Supplementary Materials for:

Modeling Soil Organic Carbon Dynamics of Arable Land across Scales: A Simplified Assessment of Alternative Management Practices on the Level of Administrative Units

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Table S1: Agro-economic regions of Saxony

Table S1. Characterization of the agro-economic regions of Saxony.

	Heath & Pond Landscape	Loess Region	Low Mountain Range & Foreland
Temperature[1] [°C]	9.6	9.3	7.8
Precipitation[1] [mm]	736	770	961
Clay content[2] [%]	4.4	9.5	13.8
Silt content[2] [%]	22.8	65.3	58.2
Stone content[2] [%]	10.4	7.4	16.2
Arable land [%]	31.9	52.5	28.4
Grassland & pasture [%]	8.1	9.8	16.7
Conservation tillage 2000/2012 [%]	13.3 / 26.5	14.5 / 34.3	14.9 / 52.1
Cover crops[3] [%]	4.5	4.0	4.6

[1] Average annual values of the period 1990-2014, [2] Average values across all soil types of agricultural land (topsoil), [3] Average values of the period 2000-2012

Table S2: Descriptive summary of the data aggregation procedure

Table S2. Descriptive summary of the data aggregation procedure for upscaling a grid-based set-up of the CCB model to the level of administrative units.

Type of dataset	Scale of model set-up	
	Grid-based (500m)	**Administrative units**
Soils	One soil type for each grid cell.	The area shares of the soil types within an administrative unit were aggregated and used as a property of the administrative unit. Subsequently, each soil type within one administrative unit was parameterized as an own CCB modeling unit (without spatial reference).
Climate	One time series dataset for temperature and precipitation (annual values) for each grid cell.	One time series dataset for temperature and precipitation (annual values) for each administrative unit, based on the area-weighted mean of the grid-based datasets within one administrative unit.
Crop types	One dataset for the crop types cultivated and their area share (annual values) for each grid cell.	One dataset for the crop types cultivated and their area share (annual values) for each administrative unit, based on the area-weighted mean of the grid-based datasets within one administrative unit.
Crop yields	One dataset on crop yields (annual values; crop type specific) for each grid cell.	One dataset on crop yields (annual values; crop type specific) for each administrative unit, based on the area-weighted mean of the grid-based datasets within one administrative unit.
Management of crop by-products	One dataset on the removal rate of crop-by products (annual values; crop type specific) for each grid cell.	One dataset on the removal rate of crop-by products (annual values; crop type specific) for each administrative unit, based on the area-weighted mean of the grid-based datasets within one administrative unit.
Fertilizer	One dataset on fertilizer application rates (annual values; fertilizer type specific) and the area share of their application for each grid cell.	One dataset on fertilizer application rates (annual values; fertilizer type specific) and the area share of their application for each administrative unit, based on the area-weighted mean of the grid-based datasets within one administrative unit.
Soil management	One dataset on the share of tillage systems (annual values) for each grid cell.	One dataset on the share of tillage systems (annual values) for each administrative unit, based on the area-weighted mean of the grid-based datasets within one administrative unit.
Initial SOC	Grid-specific initial SOC according to the approach of Drexler et al. (2020)* and the soil type and climate of the grid cell.	Administrative unit- and soil-specific initial SOC according to the approach of Drexler et al. (2020)* and the soil types and climate of the administrative unit.

*Drexler, S.; Broll, G.; Don, A.; Flessa, H. Standorttypische Humusgehalte Landwirtschaftlich Genutzter Böden Deutschlands; Thünen Report 75; Johann Heinrich von Thünen-Institut: Braunschweig, Germany, 2020; ISBN 978-3-86576-208-5.

Explanation S1: Initialization of SOC-levels

Initialization of SOC stocks is a crucial step of SOC modeling and accompanied by high uncertainties. SOC stocks need very long time periods to reach a steady state and changes in land-use, management and climate do always change theoretical steady state levels and associated SOC dynamics. Also the initial distribution of the total SOC over the different model pools can significantly affect the modeled predictions.

In a recent publication Drexler et al. [26] provided an extensive analysis of the soil organic carbon contents of the agricultural soils of Germany. The analysis was based on C_{org} measurements on 2,973 sites and resulted in a classification scheme of the site-typical SOC content of the German agricultural soils. Based on information of the land use, soil texture, C/N ratio and annual precipitation of a site it is thus possible to derive site-typical C_{org} values for Germany. We applied this classification scheme to the arable soils of Saxony for setting the initial SOC contents in our CCB model setups. Thus, we derived for each soil type in each spatial modeling unit one specific initial SOC, using the C_{org} modal value provided Drexler et al. [26]. The table below shows the distribution of the classes for soil texture and annual precipitation in Saxony based on the classification system of Drexler et al. [26]. The majority of the soils in Saxony are in the soil texture class "medium 1", followed by "light" (sandy) soils. The average initial C_{org} value across all grid-cells simulated in this study was 1.35%.

	≤700mm	**>700mm**	**≤850mm**	**>850mm**	**≤1000mm**	**>1000mm**	**≤900mm**	**Total**
light	1,589	4,045						5,634
medium 1			13,573	7,208				20,781
medium 2					2,005	839		2,844
heavy 2							72	72

Figure S1: Pools and fluxes of the CCB model

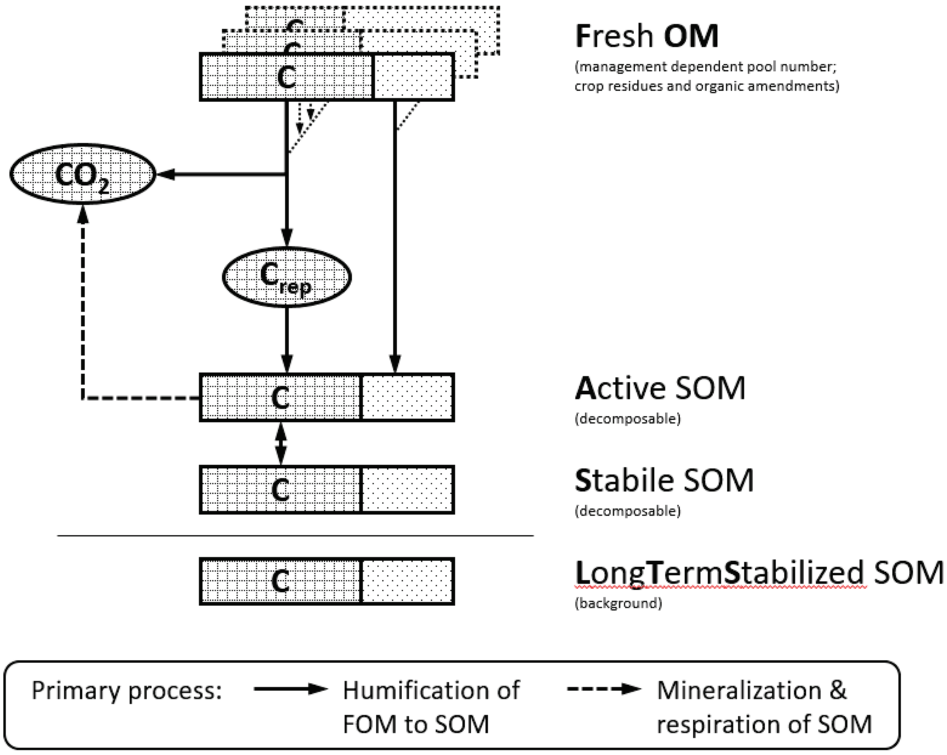
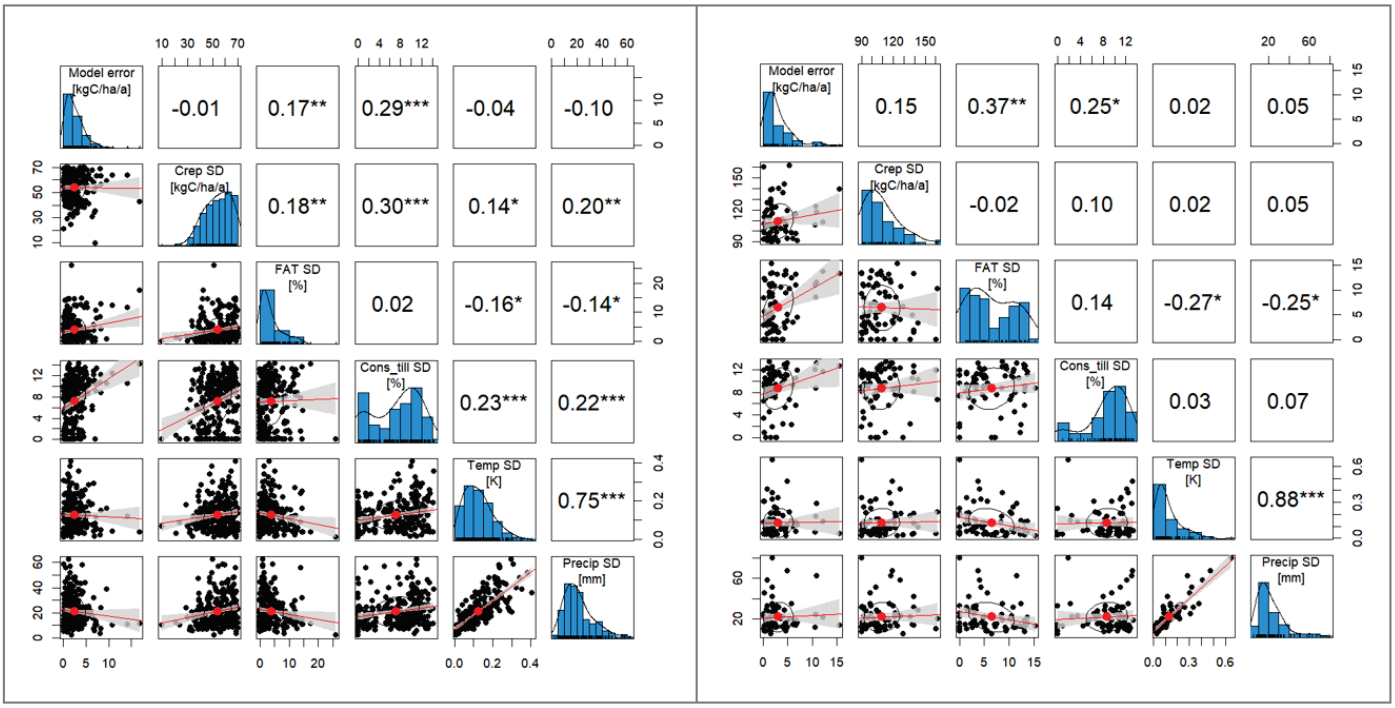


Figure S1. Overview about the carbon related pools (blocks) and fluxes (arrows) of the CCB model. C_{rep}: carbon reproduction flux from fresh organic matter (FOM) to soil organic matter (SOM).

Figure S2: Correlation matrices for LAU units with high/low spatial dispersion in the carbon influx into SOC (C_{rep})



(a) (b)

Figure S2. Correlation matrices between the absolute errors of the LAU-level model set-up and the spatial dispersion (standard deviation) of a set of predictor variables. (a) Correlation matrix for a subset of LAU regions that show a low variability in the carbon influx to SOC (C_{rep}); (b) Correlation matrix for a subset of LAU regions that show a high variability in the carbon influx to SOC (C_{rep}). The predictors of the matrices are the soil carbon reproduction flux (C_{rep}), the soil fine particle content (FAT), conservation tillage shares (Cons_till), annual mean temperature (Temp) and annual precipitation (Precip). For each predictor its regional dispersion (standard deviation - SD) within an administrative unit has been calculated from the reference dataset and used for the correlation matrices. The distribution of each variable is shown on the diagonal. Below this diagonal the bivariate scatter plots with a fitted line are displayed. Above the diagonal the value of the correlation is shown as well as its significance level (stars), where the p-values <0.001, <0.01 are associated to the symbols *** and ** respectively.

Figure S3: Correlation matrix for LAU units with high spatial dispersion in carbon turnover conditions (BAT) as well as in the carbon influx into SOC (C_{rep})

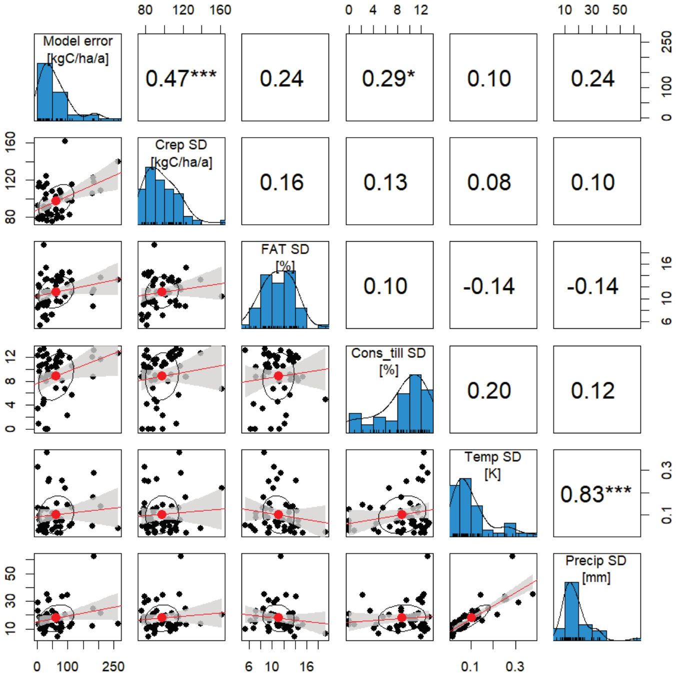
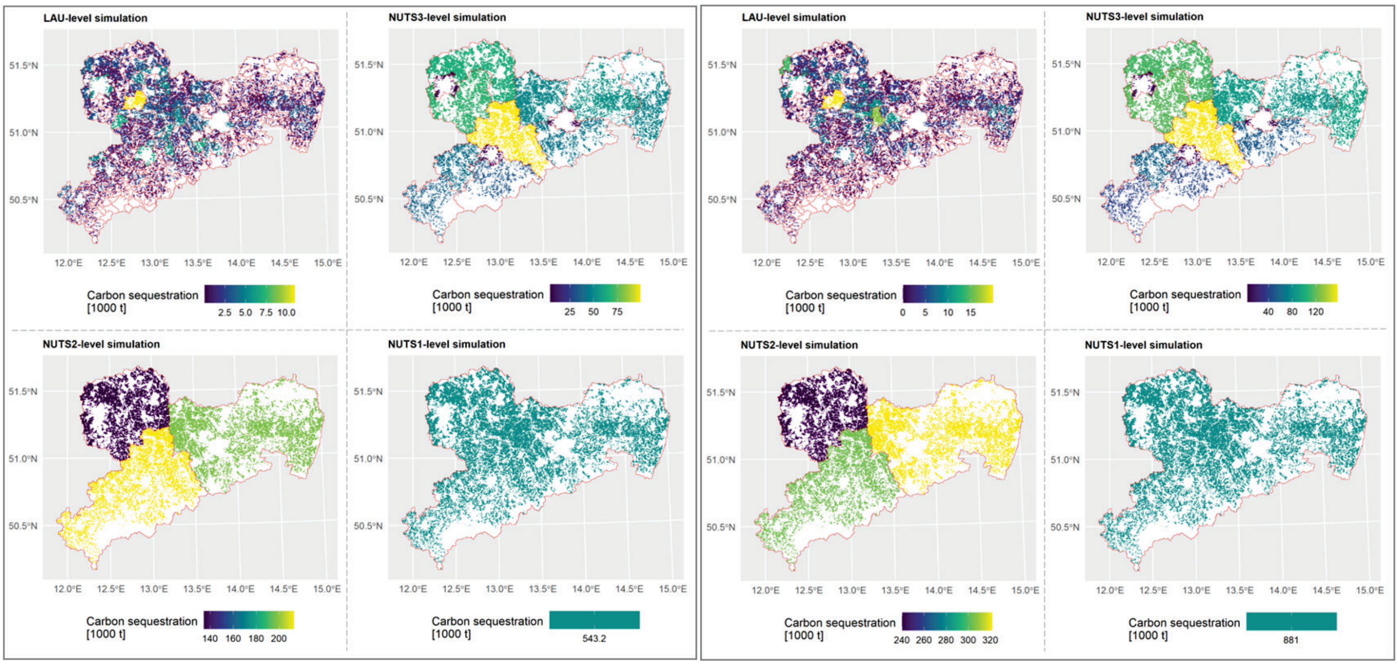


Figure S3. Correlation matrix between the absolute errors of the LAU-level model set-up and the spatial dispersion (standard deviation) of a set of predictor variables. The correlation matrix only considers a subset of LAU regions that show a high variability in carbon turnover conditions (BAT) as well as a high variability in the carbon influx to SOC (C_{rep}). The predictors of the matrix are the soil carbon reproduction flux (C_{rep}), the soil fine particle content (FAT), conservation tillage shares (Cons_till), annual mean temperature (Temp) and annual precipitation (Precip). For each predictor its regional dispersion (standard deviation - SD) within an administrative unit has been calculated from the reference dataset and used for the correlation matrices.

Figure S4: Maps of the simulated carbon sequestration potential of two alternative management practices.



(a) **(b)**

Figure S4. Soil carbon sequestration potential of two alternative management practices simulated with four different levels of data aggregation for the arable soils of the case study Saxony (NUTS1 region in Germany). The simulations were done using upscaled model set-ups on the level of administrative units (NUTS1, NUTS2, NUTS3, LAU). White areas represent non-arable land. (a) Carbon sequestration potential of the first alternative management practice (increasing soil carbon influx based on increased cultivation of field grass and cover crops). (b) Carbon sequestration potential of the second alternative management practice (reducing carbon turnover conditions by increasing the use of conservation tillage). ©EuroGeographics for the administrative boundaries.