Scaling up microbial dynamics for soil carbon cycling models

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Geoscientific Model Development

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Geosci. Model Dev., 13, 1399–1429, 2020
https://doi.org/10.5194/gmd-13-1399-2020

See more details in this GMD paper!

https://www.geosci-model-dev.net/13/1399/2020/

Development and technical paper

Dynamic upscaling of decomposition kinetics for carbon cycling models

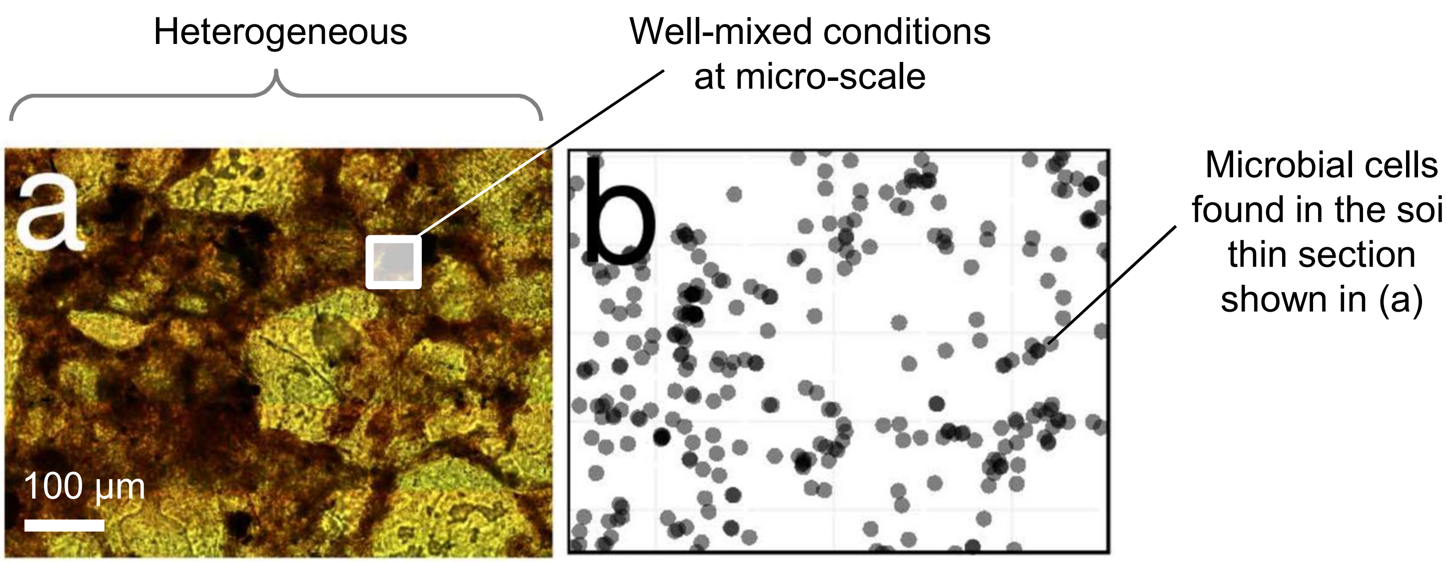
Vetenskapsrådet

formas

Bolin Centre for Climate Research

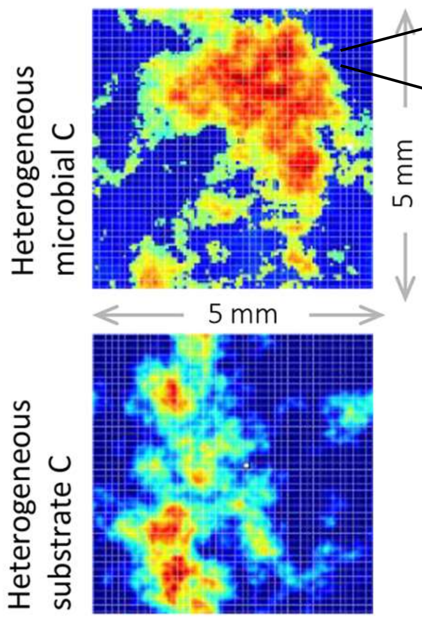
Spatial heterogeneity in soil

- Soil microbes are often physically separated from their substrate because of spatial heterogeneity
- Soils are not 'well-mixed' as assumed by C cycling models, except at the micro-scale (<100 μm)



Raynaud X, Nunan N (2014) Spatial Ecology of Bacteria at the Microscale in Soil. PLoS ONE 9(1): e87217. doi:10.1371/journal.pone.0087217

Methods



$$D = k_M C_S C_B$$

$$D = \frac{k_{MM} C_S C_B}{K_{MM} + C_S}$$

$$D = \frac{k_{IM} \; C_S C_B}{K_{IMM} + C_B}$$

Alternative decomposition kinetics at micro-scale, based on well-mixed assumption

Find spatial-average decomposition kinetics using scale transition theory

$$\overline{D} = k_M \overline{C_S}\,\overline{C_B} + \mathrm{HOT(variances\ and\ covariances)}$$

$$\overline{D} = \frac{k_{MM} \overline{C_S}\,\overline{C_B}}{K_{MM} + \overline{C_S}} + \mathrm{HOT(variances\ and\ covariances)}$$

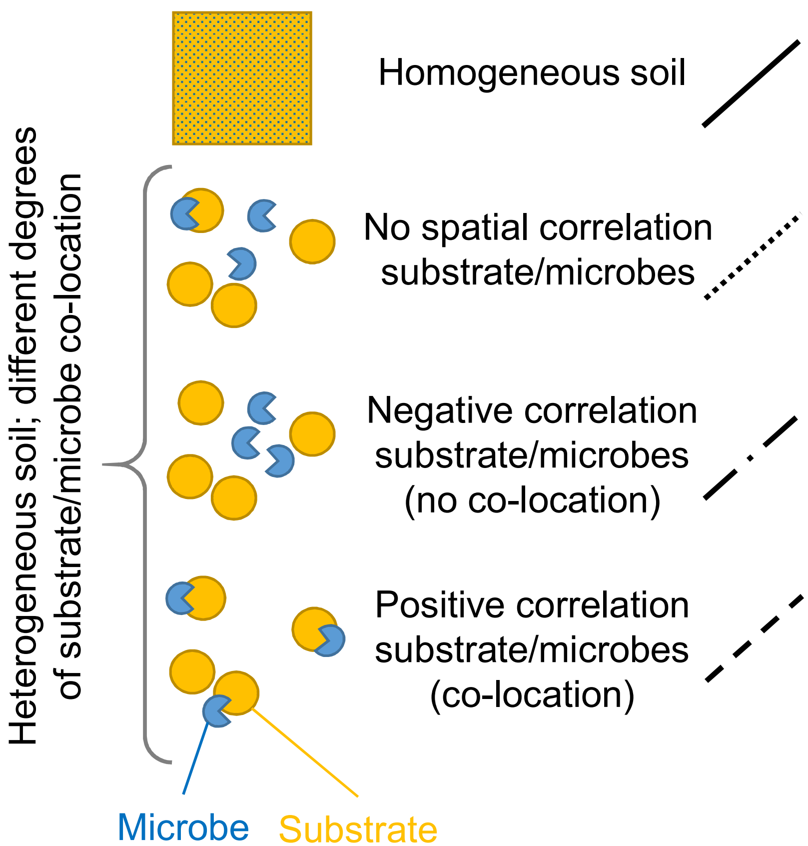
$$\overline{D} = \frac{k_{IMM} \overline{C_S}\,\overline{C_B}}{K_{IMM} + \overline{C_B}} + \mathrm{HOT(variances\ and\ covariances)}$$

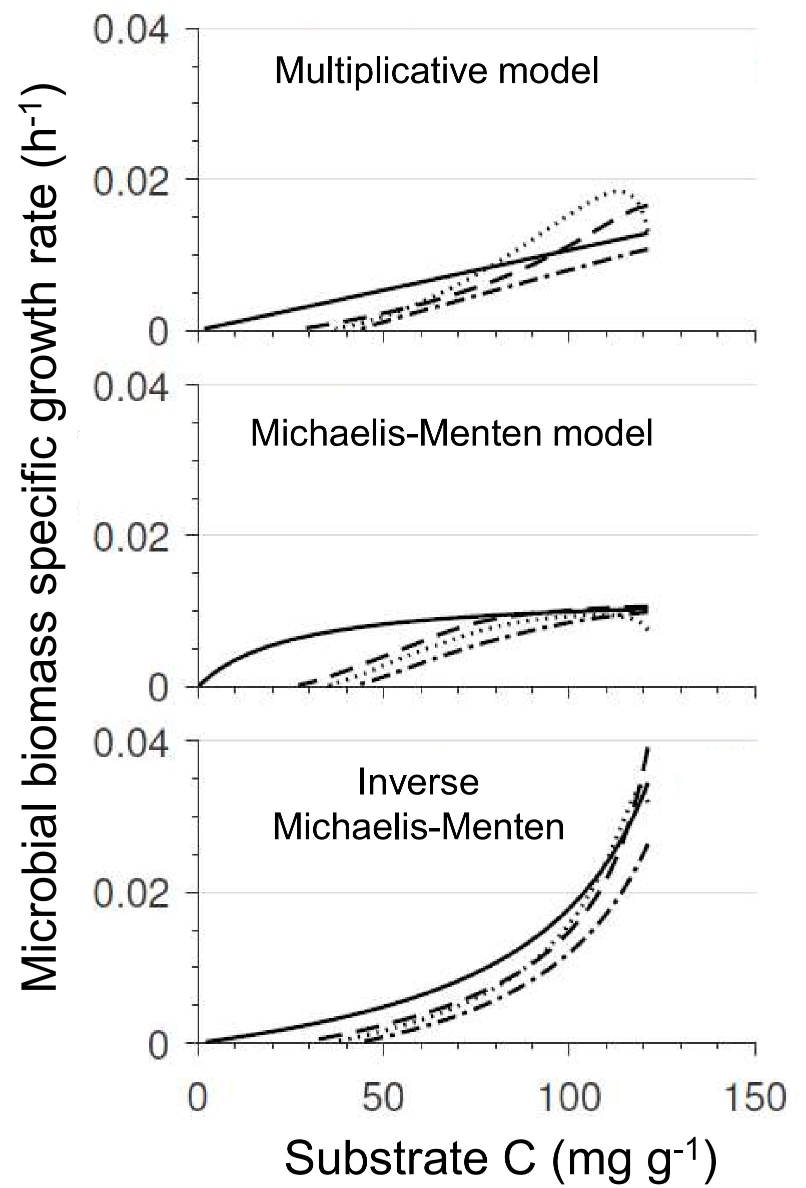
HOT: higher order terms that 'correct' the decomposition kinetics under well-mixed conditions to account for spatial heterogeneity; e.g., when HOT are negative, decomposition is inhibited due to the lack of co-location of substrate and microbes

Chakrawal et al. (2020), GMD

Results

The degrees of heterogeneity and co-location of substrates and microbes affect decomposition kinetics





Chakrawal et al. (2020), GMD

Take home messages

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1. Spatial heterogeneity affects C flow in soil by limiting contact between substrates and microbes.
2. Scale transition theory predicts that decomposition kinetics applied at scales larger than those at which conditions are well-mixed should be modified to account for spatial heterogeneity
3. The shape of the upscaled decomposition kinetics can be quite different from typical assumptions in soil C flow models
4. Substrate-microbe separation slows down decomposition (opposite is true for co-location)