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Biogenic Carbon accounting modelling: State of the art, limitations, and global trends towards the integration of realistic modelling in LCA.

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Soil Organic Carbon Modelling

January 16th, online

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Soil carbon and nitrogen cycles are linked

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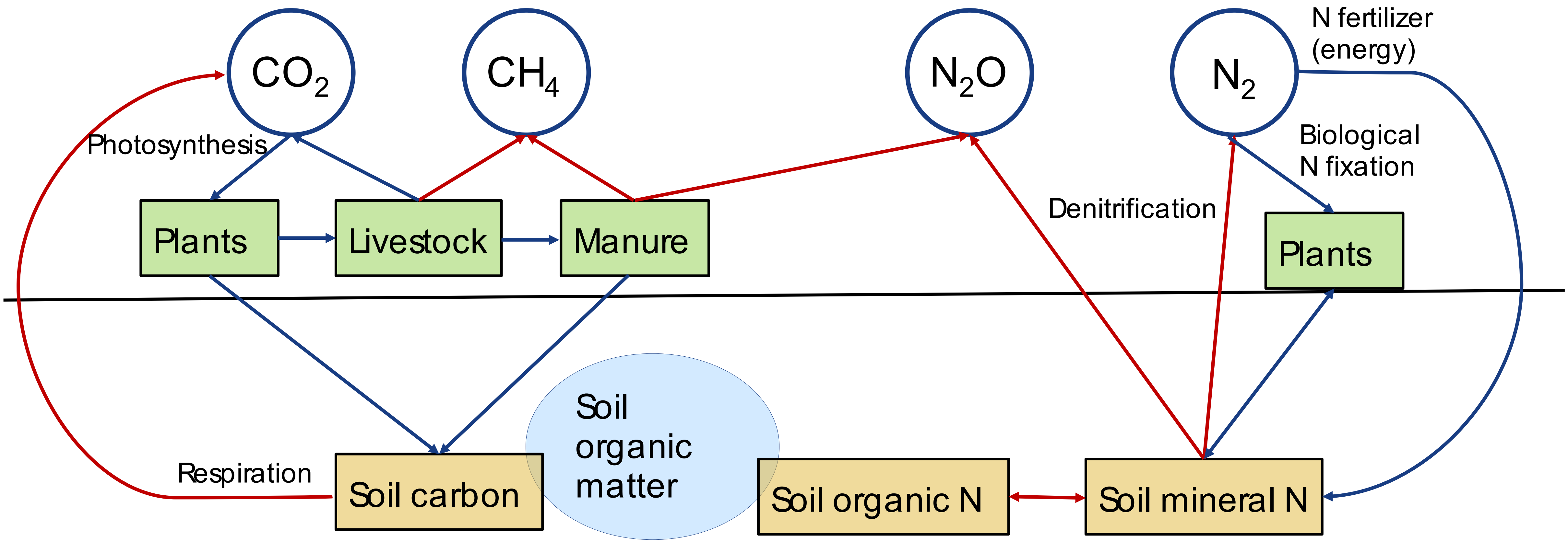

CO_2, CH_4 and N_2O losses are mostly driven by microbiological processes

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The carbon cycle simplified

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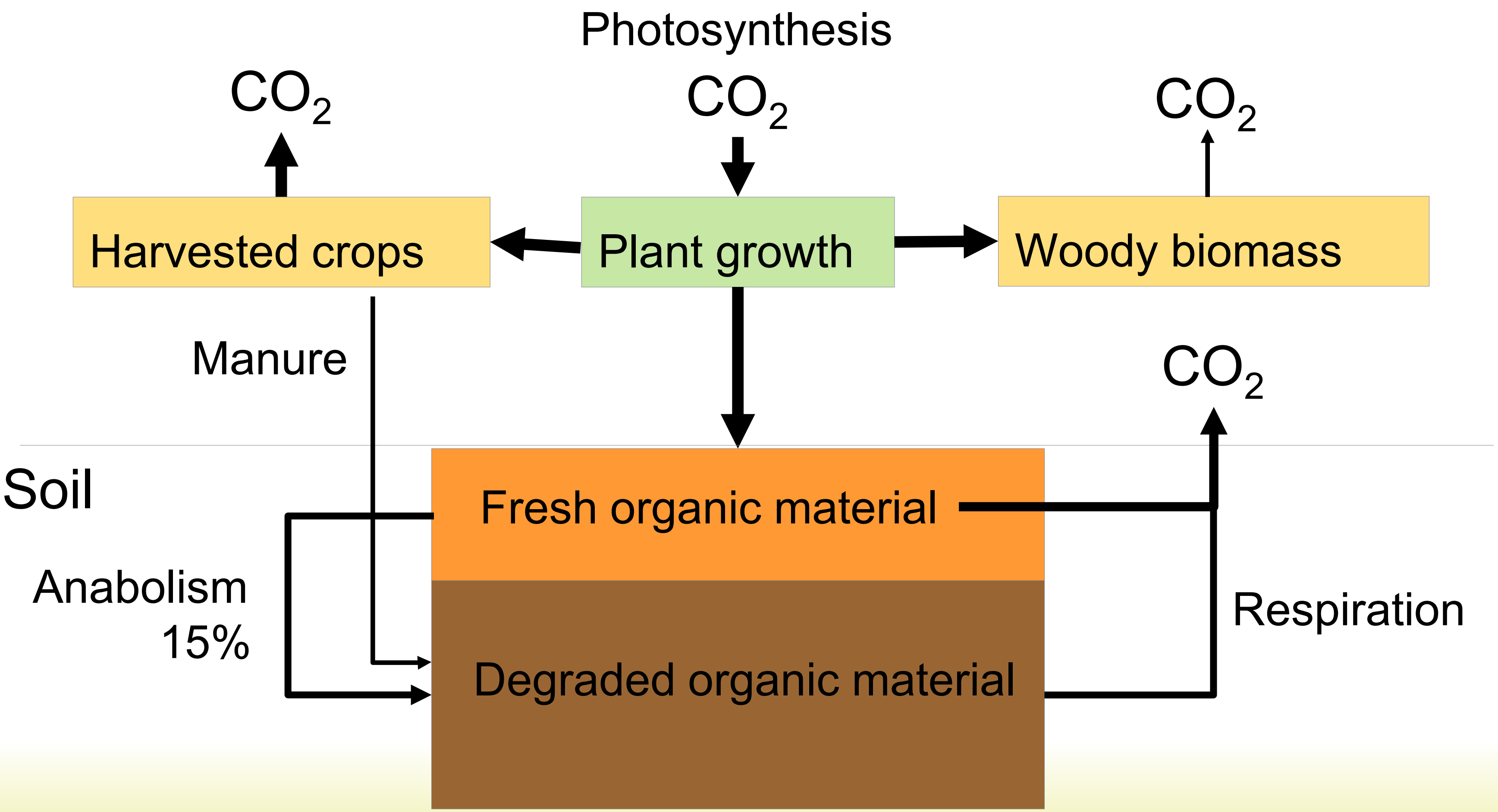

Soil carbon storage: Balance between addition and decomposition

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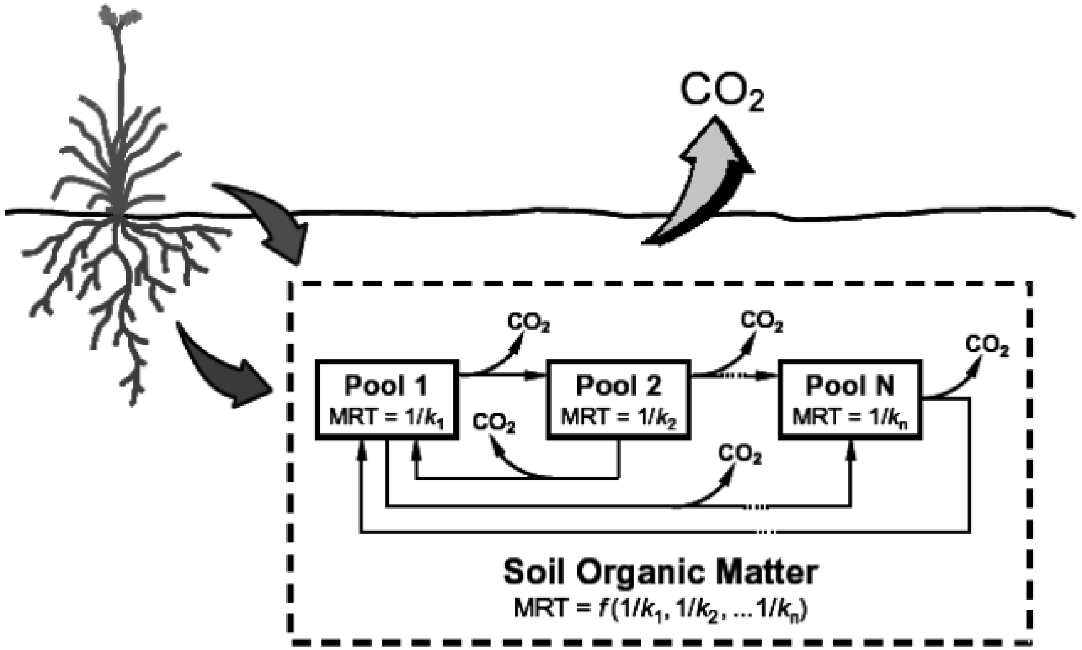
Simplified carbon modelling

The degradation of soil organic matter can be described by the simple equation of Henin and Dupuis (1945):

$$\frac{dC}{dt} = -kC + hA$$

where C is the amount of carbon stored in the soil (Mg C/ha), t is time (year), A is the amount of carbon added every year (Mg C/ha), and h is the humification coefficient. The humification coefficient denotes how much of the carbon is available after microbial degradation.



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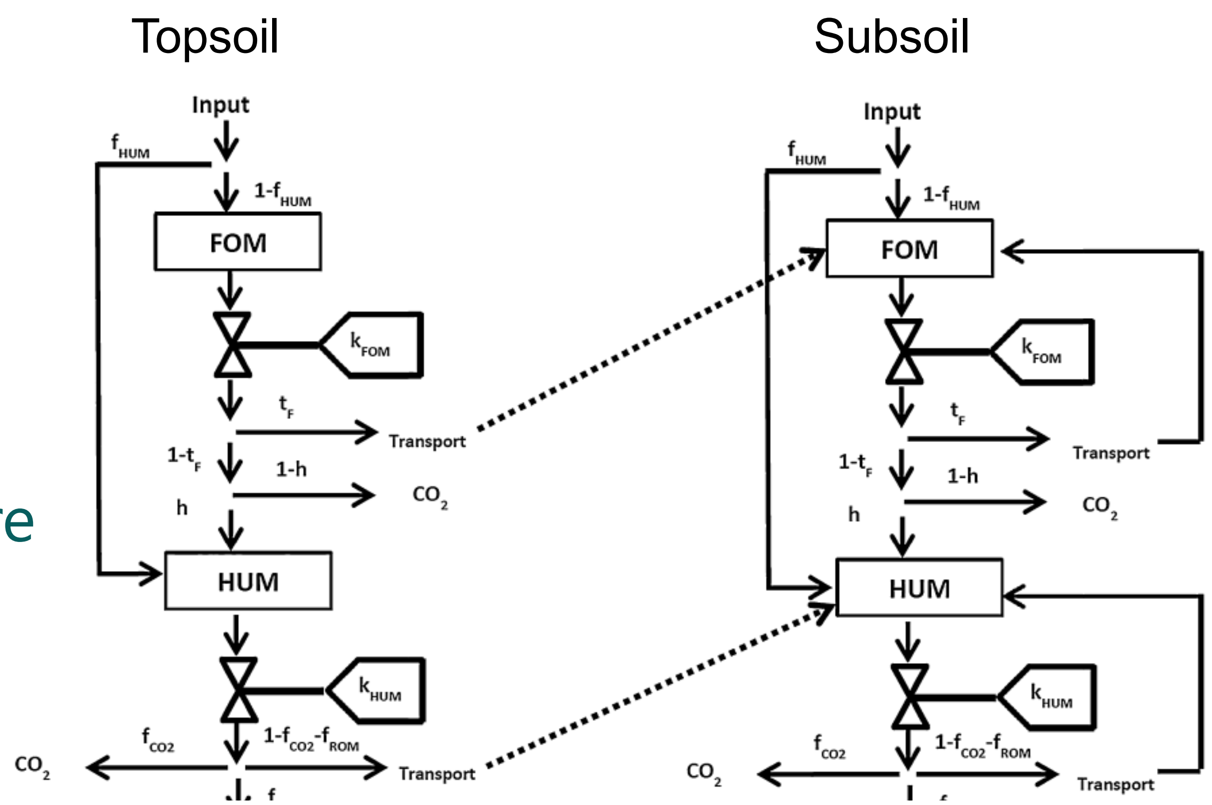
CTOOL model

Three pools
FOM: Fresh Organic Matter
HUM: Humified Organic Matter
ROM: Resistant Organic Matter

Decomposition depends on temperature
Humification depends on soil clay



CTOOL calibration

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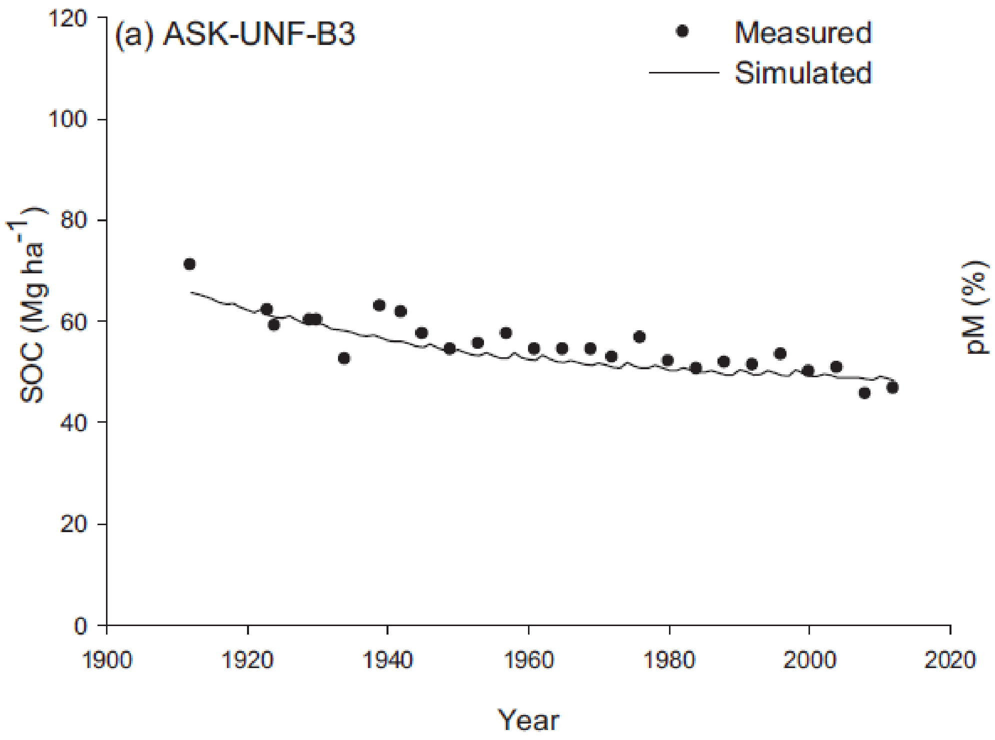
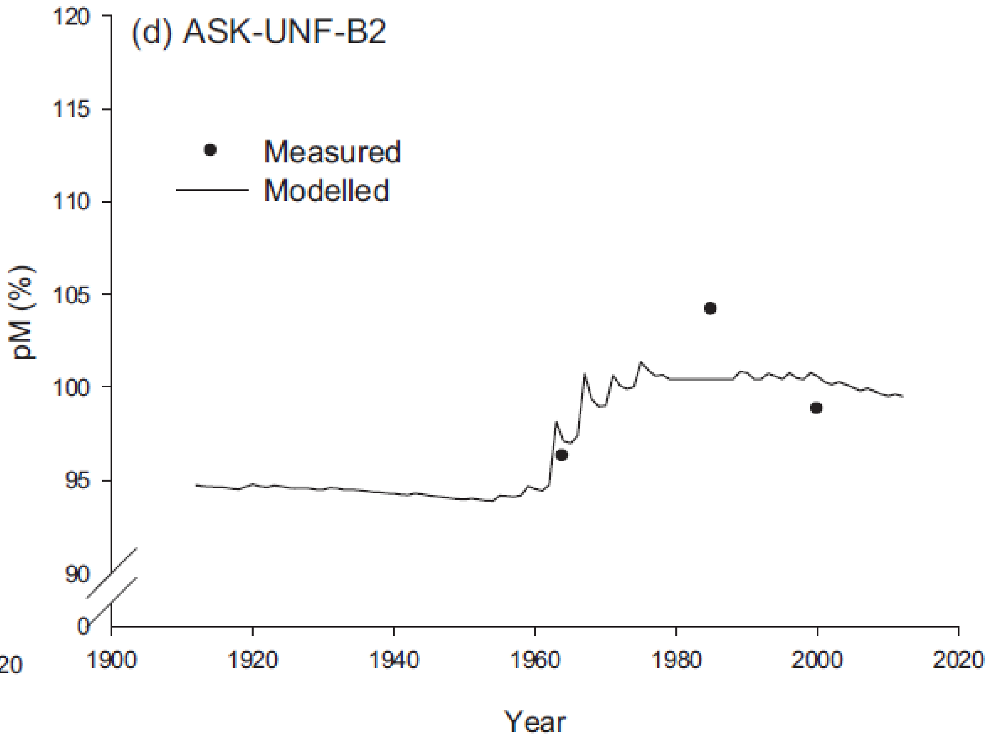
Soil carbon content



Soil radiocarbon (C14) content



Taghizadeh-Toosi et al. (2014)

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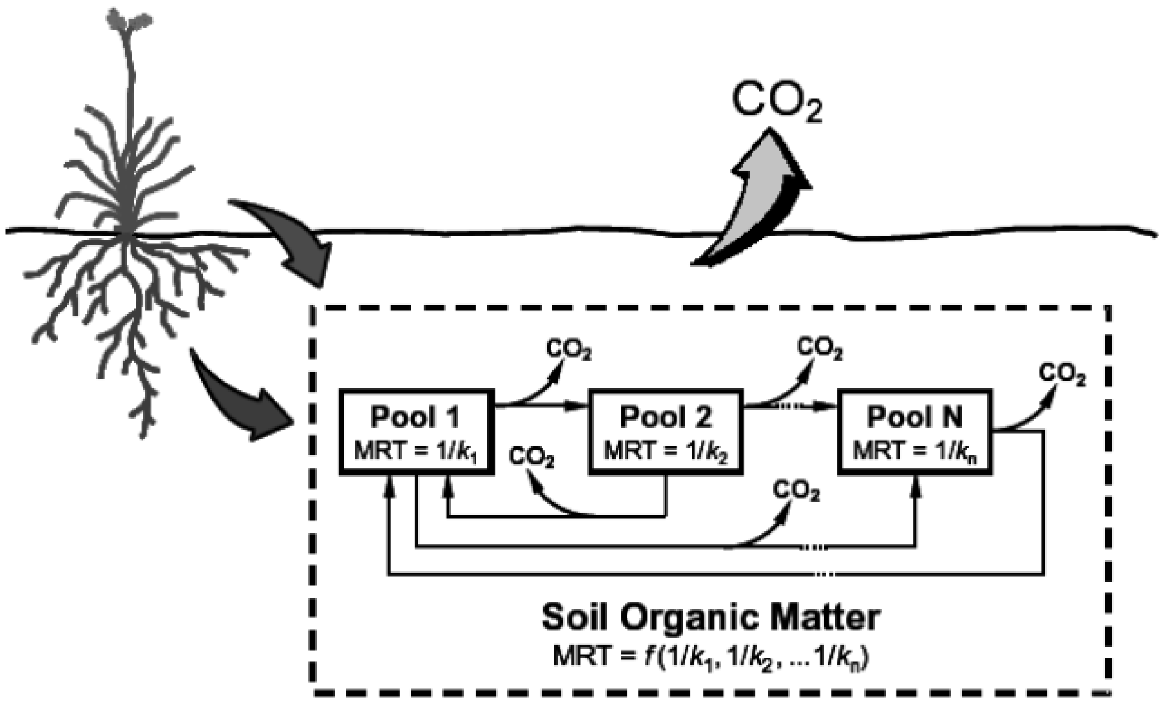
Uncertainties

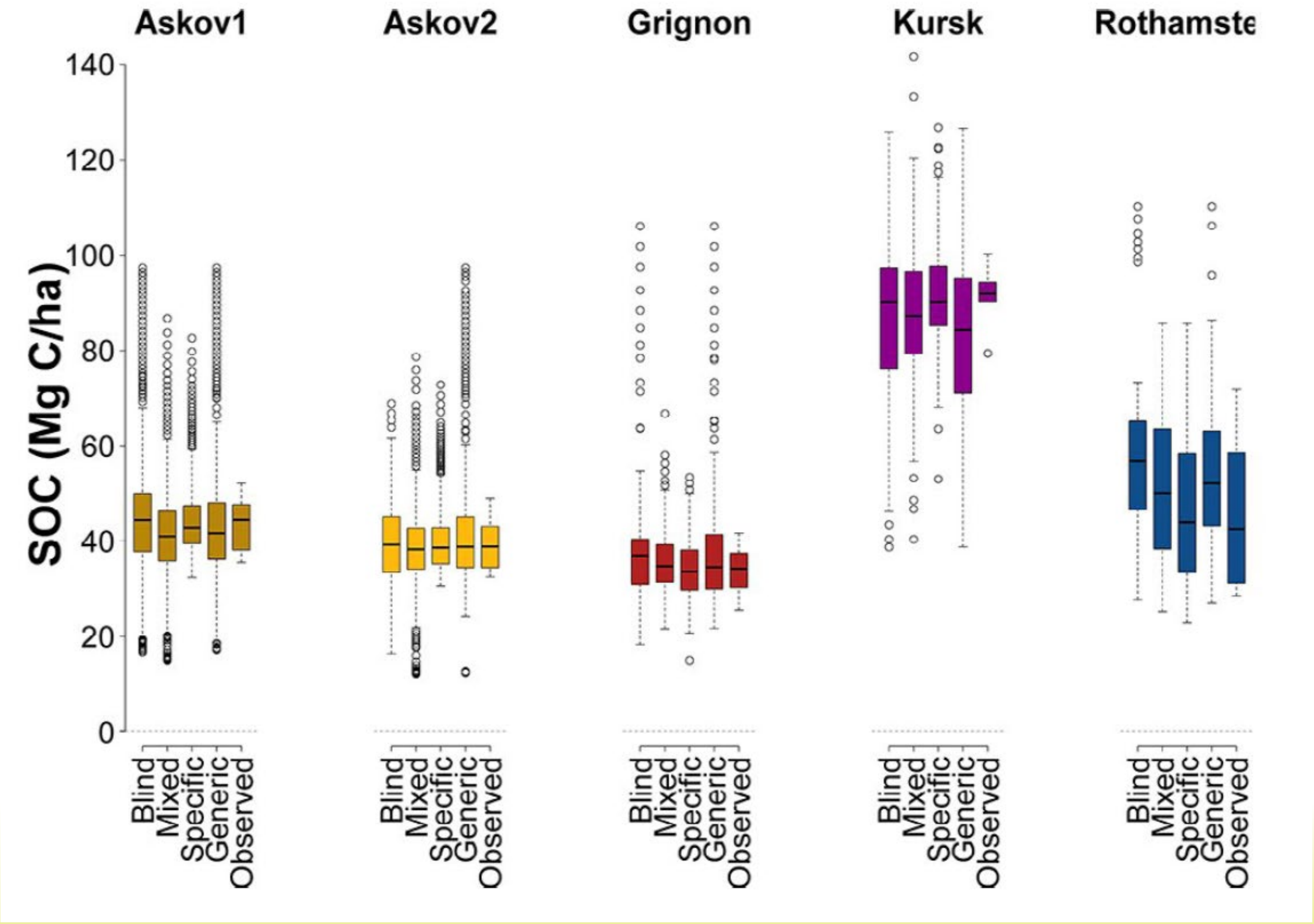
Model calibration (parameters)

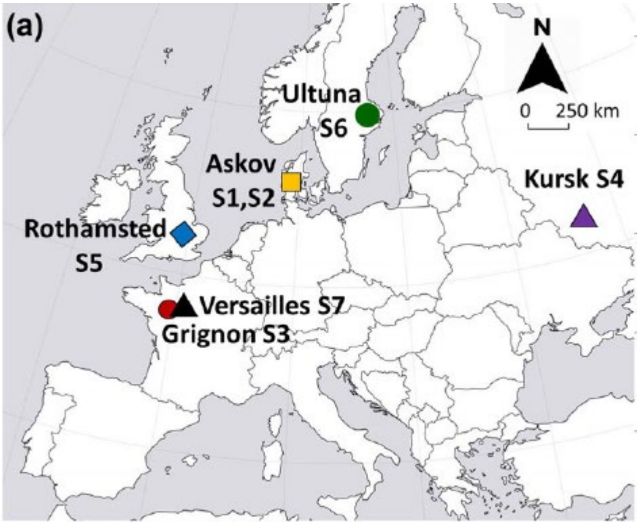
Model initialization

Model inputs

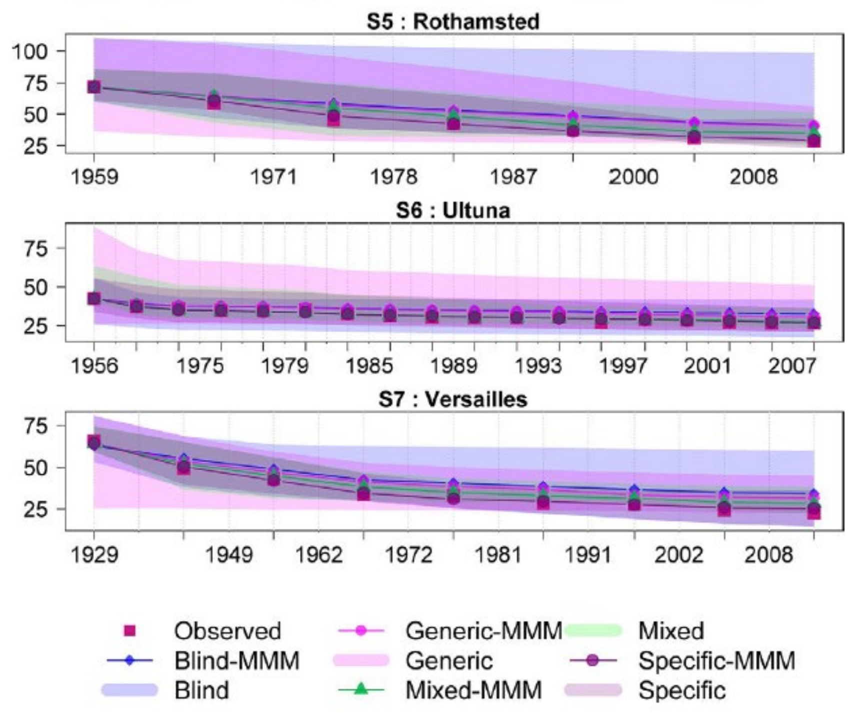


Ensemble modelling, uncertainty and robust predictions of organic carbon in long-term bare-fallow soils





Comparison of 26 models



Farina et al. (2021)

Large uncertainty in soil carbon modelling related to method of calculation of plant carbon input in agricultural systems

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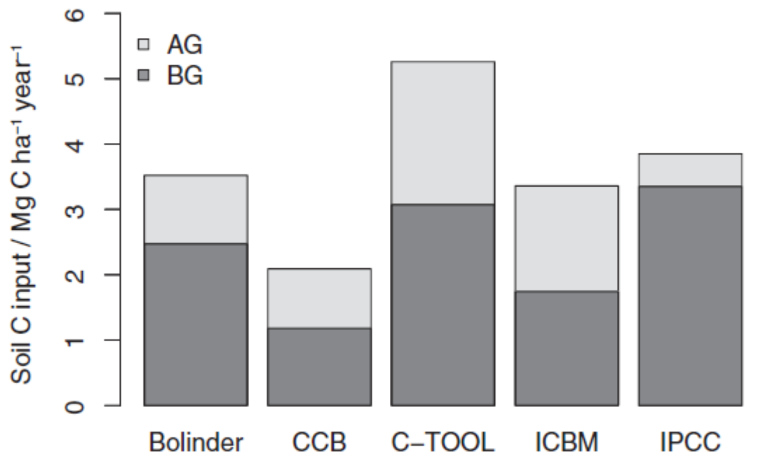

Figure 4 Annual soil carbon inputs from aboveground (AG) and below-ground (BG) plant residues to 0–1-m depth estimated with five different allometric equations (Bolinder, CCB, C-TOOL, ICBM and IPCC) for the period 1977–2004 of the DOK trial.

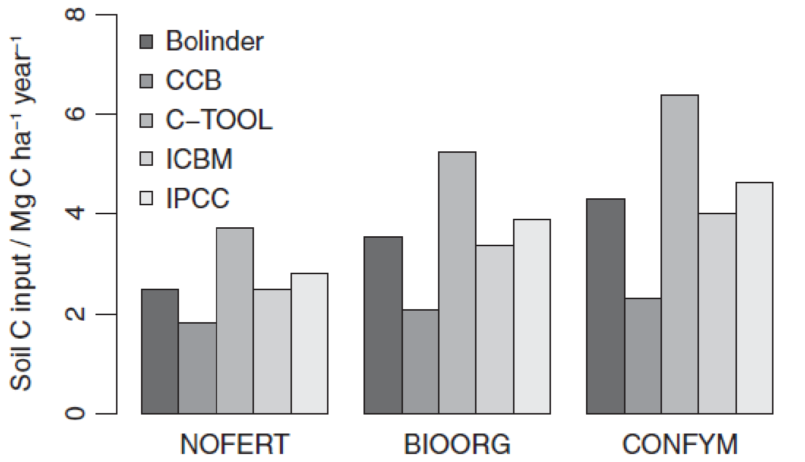

Figure 3 Soil carbon inputs to 0–1-m depth from plant residues for three treatments (NOFERT, BIOORG and CONFYM) in the DOK field trial. Estimates were derived with five different allometric equations (Bolinder, CCB, C-TOOL, ICBM and IPCC) based on measured yields. The means of four replicates per treatment are shown. The C inputs do not include inputs from manure.

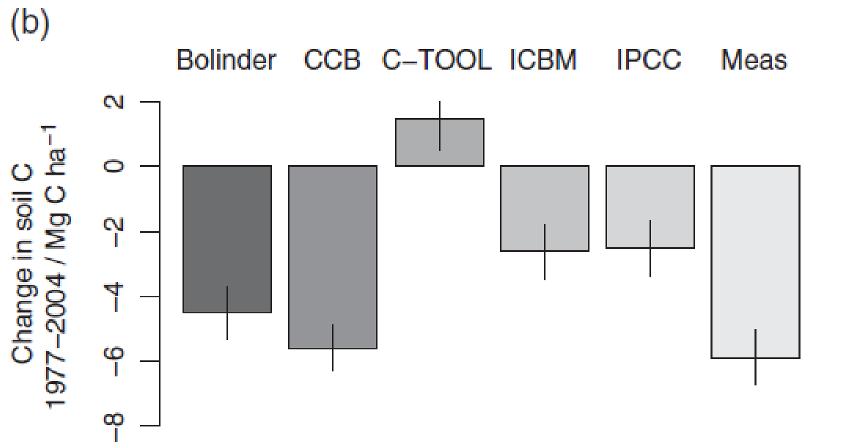

Figure 5 Changes in soil organic carbon at 0–0.2-m depth for the period 1977–2004 simulated by the model C-TOOL with soil C inputs from plant residues calculated with five different allometric equations (Bolinder, CCB, C-TOOL, ICBM and IPCC) compared to measurements (Meas). Panels (a) and (b) differ in the initial distribution of soil organic C within the profile: (a) uses the measured distribution (33% of C in the 0–1-m profile is in the top 0.2 m) and (b) uses the same distribution as in the original C-TOOL model (37.6% in 0–0.2 m). The soil C inputs from manure did not differ between allometric equations. Averages and standard errors for 20 plots of the DOK trial are shown.

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Keel et al. (2017)

Visiting dark sides of model simulation of carbon stocks in European temperate agricultural soils: allometric function and model initialization

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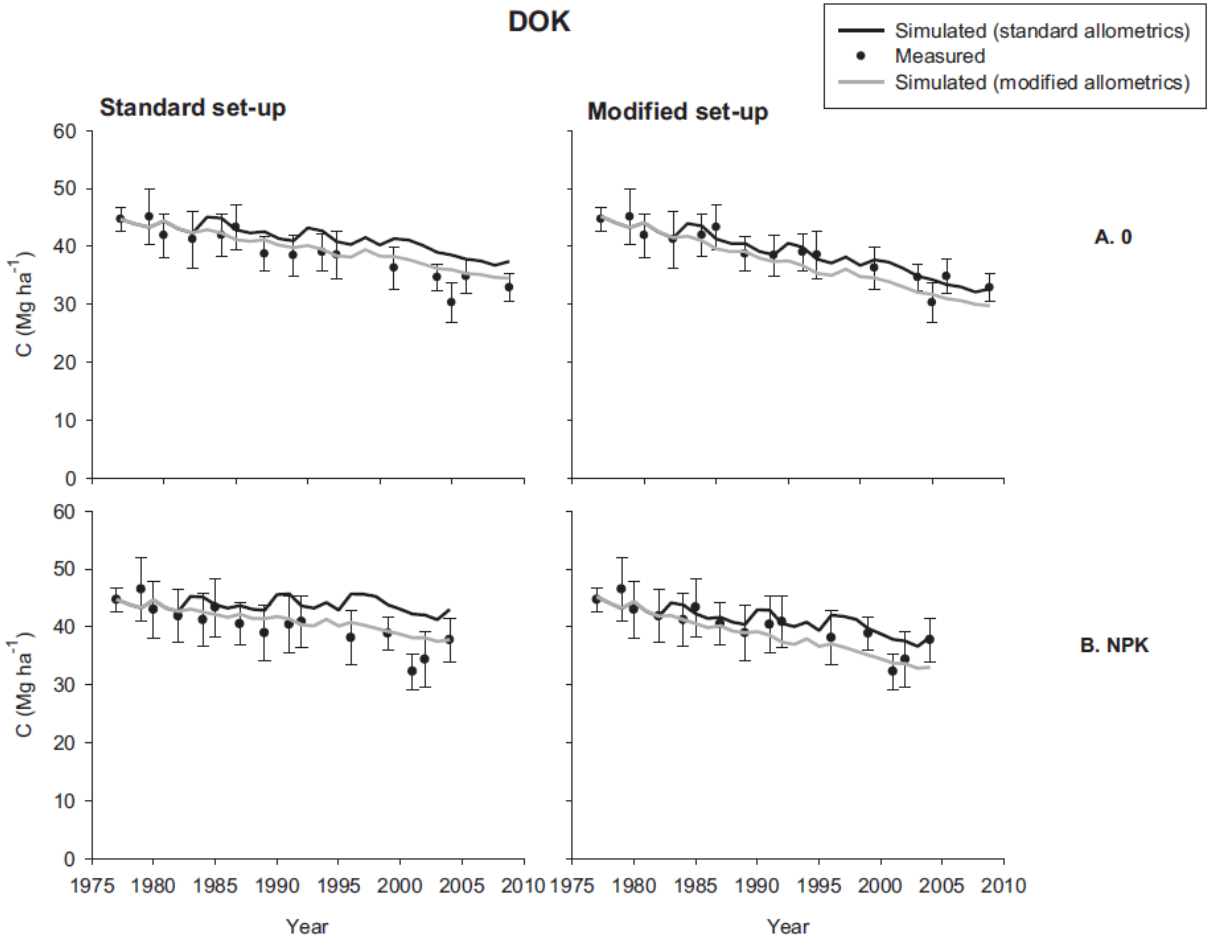
Results The modified allometric function for ley relied on fixed below-ground C input regardless of mineral fertilizer inputs and modified pool initialization involved available site history. Including available, but insufficient, pre-experiment history to adjust the initial set-up of model SOC pools did not improve to the C-TOOL simulations. Changing the allometric approach for ley from fixed shoot-to-root ratios to fixed below-ground C input decreased the soil C input dramatically and improved the C-TOOL simulation of SOC stocks for fertilized treatments in all experiments when combined with standard model set-up. For unfertilized treatments, however, the efficiency of the standard allometric function was superior to the modified one.



Taghizadeh-Toosi et al. (2020)

An approach to include soil carbon changes in life cycle assessments

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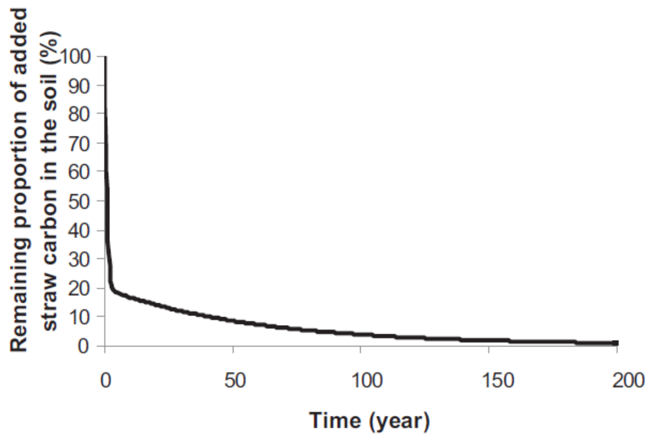

Fig. 6. Decay of one t straw carbon when added to the soil as a single event in the first year according to C-TOOL modelling.

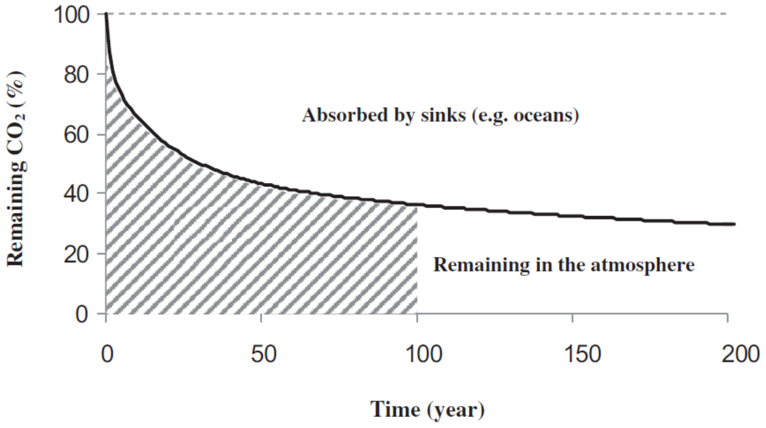

Fig. 3. Decay of CO_2 in the atmosphere, based on the **Bern** Carbon Cycle Model, f(*t*) (IPCC, 2007). The area under the curve is the time-integrated mass load of CO_2 in the atmosphere and is described by A_T (Equation (2)). An example of the time-integrated mass load of CO_2 in the atmosphere in a 100-year perspective, A_{100}, is given.

Emission reduction, R_T, carbon (C) sequestration and CO_2 reduction when incorporating one t of straw C in a soil in Denmark instead of using it for bioenergy (Example I).

Time perspective (years)	Emission reduction, R_T (%)	Carbon sequestration equivalents (kg soil Ct^{-1} straw C)	CO_2 reduction[a] (kg CO_2 t^{-1} straw C)
20	21.3	213	781
100	9.7	97	356
200	5.4	54	198

[a] The carbon sequestration is multiplied by 44/12 to get the CO_2 reduction, based on the molecular weight of CO_2 to C.

Petersen et al. (2013)

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Reflections

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There are many SOC models with varying complexities

All models simulate SOC depending on C inputs and model parameterization

The uncertainty in C inputs and pool initialization often dominate

The time-scale of consideration of changes is paramount

SOC modelling differs from the consideration of CO_2 in the atmosphere, i.e. difficulties with inclusion in LCA

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Thank you for your attention

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