Preliminary results from urban scenario experiments

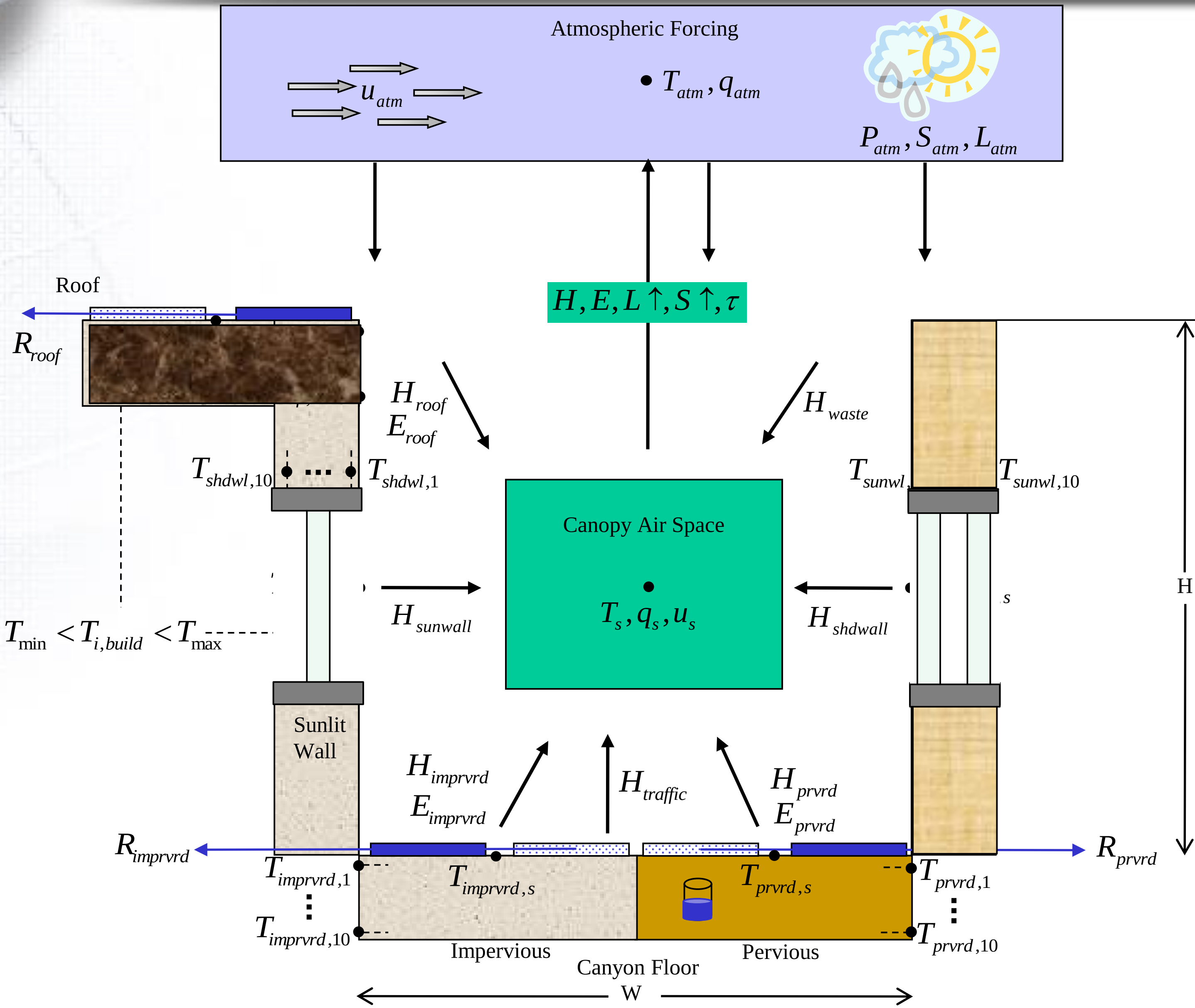
J. Feddema

K. Oleson

B. Kauffman

NSF EaSM2 project (Linking Human and Earth System Models to Assess Regional Impacts and Adaption in Urban Systems and their Hinterlands; B. O’Neill, PI).

CLMU



Atmospheric Forcing
u_{atm}
T_{atm}, q_{atm}
$P_{atm}, S_{atm}, L_{atm}$
$H, E, L\uparrow, S\uparrow, \tau$
Roof
R_{roof}
H_{roof}
E_{roof}
H_{waste}
$T_{shdwl,10}$
$T_{shdwl,1}$
$T_{sunwl,1}$
$T_{sunwl,10}$
Canopy Air Space
T_s, q_s, u_s
$H_{sunwall}$
$H_{shdwall}$
H
$T_{\min} < T_{i,build} < T_{\max}$
Sunlit Wall
$H_{imprvrd}$
$E_{imprvrd}$
$H_{traffic}$
H_{prvrd}
E_{prvrd}
$R_{imprvrd}$
R_{prvrd}
$T_{imprvrd,1}$
$T_{imprvrd,10}$
$T_{imprvrd,s}$
$T_{prvrd,s}$
$T_{prvrd,1}$
$T_{prvrd,10}$
Impervious
Pervious
Canyon Floor
W

Future Urban Design Scenarios

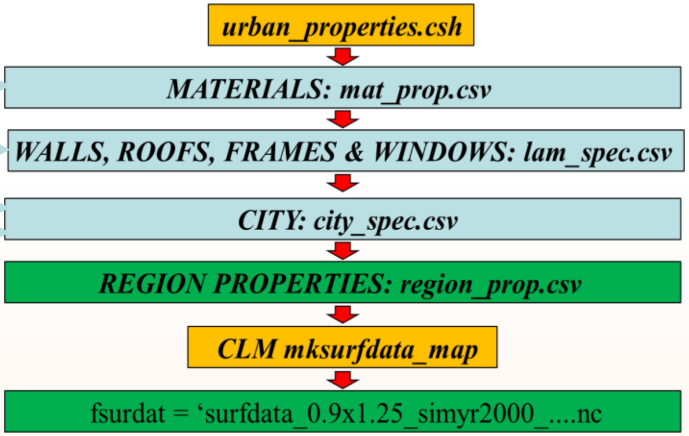
- Create a set of scenarios of building properties and urban morphologies with the objective of developing large-scale building strategies to reduce energy consumption, urban temperature, and human heat stress

- These new building types replace existing types in the model but could be viewed more as providing some guidance for new construction

- This initial project will extend some of the earlier work (and lessons learned) from urban density, triple pane windows, and white roof experiments.

Creating Scenarios – Urban Properties Tool

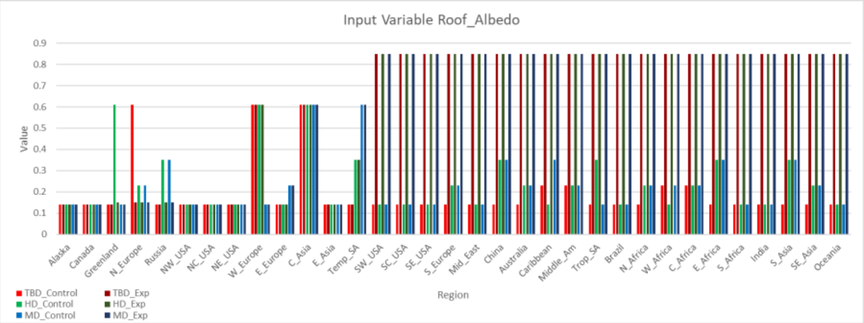
1. Outline overall scenario by region
2. Consider the need for new materials or modification of existing materials for all regions (e.g. duplicate a material but assign new albedo value) – change materials properties or add materials.
3. Modify wall or roof properties by substituting, adding or creating new types.
4. Assign wall and roof types to city types in a region
5. Alter city morphology parameters to represent building density and greenness



Building envelope strategies

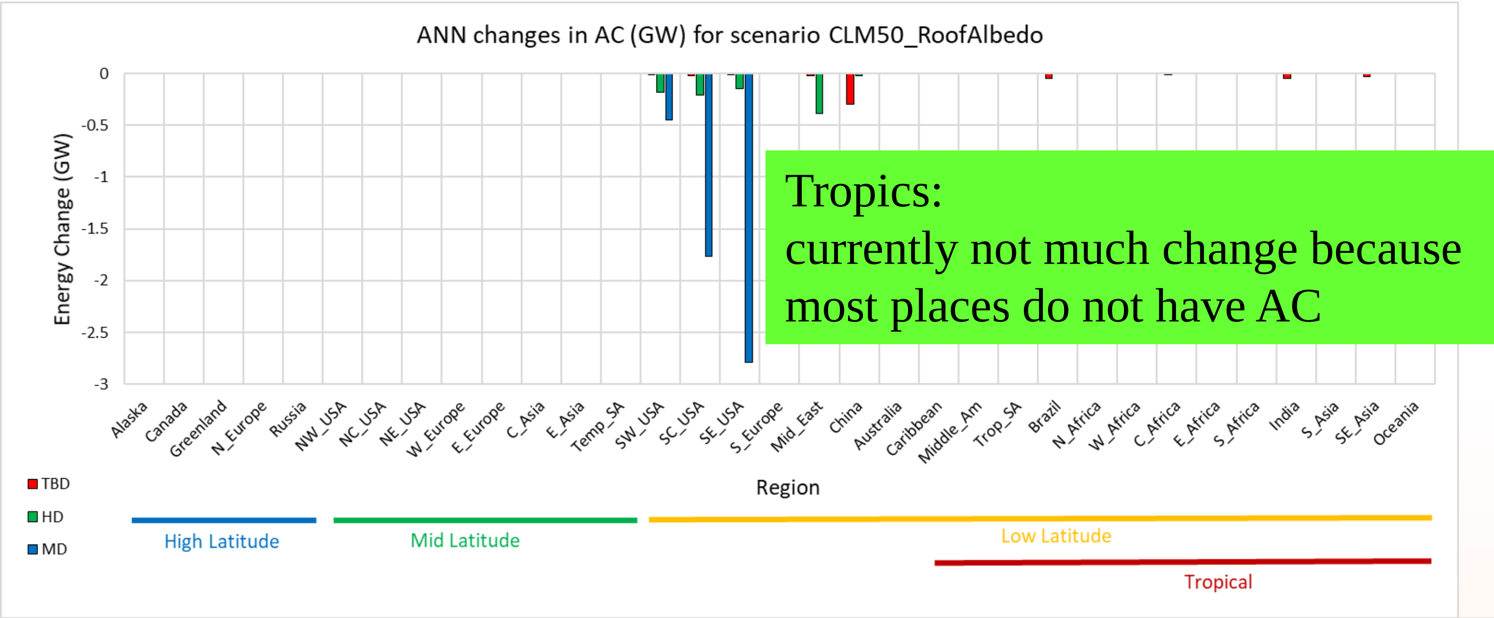
Scenario 1: Roof albedo

- In high latitude locations all roofs are assigned an albedo of 0.15 (dark roofs) to aid building energy absorption and reduce heating demand in winter (regions Alaska, Canada, Greenland, N-Europe, Russia).
- Mid-latitude regions retain original roof albedo values (NW-USA, NC-USA, NE-USA, W-Europe, E-Europe, C-Asia, E-Asia and Temperate South America).
- Low latitude regions are assigned high albedo (0.85) roofs (SW-USA, SC-USA, SE-USA, Middle Americas, Caribbean, Tropical South America, Brazil, S-Europe, N-Africa, W-Africa, C-Africa, S-Africa, E-Africa, Mid-East, S-Asia, India, China, SE-Asia, Australia, Oceania)



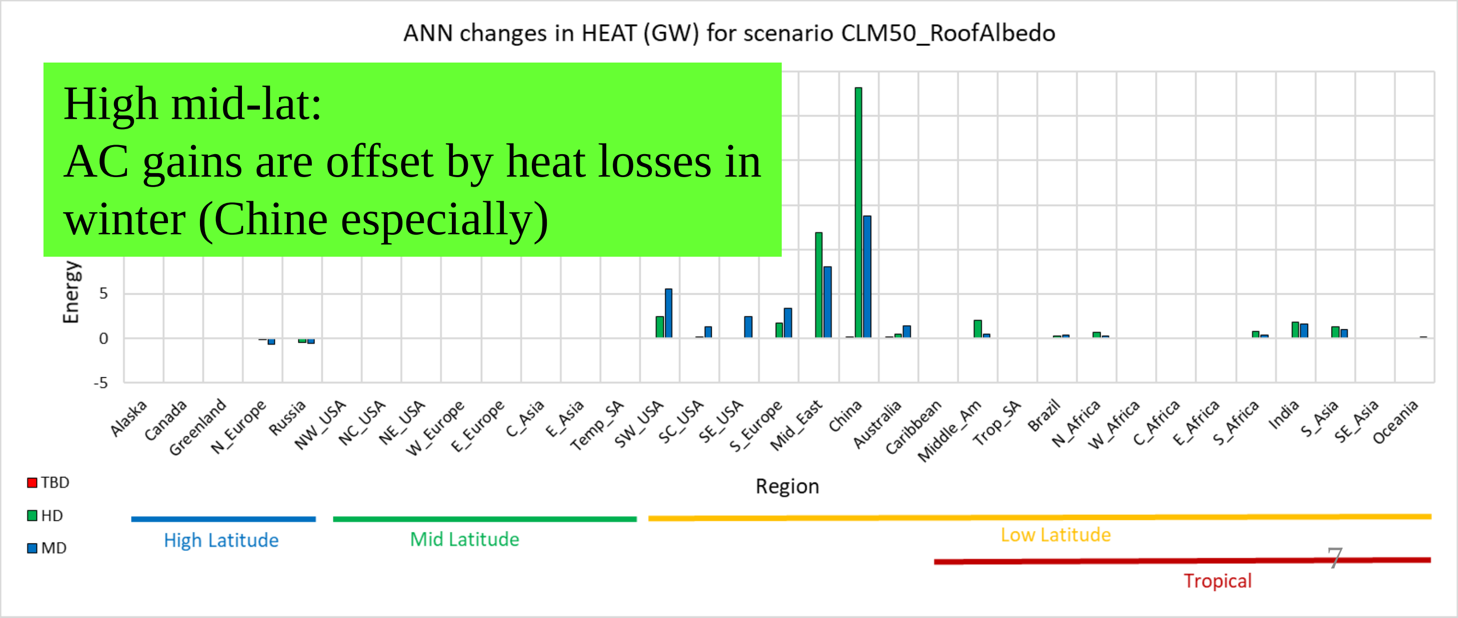
- Alterations:
  - mat_prop.csv
    - change albedo of materials
  - lam_spec.csv
    - add altered albedo materials to create altered roofs
  - city_spec.csv
    - add altered roofs to buildings

Roof Albedo: annual energy change

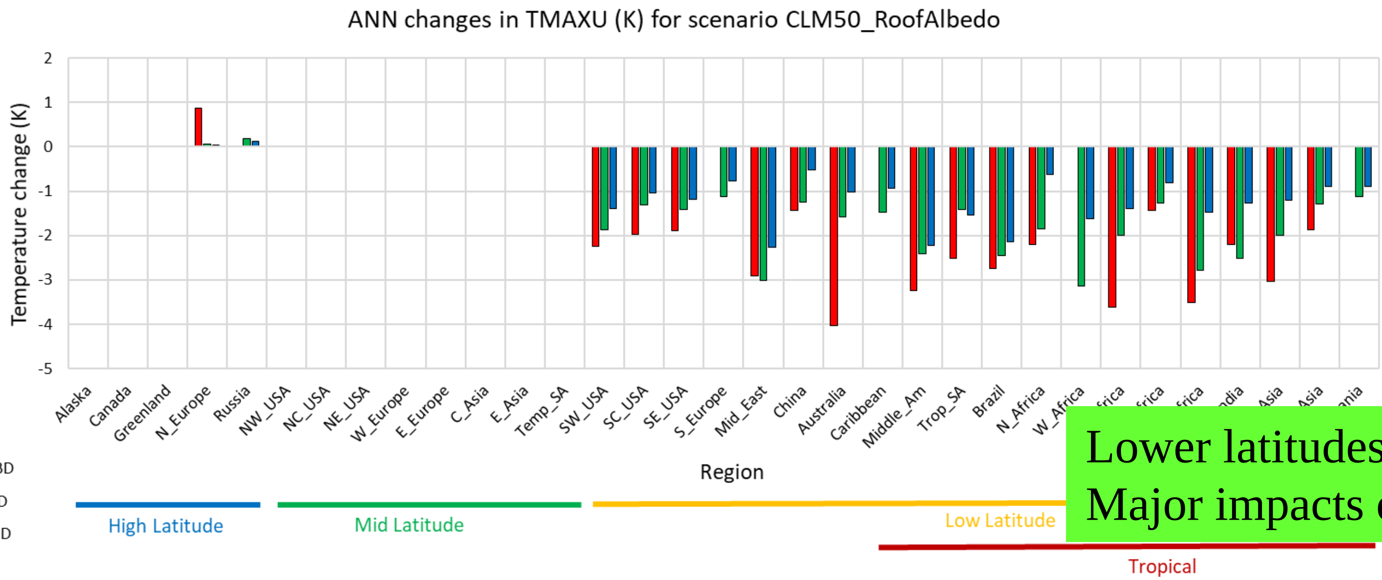


AC related energy use

Heating related energy use



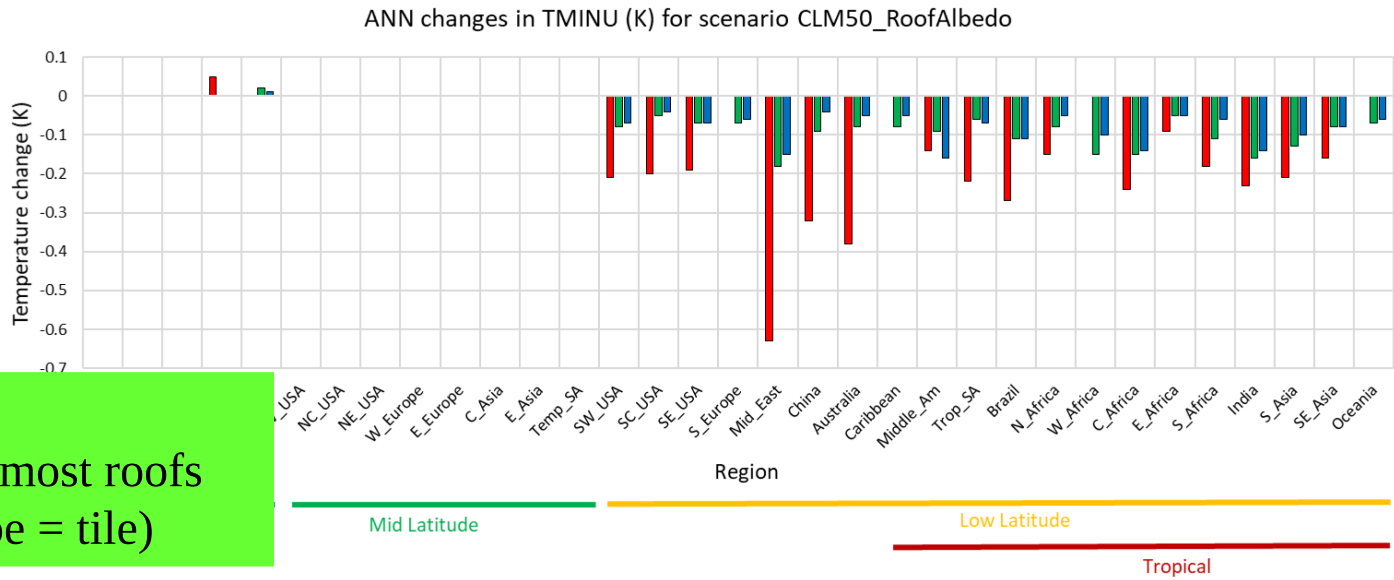
Roof Albedo: annual temperature change



T-max change

Lower latitudes:
Major impacts on UHI

T-min change

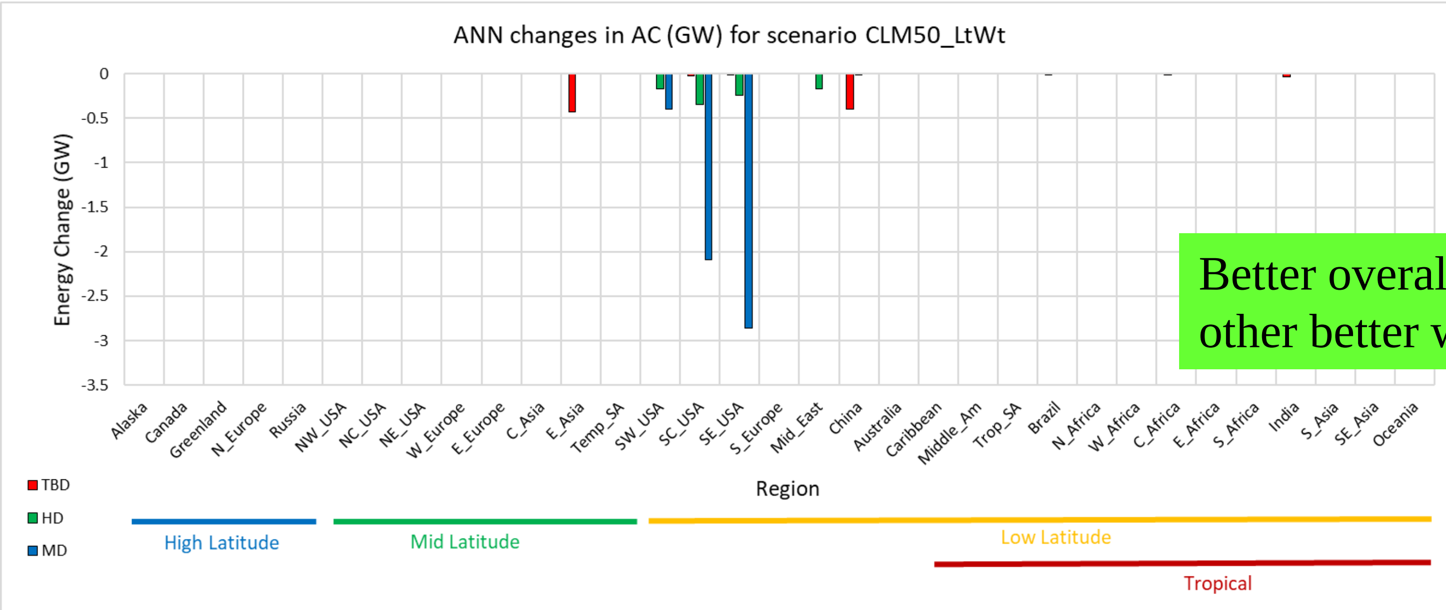


High lat:
Minor change because most roofs are dark asphalt (Europe = tile)

Scenario 6: Light Weight Insulated Walls and Roofs (LtWT)

- All walls are replaced by a lightweight (low heat capacity) wall made up of wood frames with cement particle board exteriors, extensive layers of insulation and dry wall interior walls.
- All roofs are made of EPDM, roof felt, 6 layers of insulation and two layers of interior drywall.
- Windows and window frames remain as presently specified. The walls and roofs have an albedo of 0.3 and emissivity of 0.9.
- Alterations:
  - lam_spec.csv
    - add light weight roof and wall laminates
  - city_spec.csv
    - Replace all walls and roofs globally

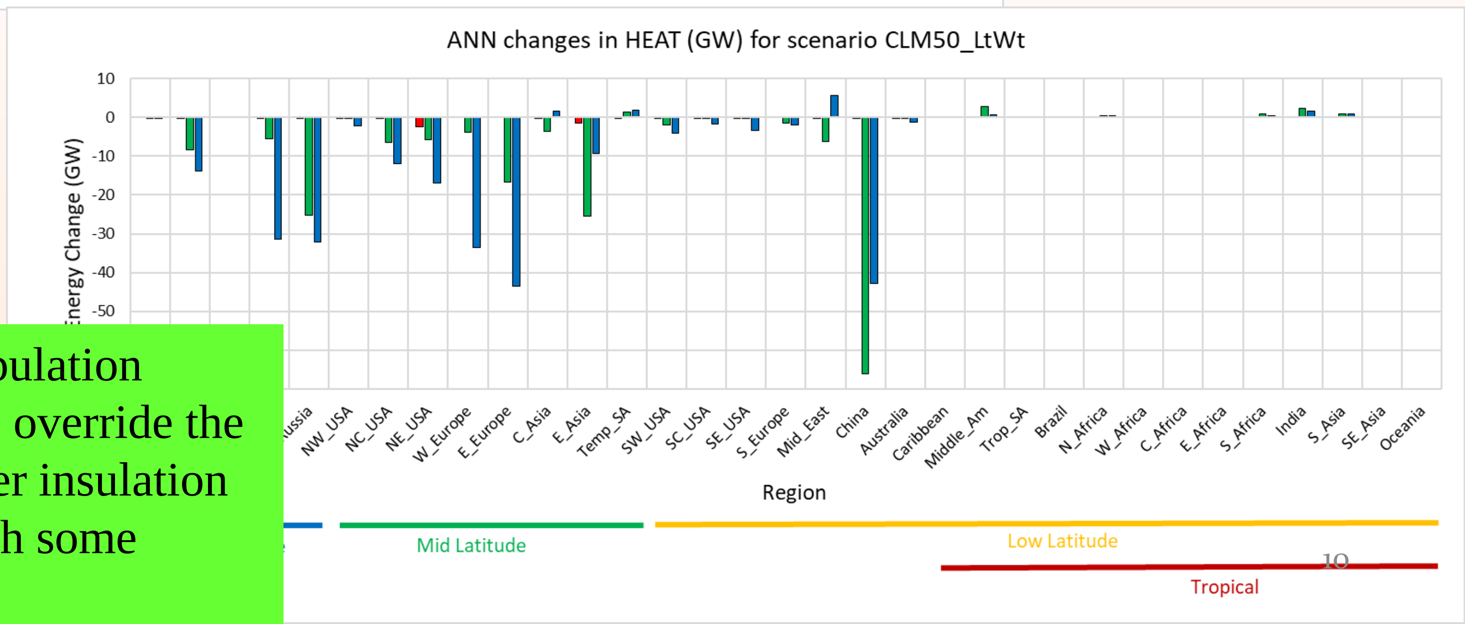
LtWt: annual energy change



AC related energy use

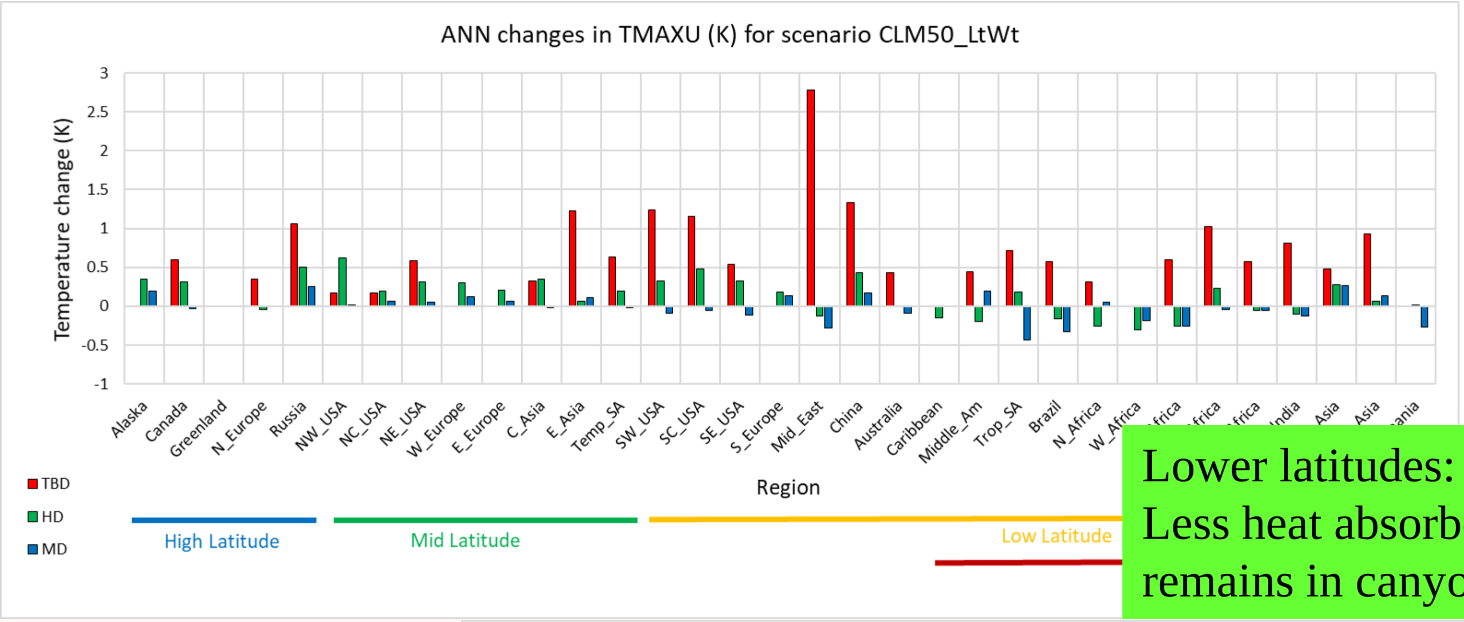
Better overall insulation – similar to other better walls but 2x magnitude

Heating related energy use



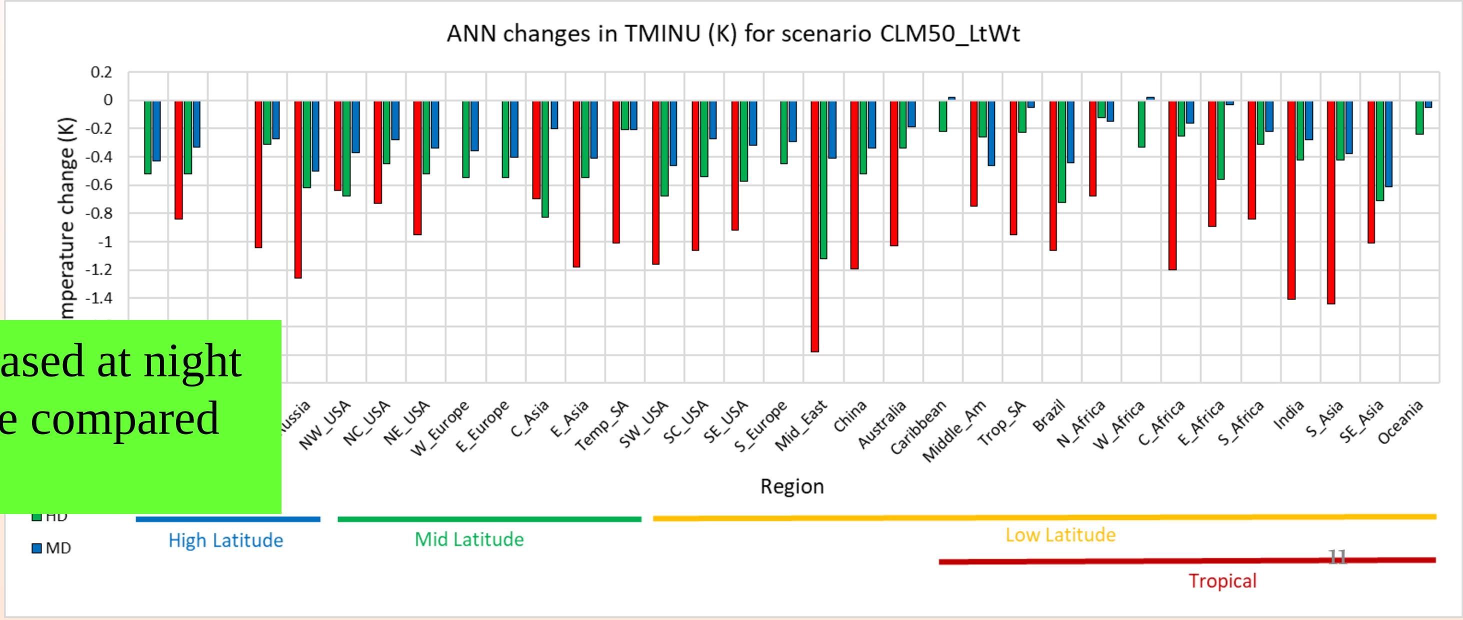
High energy usage/population (small percent change) override the signal – generally better insulation over existing walls with some exception

LtWt: annual temperature change



T-max change

Lower latitudes:
Less heat absorbed (wall R) and remains in canyon



T-min change

Less stored heat is released at night much higher magnitude compared to part brick walls

Urban planning/design strategies

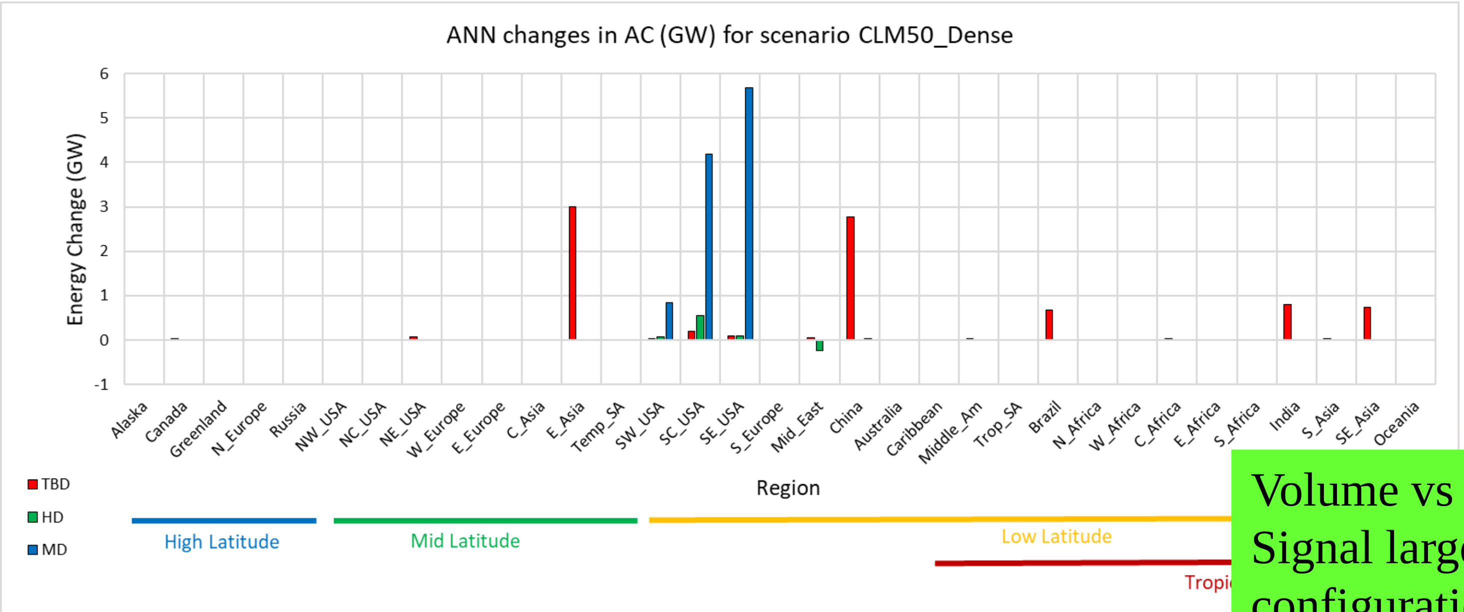
Scenario 8: Dense Urban Design

- Settings similar to the Open Urban Design scenario in terms of height, but increase density by reducing space between building and green space
- Alterations:
  - city_spec.csv
    - Alter settings as shown in table for each parameter by city type

Urban Class \ CLMU variable	Roof Area Fraction (Froof)	Building Height (Ht) (m)	Height to Width Ratio (H:W)	Pervious Area Fraction (Fperv)
Tall Building District	0.85	250	10	0.025
High Density	0.8	50	2	0.05
Medium Density	0.8	15	1	0.05
Low Density	0.5	8	0.4	0.2

Values are scaled based on the relative area needed to house equivalent populations (volume of living space)

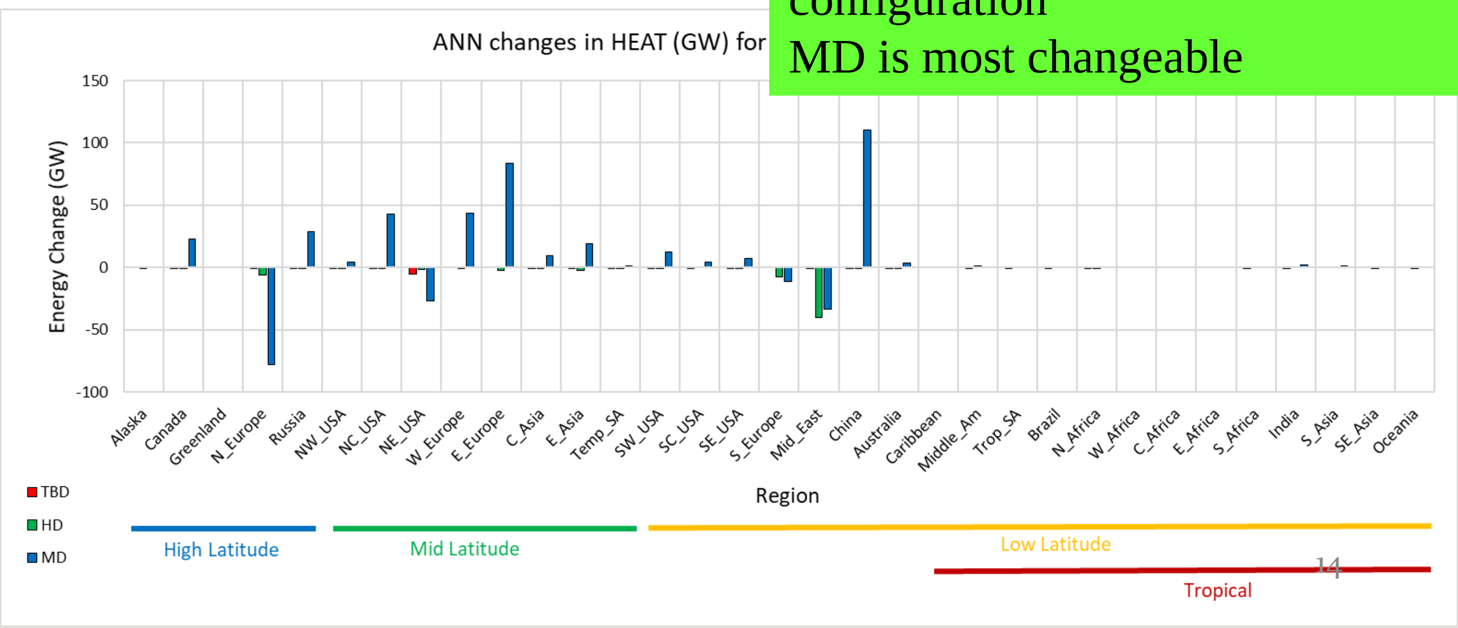
Dense: annual energy change



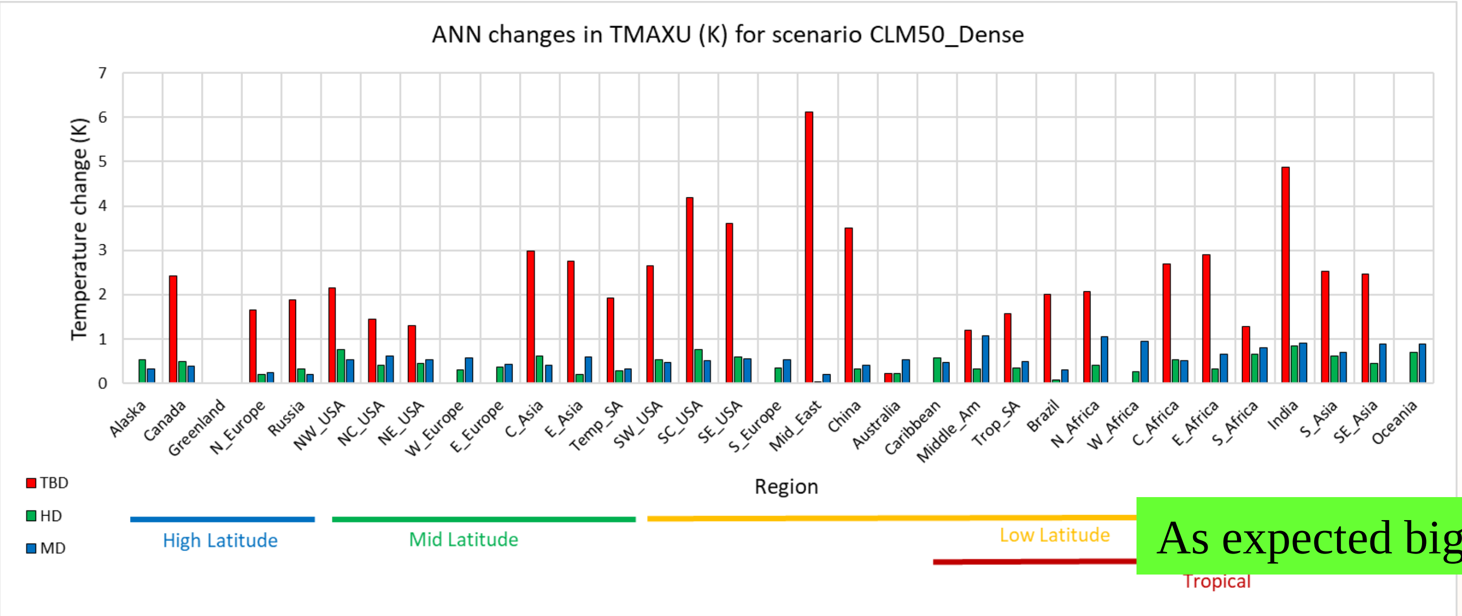
AC related energy use

Volume vs surface area + height
Signal largely depends on current configuration
MD is most changeable

Heating related energy use



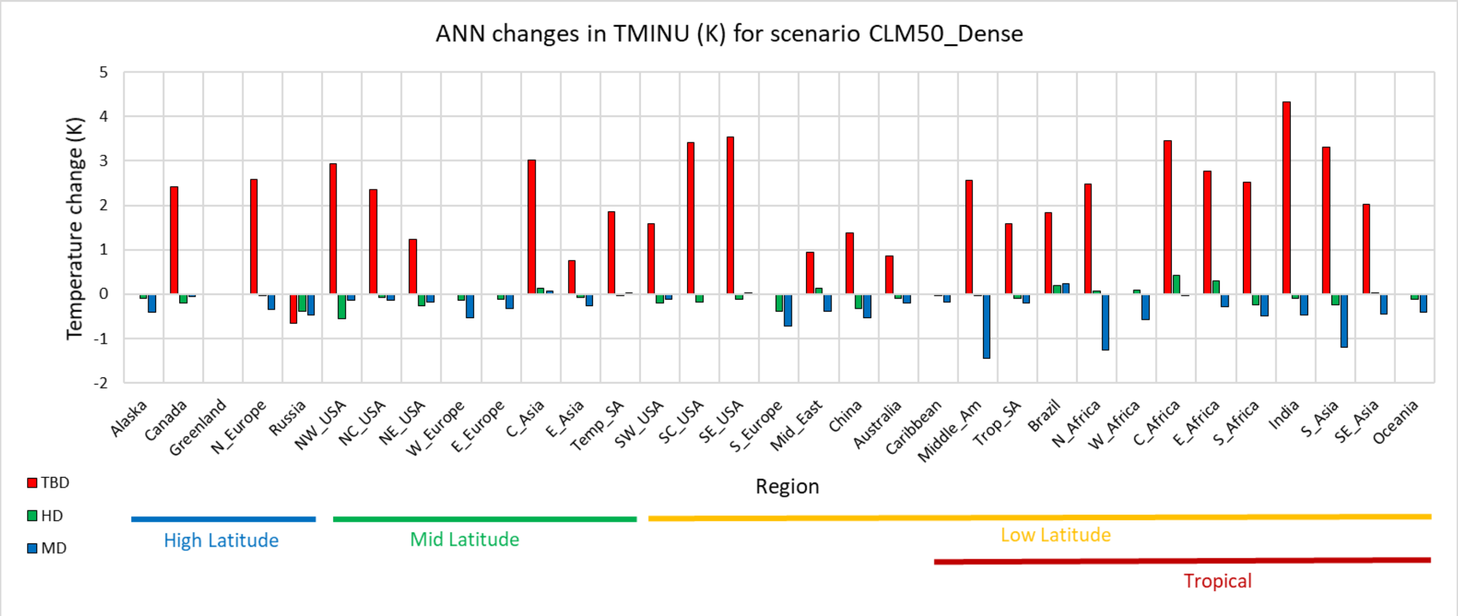
Dense: annual temperature change



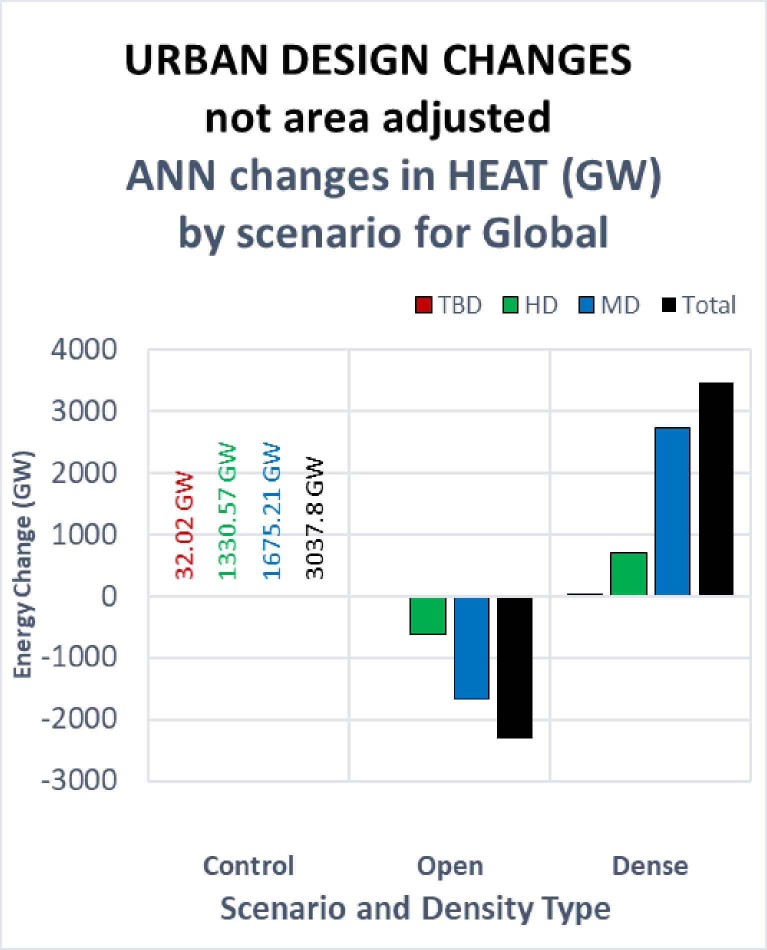
T-max change

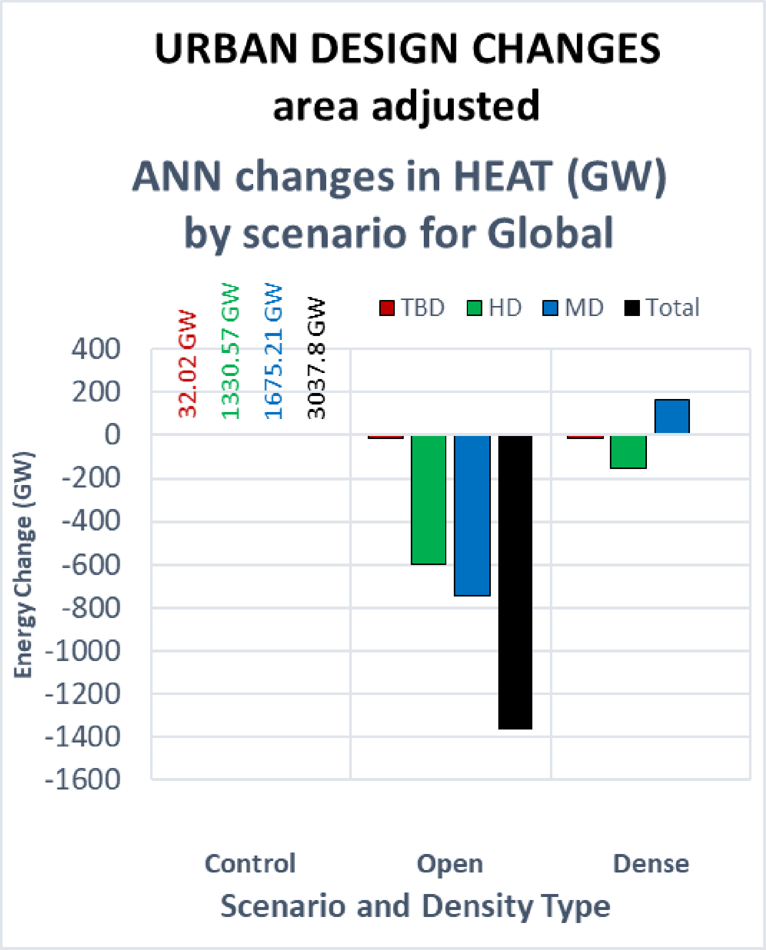
As expected biggest change in TBD

T-min change

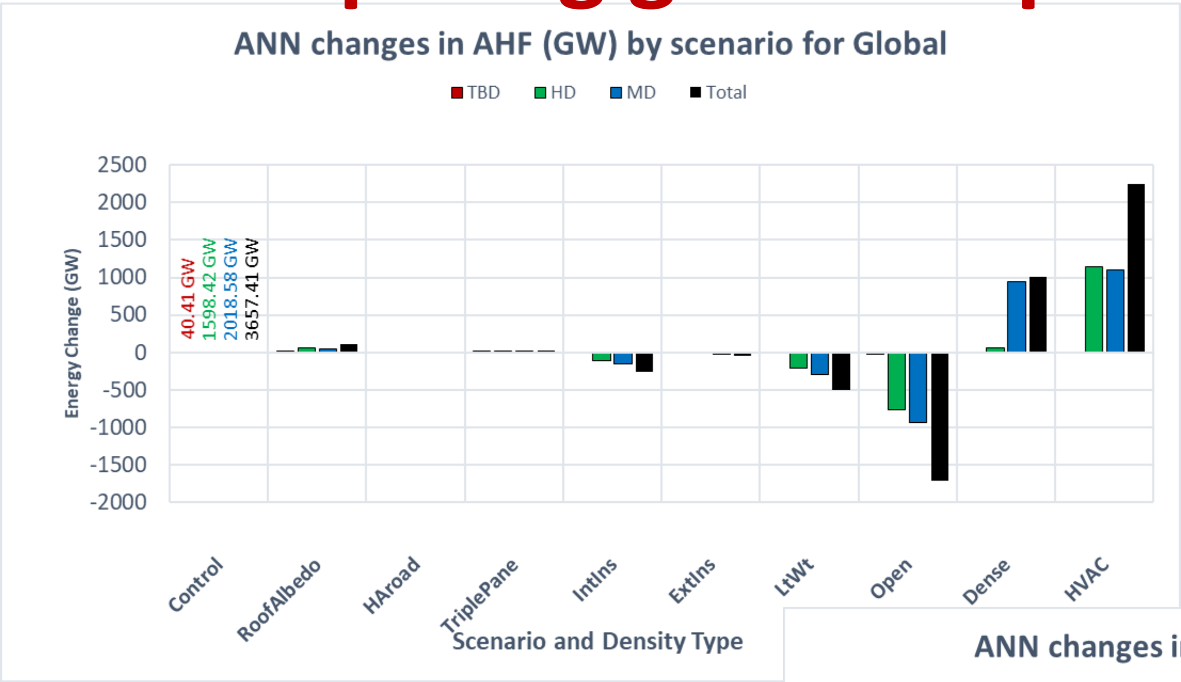


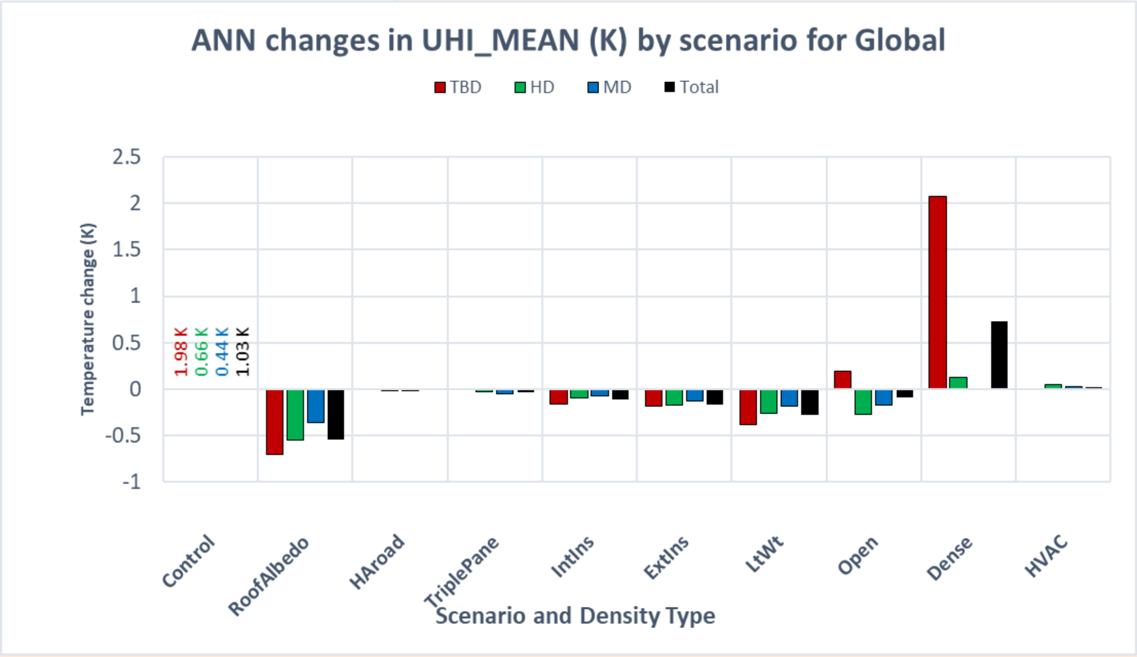
Urban Design Area Adjustments





Comparing global impacts of Scenarios





Next steps

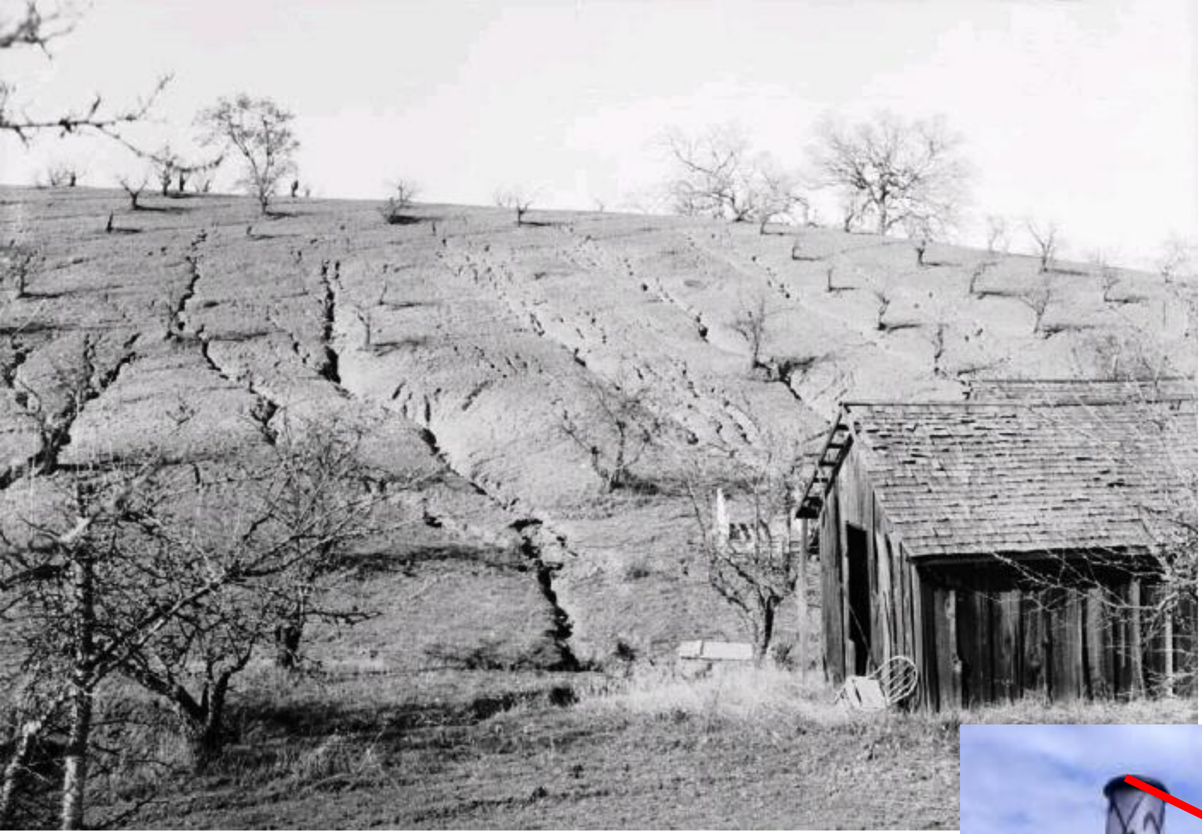
- Develop optimal scenarios for each region with respect to UHI/Energy impacts
- Development of global LZC map
- Implement LZC input data for 8 urban types

Connecting Global Land Use/Land Cover with Soils

Pei-Ling Wang

Johannes Feddema

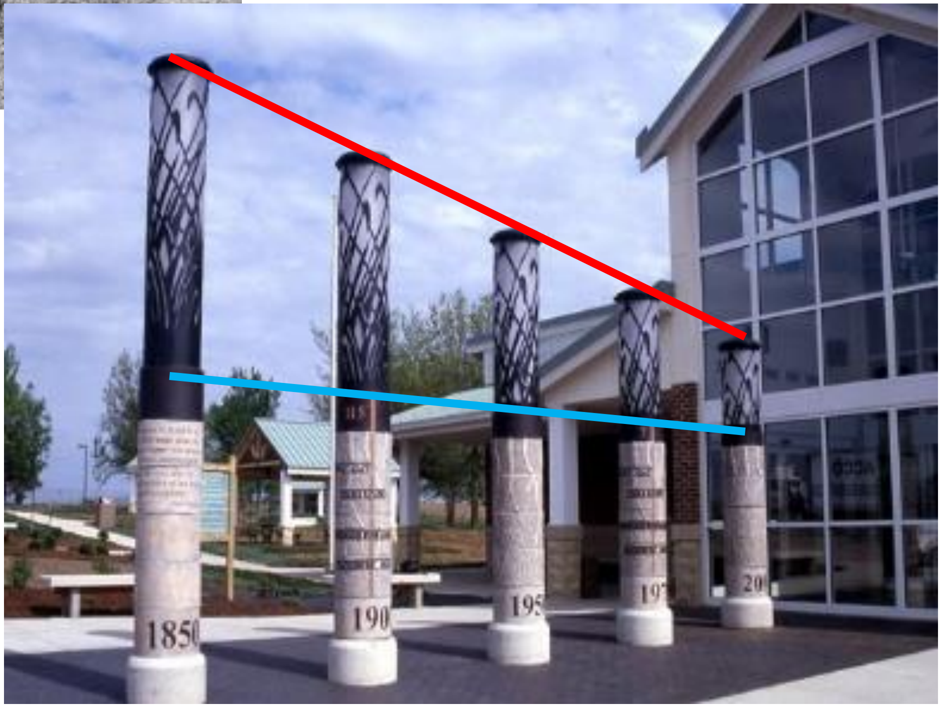
UVIC



Historical soil loss/modification 1920s Alabama

Iowa last 150 year loss of topsoil

With continued current practices areas of Midwest will have soil depths less than 2 m in 100 years.



Objectives

- Create separate soil columns by hydrologic properties at .5 degree grid resolution
- Prioritize soils based on human preference for different LULC types
- Create transient LULCC time series by soil column in each grid cell

[Part 1]

Ranking Soils

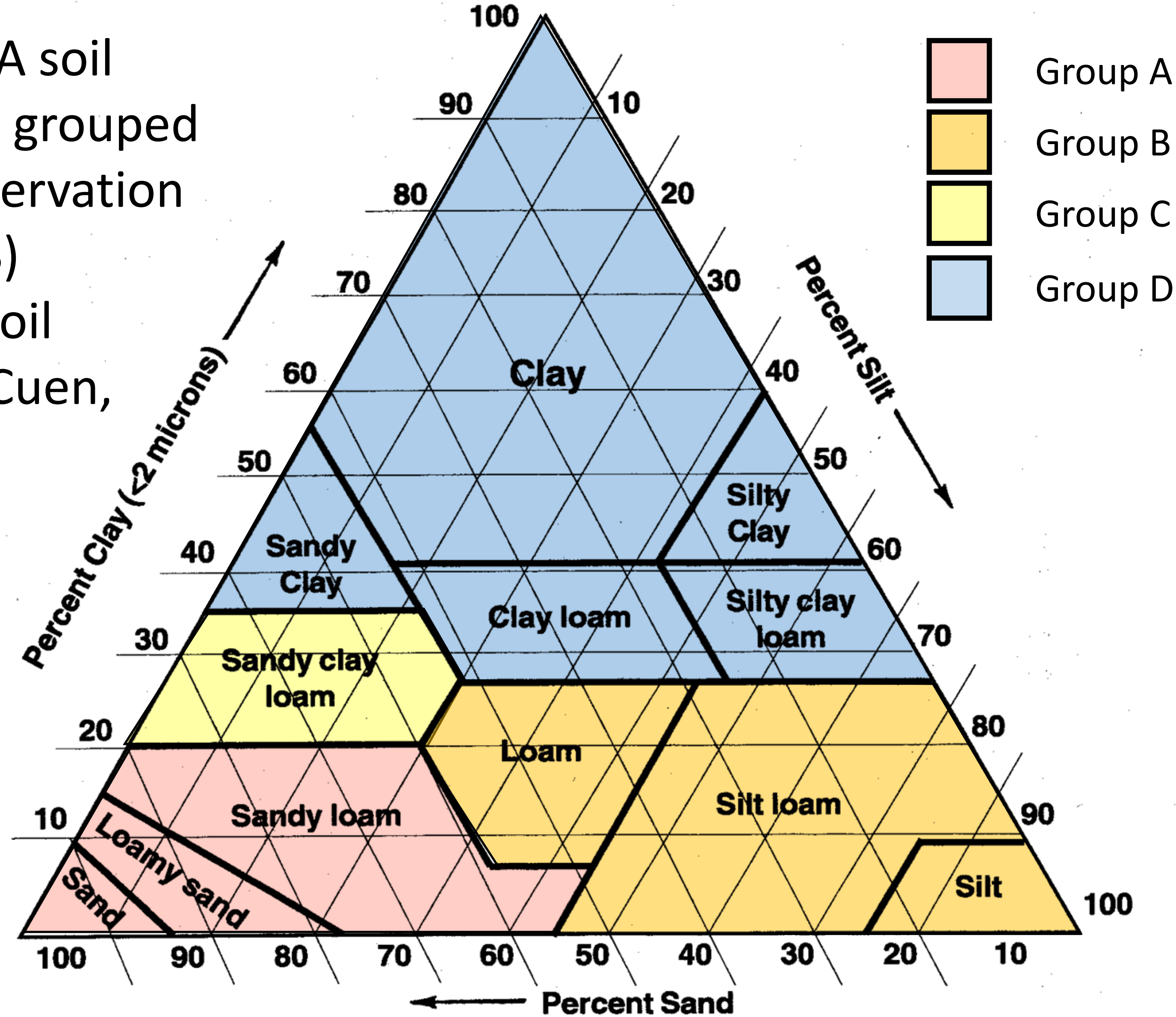
Ranking the soils from the best to the worse

Datasets

- Soil texture: SoilGrids250m [Hengl et al., 2017].
  Resolution: 250 m.
- Land uses: Land-Use Harmonization (LUH2) [Lawrence et al., 2016].
  Resolution: 0.25 degree.
- Soil depth (Shangguan et al., 2017] and [Pelletier et al. 2016]

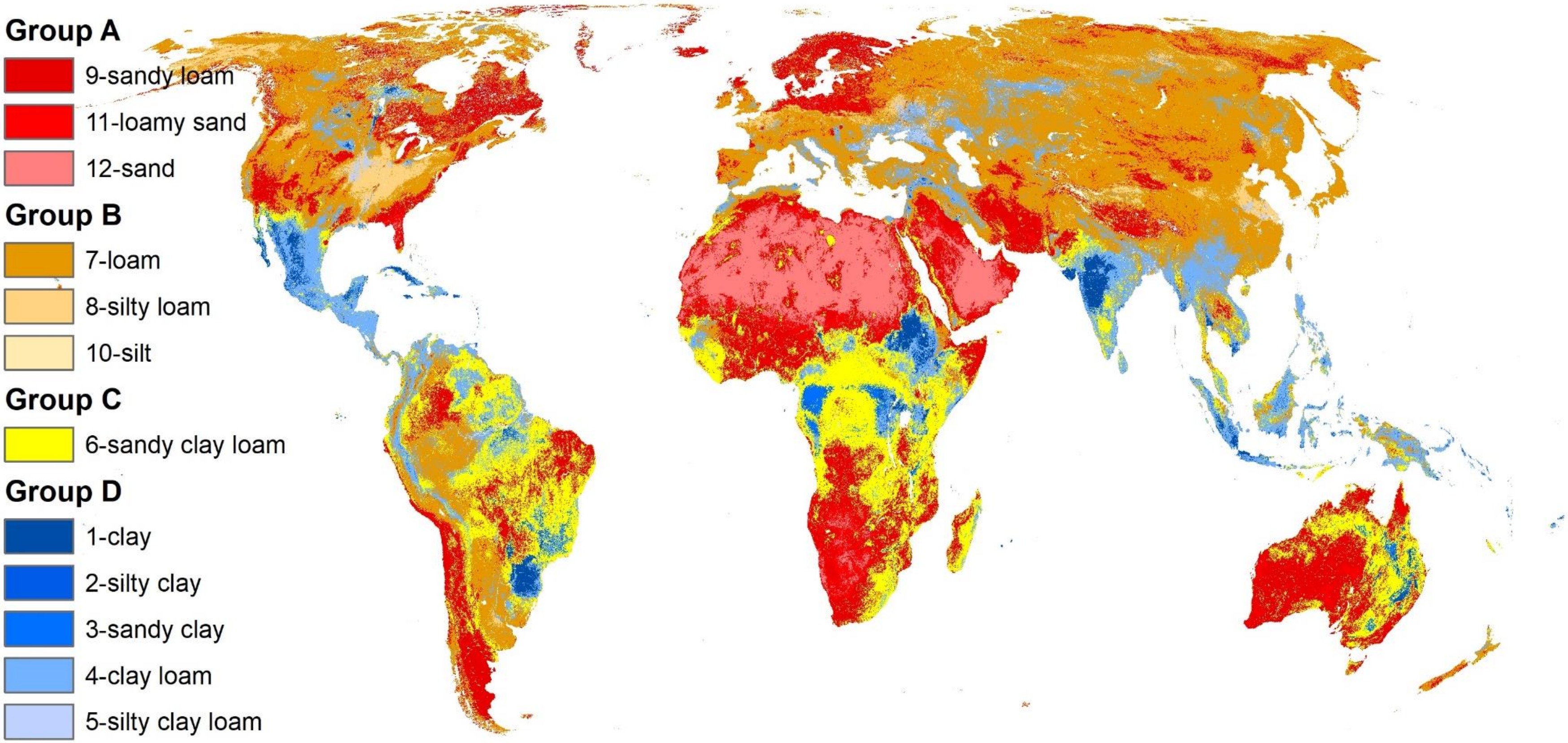
Hydrological Soil Groups

Twelve USDA soil textures are grouped by Soil Conservation Service (SCS) hydrologic soil groups [McCuen, 1982].

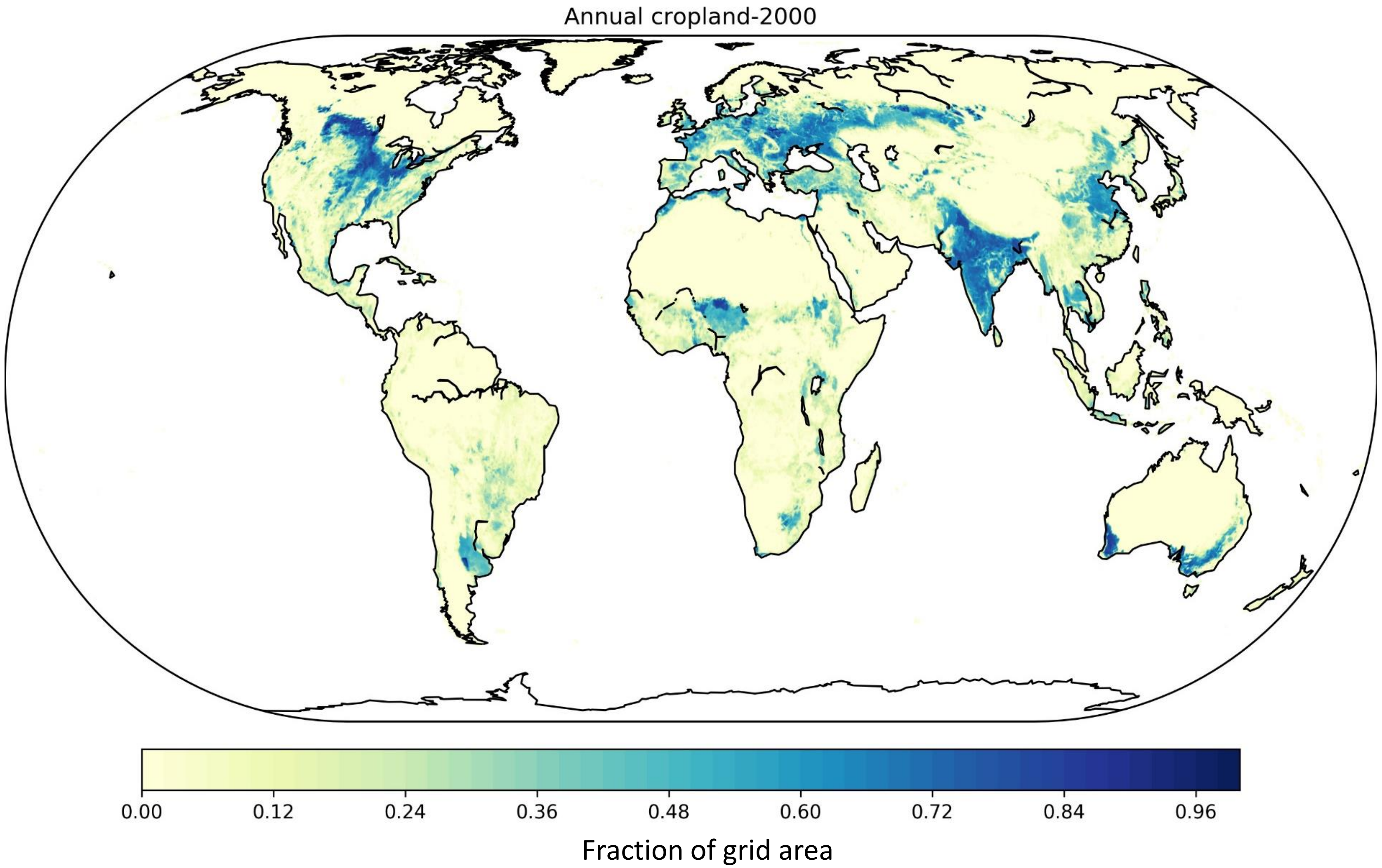


Global Soil Distribution

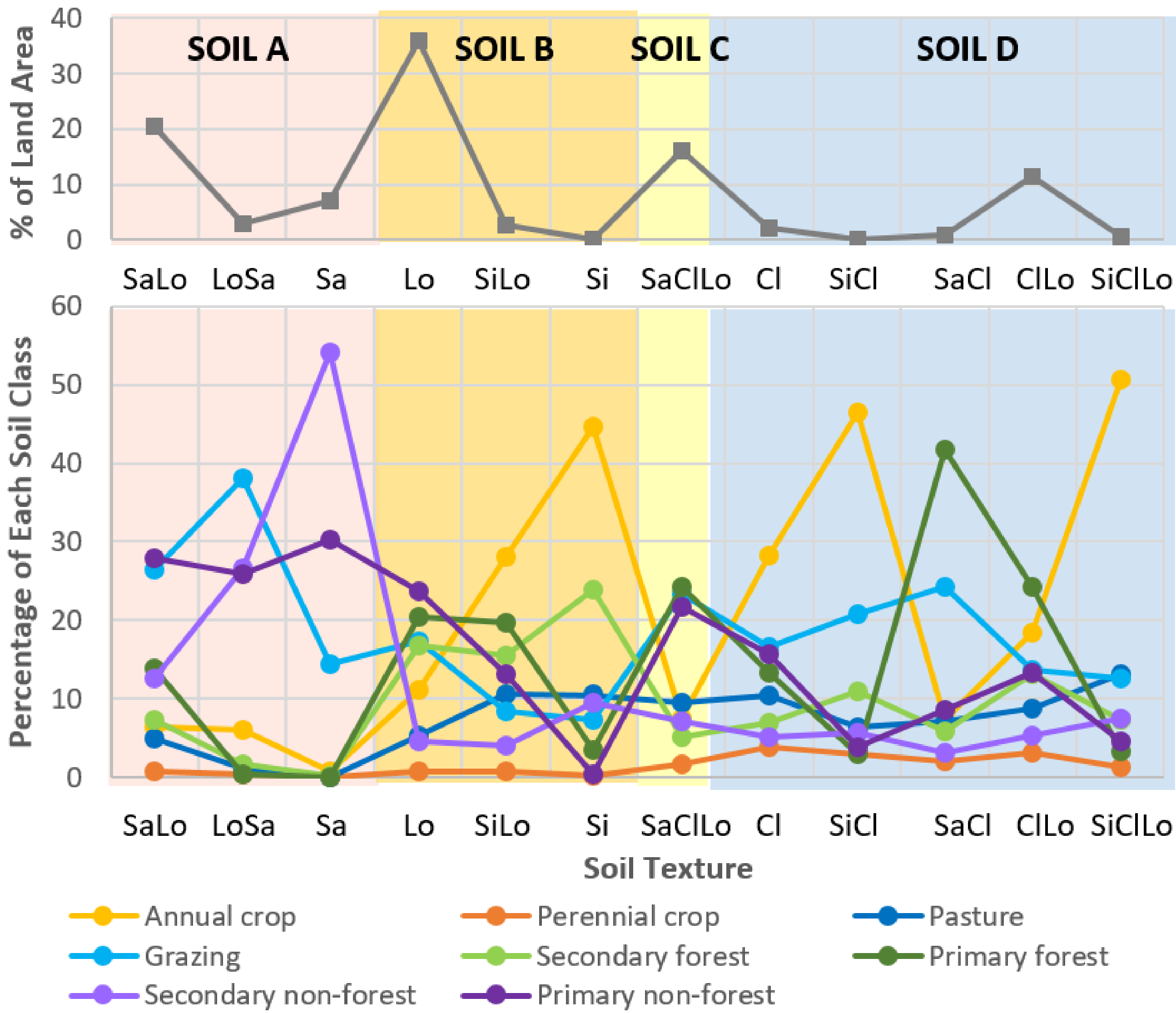
- SCS groups and USDA Soil Textures



Annual Croplands in 2000



Results of Matching Land Uses and Soils



- The percentage of soil cover
- Each group is normalized to its total area on land surface

[Summary] Soil Ranking

- Based on the analysis and observations, we determined the following ranking of the four soil groups:

(1) Soil Group B

(2) Soil Group D

(3) Soil Group C

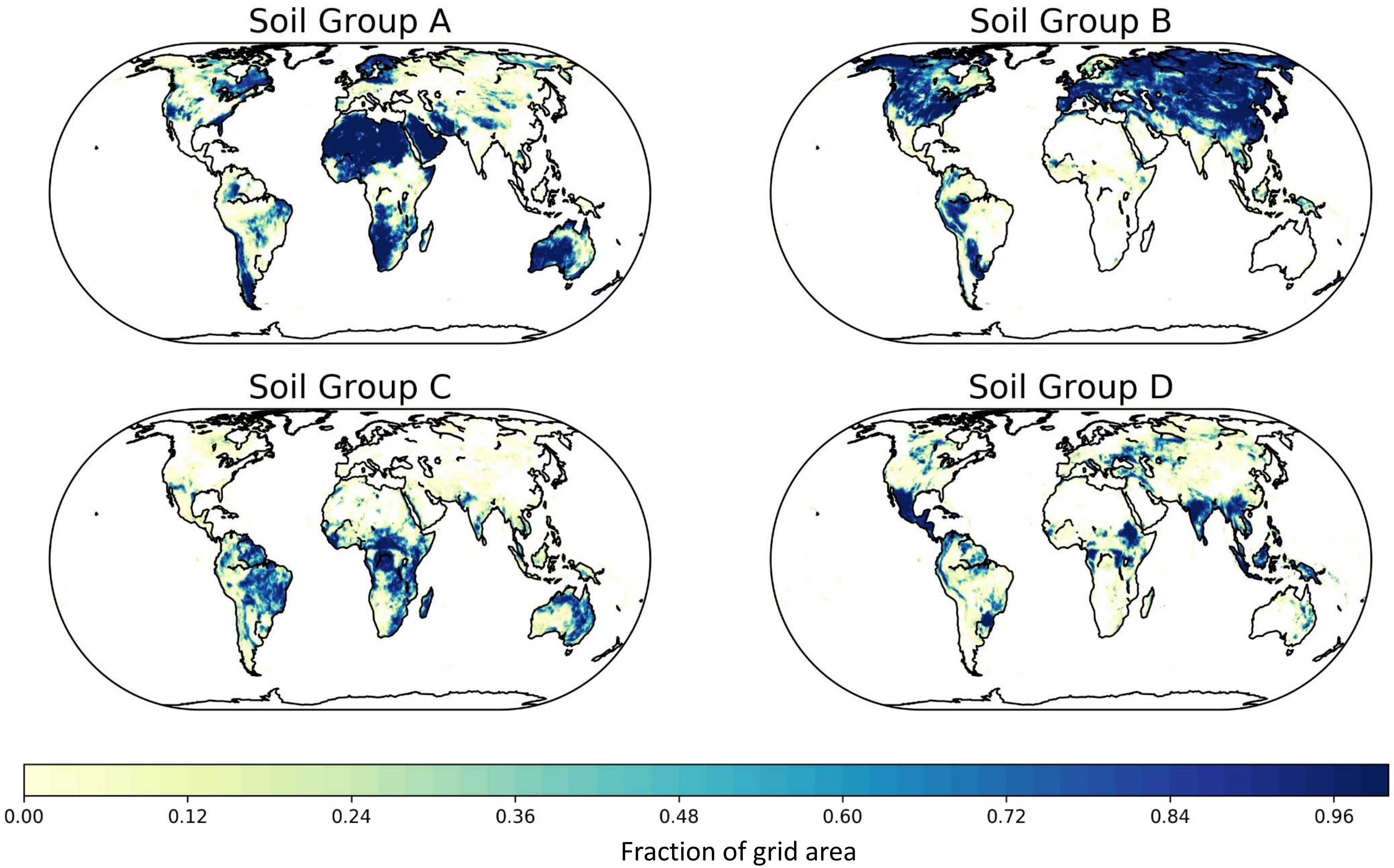
(4) Soil Group A

[Part 2]

Assigning Land Use States to Four Soil Groups

Based on the list of soils from the best to the worse

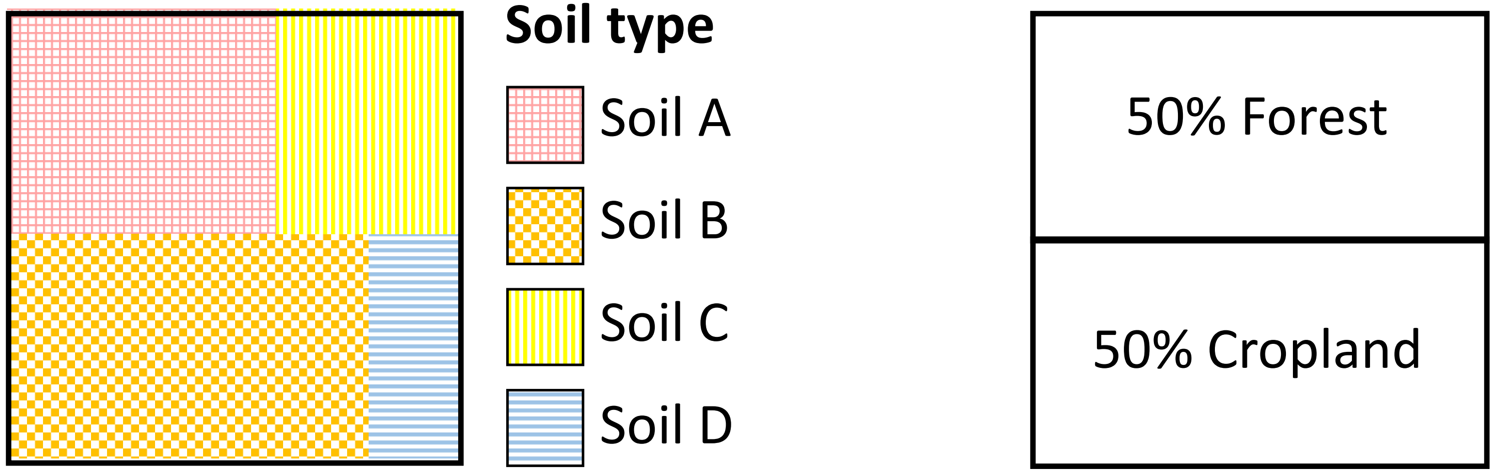
[Data] Distribution of Four Soil Groups

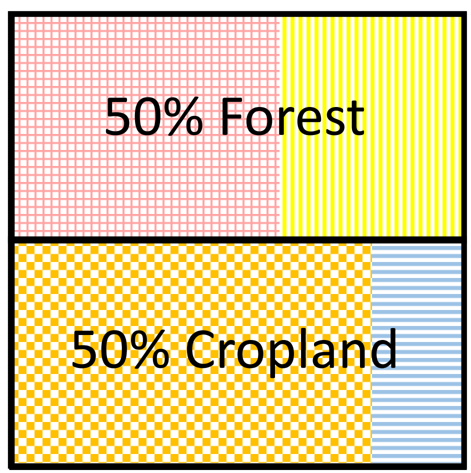


Allocating Land Uses to Soils

Unknown distribution of soils and land uses within a grid.

From soil map: **From LUH2:**



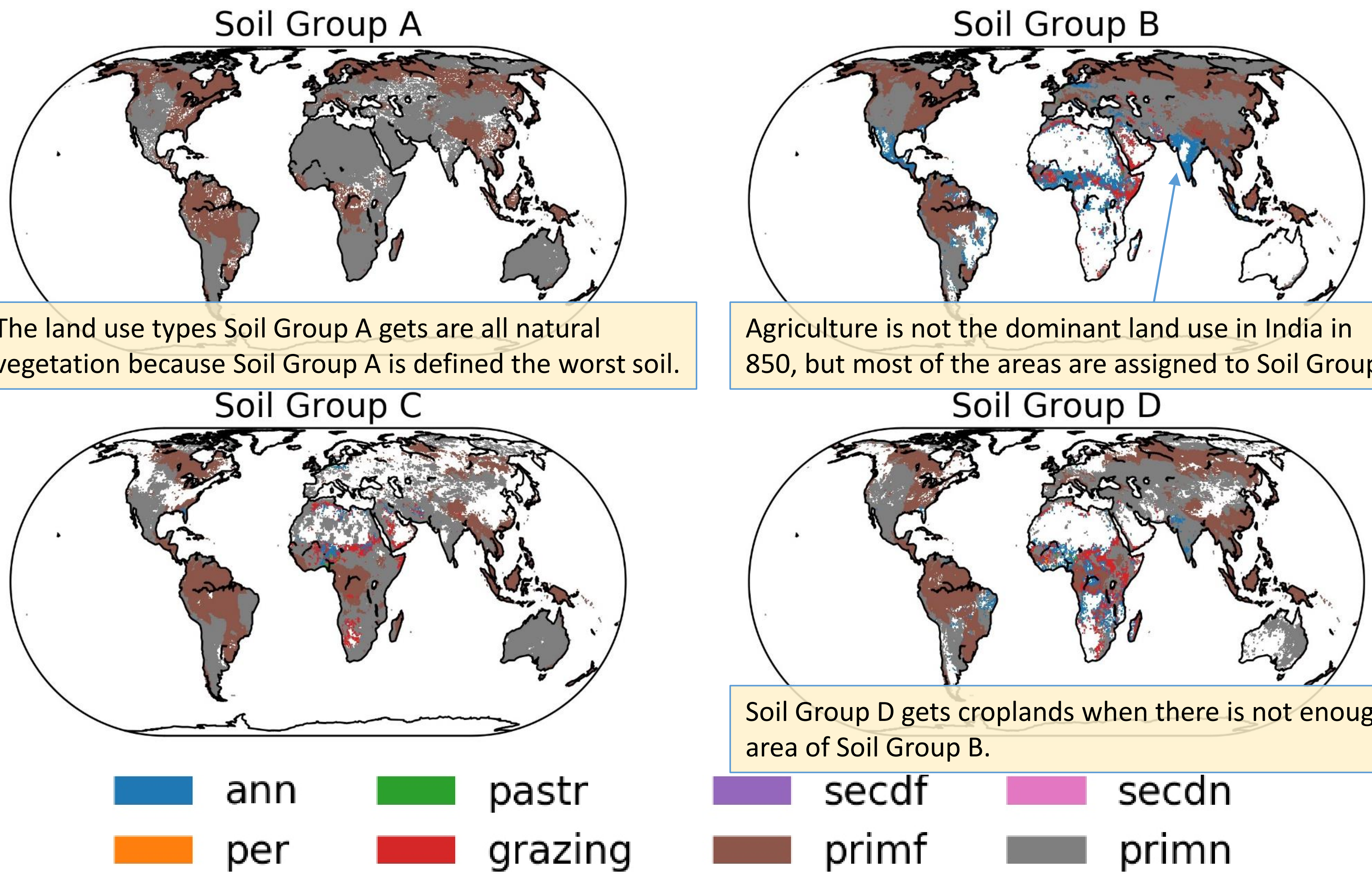


→ Cropland gets the best soils from the list of Soil Group B, D, C, A.

← Forest land gets the rest of the soils on the list of Soil Group B, D, C, A.

[Result] Soil and Land Use Match in 850

- Only the dominant land use of each grid is shown



The land use types Soil Group A gets are all natural vegetation because Soil Group A is defined the worst soil.

Agriculture is not the dominant land use in India in 850, but most of the areas are assigned to Soil Group B

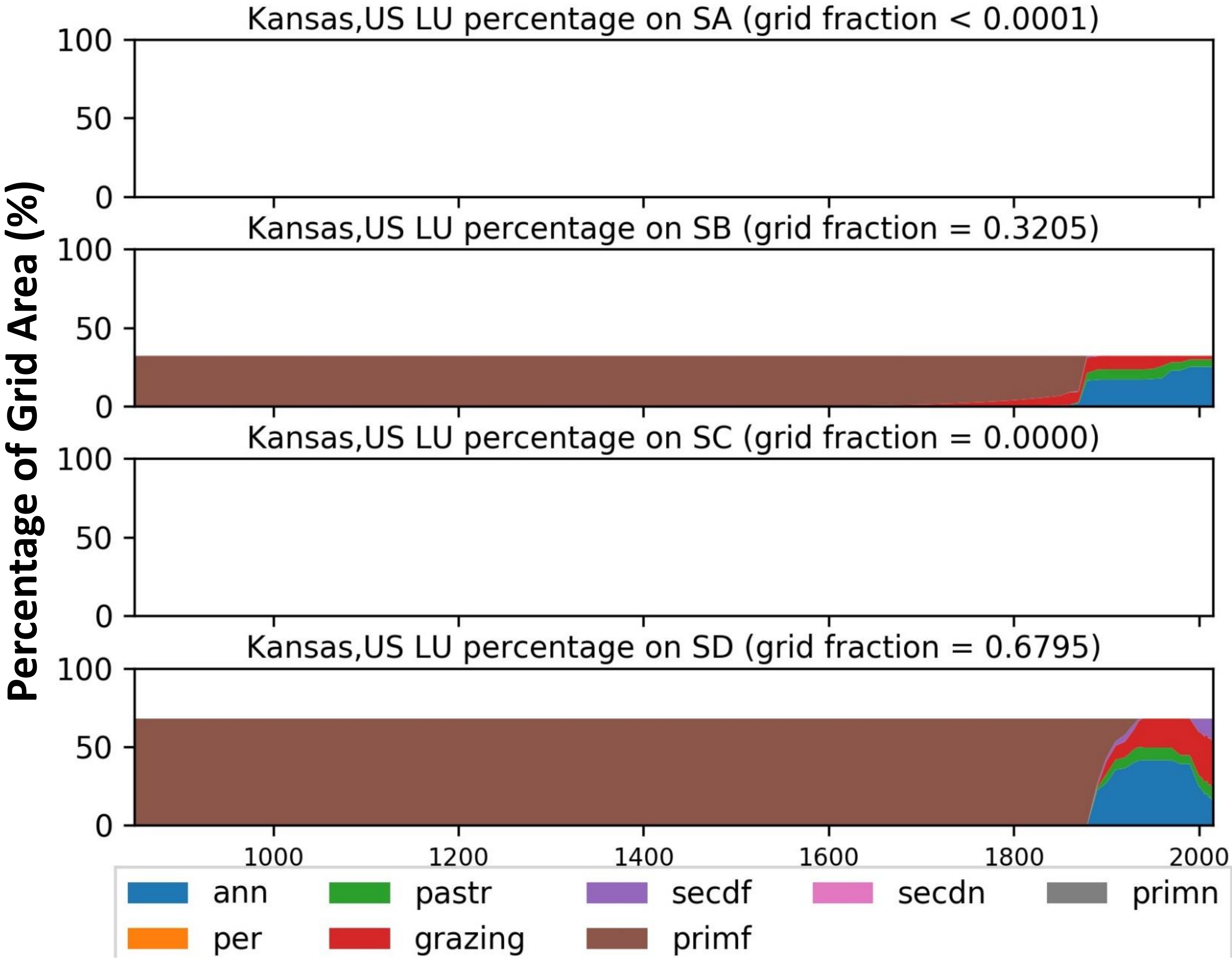
Soil Group D gets croplands when there is not enough area of Soil Group B.

[Part 3]

Allocating Land-Use Transitions to Soils Over the Past Millennium

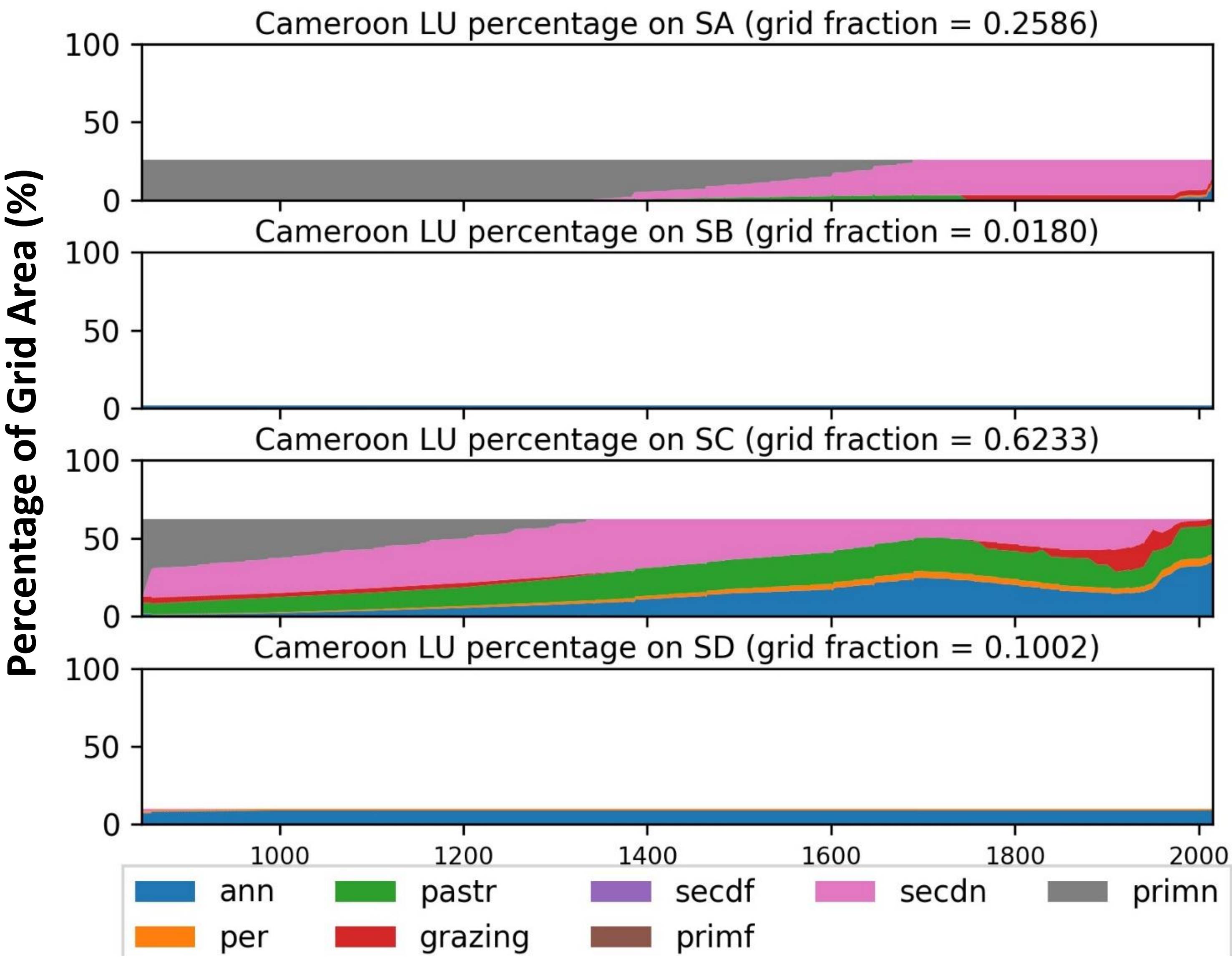
Based on the list of soils from the best to the worse and the importance of human land uses

[Result e.g.] Land-Use History in Kansas, US



Soil B is used earlier and is not affected when the cropland area decreases.

[Result e.g.] Land-Use History in Cameroon

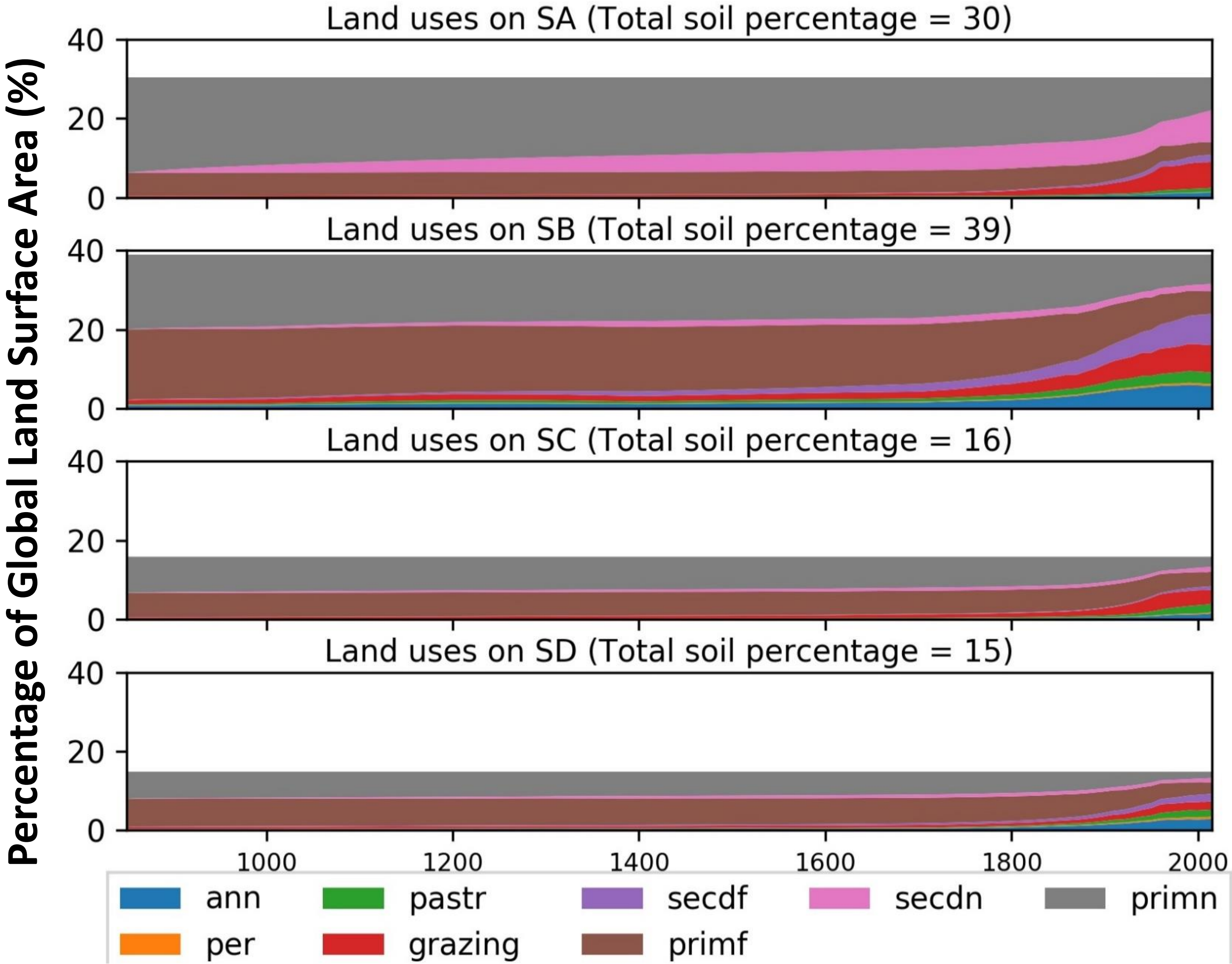


← Soil A remains its natural state until primn on Soil C is depleted.

← Soil B stays as the cropland despite its small fraction.

← Soil C, the dominant soil, shows increased human land uses.

[Result] Total Global Land-Use History on Four Soil Groups 850-2016



← Soil A is used late and has the most secdn area.

← Soil B is used early and has the most ann and secdf areas.

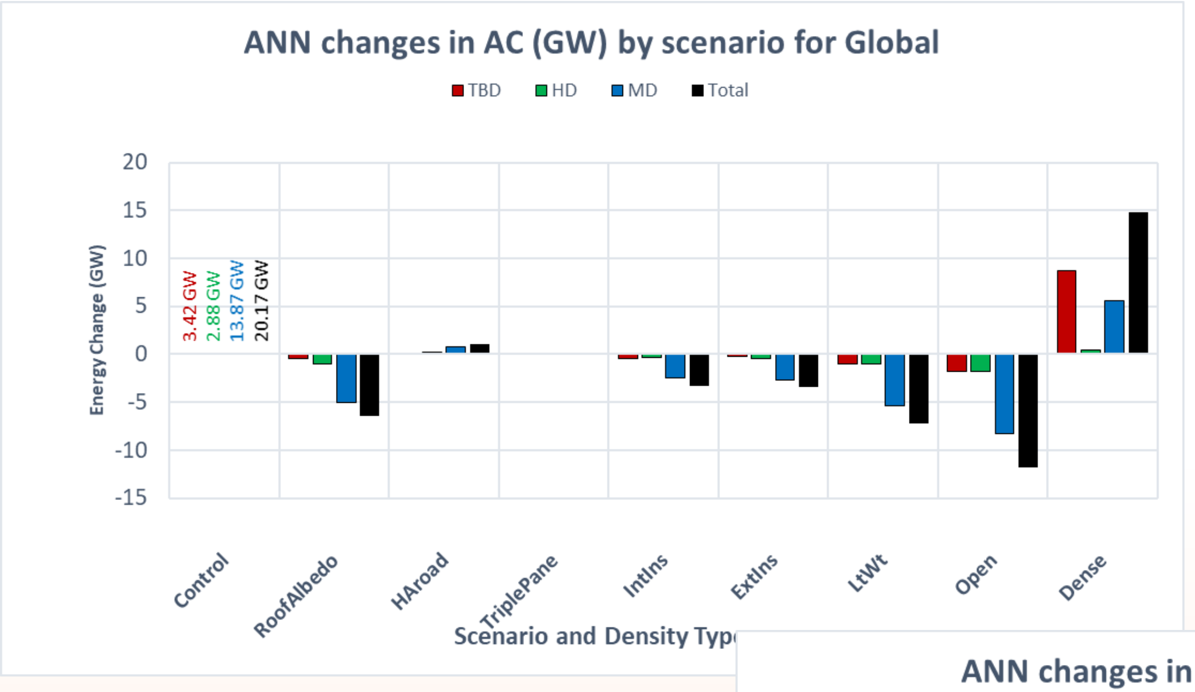
← Soil C is similar to soil D but with less ann and more grazing areas.

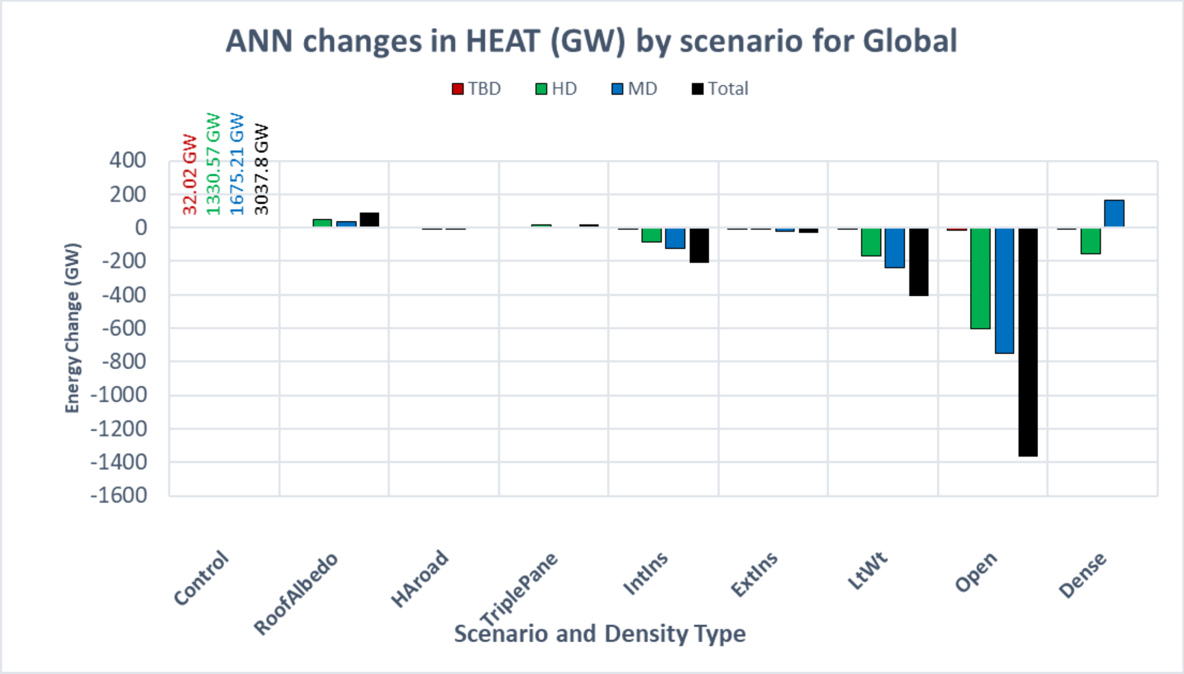
Next steps

- Writing up these results
- Use 4 or 12 soil groups?
- Develop human soil degradation model (in progress)
- Simulate human soil degradation by soil type based on LUH2 landuse and landuse transitions

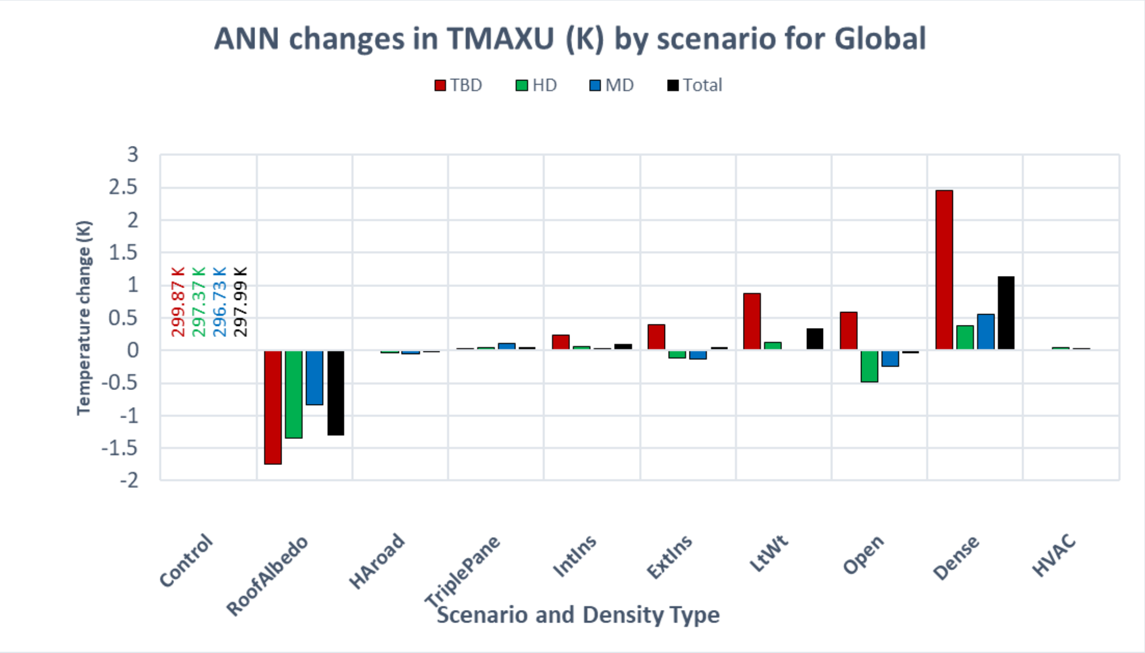
Questions?

Comparing global impacts of Scenarios

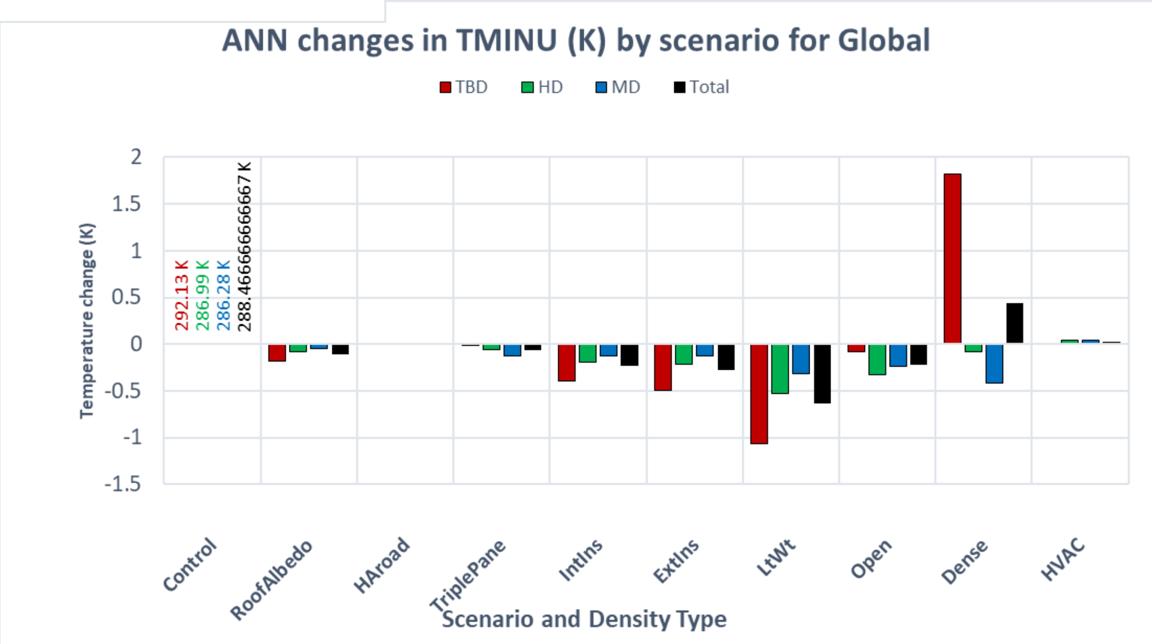




Comparing global impacts of Scenarios



Daytime UHI can be best reduced by roof albedo and dense design is a problem (the 2 might offset to some degree)



Nighttime UHI best reduced by better insulation and reduced heat capacity walls (potentially with some increase of daytime UHIs)

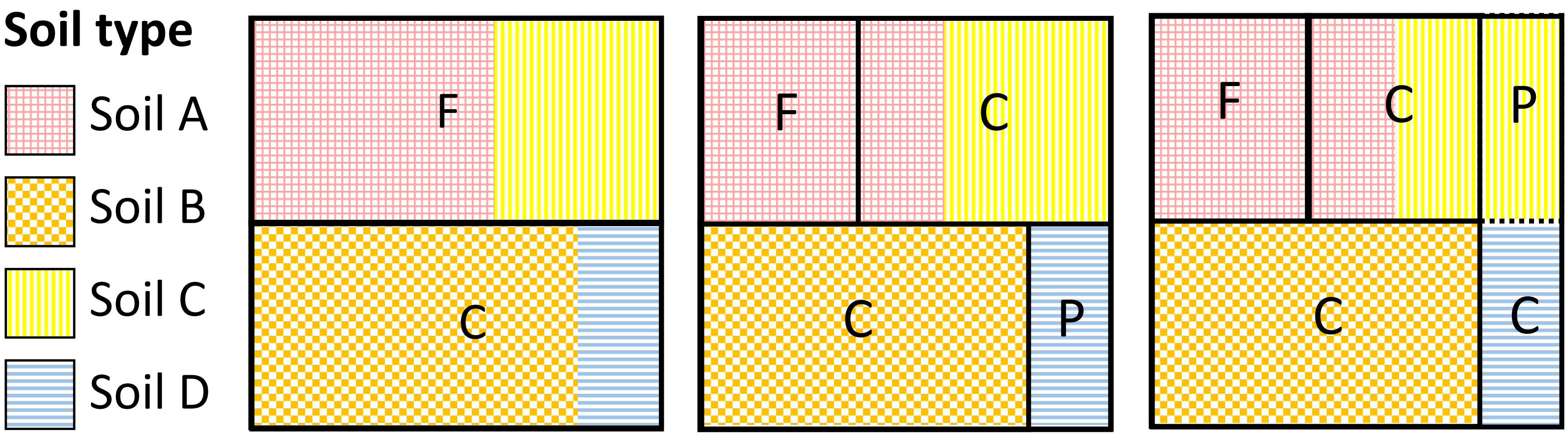
Basic Assumptions and Rules

- Assume soil type won't change over time.
- List of land uses based on the importance for human usage: ann, per, pastr, grazing, secdf, primf, secdn, primn.
- List of soil ranking: Soil Group B, D, C, A
- When a land use converts to a more important land use: taking the best soils from the original land use. This allows important land uses to always locate on good soils.
- When a land use converts to a less important land use: taking the worse soils from the original land use. This allows important land uses to keep good soils and allows poor soils to have more land-use transitions because more recovery/fellow is needed for poor soils.

Allocating Land-Use Transitions Over Time

- Unknown distribution of land-use transitions within a grid.

Land-use conversion	Year 0 (initial): 50% Forest (F) 50% Cropland (C)	Year 1: 30% F → C 10% C → Pasture (P)	Year 2: 10% P → C 10% C → P



- The cropland is taken from the best soil of the forest land.
- The pasture land is taken from the worst soil of the cropland.