Effects of Climate Change on Soil Organic Matter Chemical Composition and Carbon Content in different Physical Fractions

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Display Material

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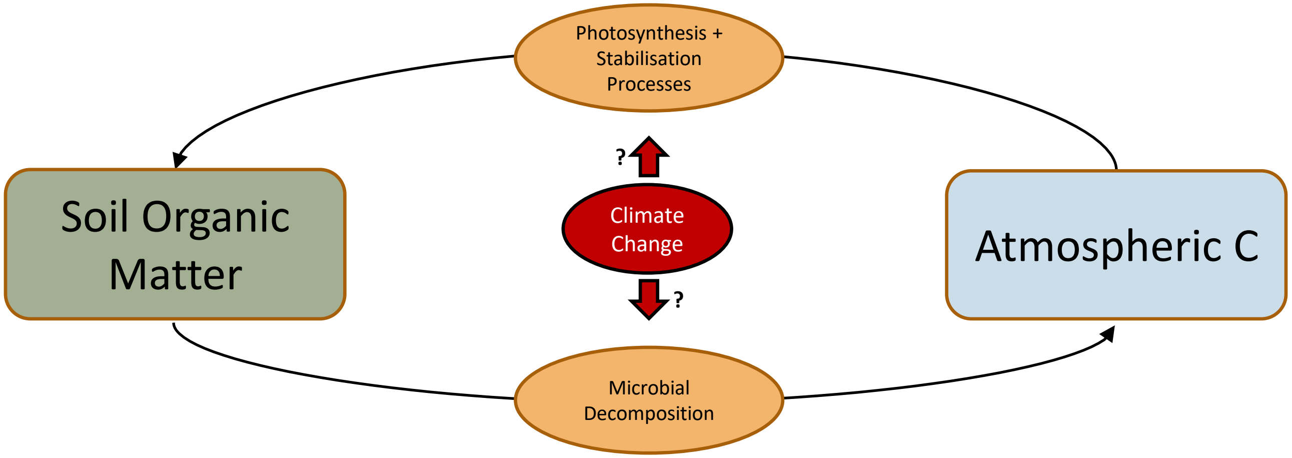
Background



Photosynthesis + Stabilisation Processes

Soil Organic Matter

Climate Change

?

?

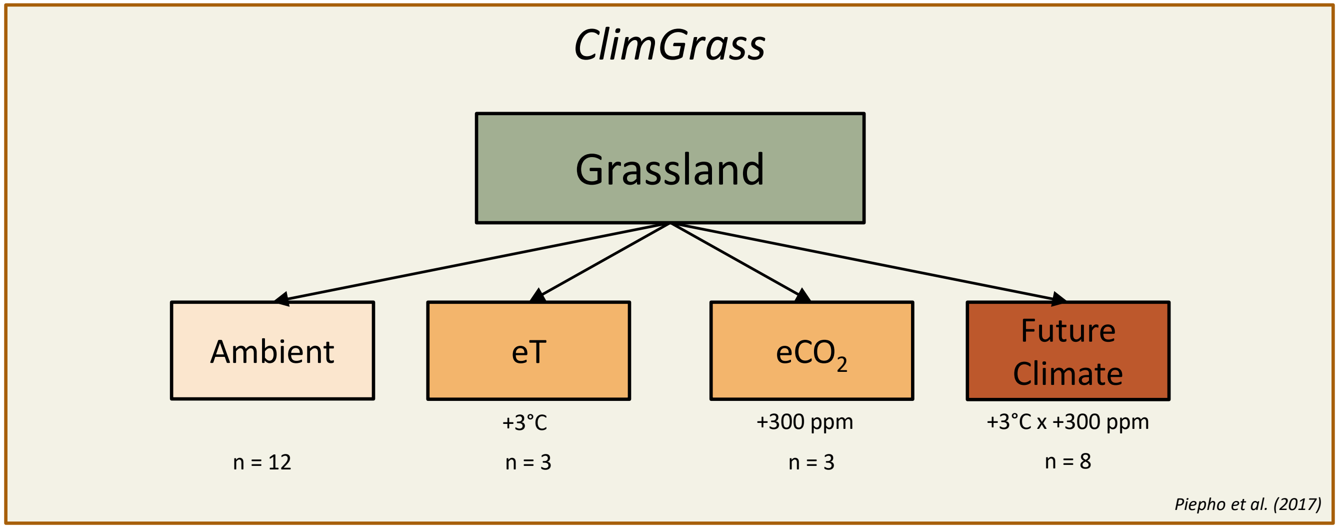
Atmospheric C

Microbial Decomposition

- Soil Organic Matter (SOM) plays an important role in global C cycling[1]
  - response to future climate conditions is still unclear
  - source or sink?
- Biogeochemical models partition Soil Organic Matter (SOM) into pools with differing properties to predict C input and output in the soil system[2]
  - physical fractions can be isolated in the lab that correspond to these model pools[3]

...what we did

We used a climate manipulation experiment in Austria to better understand the effect that elevated temperature and elevated atmospheric CO_2 concentrations have on SOM in different physical fractions



ClimGrass

Grassland

Ambient

n = 12

eT

+3°C

n = 3

eCO_2

+300 ppm

n = 3

Future Climate

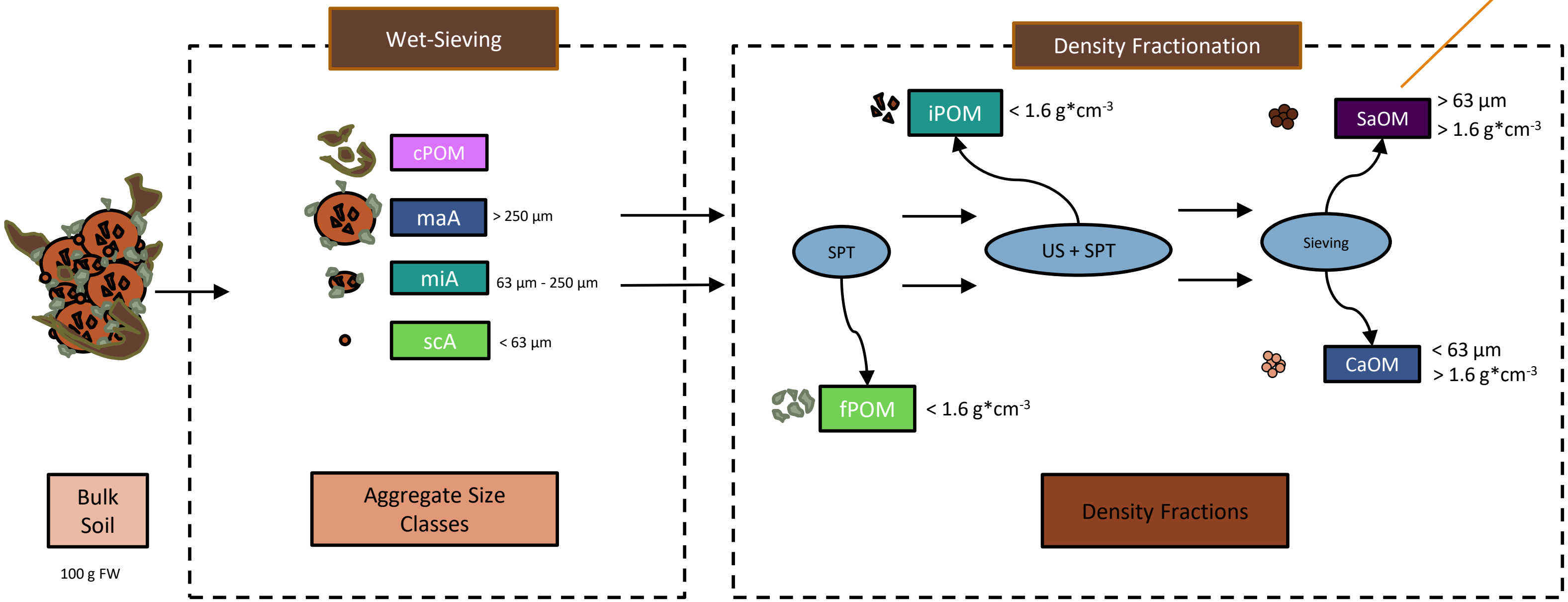
+3°C x +300 ppm

n = 8

Piepho et al. (2017)

Method

We found significant amounts of OM in the sand-sized fraction, so we treated it as an extra fraction



Wet-Sieving

cPOM

maA > 250 µm

miA 63 µm - 250 µm

scA < 63 µm

Bulk Soil

100 g FW

Aggregate Size Classes

Density Fractionation

SPT

US + SPT

Sieving

iPOM $< 1.6\ g*cm^{-3}$

fPOM $< 1.6\ g*cm^{-3}$

SaOM $> 63\ \mu m$ $> 1.6\ g*cm^{-3}$

CaOM $< 63\ \mu m$ $> 1.6\ g*cm^{-3}$

Density Fractions

cPOM: Course POM
maA: Macro-aggregates
miA: Micro-aggregates
scA: Silt & Clay sized aggregates

fPOM: Free POM
iPOM: Intra-aggregate POM
SaOM: Sand-associated OM
CaOM: Clay-associated OM

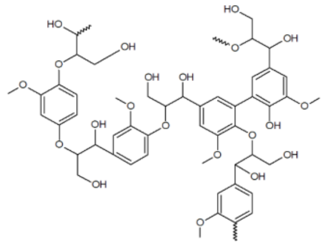
SPT: Sodium Polytungstate ($Na_6[H_2W_{12}O_{40}]$, $\rho = 1.6\ g*cm^{-3}$)
US: Ultrasonication ($58\ J * ml^{-1}$)

Analytical Methods:
- EA-IRMS: C + N-content, $\delta^{13}C$, $\delta^{15}N$
- Pyrolysis-GC/MS fingerprinting

Statistics:
- Linear Mixed Effects-Models
- PERMANOVA

Pyrolysis-GC/MS

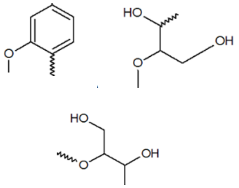
SOM: Complex, high molecular weight molecules -> difficult to characterise & analyse



Original Compound

High temperature (> 500°C)
He-atmosphere (no O_2)

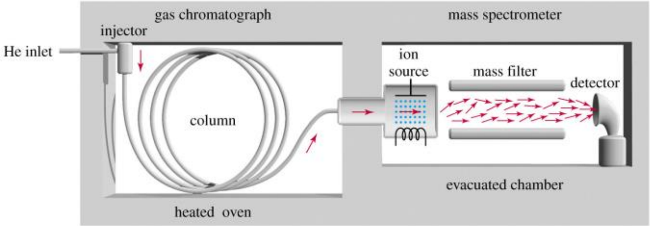
Pyrolysis



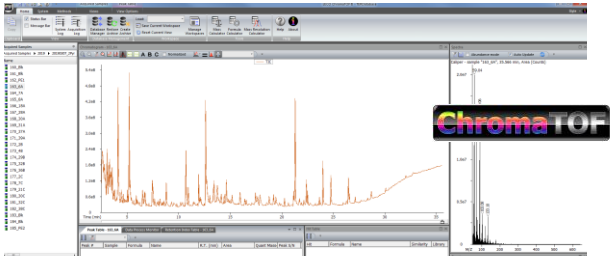
Fragments

Some with known origin molecule from literature

Separation of pyrolysis-products on GC-column, analysis on MS-system



1)



Analysis

High-throughput, semi-automated compound identification, peak integration and calculations

Relative Abundance

Ordination, Multivariate Analysis

1) *https://orgspectroscopyint.blogspot.com/2014/11/gas-chromatography-mass-spectrometry-gc.html*

Main Results

Soil Structure

	Weight by Treatment (in % of total weight)				
Size Class	**Ambient**	**eT**	**eCO_2**	**$eT \times eCO_2$**	**LME**
maA	79.43	78.58	79.88	84.41	eCO_2* ↑
miA	14.85	15.05	13.90	10.75	eCO_2* ↓
scA	5.47	6.20	5.84	4.63	n.s
cPOM	0.26	0.17	0.38	0.21	n.s

Soil was dominated by macro-aggregates

Significant CO_2 effect on maA and miA proportion

Higher proportion of maA and lower proportion of miA on $eT \times eCO_2$

C Content

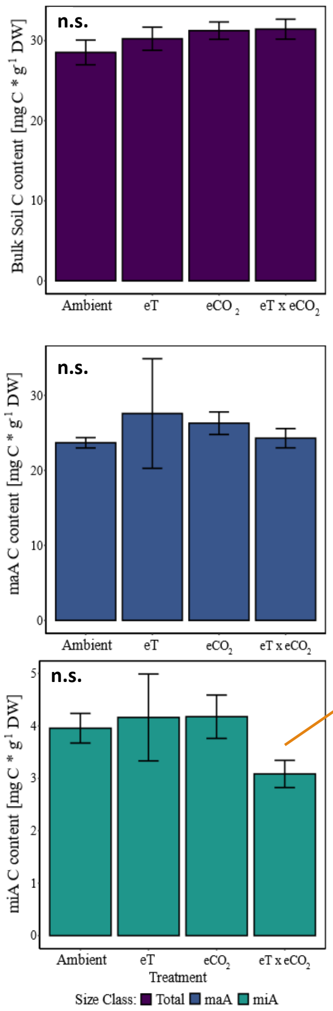
Absolute

Relative

Size Classes

maA

miA

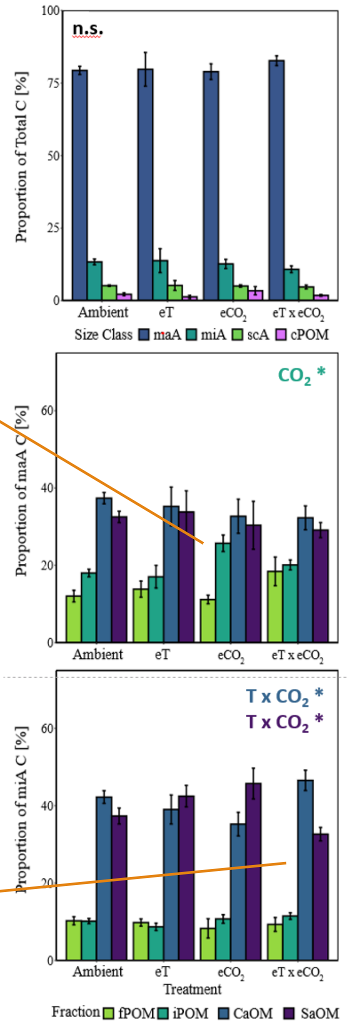


Total soil C was slightly increased with treatments (non-significant)

More intra-macroaggregate POM-C with eCO$_2$

Less miA-C on eT x eCO$_2$ (non-significant)

Combined effect of eT and eCO$_2$: More Clay-associated OM and less Sand-associated OM



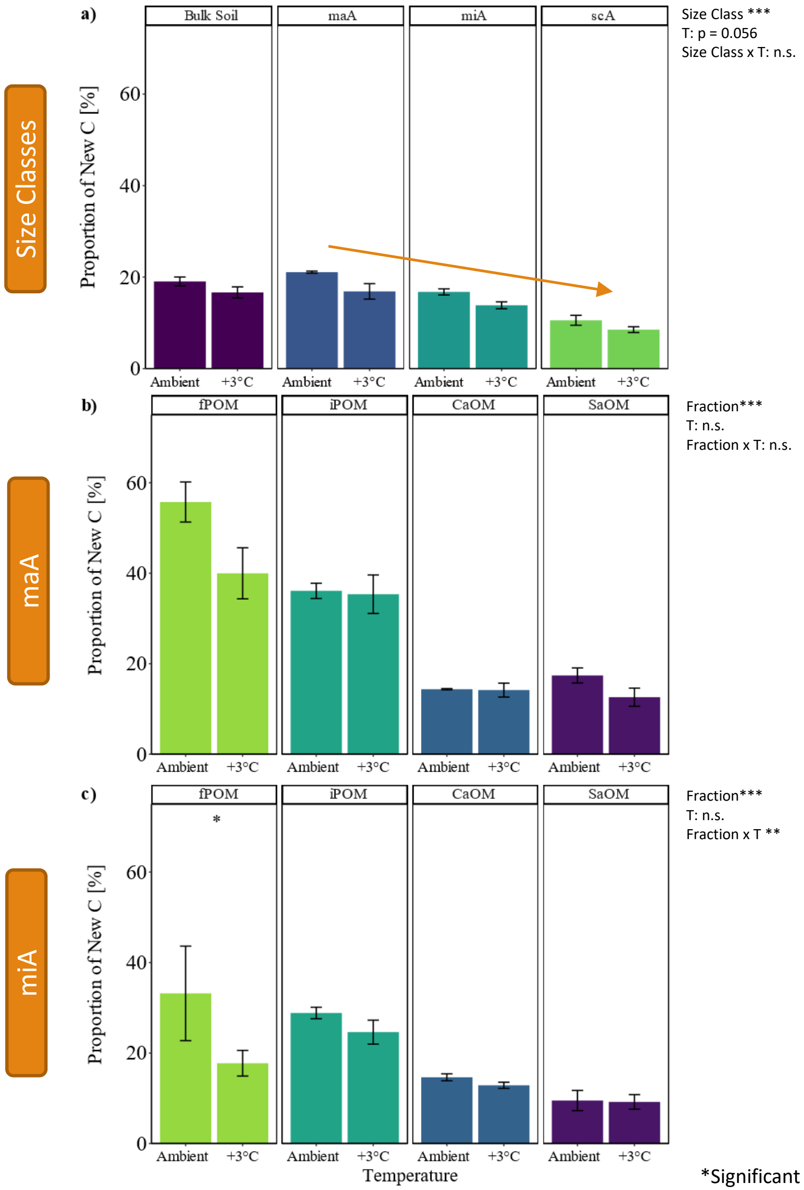
Size Classes

maA

miA

„New C“ Incorporation

Calculated via the distinct isotopic composition of added CO_2 (only on eCO_2 and eT x eCO_2 plots!)



About 20% of bulk soil was renewed after 4 years of fumigation (turnover of 20 years)

Proportion of „new C“ decreased significantly with decreasing particle size

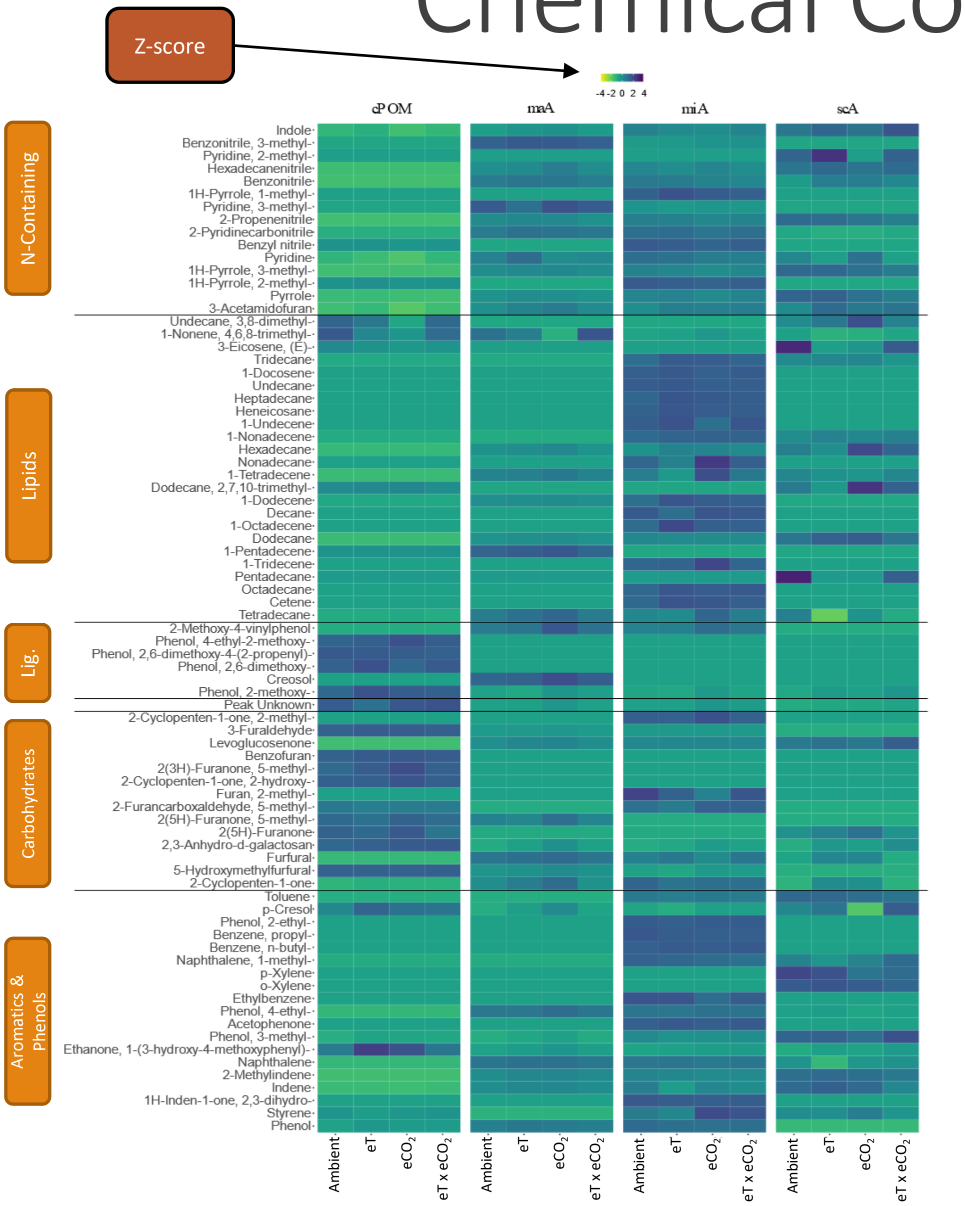
Warming reduced the incorporation of new C on eCO_2 plots

maA and miA POM: More new C compared to heavy OM (CaOM/SaOM)

In Density fractions: Warming effect mostly visible in POM

*Significant difference between ambient and warmed (Tukey-HSD, α = 0.05)

Chemical Composition



Based on relative abundance of substances with a literature-backed origin molecule class

Distinct fingerprints of each size class (and density fraction, not shown)

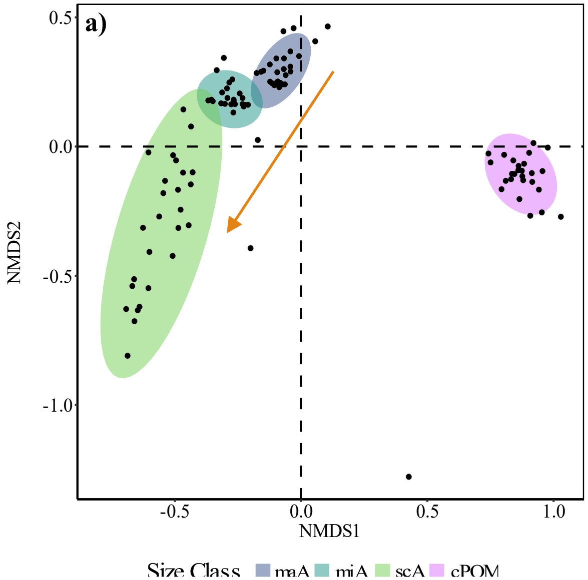
miA: Higher relative abundance of lipid- and aromatic/phenol-derived compounds than maA

Chemical Composition

NMDS and PERMANOVA based on a Bray-Curtis dissimilarity matrix using the relative abundance of pyrolysates with a known origin (from literature)

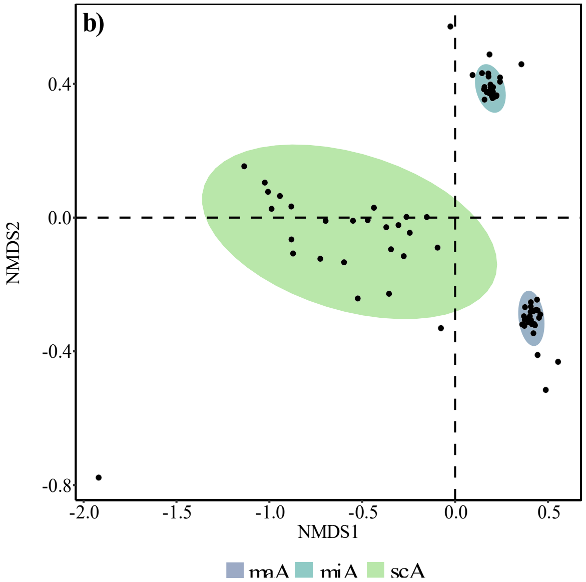
Size Classes

Fraction***
Treatment n.s.



Silt & Clay

Fraction***
Treatment n.s.



Chemical composition followed particle size

The oldest and smallest fractions (silt & clay-sized) also differed significantly from each other

Climate Change treatments did not significantly alter chemical composition

Summary

Summary (1/2)

1) Total soil C was slightly increased with treatments

The ecosystem acted more as a sink than as a source for atmospheric CO_2

2) Changes to aggregation and distribution of OM across the fractions with eCO_2

More maA and more maA POM – increased susceptibility to disturbance?

3) Warming led to less new C in size classes and fractions

C turnover was decreased with warming

Summary (2/2)

4) Each size class and fraction possessed an unique chemical fingerprint

5) Chemical composition was unaltered by elevated temperature and CO_2

Transition process from one fraction into another excerted more control on chemical composition of OM than the changed climate parameters

Many thanks to…

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…You! EGU General Assembly

Please join the breakout text chat after the live session if you have any questions!

Or, feel free to contact me anytime:

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🐦 @MMohrlok

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1)

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