Machine learning in 4 dimensions for mapping soil organic matter changes between 1953-2021 at 25m resolution in the Netherlands

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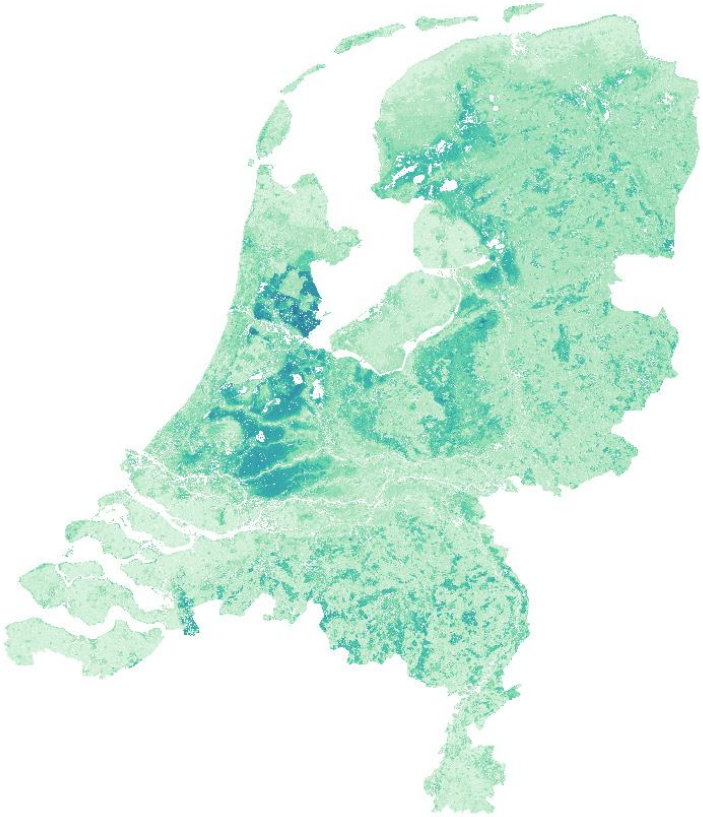

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Basisregistratie Ondergrond

Motivation

Including time in digital soil mapping (DSM):

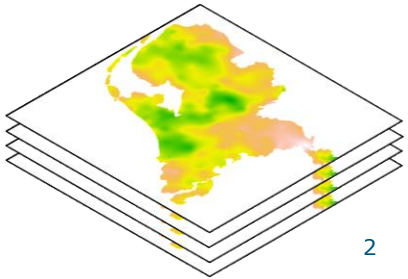
- DSM often assumes static soil observations & covariates
- But soil observations & covariates are dynamic (changing over time)
- Space-time DSM usually relies on remote sensing
- But soil legacy data often from 1950s-1980s

Aims:

- Account for temporal component in soil observations & covariates
- Assess changes in 3D space over time (> 65 years)
- "The key to the future lies in the past"

soil observations

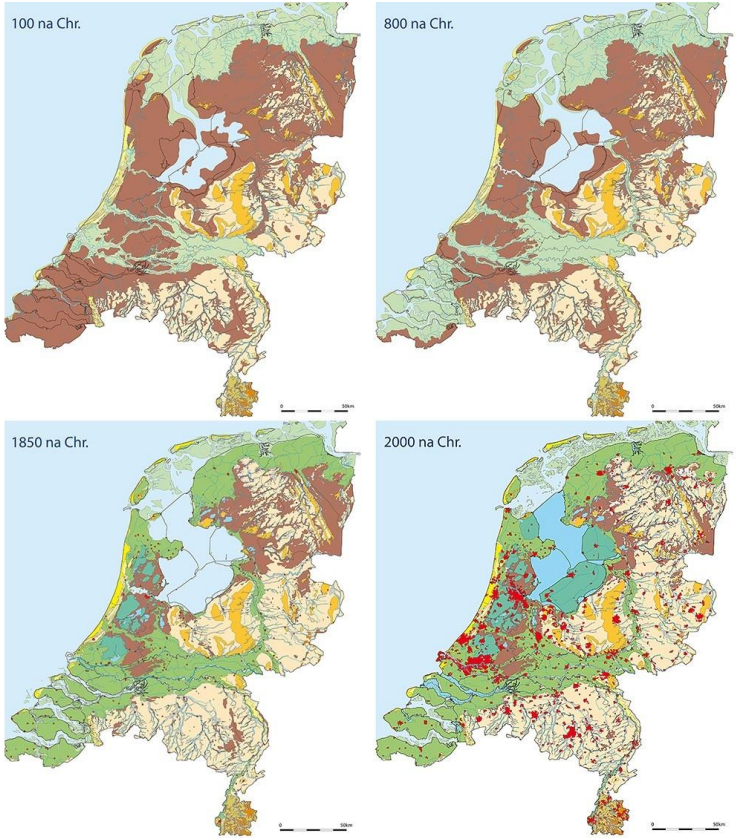
covariates



Motivation

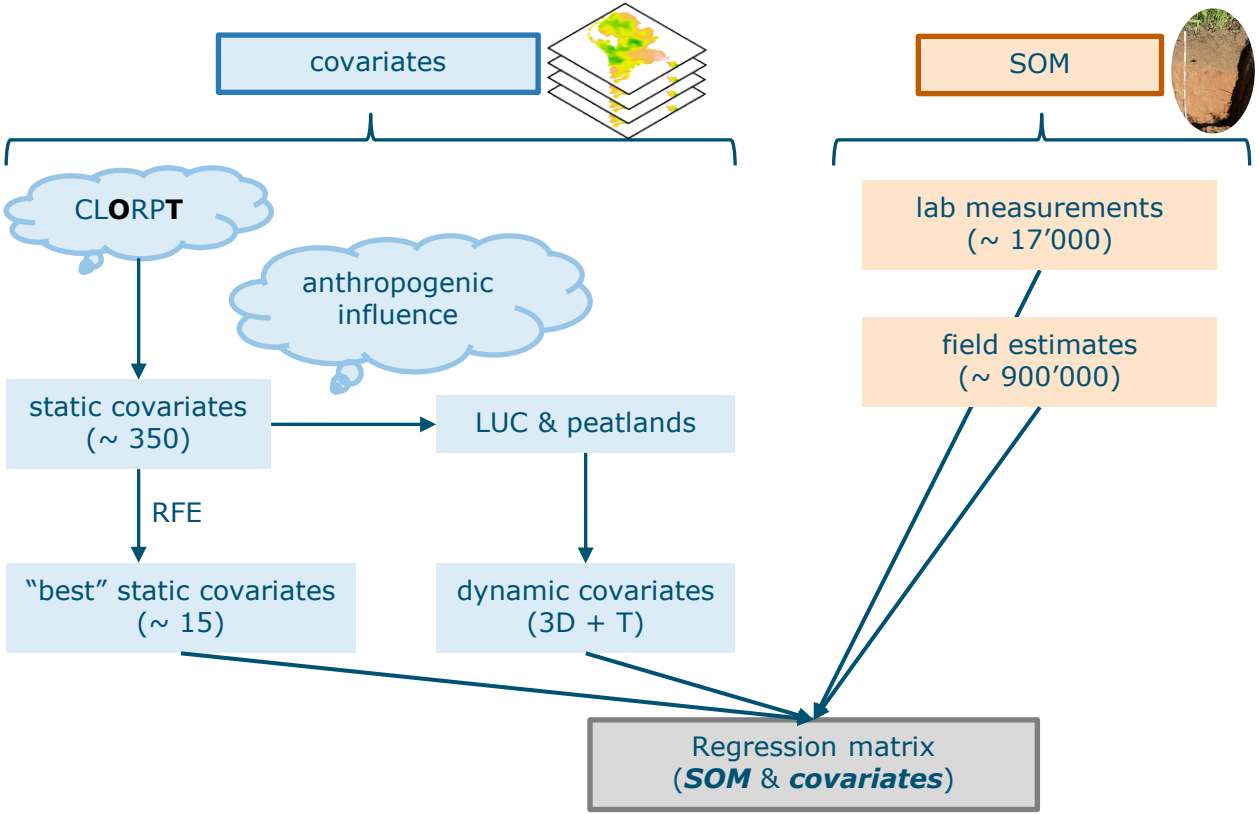
Soil organic matter (SOM):

- Soil fertility, C source/sink, ecosystem services…
- SOM is (temporally) dynamic
- SOM is especially relevant in NL:
  - ~ 15 % of land surface -> (managed) peatlands
  - ~ 20 % reclaimed from the sea
  - high groundwater levels
  - tremendous anthropogenic influence (~ 82 % agricultural & built up)
  - soils often disturbed or completely human-made



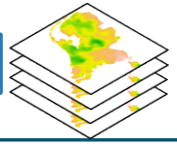
Atlas Holocene Netherlands

Methods


covariates
SOM
CLORPT
anthropogenic influence
lab measurements (~ 17'000)
field estimates (~ 900'000)
static covariates (~ 350)
LUC & peatlands
RFE
"best" static covariates (~ 15)
dynamic covariates (3D + T)
Regression matrix (SOM & covariates)

Methods

covariates



SOM

- machine learning
- map quality assessment
- prediction

CL**O**RP**T**

anthropogenic influence

static covariates (~ 350)

RFE

"best" static covariates (~ 15)

LUC & peatlands

dynamic covariates (3D + T)

lab measurements (~ 17'000)

field estimates (~ 900'000)

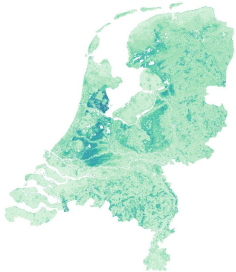
Regression matrix (***SOM*** & ***covariates***)

tuning hyperparameters

QRF calibration

statistical validation

soil maps (3D + T predictions)



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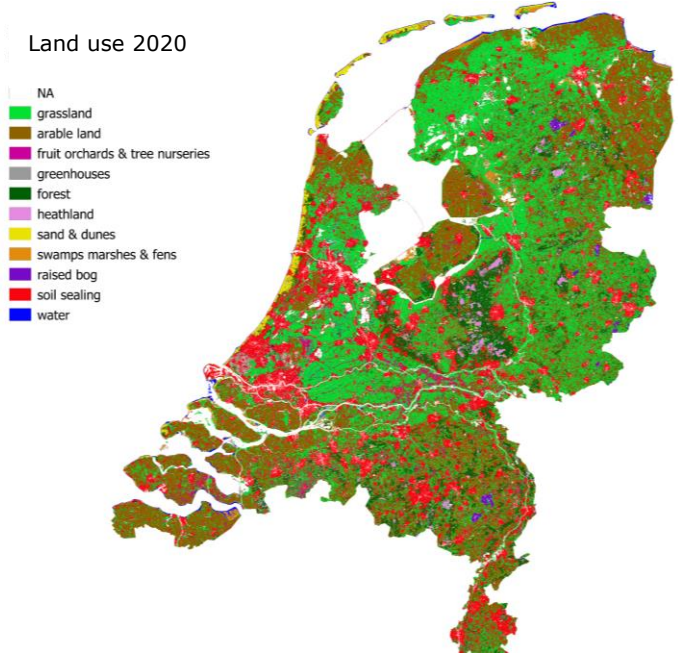
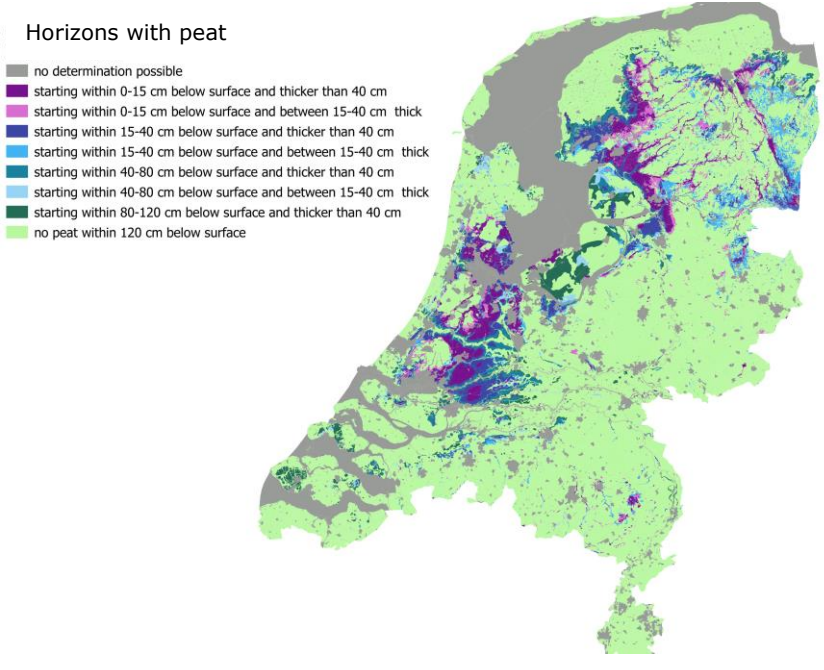
Covariates

- Static covariates (Helfenstein et al. 2022)
- Selection dynamic covariates over ~70 year period:

1. Land use changes (LUC)	2. Soil horizons with peat (drainage, oxidation, sand)

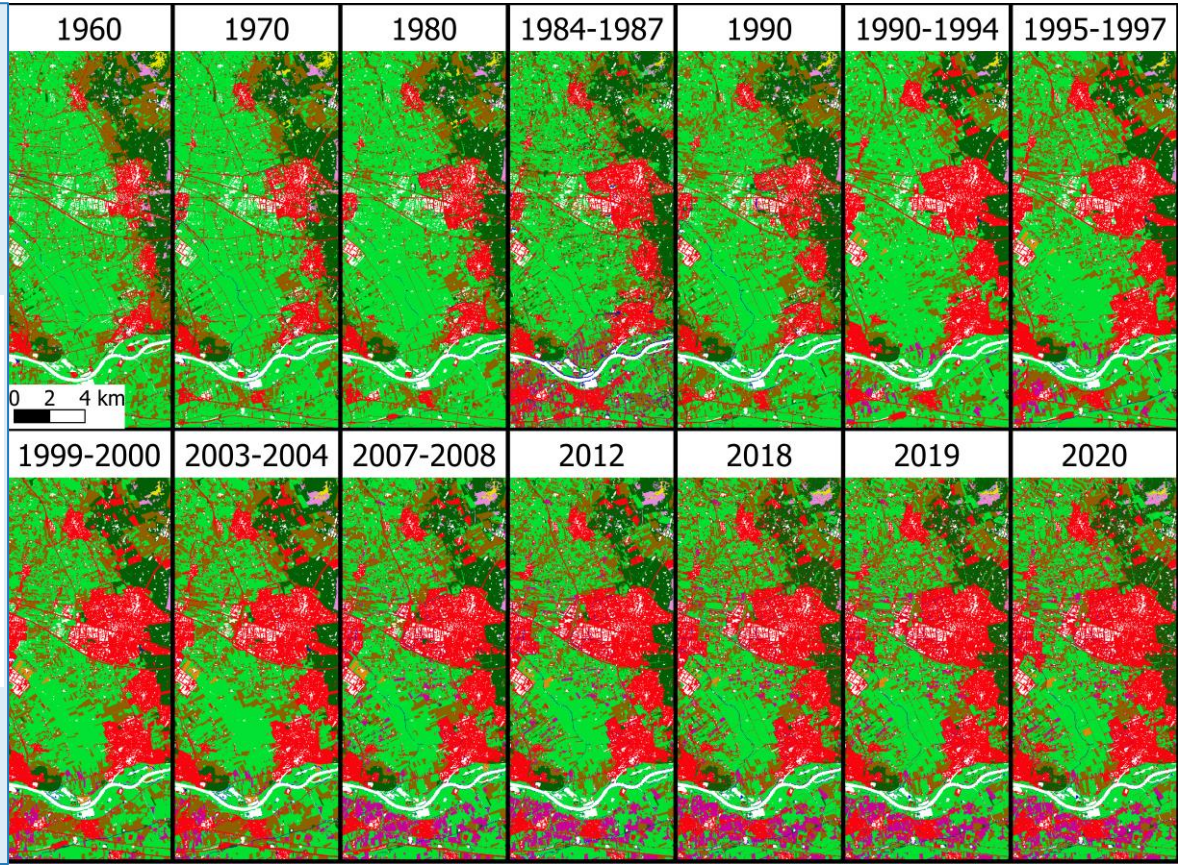




Dynamic covariates: land use

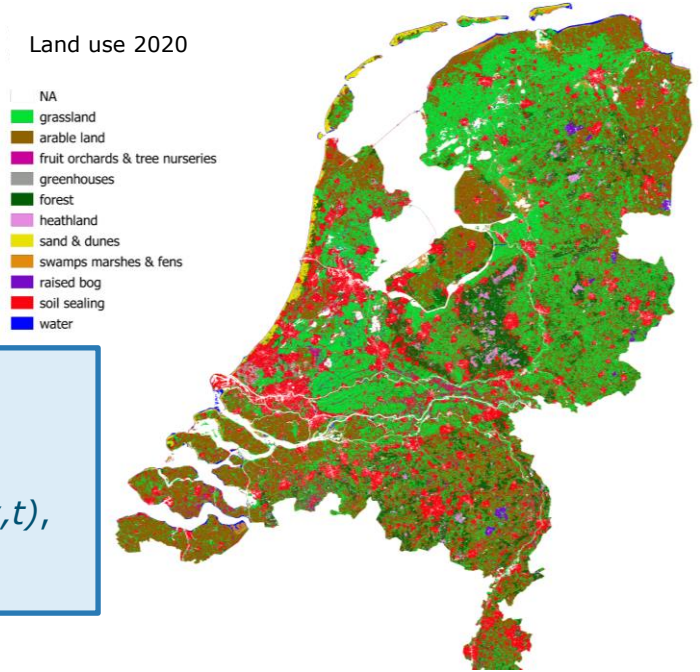
- Preparation of dynamic land use (LU) covariates:
  1. Assemble LU maps (1960-2020)
  2. Reclassify to common categories

  3. Fill in missing "gaps" using LU from closest year



Dynamic covariates: land use

- Preparation of dynamic land use (LU) covariates:
  1. Assemble LU maps (1960-2020)
  2. Reclassify to common categories
  3. Fill in missing "gaps" using LU from closest year
  4. Obtain covariate *LU(x,y,t)*, i.e. LU at location with coordinates ***x,y*** at time ***t*** (year of soil observation)
  5. Obtain additional covariates *LU_Δ5(x,y,t)*, *LU_Δ10(x,y,t)*, *LU_Δ20(x,y,t)* and *LU_Δ40(x,y,t)*

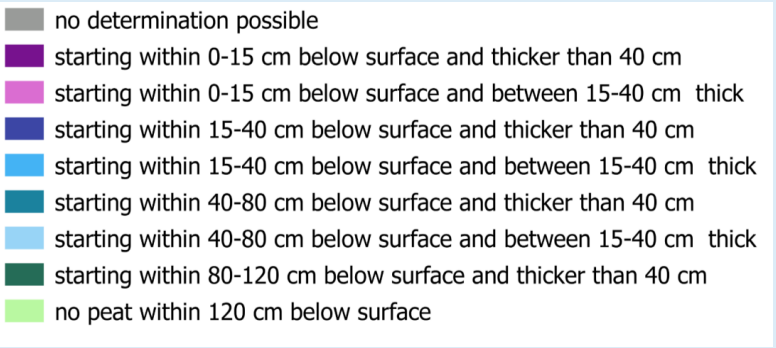


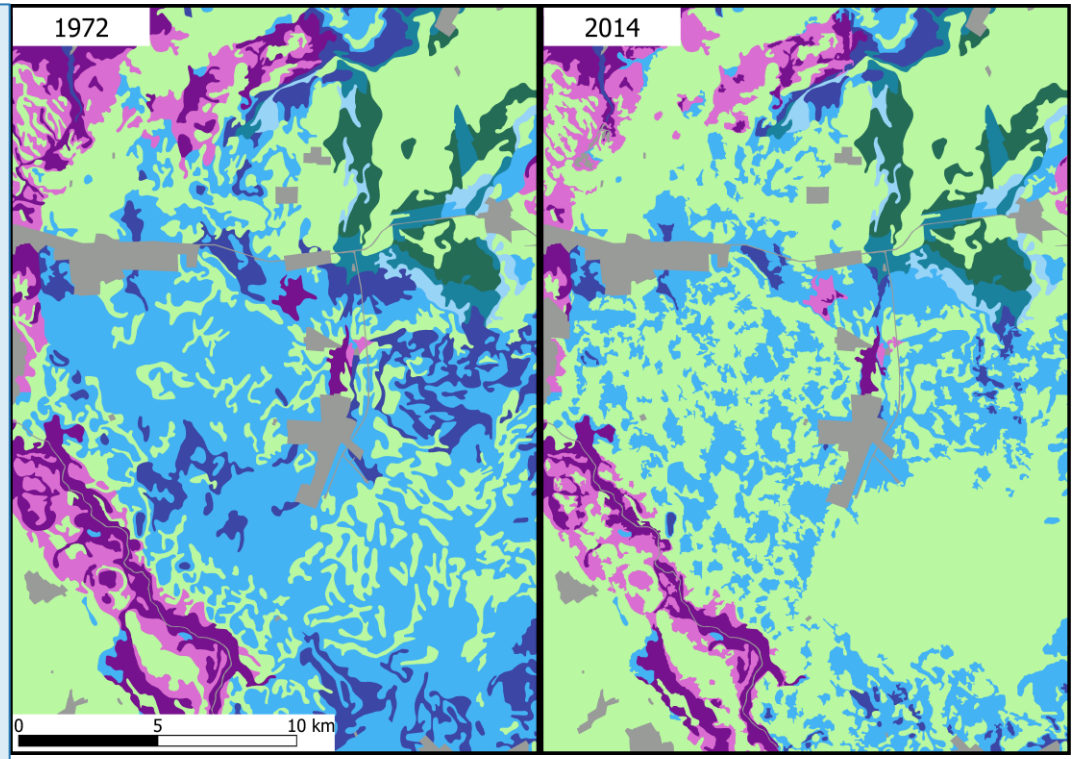
Dynamic covariates: peat horizons

- Preparation of dynamic peat horizon covariates:

1. Assemble national soil type maps: original (1960-1995) & updated (2014-2021)

2. Reclassify to common categories by:
   a) **Starting depth of peat horizon**
   b) **Thickness of peat horizon**

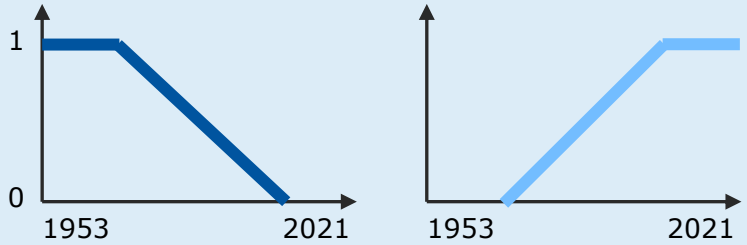


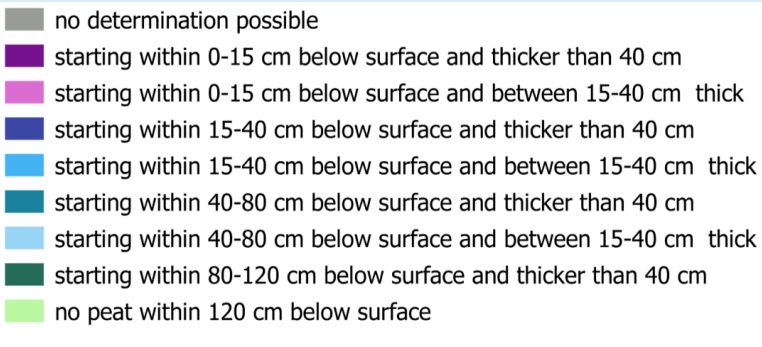


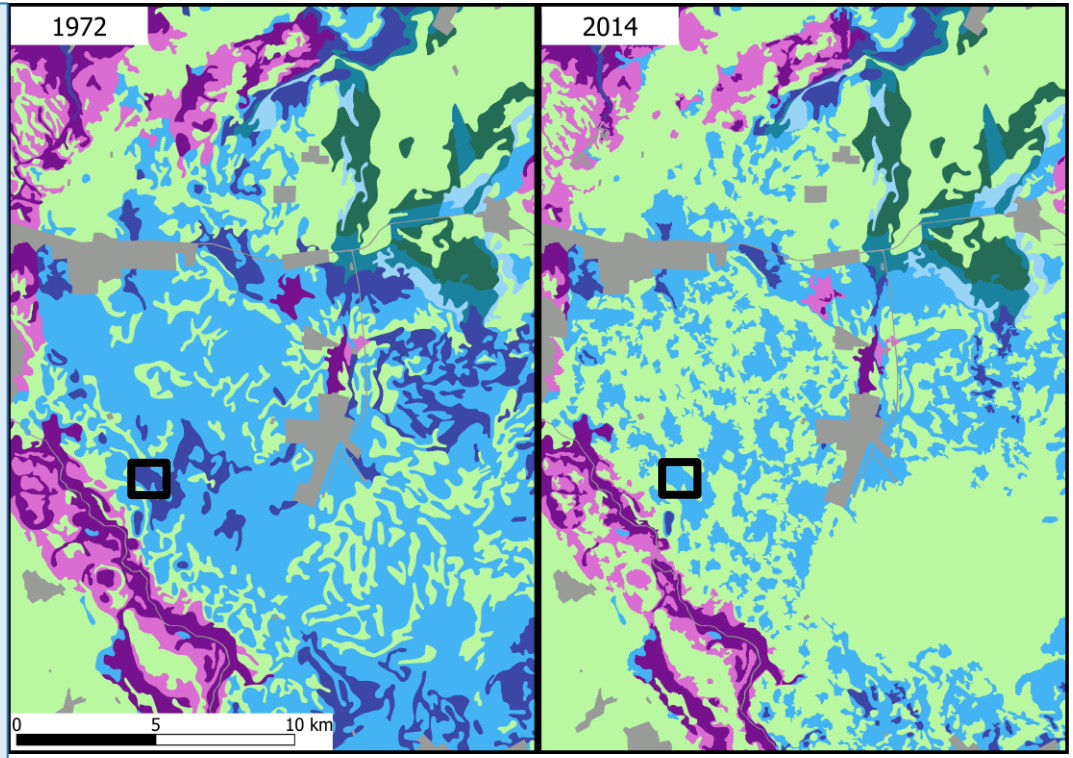
Dynamic covariates: peat horizons

- Preparation of dynamic peat horizon covariates:

  3. Fill in missing "gaps" using **fuzzy membership**







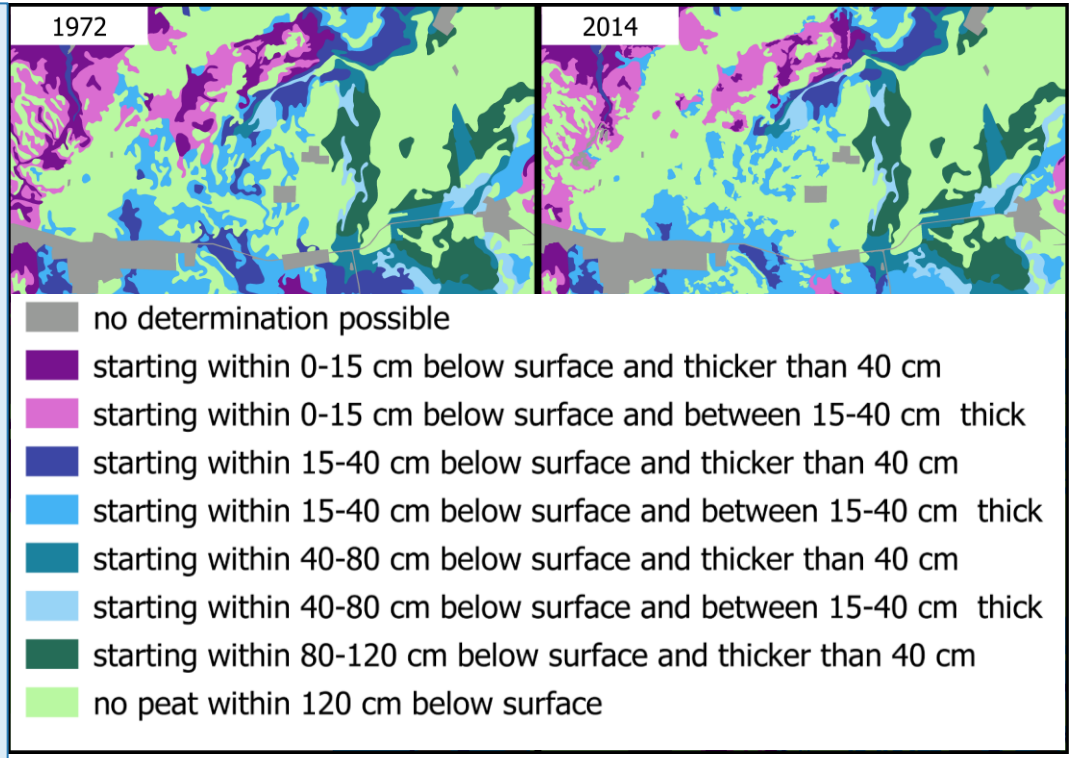
Dynamic covariates: peat horizons

- Preparation of dynamic peat horizon covariates:

  3. Fill in missing "gaps" using **fuzzy membership**

  4. Obtain *peat_class1(x,y,t), …., peat_class9(x,y,t)*, i.e. fuzzy membership peat class at location with coordinates ***x,y*** at time ***t*** (year of soil observation)

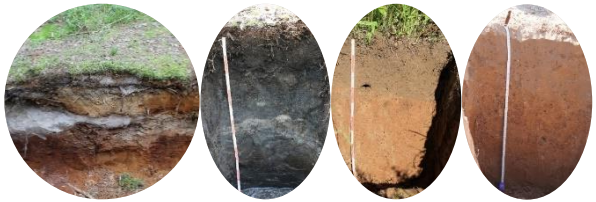
  5. Obtain *peat_class1(x,y,**d**,t), …., peat_class7(x,y,**d**,t)*, i.e. fuzzy membership peat class at location with coordinates *x,y* at **depth *d*** & time *t* (year of soil observation)

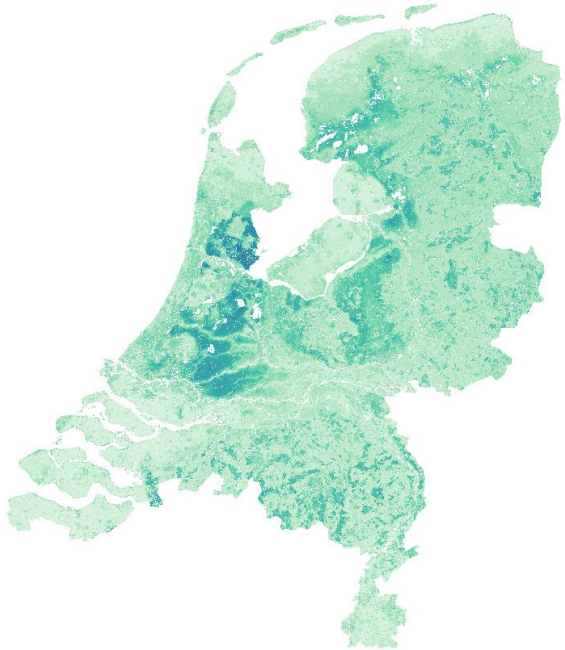


Thank you for your attention!

- anatol.helfenstein@wur.nl
- https://github.com/anatol-helfenstein

- "BIS-4D" project website
- Video pitch: https://www.youtube.com/watch?v=ENCYUnqc-wo





References:

- Helfenstein, A., Mulder, V.L., Heuvelink, G.B.M., Okx, J.P., 2022. Tier 4 maps of soil pH at 25 m resolution for the Netherlands. *Geoderma* 410, 115659. https://doi.org/10.1016/j.geoderma.2021.115659

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