Fachagentur Nachwachsende Rohstoffe e.V.

Gefördert durch:

Bundesministerium für Ernährung und Landwirtschaft

aufgrund eines Beschlusses des Deutschen Bundestages

Humus (and nutrient) effects of organic residues

Bessler H. [1], Nielsen K. [2], Adam A. [1], Radelhof T. [1], Engels C. [1]

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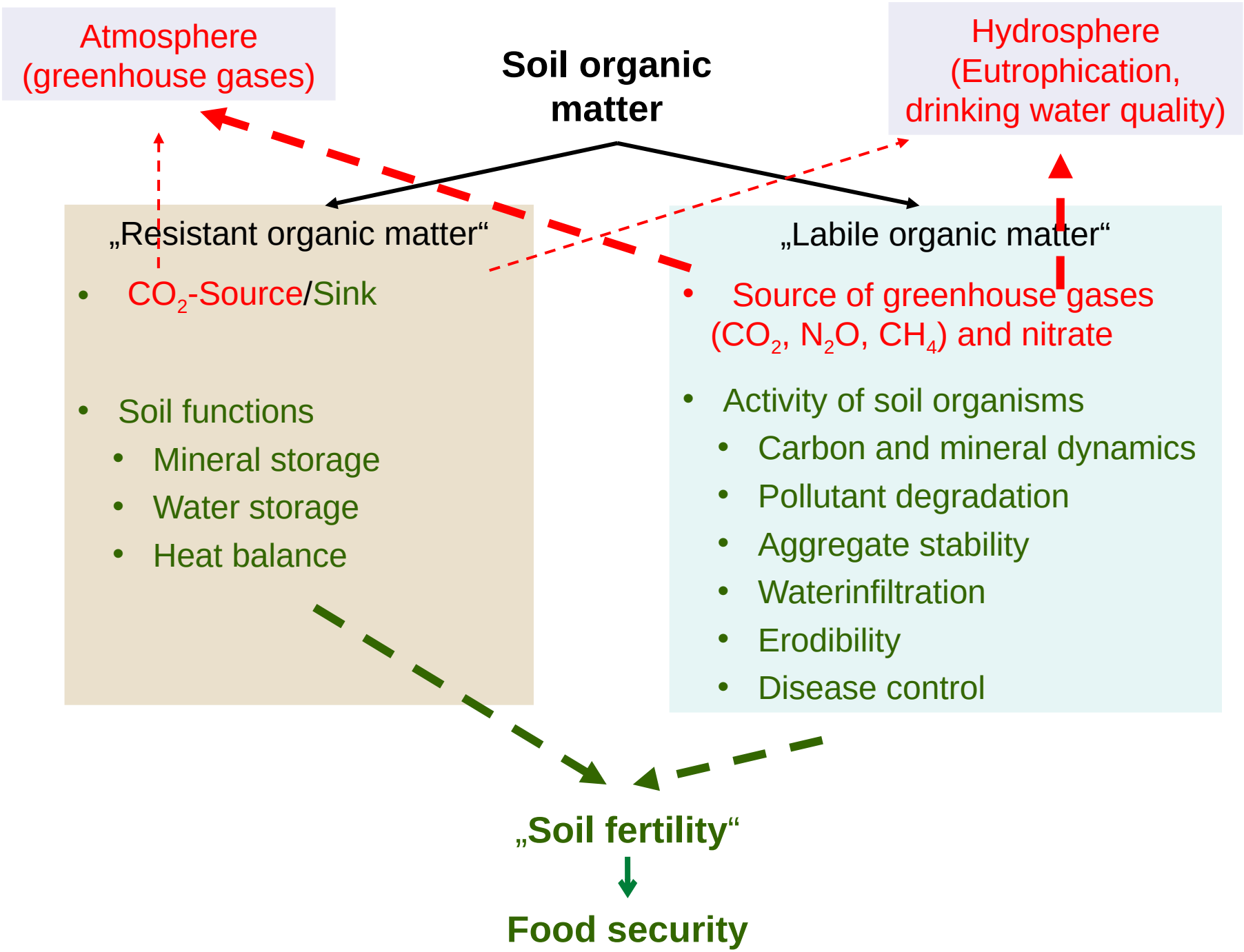
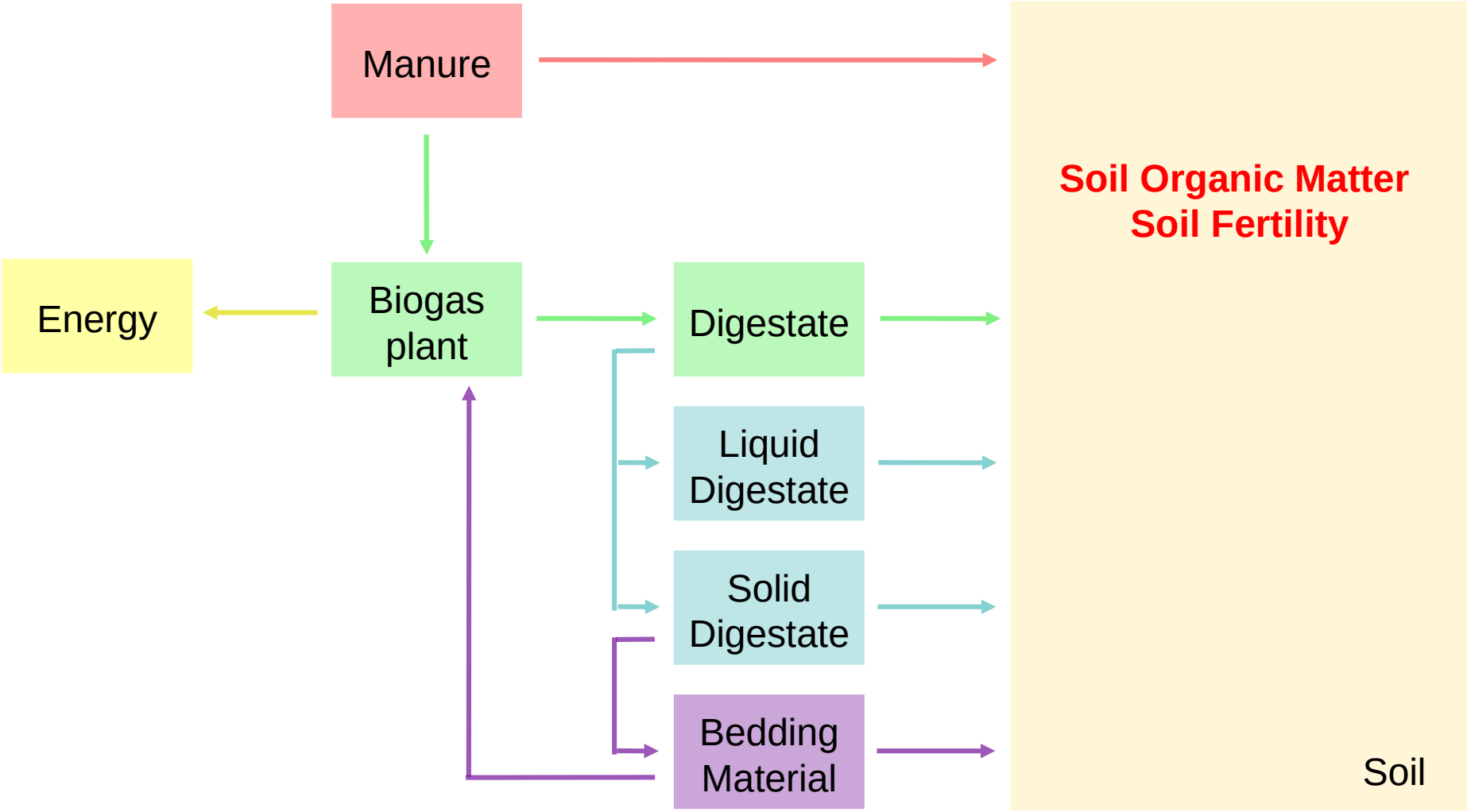
Relevance of SOM for agriculture and society



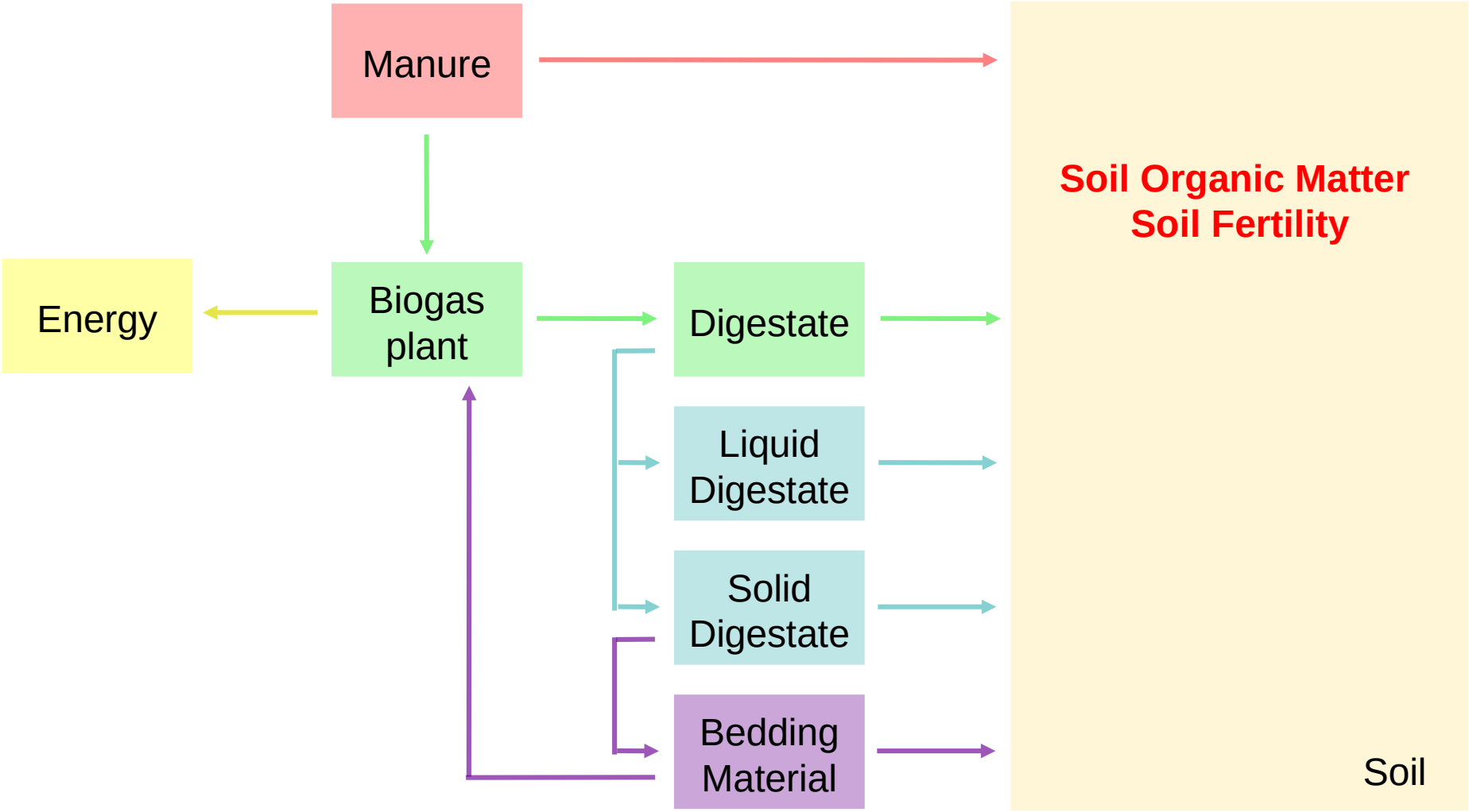
Alternative pathways for using organic residues lead to a large diversity of organic residues incorporated into the soil



1. How can we determine the effect of the many different organic residues on soil organic matter/soil fertility?

2. Does anaerobic digestion of animal excreta come at the expense of soil organic matter?



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I. Introduction

II. How to assess the effect of organic residues on soil organic matter (SOM)?

- Field experiments

- Simplified fast method

III. Does anaerobic digestion of animal excreta come at the expense of SOM?

Assessment of the effect of organic residues on soil organic carbon in a static field experiment in Berge (experimental station of IASP); start: 2011

Protocol:

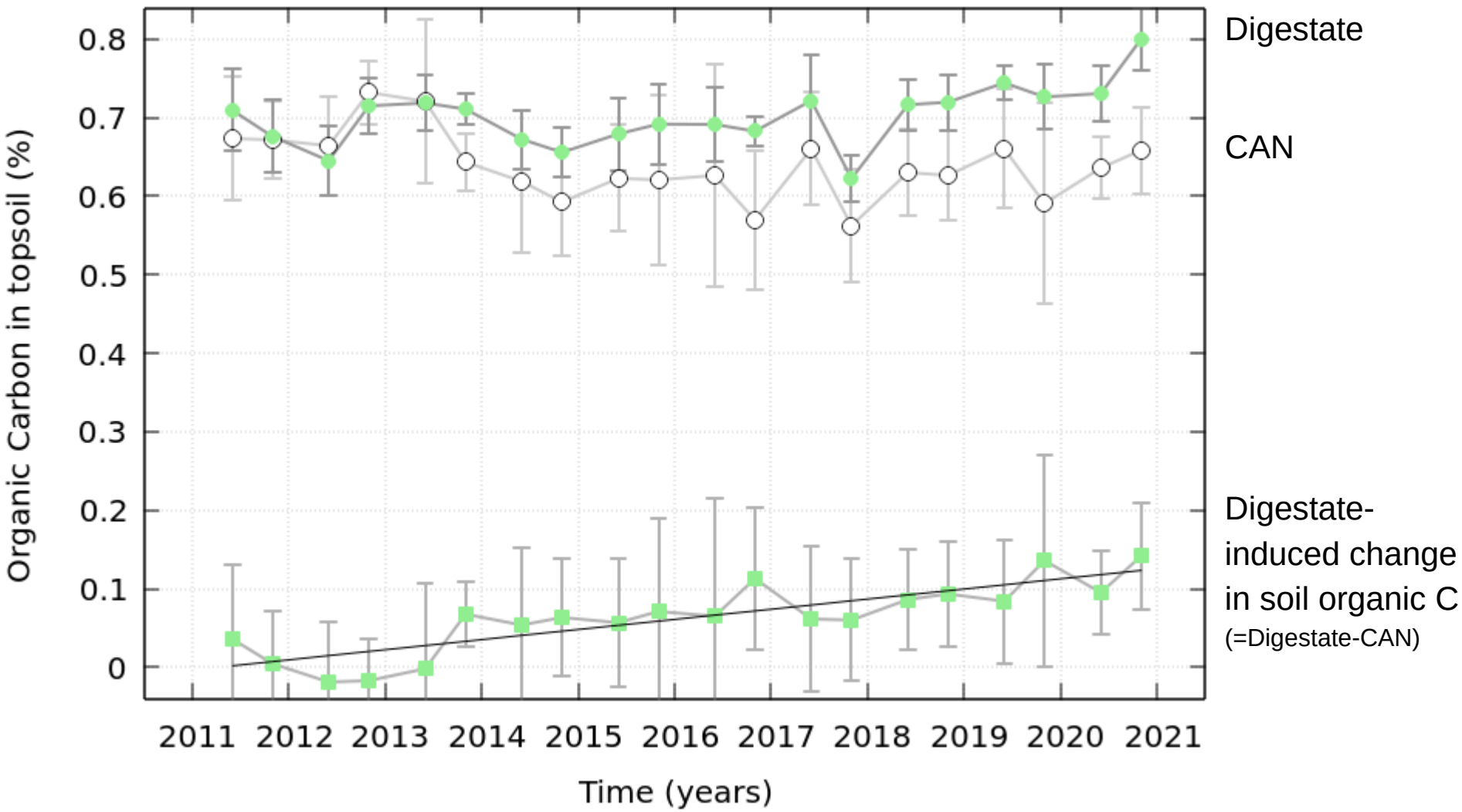
Annual application of 1000 kg C ha^{-1}

Seven different organic residues

- 5 digestates
- 1 slurry
- 1 manure
- 1 control without organic residue but addition of equivalent rates of N in form of calcium ammonium nitrate (CAN)
- 1 control without any fertilization

Crop rotation:
silage maize – green rye – sorghum millet – green rye

Changes in soil organic carbon in topsoil (0-20 cm) induced by repeated application of a digestate or mineral fertilizer only (CAN) in a static field experiment in Berge (start: 2011)



► ***Residue-induced changes in SOM can be measured in the field but only in long-term (decades) experiments.***

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Quantification of an indicator of the residue carbon fraction, that potentially is retained in SOM in long-term using long-term incubations

1) Measurement of CO_2 release from soils without and with residue addition over time using alkali-trap method

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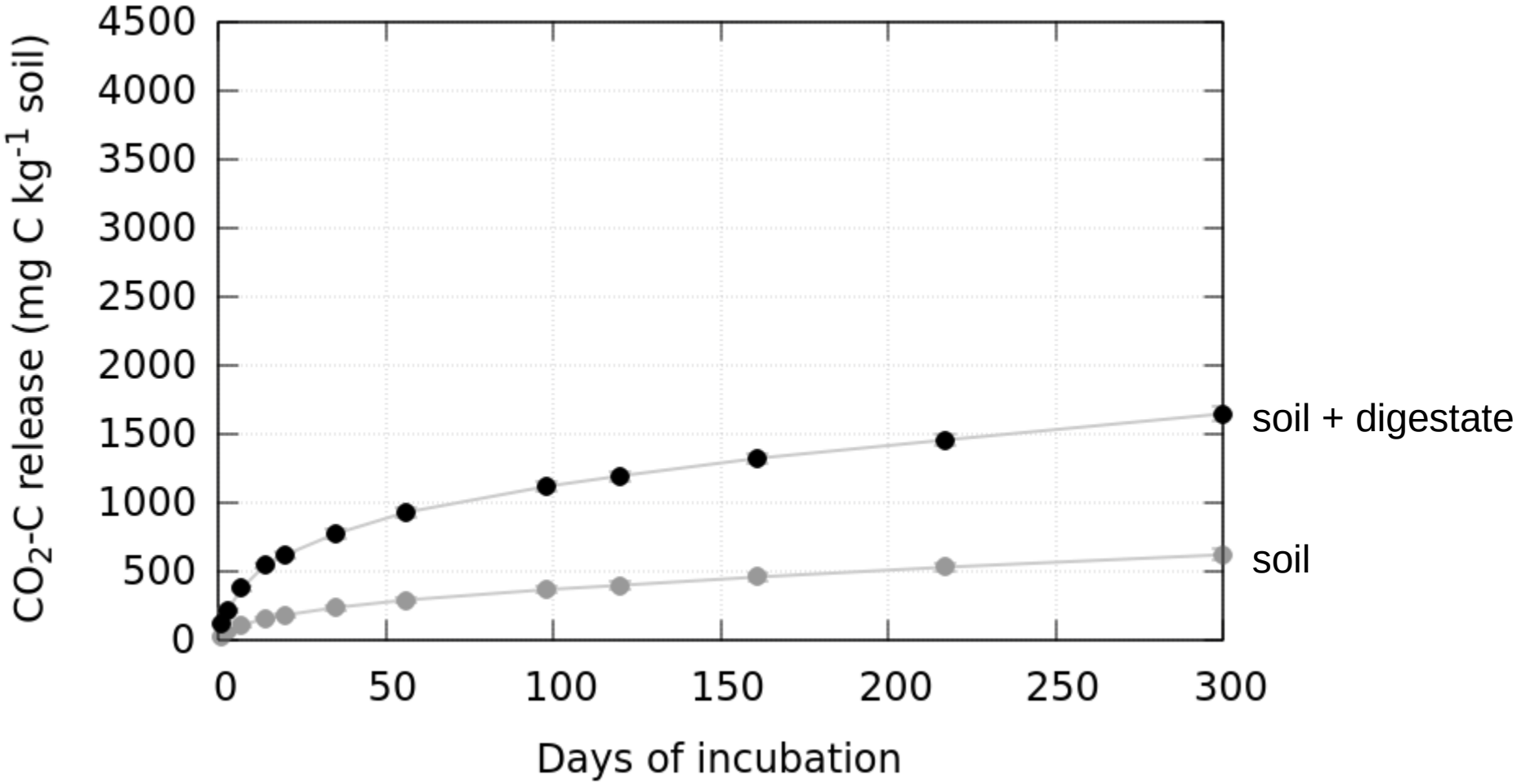
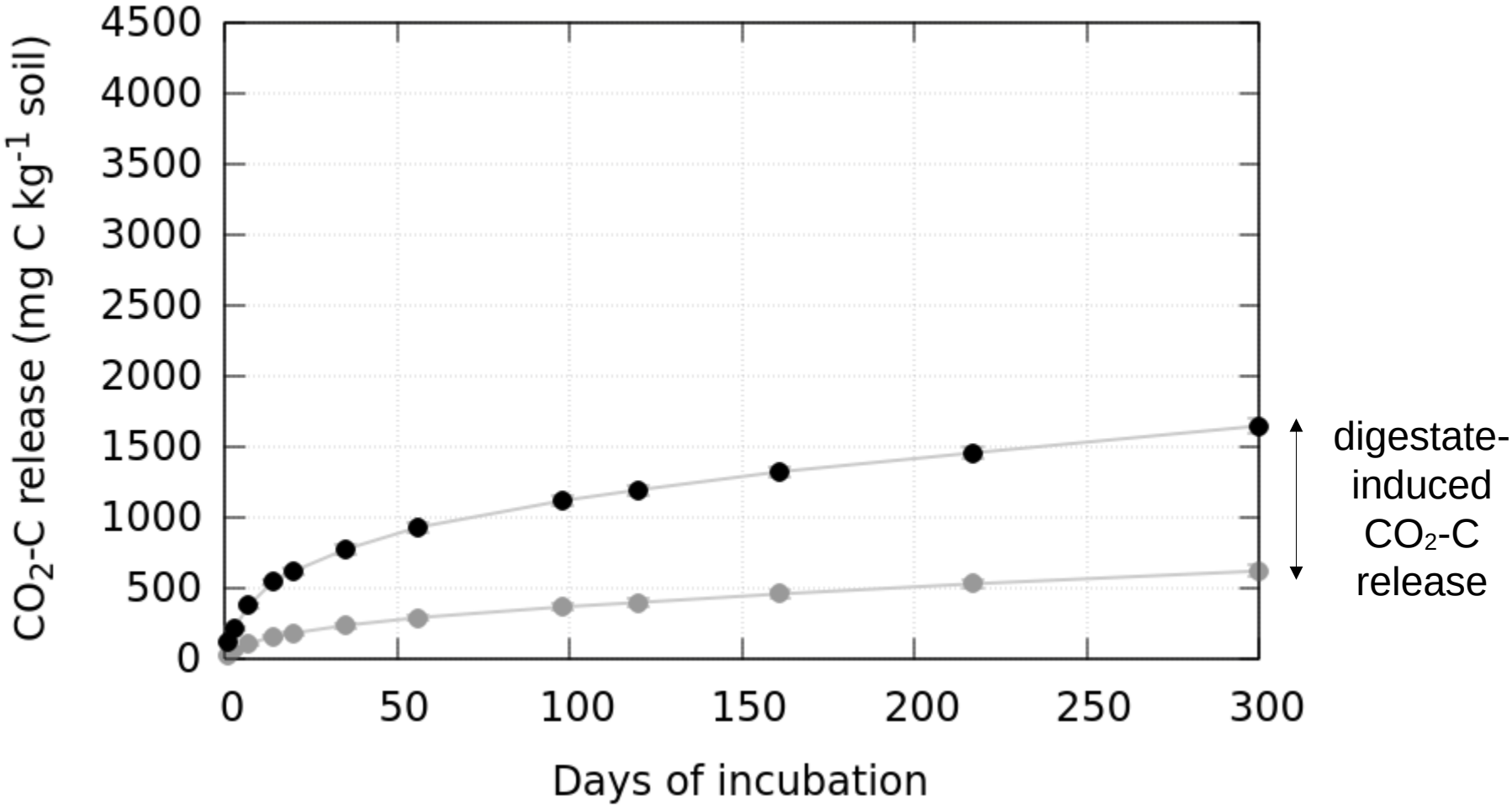


Quantification of an indicator of the residue carbon fraction, that potentially is retained in SOM in long-term using long-term incubations

2) Calculation of the residue-induced CO_2-C release

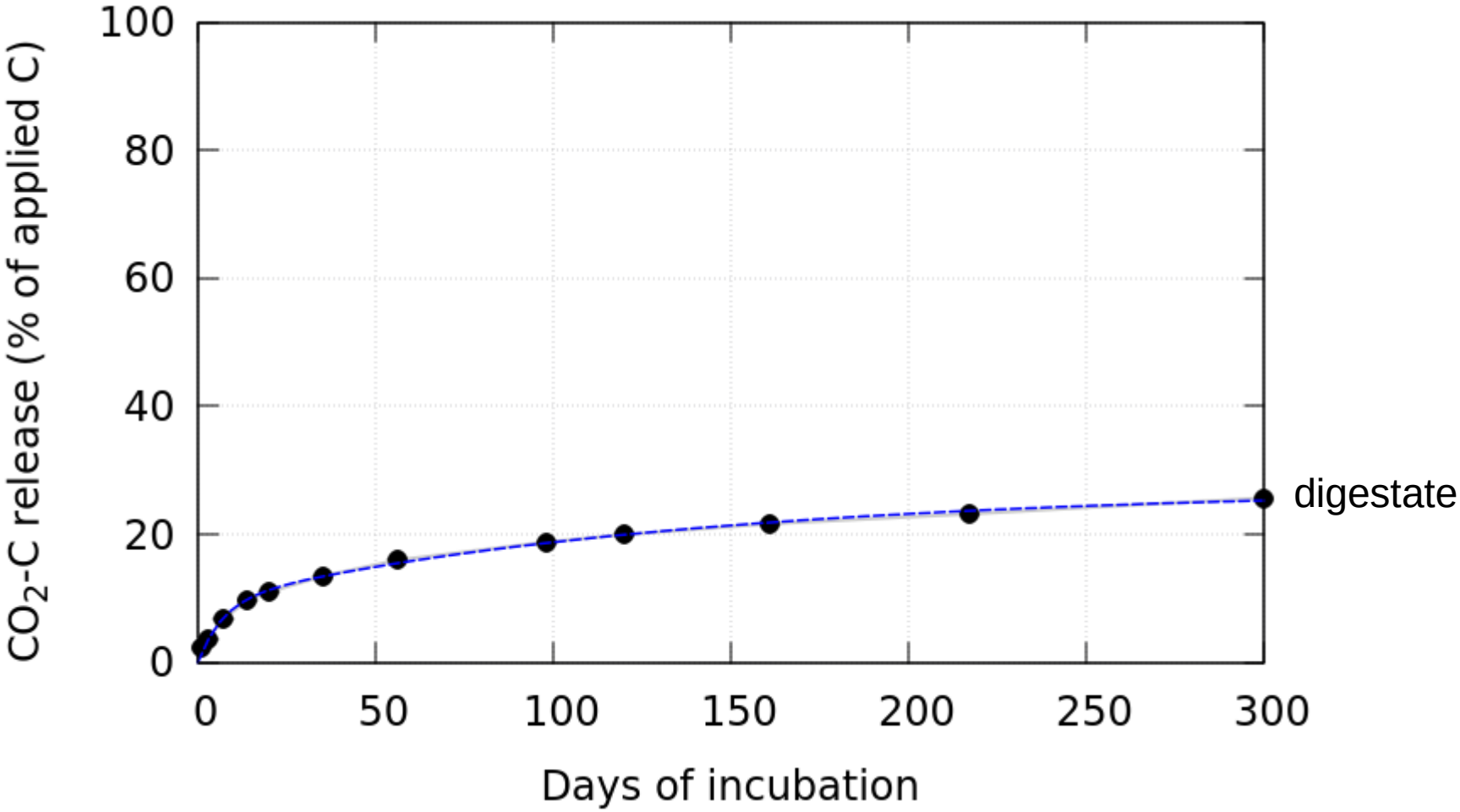
(= Difference in CO_2-release between soil with residue and soil without resiude)



Quantification of an indicator of the residue carbon fraction, that potentially is retained in SOM in long-term using long-term incubations

3) Fit mineralization kinetic model to the data

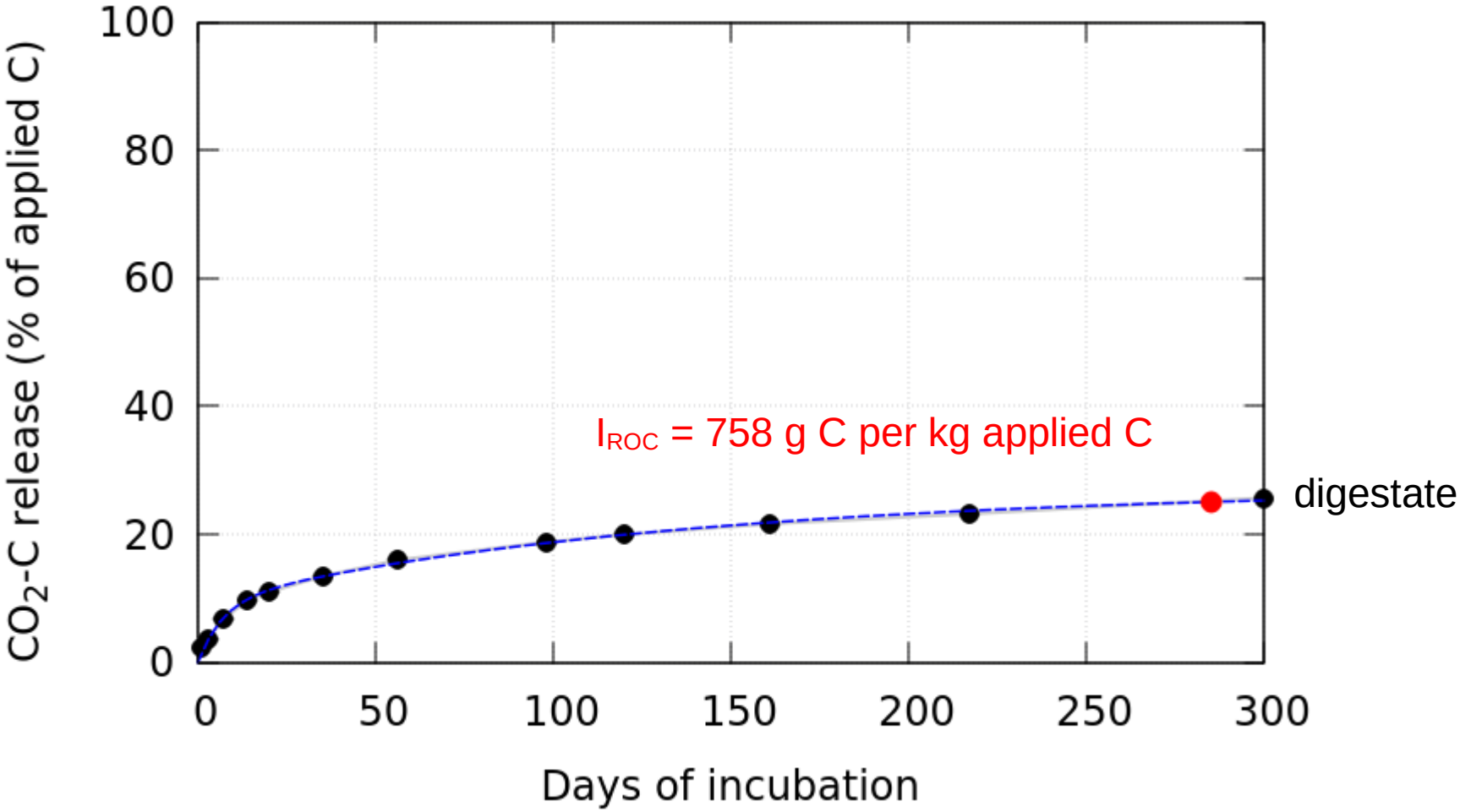
(e.g.: $C(t) = C_{A,f}\{1 - \exp(-k_f t)\} + C_{A,s}\{1 - \exp(-k_s t)\} + C_{A,r}$)



Quantification of an indicator of the residue carbon fraction, that potentially is retained in SOM in long-term using long-term incubations

4) Calculation of residue C remaining when the mineralization rate of remaining residue C reached the mineralization rate of soil organic matter (≅2% year^{-1}).

= **Indicator of residue C fraction potentially retained in SOM in long-term** (**I_{ROC}**; Lashermes et al. 2009)



Lashermes G et al 2009. European Journal of Soil Science 60, 297-310.

Can we predict the residue-specific indicator value (I_{ROC}) by short-term incubation studies and chemical residue characteristics?

Correlations between I_{ROC} determined in long-term incubations and residue-induced CO_2-release in short incubation and chemical residue characteristics (n=83; Lashermes et al. 2009).

	CO_2-release in	Fiber analysis (Van Soest)			
	3 days of incubation	SOL	LIC	HEM	CEL
I_{ROC}	**-0.79*****	**-0.45*****	**0.68*****	**-0.42*****	0.11

► Regression model for prediction of I_{ROC}

$$I_{ROC} = 445 + 0{,}5\ SOL - 0{,}2\ CEL + 0{,}7\ LIC - 2{,}3\ C_{3d} \quad (R^2=0{,}74)$$

SOL = Soluble fraction* (g organic matter kg^{-1} total organic matter)
CEL = Cellulose (g organic matter kg^{-1} total organic matter)
HEM = Hemicellulose (g organic matter kg^{-1} total organic matter)
LIC = Lignin+cutin-like fraction (g organic matter kg^{-1} total organic matter)
C_{3d} = residue-induced CO_2-C mineralisation after 3 d (% of added C)
*Soluble fraction: in boiling water extractable org. matter + NDF fraction of Van Soest - Extraction

► ***The residue-specific indicator value (I_{ROC}) can be derived from long-term incubations or short-term incubations and chemical analyses.***

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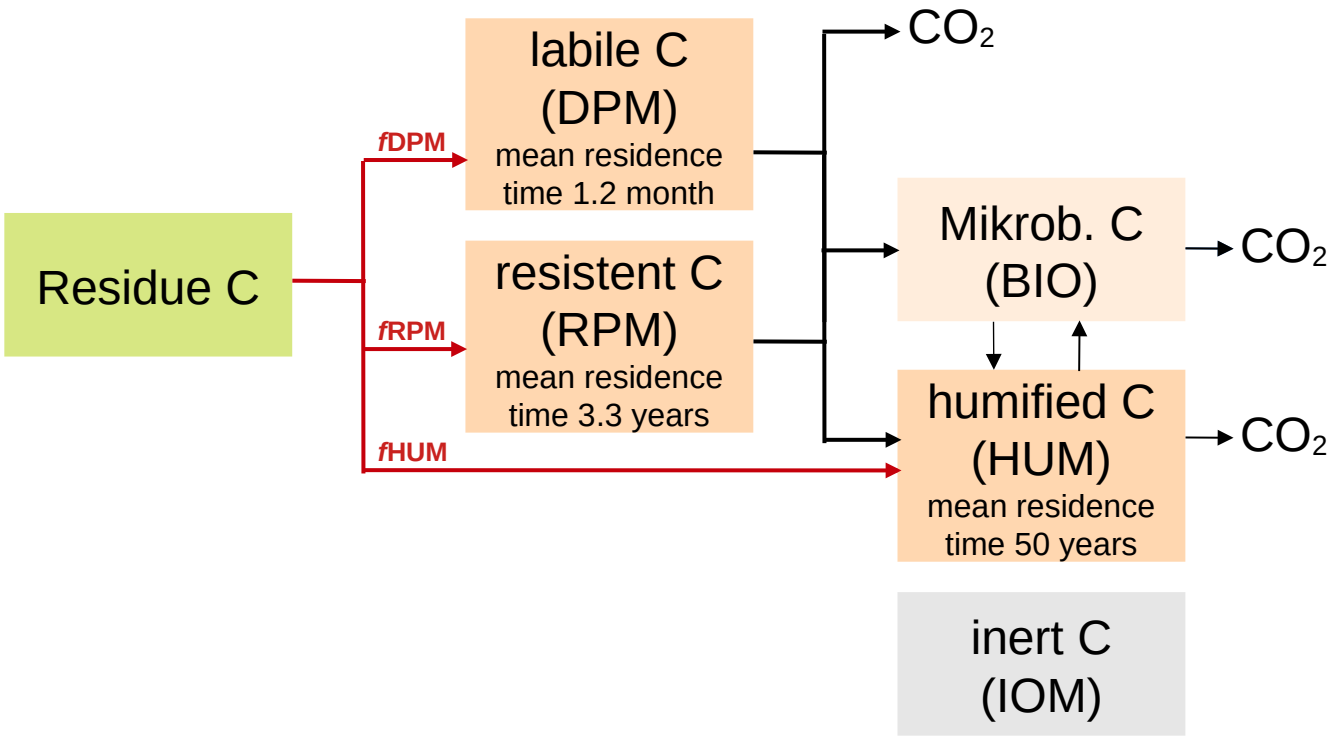
Structure and input data required for parameterization of the RothC Model

Model structure of RothC-26.3



Input data
- Residue partition coefficients (f_{DPM}, f_{RPM}, f_{HUM})
- C input from residues
- Site characteristics (temperature, precipitation, open-pan evaporation, clay content, fallow duration)

How to derive the partition coefficients?

$$f_{DPM} = -1.254 \times I_{ROC} + 115.922$$
$$f_{RPM} = 0.979 \times I_{ROC} - 8.928$$
$$f_{HUM} = 100 - f_{DPM} - f_{RPM}$$

Peltre C et al 2012. Soil Biology & Biochemistry 52, 49-60.

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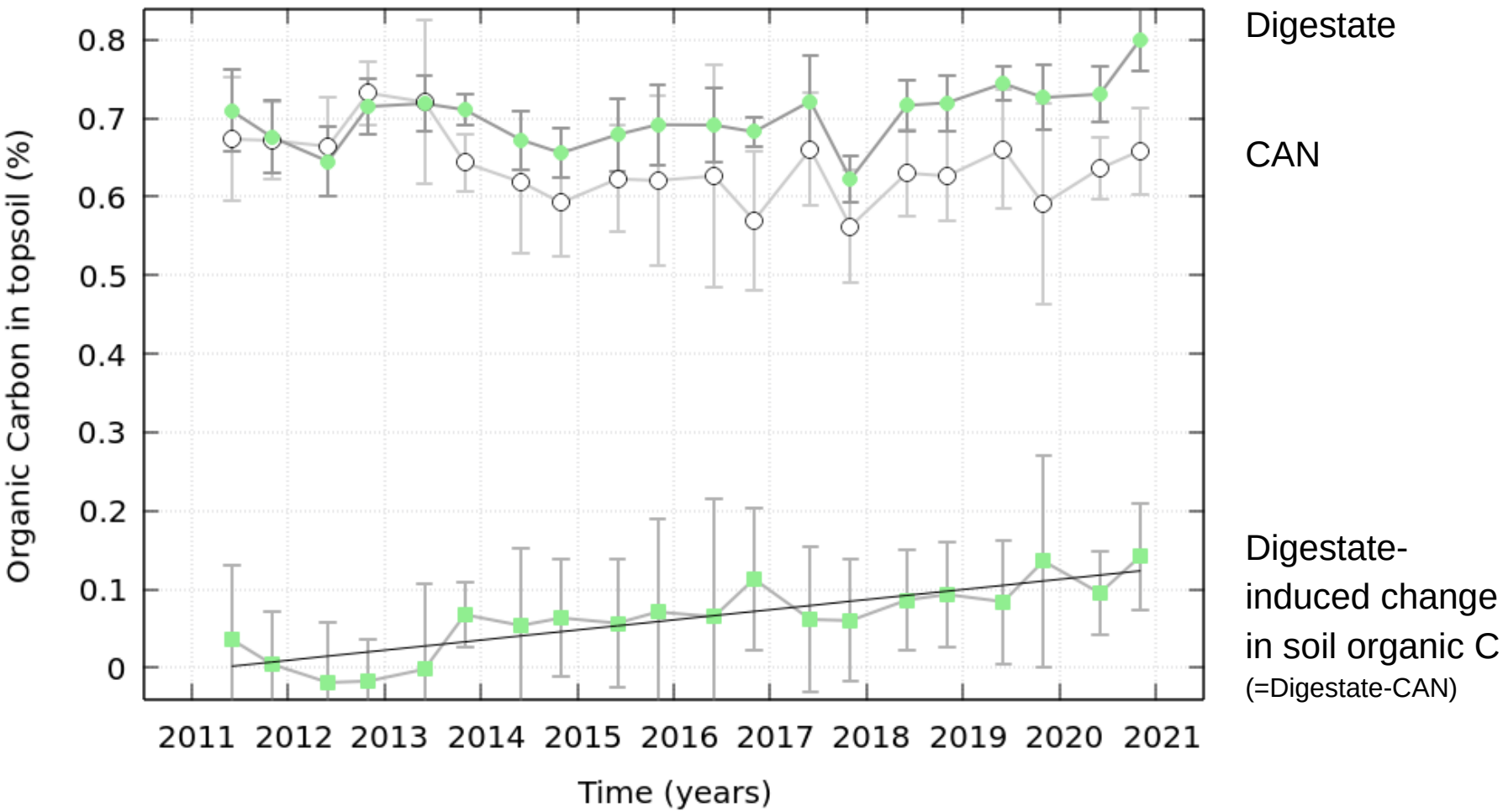
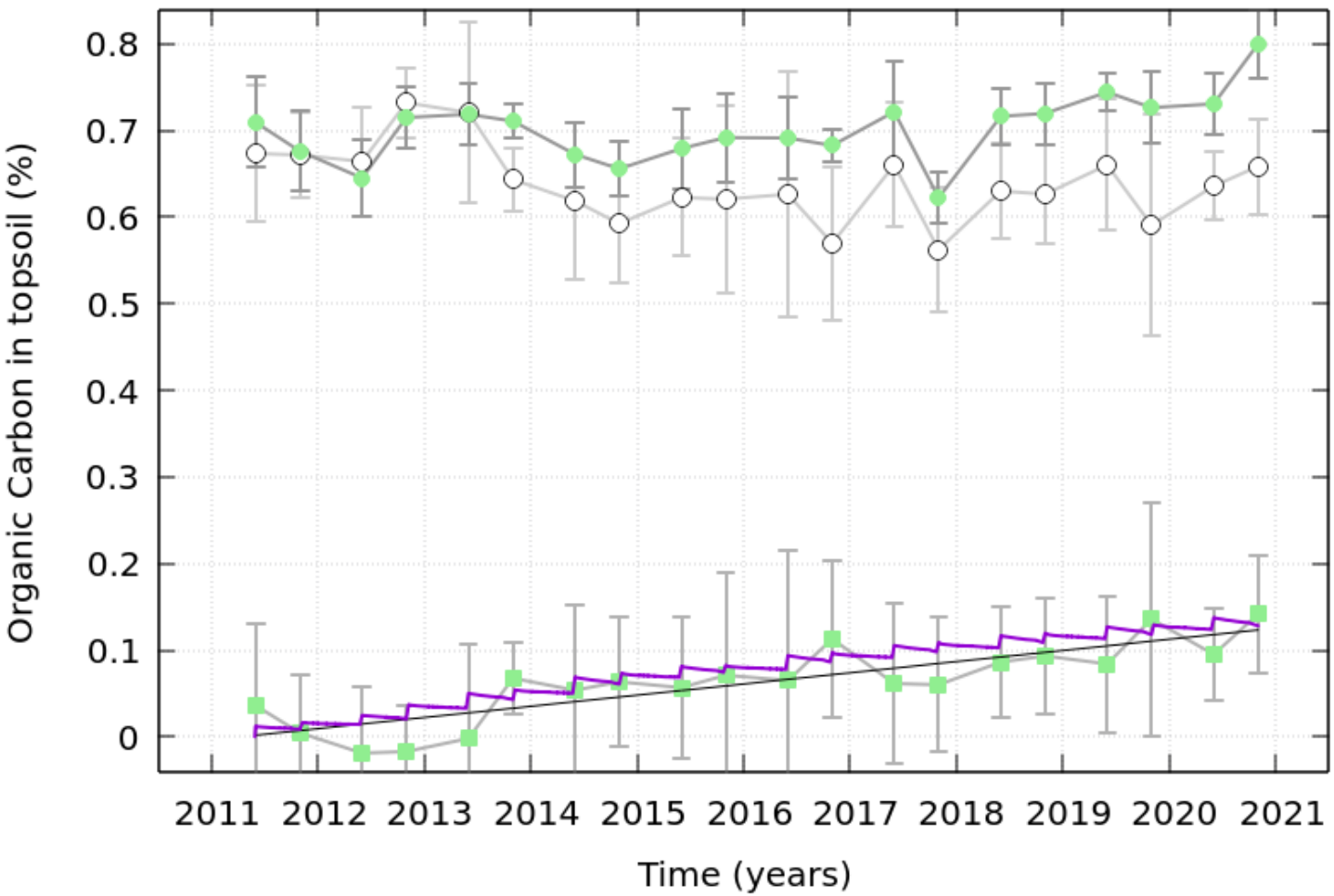
Can we predict the digestate-induced accumulation of soil C in the Berge experiment by the simplified method?



<u>Procedure</u>

1. Short incubation + chemical analyses of added digestate to quantify I_{ROC} (= 67%)
2. Calculation of partition coefficients from I_{ROC} (f_{DPM} = 32, f_{RPM} = 56, f_{HUM} = 11%)
3. Parameterization of RothC with partition coefficients, C inputs, site characteristics
4. Simulation of digestate-induced accumulation of soil C

Can we predict the digestate-induced accumulation of soil C in the Berge experiment by the simplified method?



Digestate

CAN

Digestate-induced change in soil organic C (=Digestate-CAN)

Simulation result

► ***The simplified method worked with adequate accuracy.***

• *Conclusion*

- *How can we determine the effect of the many different organic residues on soil organic matter/soil fertility?*
- The results indicate that the ability of organic residues for build up of soil organic matter can be assessed with a simple method combining short-term incubation and chemical characterization of the residues with modelling. The simple method would allow development of more specific recommendations for residue applications for farmers. However, the method needs further validation.

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Does anaerobic digestion of animal excreta come at the expense of SOM?

Approach

- Sampling of 4 slurry/manure-mixtures from dairy farms before and after anaerobic digestion

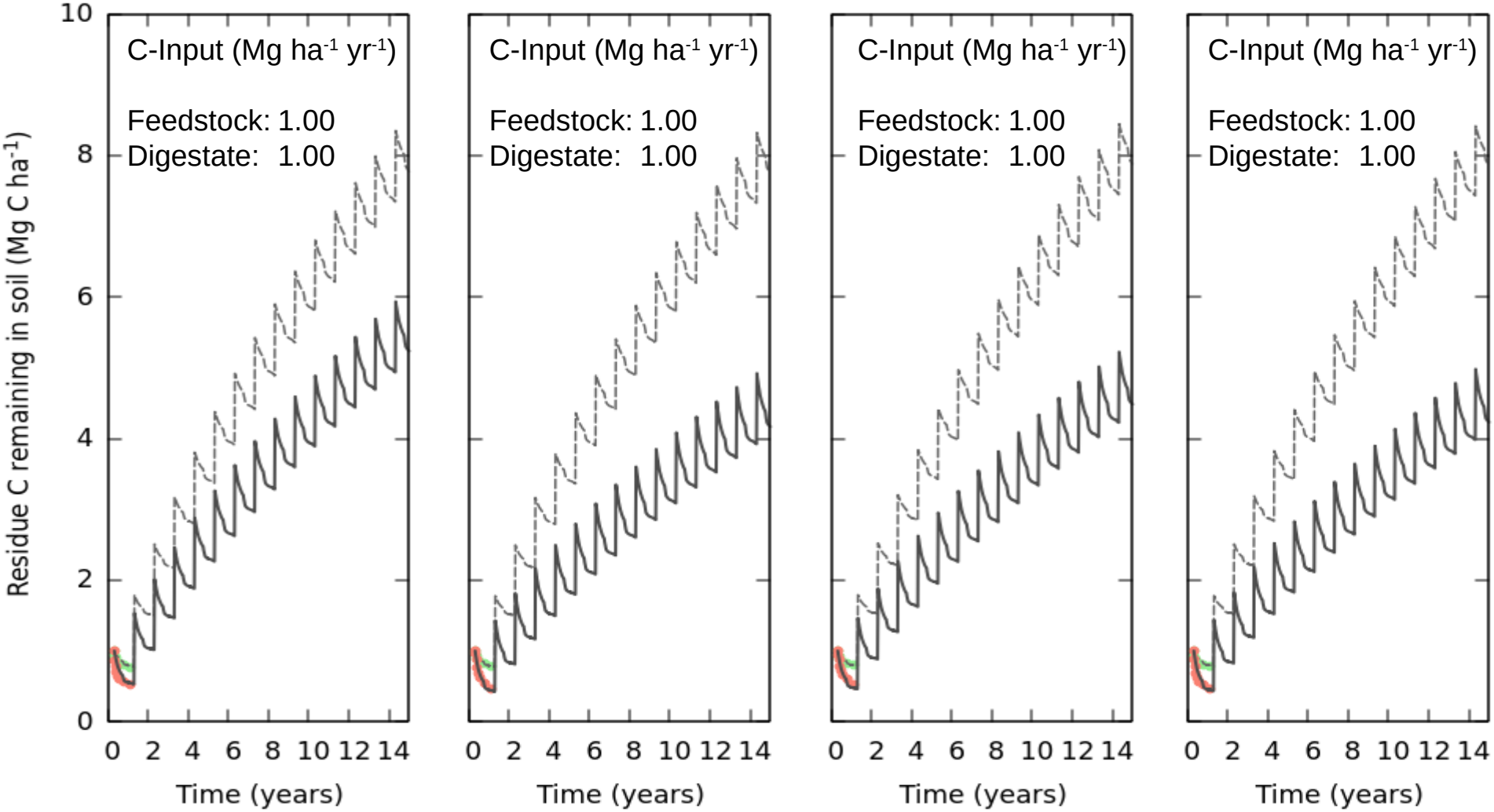
- Quantification of I_{ROC} in long-term incubations

- Simulation of soil organic carbon accumulation induced by repeated applications of feedstocks (raw slurry/manure-mixtures) or digestates for 20 years for two scenarios:

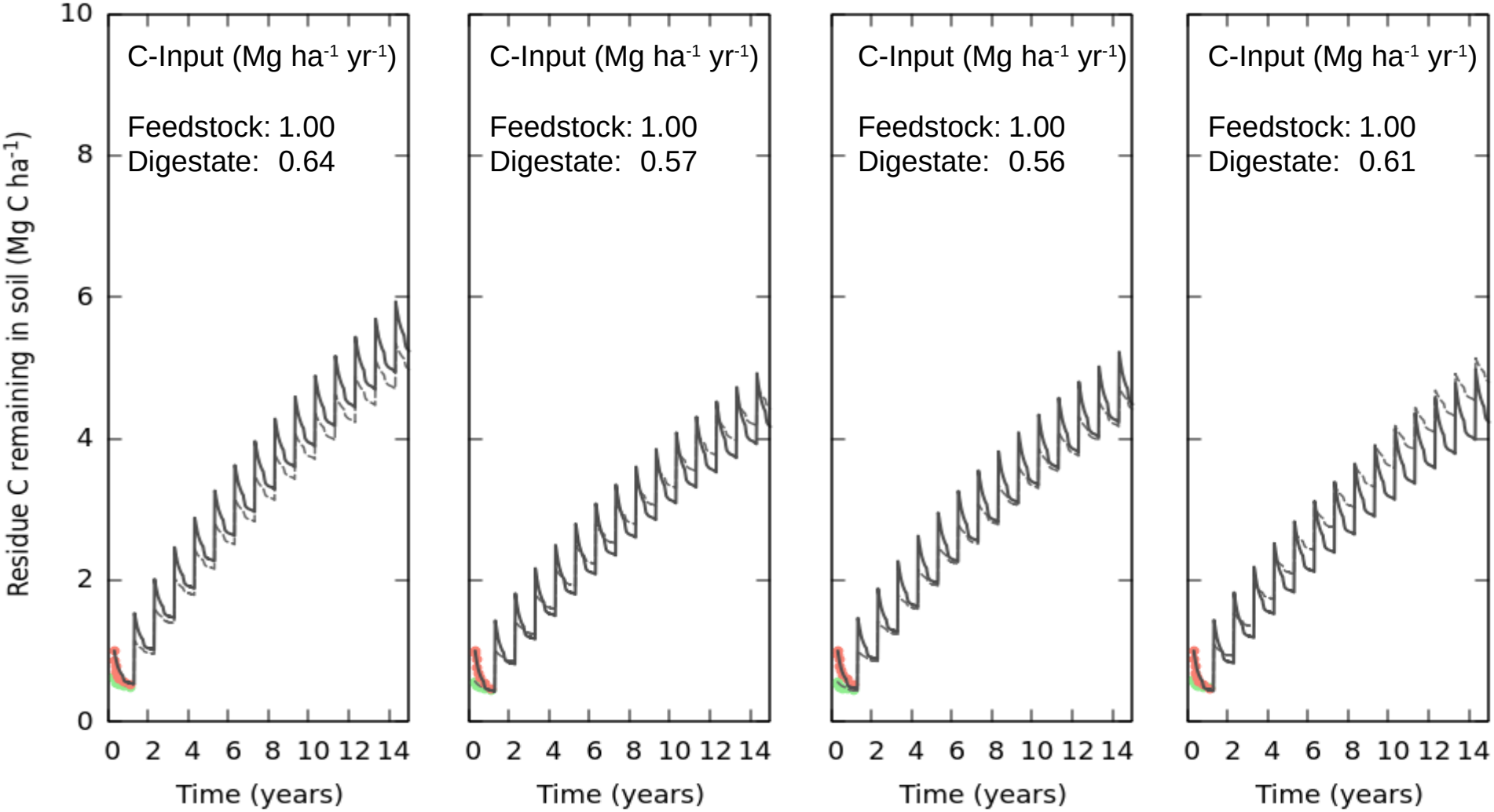
Scenario 1:
C input by digestates = C input by feedstocks (1 Mg C ha^{-1} yr^{-1})

Scenario 2:
C input by digestates = C input by feedstocks (1 Mg C ha^{-1} yr^{-1}) minus gaseous loss of C during anaerobic digestion (~36-44% of feedstock C; calculated from feedstock composition and reference values)

Organic carbon remaining in soil from slurry / manure – mixtures applied before or after anaerobic digestion as measured in incubation experiments (•) or simulated with RothC (-) for scenario 1



Organic carbon remaining in soil from slurry / manure – mixtures applied before or after anaerobic digestion as measured in incubation experiments or simulated with RothC for scenario 2



• *Conclusion*

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- The results indicate that the ability of organic residues for build up of soil organic matter can be assessed with a simple method combining short-term incubation and chemical characterization of the residues with modelling. The simple method would allow development of more specific recommendations for residue applications for farmers. However, the method needs further validation.

- *Does anaerobic digestion of animal excreta come that the expense of soil organic carbon?*
- Not necessarily, as the ratio of organic carbon remaining in soil is higher for digestates than for feedstocks (mixtures of slurry and manures).