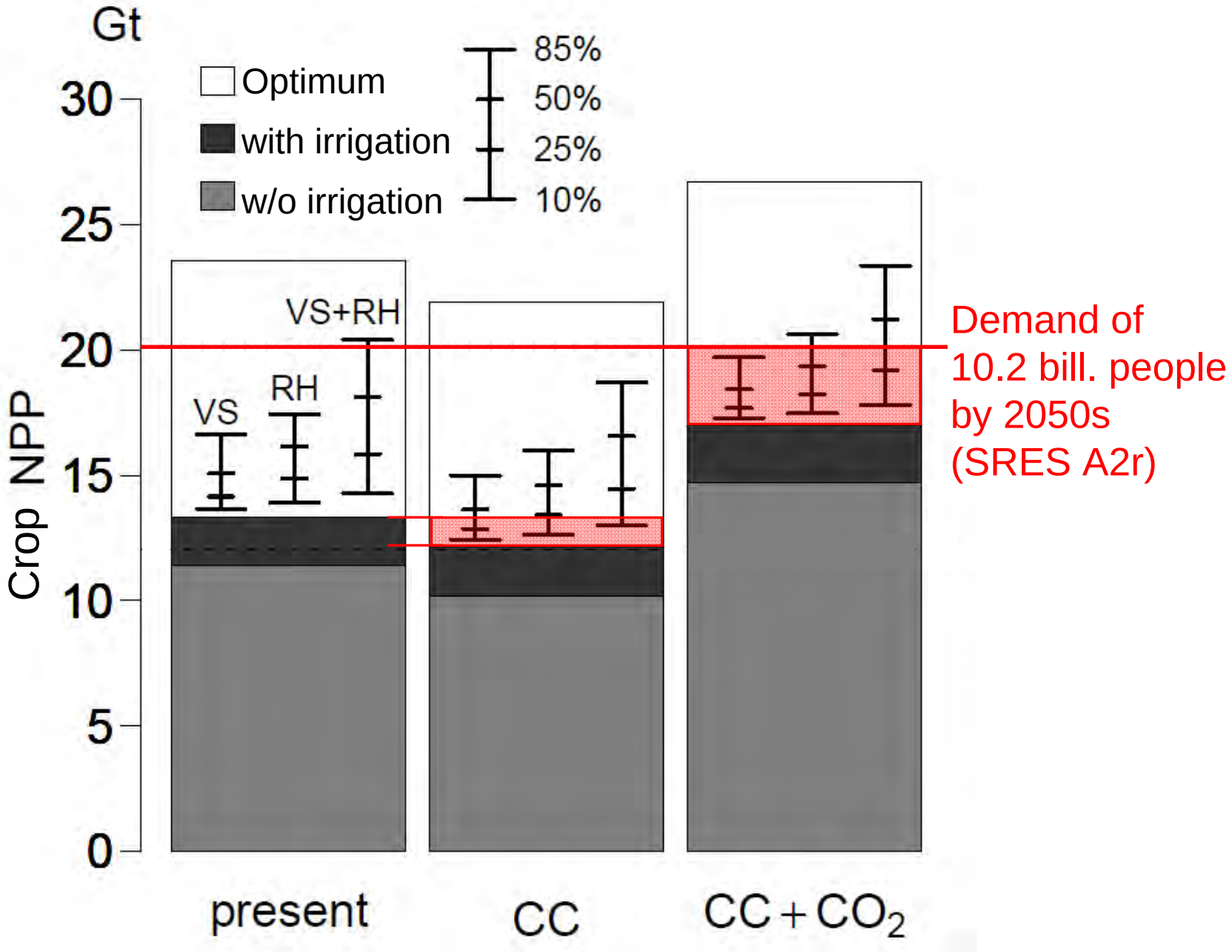
Rost et al. 2009

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!