The implication of input data aggregation on upscaling of soil organic carbon changes

Grosz, Balázs[1]; Dechow, Rene[1]; Hoffmann, Holger[2]; Zhao, Gang2; Constantin, Julie[3]; Raynal, Helene[3]; Wallach, Daniel[3]; Coucheney, Elsa[4]; Lewan, Elisabet[4]; Eckersten, Henrik[5]; Specka, Xenia[6]; Kersebaum, Kurt-Christian[6]; Nendel, Claas[6]; Kuhnert, Matthias[7]; Yeluripati, Jagadeesh[8]; Kiese, Ralf[9]; Haas, Edwin[9]; Klatt, Steffen[9]; Teixeira, Edmar[10]; Bindi, Marco[11]; Trombi, Giacomo[11]; Moriondo, Marco[12]; Doro, Luca[13]; Roggero, Pier Paolo[13]; Zhao, Zhigan[14]; Wang, Enli[14]; Vanuytrecht, Eline[15]; Tao, Fulu[16]; Rötter, Reimund[16]; Cammarano, Davide[17], Asseng, Senthold[17]; Weihermüller, Lutz[18]; Siebert, Stefan[2]; Gaiser, Thomas[2]; Ewert, Frank[2]

[1]*Thünen-Institute of Climate-Smart-Agriculture, Bundesallee 50, 38116 Braunschweig, DE*

[2]*Institute of Crop Science and Resource Conservation/Crop Science Group, University of Bonn, Katzenburgweg 5, 53115 Bonn, DE*

[3]Equipe MAGE, INRA, 24 Chemin de Borde Rouge – Auzeville CS 5267, 31326 Castanet-Tolosan Cedex, FR

[4]Biogeophysics and water quality, Department of Soil and Environment, Swedish University of Agricultural Sciences, Lennart Hjelms väg 9, 750 07 Uppsala, SE

[5]Department of Crop Production Ecology, Swedish University of Agricultural Sciences, *Ulls väg 16, 750 07 Uppsala, SE*

[6]*Institute of Landscape Systems Analysis, Leibniz Centre for Agricultural Landscape Research, 15374 Müncheberg, DE*

[7]*Biological and Environmental Sciences, School of Biological Sciences, University of Aberdeen, 23 St Machar Drive, Aberdeen AB24 3 UU, Scotland, UK*

[8]*The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8 QH, UK*

[9]*Institute of Meteorology and Climate Research – Atmospheric Environmental Research, Karlsruhe Institute of Technology, Kreuzeckbahnstraße 19, 82467 Garmisch-Partenkirchen, DE*

[10]*Systems Modelling Team (Sustainable Production Group), The New Zealand Institute for Plant and Food Research Limited, Canterbury Agriculture & Science Centre, Gerald St, Lincoln 7608, NZ*

[11]*Department of Agri-food Production and Environmental Sciences - University of Florence, Piazzale delle Cascine 18, 50144 Firenze, IT*

[12]*Marco Moriondo, CNR-Ibimet, Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy*

[13]*Desertification Research Group, Universitá degli Studi di Sassari, Viale Italia 39, 07100 Sassari, IT*

[14]*CSIRO Land and Water, Clunies Ross Street, Canberra, ACT, AU*

[15]*Division Soil & Water Management, KU Leuven, Celestijnenlaan 200E, PO 2411, 3001 Heverlee, BE*

[16]*Climate Impacts Group, Natural Resources Institute Finland (Luke), 00790 Helsinki, FI*

[17]*Agricultural & Biological Engineering Department, University of Florida, Frazier Rogers Hall, Gainesville, FL 32611, USA*

[18]*Institute of Bio- & Geosciences Agrosphere (IBG-3), Forschungszentrum Jülich, 52425 Jülich, DE*

MACSUR Project - Modelling European Agriculture with Climate Change for Food Security

Scop of the project:

- How do soil properties (SOC) and yield security interact
- Where are the vulnerable regions for SOC and yield security for climate scenarios
- How does the quality of soil, meteo and managament data affect risk analyses

Crop M group – scaling exercise

- Integration of biophysical, economic and climate models
- The upscaling of ecological models has resulted in errors and uncertainty that are not determined/quantified.
- Accurate assessment of scaling methods could help in understanding and estimating of the quantity of the error. Therefore it helps to quantify the uncertainty in applying ecological models for larger area.

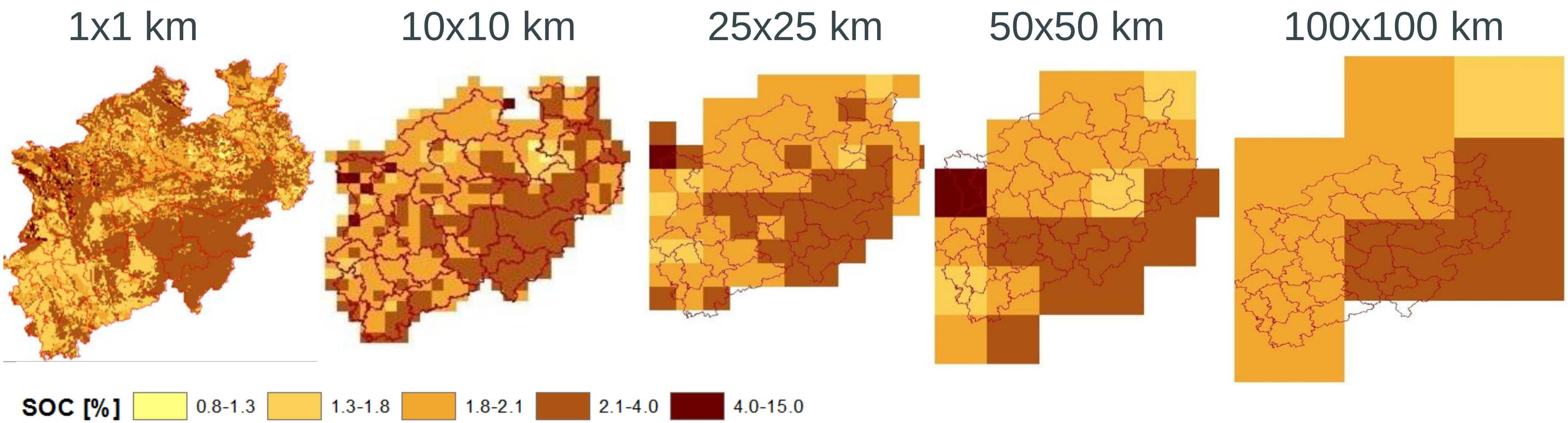
Applied models

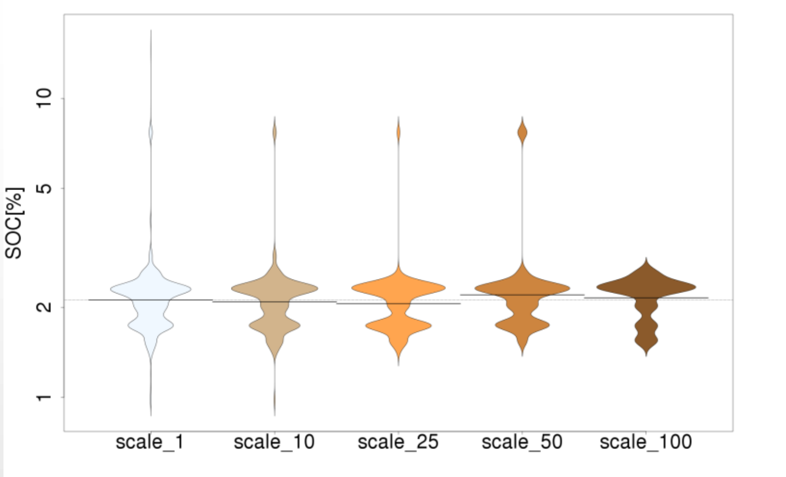
DAYCENT	three different pools, two active pools, a fast, a slow and a passive pool	The decomposition controlled by modifiers based on nitrogen availability, soil water content and temperature.
COUP	The soil is divided into several organic pools for carbon and nitrogen. Some of these pools are compulsory while others can optionally be switched on or off.	Soil moisture, temperature; substrate controlled and follows first-order kinetics
HERMES	The nitrogen pools for mineralization are calculated based on the Corg content and the CN ratio. The nitrogen pools described below and calculated the Corg assuming that the CN ratio remains constant.	Corg content and the CN ratio depending on temperature and soil moisture, crop residues and manure.
MONICA	Soil carbon dynamics is described using three pairs (rapid and slow turn-over) of conceptional pools (soil organic matter, microbial biomass and freshly added organic matter).	soil temperature and moisture and describe the environemntal conditions of the simulated site. Microbial biomass death and respiration rates are additionally influenced by soil clay content
STICS	The fresh organic matter, the microbial biomass and humified organic matter, the last compartment being composed of an active and an inert fraction.	C:N ratio, soil temperature and water content, and four parameters: the humification constant, the decomposition rate constant of the residues, the decay rate of the microbial biomass and the assimilation yield of residue-C by the microbial biomass.
APSIM	APSIM simulates the SOC in three pools: fresh organic matter pool (FOM), microbial biomass pool (BIOM), and humic matter pool (HUM)	Decomposition rates of each pool are mainly influenced by soil temperature and moisture.
CENTURY	three different pools, two active pools, a fast, a slow and a passive pool	The decomposition controlled by modifiers based on nitrogen availability, soil water content and temperature.

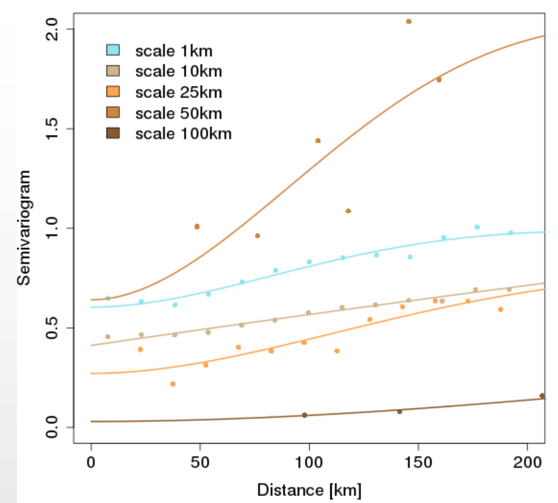
Scaling and aggregation steps

- **Resolutions: 1x1km, 10x10km, 25x25km, 50x50km, 100x100km**
- **Variable soil properties; constant climate and management ; cropland is assumed to completely cover Nordhrein Westfalia (NUT2).**
- **Variable climate; constant soil properties and management; cropland is assumed to completely cover Nordhrein Westfalia**
- **Soil properties: dominant soil**
- **Weather: mean values**
- **Scenarios: <u>Nitrogen-water limited</u>,** water unlimited, nitrogen-water unlimited
- **Time period: 1982-2012**
- **Modeled crops: maize, wheat**

Soil properties – SOC 30cm (%)

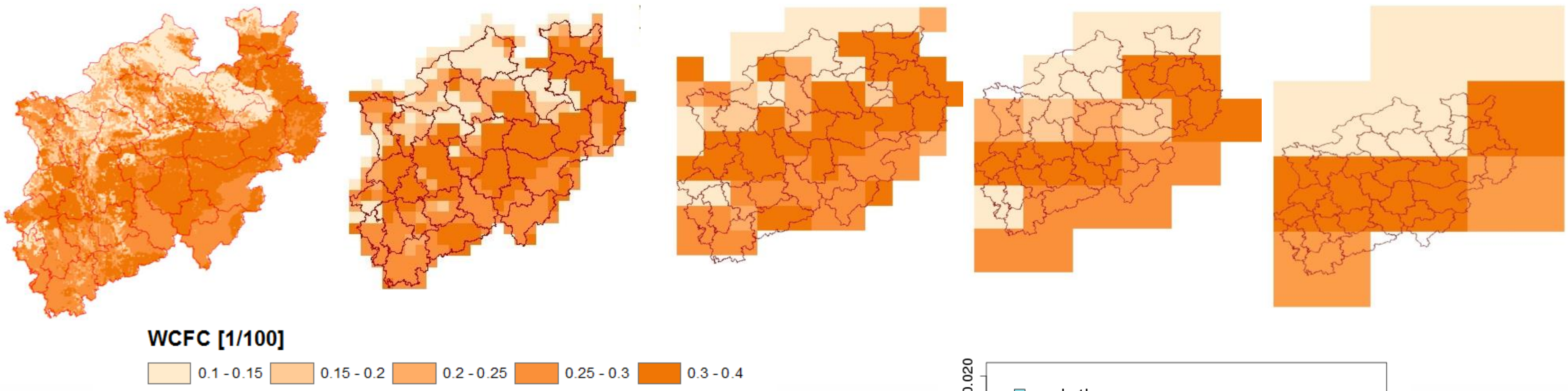


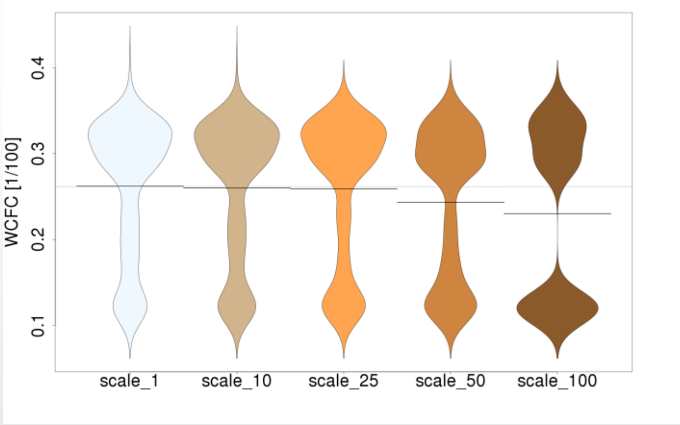


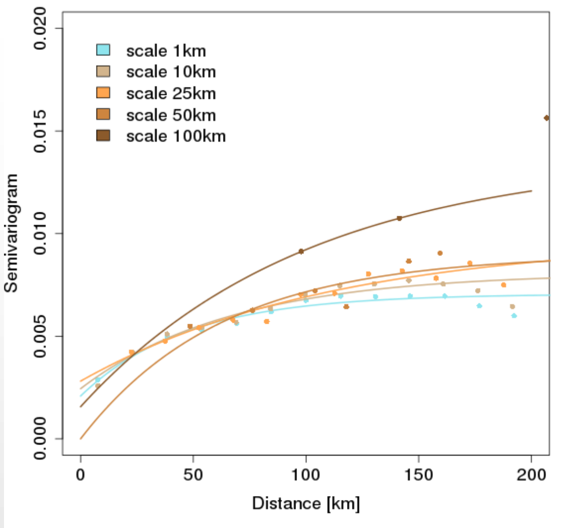


Water content at field capacity

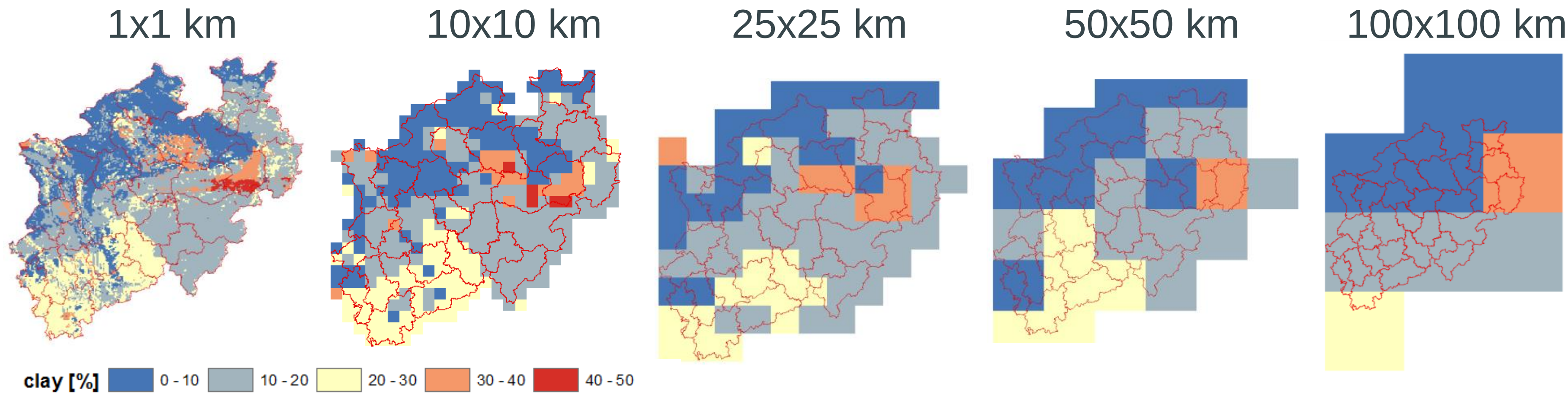
1x1 km 10x10 km 25x25 km 50x50 km 100x100 km

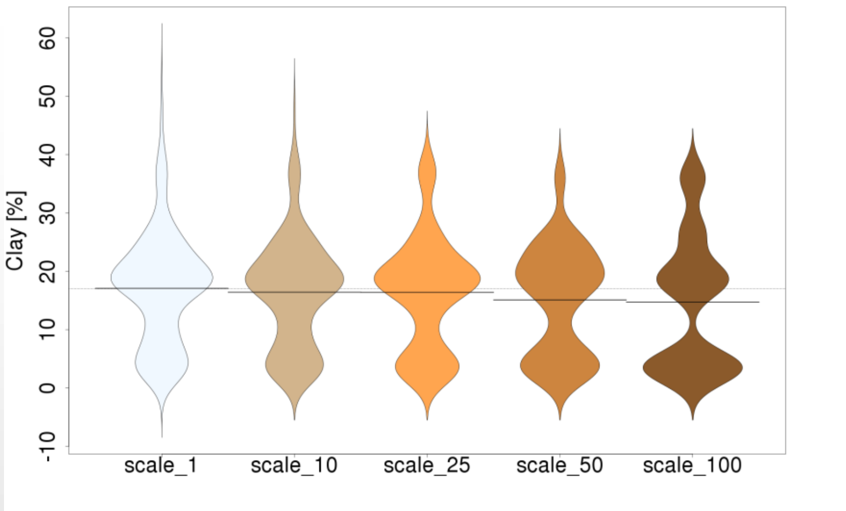


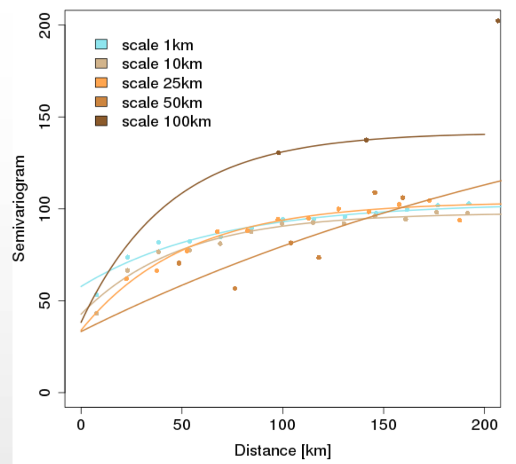




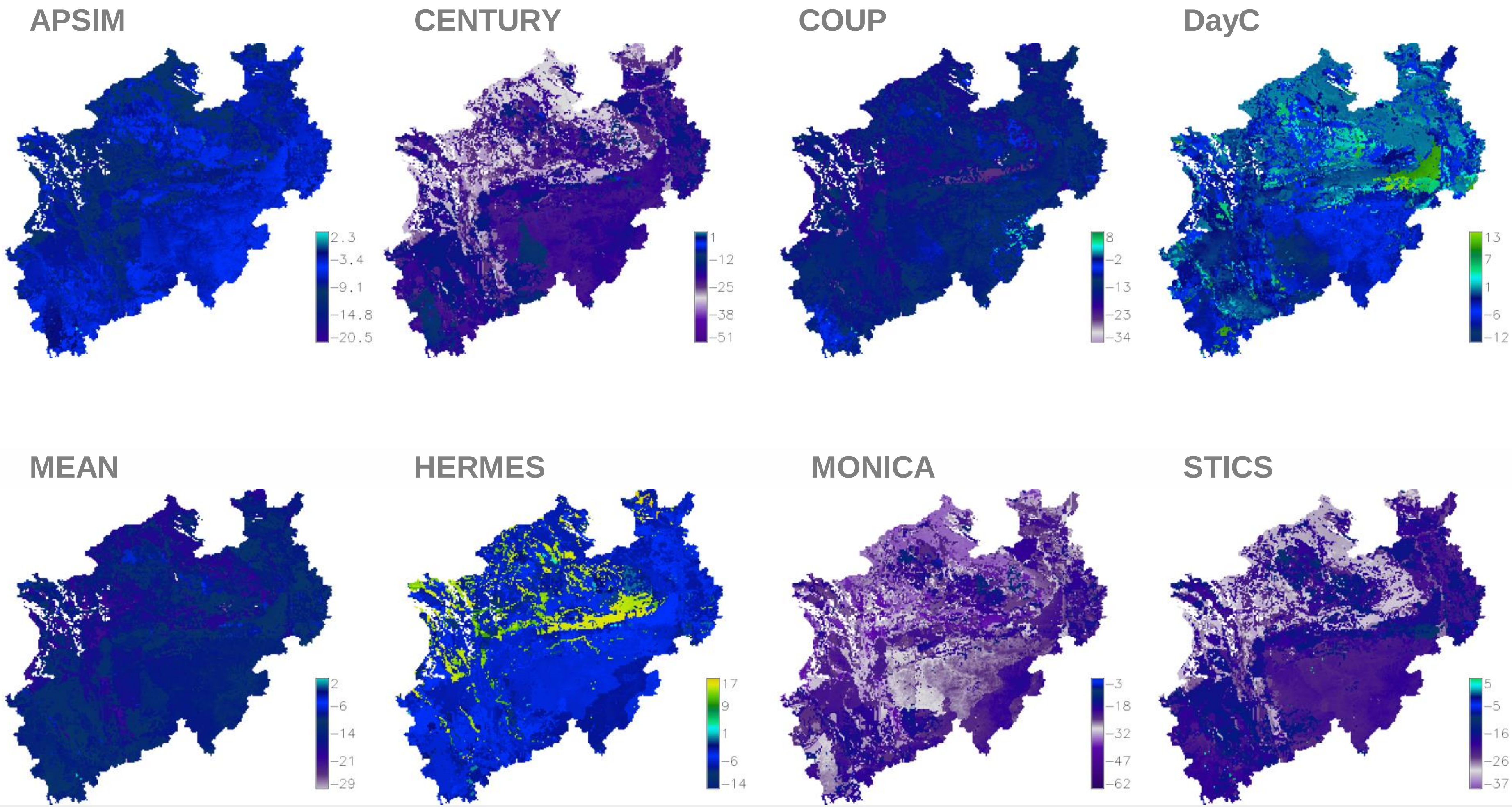
Clay content (%)



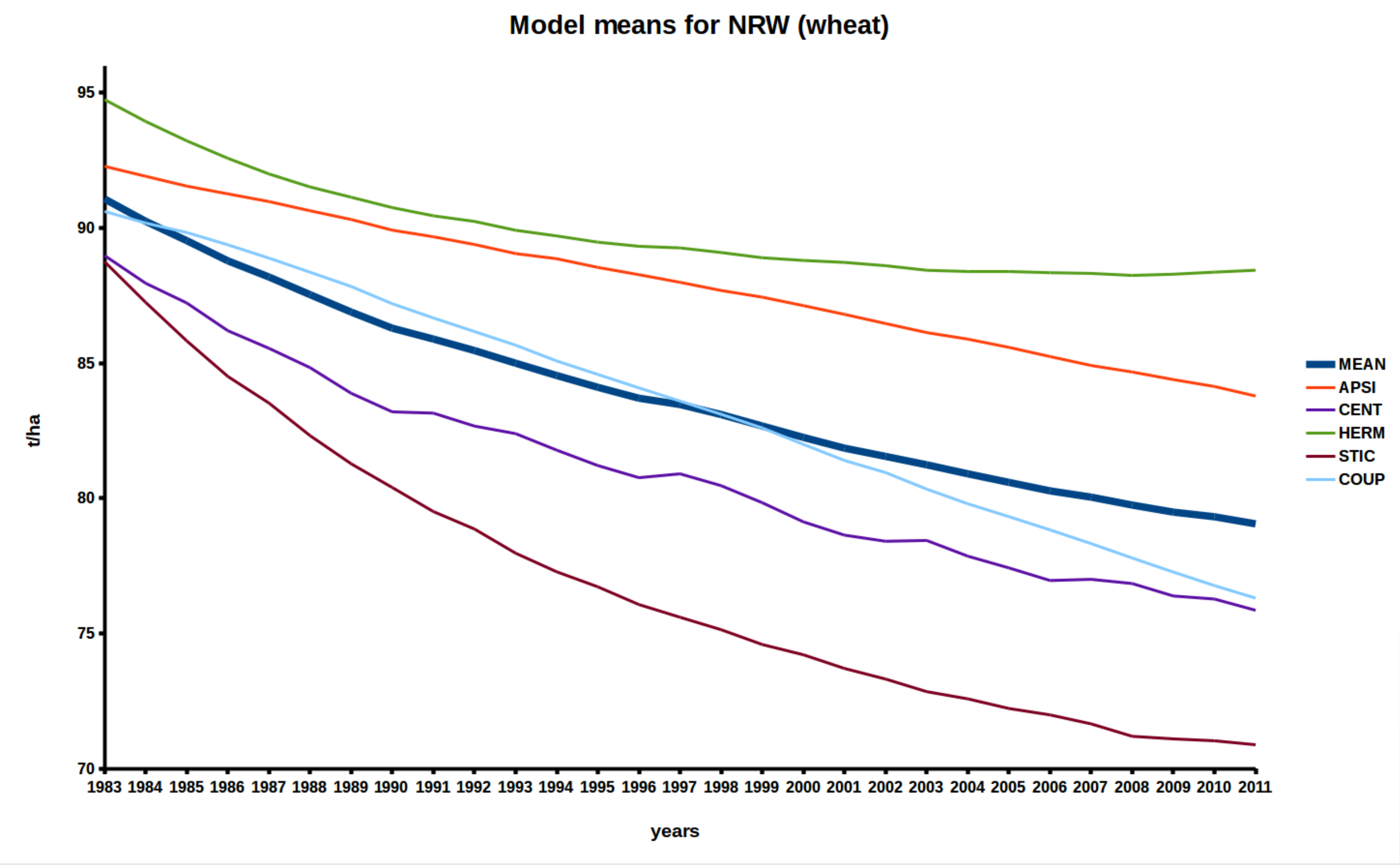




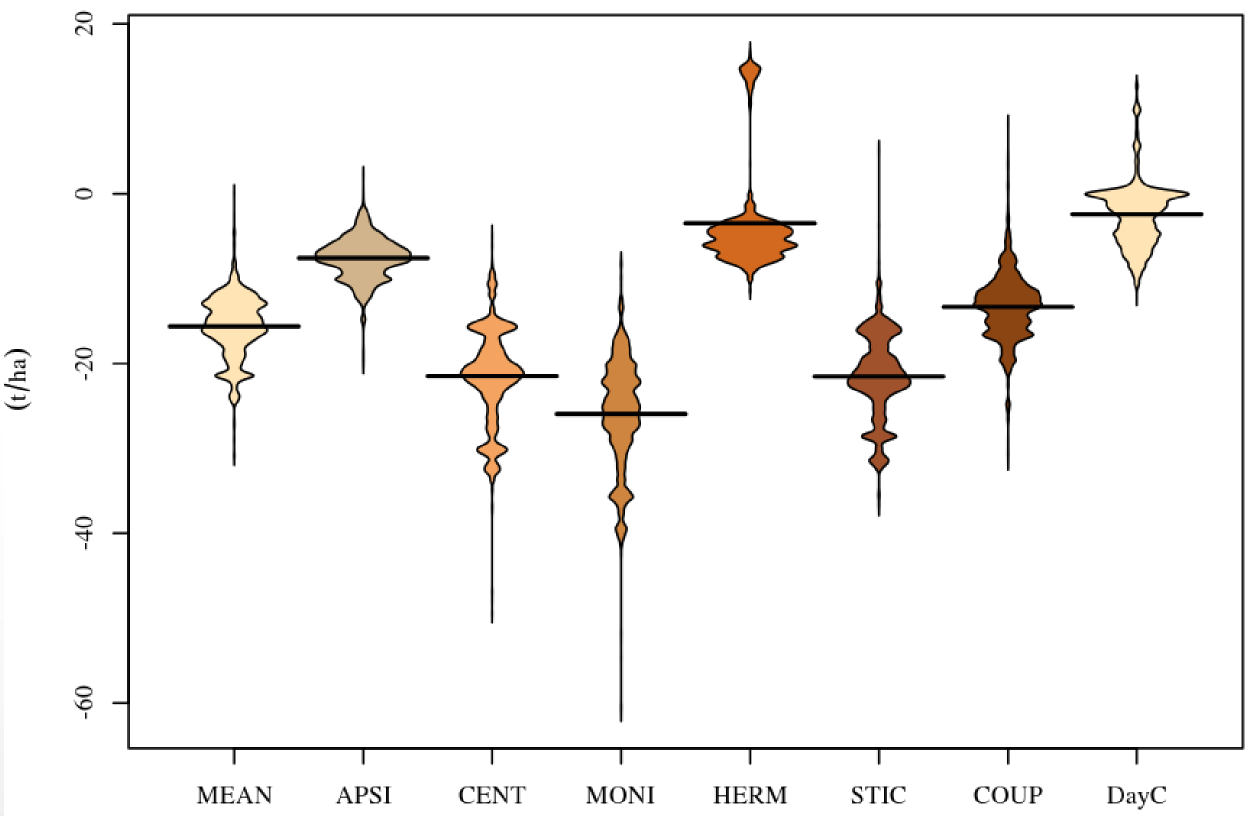
The spatial distribution of the difference of initial and final SOC - wheat



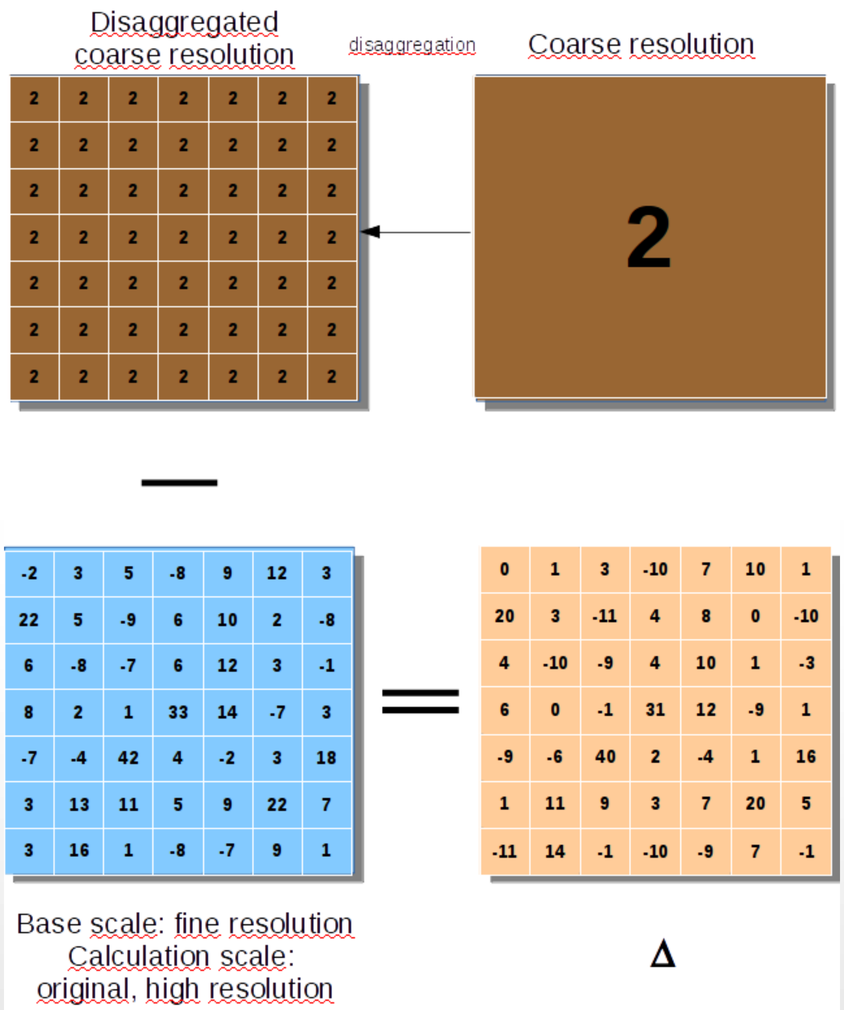
The temporal changes of the SOC for NRW - wheat



The distribution of the changes of the SOC - wheat



Schematic illustration of disaggregation method and quantification of the data aggregation effects (DAEs). Modified after Zhao et al. (accepted).



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2	2	2	2	2	2	2
2	2	2	2	2	2	2
2	2	2	2	2	2	2
2	2	2	2	2	2	2

-2	3	5	-8	9	12	3
22	5	-9	6	10	2	-8
6	-8	-7	6	12	3	-1
8	2	1	33	14	-7	3
-7	-4	42	4	-2	3	18
3	13	11	5	9	22	7
3	16	1	-8	-7	9	1

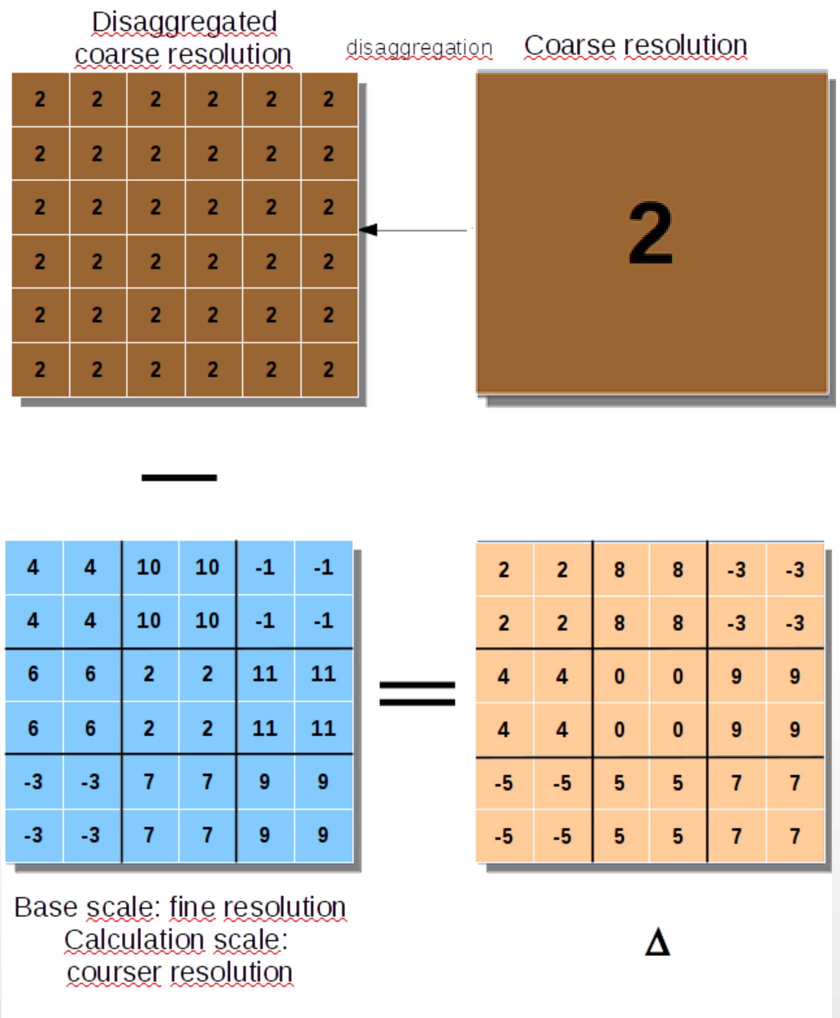
0	1	3	-10	7	10	1
20	3	-11	4	8	0	-10
4	-10	-9	4	10	1	-3
6	0	-1	31	12	-9	1
-9	-6	40	2	-4	1	16
1	11	9	3	7	20	5
-11	14	-1	-10	-9	7	-1

$$\Delta_{i,j} = DC_{i,j} - OH_{i,j}$$

$$RMSE_i = \sqrt{\frac{\sum_{j=0}^{n} \Delta_{i,j}^2}{n}}$$

- ***$DC_{i,j}$*** is the disaggregated values for a specific grid cell
- ***$OH_{i,j}$*** is the original values (original high resolution, 1 km resolution) for a specific grid cell
- ***n*** is the number of grid cells of the highest resolution
- ***i*** indicates different variables
- ***j*** indicates different grid cell

Schematic illustration of disaggregation method and quantification of the data aggregation effects (DAEs). Modified after Zhao et al. (accepted).



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- ***i*** indicates different variables
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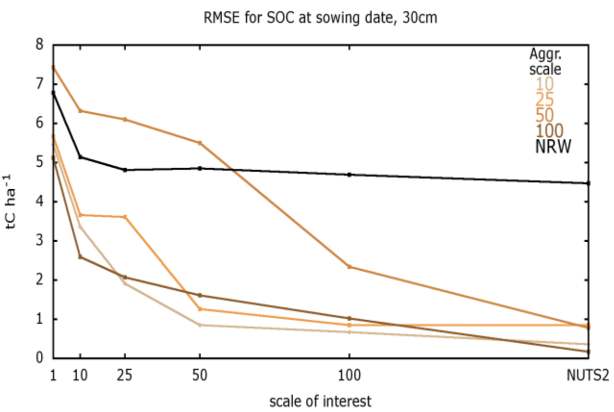
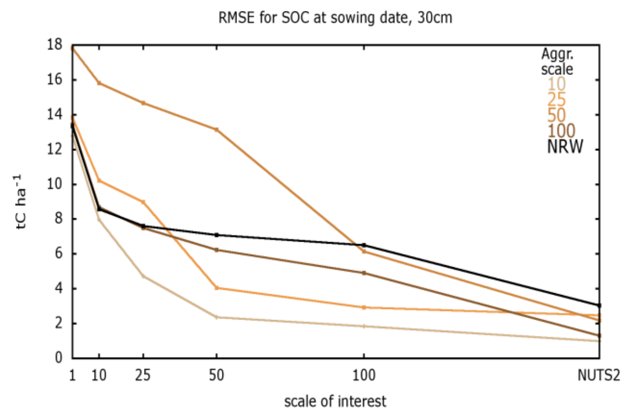
Root-mean-square error, soil aggr., maize, scale of interest: 1x1km, 10x10km, 25x25km, 50x50km, 100x100km, NRW

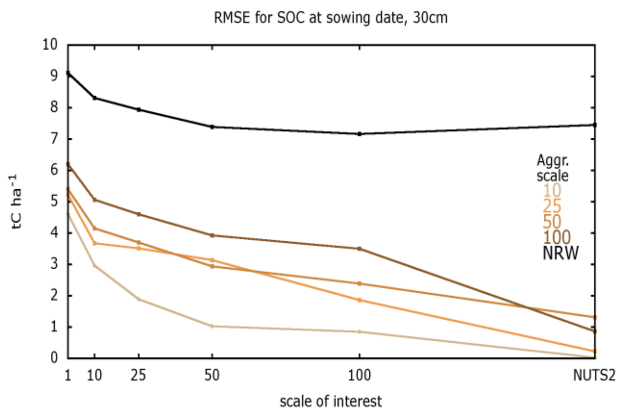
APSIM



CENTURY



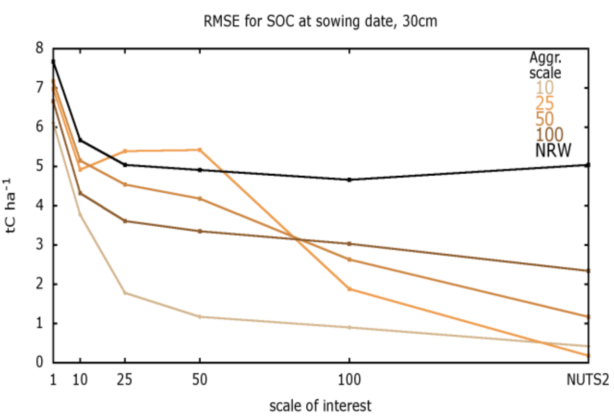
DayC



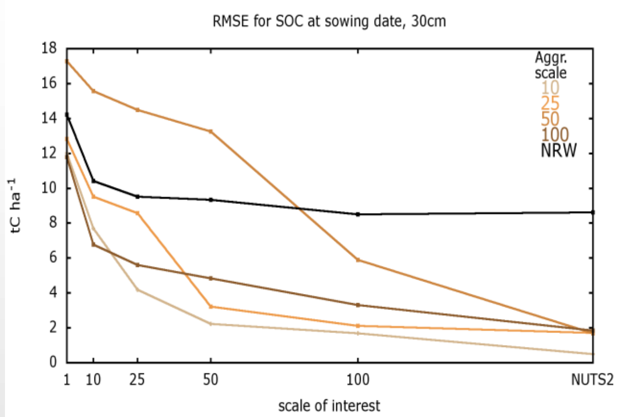
$RMSE_{NRW}$ of models: 8.346 tC/ha

$RMSE_{1x1km}$ of models: 8.931 tC/ha

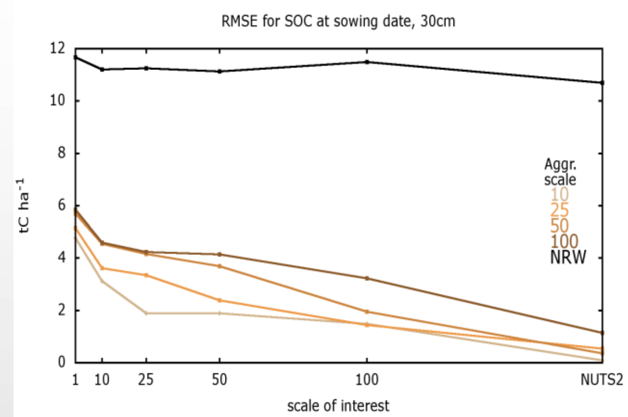
HERMES



MONICA

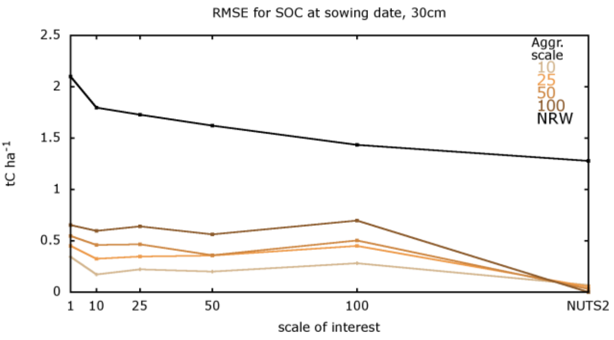


STICS

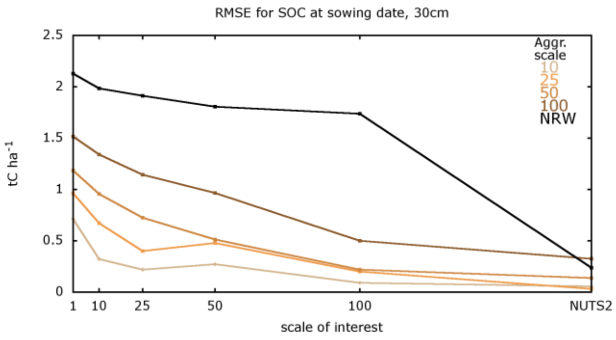


Root-mean-square error, climate aggr., maize, scale of interest: 1x1km, 10x10km, 25x25km, 50x50km, 100x100km, NRW

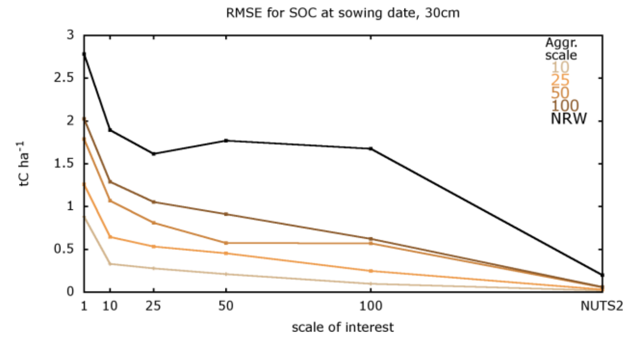
APSIM



CENTURY

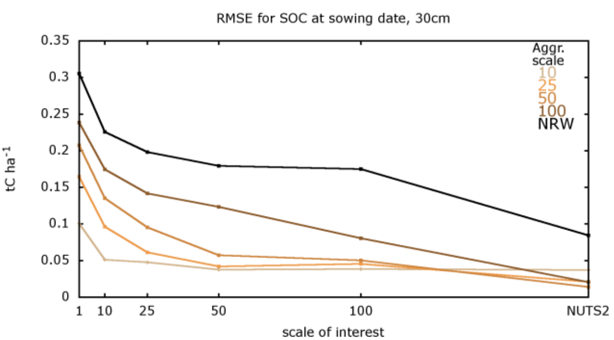


DayC

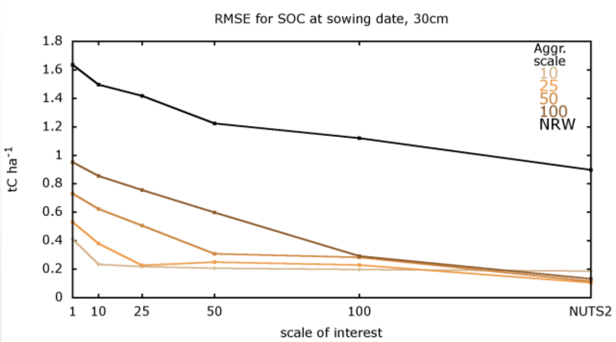


$RMSE_{NRW}$ of models: 8.346 tC/ha **$RMSE_{1x1km}$ of models: 8.931 tC/ha**

HERMES



MONICA



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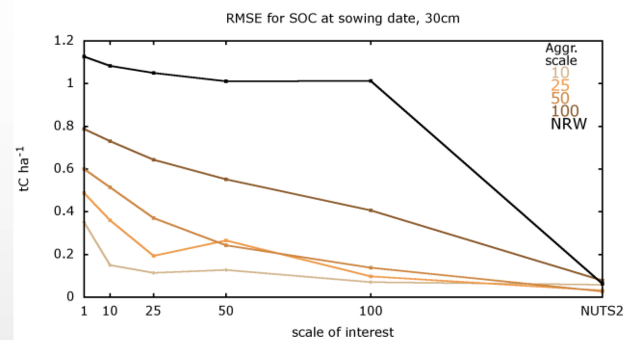
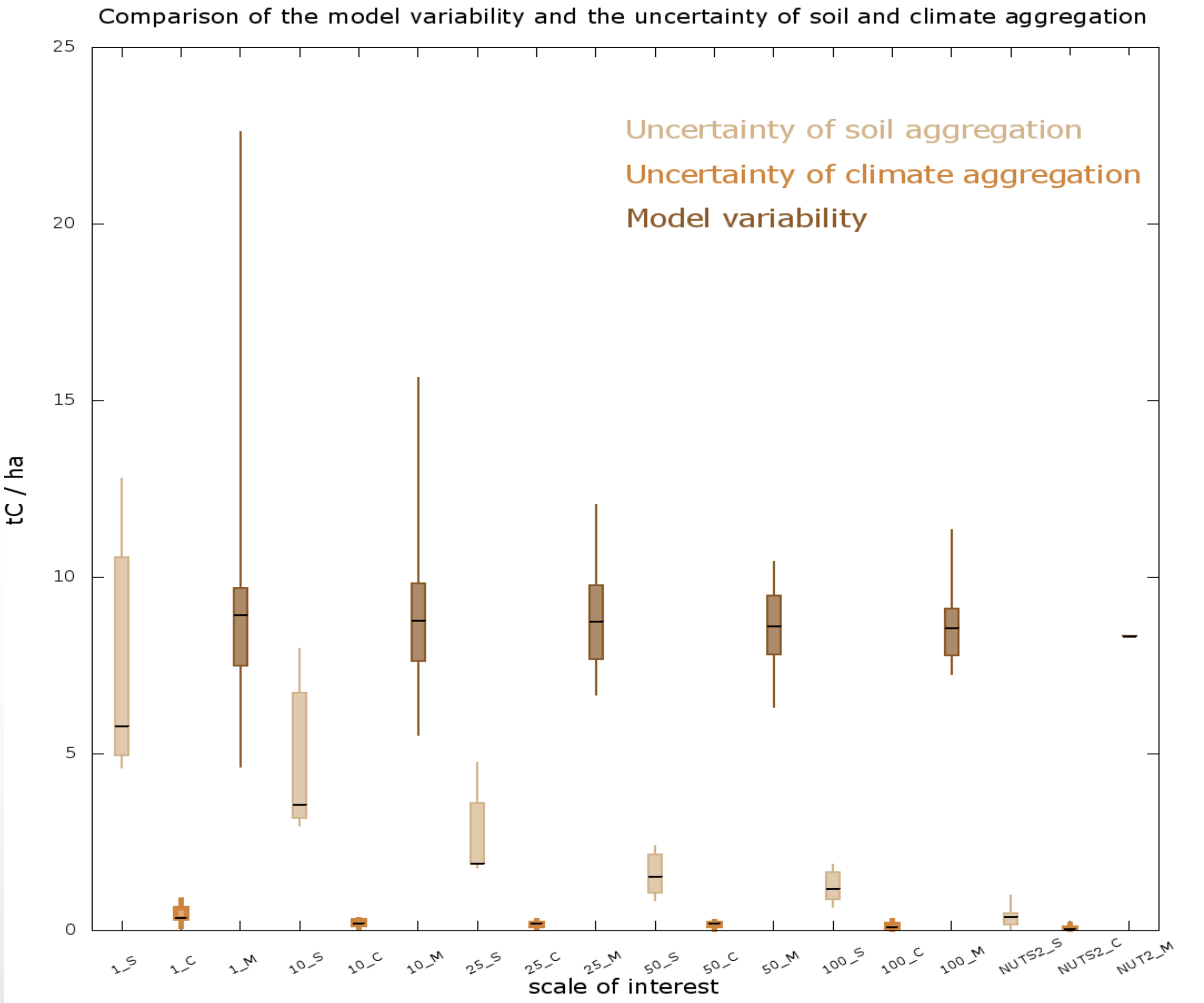
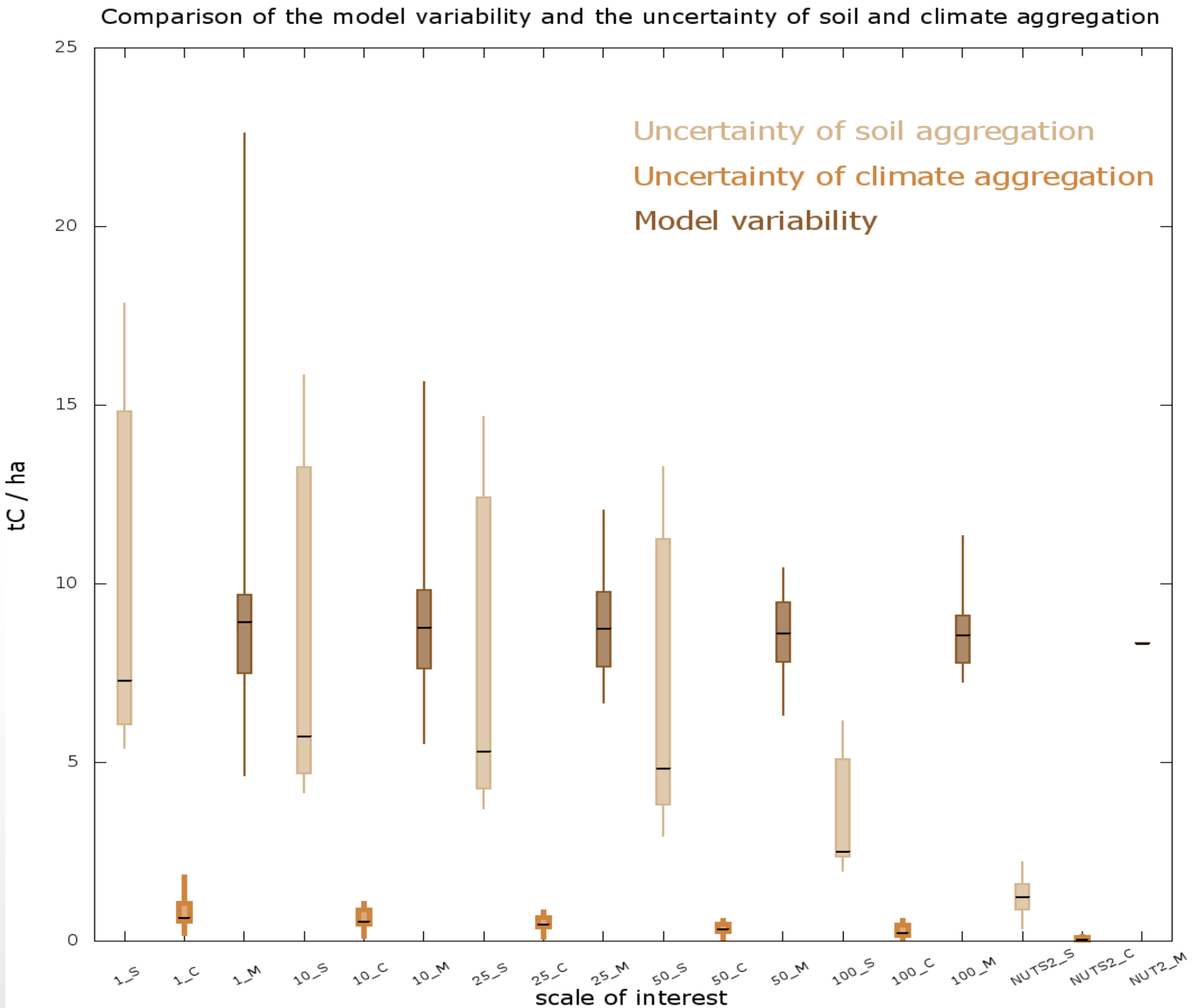


Comparison of the model variability and the uncertainty of soil and climate aggregation (aggregation level 10)



Comparison of the model variability and the uncertainty of soil and climate aggregation (aggregation level 50)



Conclusions

- The results show that the aggregation of weather data can cause significant, but small regionalization errors in estimating C stock changes in agricultural soils
- In contrast aggregation errors caused by soil property aggregations are high
- An aggregation of soil properties on 10x10 km cause less than 20% regionalization errors in estimating C stock changes in agricultural soils.
- Aggregation levels at 50x50km and 100x100km resolution may lead to reliable averages at NUTS 2 level (NRW)
- The scaling exercise shows the high sensitivity of modelled soil organic carbon changes on the accuracy of initial C stocks
- The aggregation procedure is of high relevance for the resulting model error. While weather aggregation by averaging resulted in a continuous decrease of the mean model error from coarse to fine resolution the aggregation of soil information did not.

Thank you for your attention!

Acknowledgement
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RMSE

- RMSE is a frequently used measure of differences between value predected by model or an estimator and the values actually observed.
- The RMSE represent the standard deviation of the differences between predicted and observed values.