Field observations of subsurface flow path evolution over 10 millennia

Anne Hartmann, Ekaterina Semenova, Theresa Blume, Markus Weiler

DFG and SNF

Landscape and soil evolution for the more impatient: place for time substitution

Chronosequences

- e.g. land-use change impact studies: site selection based on years since disturbance
- Or: site selection based on years since hillslope formation

(e.g. Lohse and Dietrich, 2005: 300 year vs 4 million year old volcanic soils)

Hillslope evolution in the field
Our testbed: glacial moraines

Advantages:

- Hillslopes of different ages in close proximity: place for time

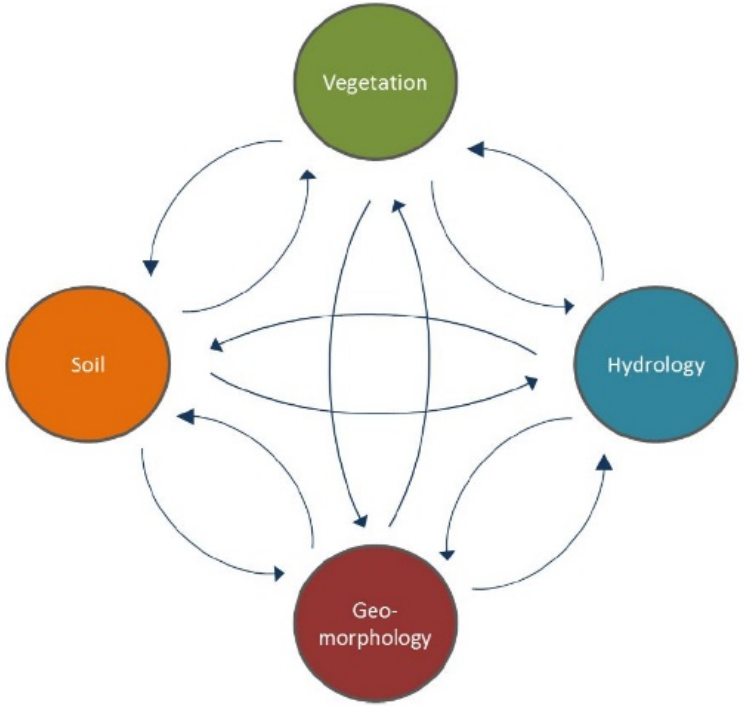
  ⟹ glacial forefields provide unique opportunities

Challenges:

- Short field seasons
- Harsh environment

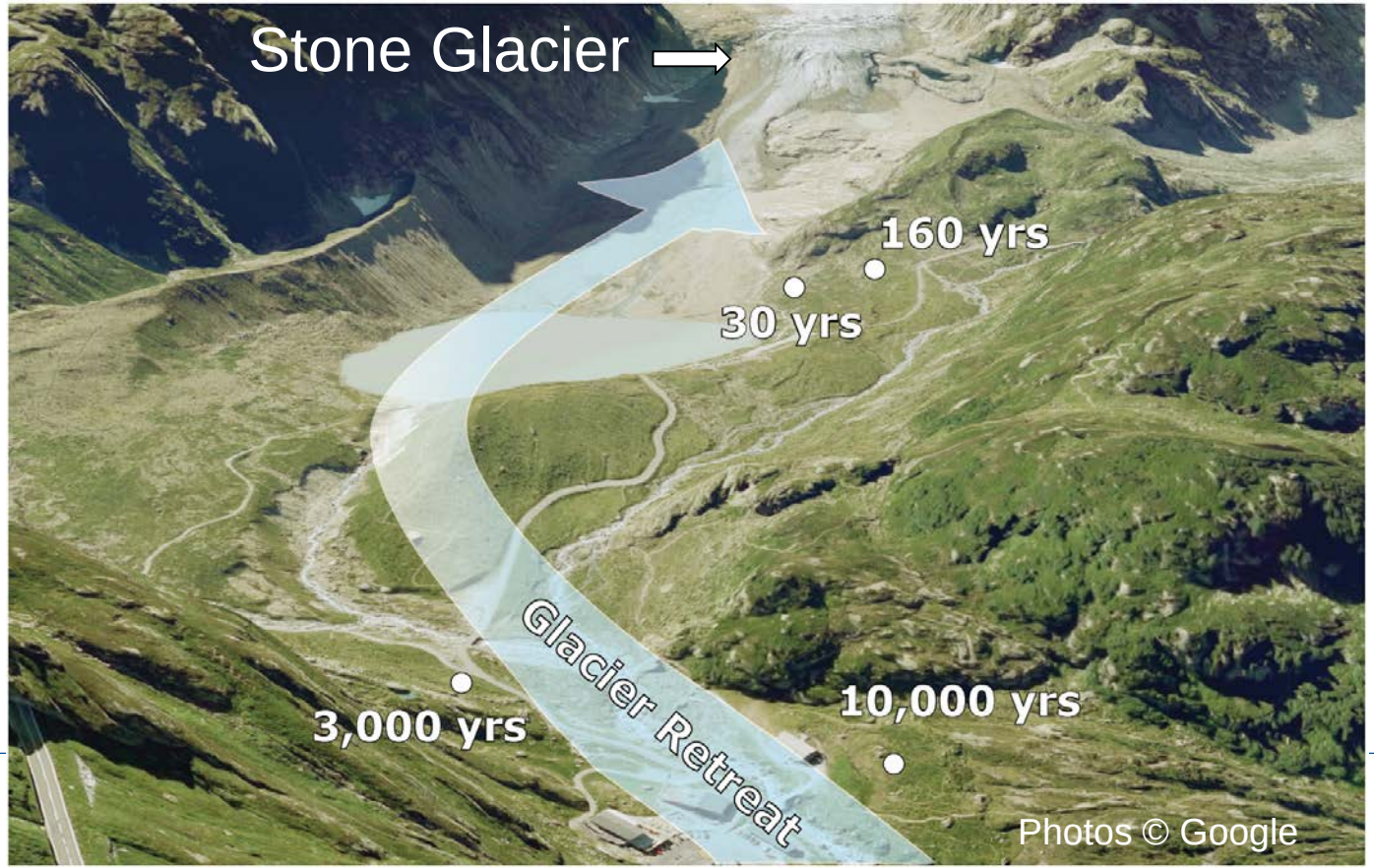
  ⟹ difficult for long-term monitoring hydrological processes

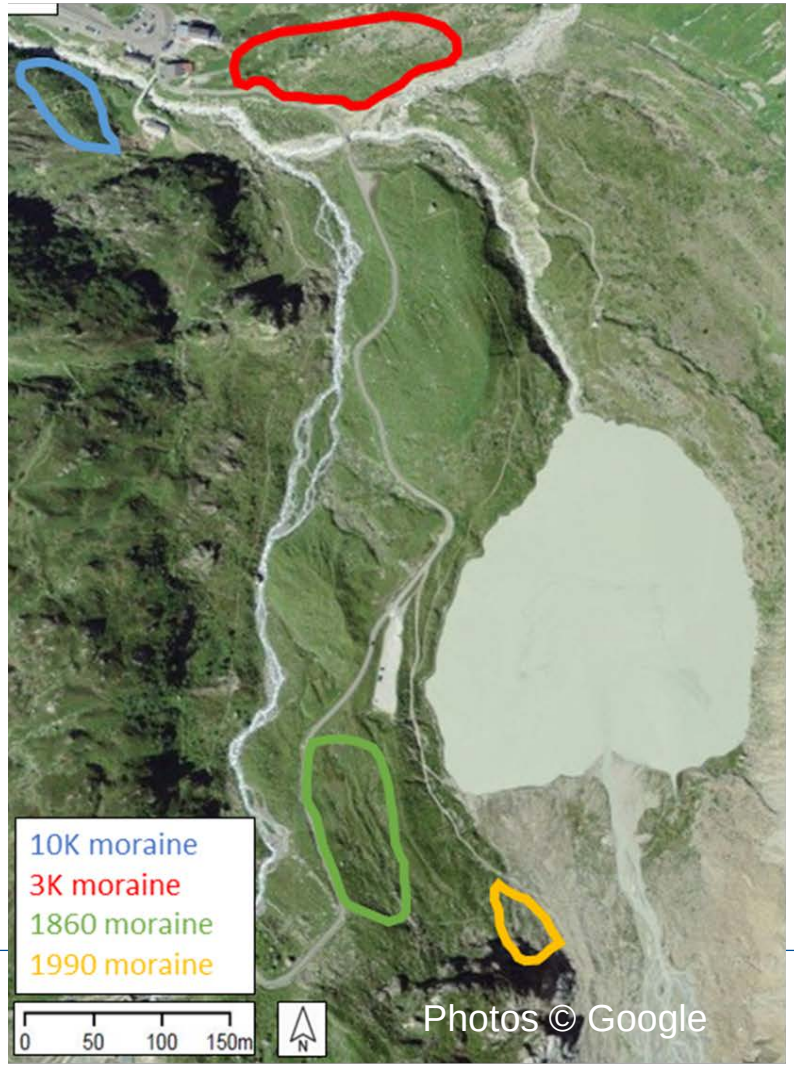
Interdisciplinary study of hillslope evolution

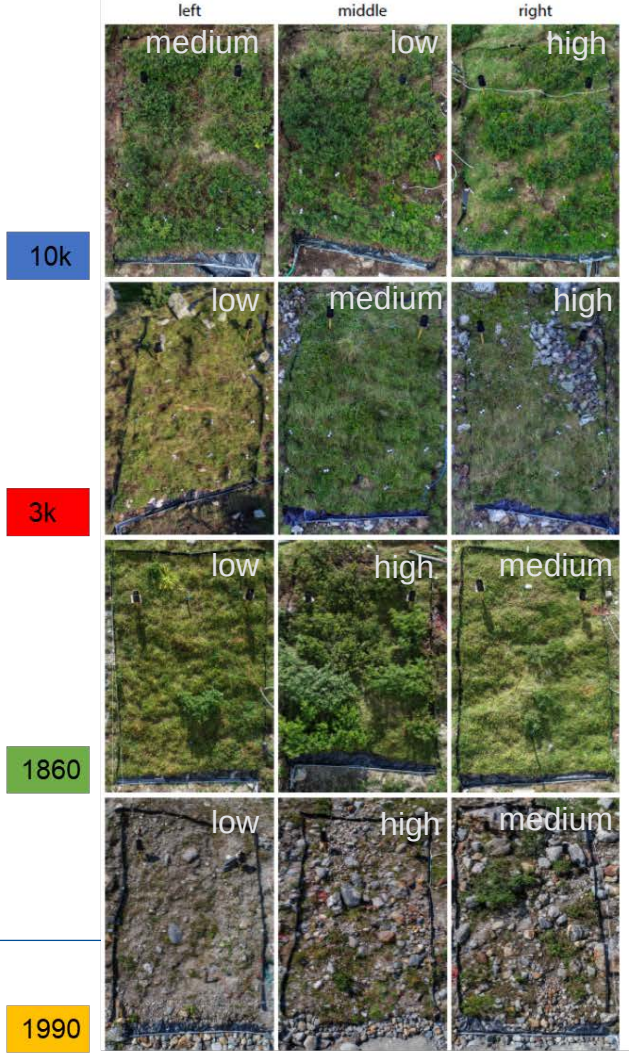


The HILLSCAPE Project involves soil scientists, geomorphologists, weathering experts, biologists and hydrologists

Our chronosequence in the Swiss Alps







GFZ Helmholtz Centre Potsdam

ELMHOLTZ

Experimental design

3 plots per moraine, a gradient in vegetation complexity

low complexity → high complexity

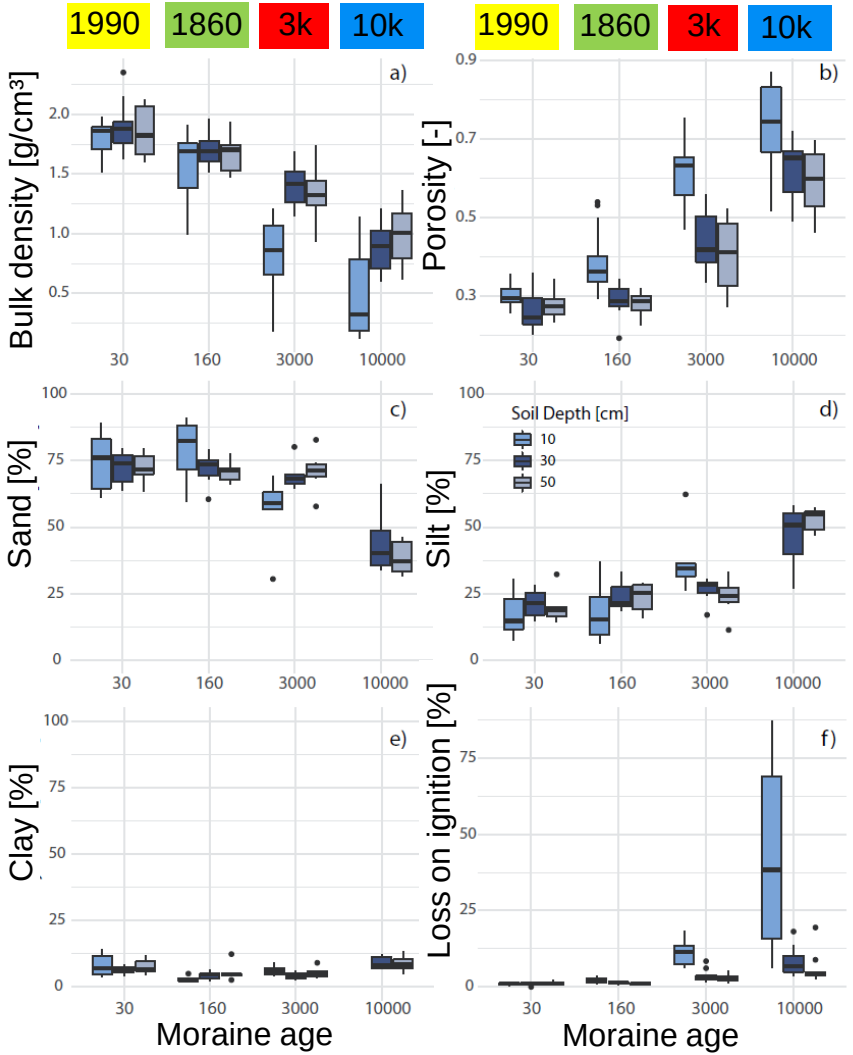
hillslopes ice-free 1990

low complexity → high complexity

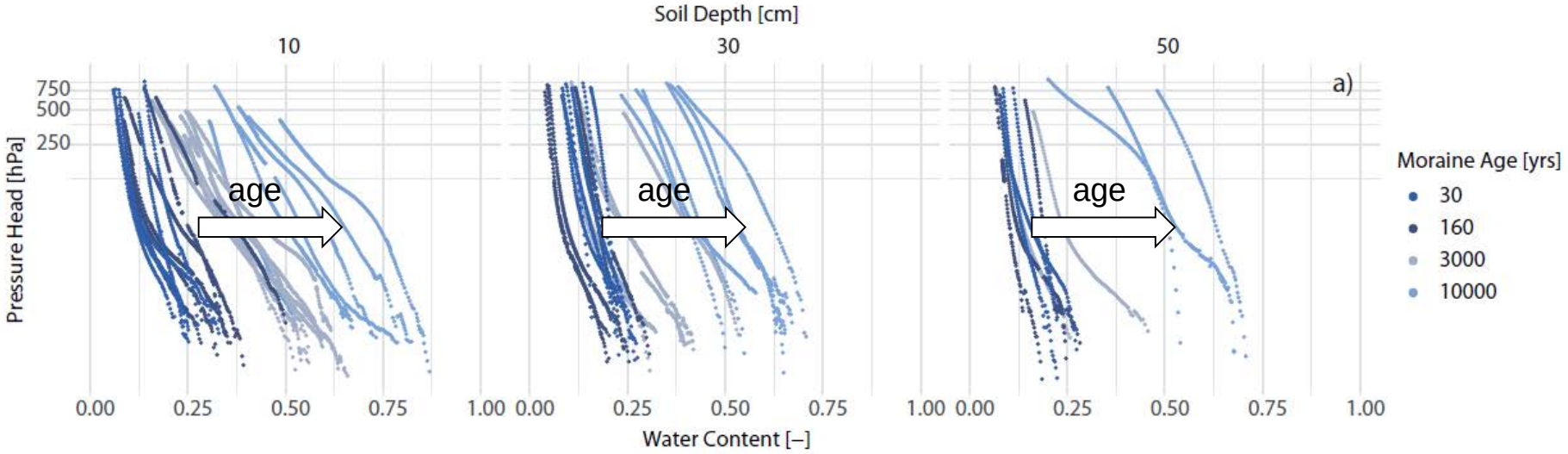
hillslopes ice-free 1860

Soil development

Bulk density decreases, porosity and silt content increase with age



Soil water retention curves



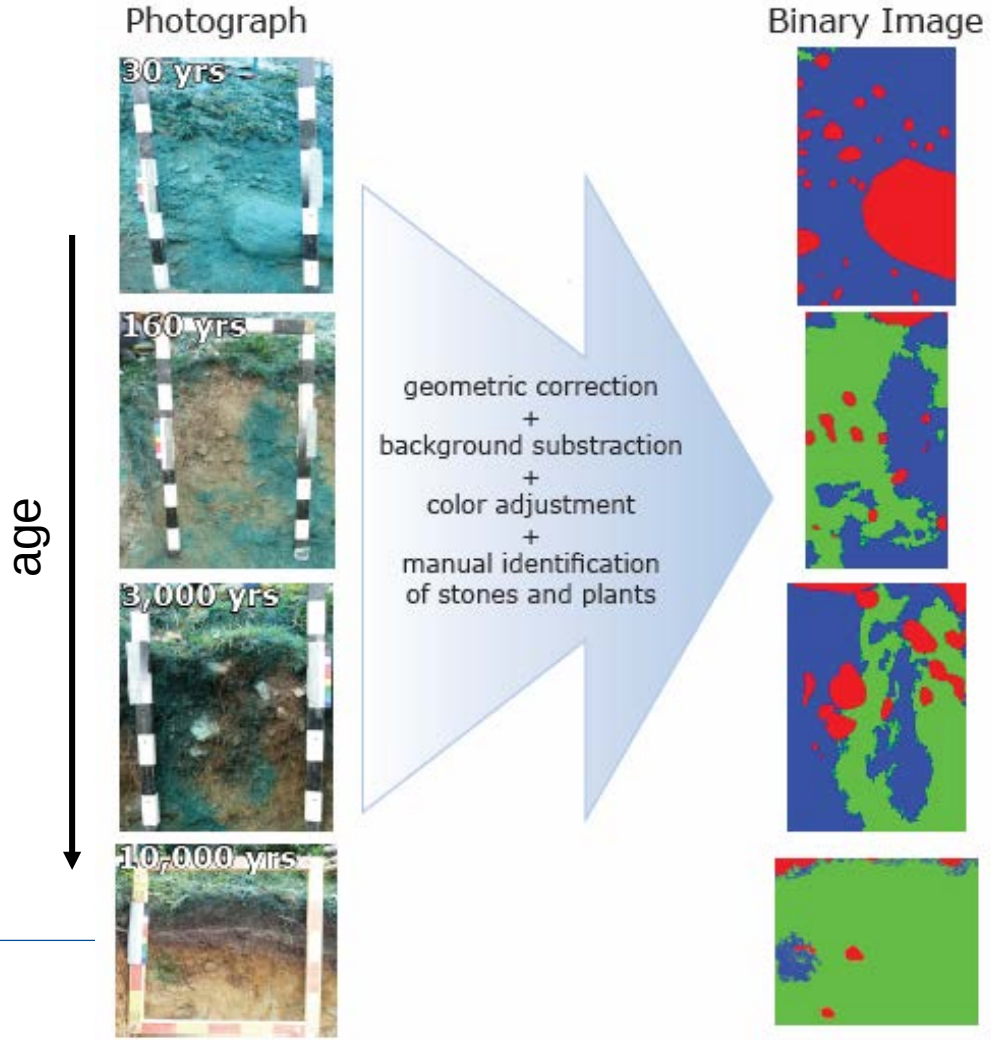
Water retention increases with age

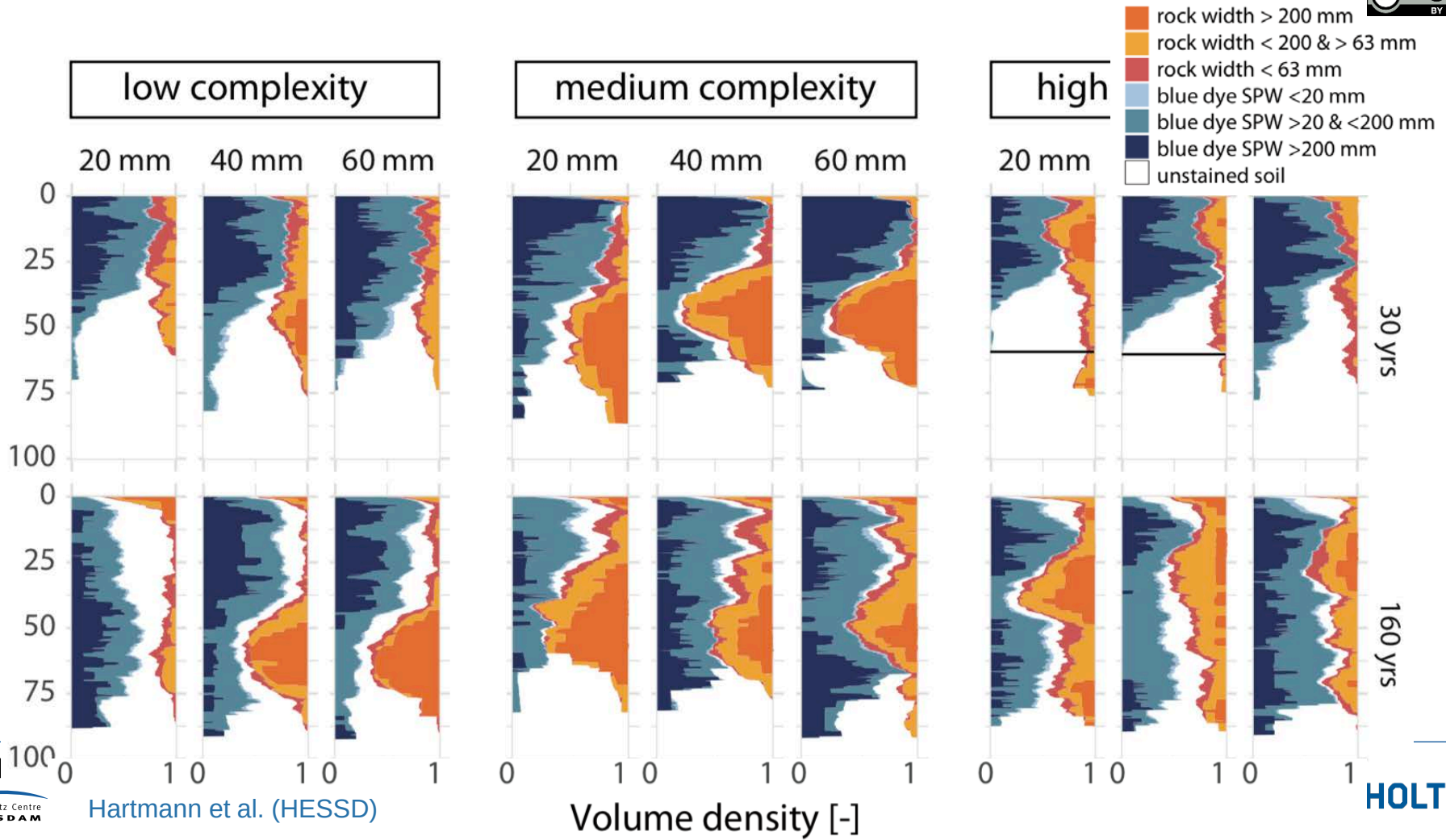
Hartmann et al. (submitted to ESSD)

Brilliant Blue dye tracer experiments

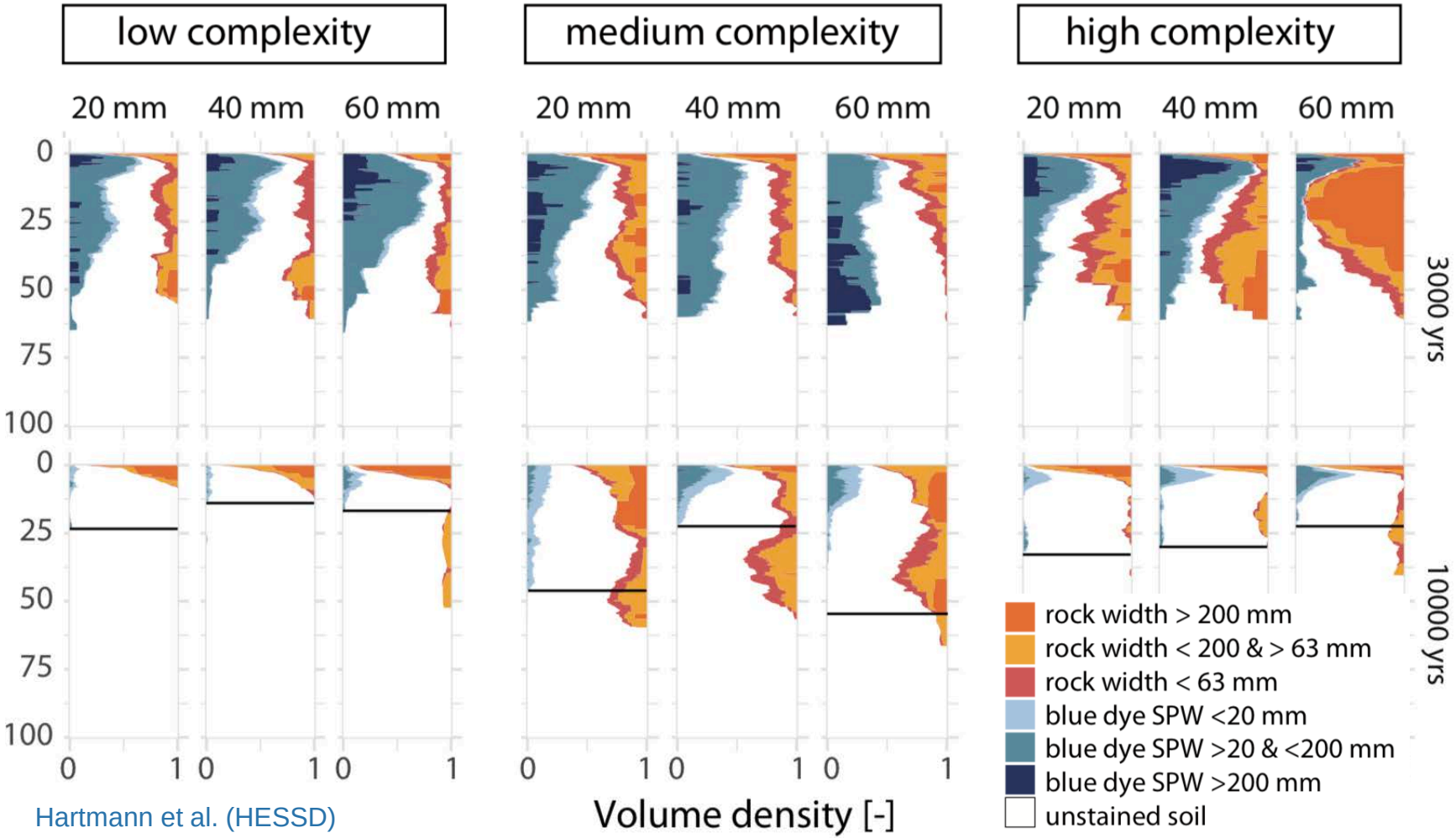
Dye tracer experiments

- 36 dye tracer experiments
- following the same design as the large rainfall experiments along age and vegetation complexity gradients



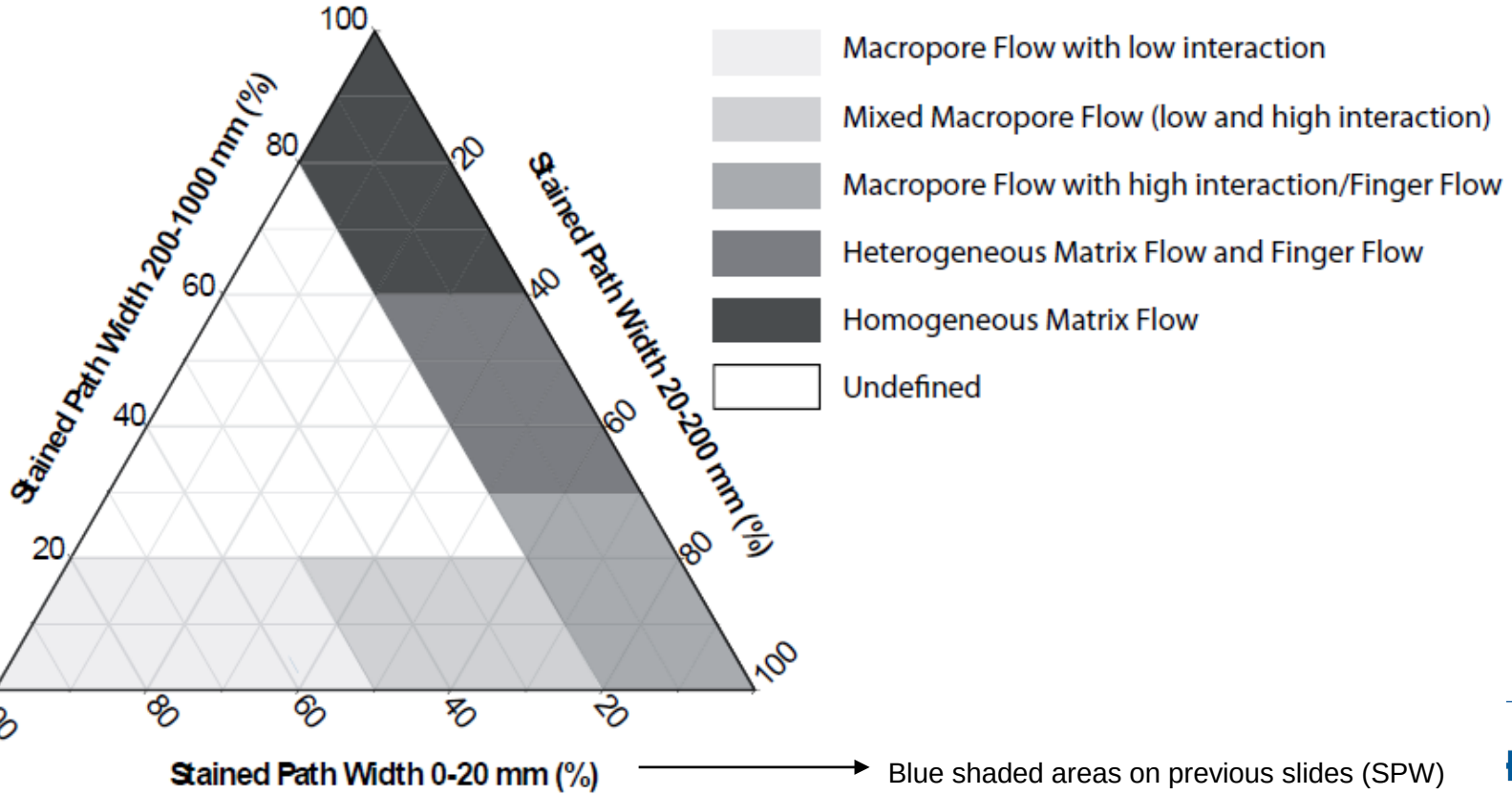


Hartmann et al. (HESSD)



Hartmann et al. (HESSD)

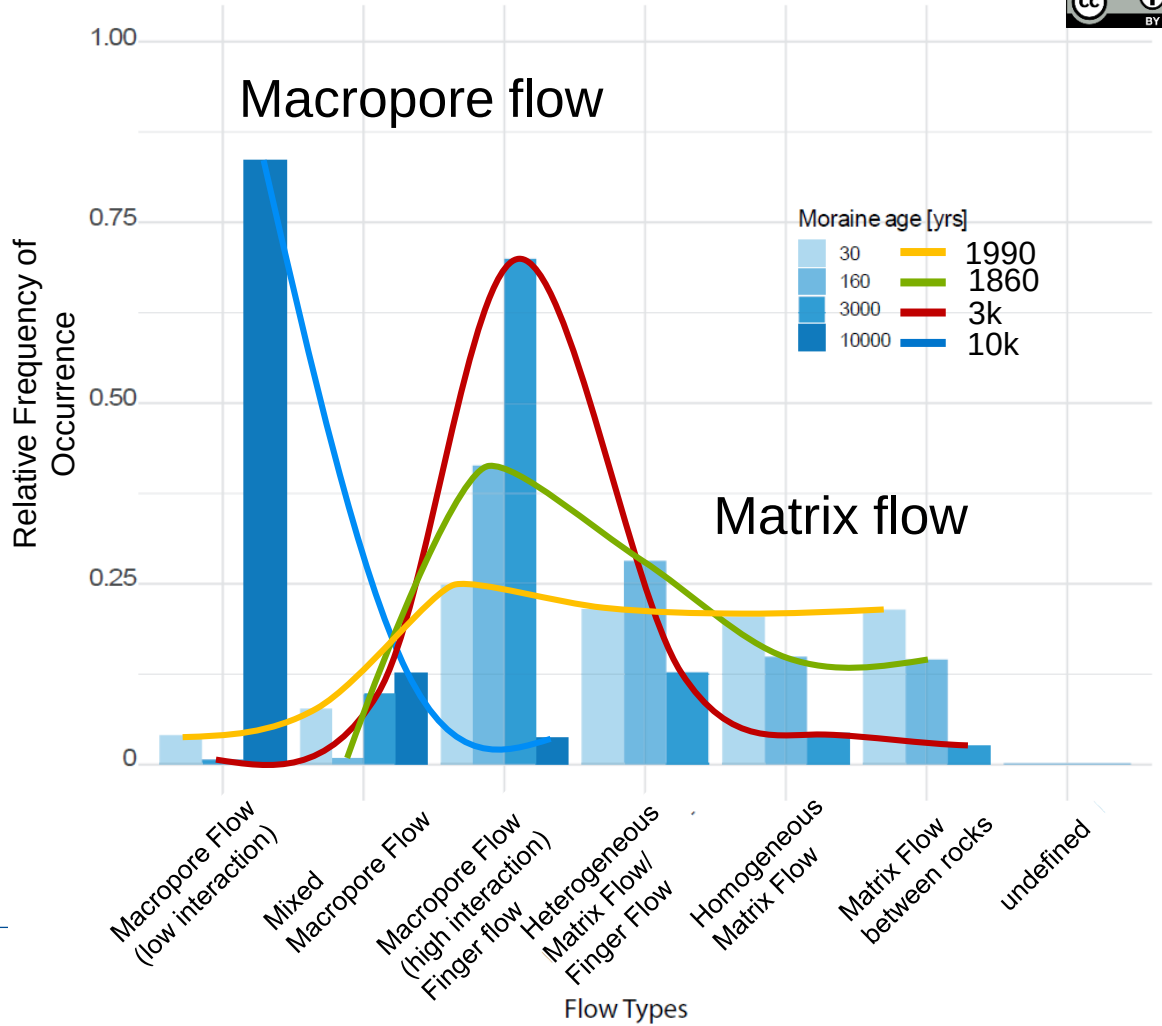
Flow type classification

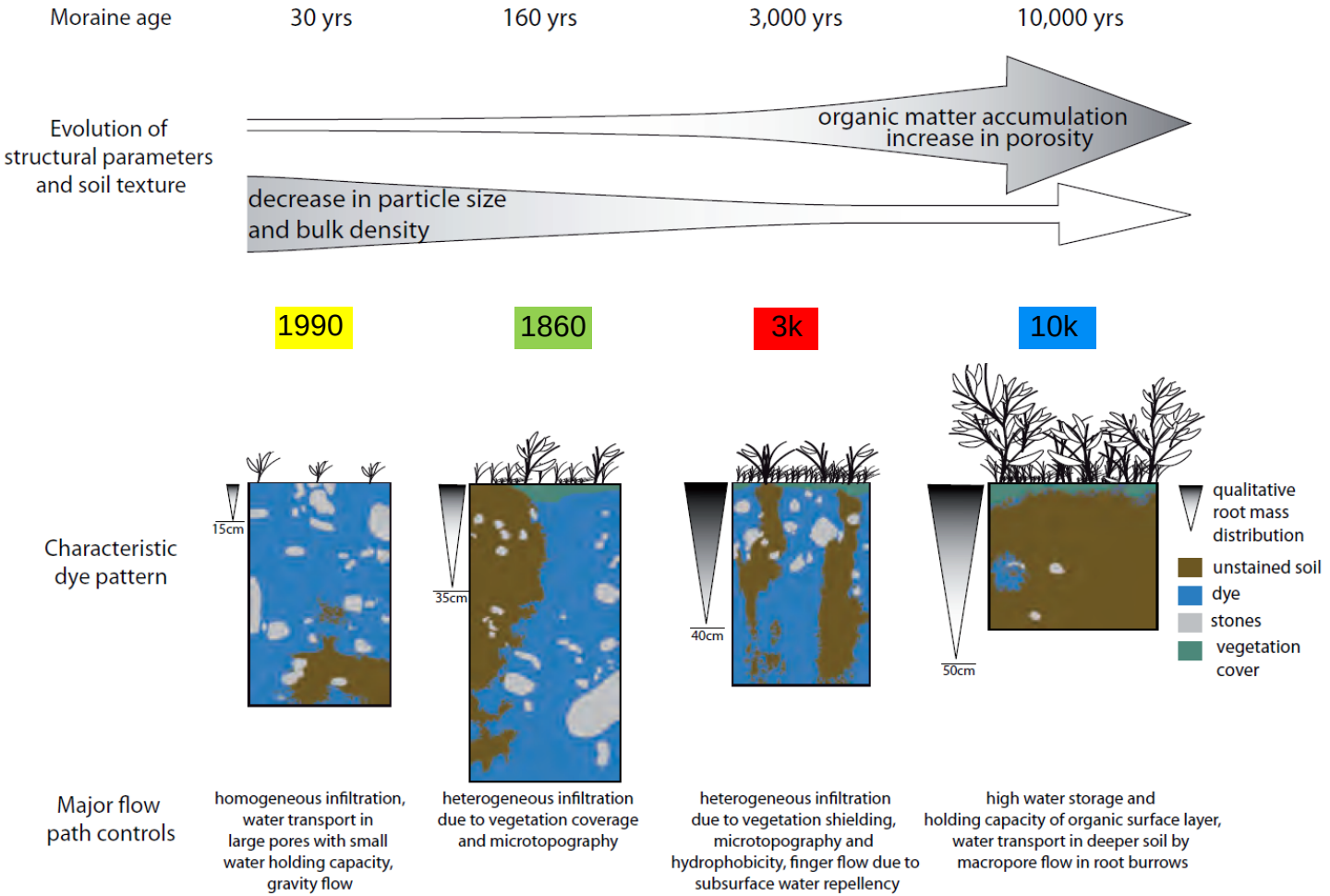


→ Blue shaded areas on previous slides (SPW)

Flow type identification

Relative frequency of macropore flow increases with age




Moraine age
30 yrs
160 yrs
3,000 yrs
10,000 yrs
Evolution of structural parameters and soil texture
organic matter accumulation
increase in porosity
decrease in particle size
and bulk density
1990
1860
3k
10k
Characteristic dye pattern
15cm
35cm
40cm
50cm
qualitative root mass distribution
unstained soil
dye
stones
vegetation cover
Major flow path controls
homogeneous infiltration, water transport in large pores with small water holding capacity, gravity flow
heterogeneous infiltration due to vegetation coverage and microtopography
heterogeneous infiltration due to vegetation shielding, microtopography and hydrophobicity, finger flow due to subsurface water repellency
high water storage and holding capacity of organic surface layer, water transport in deeper soil by macropore flow in root burrows

Conclusions

- A LOT of change already happens in the first 160 years

Generally:

- Pronounced changes in subsurface structure/texture (soil physics)
- Pronounced changes in flow paths
- Pronounced changes in water storage

So what?

Understanding how **hillslope structure (hillslope form)**  evolves and how this affects, and is affected by, vegetation and hydrological and biogeochemical cycles (**hillslope function**)  is important to:

- manage hillslopes (including newly developed hillslopes, such as those created after mining)
- effectively restore *degraded hillslopes*

More information:

- Hartmann, A., Semenova, E., Weiler, M., and Blume, T.: Field observations of soil hydrological flow path evolution over 10 Millennia, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2020-28, in review, 2020.

https://www.hydrol-earth-syst-sci-discuss.net/hess-2020-28/

- Hartmann, A., Weiler, M., and Blume, T.: The impact of landscape evolution on soil physics: Evolution of soil physical and hydraulic properties along two chronosequences of proglacial moraines (submitted to ESSD)