Stability of Black Carbon/Biochar

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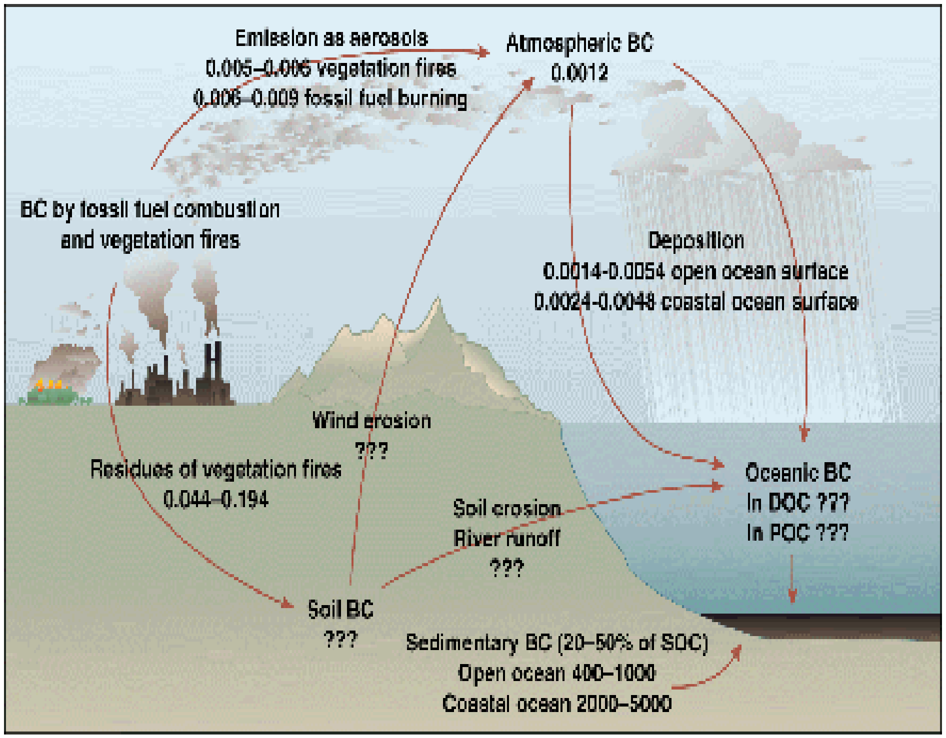
Why Stability?



BC stability – how to estimate it?

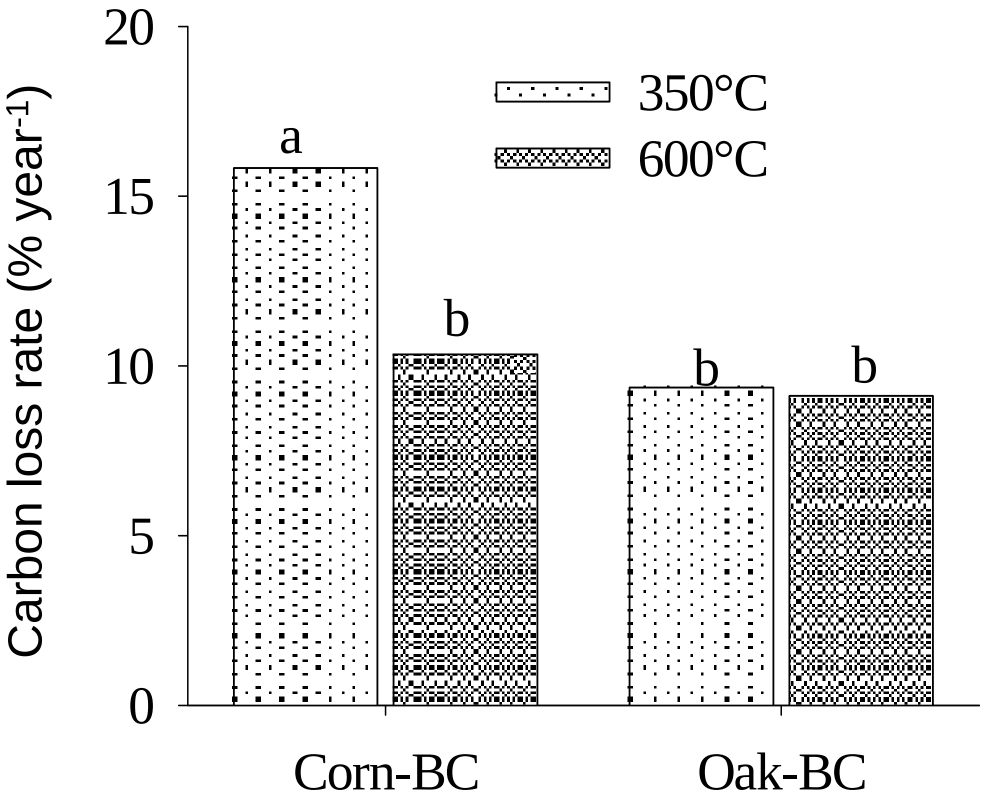
- **Age of BC?**

- **Decomposition experiments?**

- **Mass balance after BC addition using archived samples or chronosequences?**

- **Modeling of disappearance in steady state?**

Decomposition Experiments

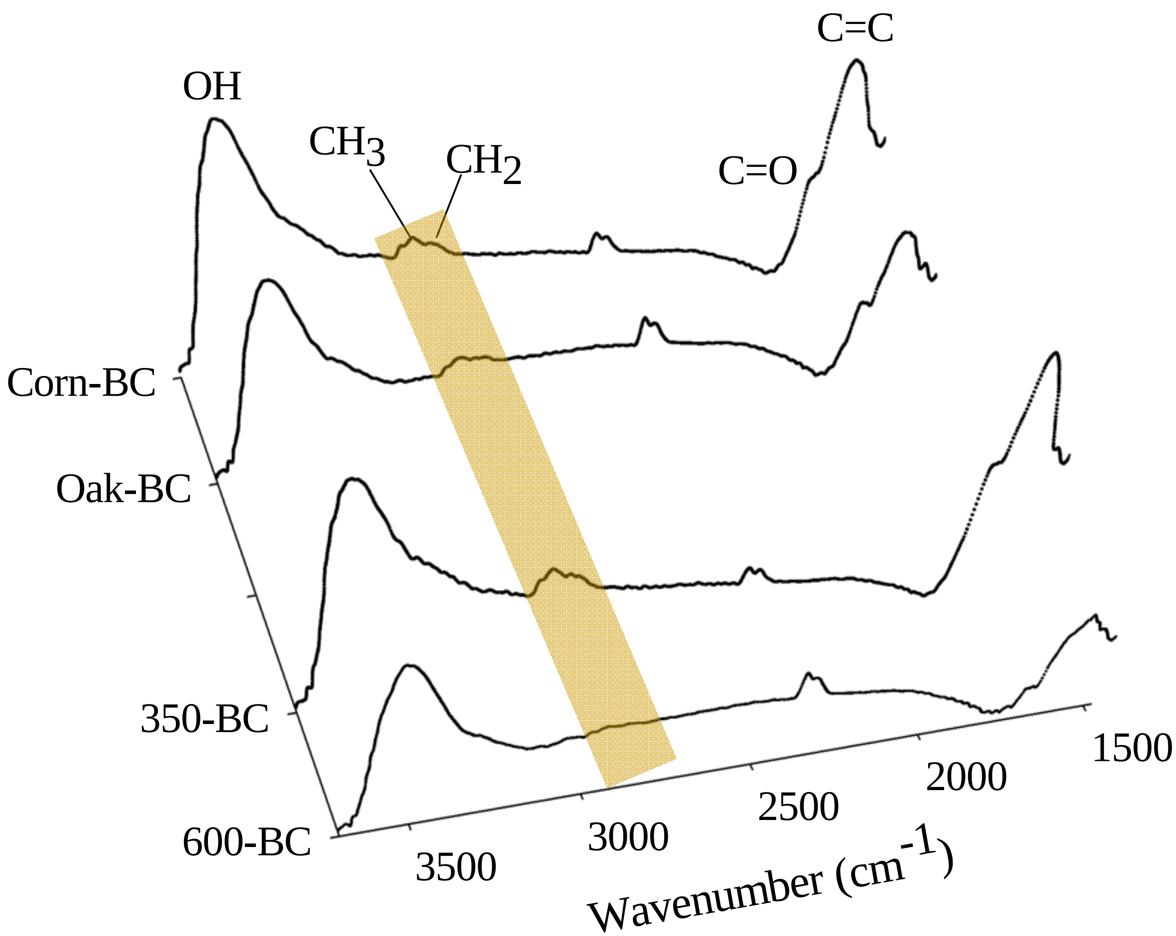


Decomposition of comparatively labile BC fraction?

(1 year, 30°C, in sand culture, N=8)

Nguyen et al., unpubl.

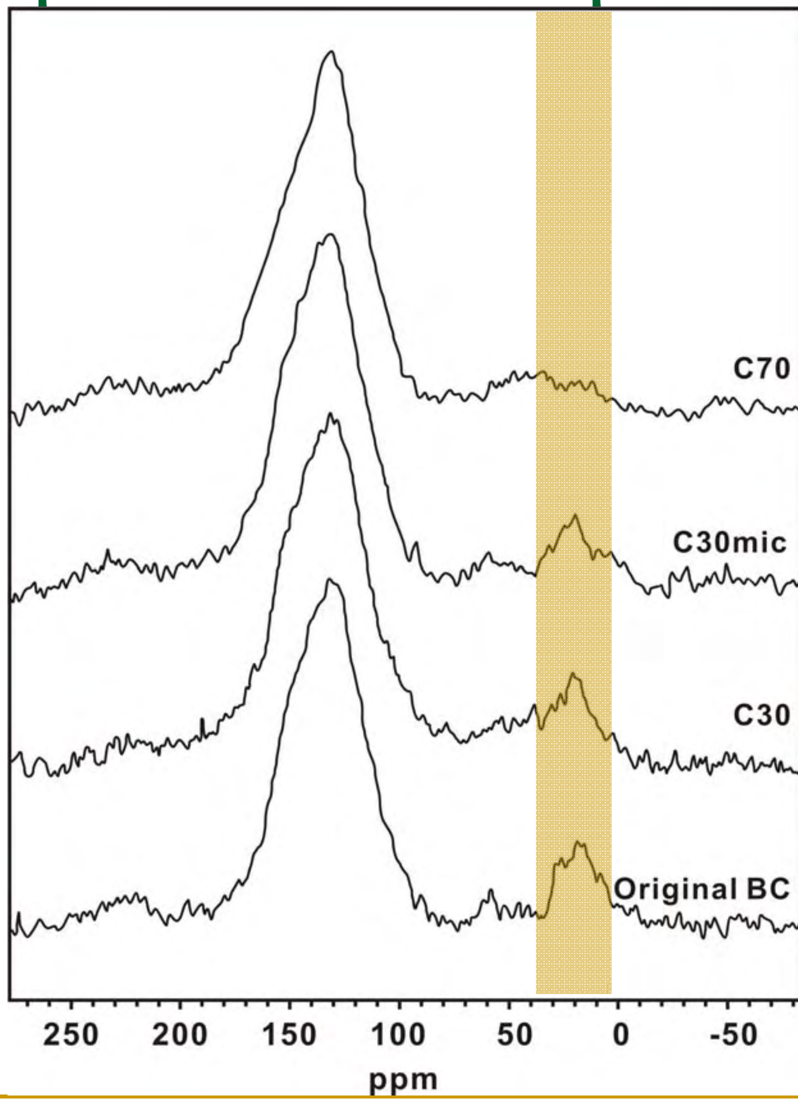
Decomposition Experiments



Significant proportion of aliphatic C bonds ("oils"?)

Nguyen et al., unpubl.

Decomposition Experiments

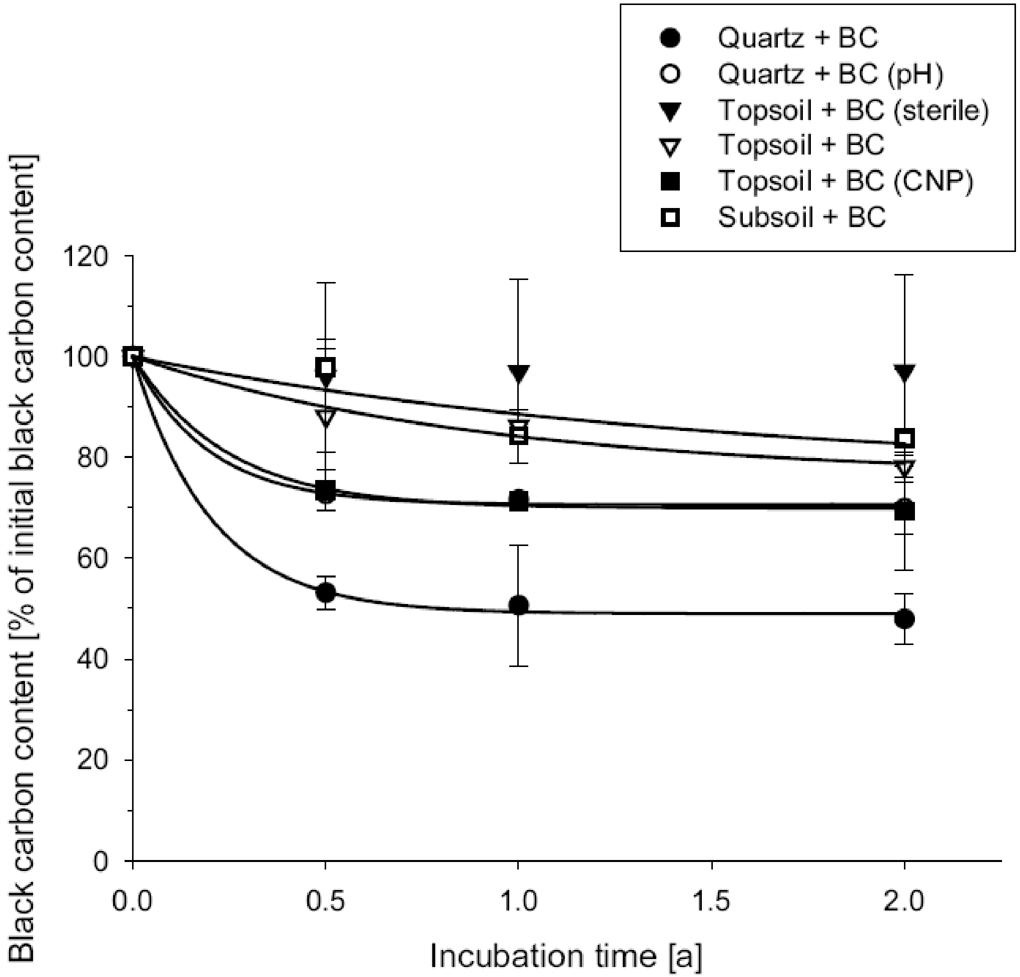


Disappearance of aliphatic C

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

Cheng et al., 2006 *Organic Geochemistry* 37: 1477-1488.

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)

Brodowski, 2005, PhD thesis

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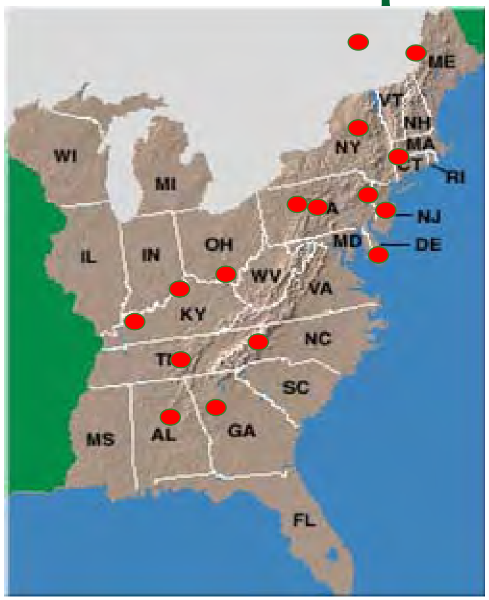
Decomposition Experiments

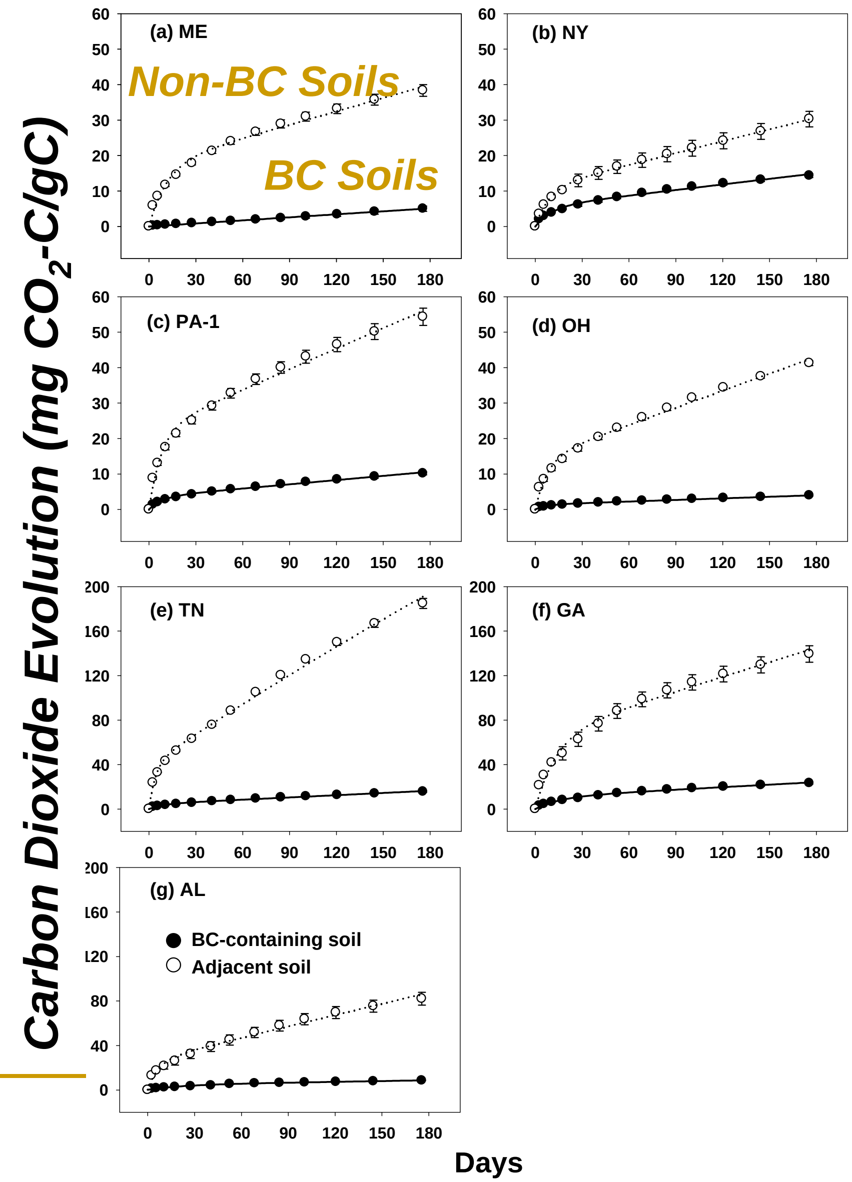


Biochar from storage areas for historical pig iron production (130 years old)

Half life of 925 yrs at 10°C MAT

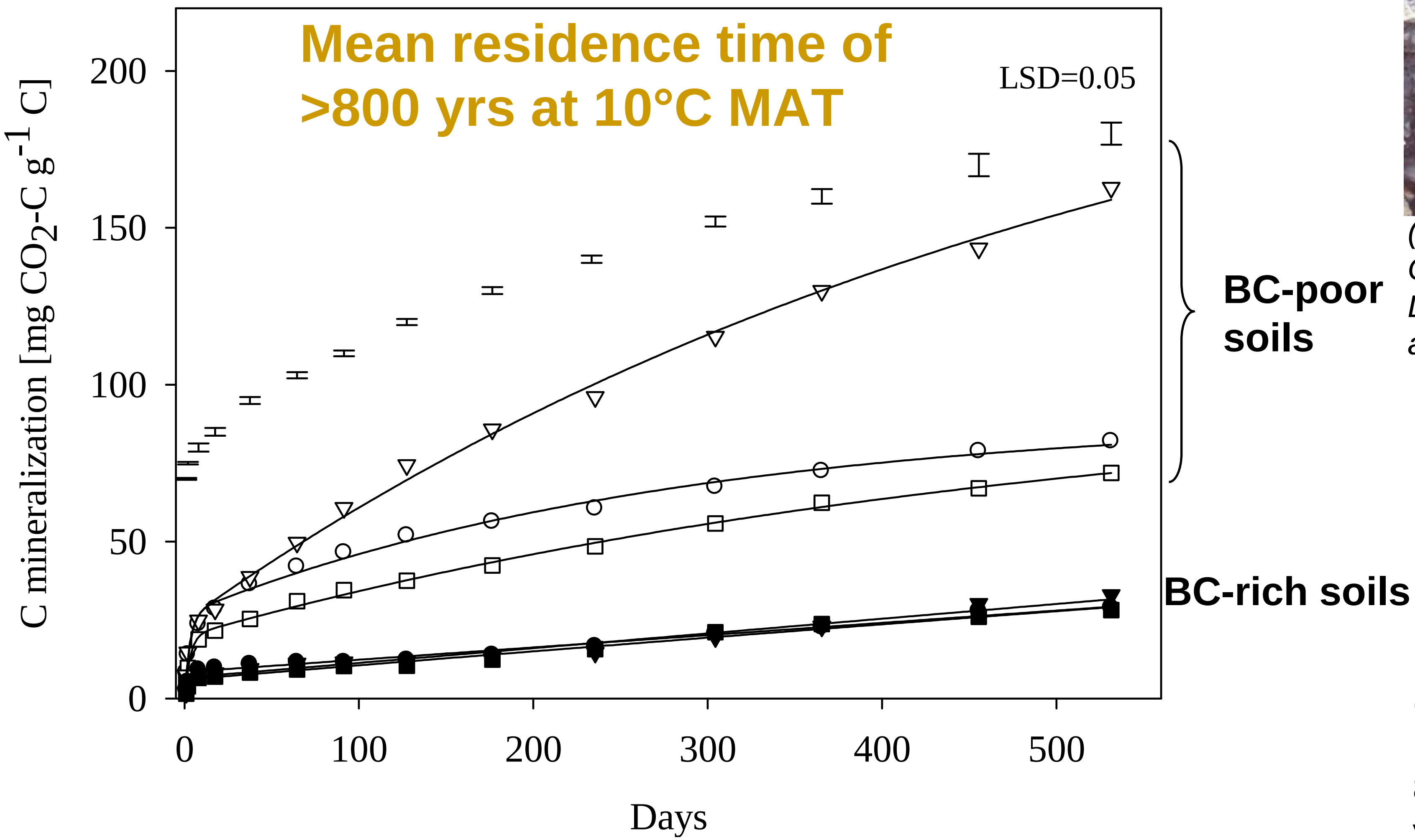
Stability of remaining did not change across the climate gradient.

(130 years)



Cheng, Lehmann et al., 2008,
Journal of Geophysical Research, 113, G02027

Decomposition Experiments



(Terra Preta Central Amazon Defined period of BC accumulation)

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

Liang, Lehmann et al., 2008, *Geochimica et Cosmochimica Acta* in press

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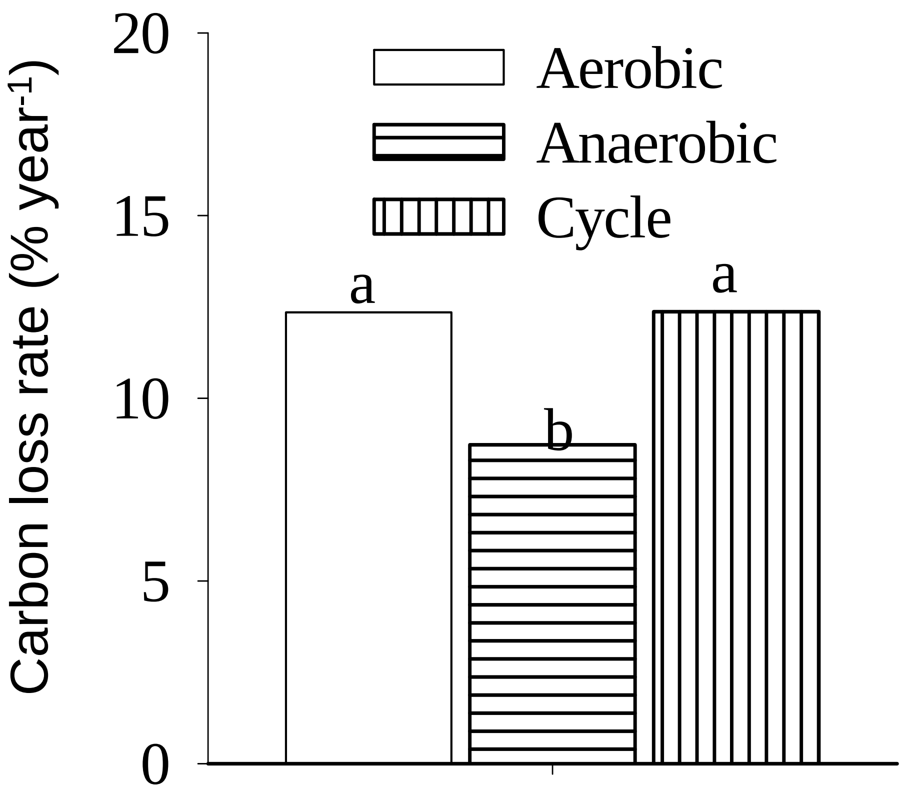
Decomposition Experiments

Opportunity to directly measure processes that control BC stability:

- Water
- Temperature

Decomposition Experiments - Moisture



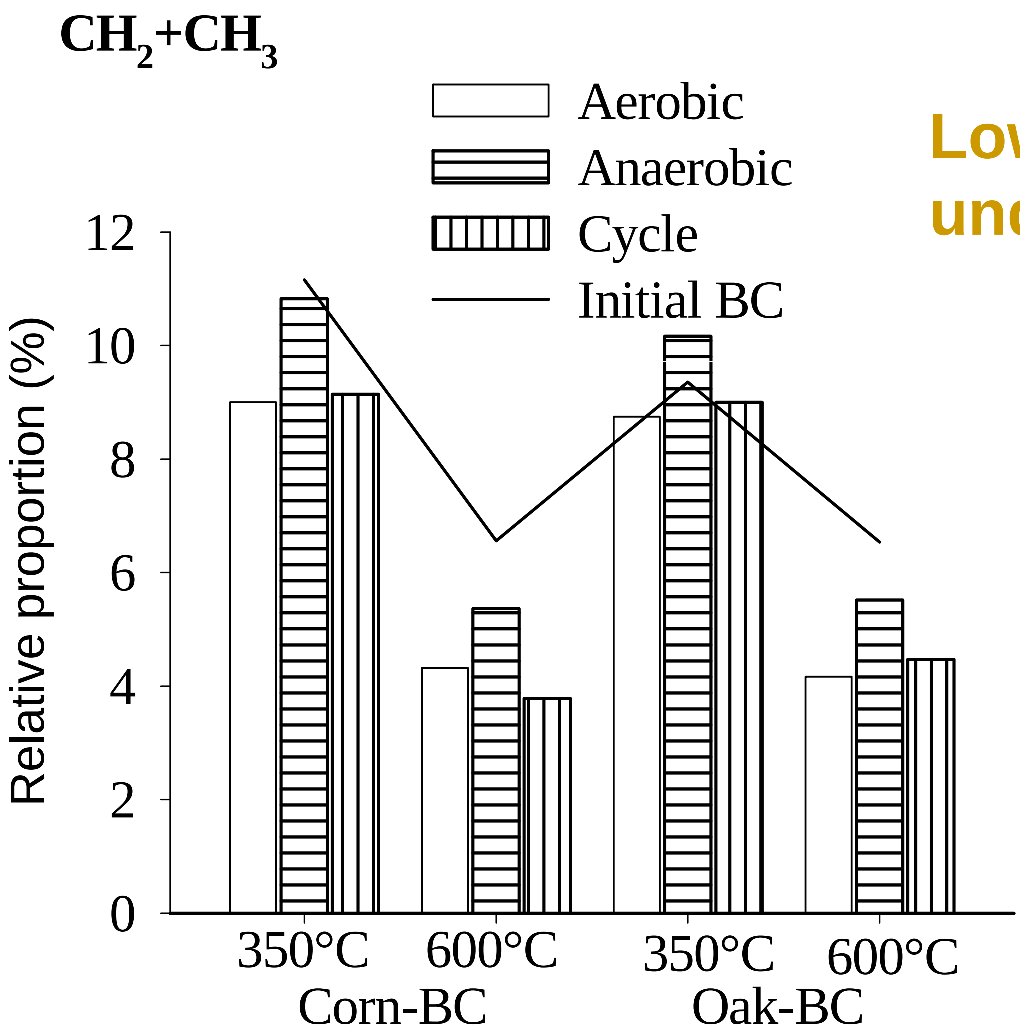
Lower mineralization under anaerobic conditions

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)

Nguyen et al., unpubl.

Decomposition Experiments - Moisture

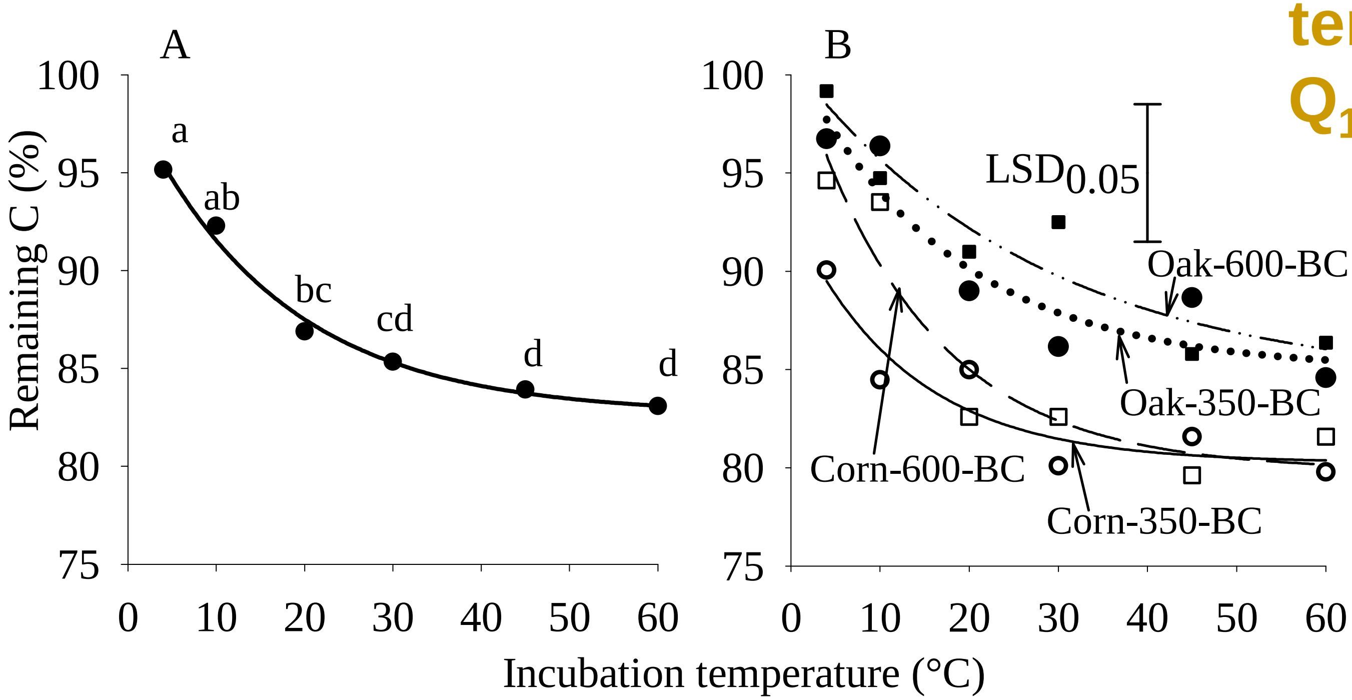


Lower decrease of aliphatic C under anaerobic conditions

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

Nguyen et al., unpubl.

Decomposition Experiments – Temp.



Greater increase in mineralization at lower temperature

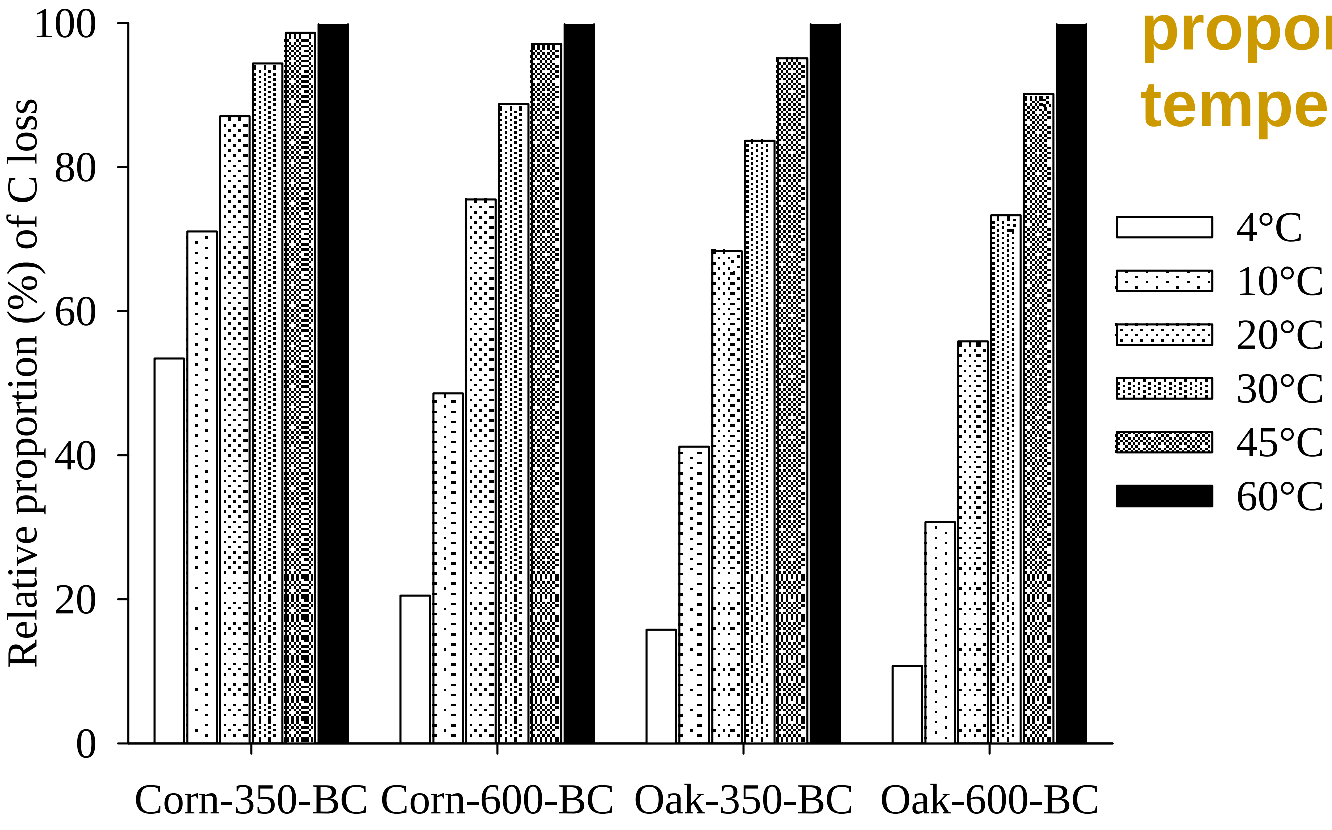
Q_{10} of about 3-4 at 10°C

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

Nguyen et al., unpubl.

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)

Nguyen et al., unpubl.

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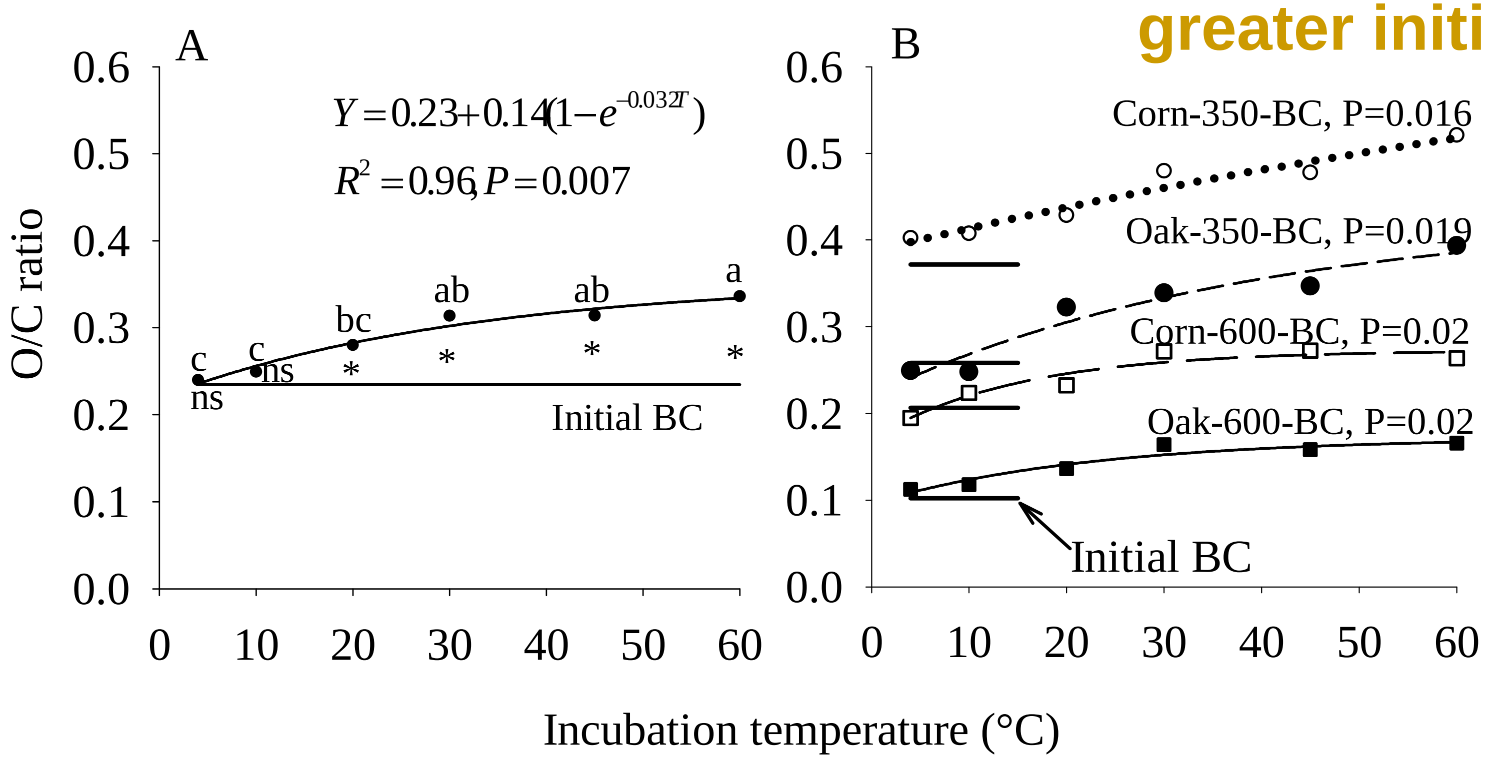
Decomposition Experiments – Temp.

At low temperature, limited oxidation of remaining C

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

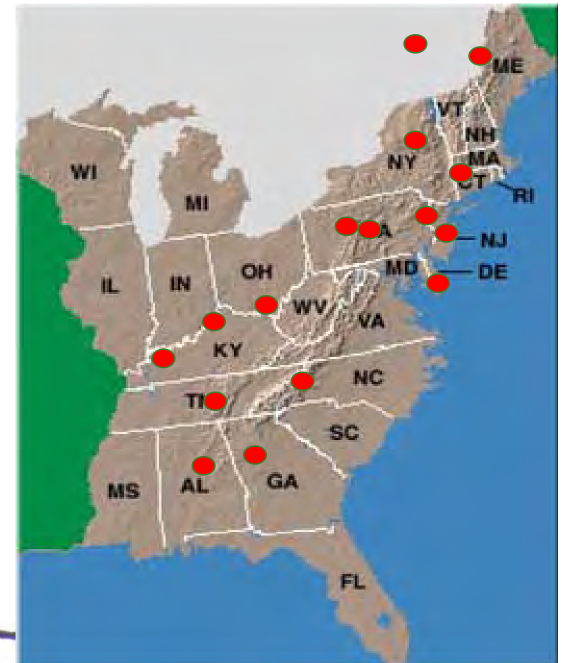


(N=8, 60% WHC, 1 year, in sand culture)

Nguyen et al., unpubl.

Climosequence – Temp.

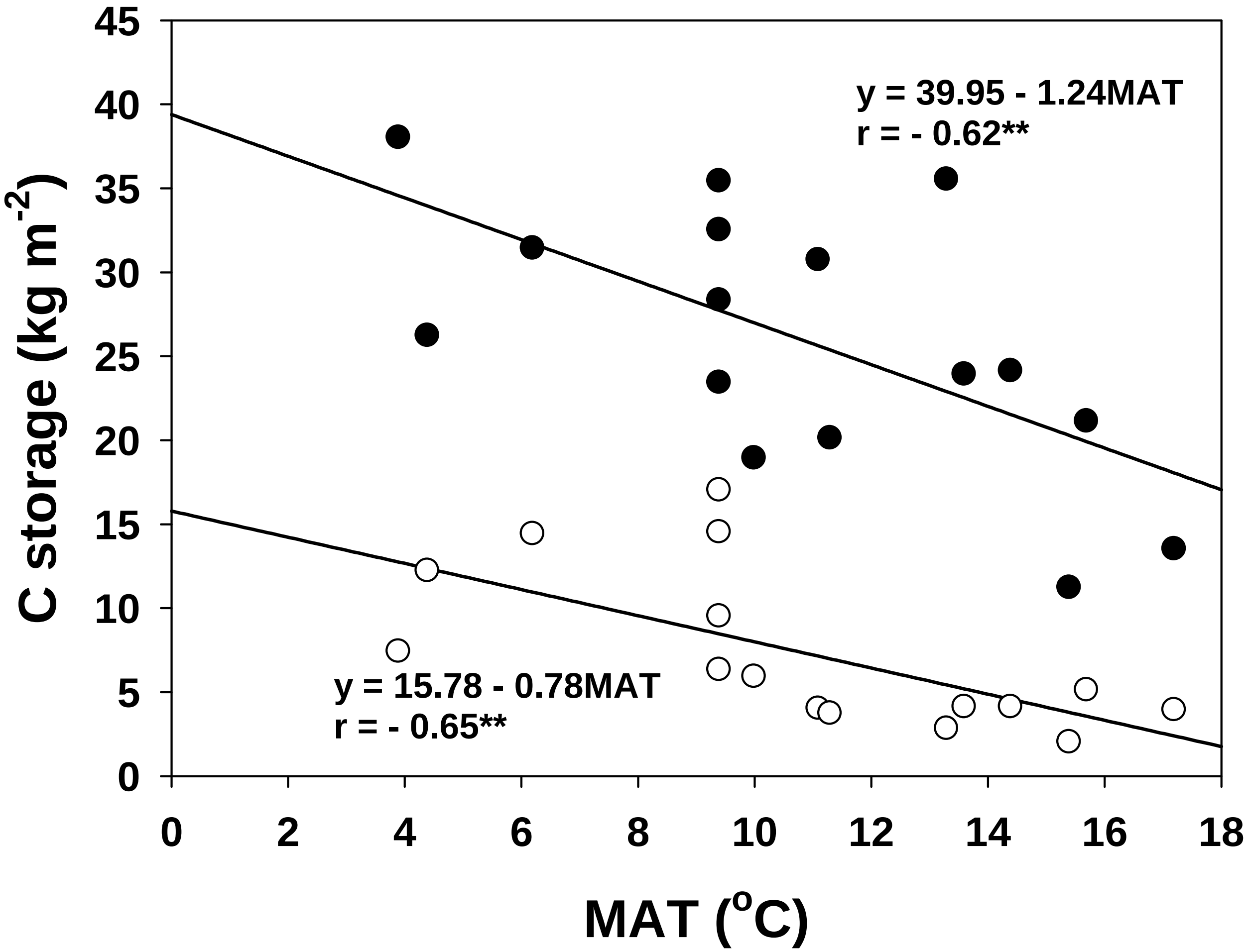
Some opportunity to measure long-term temperature effects with climosequences



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

Cheng, Lehmann, et al., 2008, *JGR* 113, G02027

Climosequence – Temp.



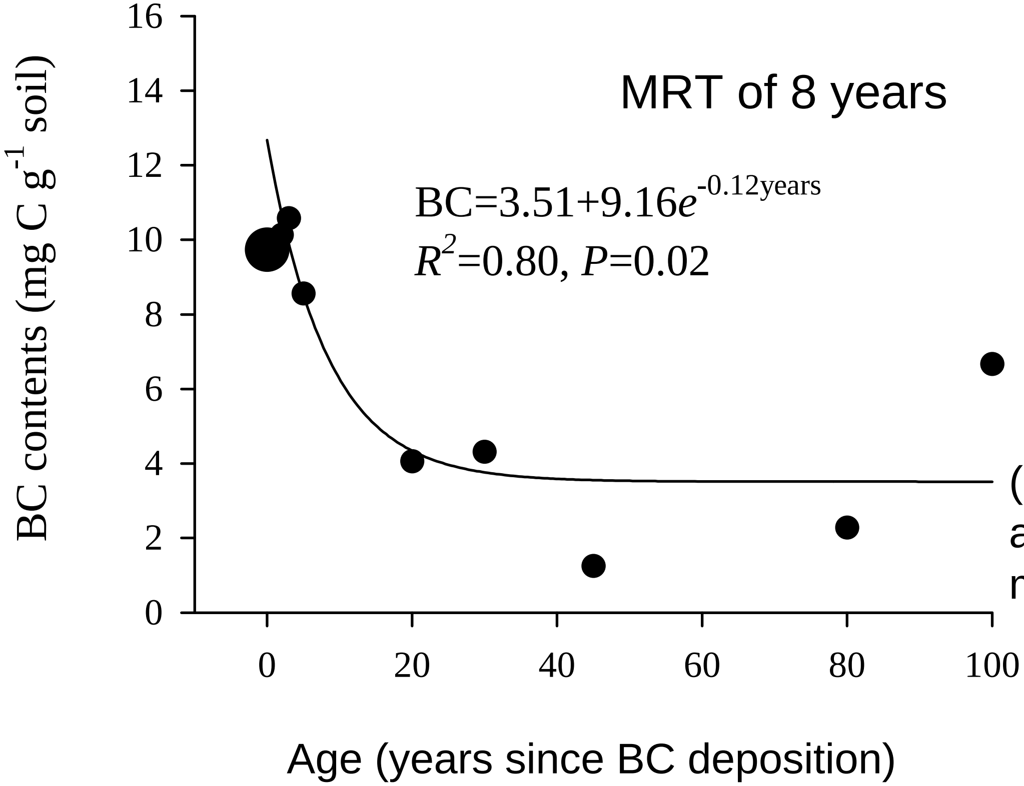
Q_{10} of 3.8

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

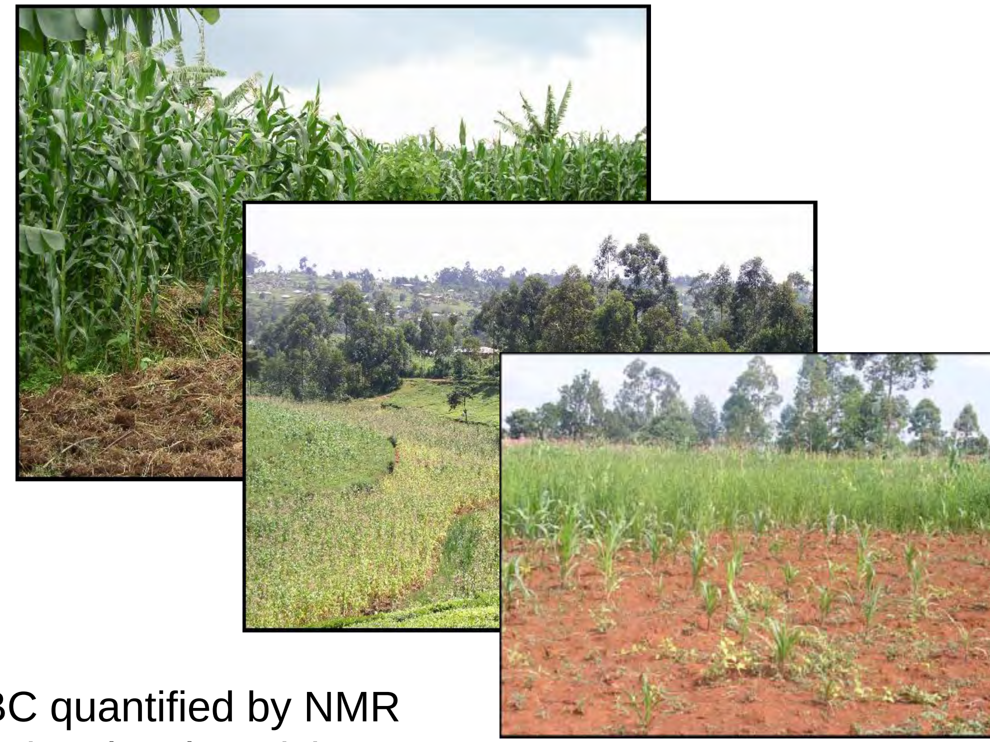
(calculation of relative decomposition rates between MAT (no relationship with MAP); controlling for non-BC changes; assuming negligible decomposition at 0°C)

Cheng, Lehmann, et al., 2008, *JGR* 113, G02027

Chronosequences



(BC quantified by NMR and molecular mixing model)



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

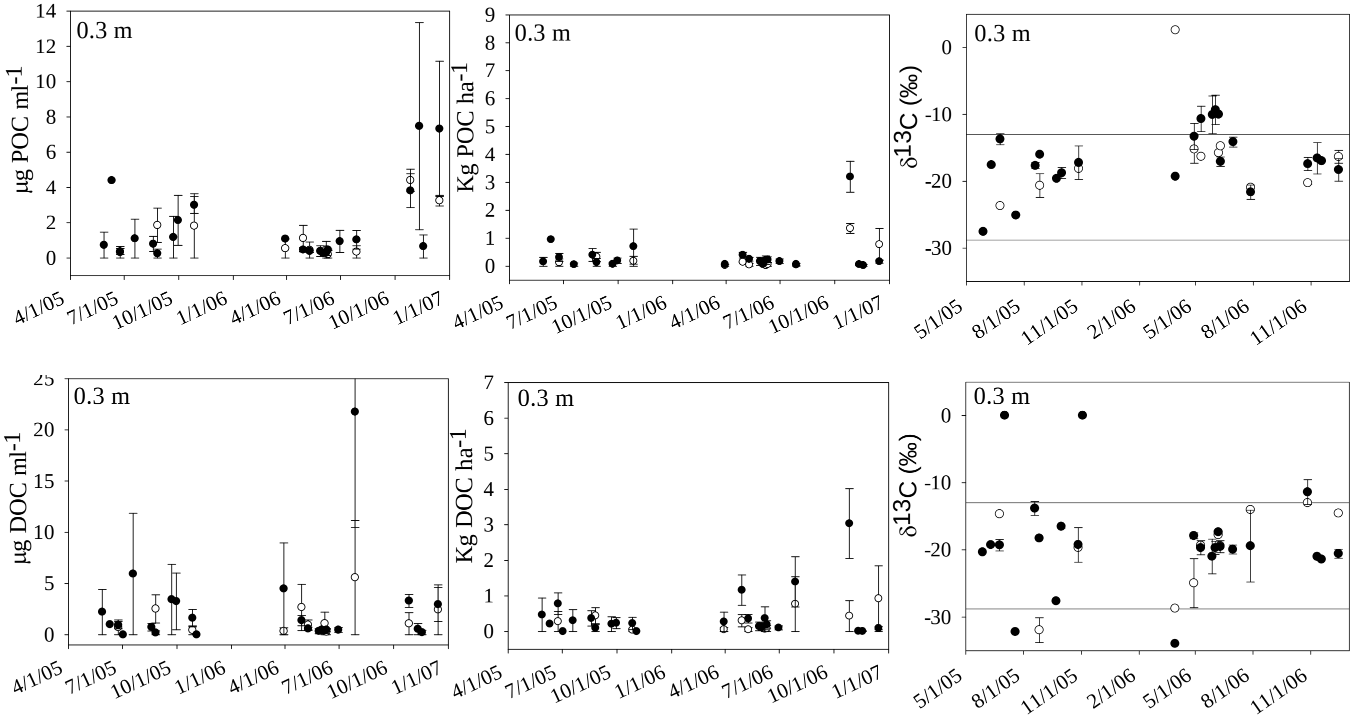
Large proportion of physical export likely

Nguyen, Lehmann et al., 2008, *Biogeochemistry* 89: 295-308

Mass Balance

Leaching of POC, DOC Mineralization

Colombian Llanos



Major et al., unpubl.

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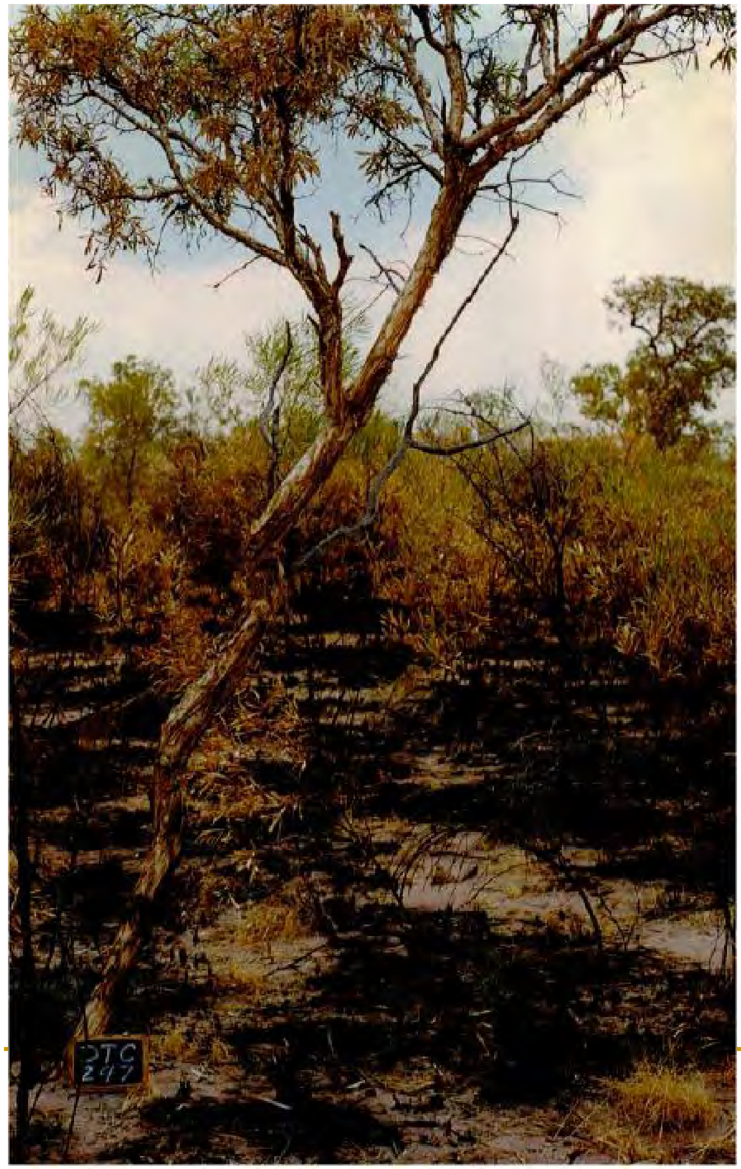
Mass Balance

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

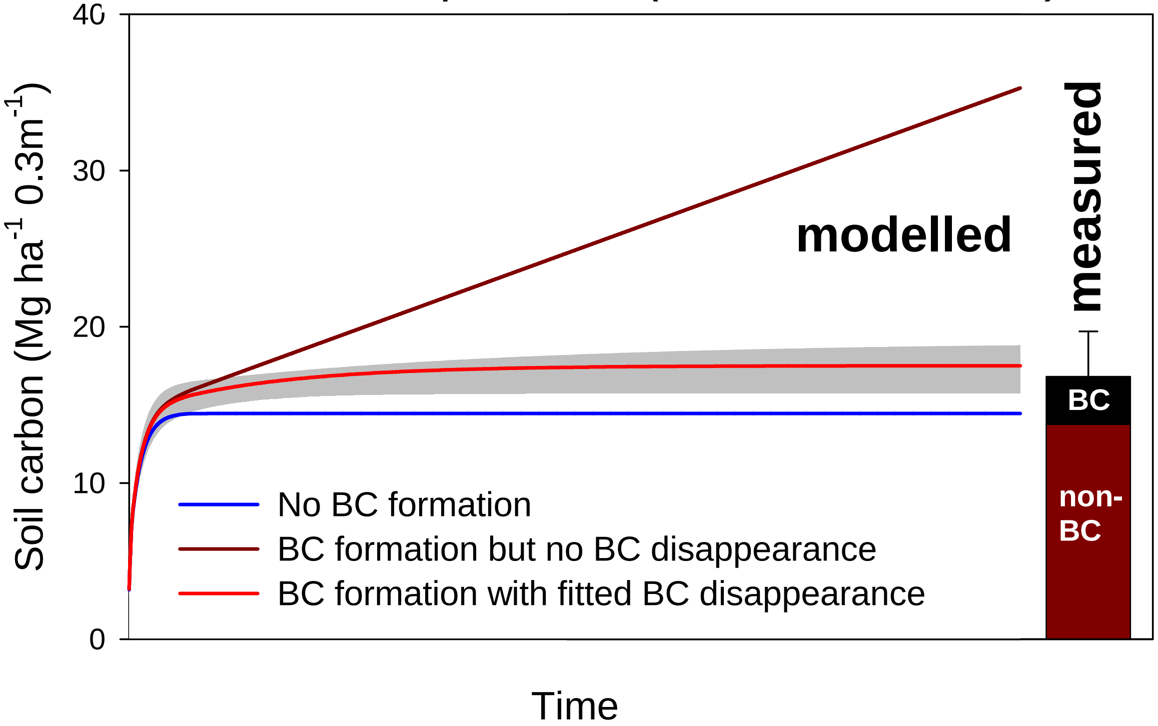
Similar order of magnitude of leaching and mineralization (erosion was not directly measured)

Major et al., unpubl.

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 (MAP[1] 887 mm; MAT[2] 27°C; clay 13%)		
60	4292	1715	1074
70	3674	1471	921
80	3212	1300	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	2603	1623
90	5841	2310	1444

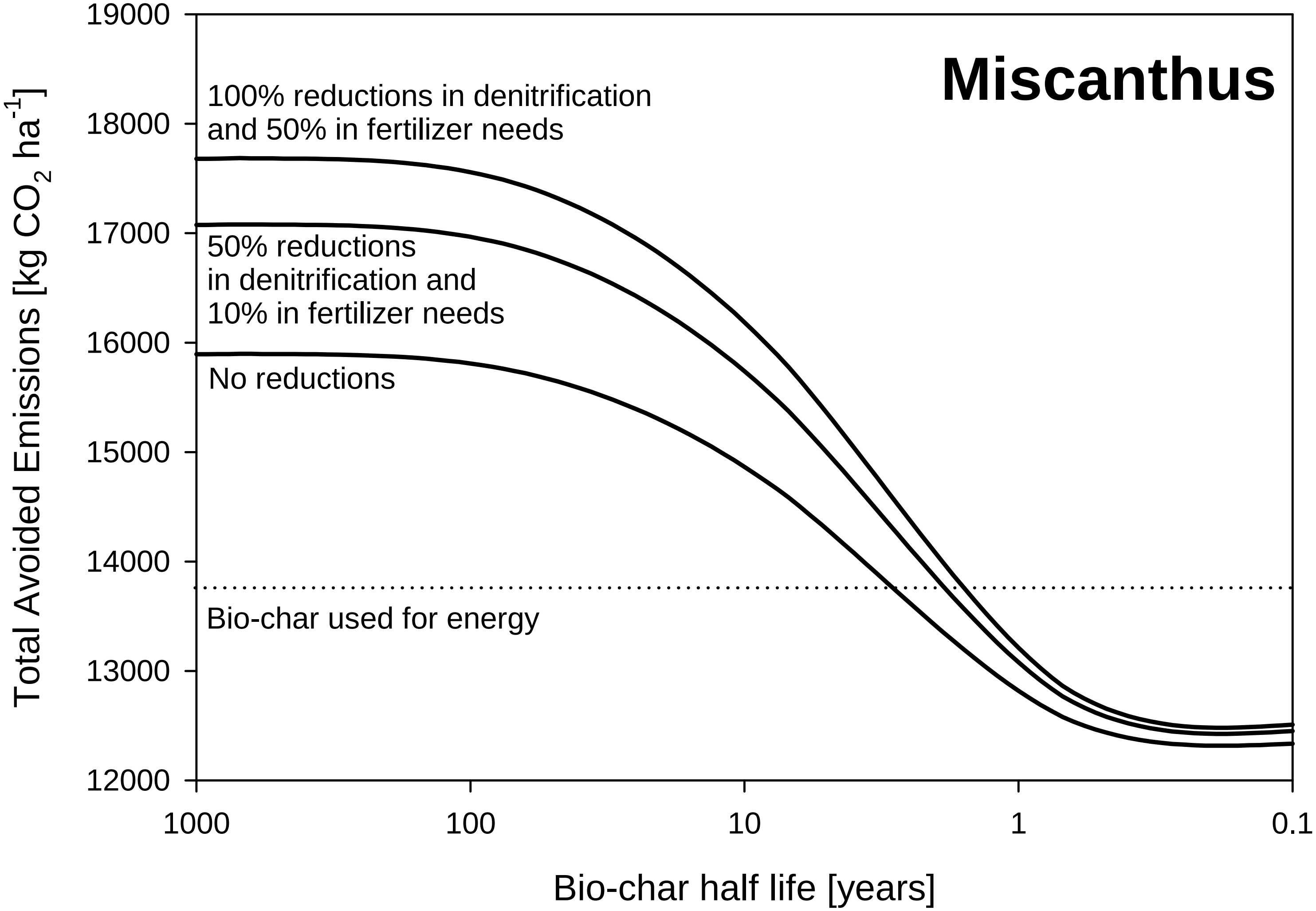
If MRT is mineralization, not considered:
re-burning,
erosion,
leaching below 1m

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



Gaunt and Lehmann, 2008, *Environ. Sci. Technol.* 42: 4152-4158

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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