Soil Building as a Climate Mitigation Strategy

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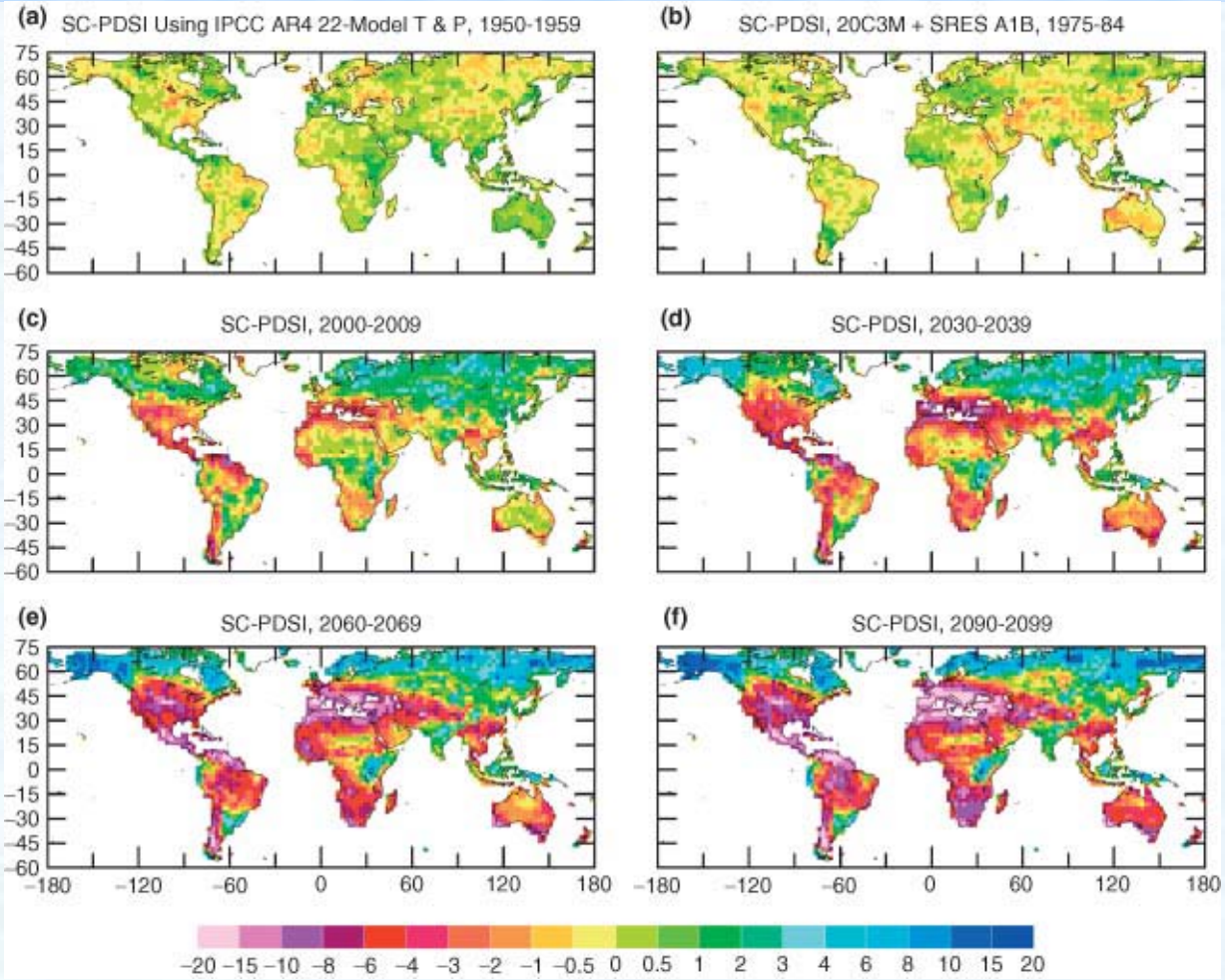
Global warming will dry out most land areas

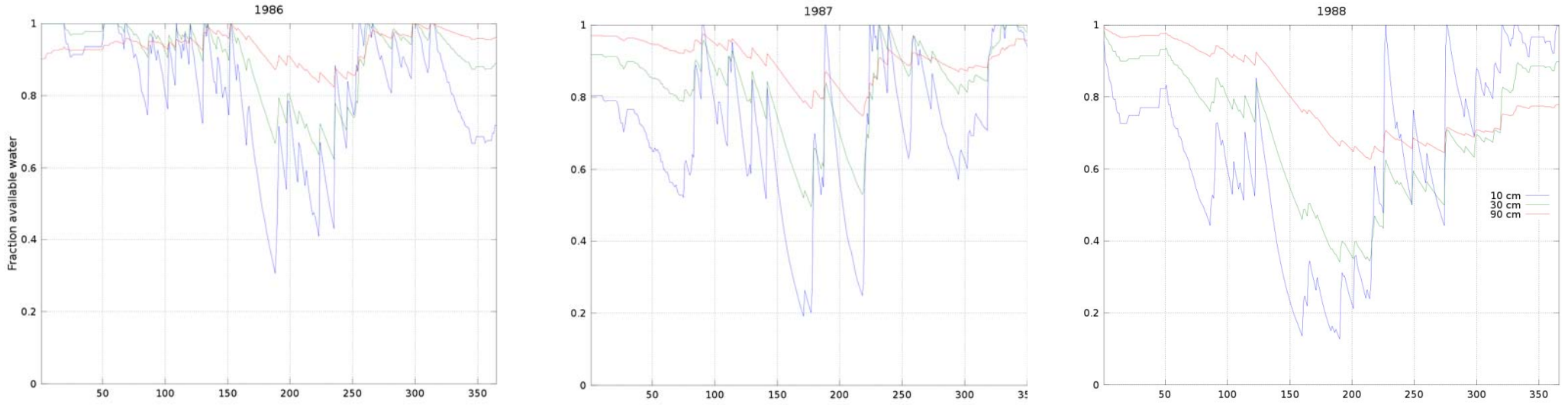


"drought may become so widespread and so severe in the coming decades that current drought indices may no longer work properly in quantifying future drought" (Dai, 2011)

Why drought adaptation is becoming more necessary for agriculture

- Mean conditions in mesic regions (Europe, east US, …) are changing so that droughts severe enough to threaten plant growth are more common and longer
- Precipitation is likely to be more concentrated in extreme events (not necessarily captured in monthly statistics)

Root-zone water capacity determines impact of short to medium term drought on plants

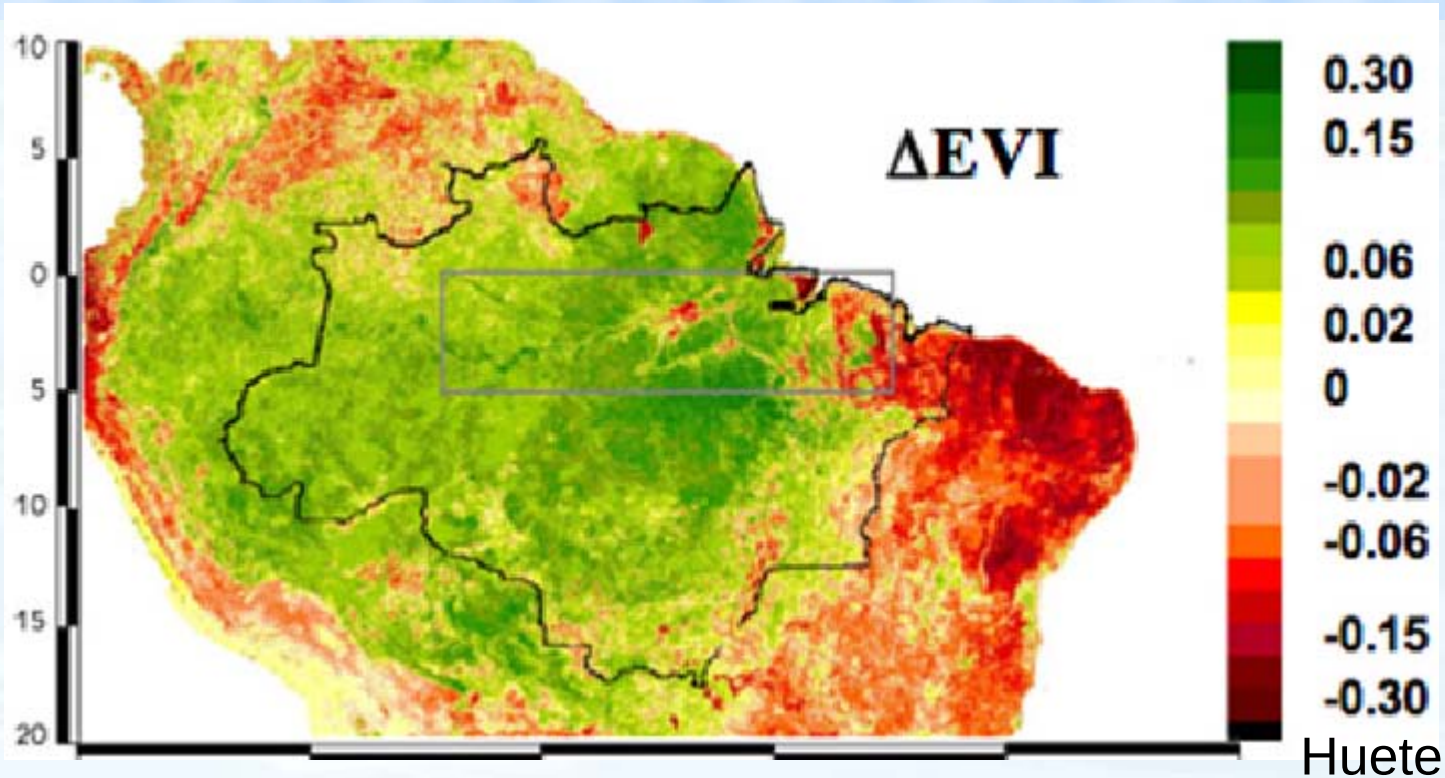


- A large water storage can buffer short-term fluctuations, and even moderate them (more later)

How do plants build water capacity?

- Promote soil formation
- Prevent erosion (increase cohesion, shield water and wind energy)
- Deposit organic materials with high water holding capacity
- Hydraulic redistribution
- Deep roots

Consequences: Amazon basin



Huete 2006

- Trees access ~10 m of soil depth; productivity *increases* during dry season

(vegetation response to drought could be used to retrieve rooting depth)

- In experimental drought experiment, trees survived well for 3 years, after which deep soil water ran out

What controls plant rooting depth?

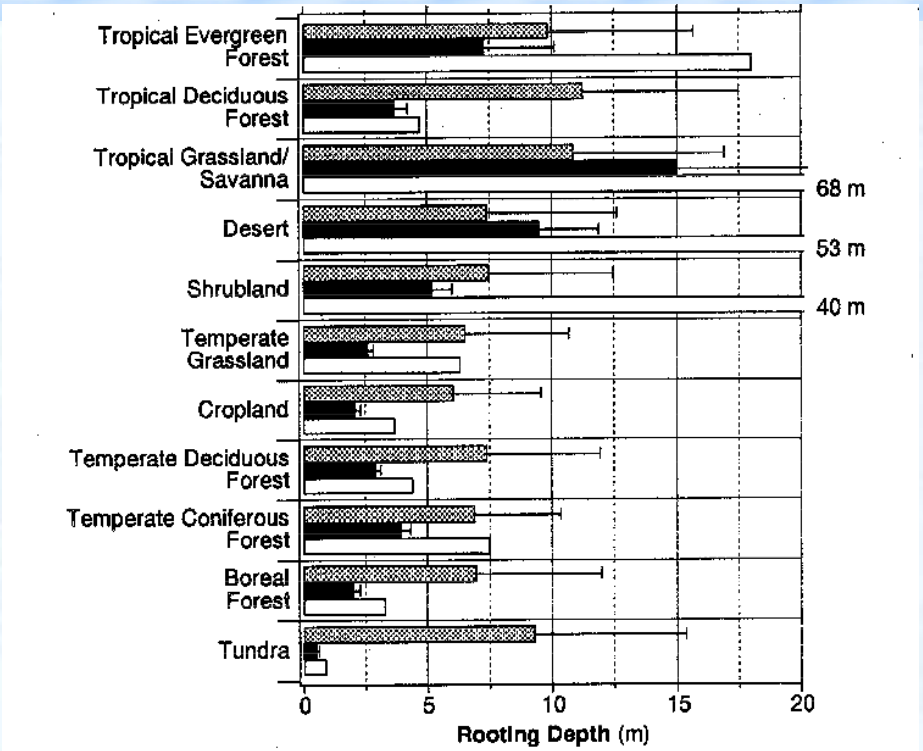


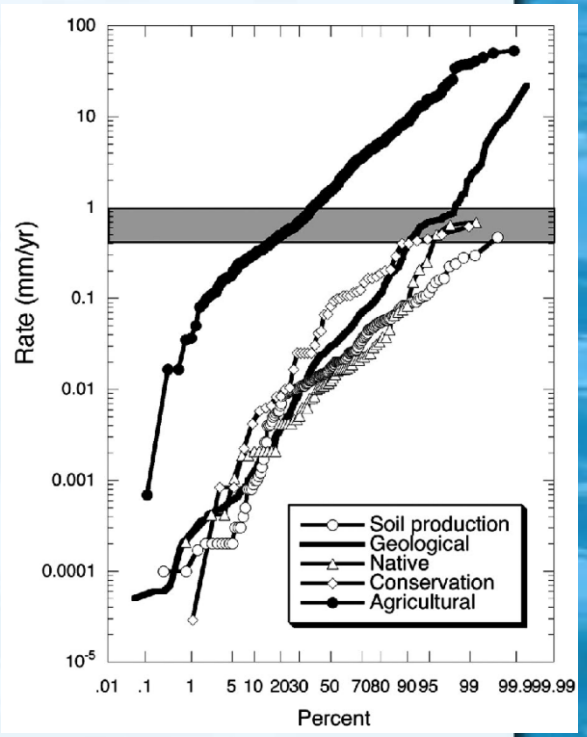
Figure 1. Comparison of biome averages of optimum rooting depth obtained by maximisation of *NPP* (grey bars) to observations (black bars) by Canadell et al. (1996). Also shown are maximum values reported in field studies for each biome (white bars). Error bars show one standard deviation.

Kleidon 1998

- Perennial plants are likely to have deep roots compared to annuals
- Varieties adapted to droughty climate are likely to have deep roots

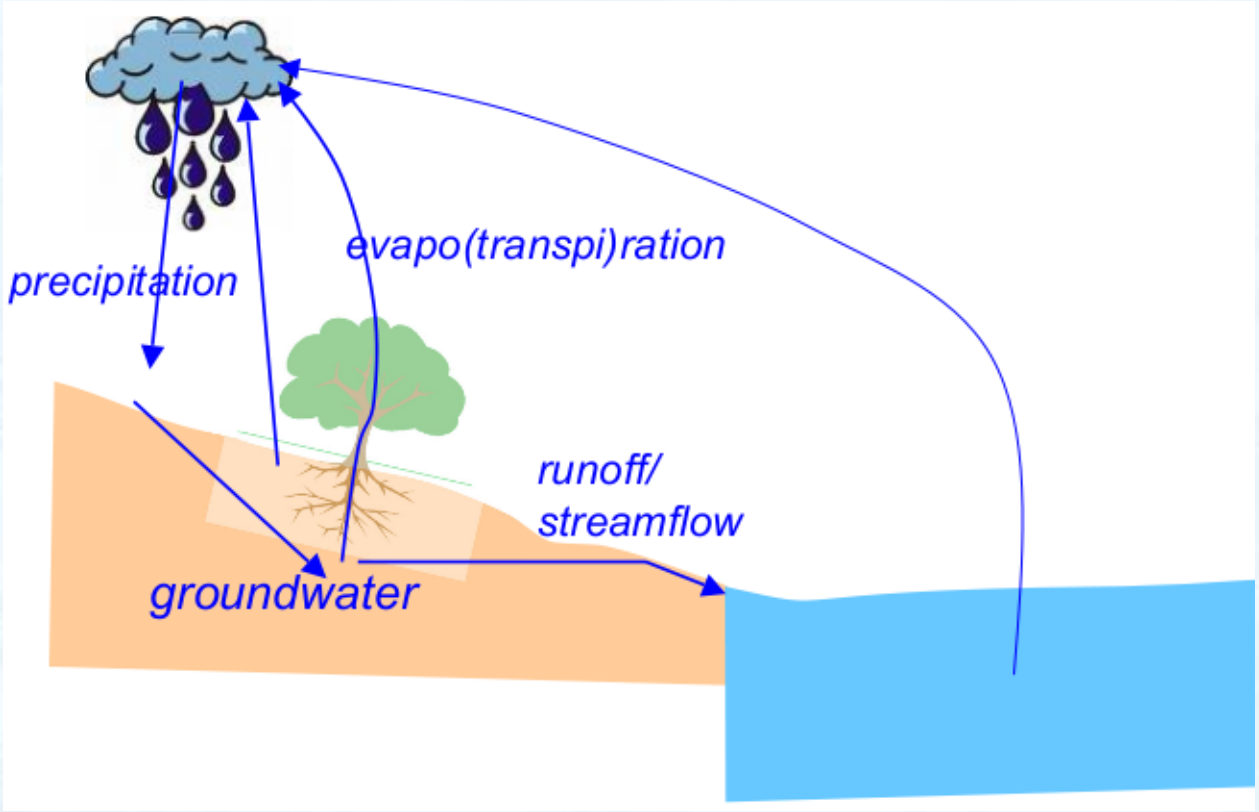
Why are agricultural ecosystems poorly adapted to drought?

- Bare soil and plowing promotes erosion
- Compaction decreases water holding capacity
- Chemical fertilizer promotes loss of soil organic matter
- Annual plants have shallow roots



Montgomery 2007

How does water holding capacity moderate climate?



- Extended evaporation thru dry spells reduces potential evaporation and temperature and promotes cloudiness and precipitation

Model experiment: plants' impact on global climate

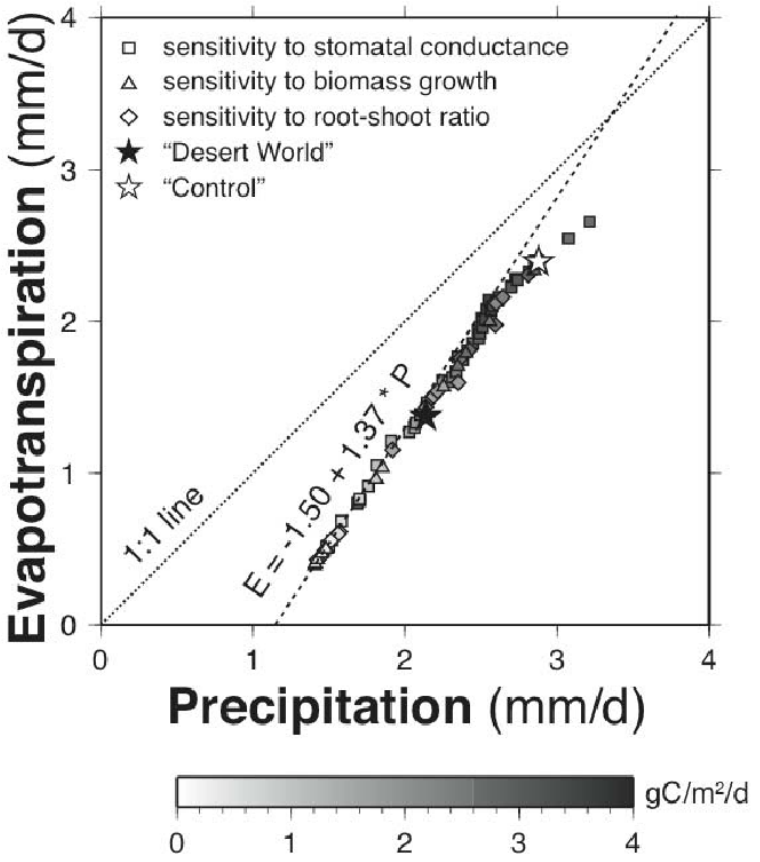
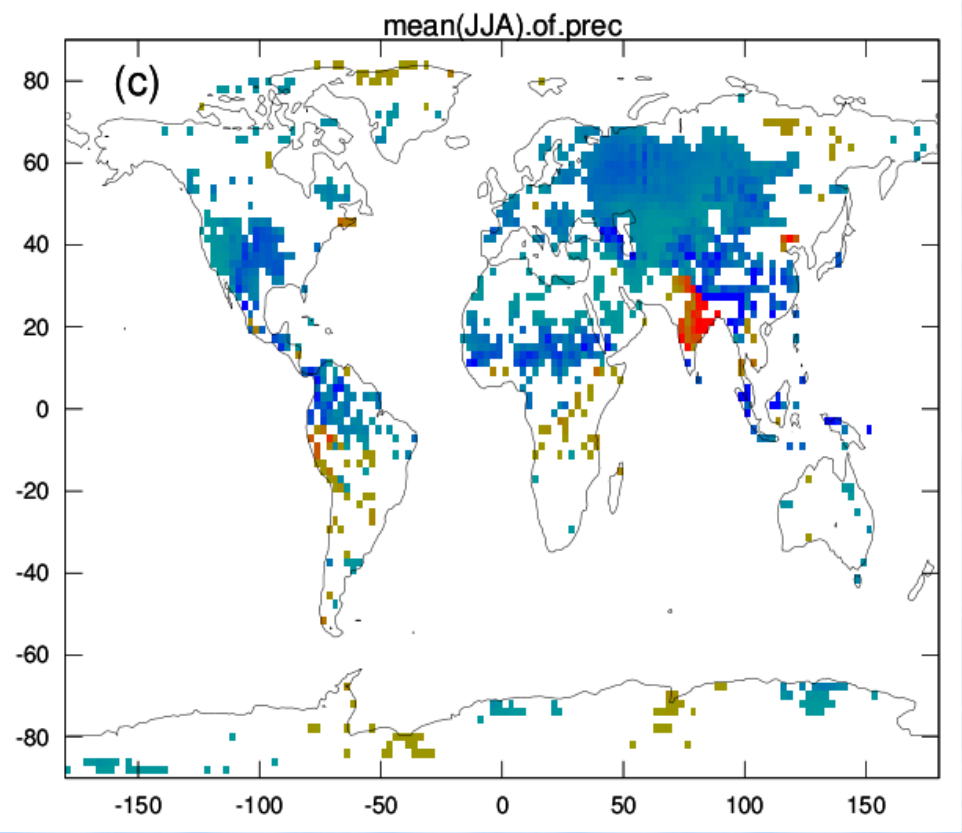


Fig. 4. Possible range of steady states of the terrestrial water balance, in terms of the annual means of precipitation and evapotranspiration. Also shown for comparison is the 1:1 line and a linear best fit line.

- "the emergent climatic conditions at the land surface seem to be close to optimal for the functioning of the terrestrial biosphere" (Kleidon, 2006)

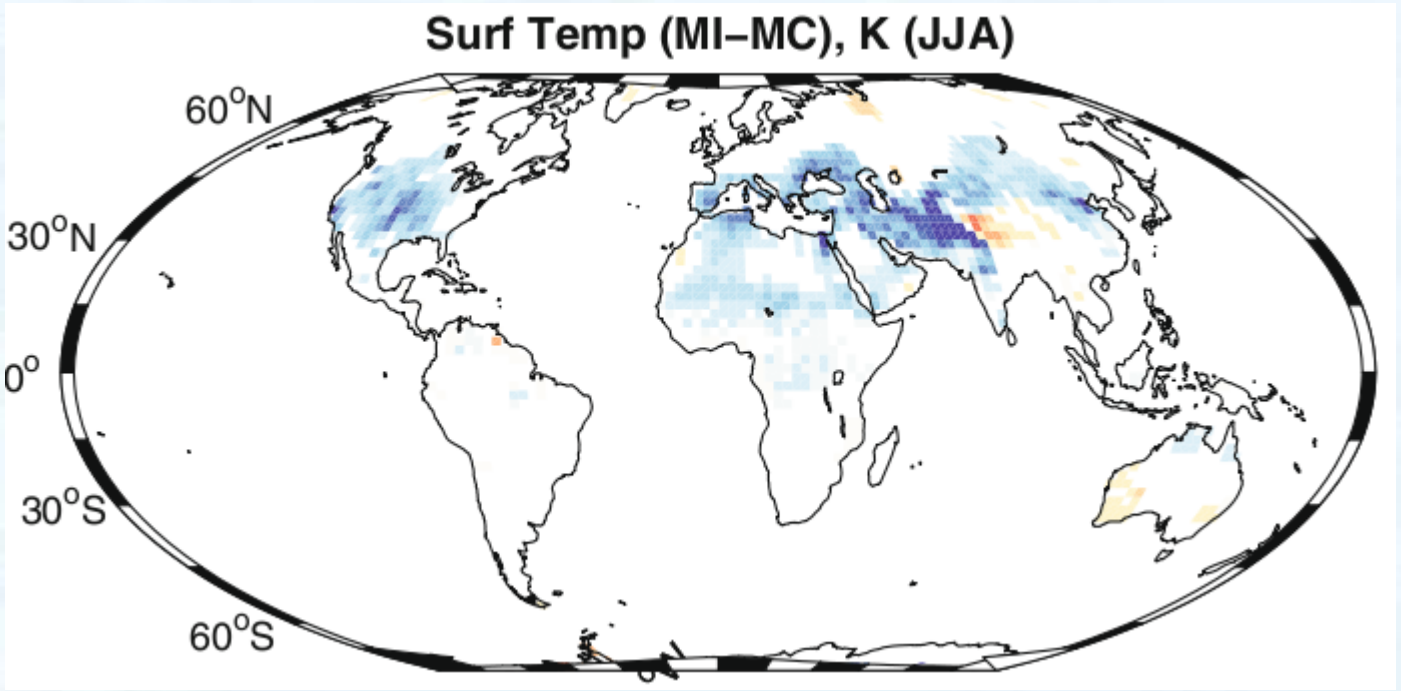
Model experiment: soil water capacity



Krakauer 2010

- Keep soil moisture at climatology worldwide , even thru dry spells
- Result: cooler, moister, fewer heat waves

Model experiment: current effect of irrigation on climate



Cook, in press

- Global warming is likely to be regionally amplified as unsustainable water sources run out

Suggestions for agricultural policy

- Promote cover crops and mulching
- Promote organic farming (known to have better drought resistance and better yields under drought than chemical-fertilizer farming)
- Promote tree crops and perennial grasses (cf. The Land Institute)

Directions for research

- Explicitly model the impact of stored water on crop yield under contemporary and future climate for the major agricultural species and regions
- Remote sensing + data assimilation to quantify plant-available water
- Evaluate influence of soil moisture and evaporation on cloudiness and precipitation through Fluxnet, reanalysis, and satellite data