Which biochar is best?

Alice Budai,
Daniel P. Rasse,
and many others

Terra Preta Project
September 1st, 2014, Budapest

Image from climateforce.wordpress.com
Image from http://www.diacarbon.com/blog/what-are-the-effects-of-biochar-in-soil/

Outline

- What is Biochar and what can it do for us?
- Biochar characterization
  - Surface properties
  - Stability
  - Methods for identification
- Choosing the proper produciton method

Why Biochar?

- Obatined through charring of biomass
- Porous (high surface area)
  - Microbial habitat
  - Water holding capacity
- Liming potential
  - Up to pH 10
- Binding capacity
  - CEC of fresh biochar: 200 $mmol_c\ kg^{-1}$
  - CEC of clay minerals: 700 – 2500 $mmol_c\ kg^{-1}$
  - CEC of SOM (humus): 4000 – 9000 $mmol_c\ kg^{-1}$

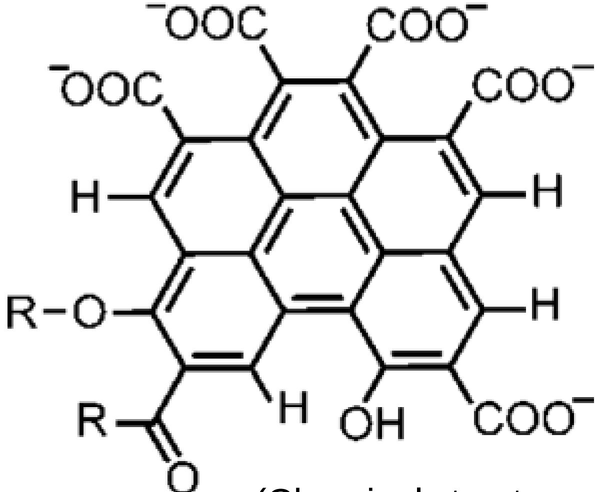
  Soil CEC increases with organic C content

Image from http://media.treehugger.com/assets/images/2011/10/20100607-biochar-spreading.jpg

What is biochar?

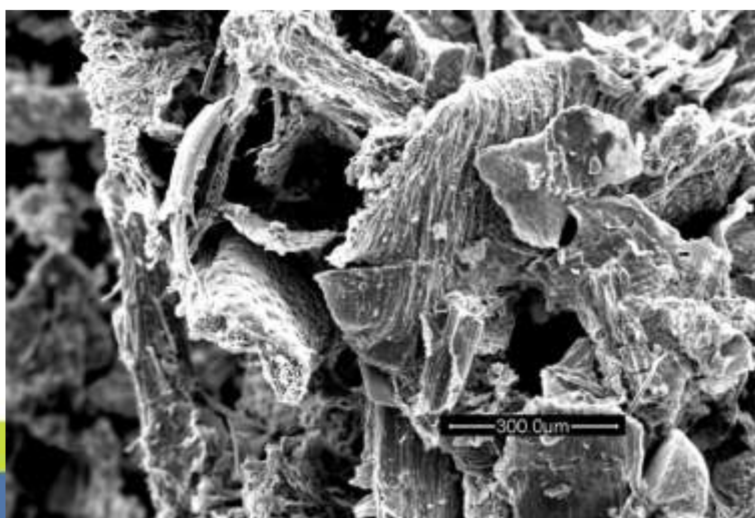
- 1 – 5 % Hydrogen
- 5 – 40 % Oxygen
- 50 – 90 % Carbon

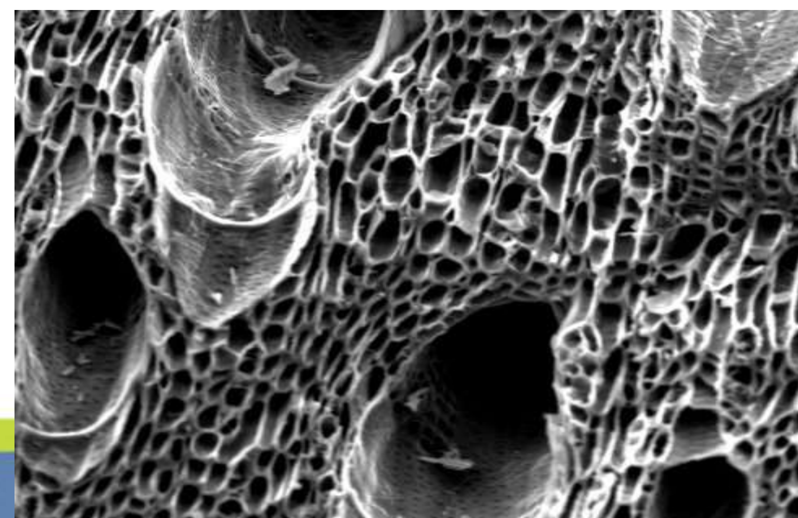
  + other elements



(Chemical structure proposed by Mao et al 2012)

Charcoal produced for soil application:

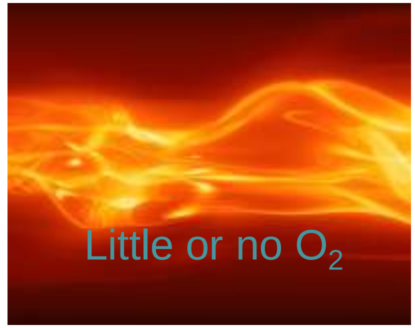




Images from http://www.treepower.org/biochar/main.html

Pyrolysis / Carbonization

Biomass



→ **Gas**

→ **Tar**

→ **Char (Biochar)**

– Quality of the product depends on HTT, P, carrier gas, sample size…

Image from http://www.biochar-us.org/then%20&%20now.html

Biochars of my PhD work

Two feedstocks x **Three production methods =** 34 chars

Slow Pyrolysis

NTNU

Flash Carbonisation

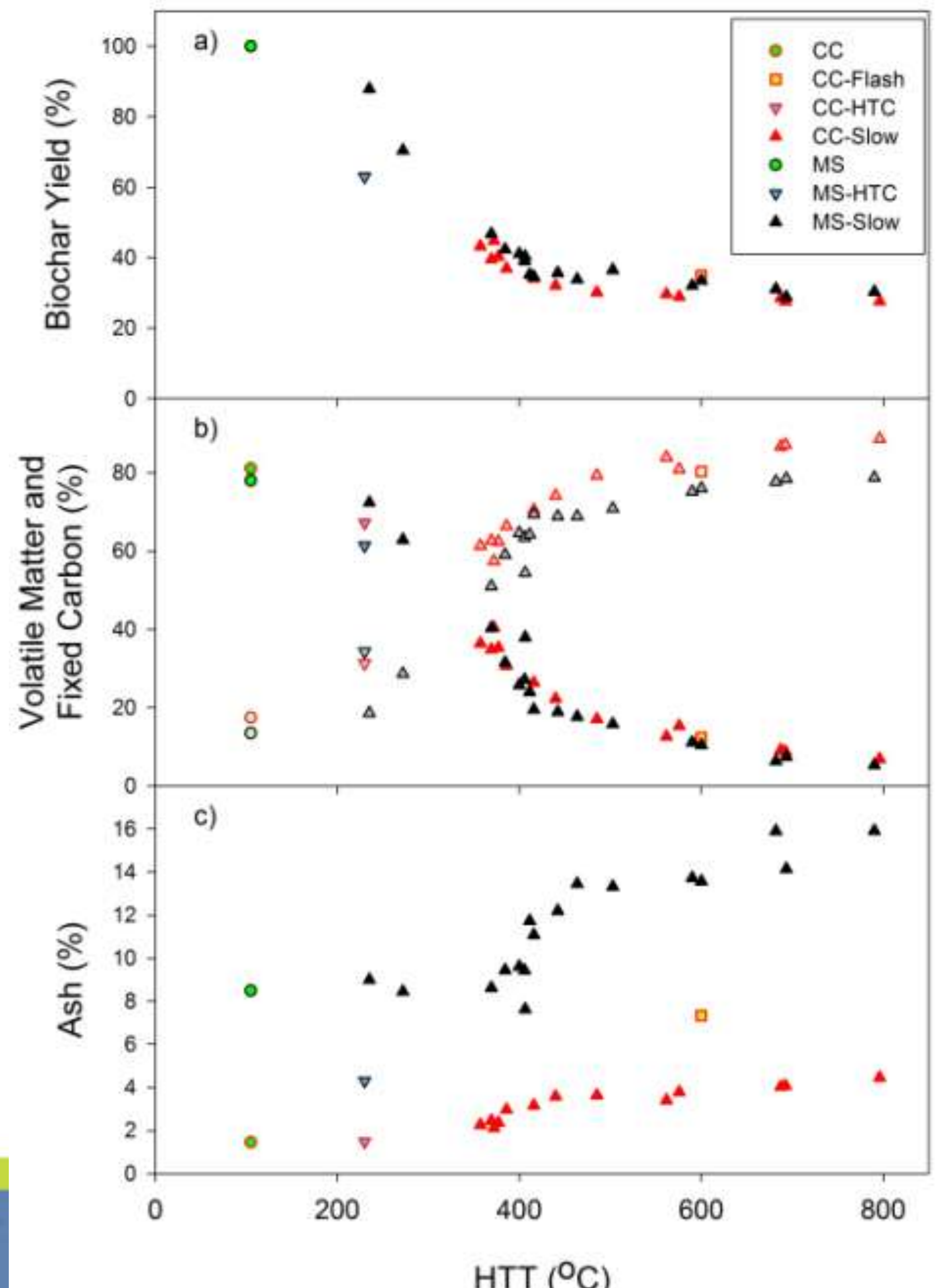
HNEI

Hydrothermal C.

MPG

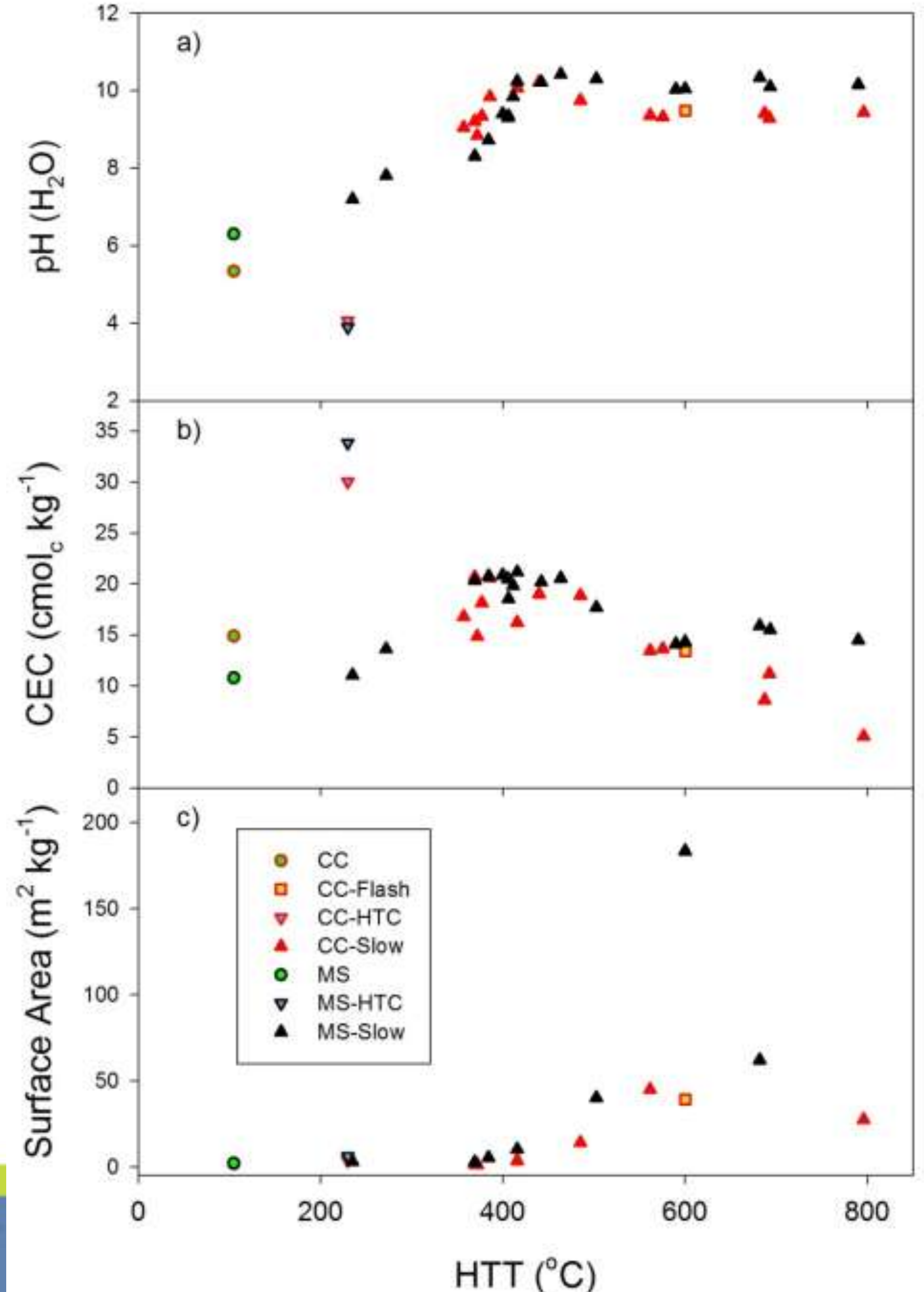
Biomass transformation through pyrolysis

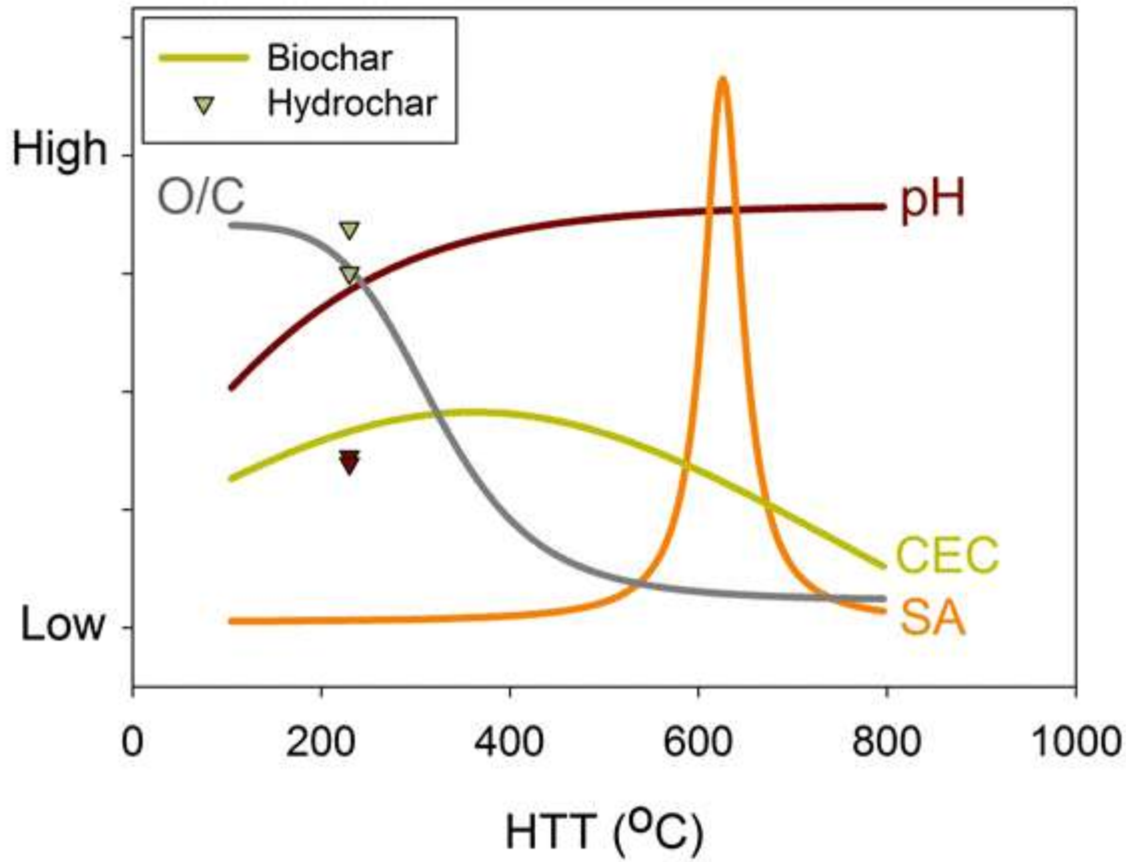
- Most change occurs at 200 – 400 °C
- Minerals (K, Mg, P, Fe, Na, Mn) are concentrated
  - Some minerals are volatilized at these temperatures but can still accumulate (Al)



Surface properties

- Greatest liming potential: > 400 °C
- Highest CEC: 400 °C
- Highest SA: 600 °C




Biochar
Hydrochar
High
Low
O/C
pH
CEC
SA
0
200
400
600
800
1000
HTT (°C)

Carbon sequestration

How stable is biochar?

By decreasing soil carbon flux by 5 %, we could seqeuster enough CO_2 to offset half of anthropogenic emissions

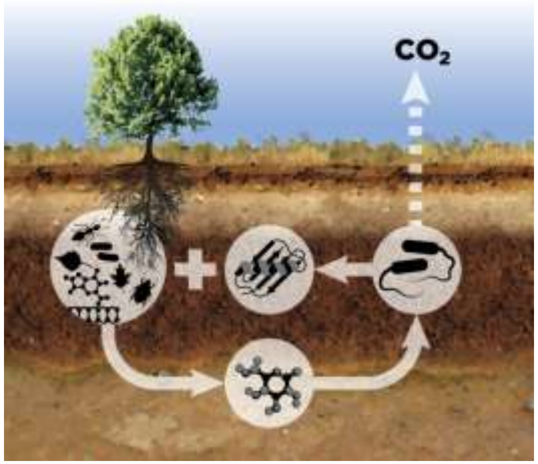


Image from http://www.newswise.com/articles/ornl-researchers-improve-soil-carbon-cycling-models

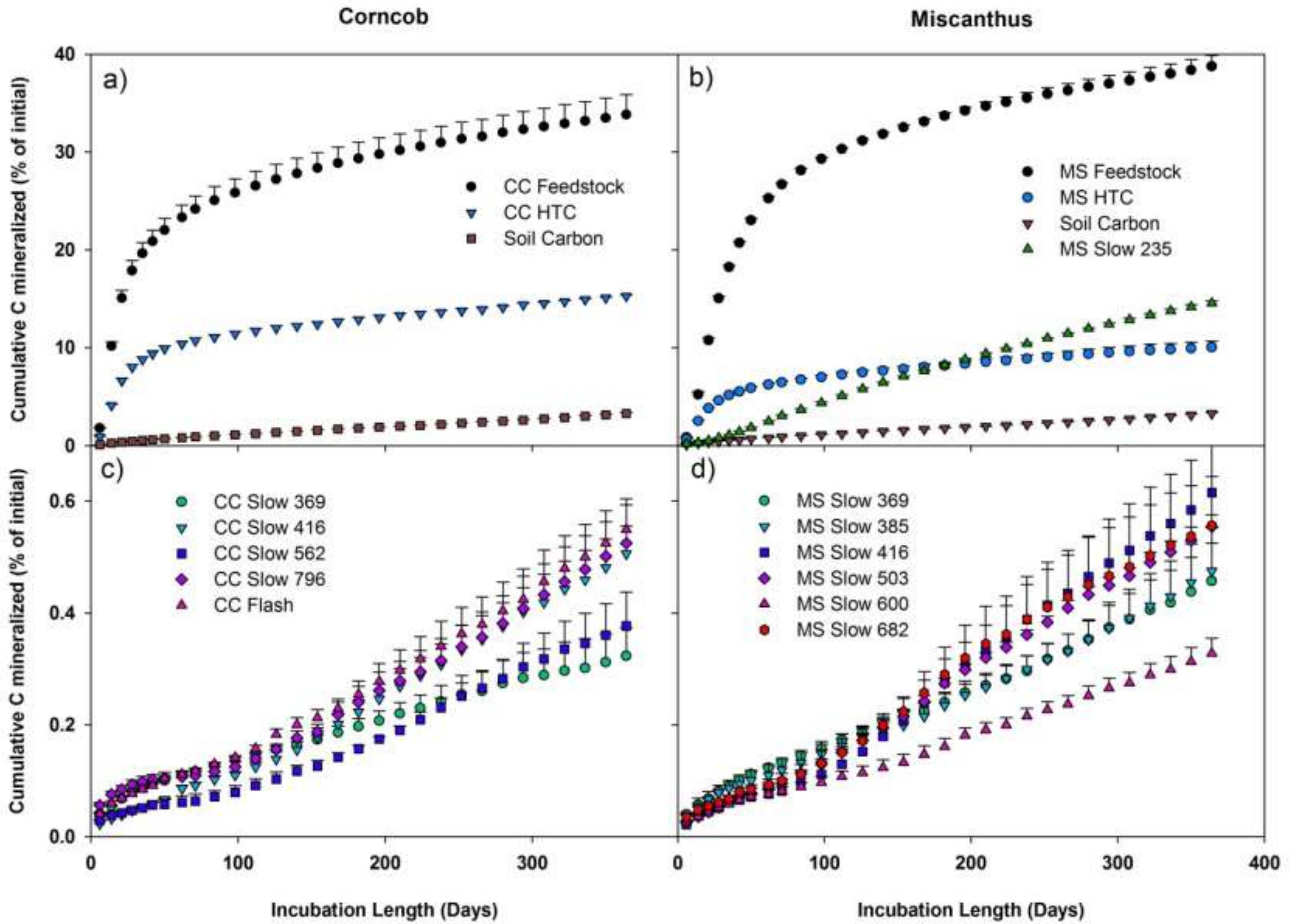
Bioforsk

Incubation

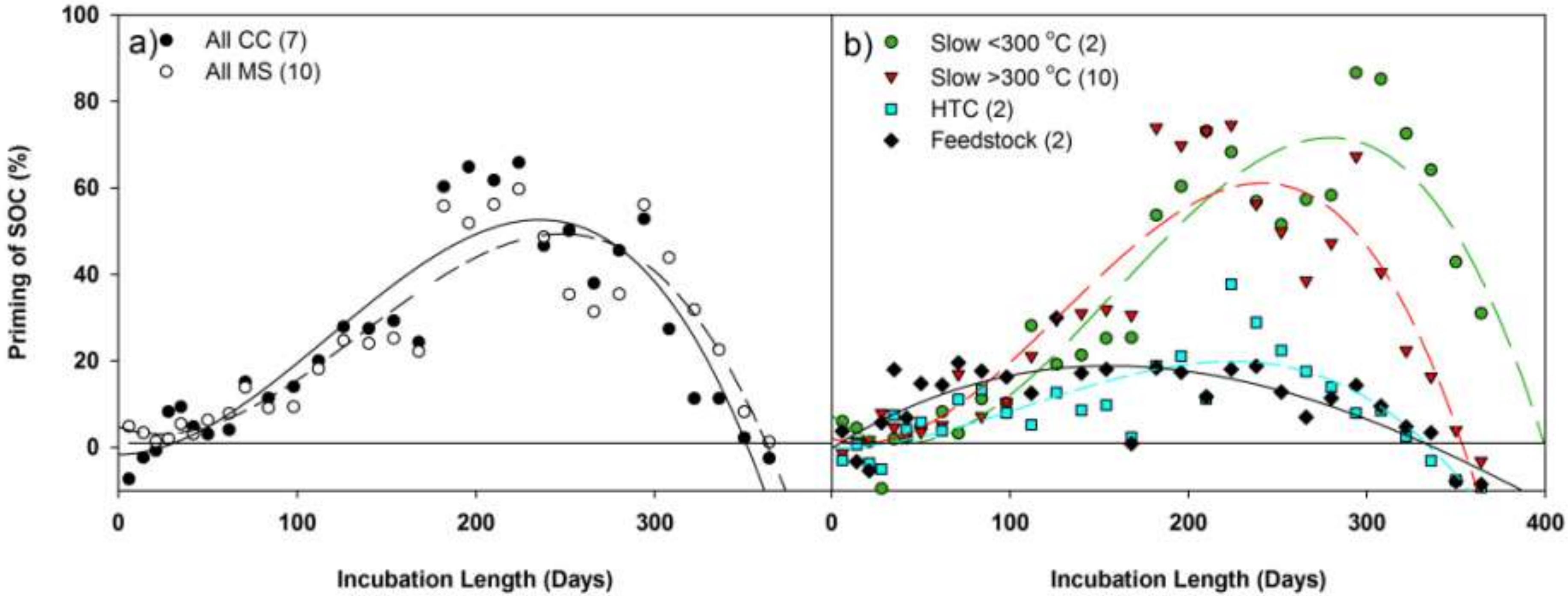
Method:

- 1 year duration
- Flasks are closed at all times
- Natural abundance of ^{13}C from C4

Stabilities in soil



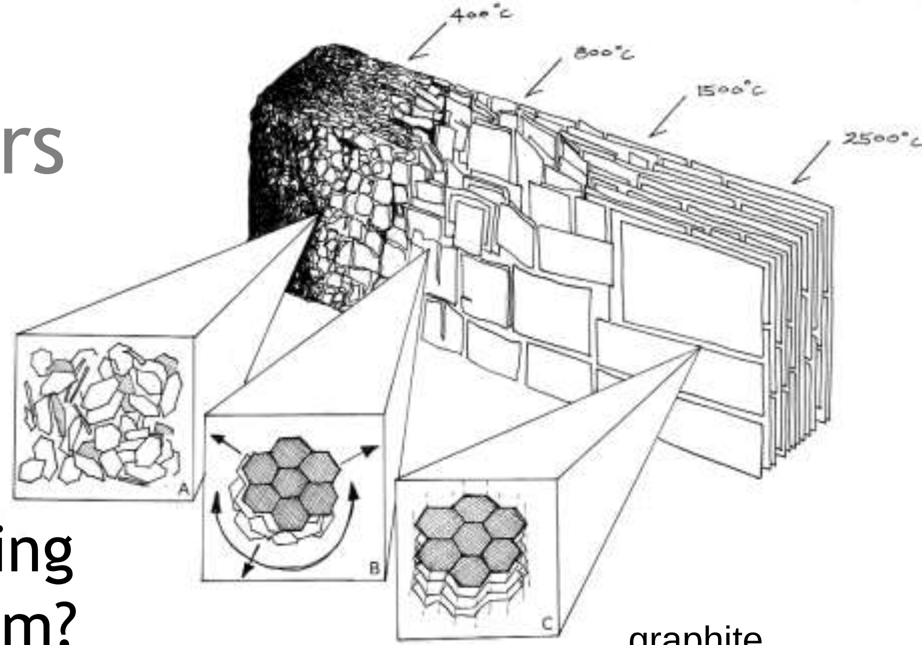
Priming of Soil Carbon



$$\text{Priming}\ (\%) = \frac{\text{Rate}_{\text{Sample}} - \text{Rate}_{\text{Control}}}{\text{Rate}_{\text{Sample}}} * 100\%$$

Characterizing biochars

- How different are they?
- Is there a ruler for measuring along the biochar continuum?



graphite

Image from Lehmann and Joseph eds., Biochar for Environmental Management, 2009

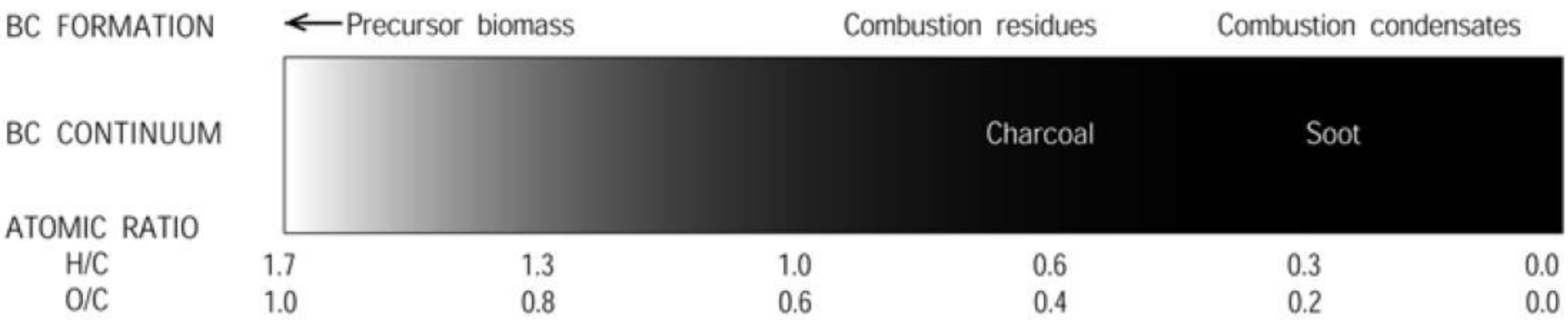
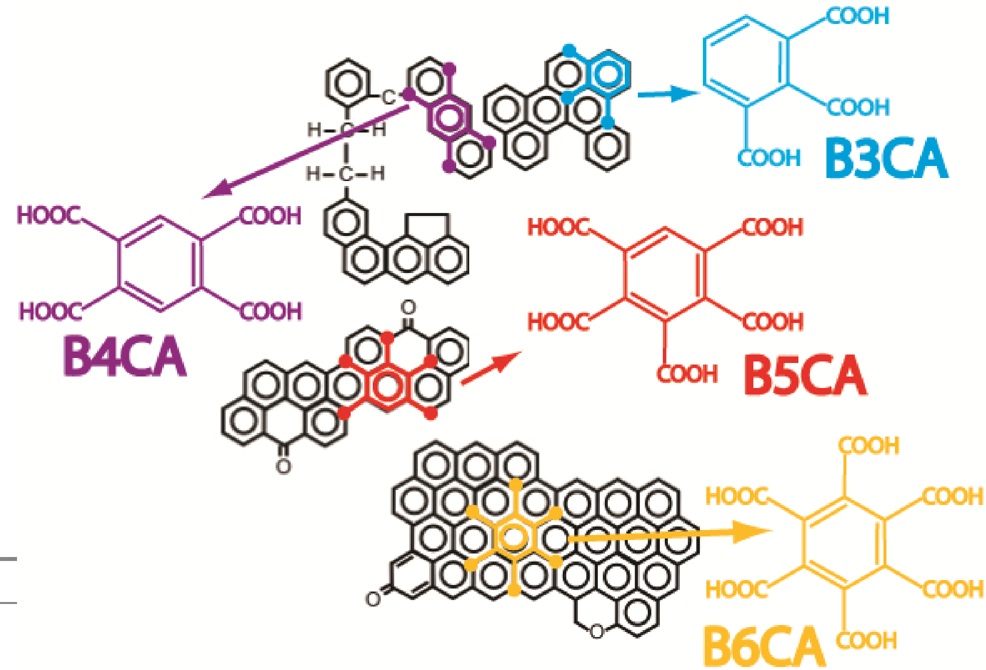
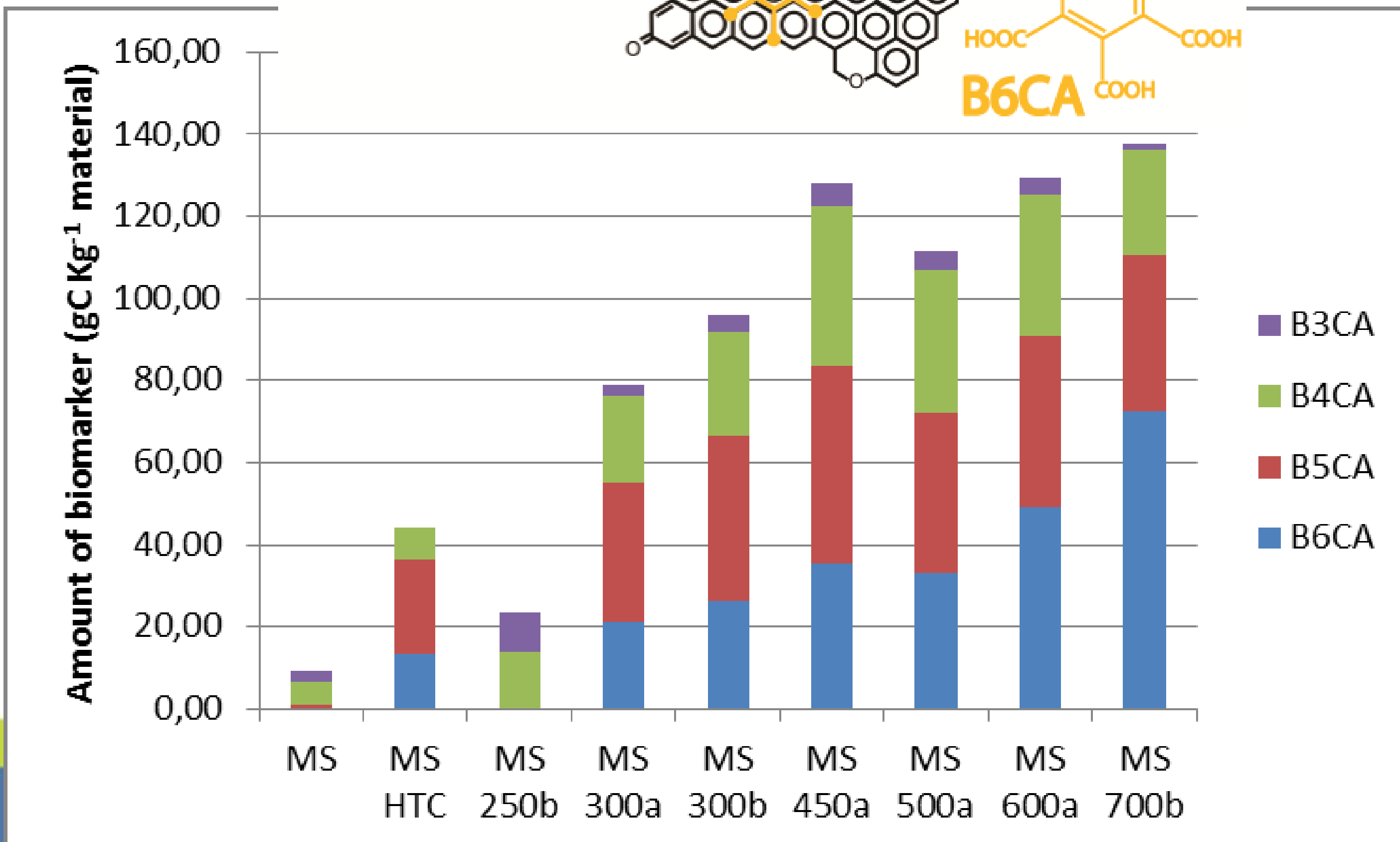


Image from Hammes et al. 2007

BPCA


B3CA
B4CA
B5CA
B6CA
COOH
HOOC
H–C–H
C
O


Amount of biomarker (gC Kg-1 material)
160,00
140,00
120,00
100,00
80,00
60,00
40,00
20,00
0,00
MS
MS HTC
MS 250b
MS 300a
MS 300b
MS 450a
MS 500a
MS 600a
MS 700b
B3CA
B4CA
B5CA
B6CA

Conclusions

- Biochar properties change with production temperature and method (as expected)
- CC and MS feedstocks produced similar biochars but a different class of biomass could produce biochars with different properties
- Surface properties can not be predicted from composition indicators
  - SA and CEC do not correlate
- Biochar is stable, especially when produced above 300 ºC

Image from http://climateforce.wordpress.com/2012/01/12/geoengineering-potential-biochar-application/

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Biochar composition indicators

- The degree of carbonization is captured by elemental ratios H/C and O/C, and volatile matter content
  - HTC at 230 C = slow pyrolysis at 300 ºC
  - Flash carbonization = slow pyrolysis at 600 ºC