Scaling up microbial dynamics for soil carbon cycling models

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

Methods

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

Find spatial-average decomposition kinetics using scale transition theory

\[
D = k_M C_S C_B
\]

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

\[
D = \frac{k_{IM} C_S C_B}{K_{IMM} + C_B}
\]

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.

Homogeneous soil
- No spatial correlation substrate/microbes
- Negative correlation substrate/microbes (no co-location)
- Positive correlation substrate/microbes (co-location)

Heterogeneous soil; different degrees of substrate/microbe co-location

Chakrawal et al. (2020), GMD
Take home messages

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).