Modelling Global Land-Use and Land-Cover Impacts on Soil Physical Properties and Water-Holding Capacity

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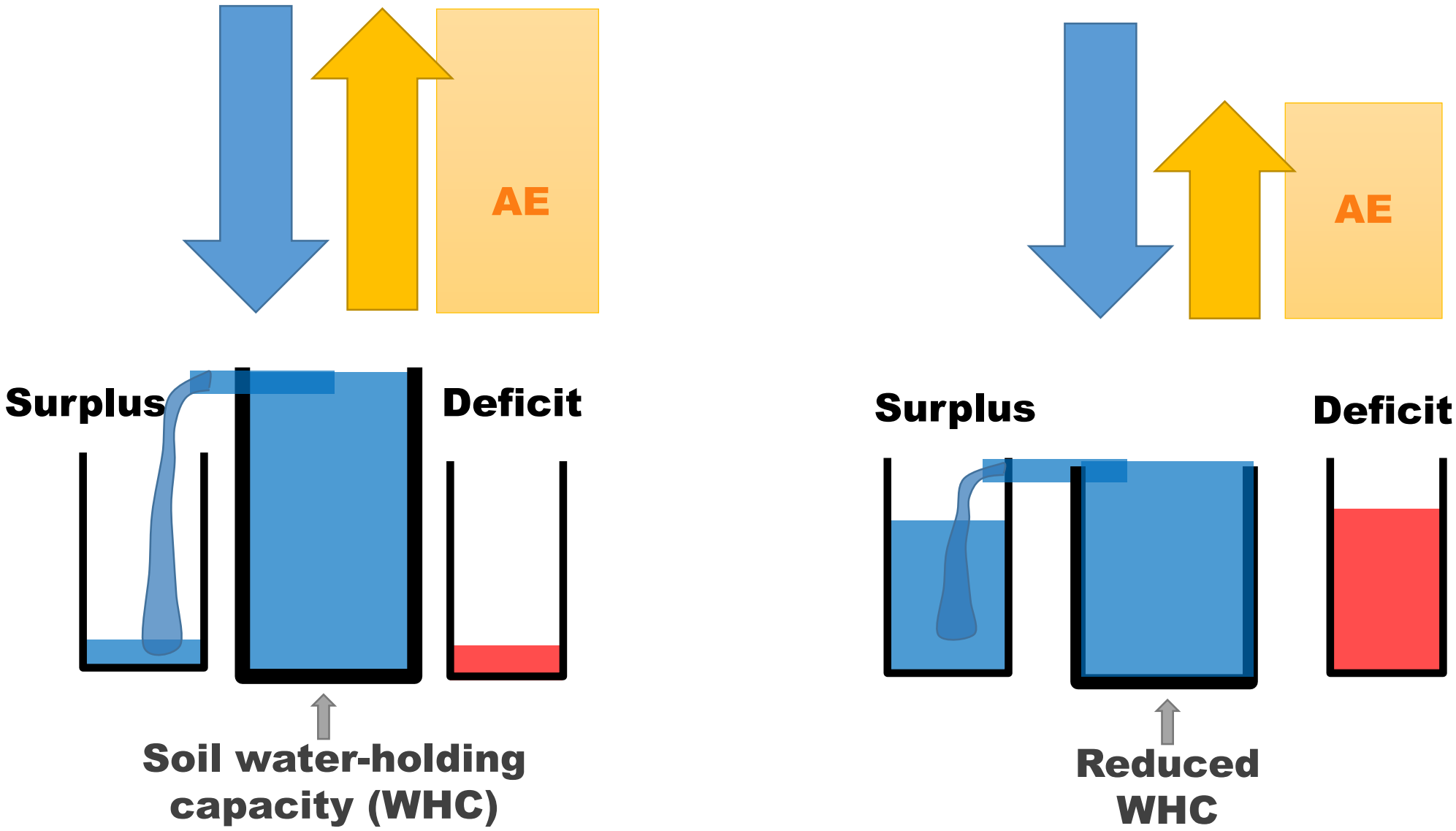
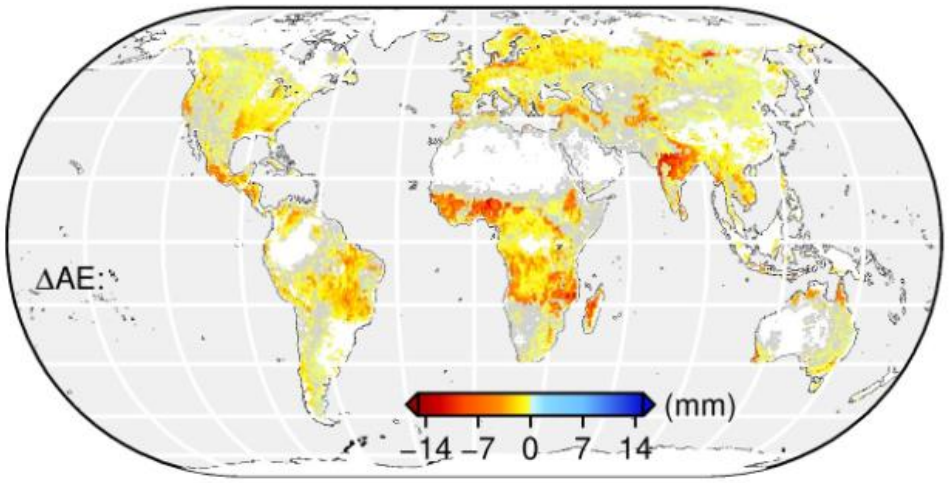
Soil as A Bucket



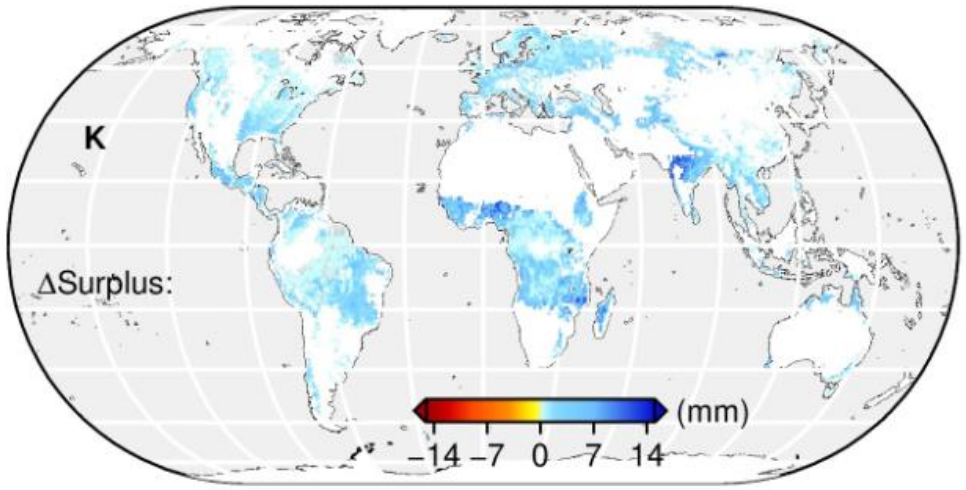
Decreased Global AE and Increased Deficit and Surplus due to Soil WHC Changes under Human Land Uses

ΔAE

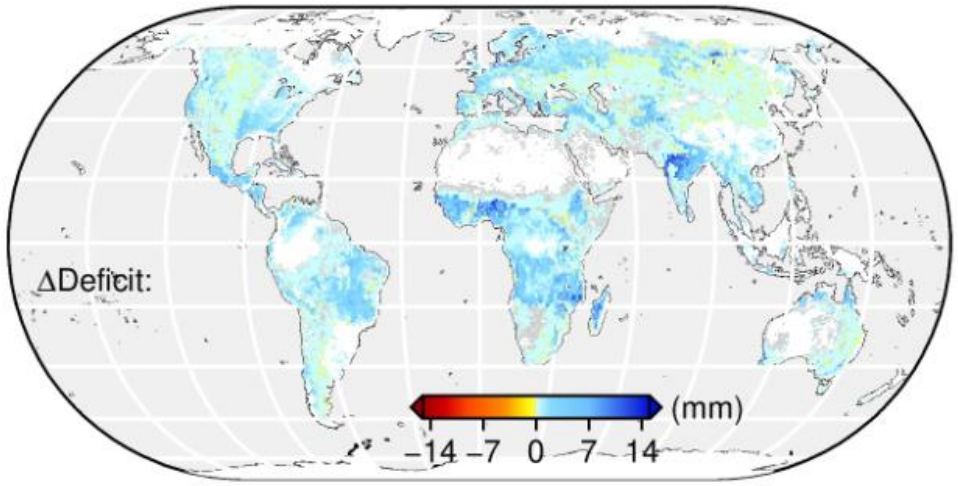


- Thornthwaite-type water balance model (Feddema, 2005)
- Areas of moist climates (but not constantly wet) and with high seasonality are most affected.

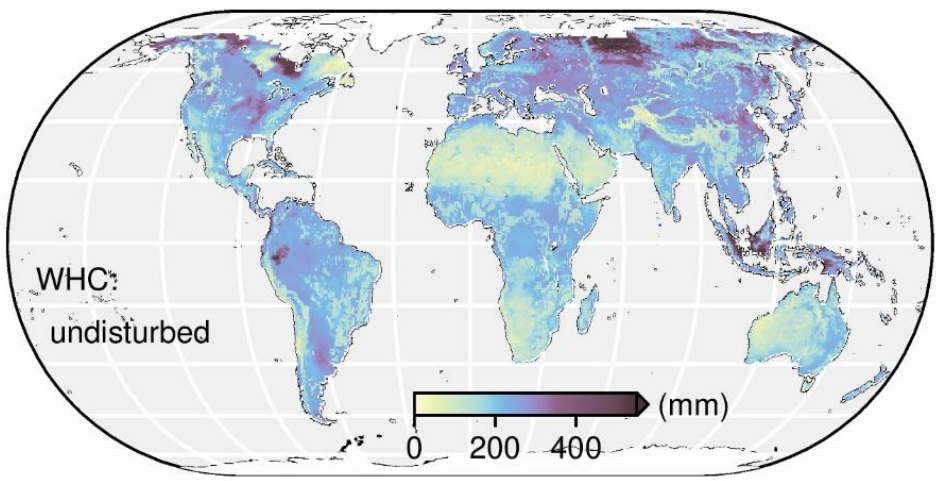
ΔSurplus

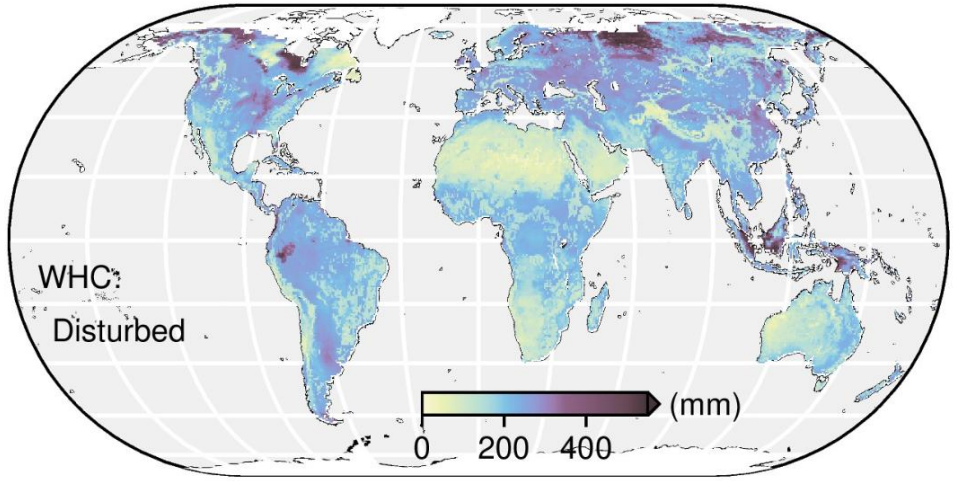


ΔDeficit

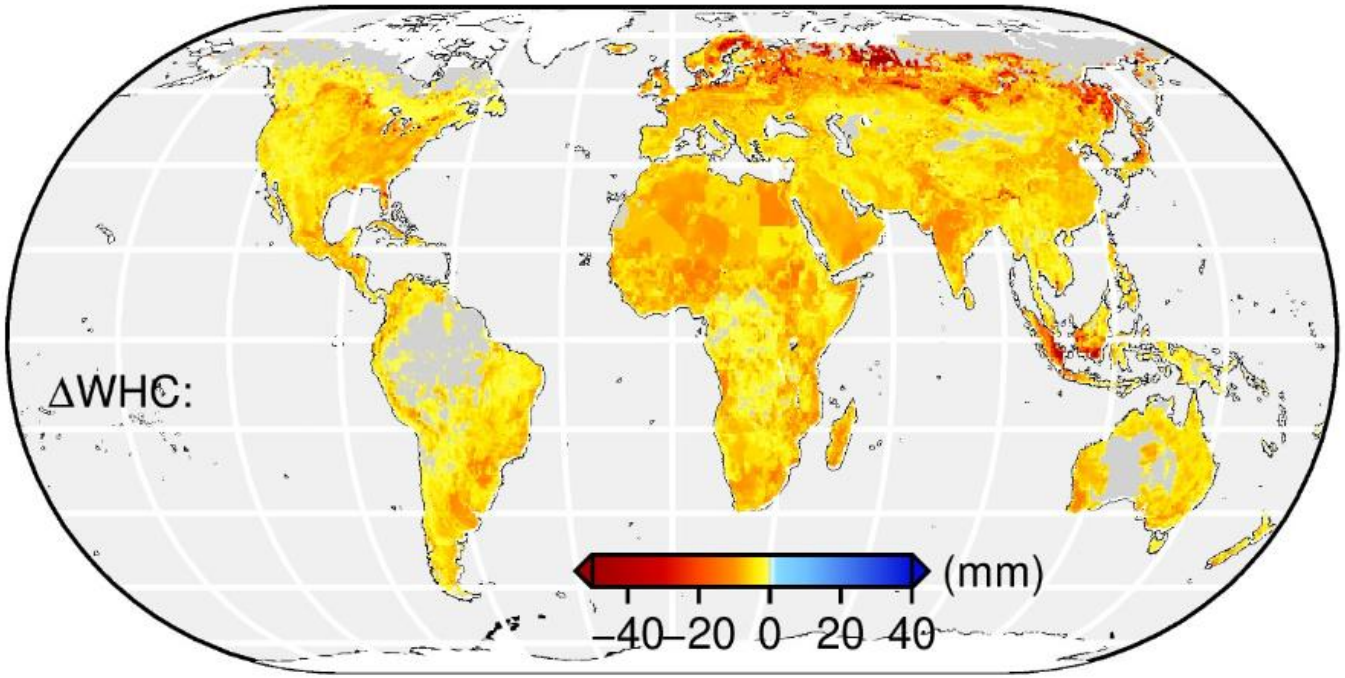


Soil WHC Changes by Human Land Uses

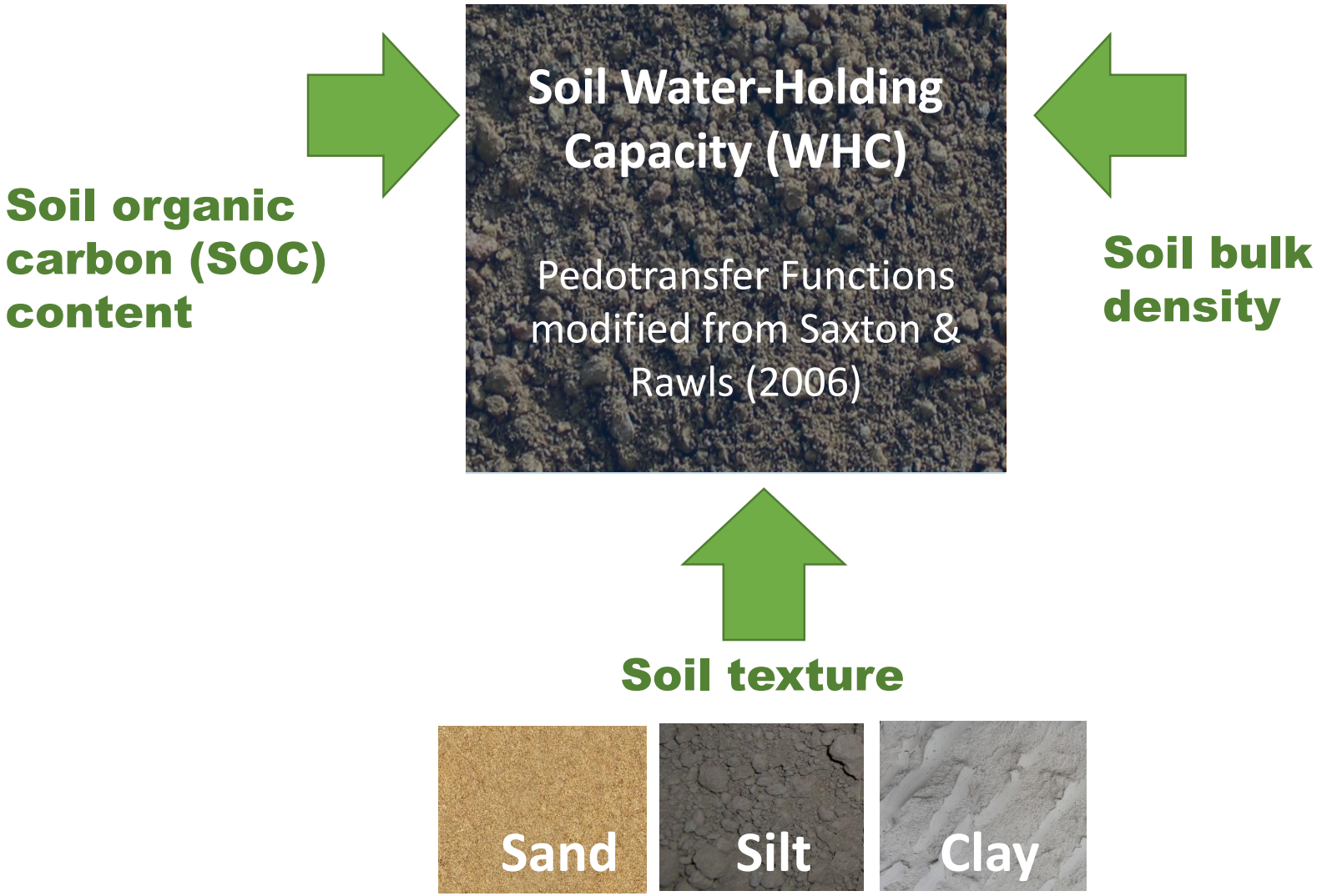




Difference disturbed - undisturbed



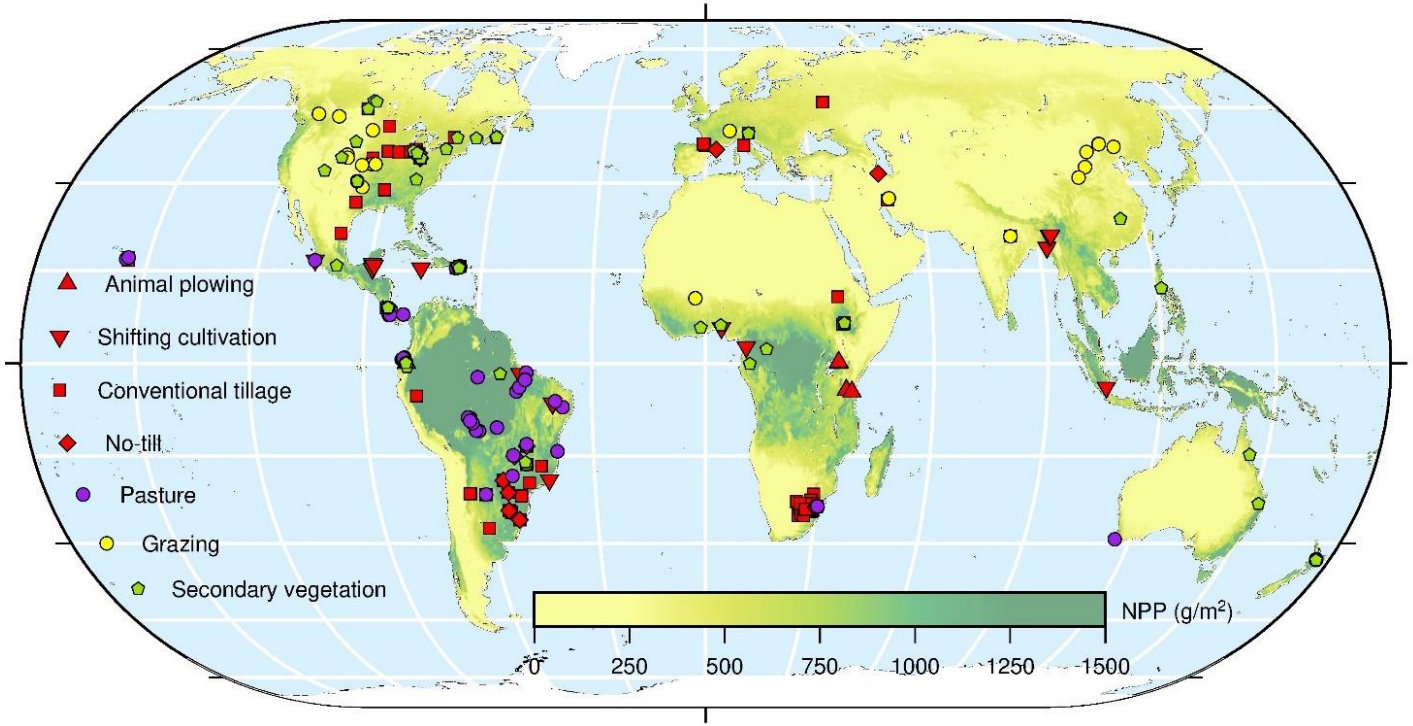
Estimating Soil WHC from Soil Properties



How We Model Human-Induced Soil Property Changes

- How human land uses alter each soil property?
- How environmental conditions affect soil change?
- What's the vulnerability of soil?
- How the impacts change with depth?

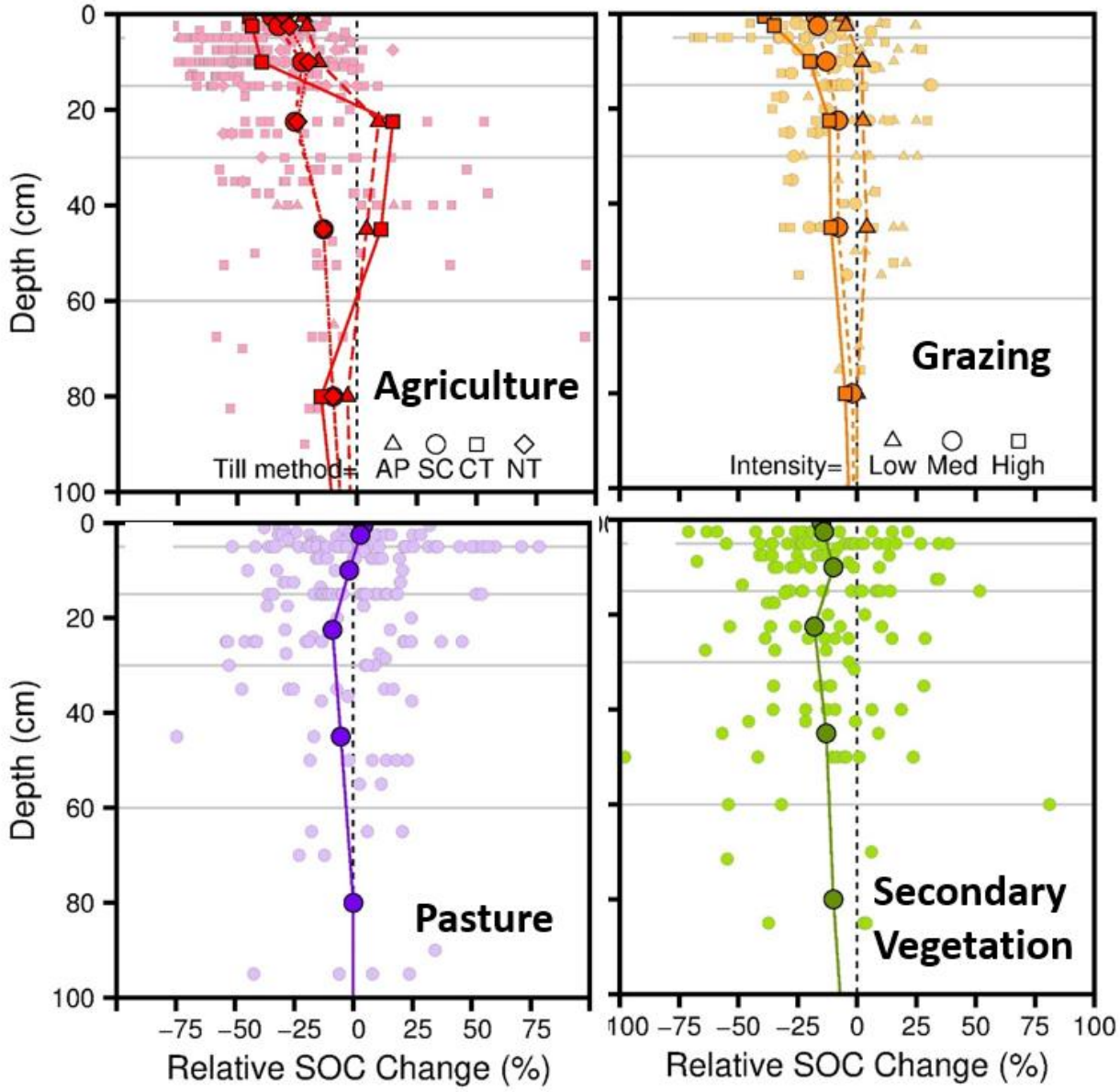
Meta-Analysis of Human-Induced Soil Property Changes



- **Soil properties:**
  pair observations (primary vegetation & disturbed)
  140 Papers with 737 paired observations

- **Environmental Factors:**
  NPP, slope, rainfall intensity, soil texture, moisture index, moisture index range

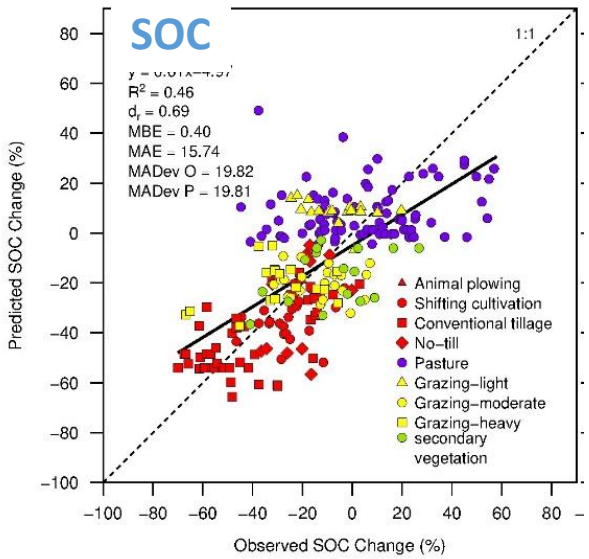
Estimating LULC Impacts along Depth

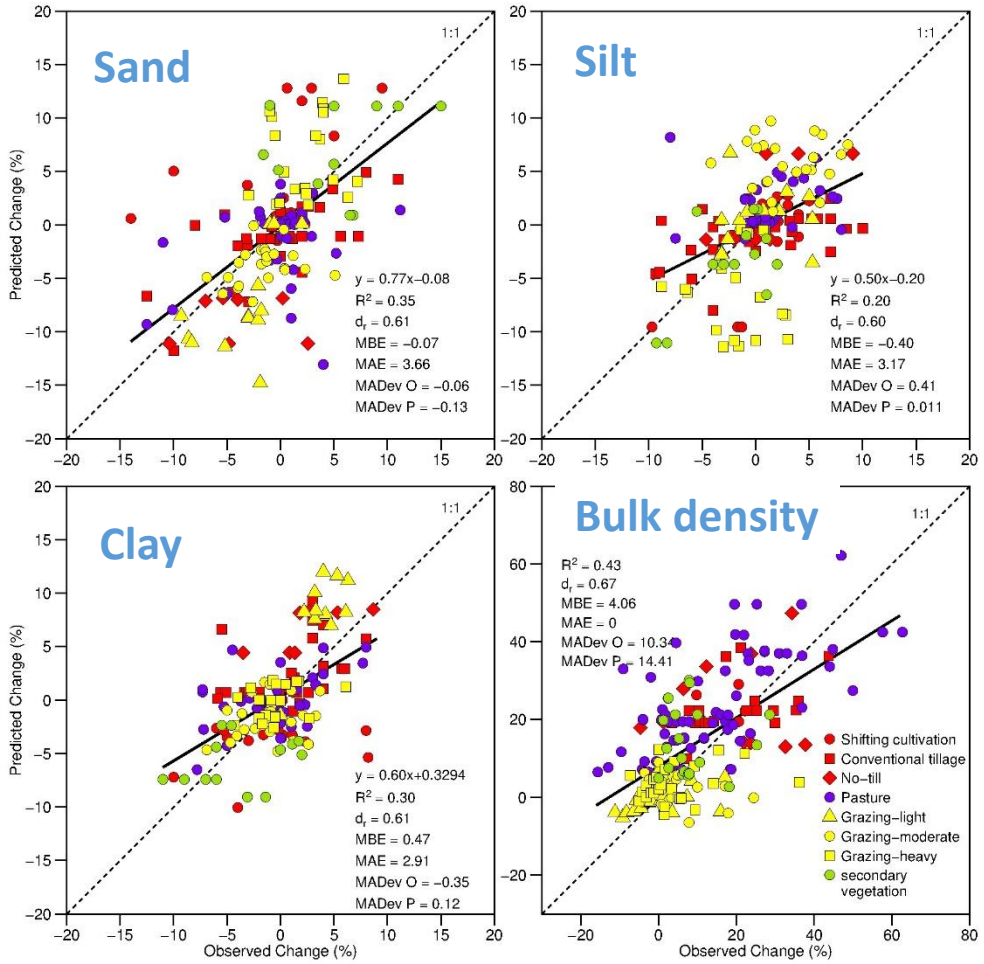


Soil Degradation Models

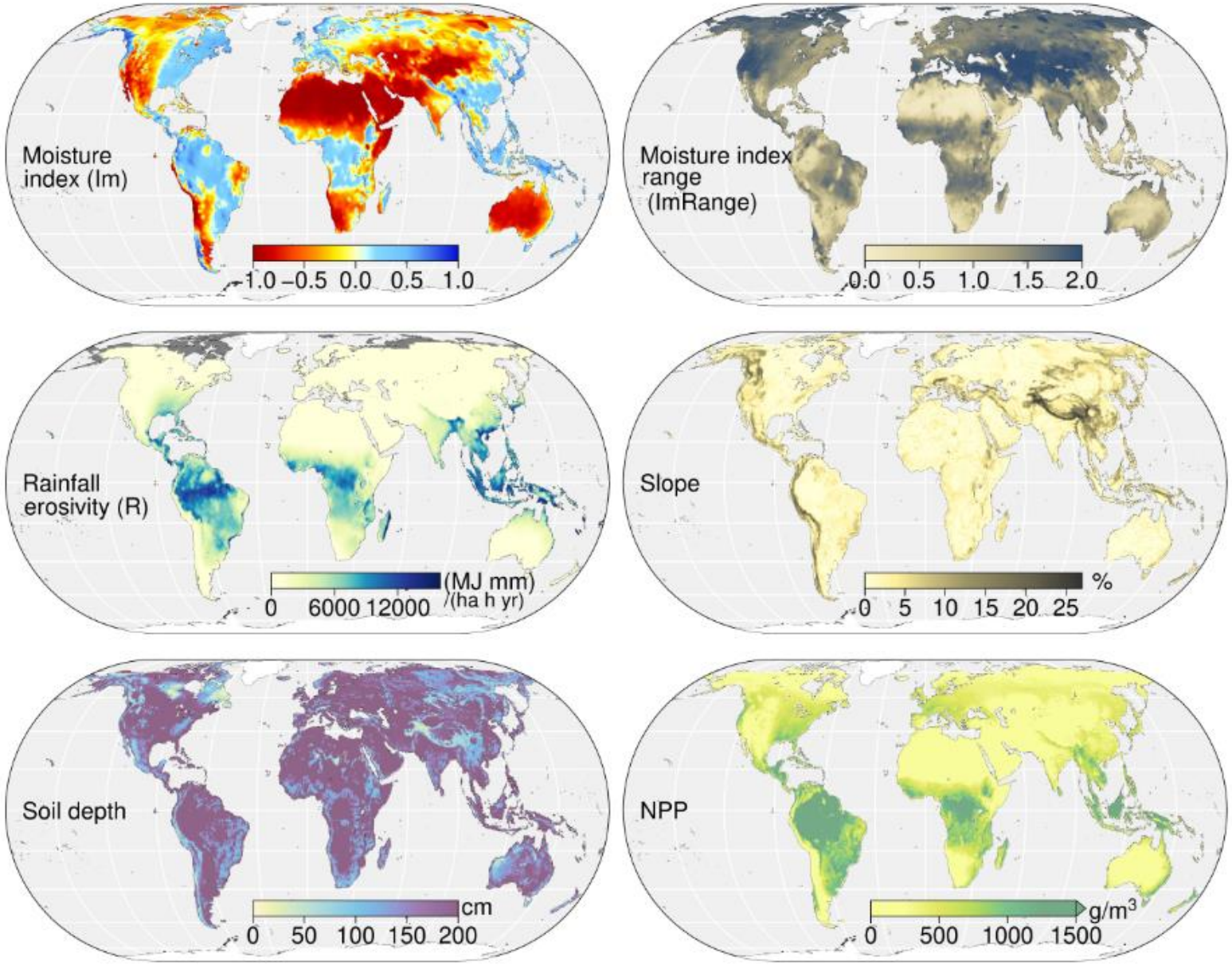
For each soil property of SOC, sand, silt, clay, BD:

Δsoil = *f* (LULC factors, NPP, slope, rainfall intensity, moisture index, moisture index range, clay content , depth factors)

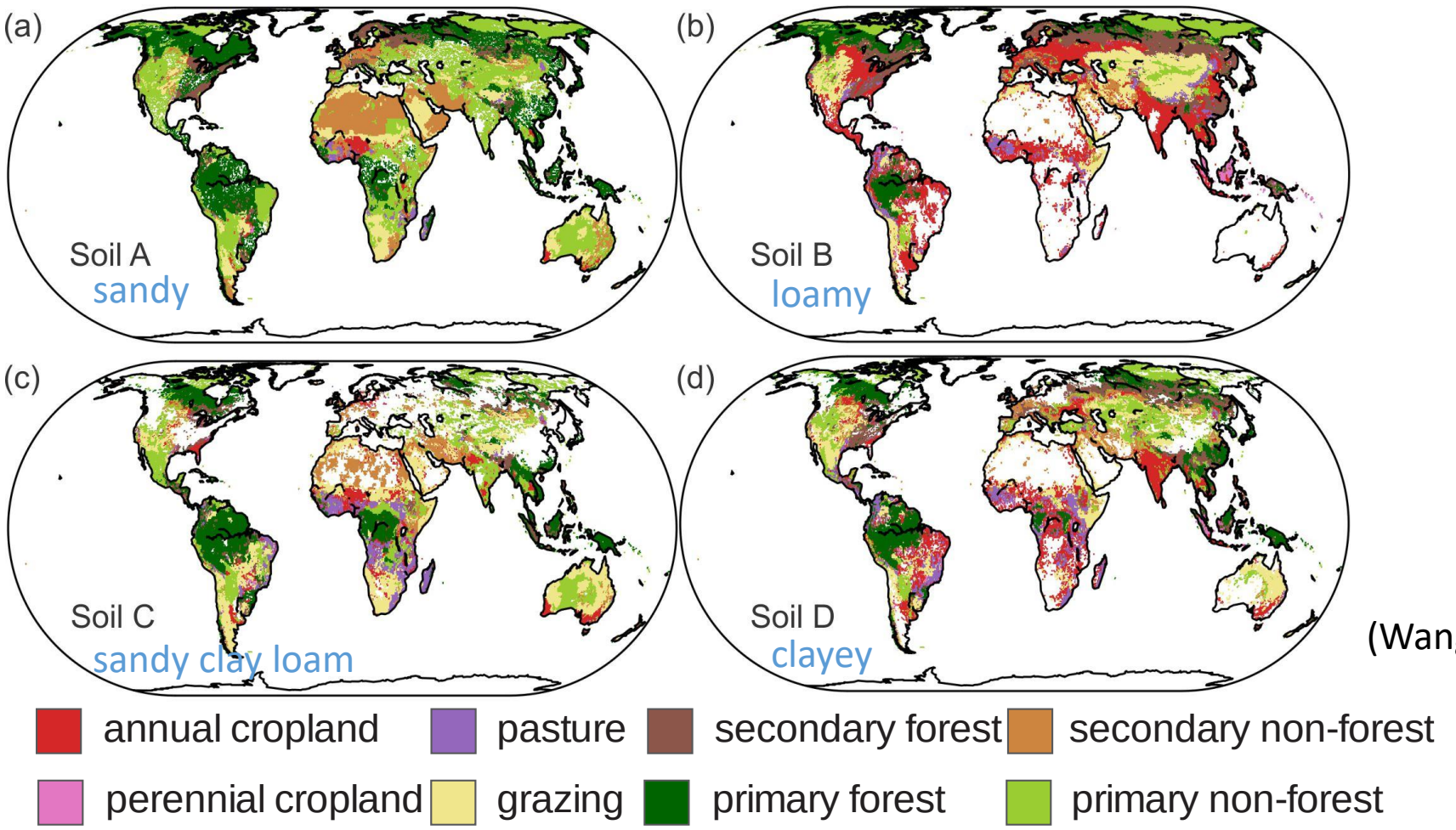




Global Environmental Factors



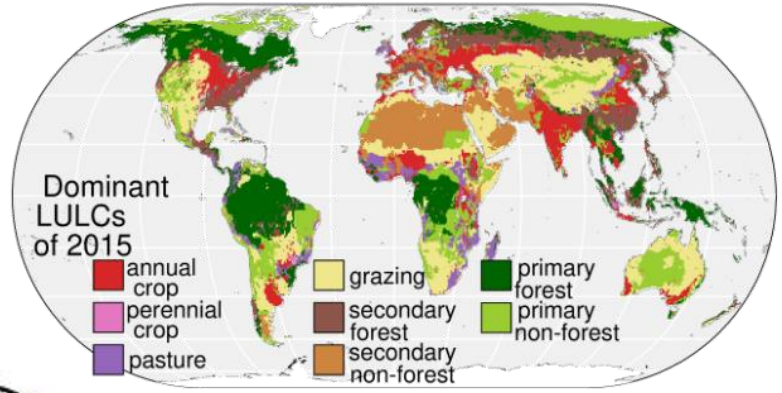
Dominant LULCs on 4 Soil Groups of 2015

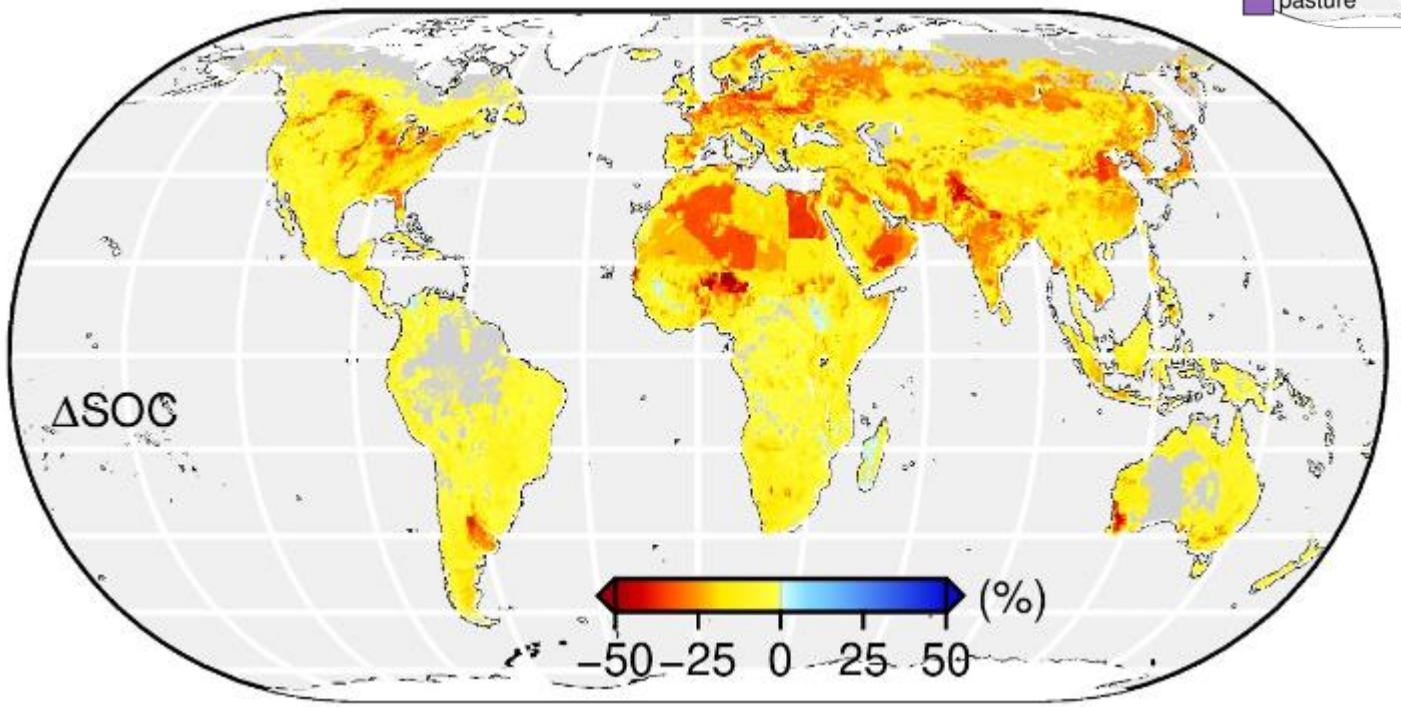


(Wang & Feddema, 2020)

+ Global Soil Datasets: SoilGrids250m (Hengl et al., 2017) → SOC, sand, silt, clay, bulk density

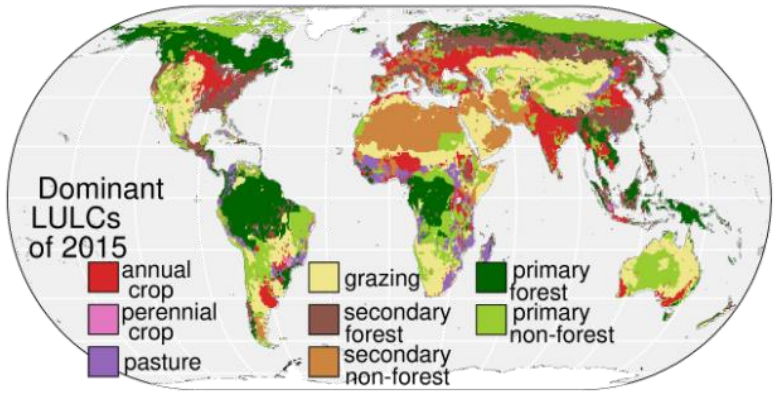
Potential SOC% Change under Global LULCs of 2015

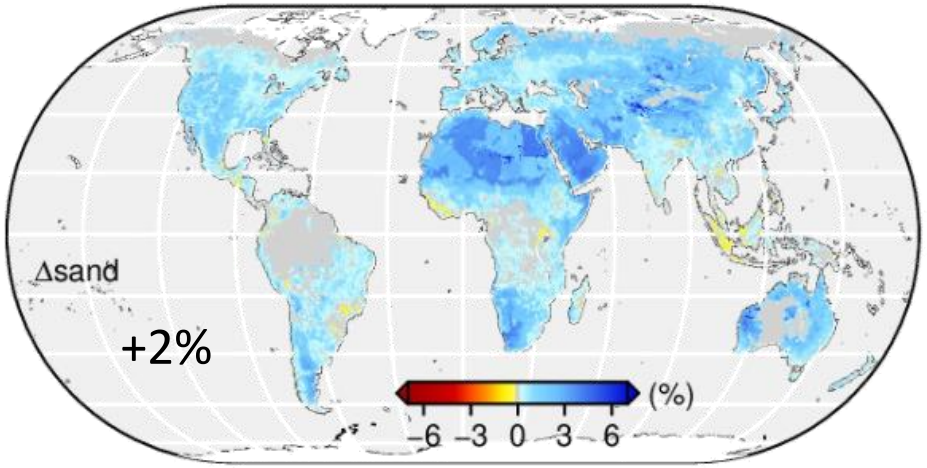


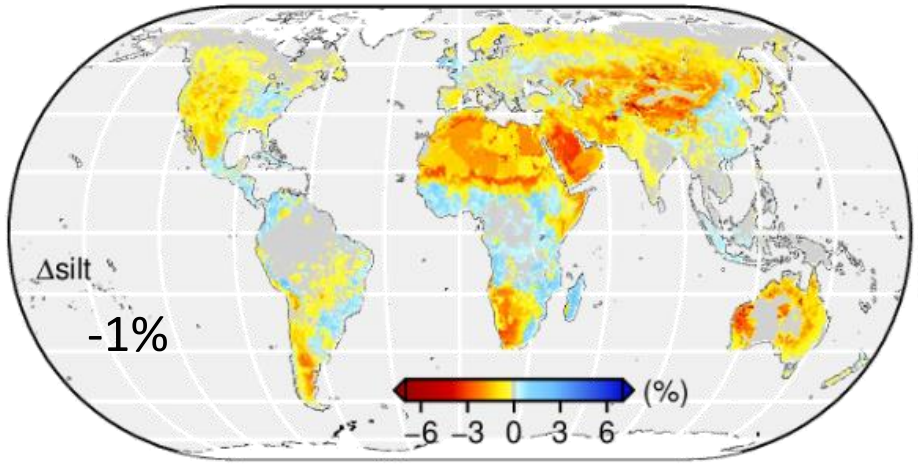


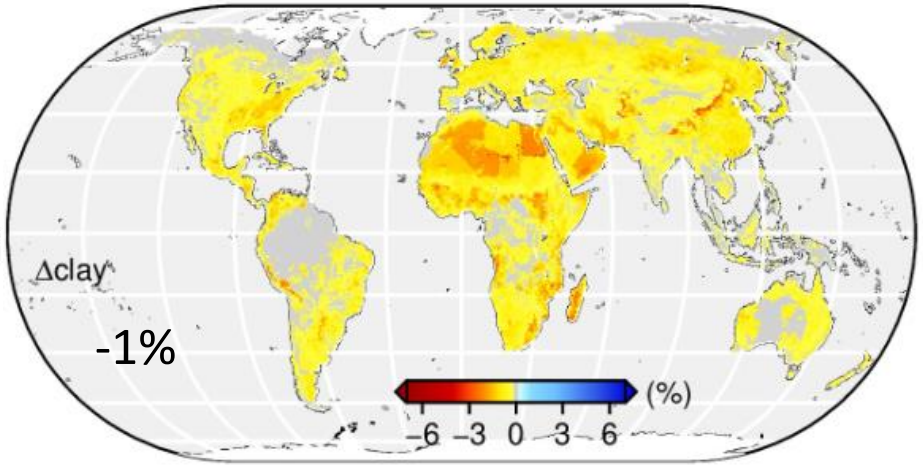
- Increase SOC: pasture (4%) and light grazing (2%)
- Other human LULCs decrease SOC

Potential Soil Texture Change (%) under Global LULCs of 2015

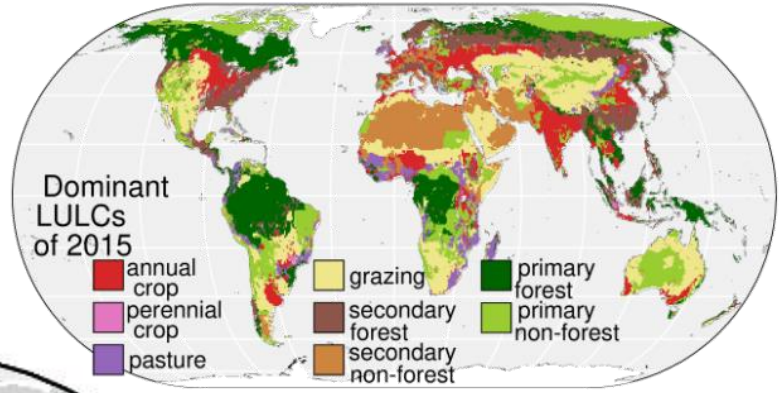


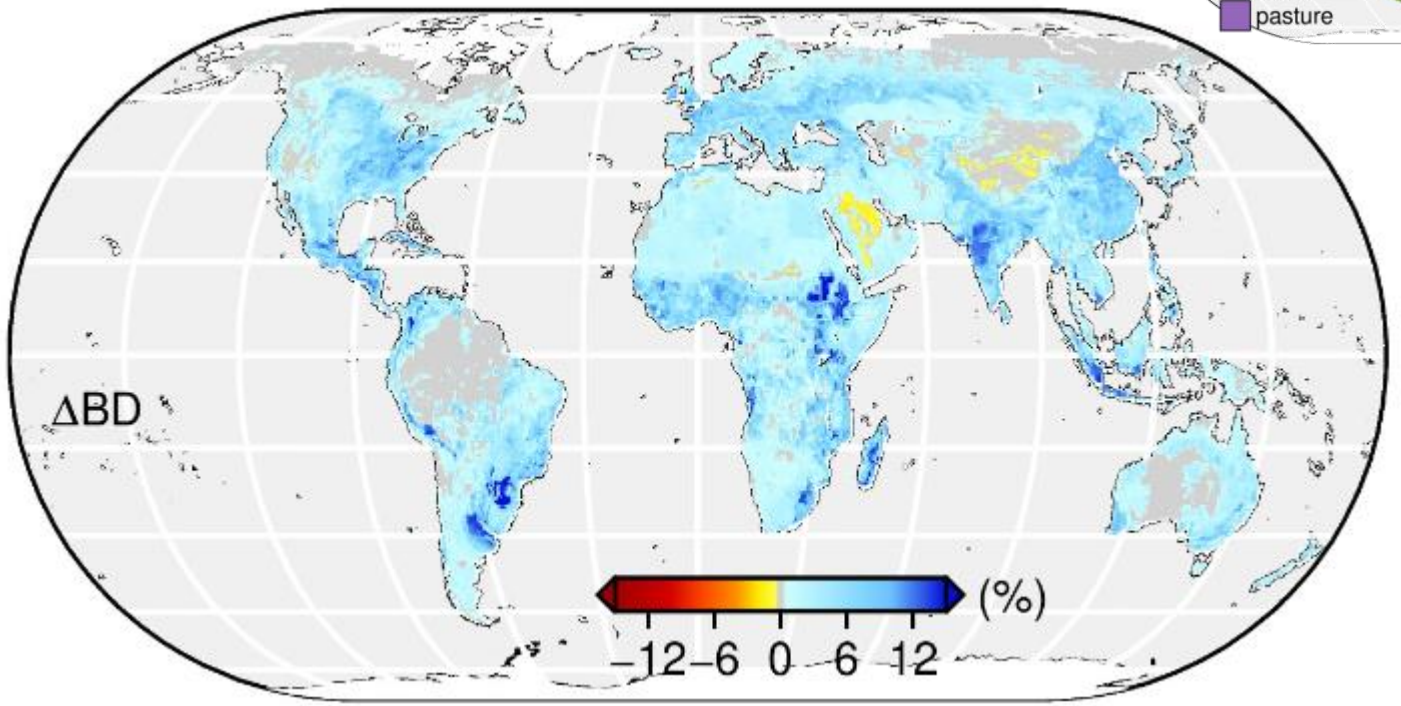






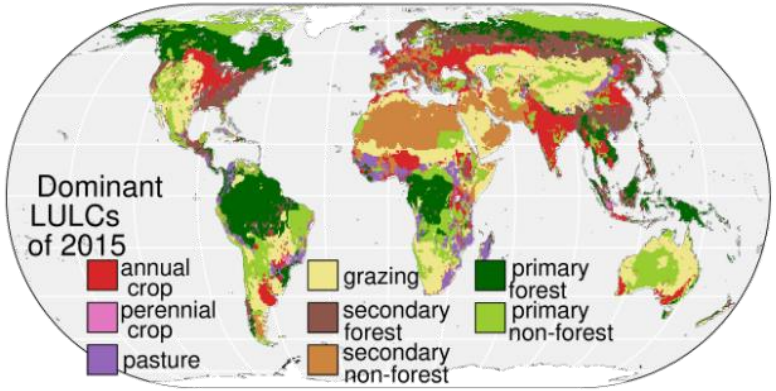
Potential Soil Bulk Density Change (%) under Global LULCs of 2015



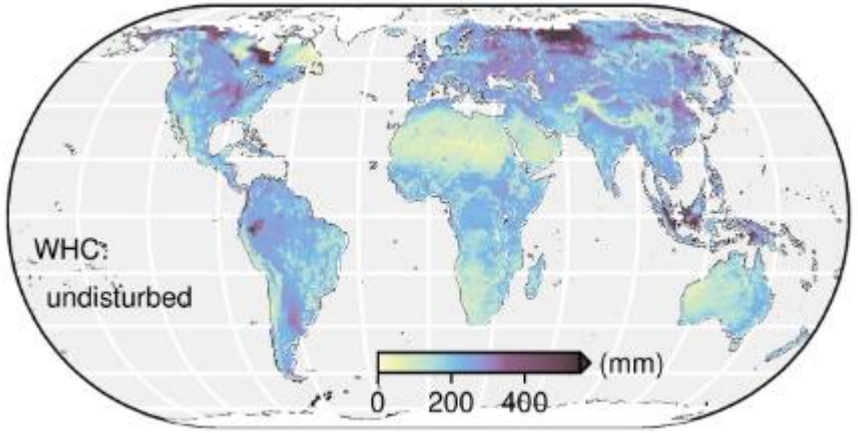


- All human LULCs increase soil bulk density (mean 6%) except grazing under dry environments

Soil WHC Changes under Different Land-Use Intensities



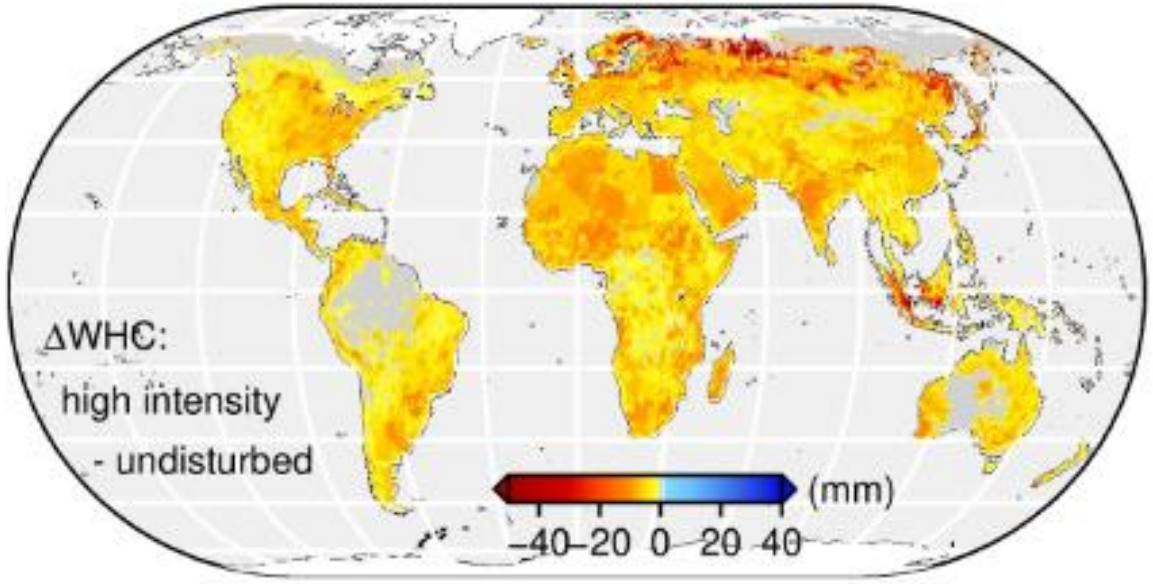
Undisturbed Soil WHC



High intensity

Agriculture = conventional tillage

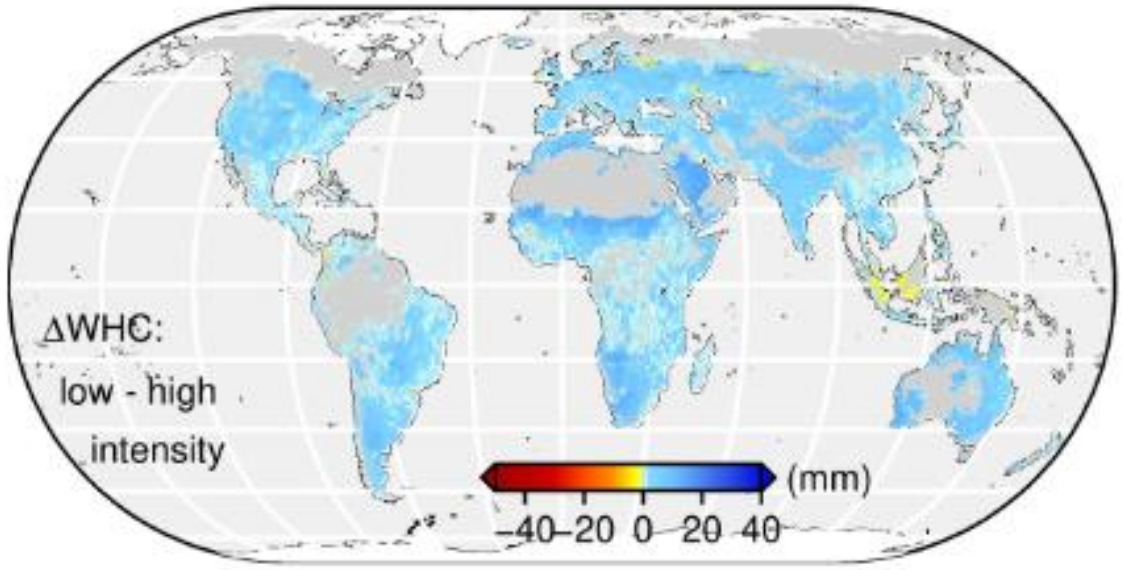
Grazing = heavy intensity



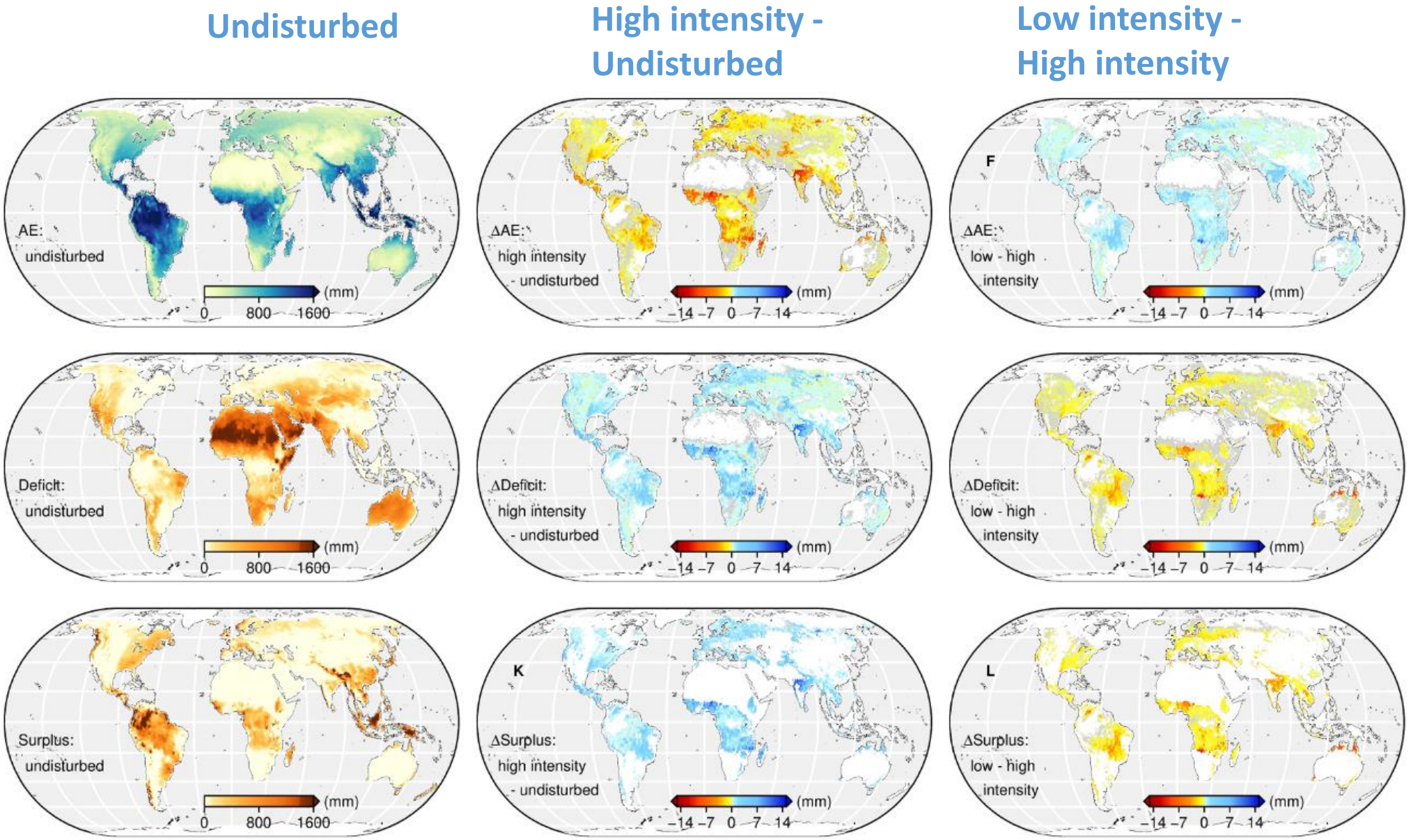
Low intensity

Agriculture = no-till

Grazing = light intensity



Water Balance Change under Different Land-Use Intensities



Global Mean Soil WHC Change (%) by Individual LULCs

Land use	A: sandy	B: loamy	C: Sandy clay loam	D: clayey	Average
annual cropland = conventional tillage	-14.06	-14.22	-14.30	-14.73	-14.34
annual cropland = no-till	-1.93	-6.43	-4.60	-8.68	-6.23
perennial cropland (no-till)	-2.37	-12.41	-5.46	-14.02	-10.66
pasture land	-13.58	-9.23	-14.44	-12.19	-11.88
grazing land = low intensity	4.23	0.54	-0.15	-4.33	1.15
grazing land = heavy intensity	-7.58	-6.07	-7.07	-5.80	-6.74
secondary forest cover	-16.48	-14.19	-9.27	-9.11	-13.40
secondary non-forest cover	-9.56	-6.89	-9.12	-6.62	-8.85

- Largest impact: conventional tillage
- Positive impact: low-intensity grazing
- Clayey soils show higher impacts by high intensity human LUs

Summary and Future Work

- Conventional tillage has the largest impact on soil WHC
- Water balance: moist climates with high seasonality are most affected by changed soil WHC
- Land use management such as rotating light and heavy land uses can potentially recover/improve soil WHC

Future work:

- Including soil erosion
- Constructing historical soil property datasets
- Applying in Earth system models

Thank You!

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