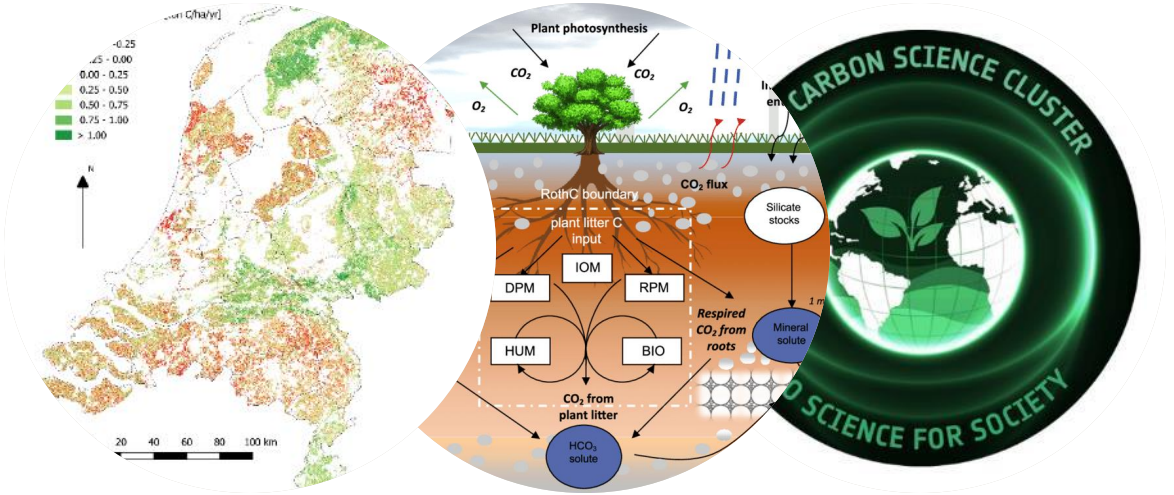
EO4CSM – A case study for the Netherlands

An **E**arth **O**bservation framework for soil **C**arbon **S**equestration **M**onitoring (EO4CSM)

Wouter Meijninger[1], Jan Peter Lesschen[2], Chantal Hendriks[2], Allard de Wit[1], Gerbert Roerink[1] and Johnny te Roller[1]

WUR: [1]Team Earth Observation and Environmental Informatics; [2]Team Sustainable Soil Management

09-10-2025 – EO for MRV (EEA, ESA) Copenhagen



CARBON CYCLE SCIENCE

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EO4CSM - Project Team

- Wageningen Environmental Research (WENR)
  - Research institute within Wageningen University & Research (WUR)

- WENR - Team Earth Observation and Environmental Informatics
  - Wouter Meijninger, Gerbert Roerink, Allard de Wit and Johnny te Roller

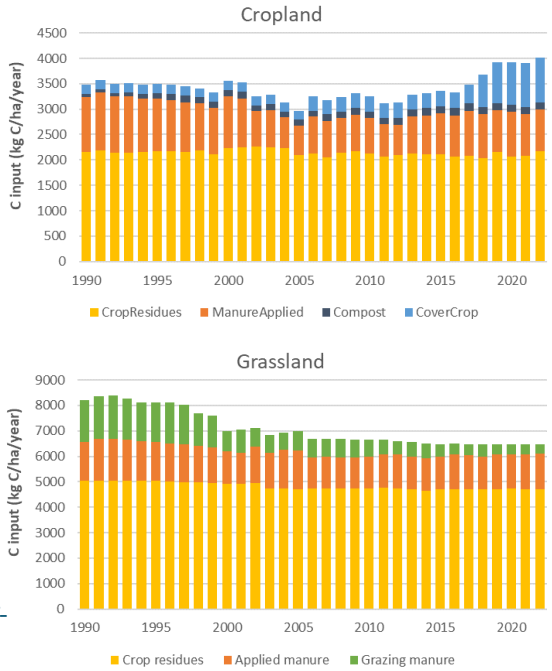



- WENR - Team Sustainable Soil Management
  - Jan Peter Lesschen and Chantal Hendriks

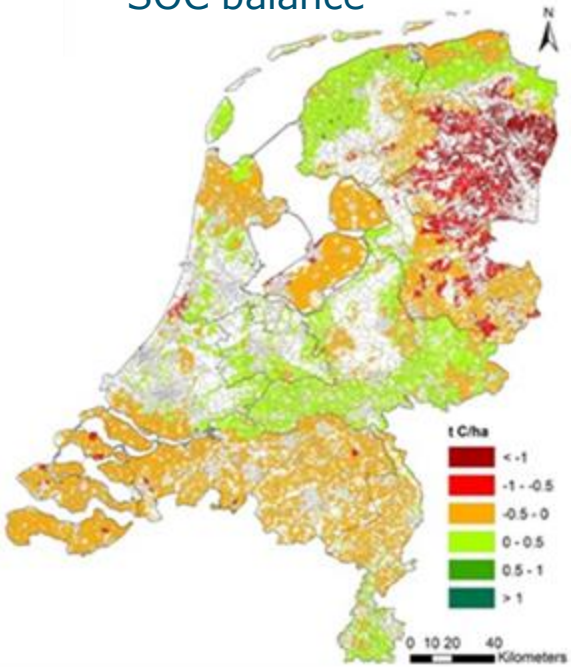

GHG Reporting LULUCF sector - Netherlands

- **Carbon stock changes in mineral soils** for **cropland** (remaining cropland) and **grassland** (remaining grassland) under agricultural to account for soil management practices that enhance carbon sequestration
- Tier 3 approach, soil carbon model **RothC**, ZIP code level (~3400 units)

C-input



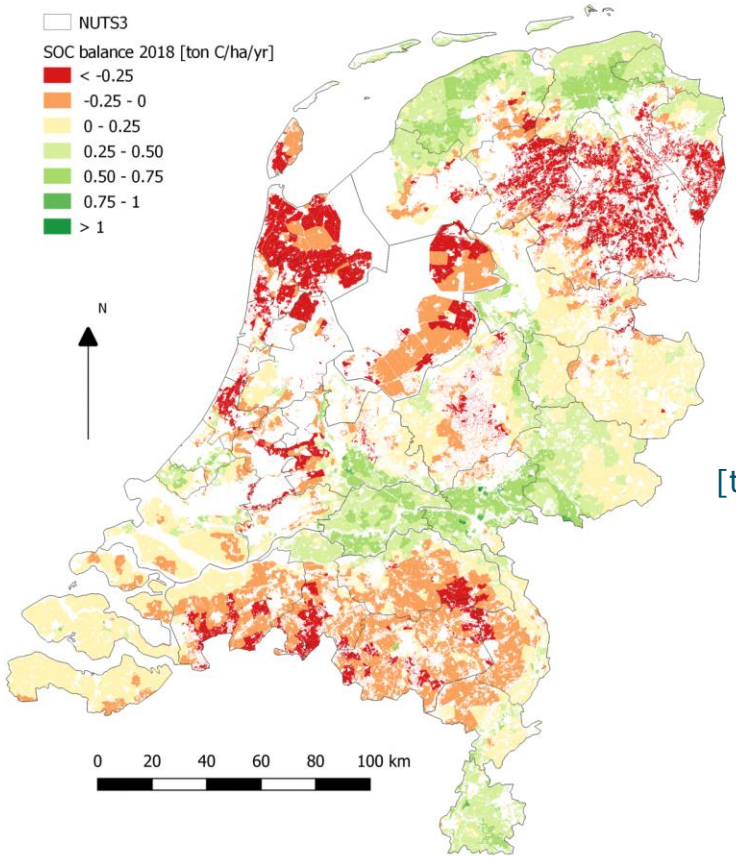
SOC balance



van Baren, S. A., Arets, E. J. M. M., Hendriks, C. M. J., Kramer, H., Lesschen, J. P., & Schelhaas, M. J. (2024). Greenhouse gas reporting of the LULUCF sector in the Netherlands: Methodological background, update 2024. (WOT-technical report; No. 255). WOT Natuur & Milieu. https://doi.org/10.18174/648278

Inputs RothC – GHG reporting LULUCF

- Monthly vegetation cover (fixed tables)
- C-inputs from:
  - Manure, compost (prov.)
  - Crop residues:
    - Grassland (3 classes, fixed values)
    - main arable crops (LPIS → ZIP, fixed values per crop)
    - cover crops (LPIS → ZIP, fixed values per crop)



Annual SOC balance [ton C/ha/yr] 2018-2022

EO4CSM – main goal

Develop a methodology that can improve the national monitoring of carbon (C) sequestration of agricultural soils.

The methodology, based on LULUCF-NL methodology (van Baren et al., 2024):

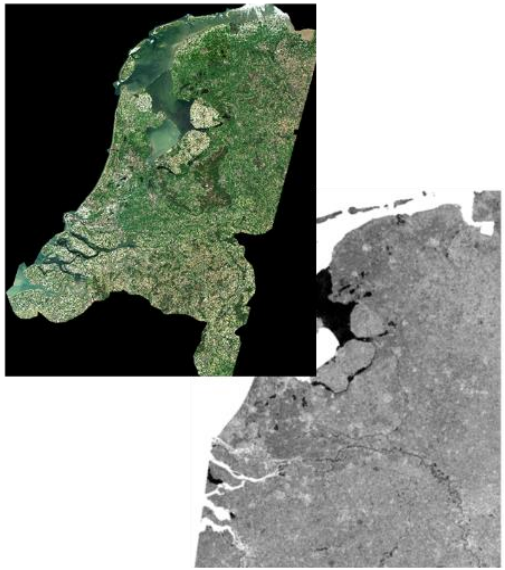
- Dynamic carbon turnover model RothC coupled with EO-data @ parcel level (LPIS)
- Exploits strengths of both RothC model, LPIS and EO-data:
    - RothC: model to simulate the turnover of organic C in arable topsoil (Rothamsted long-term field experiments). Rel. simple model, easy to use, requires little input data, widely used and scientifically acknowledged.
    - EO-data: rel. simple indicators, easy to derive from satellite imagery (Sentinel-2, Sentinel-1), BUT highly relevant for monitoring carbon sequestration:
        - more realistic, more accurate, and at higher resolution than most national data sources currently used
- Combined: monitor SOC balance at parcel level - country wide

Improvements (based EO and LPIS)

1. From ZIP-level to LPIS field level
    - EO-data @ field level
2. Updated RothC-inputs, based on EO-data at field level
    - Monthly vegetation cover
    - Updated C-input from grassland
        - Updated grassland classification
    - Updated C-input cover crops:
        - Presence of cover crops & growing season (SOS, EOS)
        - Estimate C-input
            - supported with Crop modelling (LINTUL, fAPAR timeseries)
            - LINTUL: Light INTensity UtiLisation

RS data processing & LPIS

Sentinel-2 **images** (10m NDVI, reflectances)
2018 - 2024



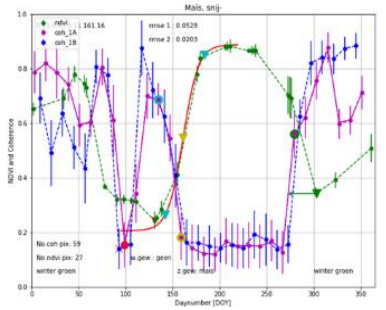
Sentinel-1 **images** (20m coherence)
2018 - 2024

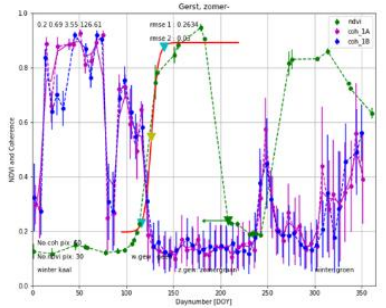
Parcels (LPIS)
2018 - 2024

Time series:

- NDVI (mean + std)
- Reflectances (mean + std)
- Coherence (mean + std)

for all LPIS parcels

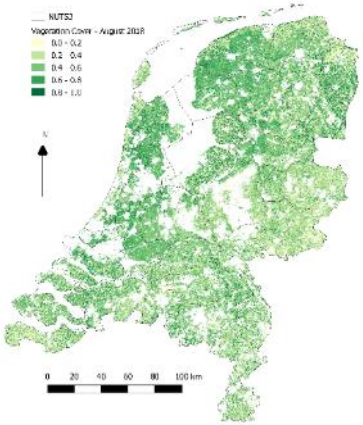




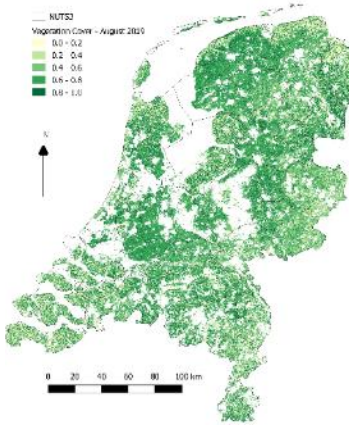
https://agrodatacube.wur.nl/

1:Monthly vegetation cover

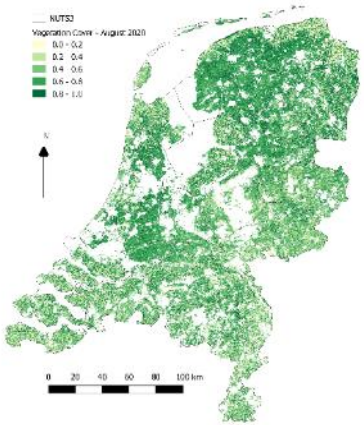
August 2018



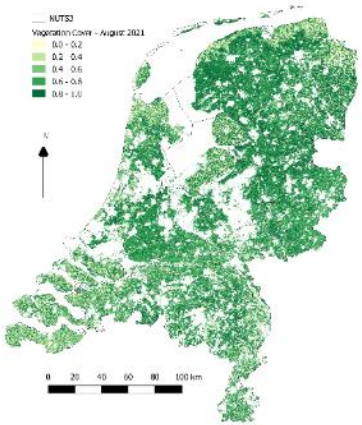
August 2019



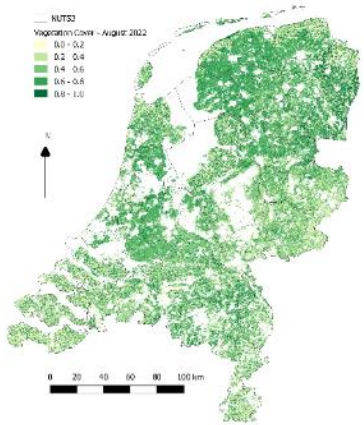
August 2020



August 2021



August 2022



Timeseries reflectances → Sen2Cor (biophysical parameters) LAI, fCover, fAPAR
→ Monthly fCover at field level → rescaled to RothC requirements
EO-data introduces variations in space and time, and includes cover crops

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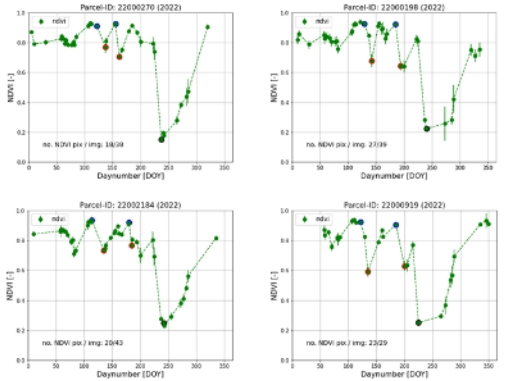
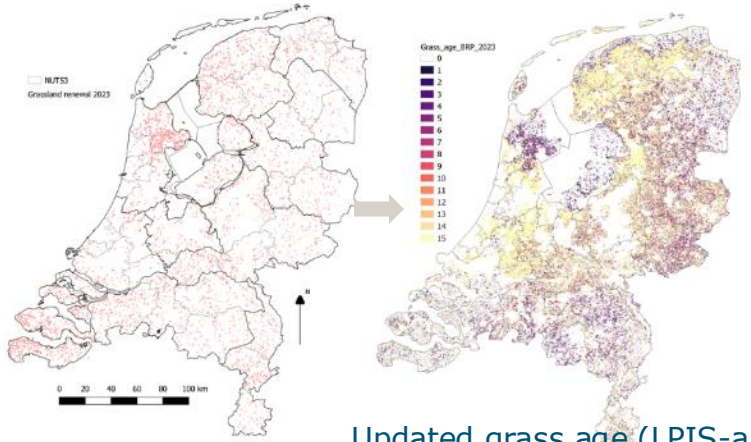
2: C-input crop residues grassland

- LPIS grassland classes
  - Natural grassland (C-input 5.1 ton C/ha/yr)
  - Permanent grassland (C-input 5.1 ton C/ha/yr)
  - Temporary grassland (C-input 3.4 ton C/ha/yr)



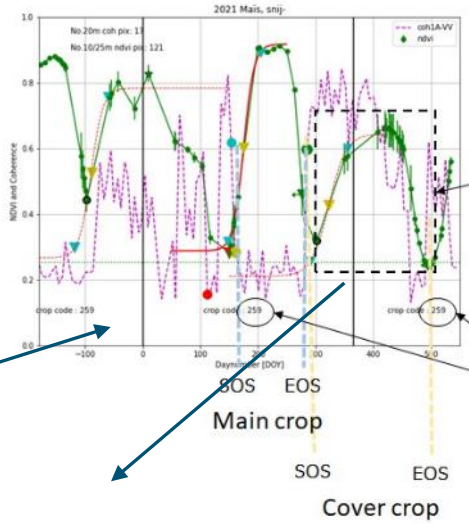
- NDVI-time series: detect grassland renewal activities
  - Typically, ~6000 fields per year
  - LPIS archive (2009) → grass age
- Updated C-input:
  - 1 year: 1.7 ton C/ha/yr
  - 2 year: 3.4 ton C/ha/yr
  - >2 year: 5.1 ton C/ha/yr



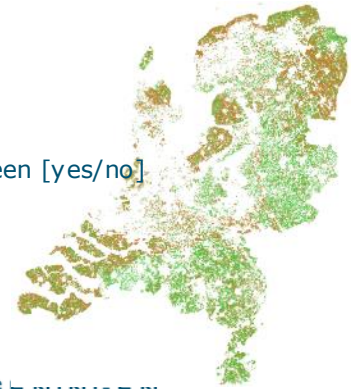
Updated grass age (LPIS-archive)

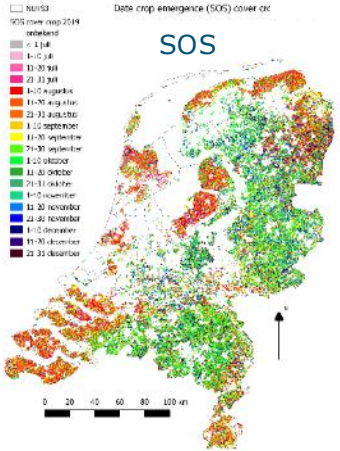
2: C-input cover crops

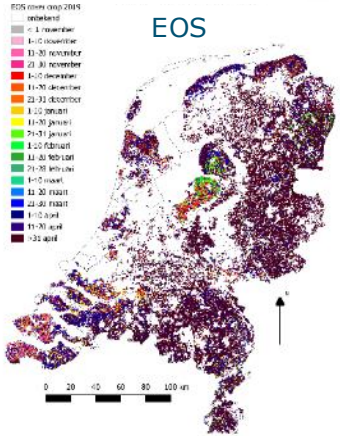
- LPIS 2nd crops
  - LPIS is incomplete
  - Fixed C-input per cover crop
- EO-detection of cover crops
  - NDVI-time series [yes/no]
  - SOS, EOS, AUC



Winter green [yes/no]







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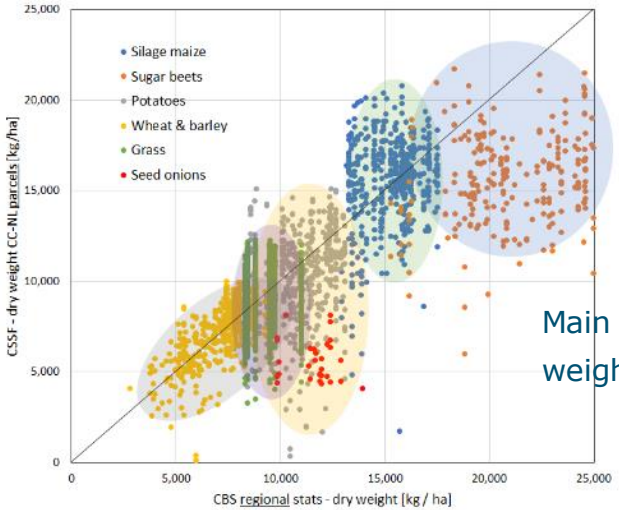
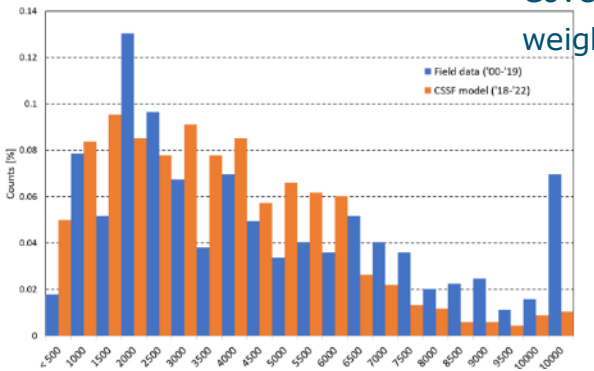
Crop modelling

- Limited to 600 fields
- LINTUL (Light INTensity UtiLisation) model:
  - "Off the shelf crop parametrizations"
  - SOS, EOS
  - *Modified*, EO - fAPAR time series
- Main crops:
  - potatoes, silage maize, sugar beets, onions, grassland, s/w wheat and barley
  - cover crops, parametrization

Cover crop	***Related main crop***	***Plant family***
Fodder radish (bladrammenas)	Rapeseed	Brassicaceae
Yellow musterd (gele mosterd)	Rapeseed	Brassicaceae
Other cover crops (green manures)	Unknown, rapeseed is used	
Italian grass	English ryegrass	*Gramineae*
Westerwolds ryegrass	English ryegrass	*Gramineae*
English ryegrass	English ryegrass	*Gramineae*
Japanese oats	Spring barley	*Gramineae*
Winter rye	Winter-wheat	*Gramineae*



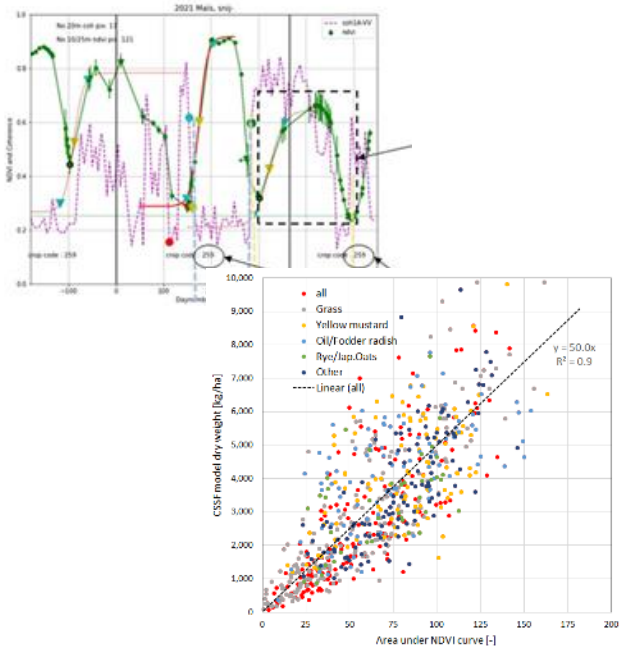
Main crops – dry weight [kg ha^{-1}]

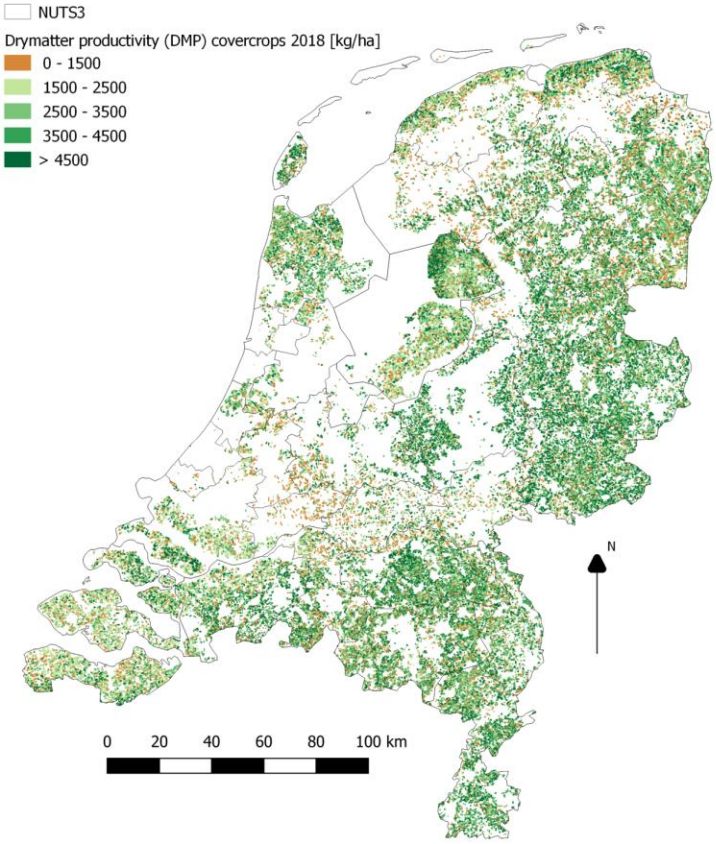


Cover crops – dry weight [kg ha^{-1}]

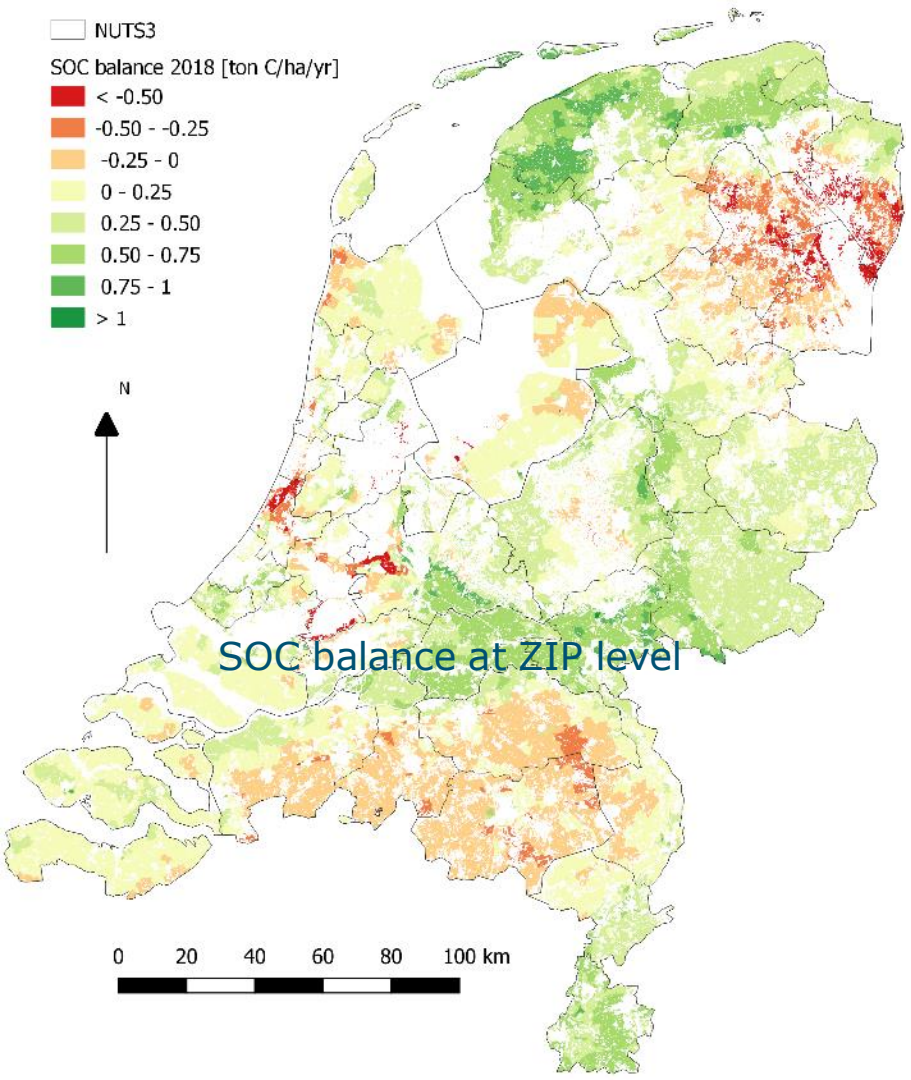
Selin Noren, I., van Geel, W., de Haan, J. (2021) Cover crop reference values: effective organic matter and nitrogen uptake, Wageningen Research, Report WPR 877. https://doi.org/10.18174/544859

C-input cover crops @ national level

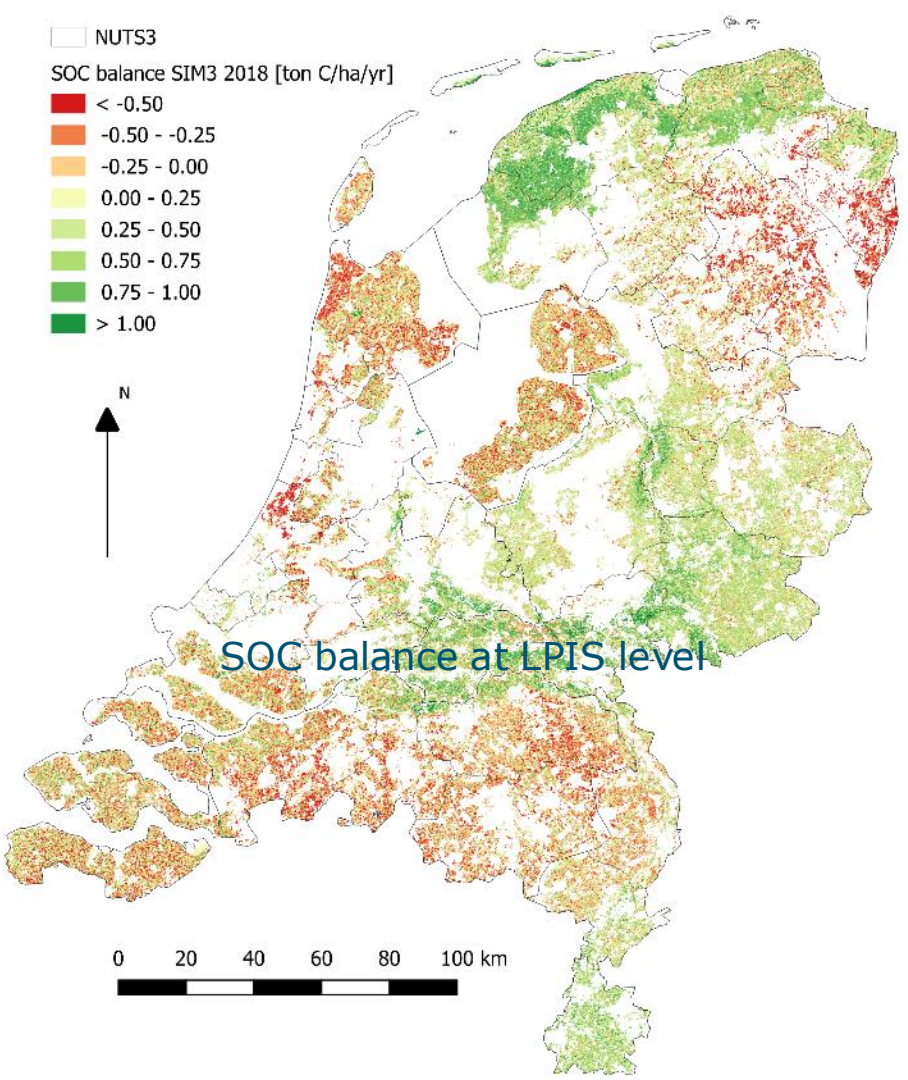




Based on 7 years, different crops

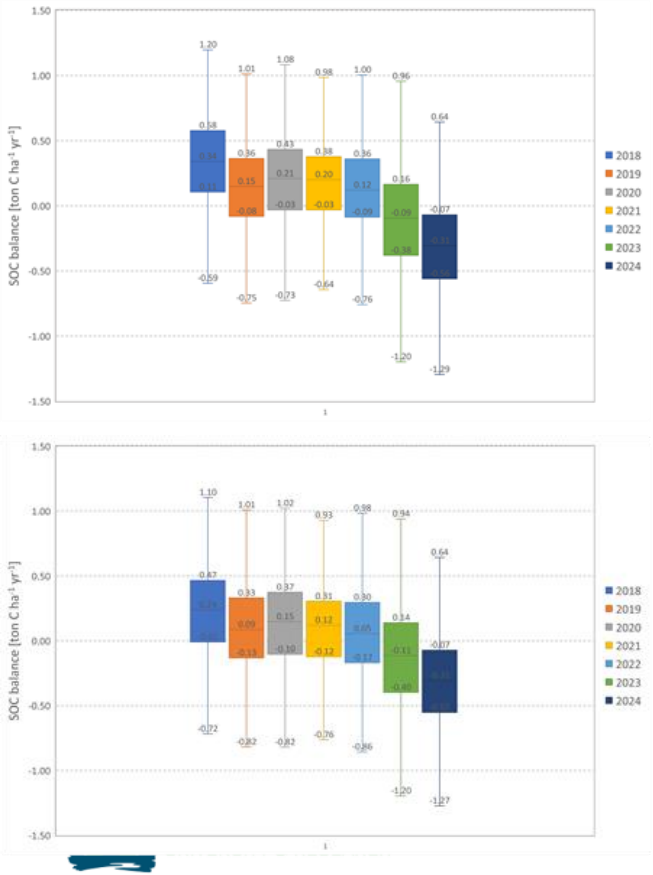


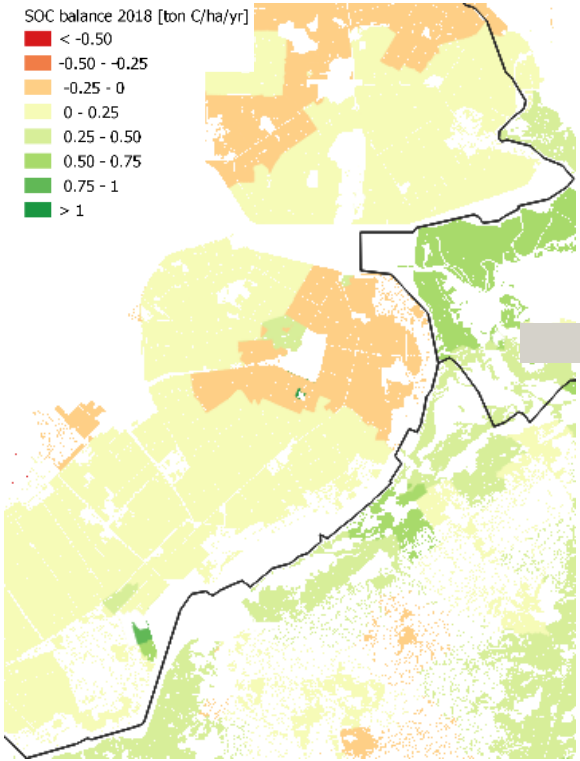
SOC balance at ZIP level

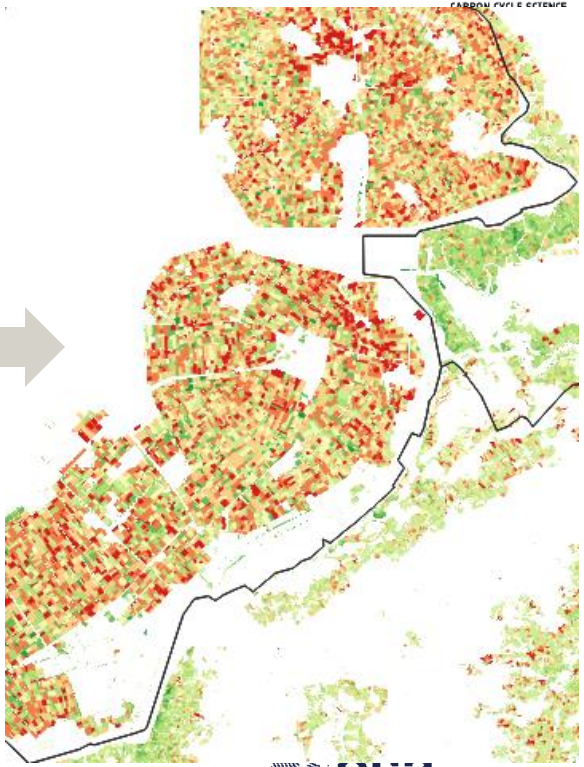


SOC balance at LPIS level

Current versus updated method







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Conclusions

- Successfully downscaled SOC simulations to LPIS field level
    - RothC enriched with EO-data:
        - monthly VC, updated C-input from grassland and cover crops
- Results at national level are comparable
    - Impact RS is small (RothC @ ZIP-level ≅ RothC + EO @ field-level)
        - On average EO-based C-inputs are similar to RothC default values
    - BUT show much more detail (in space and time)
    - Opens new applications such as MRV-like monitoring system

- Next steps:
    - Validation of RothC simulations (~600 fields) based on SOC field measurements

Thank you

Wouter Meijninger

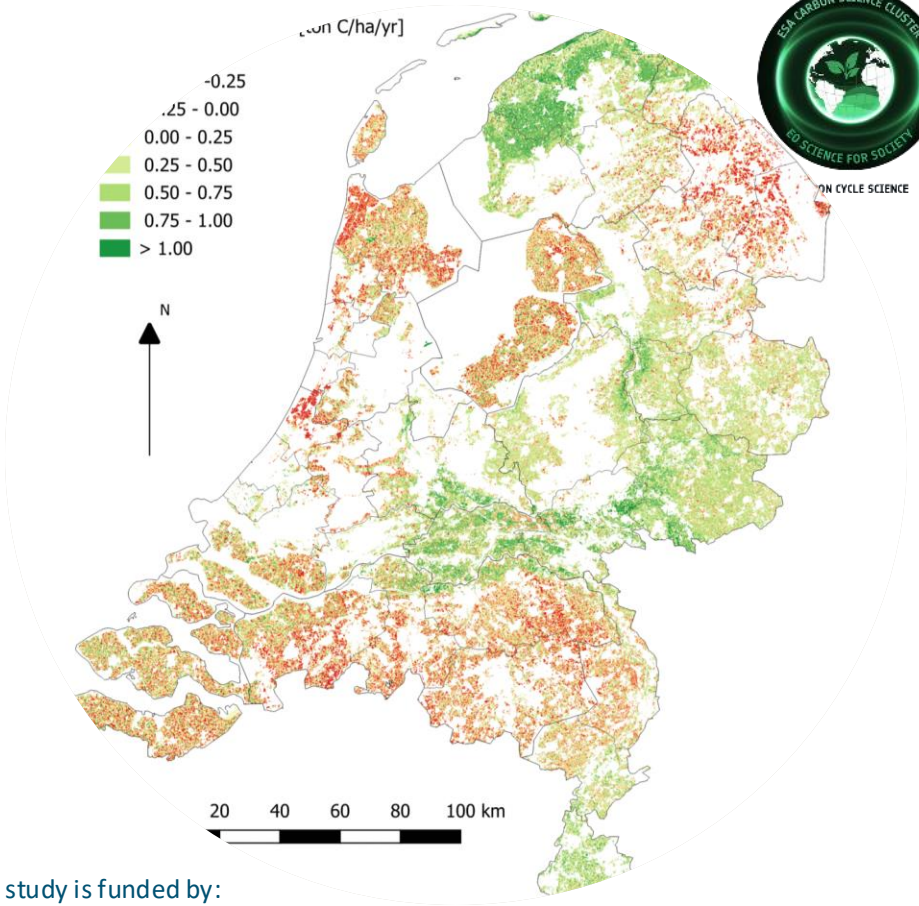
wouter.meijninger@wur.nl

More information?

ArcGis Storymap:

+ Poster

SCAN ME



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