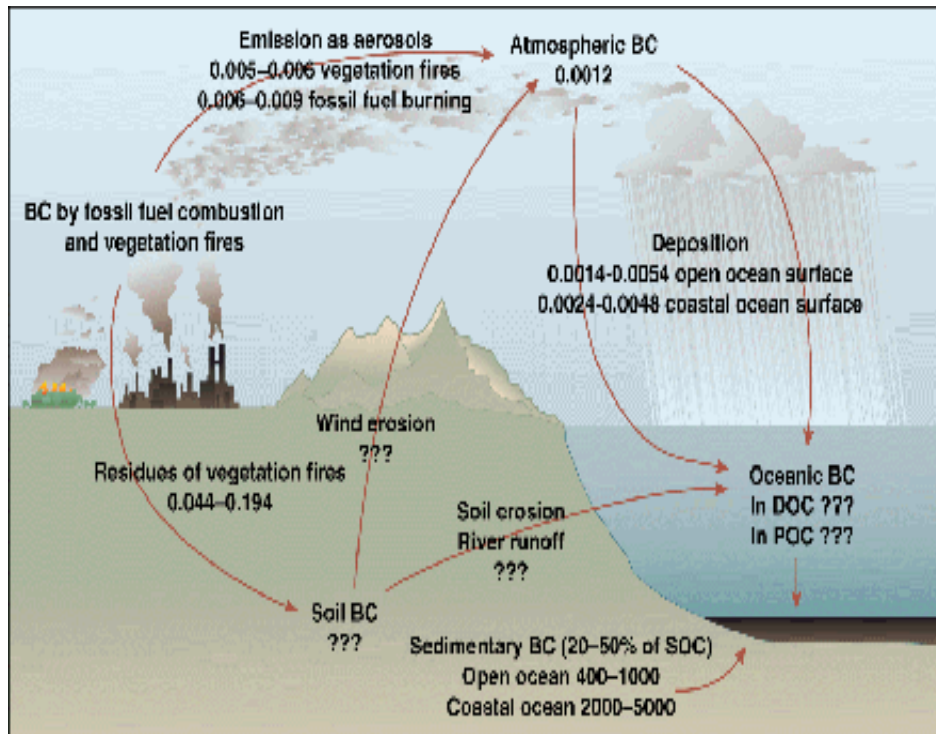

Stability of Black Carbon/Biochar

Johannes Lehmann, Binh Nguyen, Chih-Hsin
Cheng, Biqing Liang, Julie Major

*Department of Crop and Soil Sciences
Cornell University*

Evelyn Krull, Jan Skjemstad
CSIRO

Why Stability?

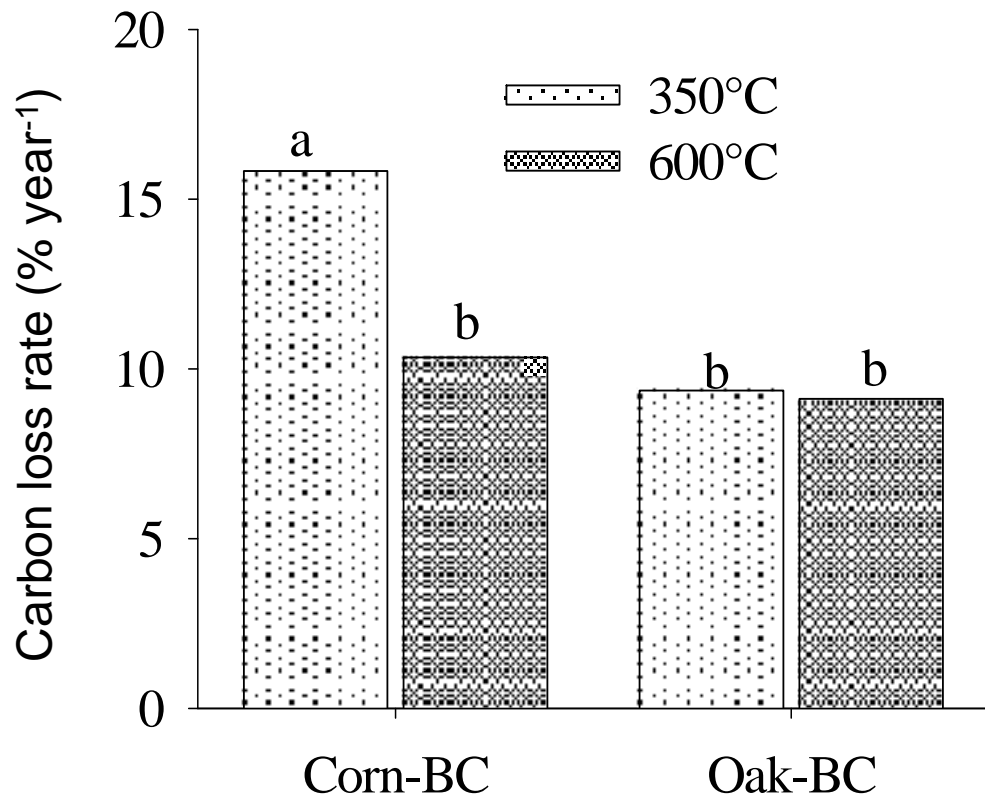


BC stability – how to estimate it?

- **Age of BC?**
- **Decomposition experiments?**
- **Mass balance after BC addition using archived samples or chronosequences?**
- **Modeling of disappearance in steady state?**



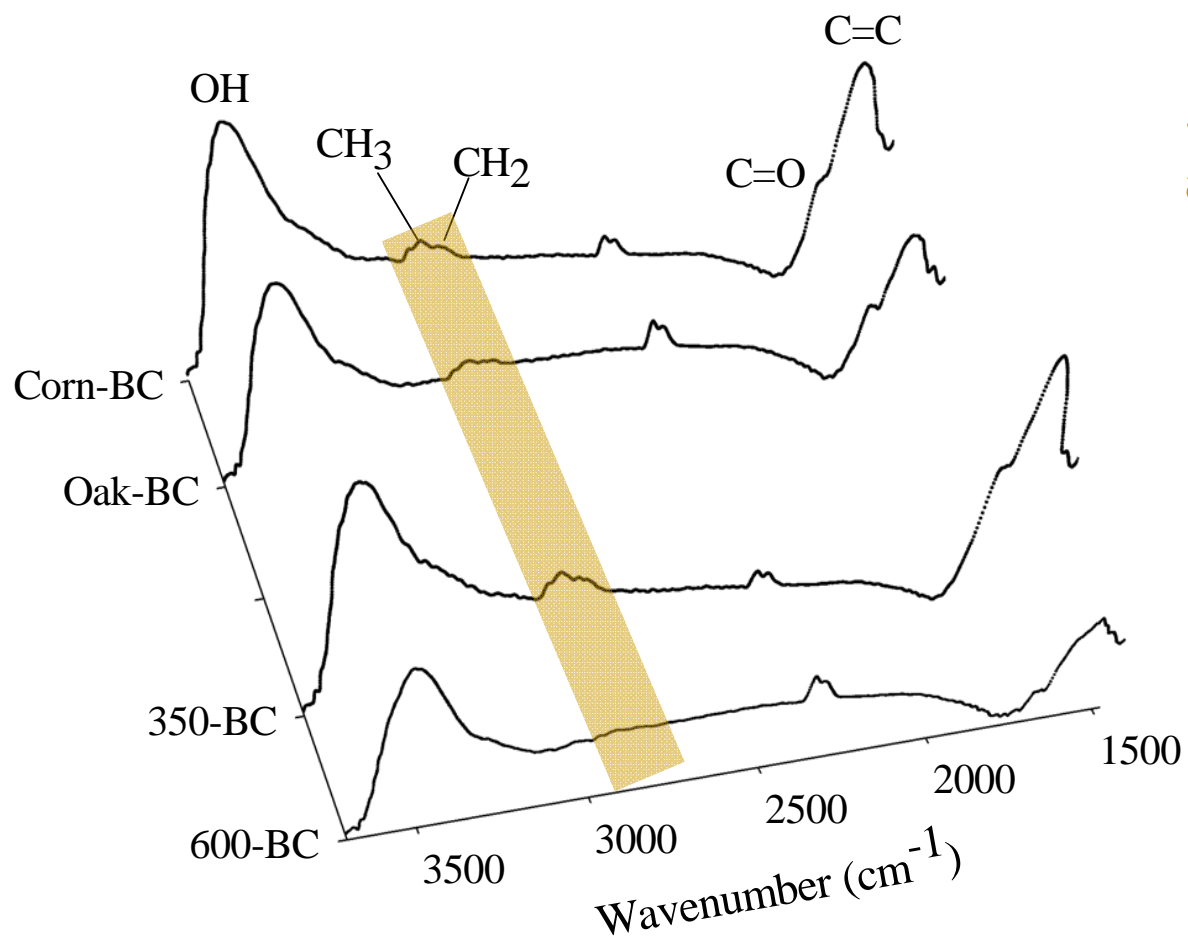
Decomposition Experiments



Decomposition of comparatively labile BC fraction?

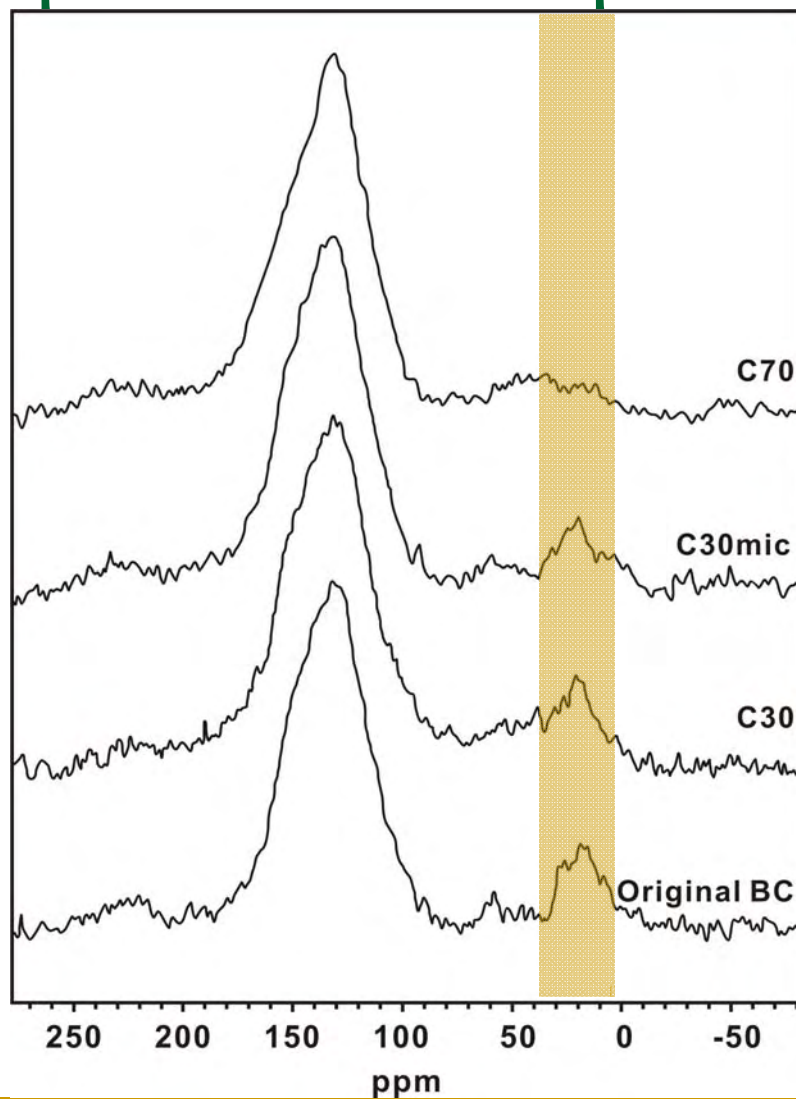
(1 year, 30°C, in sand culture, N=8)

Decomposition Experiments



Significant proportion of aliphatic C bonds (“oils”?)

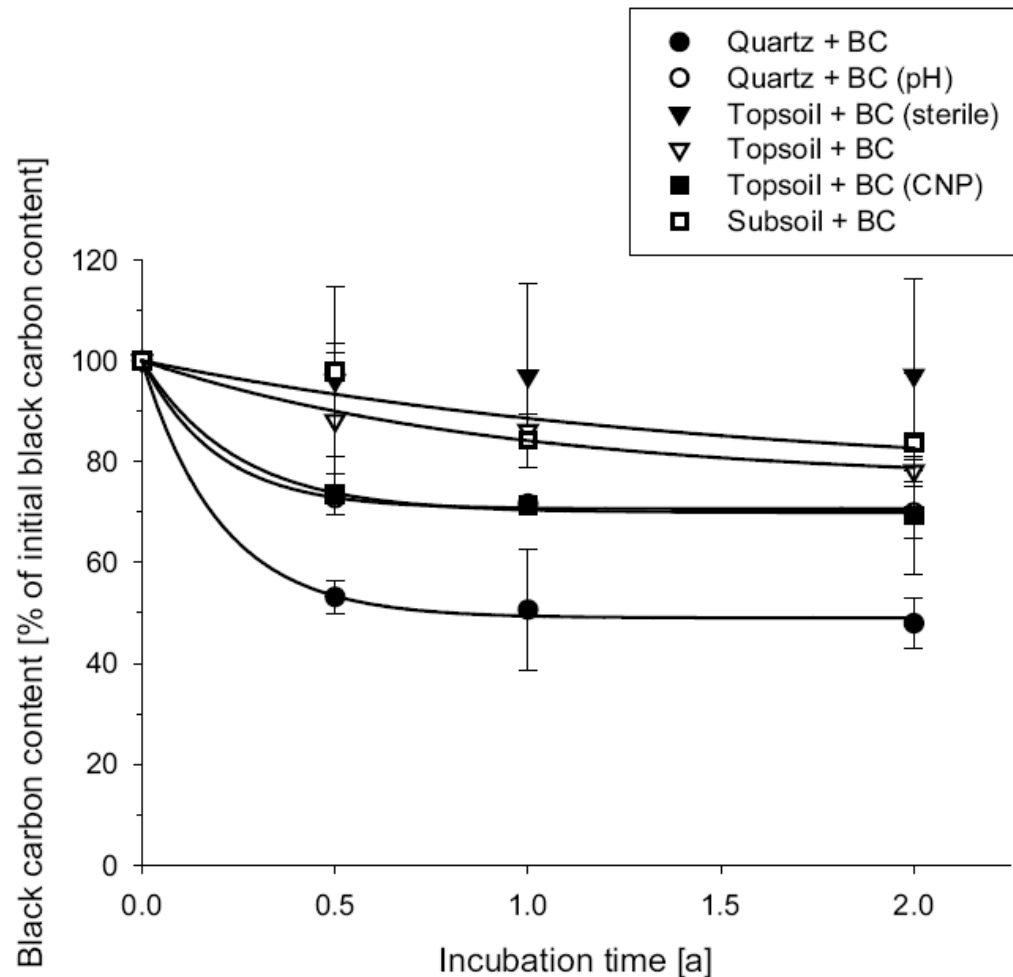
Decomposition Experiments



**Disappearance of
aliphatic C**

(4-month incubation, 30°C
and 70°C, 55% WHC, 4
replicates)

Decomposition Experiments



Disappearance of aliphatic C and surface oxidation

(pooled data from corn and rye BC (350°C), 20°C, at 70% water holding capacity, 3 replicates)

Decomposition Experiments

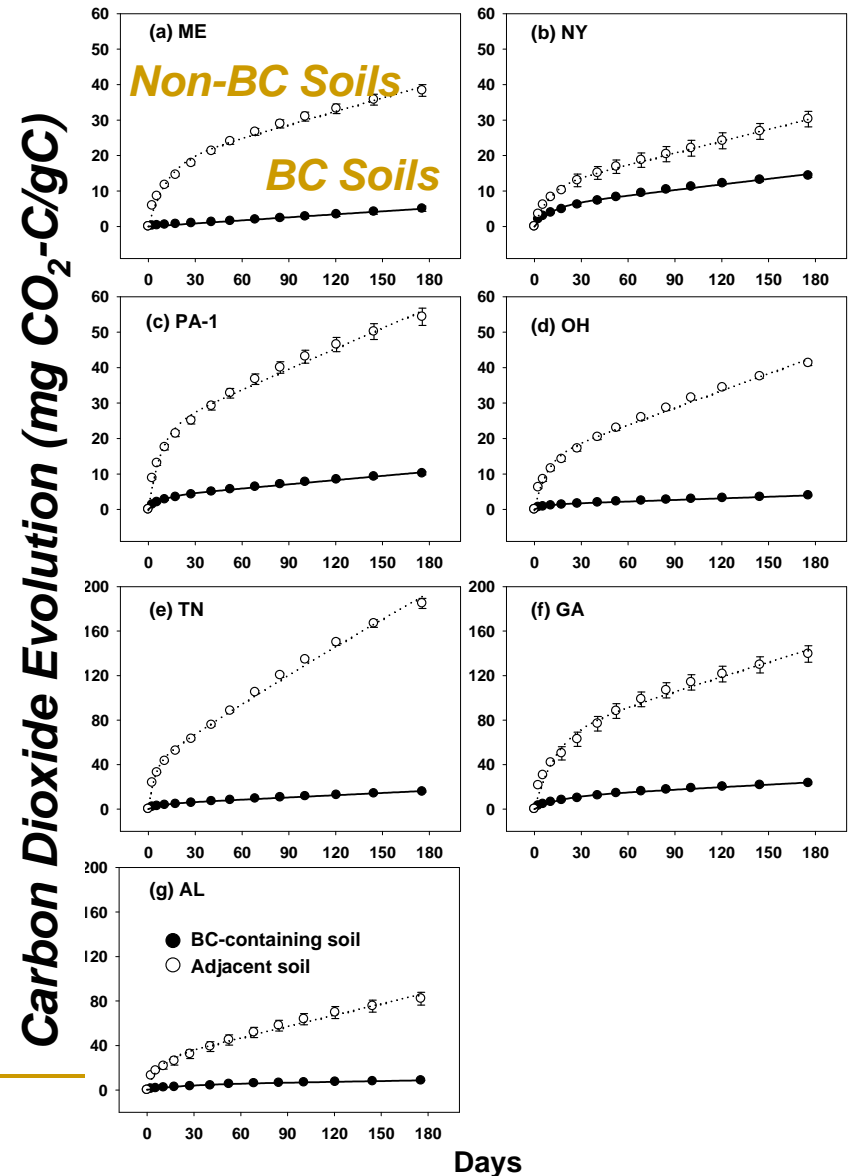


Biochar from storage areas for historical pig iron production (130 years old)

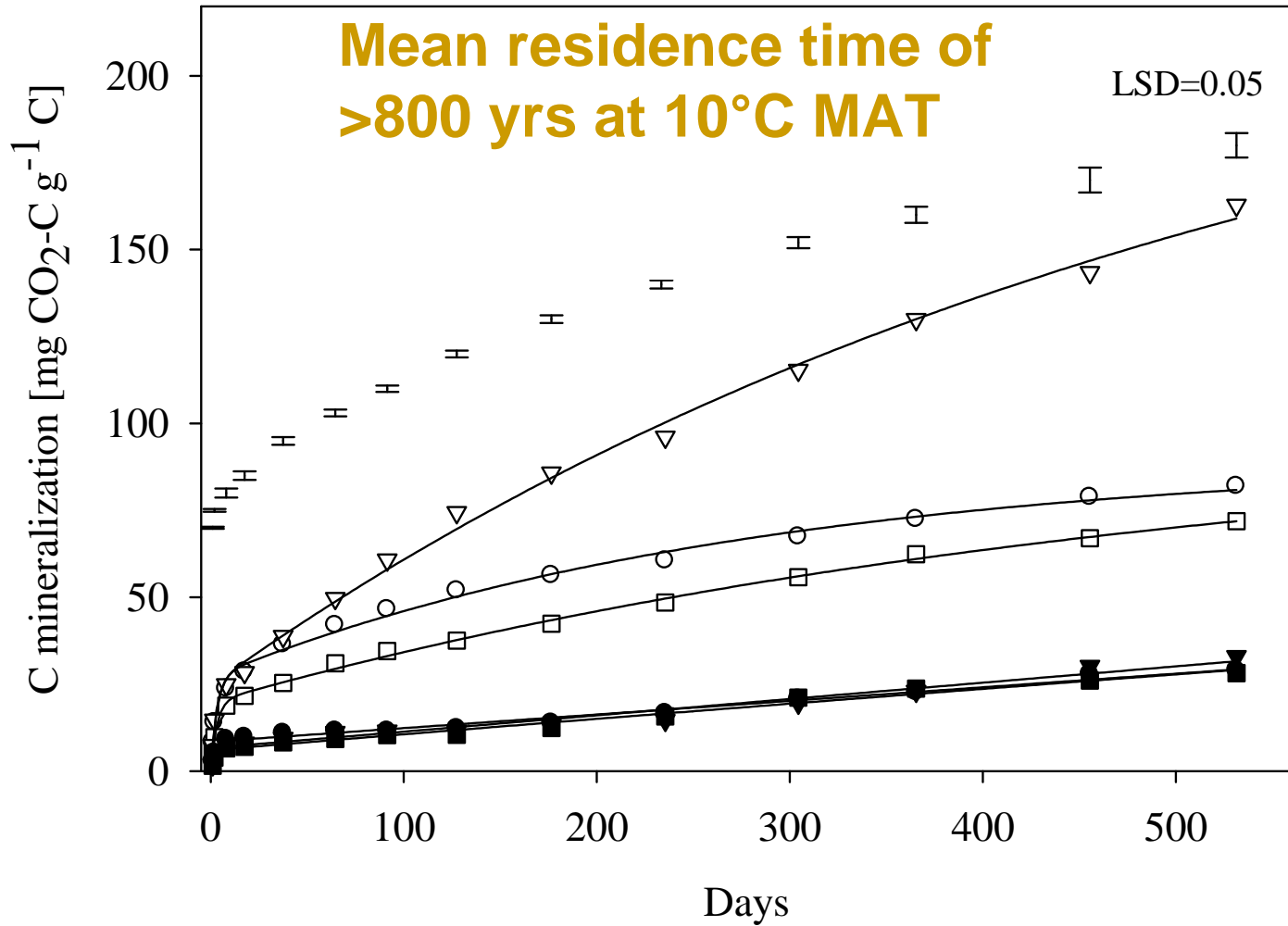


Half life of 925 yrs at 10°C MAT

Stability of remaining did not change across the climate gradient. (130 years)



Decomposition Experiments



(Terra Preta
Central Amazon
Defined period of BC
accumulation)

**BC-poor
soils**

BC-rich soils

(N=3; BC age
ranges from
800 to 7,000
years)

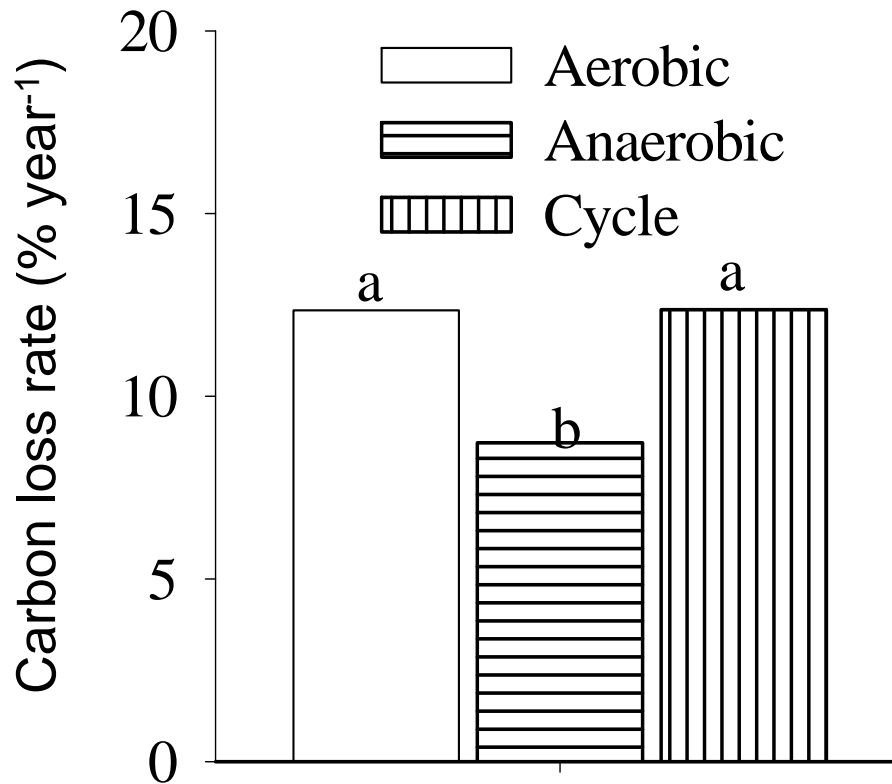
Decomposition Experiments

Opportunity to directly measure processes that control BC stability:

- **Water**
- **Temperature**



Decomposition Experiments - Moisture

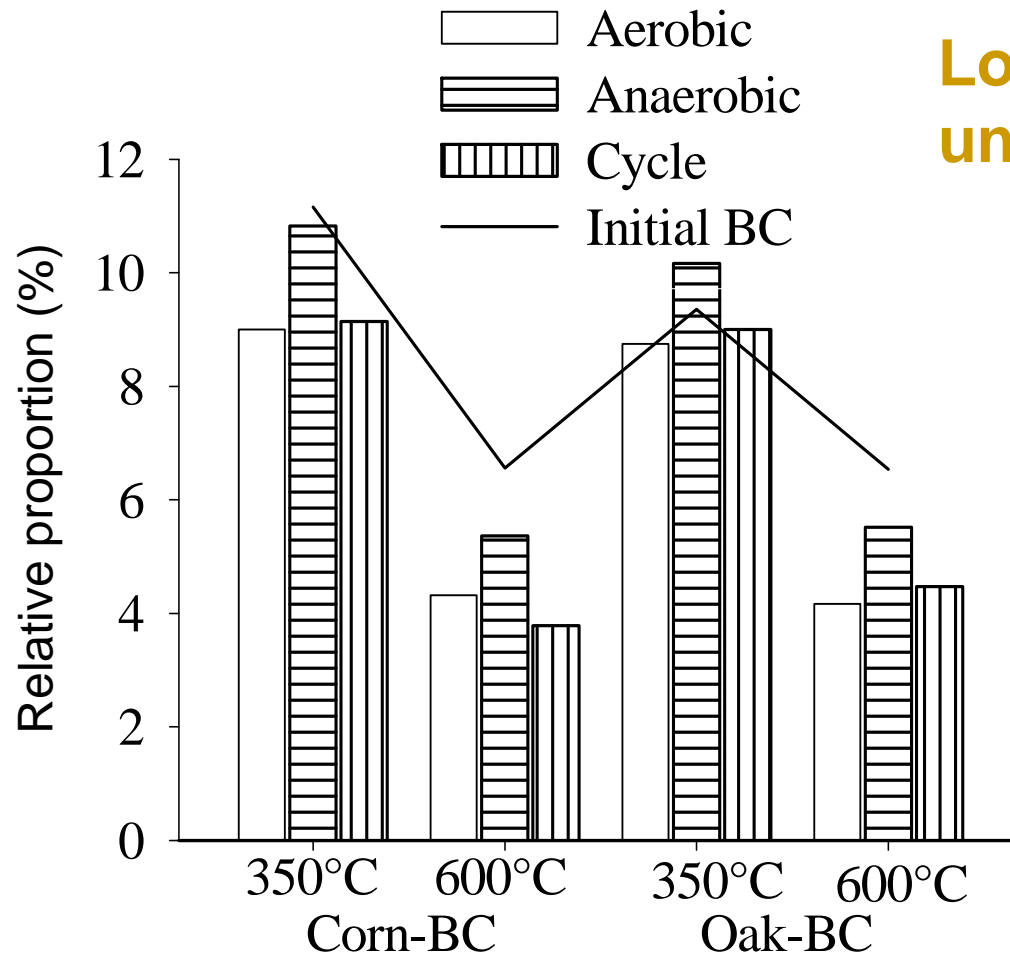
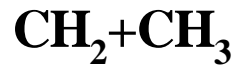


Lower mineralization under anaerobic conditions

No change under alternating wet-dry conditions

Pooled results from corn and oak BC
60% WHC, fully submerged or 7-day cycles
(1 year, 30°C, in sand culture, N=16)

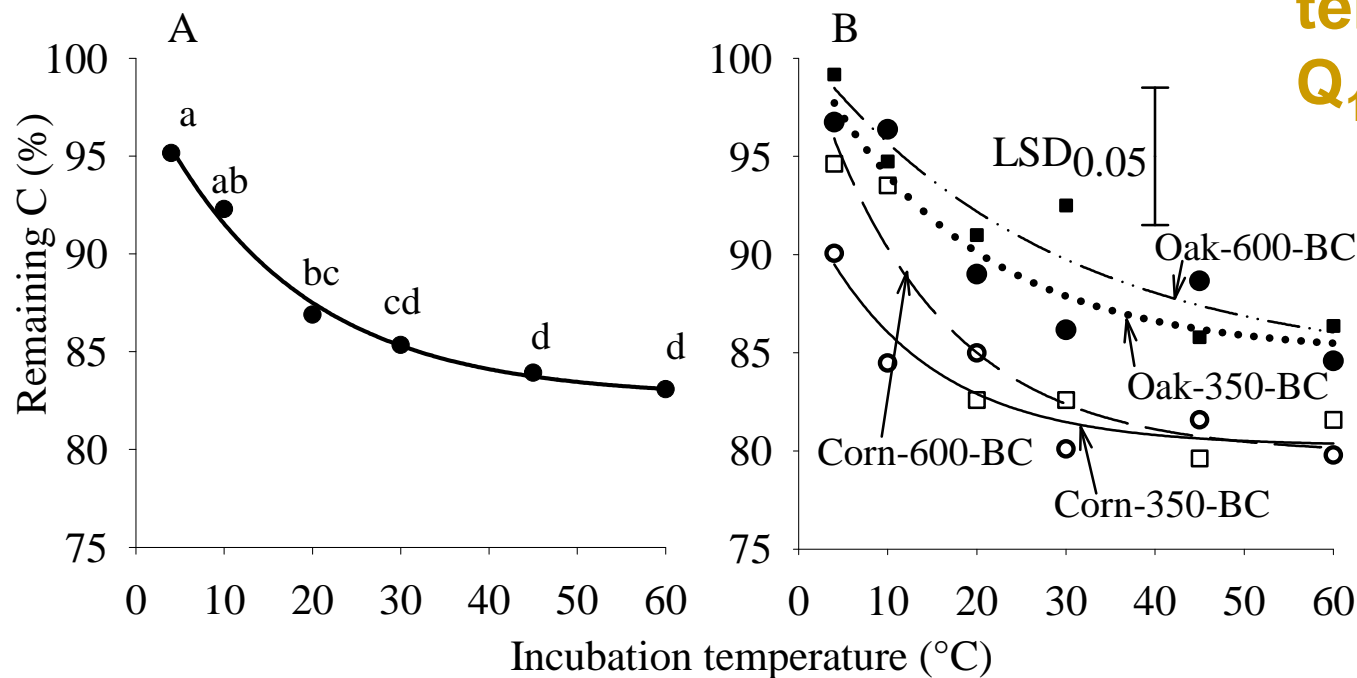
Decomposition Experiments - Moisture



Lower decrease of aliphatic C under anaerobic conditions

FTIR from pooled samples (from N=8)
60% WHC, fully submerged or 7-day cycles
(1 year, 30°C, in sand culture)

Decomposition Experiments – Temp.

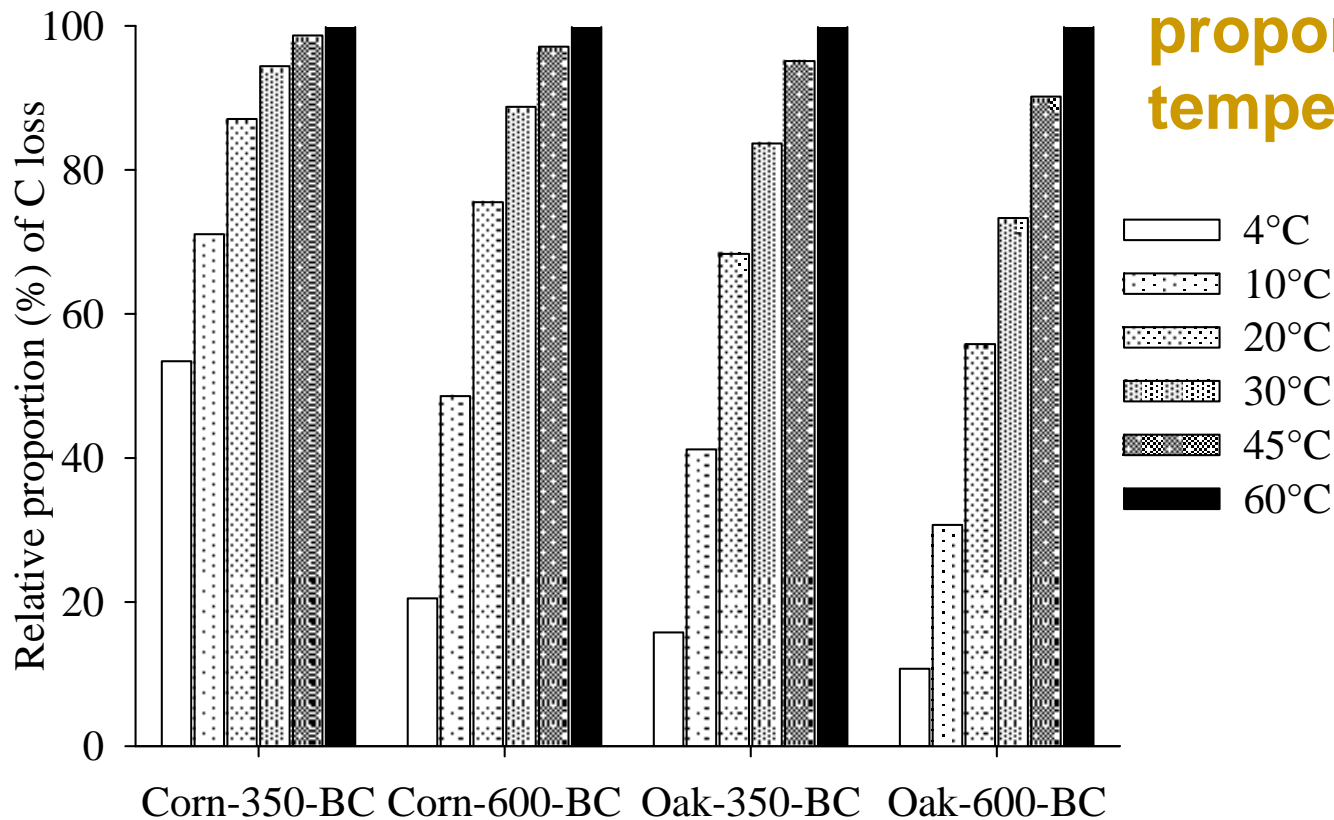


Greater increase in mineralization at lower temperature
 Q_{10} of about 3-4 at 10°C

(N=8, 60% WHC, 1 year, in sand culture)

Decomposition Experiments – Temp.

The more stable BC (oak and 600°C) showed greater proportional reaction to temperature increase

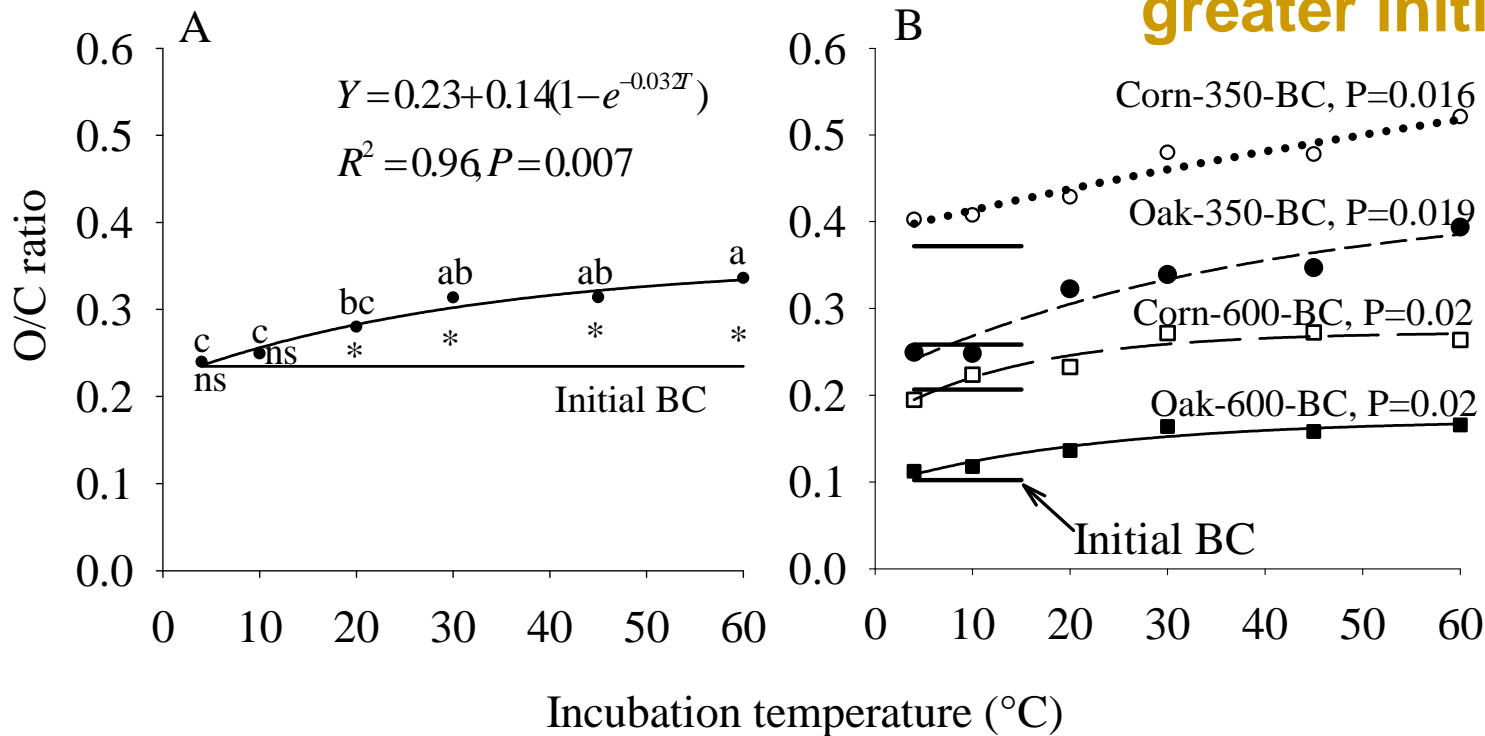


(N=8, 60% WHC, 1 year, in sand culture)

Decomposition Experiments – Temp.

At low temperature, limited oxidation of remaining C

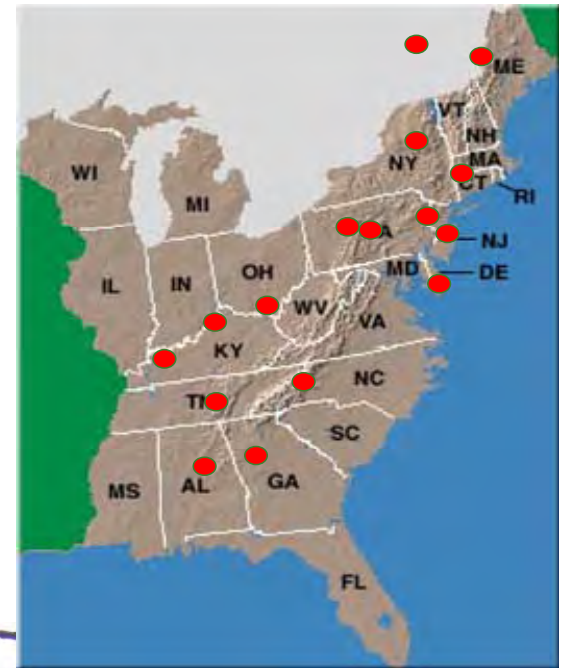
Greater increase in O/C with greater initial O/C



(N=8, 60% WHC, 1 year, in sand culture)

Climosequence – Temp.

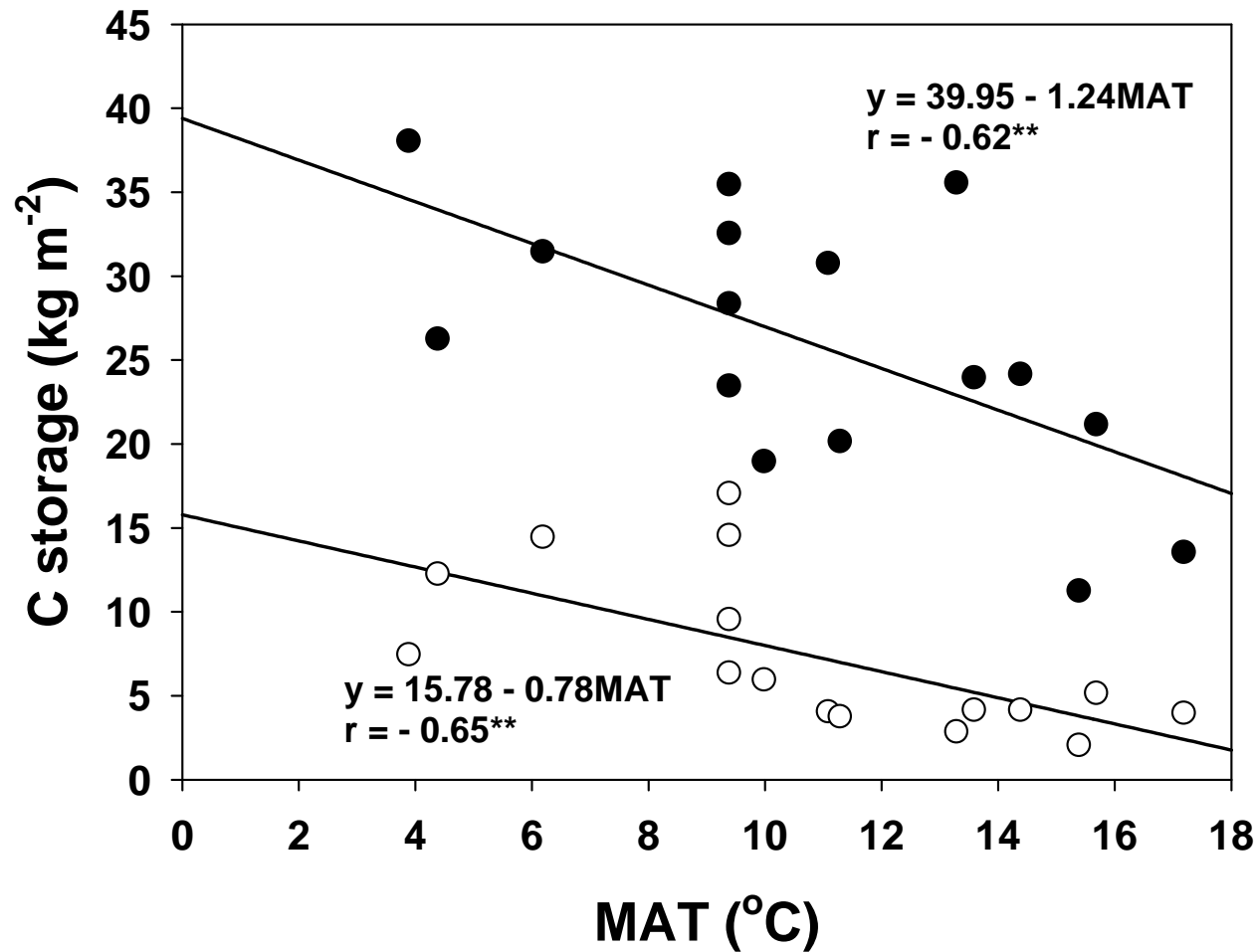
Some opportunity to measure long-term temperature effects with climosequences



**130-year-old Biochar
(from pig iron production)
in comparison to biochar
made with traditional
kilns**



Climosequence – Temp.

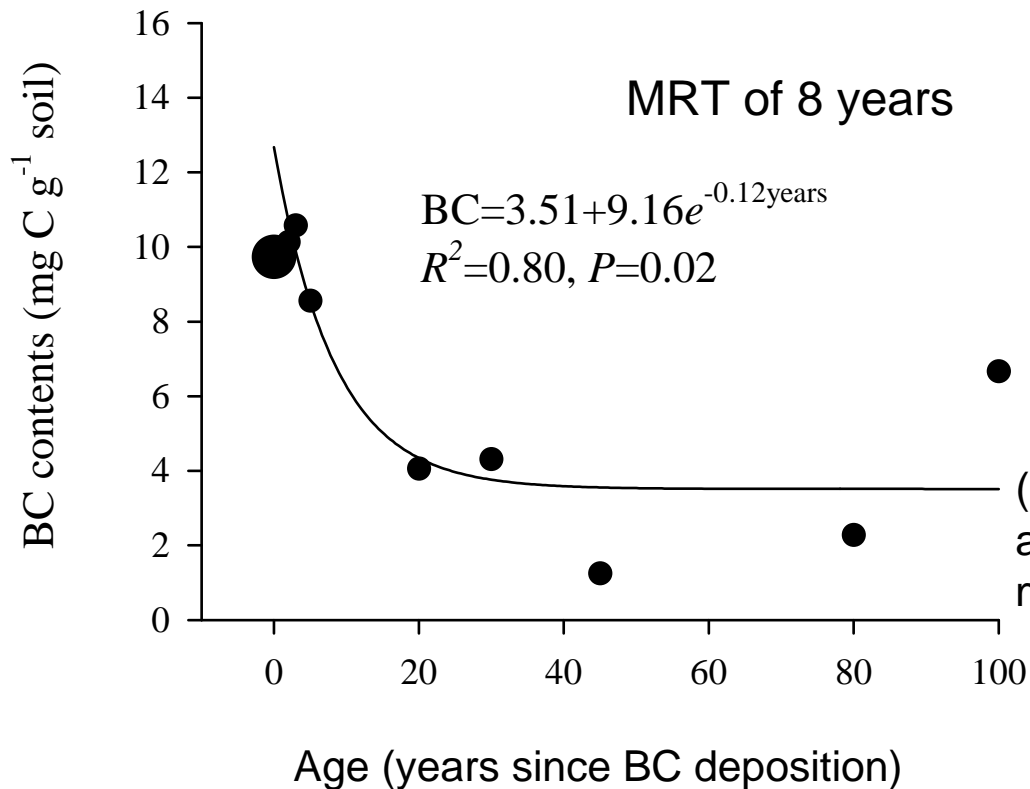


Q₁₀ of 3.8

(2-3.4 for 12 different plant residues; Fierer et al., 2005, Ecology)

(calculation of relative decomposition rates between MAT (no relationship with MAP); controlling for non-BC changes; assuming negligible decomposition at 0°C)

Chronosequences



(BC quantified by NMR and molecular mixing model)

Large proportion of physical export likely



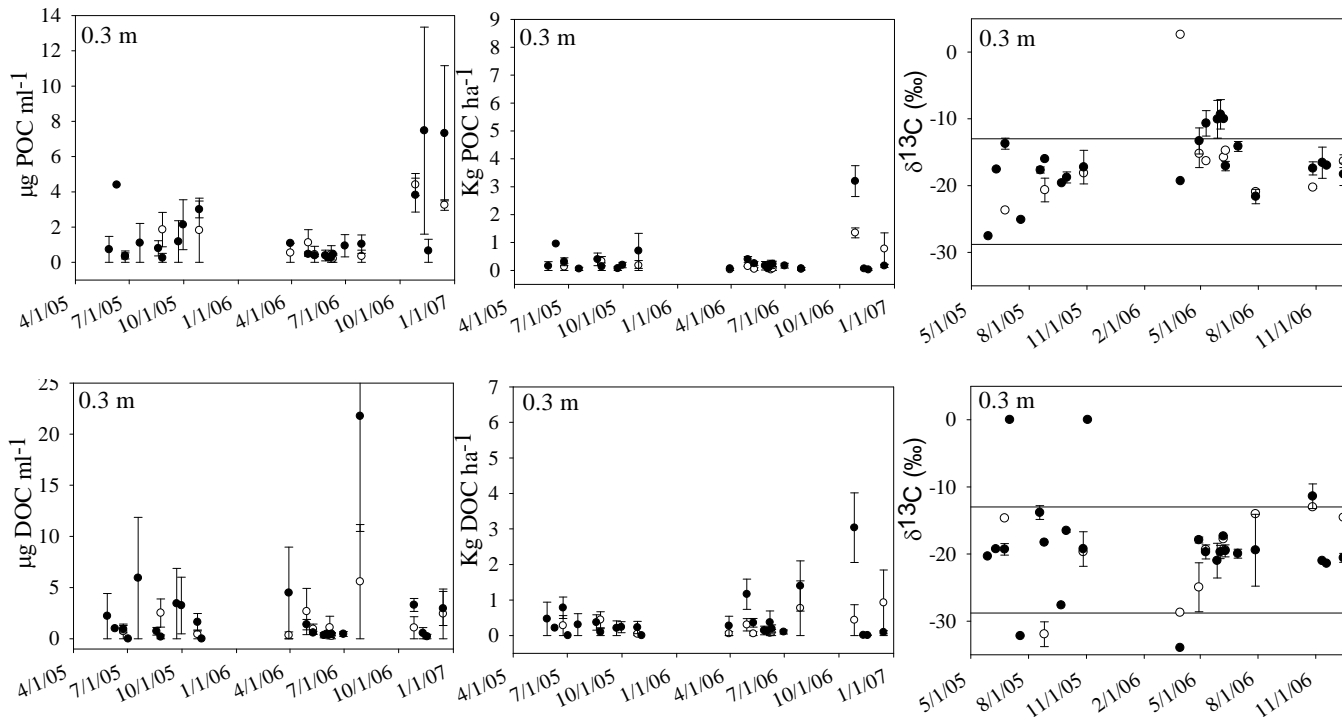
(BC from forest clearing, false-time series on Ultisols Western Kenya)

Mass Balance

Leaching of POC, DOC Mineralization



Colombian Llanos



Major et al., unpubl.



Cornell University

Mass Balance

| Cumulative flux over 2 years | Proportion of applied BC (%) |
|------------------------------|------------------------------|
| Respired as CO ₂ | 4.0 |
| Leached as POC (below 0.3m) | 0.5 |
| Leached as DOC (below 0.3m) | 2.0 |

Similar order of magnitude of leaching and mineralization (erosion was not directly measured)

Modeling from Equilibrium Conditions

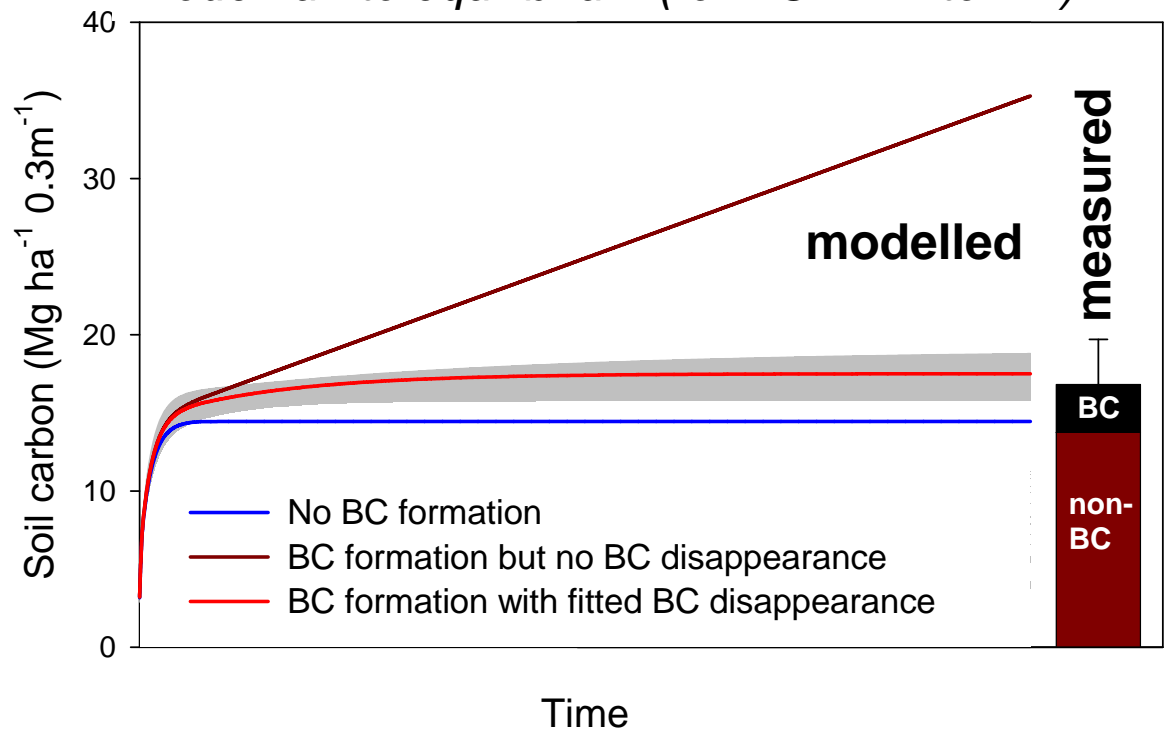
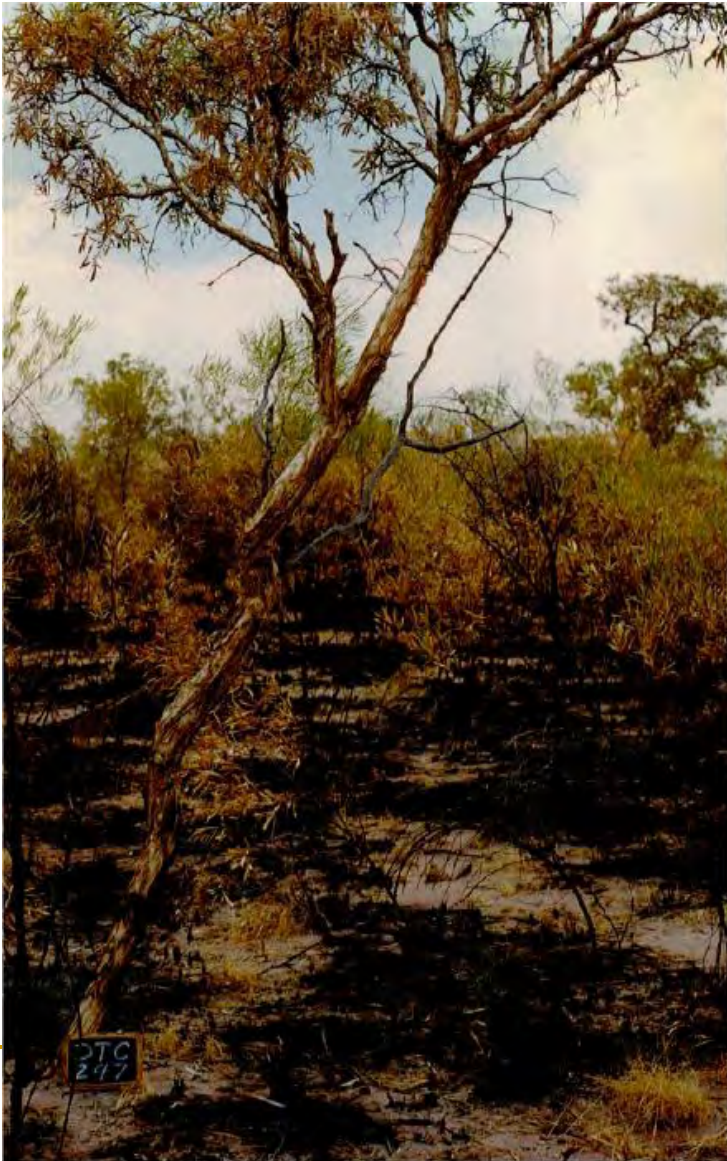
Inceptisols (Northern Territory, Australia)

13 and 15 profiles

27°C MAT, 887 mm MAP

Under varying assumptions of burning severity and BC formation

Model run to equilibrium (for BC MRT to 1m)



Modeling from Equilibrium Conditions

Mean residence time (years)

Black C formation of (% of C in burned vegetation)

1

2.5

4

Vegetation burnt
(% of total vegetation)

Light-textured Inceptisols at Katherine
(MAP¹ 887 mm; MAT² 27°C; clay 13%)

| | | | |
|----|------|-------------|------|
| 60 | 4292 | 1715 | 1074 |
| 70 | 3674 | 1471 | 921 |
| 80 | 3212 | <u>1300</u> | 806 |
| 90 | 2856 | 1145 | 718 |

Heavy-textured Inceptisols at Daly Waters
(MAP 738 mm; MAT 27°C; clay 21%)

| | | | |
|----|------|-------------|------|
| 60 | 9259 | 3506 | 2163 |
| 70 | 7704 | 2984 | 1855 |
| 80 | 6631 | <u>2603</u> | 1623 |
| 90 | 5841 | 2310 | 1444 |

If MRT is mineralization,
not considered:
re-burning,
erosion,
leaching below 1m



What is a *my* Estimate of MRT?

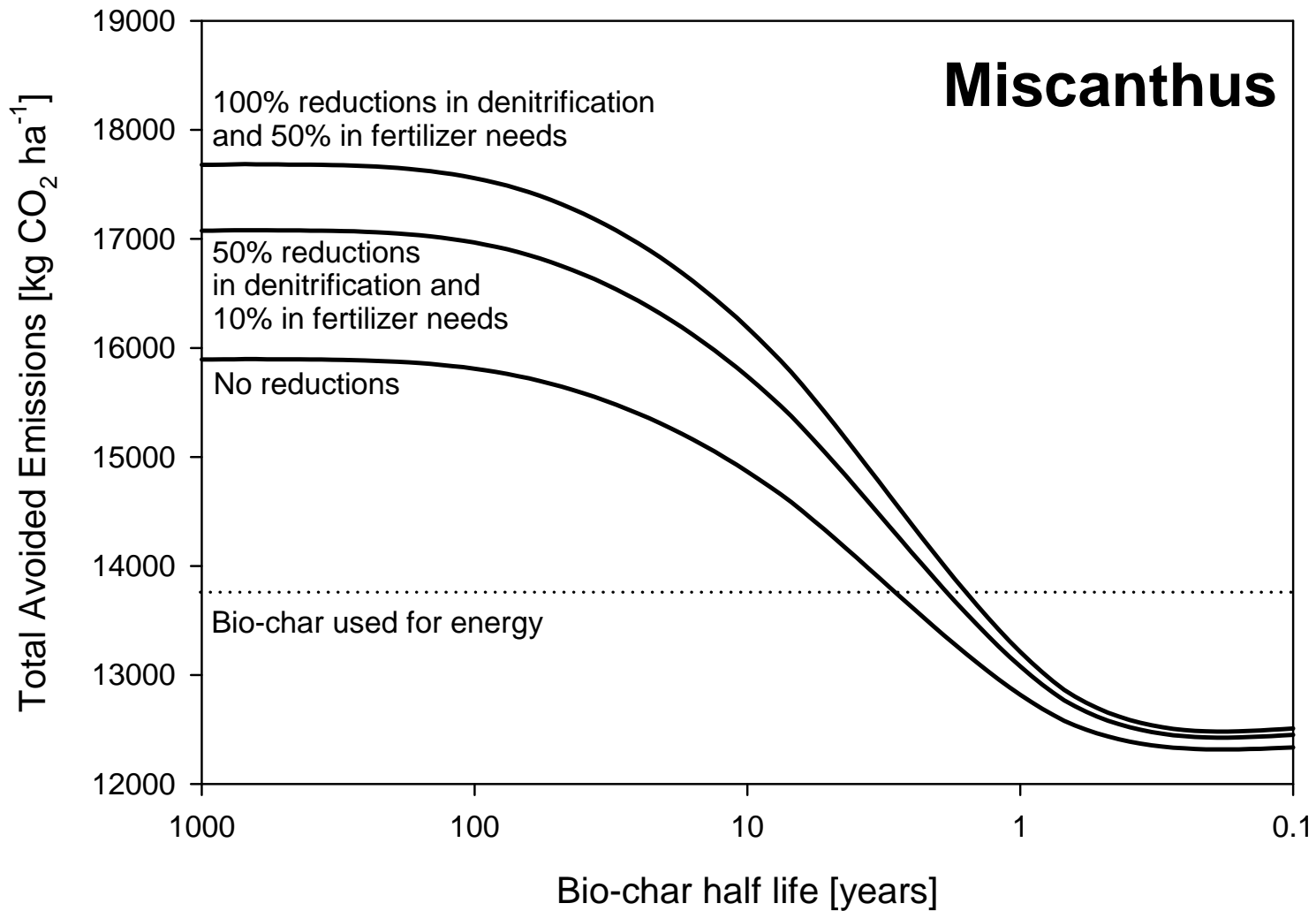
- ❑ Easily mineralizable BC fraction ranges from 1-20%
- ❑ MRT of aromatic portion in the lower thousands



How stable does biochar need to be?



Total Avoided Emissions – Life Cycle Analysis



The way forward

- ❑ **Quantification of stability of different types of BC**
- ❑ **Better understanding of the mechanisms of BC stability**
- ❑ **Better understanding of the importance of stabilization of BC for its longevity**



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Natural Museum

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