Biochar and GHG mitigation

Which are the Trade Offs?

Kor Zwart

KB-13-005-008

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Alterra Introduction

- Wageningen UR
  - University
  - 6 Research Institutes
  - Alterra:
    - Soil, Water & Climate, Ecology, Landscape
    - Ca. 500 staff
    - Project Organisation
    - 50-60 Million €/year
- Team: Sustainable Soil Management

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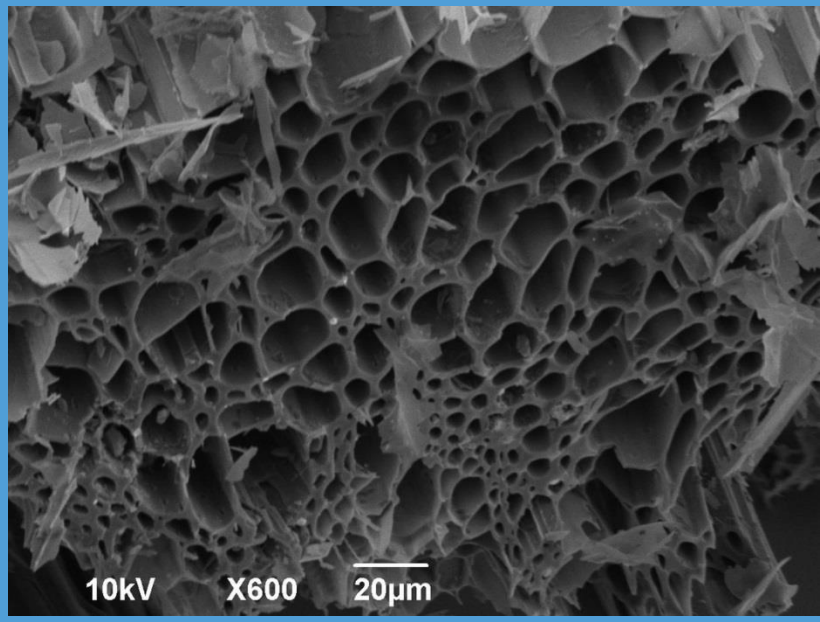
Kor Zwart Introduction

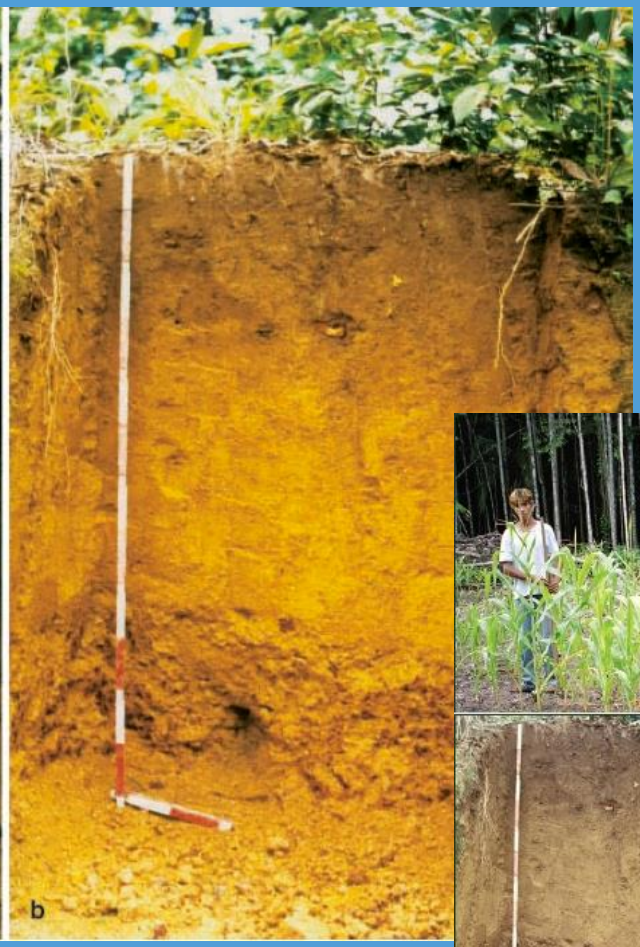
- Biobased Economy
  - Bioenergy, sustainability,
  - Biochar application
  - Biorefinery
  - ‘New’ Organic Fertilizers from waste
- Nitrates Directive evaluation in EU-27
- Sustainable Soil Management

Biochar Introduction

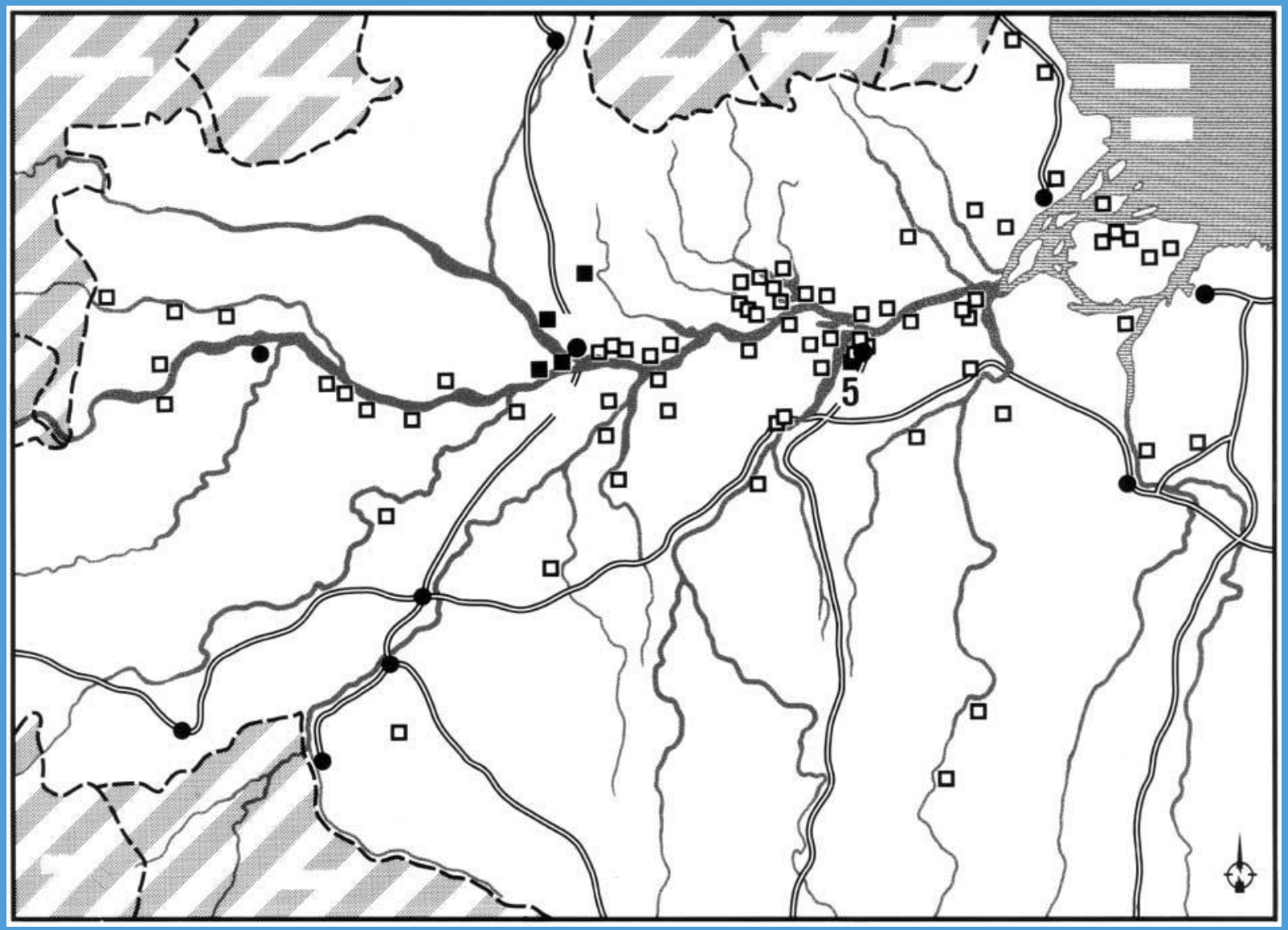
- Carbonized biomass
  - specifically produced to be applied into the soil



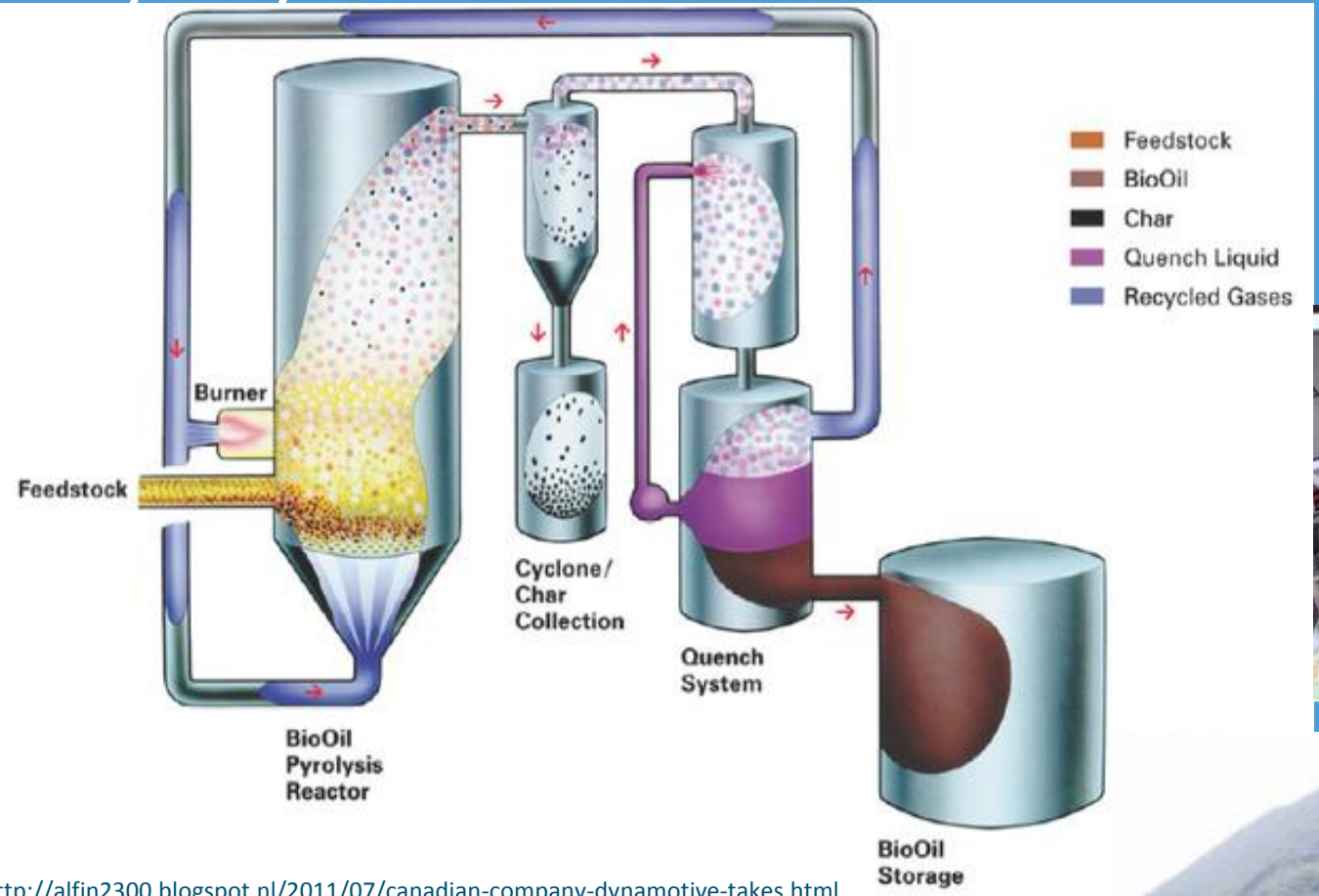
Terra preta (Black soils) Amazon Basin



Terra preta (Black soils) Amazon Basin



Pyrolysis Proces -> Biochar



http://alfin2300.blogspot.nl/2011/07/canadian-company-dynamotive-takes.html

http://www.adpholdings.com/images/tire-2.jpg

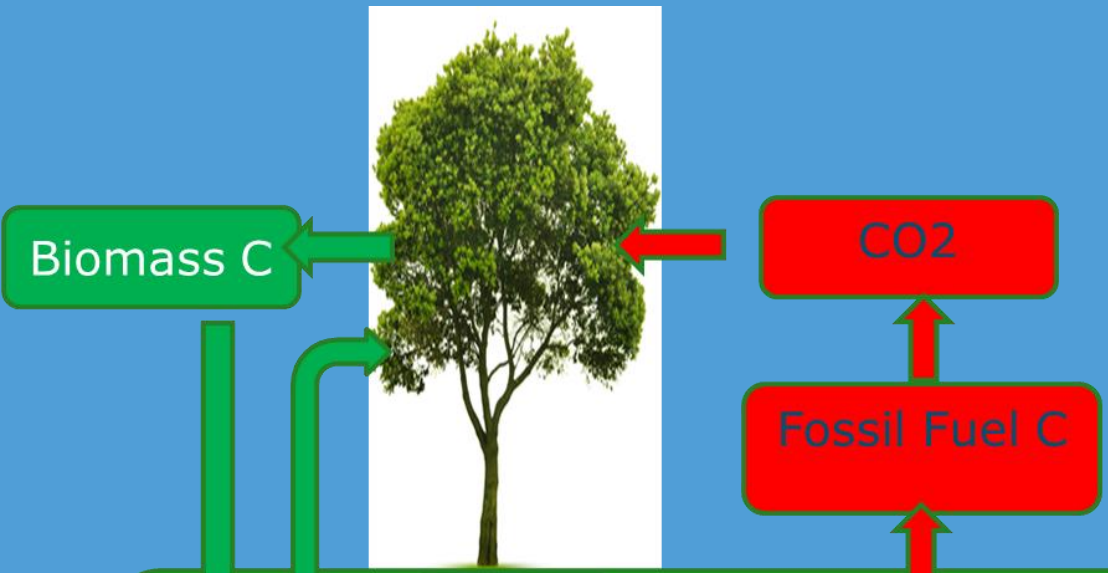
Biochar Yields % kg DM^{-1}

Pyrolysis	Commercial Softwood Pellets	Anaerobic Digestate	Mixed Wood Chip	Green Waste
Char Yield	23.9	44	25.2	60.6
Carbon	0.89	0.52	0.87	0.18
Liquid Yield	37	24.3	33.9	12.9
Syngas Yield	39.1	31.7	40.8	26.5

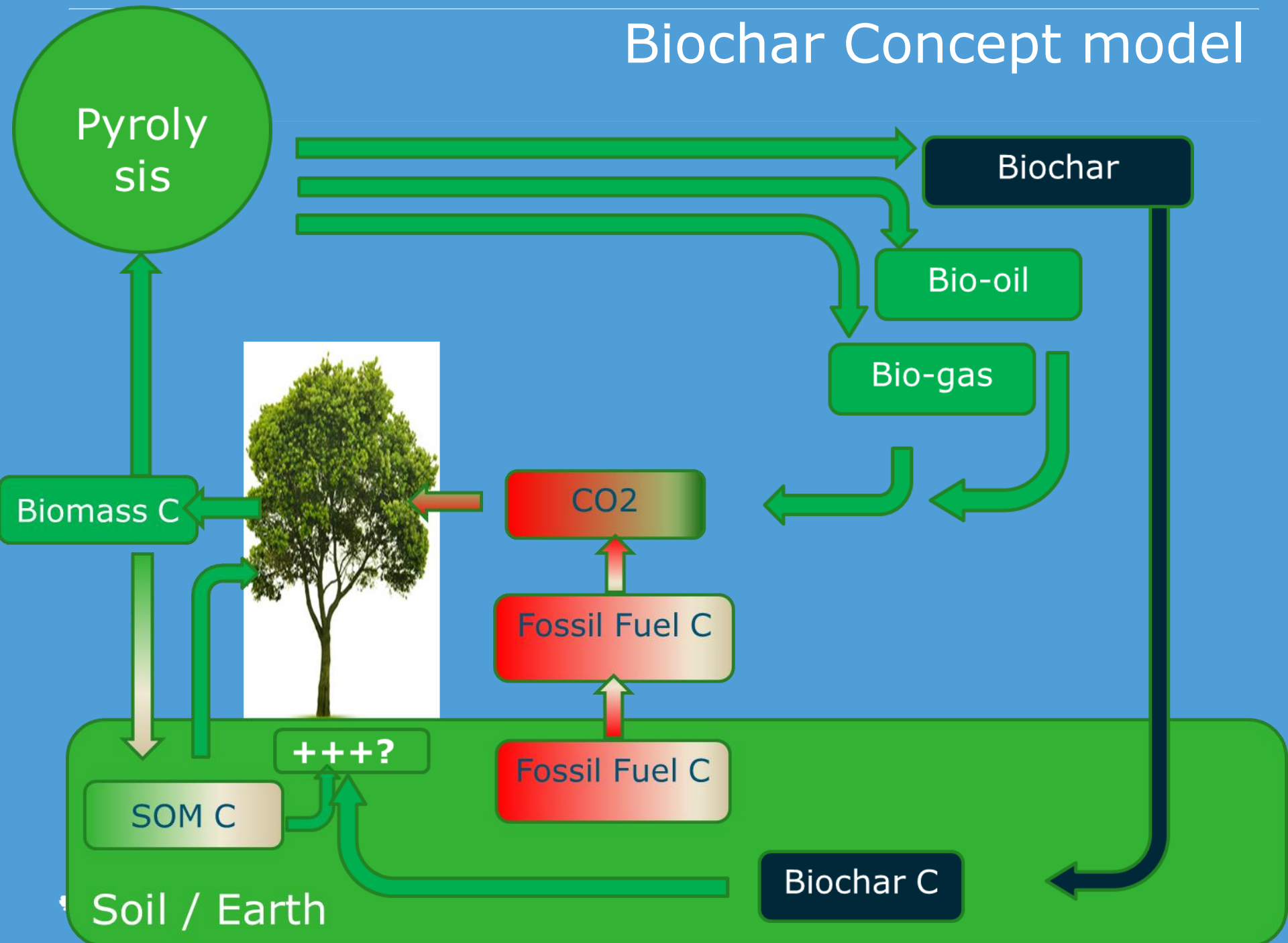
Markus Roedger, Biochar Climate Saving Soils

GHG mitigation concept of biochar

Current situation



Biochar Concept model



Trade offs / Considerations

Biochar for climate mitigation?

- Which are the important questions to be addressed?

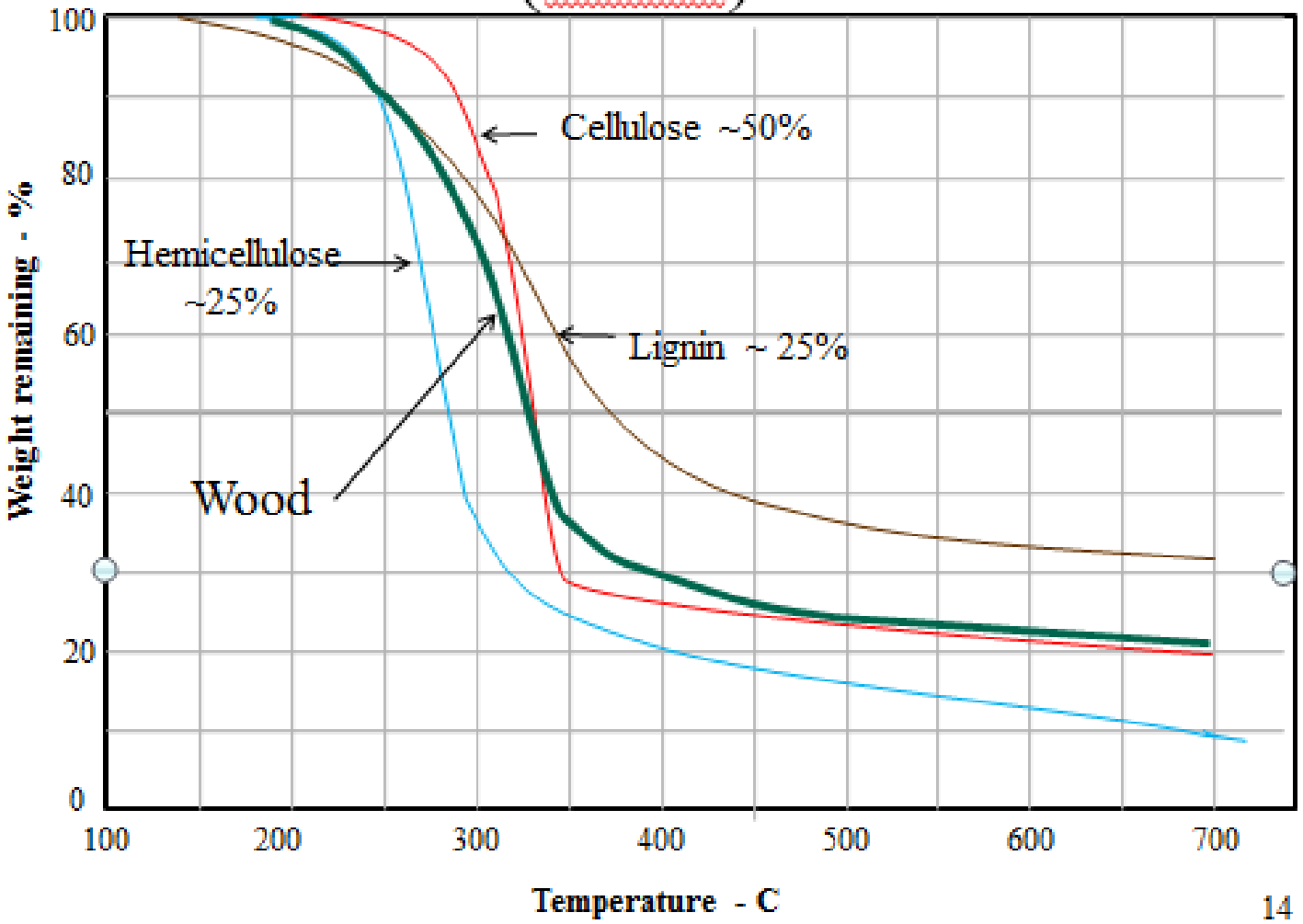
Trade offs / Considerations

- Biochar stability > 100 years?
- Is biochar improving Soil fertility / Soil quality and how?
- Biochar C for energy or for C-sequestration?

Stability of biochar

- Biochar properties

Pyrolysis of Biomass Components (TGA)



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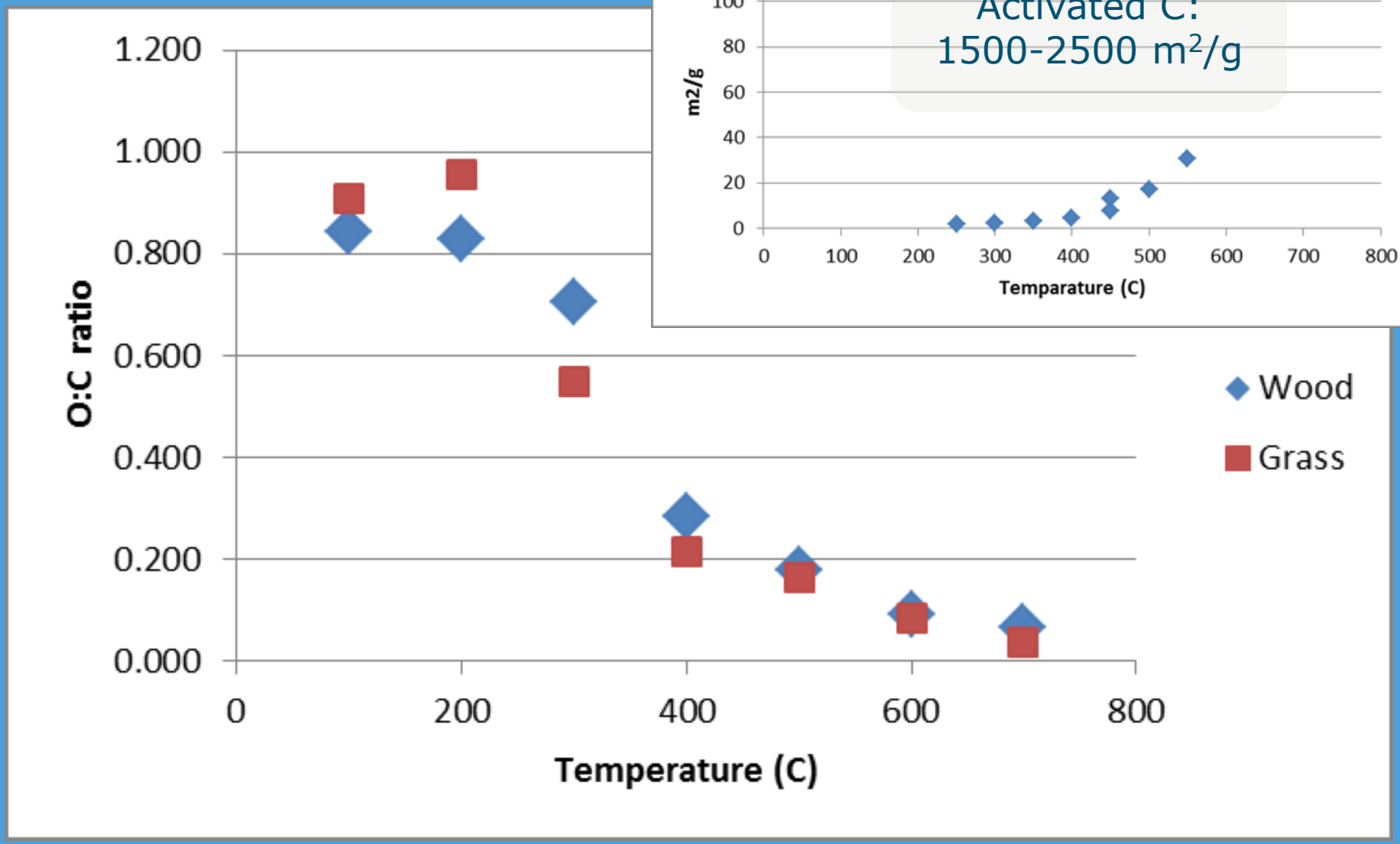
Reed and McLaughlin North American Biochar 2009

Pyrolysis conditions



Activated C:
1500-2500 m^2/g

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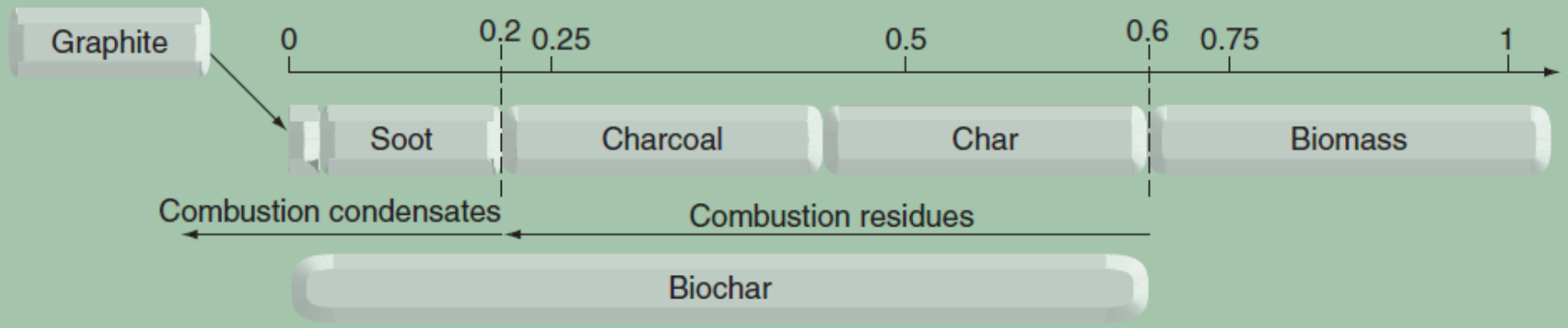
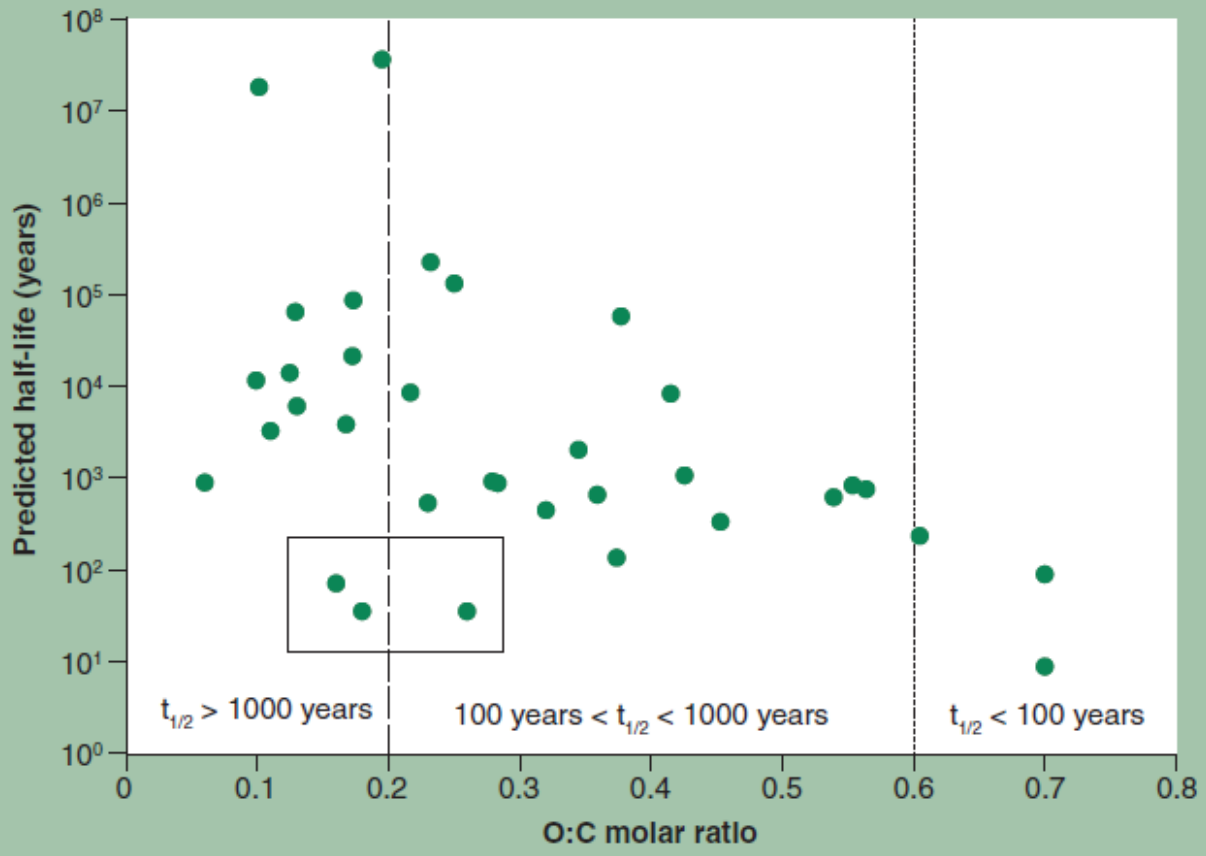
Keiluweit et al, (2010) Environ. Sci. Technol.





Spokas (2010) Carbon Management (2010) 1(2)

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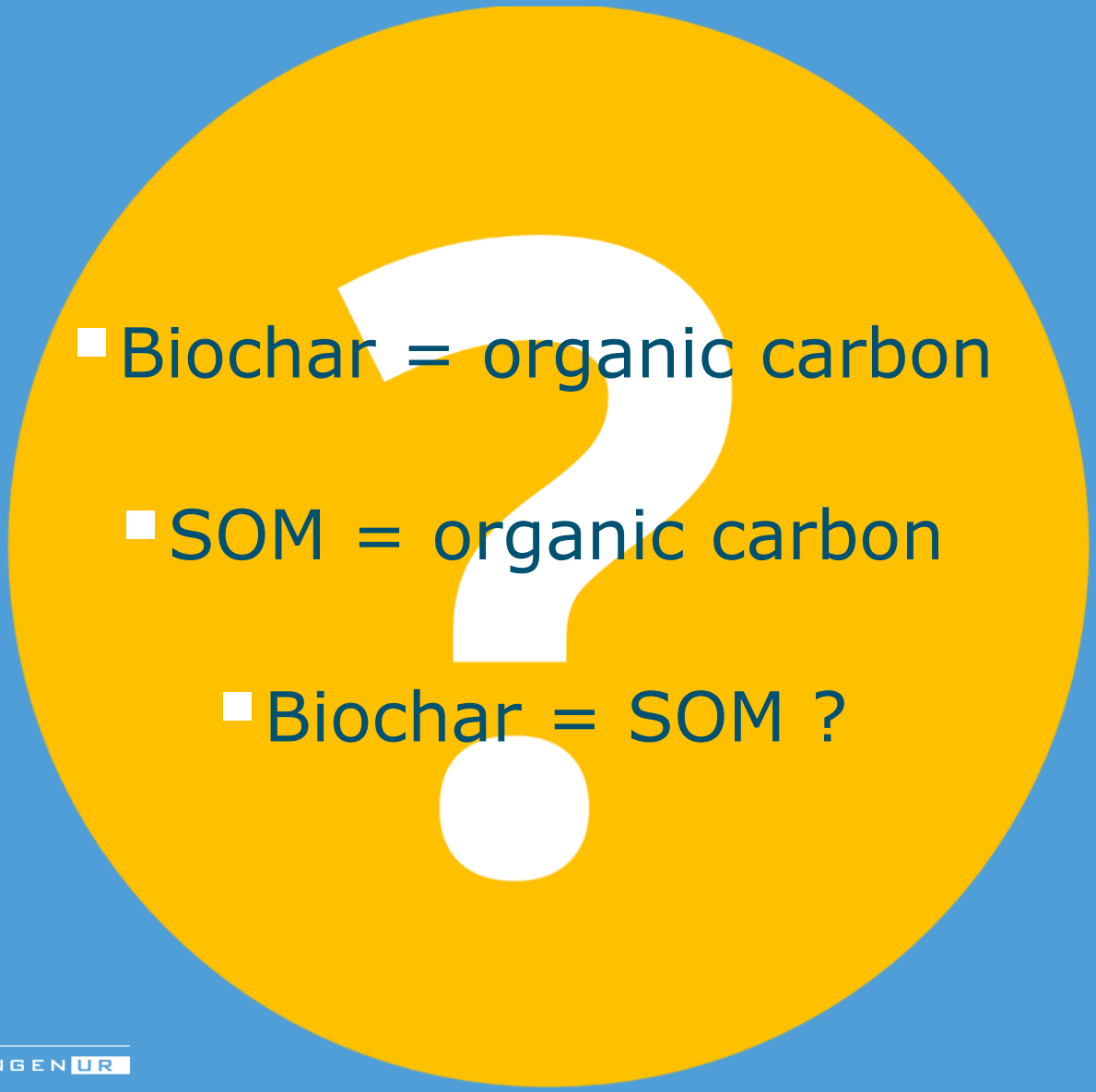
Conclusions stability

- Stable biochar can be produced, fits C-sequestration in soils
- Stability depends on pyrolysis conditions -> biochar composition
- Composition also determines other biochar properties

Role of biochar in soil properties and functions

SOM and BIOCHAR - Algebra



- Biochar = organic carbon
- SOM = organic carbon
- Biochar = SOM ?

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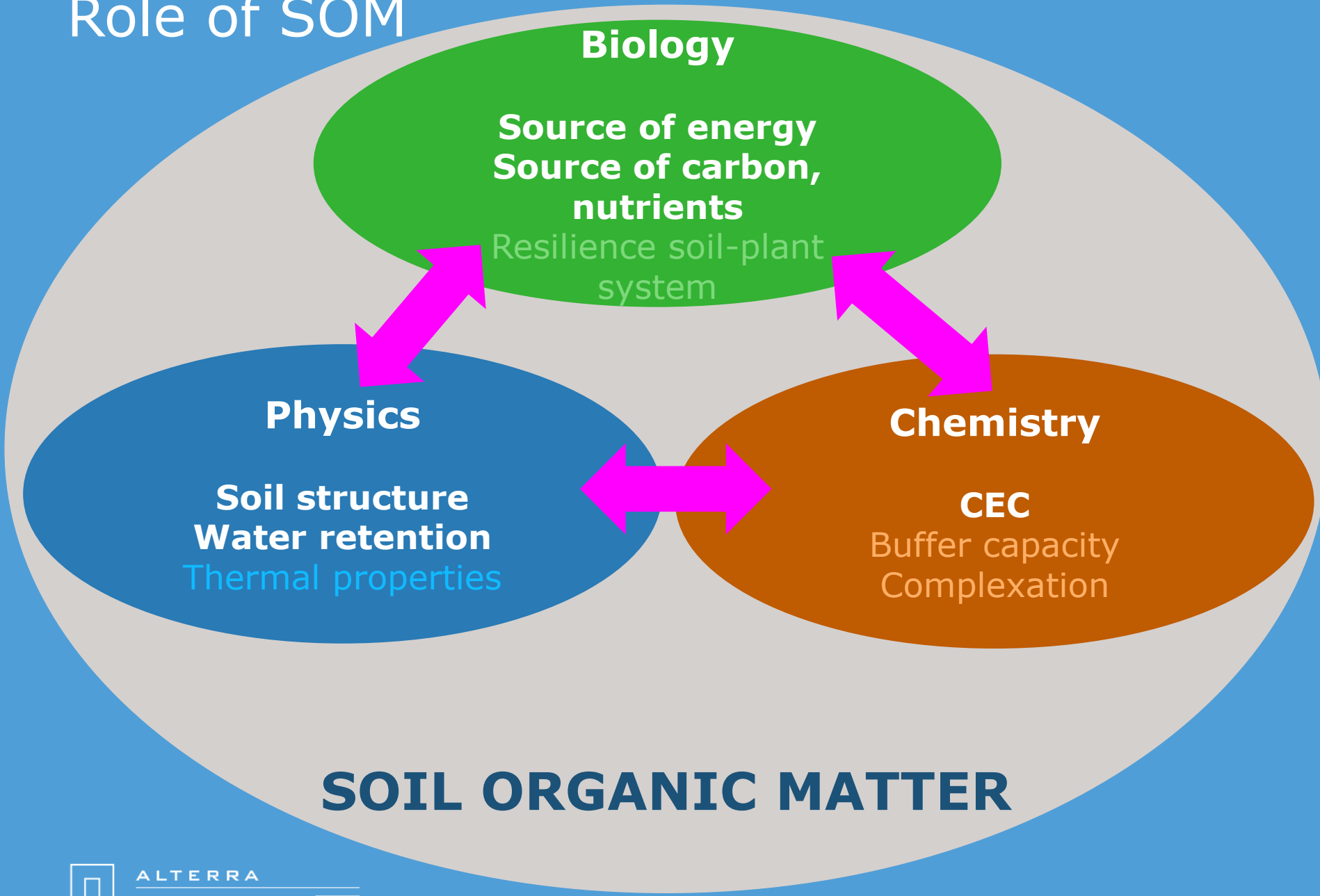
Role of SOM



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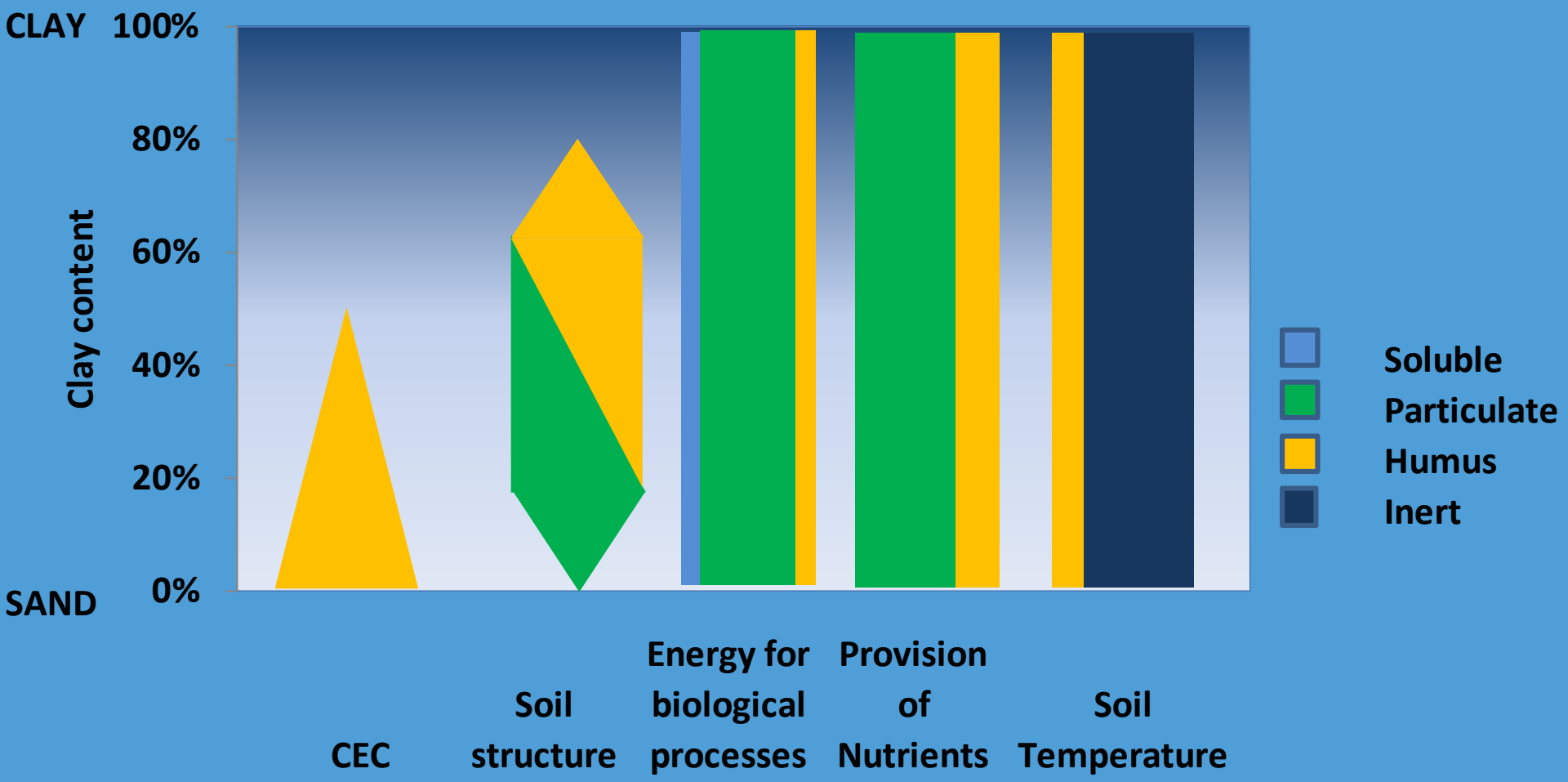
After Baldock and Skjemstad, 1999

Role of SOM in SOIL types

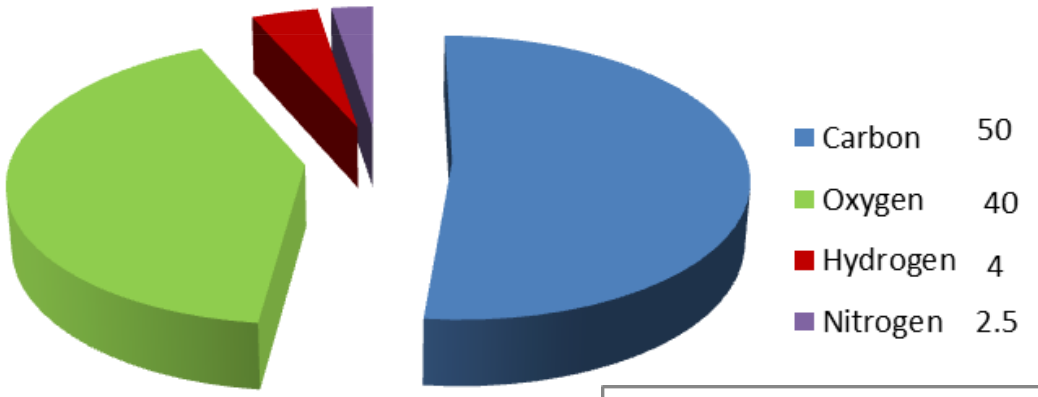


After: http://grdc.com.au/uploads/documents/cso000291.pdf

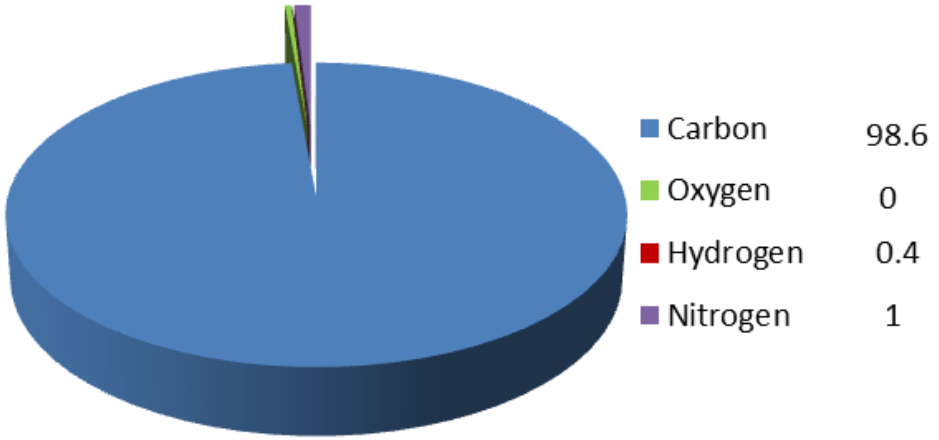
Biochar **Claims** in Soil Properties

- Microbiology, nutrient delivery
- Water retention
- Nutrient buffering (CEC)

Natural Organic Matter



Biochar



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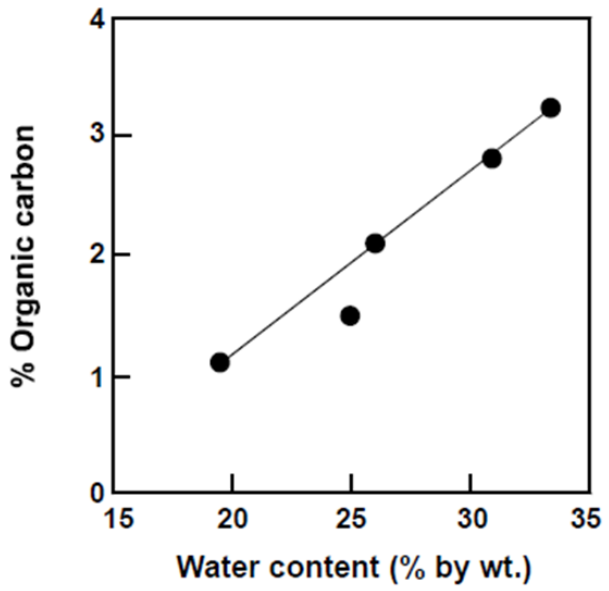
http://www.treepower.org/biochar/main.html

Biochar Carbon = Energy for micro-organisms?

- Thermodynamically: No problem, 30 GJ/t
- Enzymatically: ??, especially at low O:C ratio's
- CO_2 evolution: Low in soil incubations

Relation SOM-plant available water (pF 2-4.2)



SOM %	Plant available water mm
2	50
4	66
5	70
6	75
8	81
10	86

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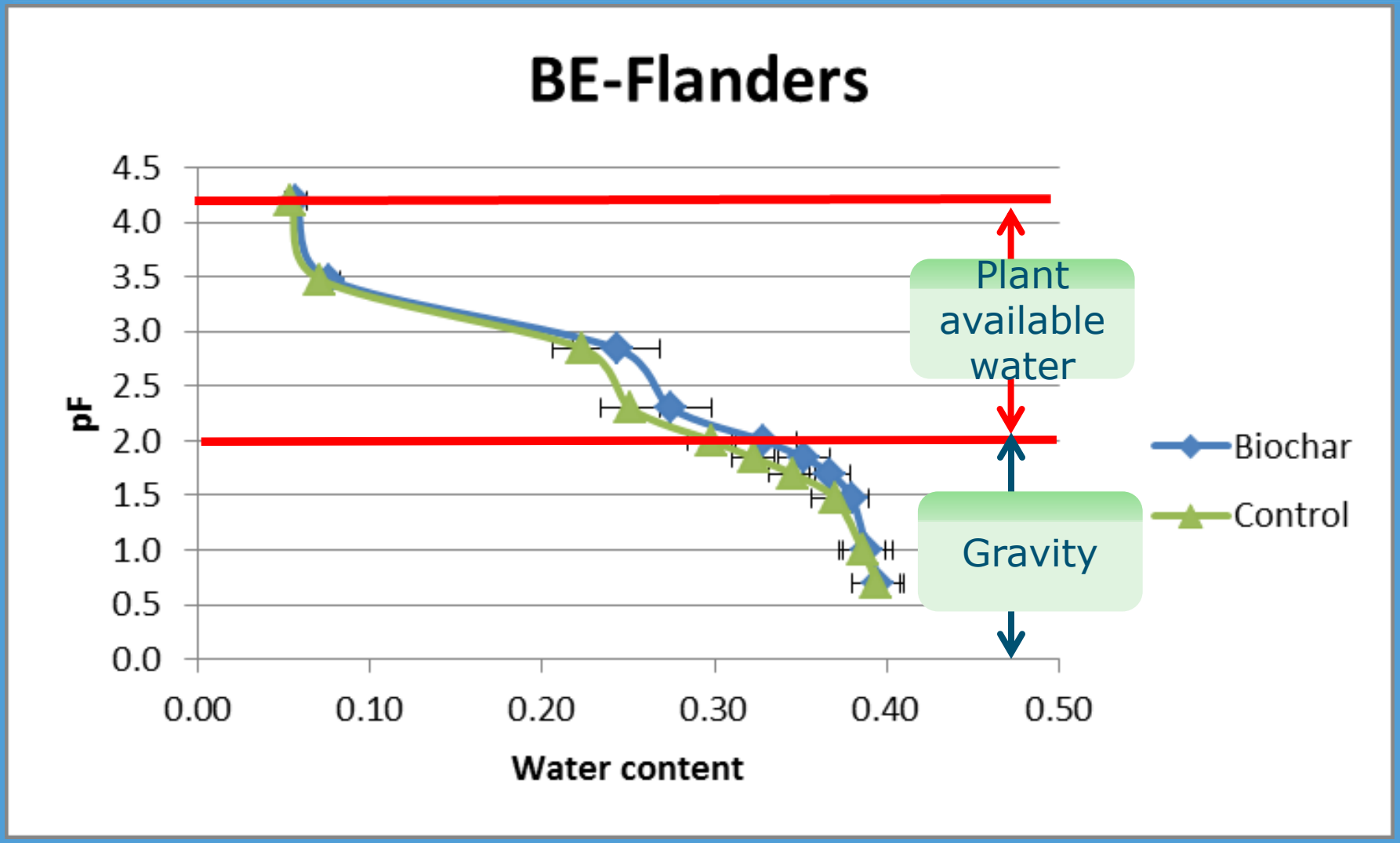
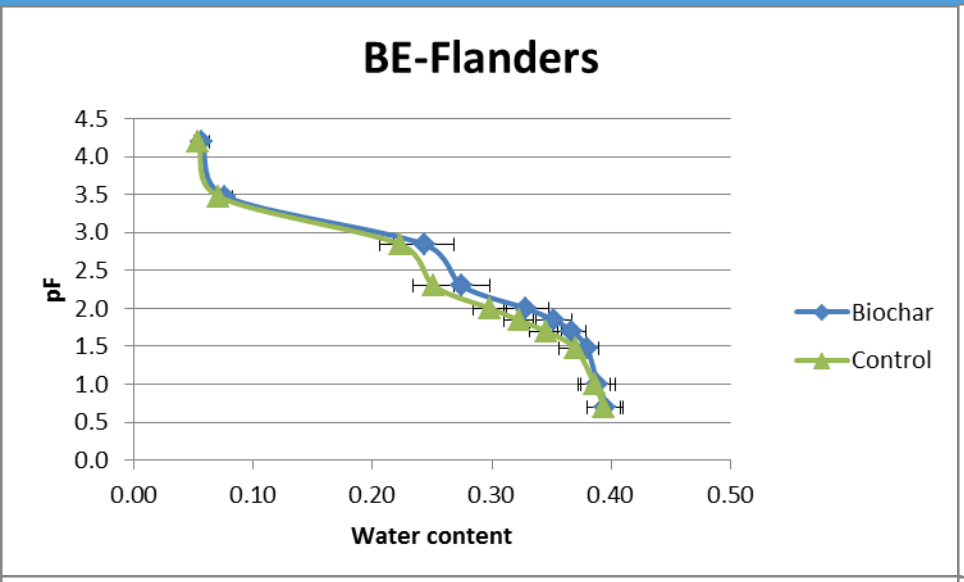
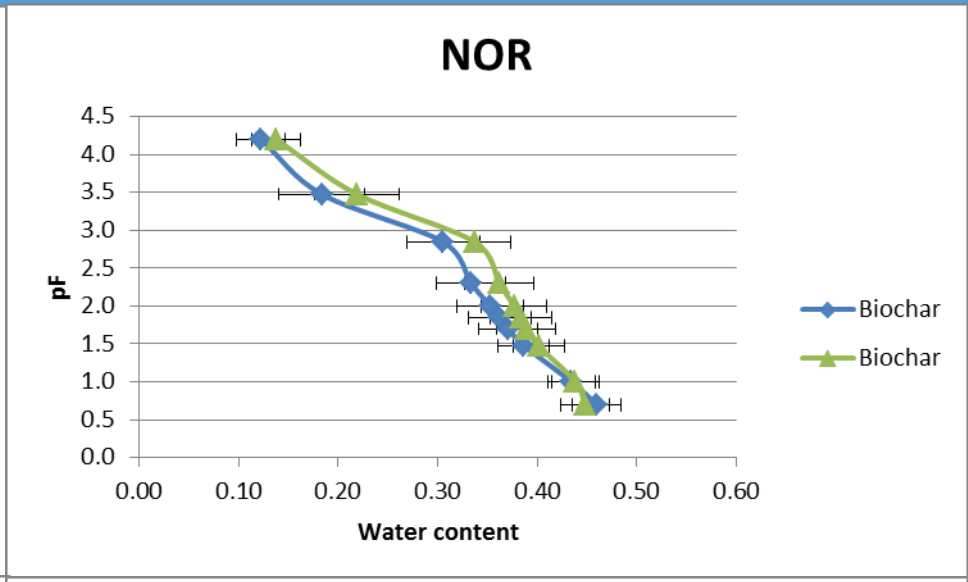
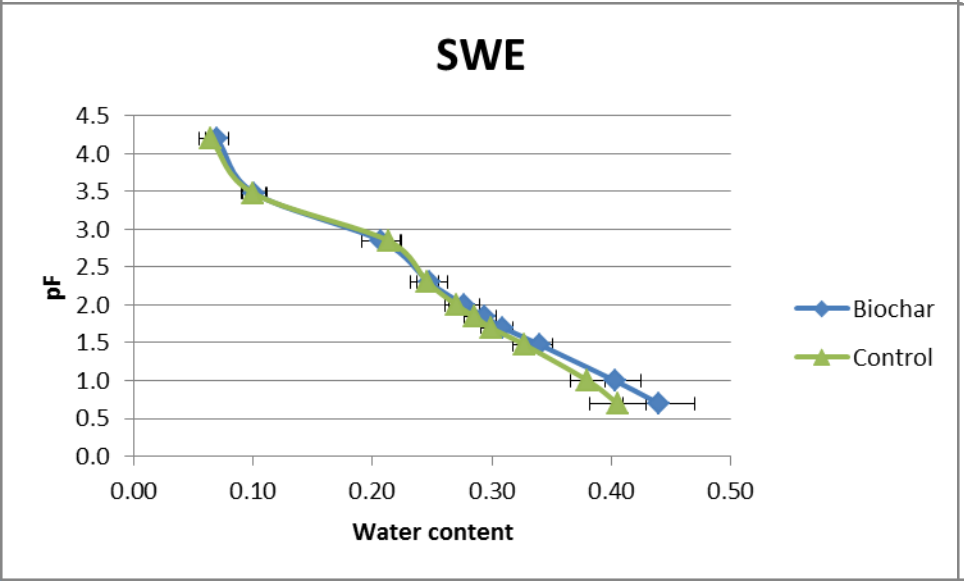
Water retention

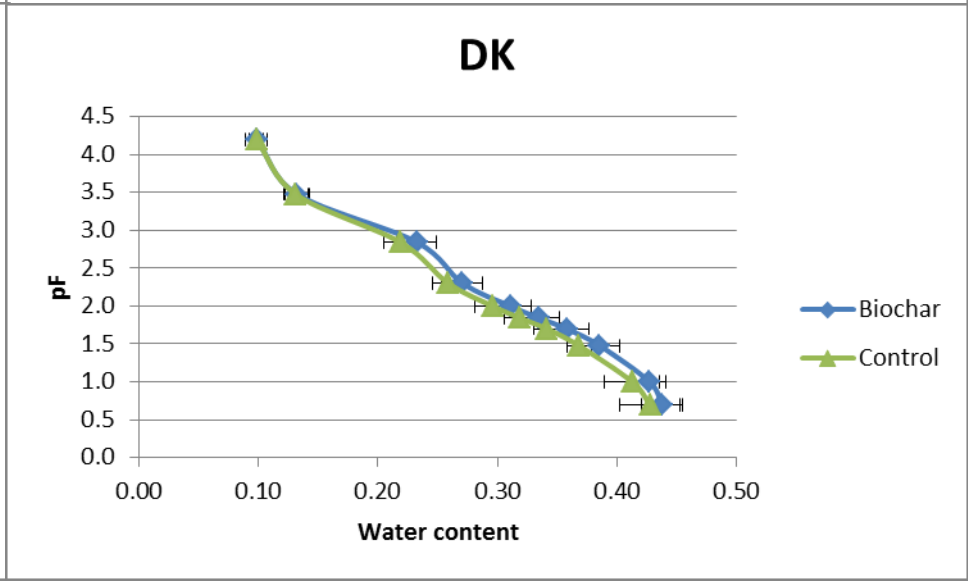


Water retention Interreg Biochar Project

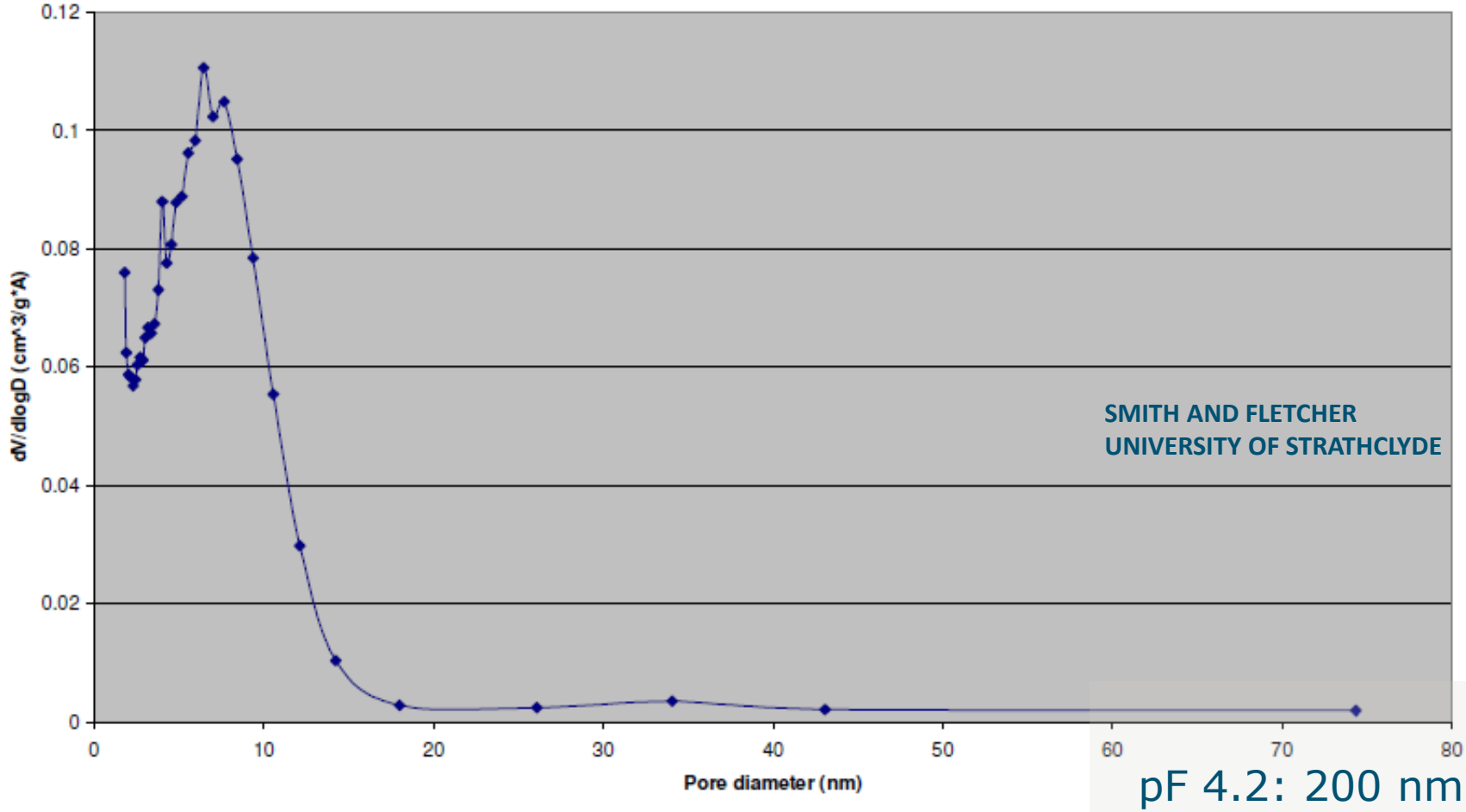








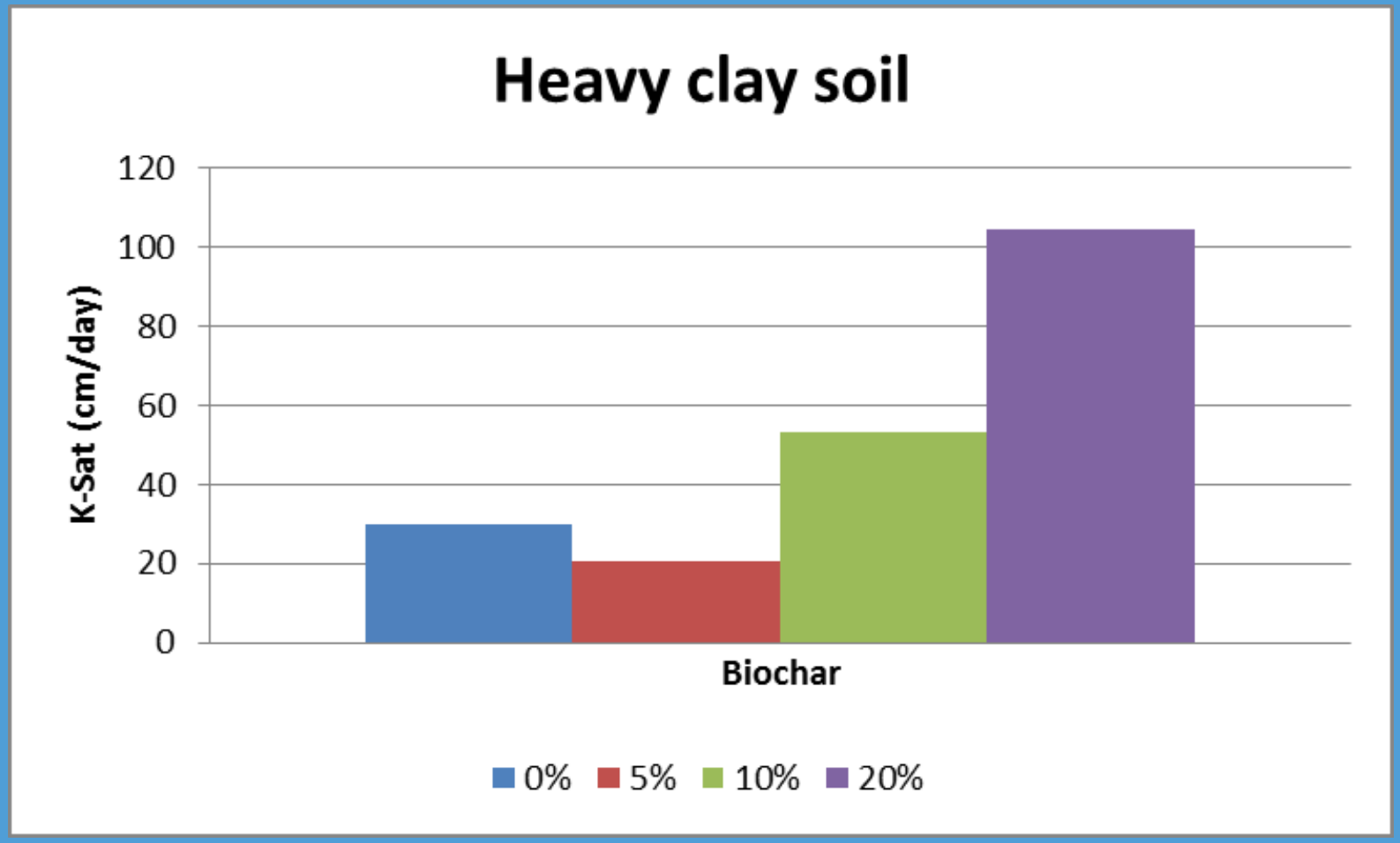
Pore size distribution



pF 4.2: 200 nm

FIGURE 2.4: PORE SIZE DISTRIBUTION FOR COARSE CHAR

Water infiltration Interreg Biochar Project



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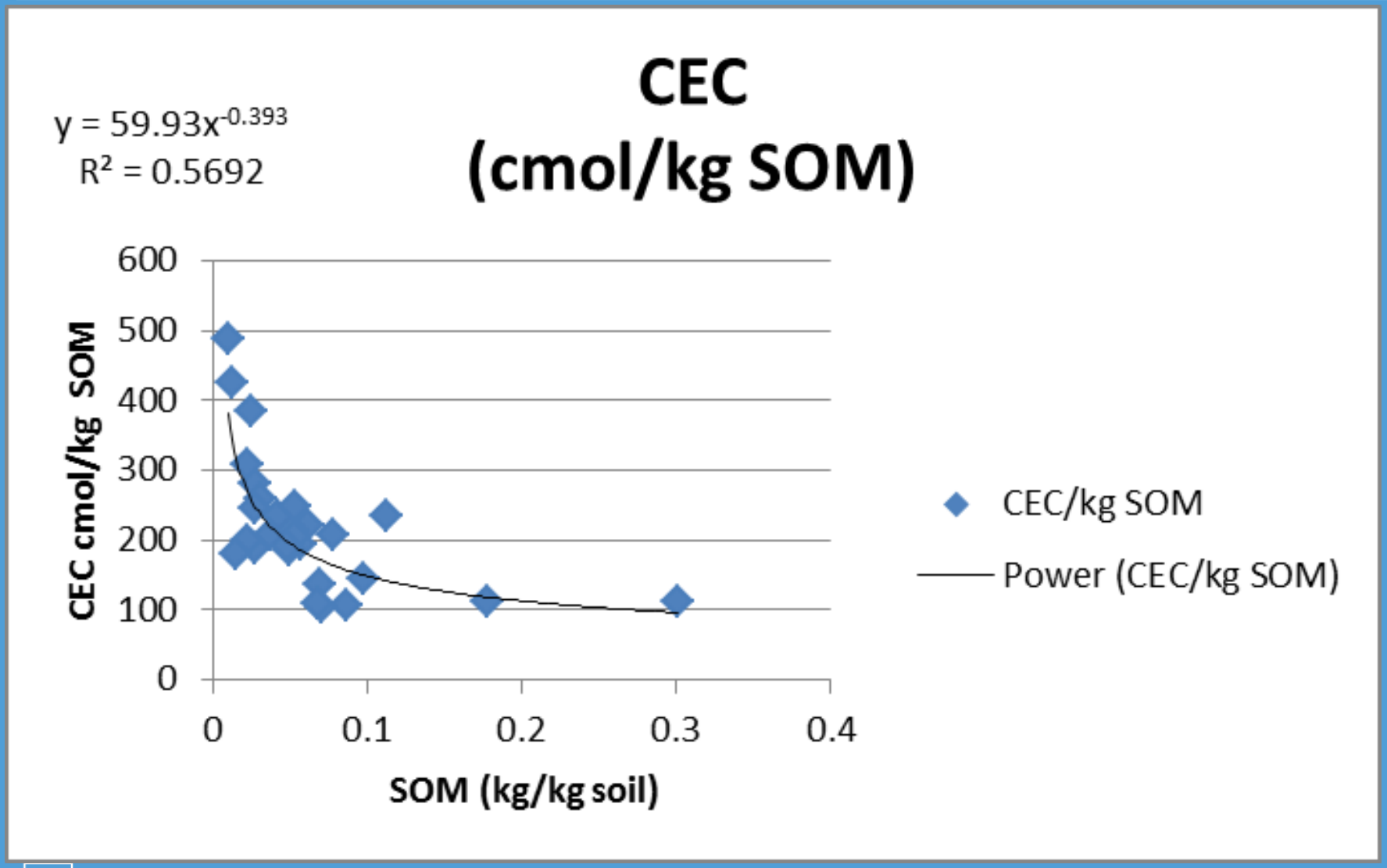
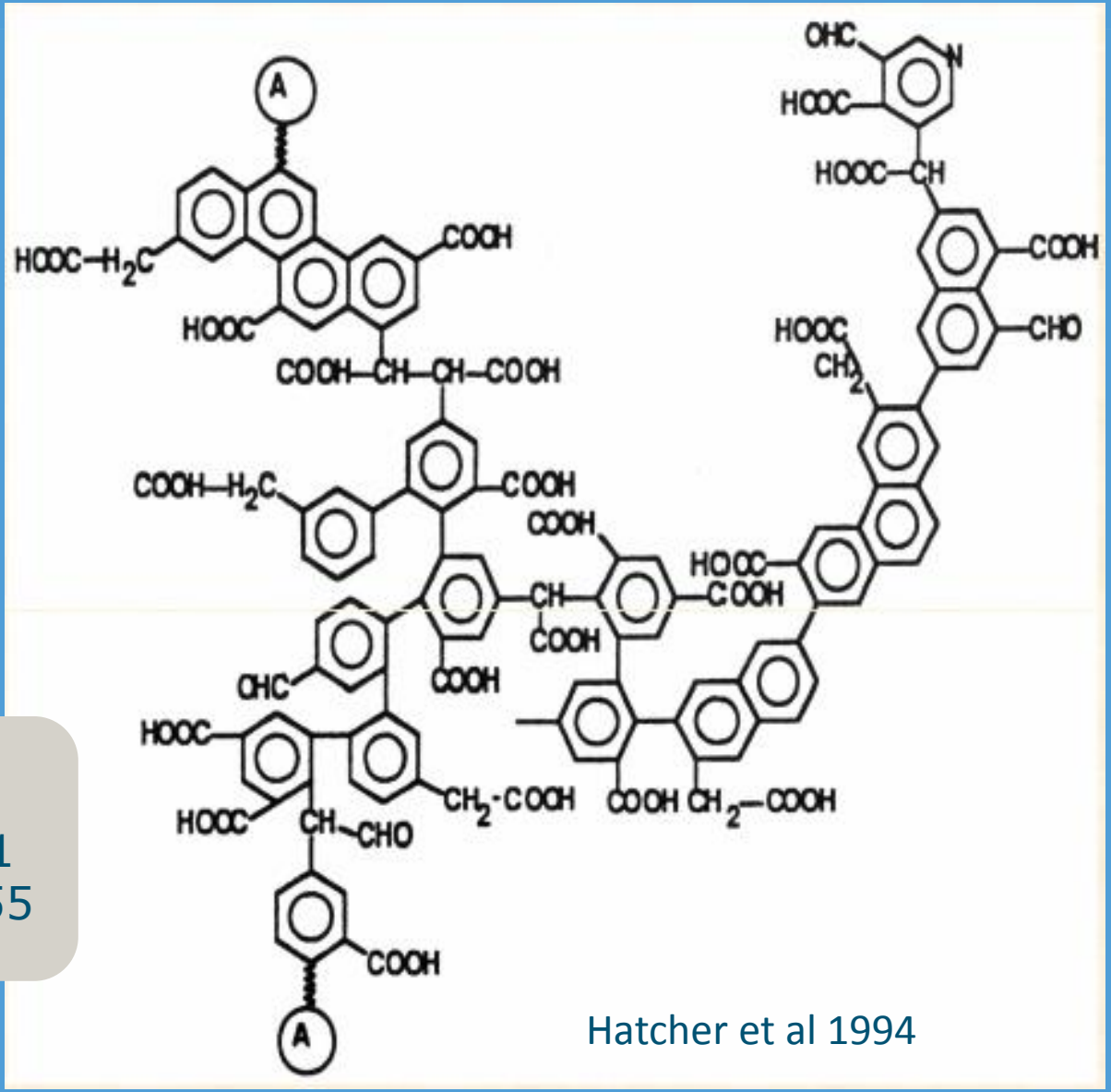
CEC reclaimed peat soils

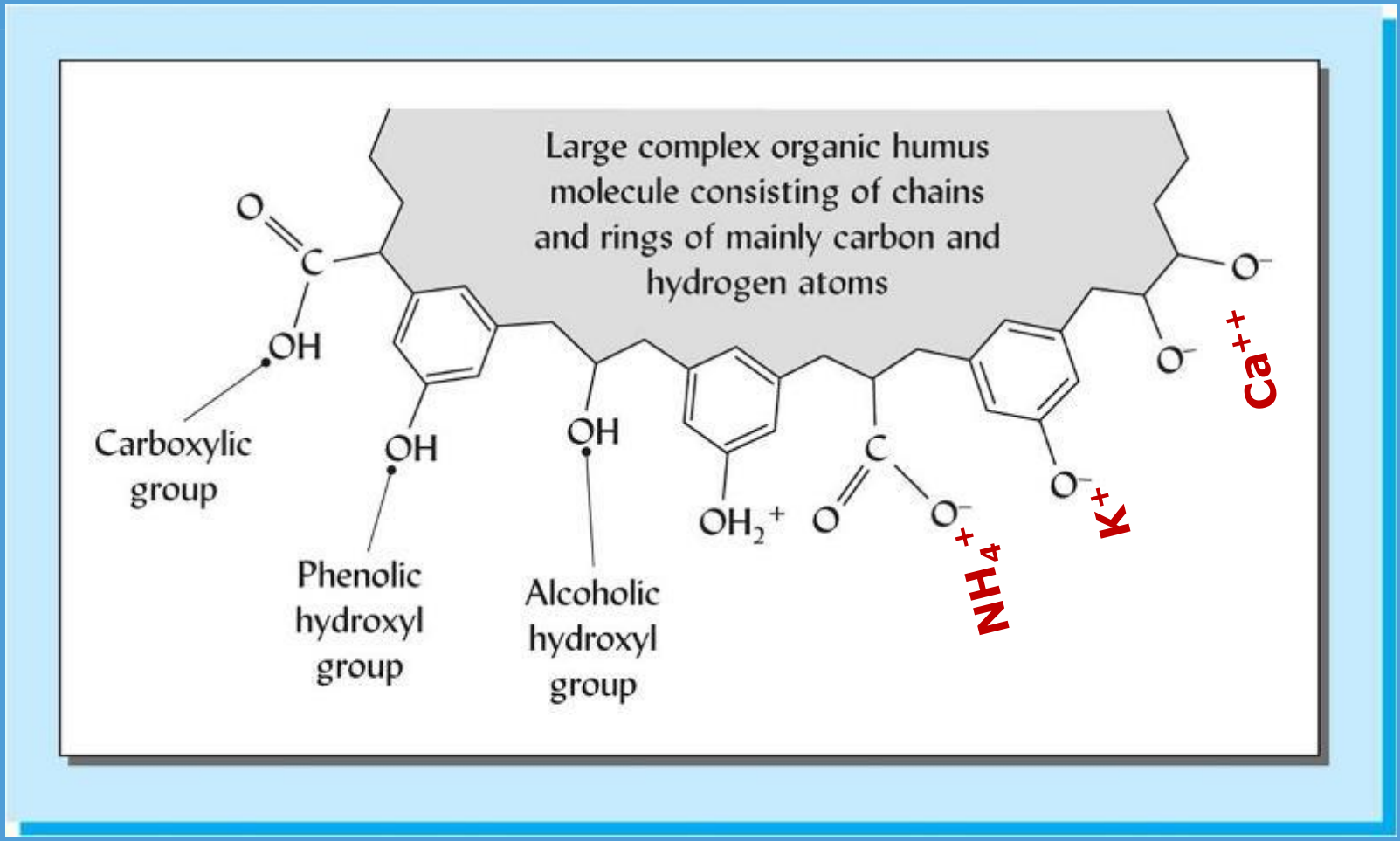


Humic Acid structure



Hatcher et al 1994

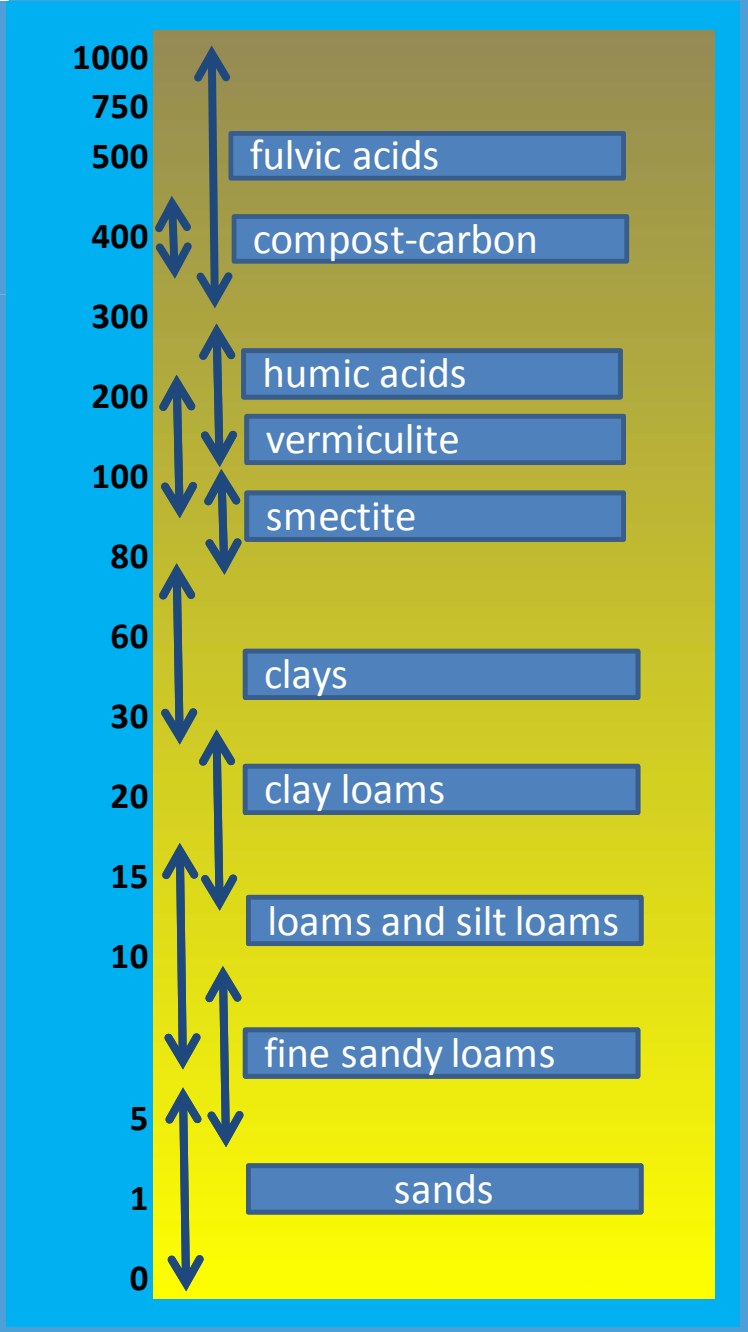
C:O
Fulvic acids: 1
Humic acids : 0.55

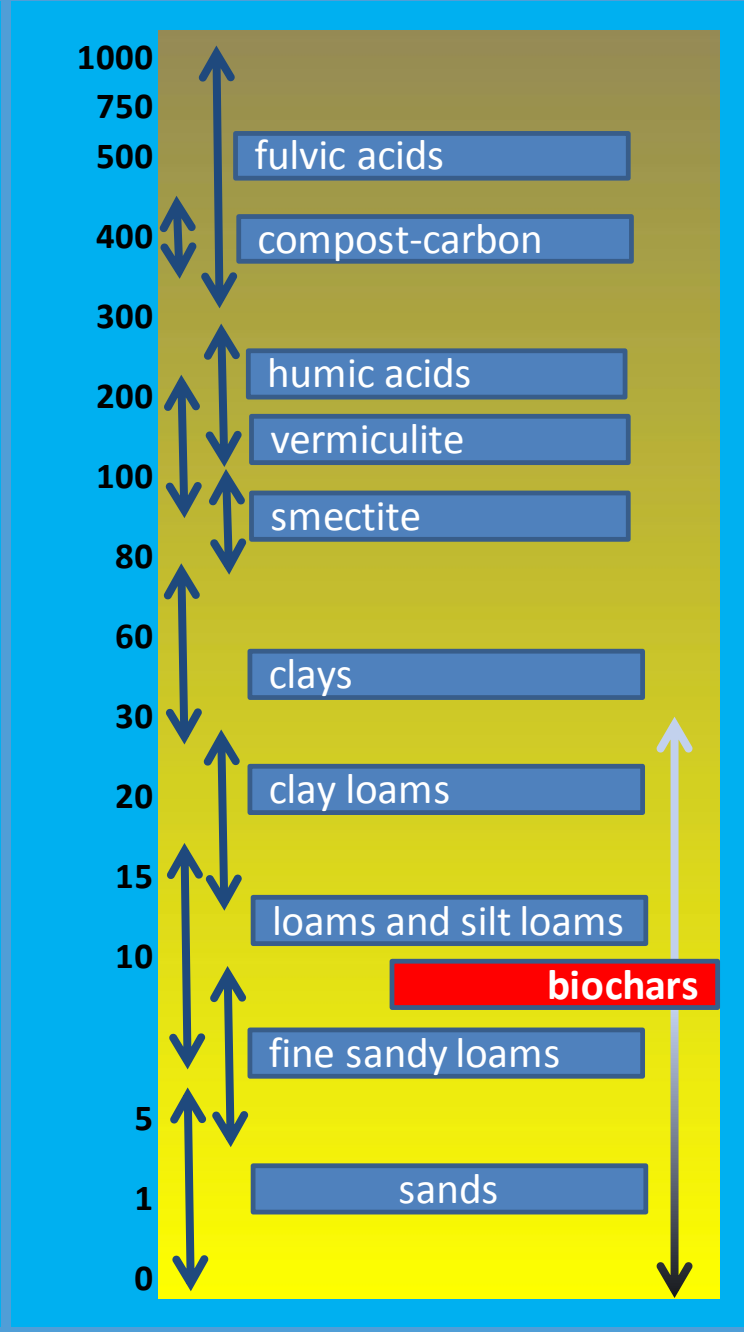


NO_3^- NO_3^-

NH_4^+ K^+ Ca^{++}

CEC (cmol/kg)


1000
750
500
400
300
200
100
80
60
30
20
15
10
5
1
0
fulvic acids
compost-carbon
humic acids
vermiculite
smectite
clays
clay loams
loams and silt loams
fine sandy loams
sands


1000
750
500
400
300
200
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30
20
15
10
5
1
0
fulvic acids
compost-carbon
humic acids
vermiculite
smectite
clays
clay loams
loams and silt loams
biochars
fine sandy loams
sands

Biochar Evidence in Soil Properties

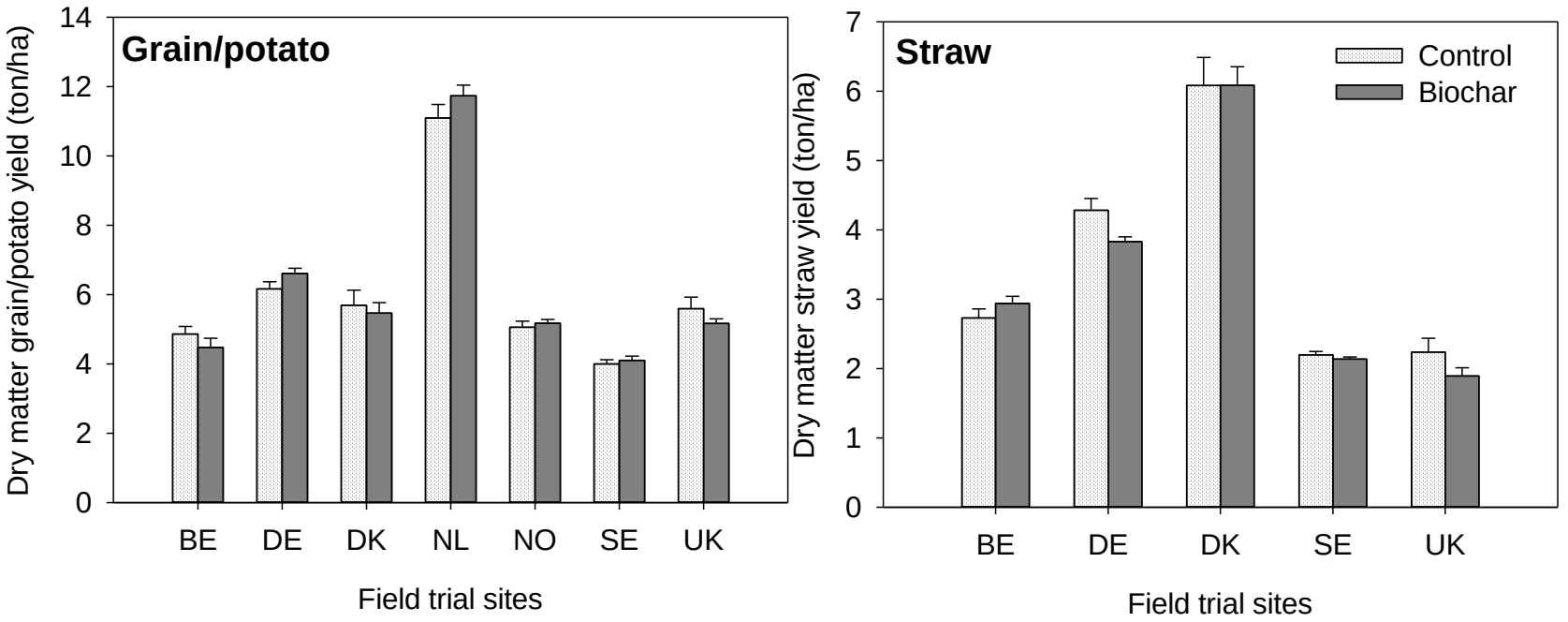
- Microbiology, nutrient delivery
- Water retention
- Nutrient buffering (CEC)

Modification of Biochar

- Activation (?)
- Adsorption of SOM
- Biological modification (?)
- Chemical modification
    - Functional groups CEC
    - Functional groups AEC (NR_4^+)

1. Biochar North Sea ring trial

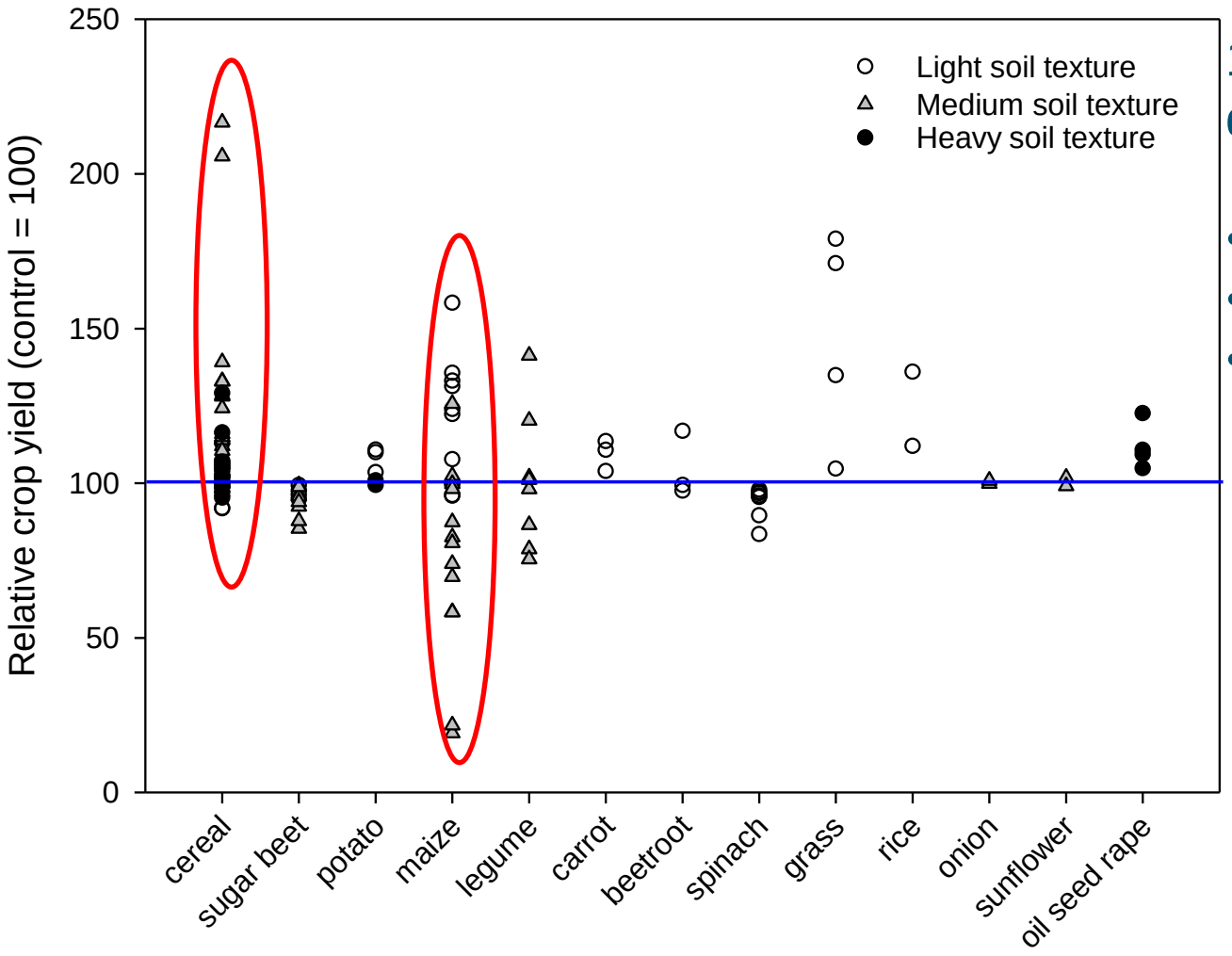
2013 crop yield



=> No significant differences

ILVO Instituut voor Landbouw- en Visserijonderzoek
RA NING
The Interreg IVB North Sea Region Programme
European Union
The European Regional Development Fund
BIO CHAR

3. European biochar field experiments



127 site - biochar type – dose – year combinations

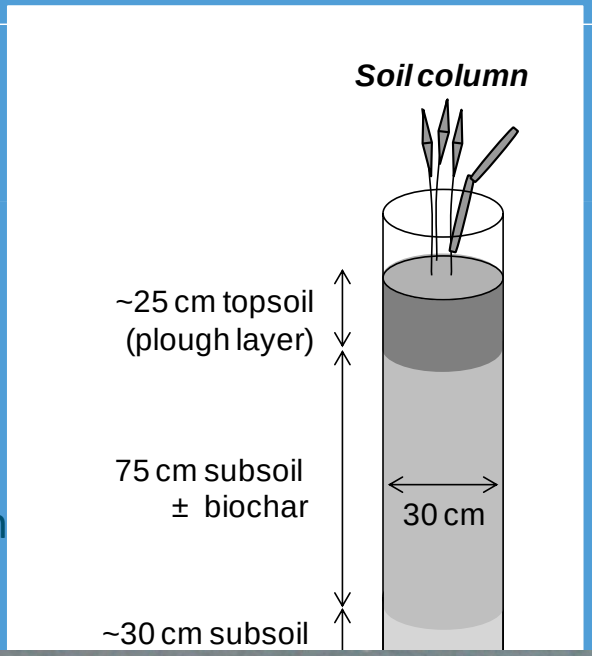
- 75% not significant
- 17% positive effect
- 9% negative effect

Principal study: Root growth of common bean in a sandy subsoil with increasing

Emilie M. Ø. Hansen, BSc project; KU Science 2010-11

The experiment

- Spring Barley, 18 columns, six subsoil treatments (n=3)
- Water and nutrient (~200 kg N ha^{-1}) supply in excess

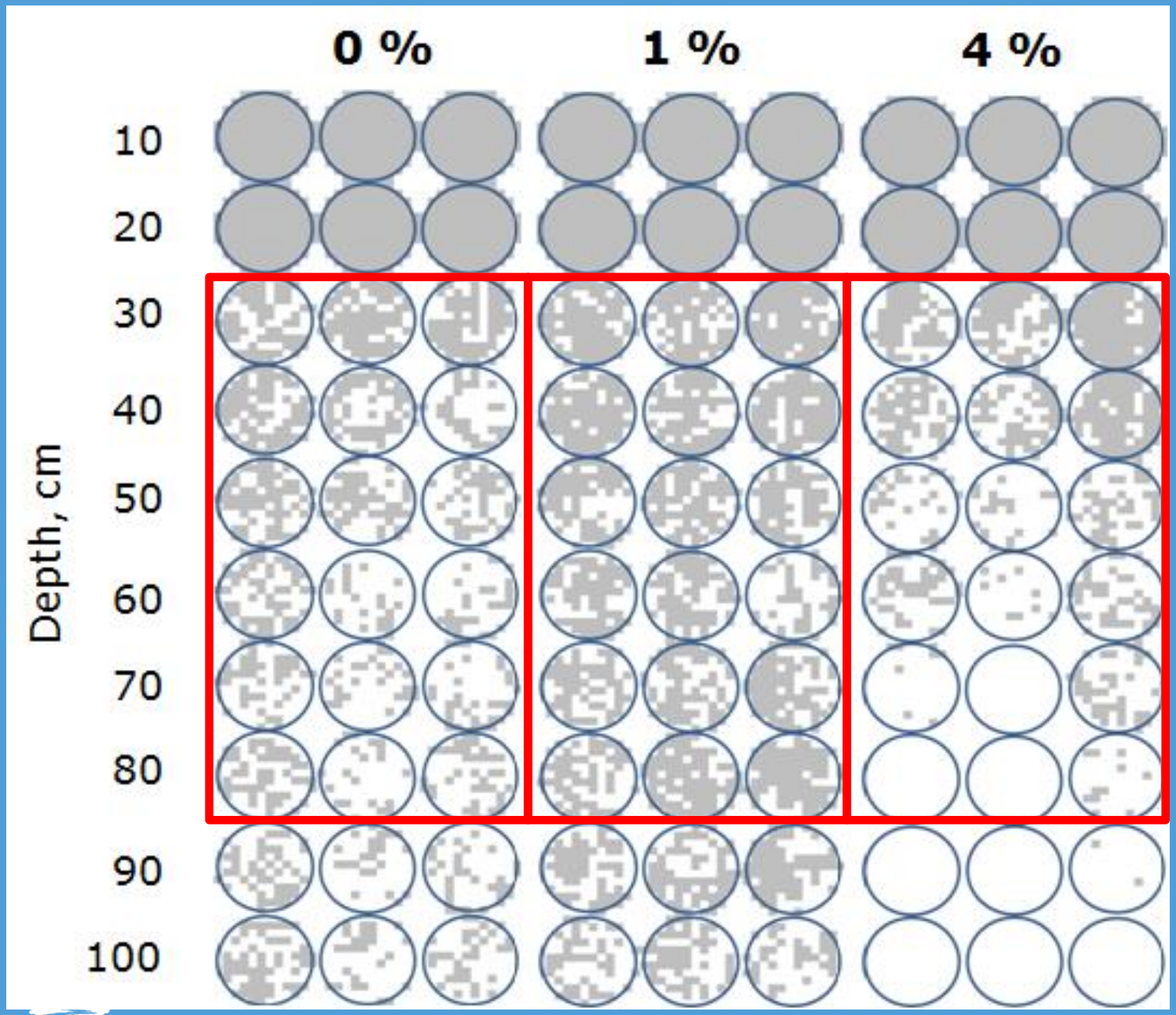


Subsoil treatments :

(25-100 cm, n=3)

O % (Control) **½ %** **1 %** **2 %** **4 %** **2 %** (Wood-biochar)

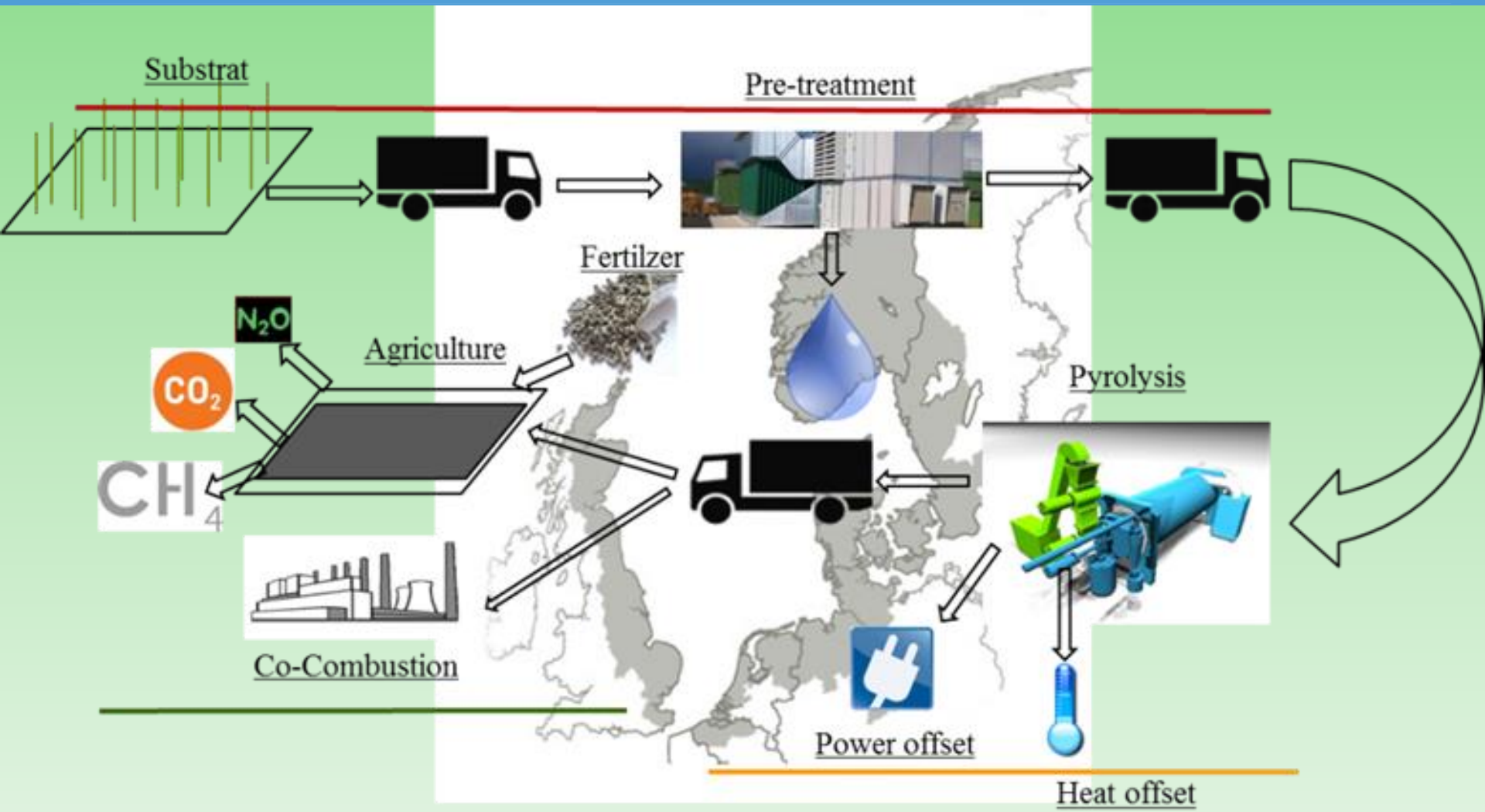
Straw-biochar incorporation



Root coverage at different depths

Energy or C-sequestration?

LCA

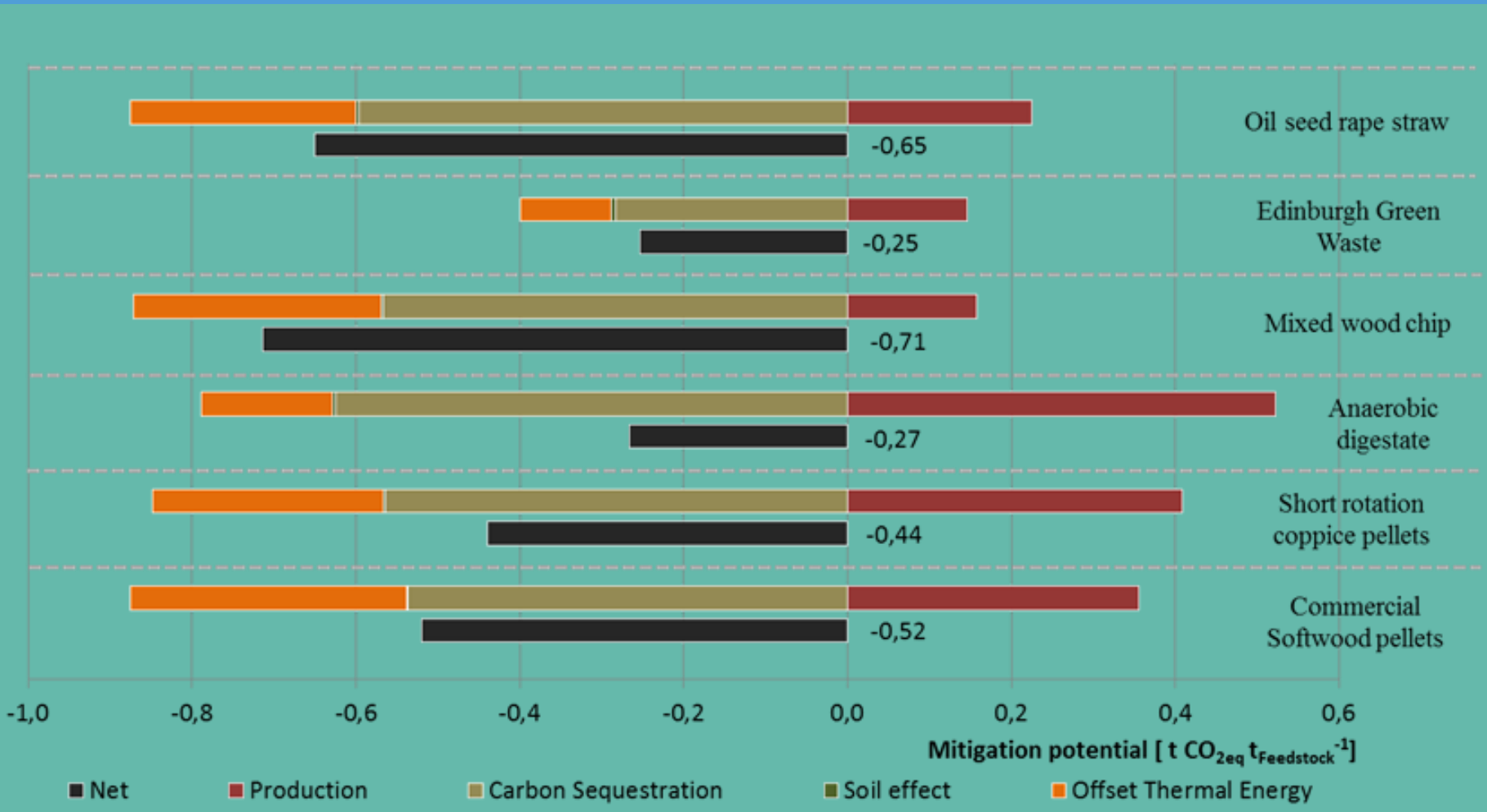

Substrat
Pre-treatment
Fertilzer
N_2O
Agriculture
CO_2
CH_4
Pyrolysis
Co-Combustion
Power offset
Heat offset

Biochar energy content MJ/kg^{-1}

	Pyrolysis	Commercial Softwood Pellets	Anaerobic Digestate	Mixed Wood Chip	Green Waste
Biochar	HHV	33.6	16.9	32.2	8
Liquid	HHV	12.8	10.9	13	13.8
Syngas	HHV	15.3	11.3	13.3	11.5

Markus Roedger, Biochar Climate Saving Soils

LCA results



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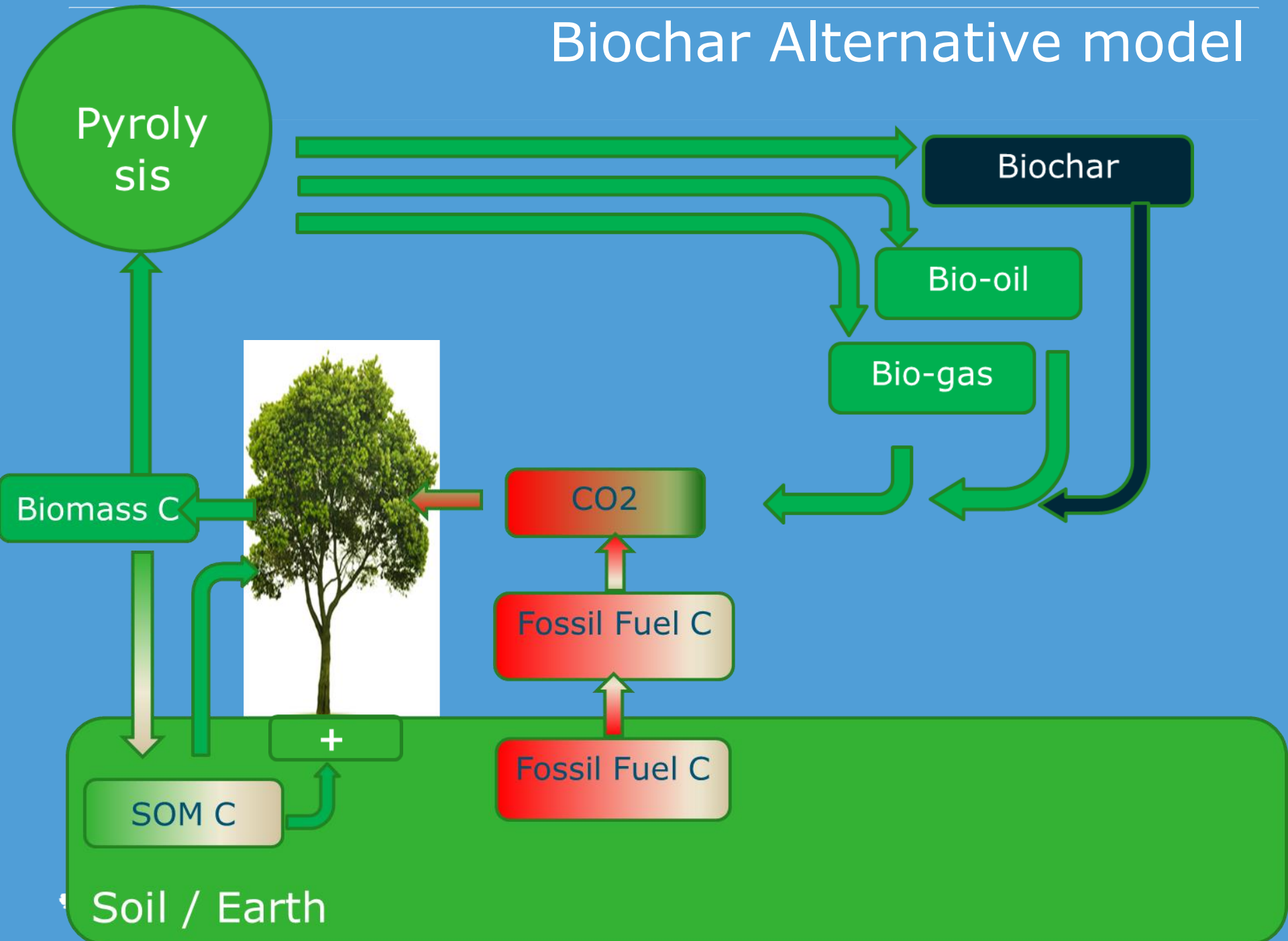
Conclusions

- Biochar can be used to sequester short cyclic C in the soil
- Biochar is rather different from SOM
- Application of biochar in agriculture? Not Yet

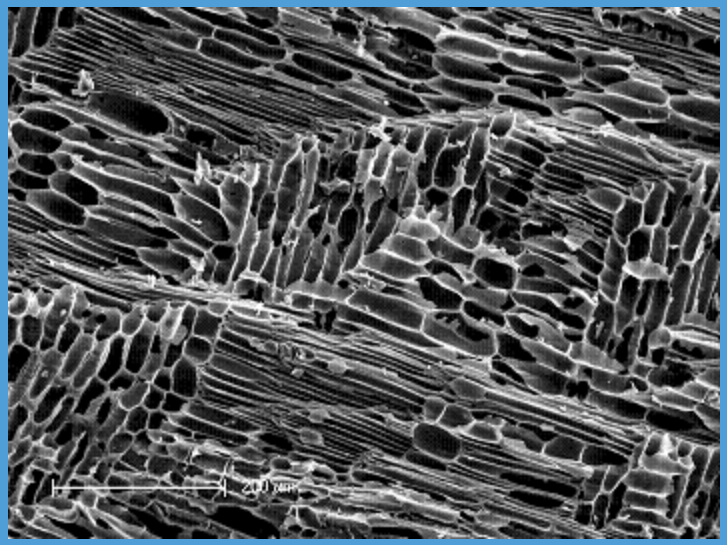
- Energy or C-sequestration?

Biochar Alternative model



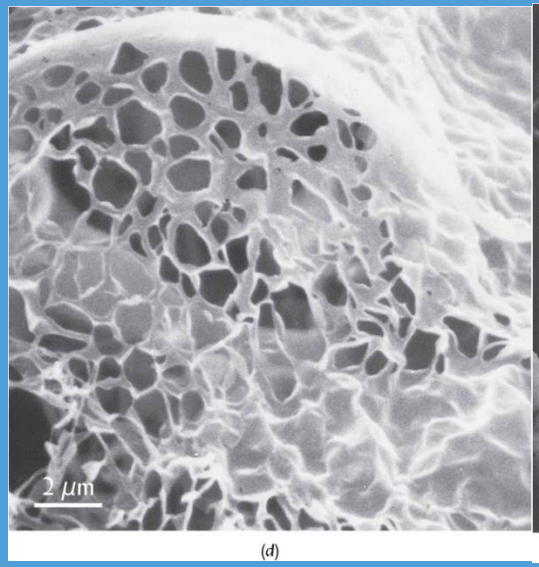
Biochar Refuge for micro-organisms ?

Biochar

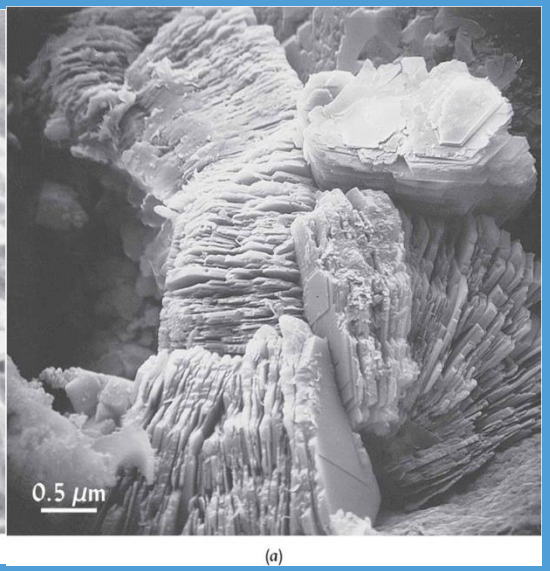


Sohi et al (2009)

Humic acid



Clay



faculty.yc.edu/ycfaculty/ags105/week08/soil_colloids/soil_colloids_print.html

Hydrophobic interaction Fluidized bed reactor

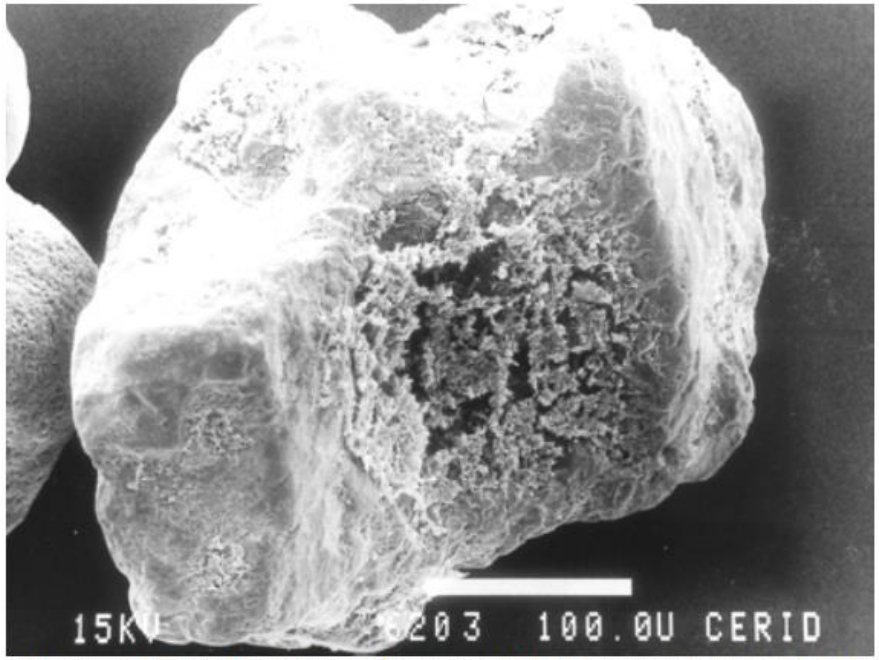


Figure 4. Representative sand particle partially covered with an anaerobic biofilm of thin thickness.

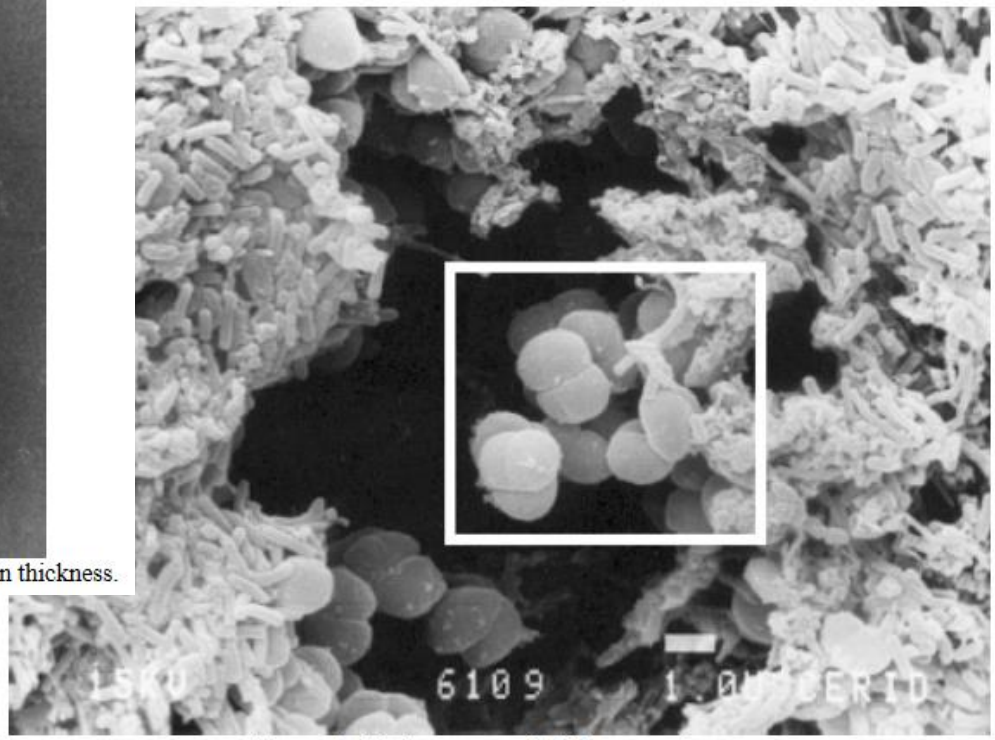
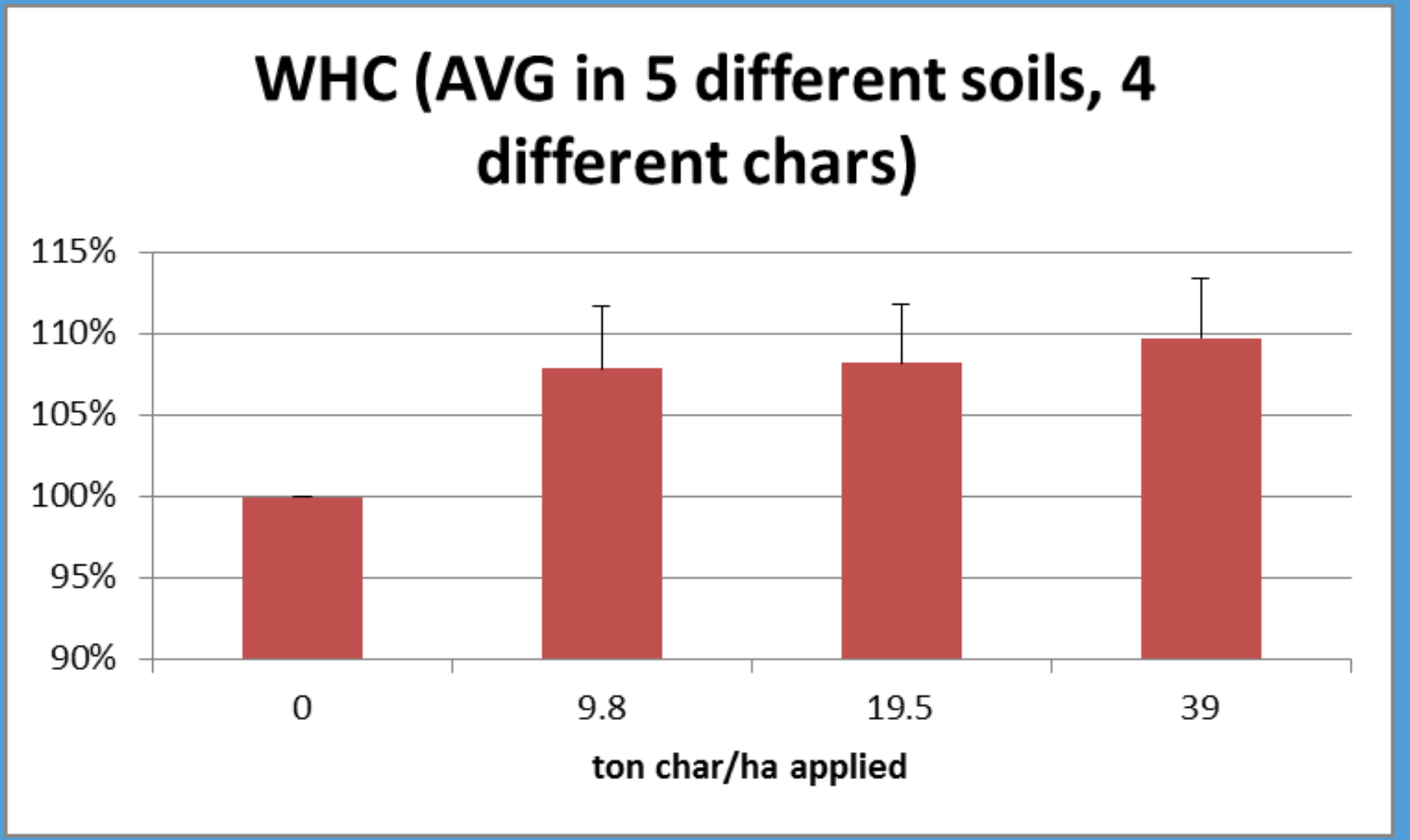


Figure 3. Methanogens: *Methanosarcina sp*

Mussati et al, 2005

WHC effect biochar



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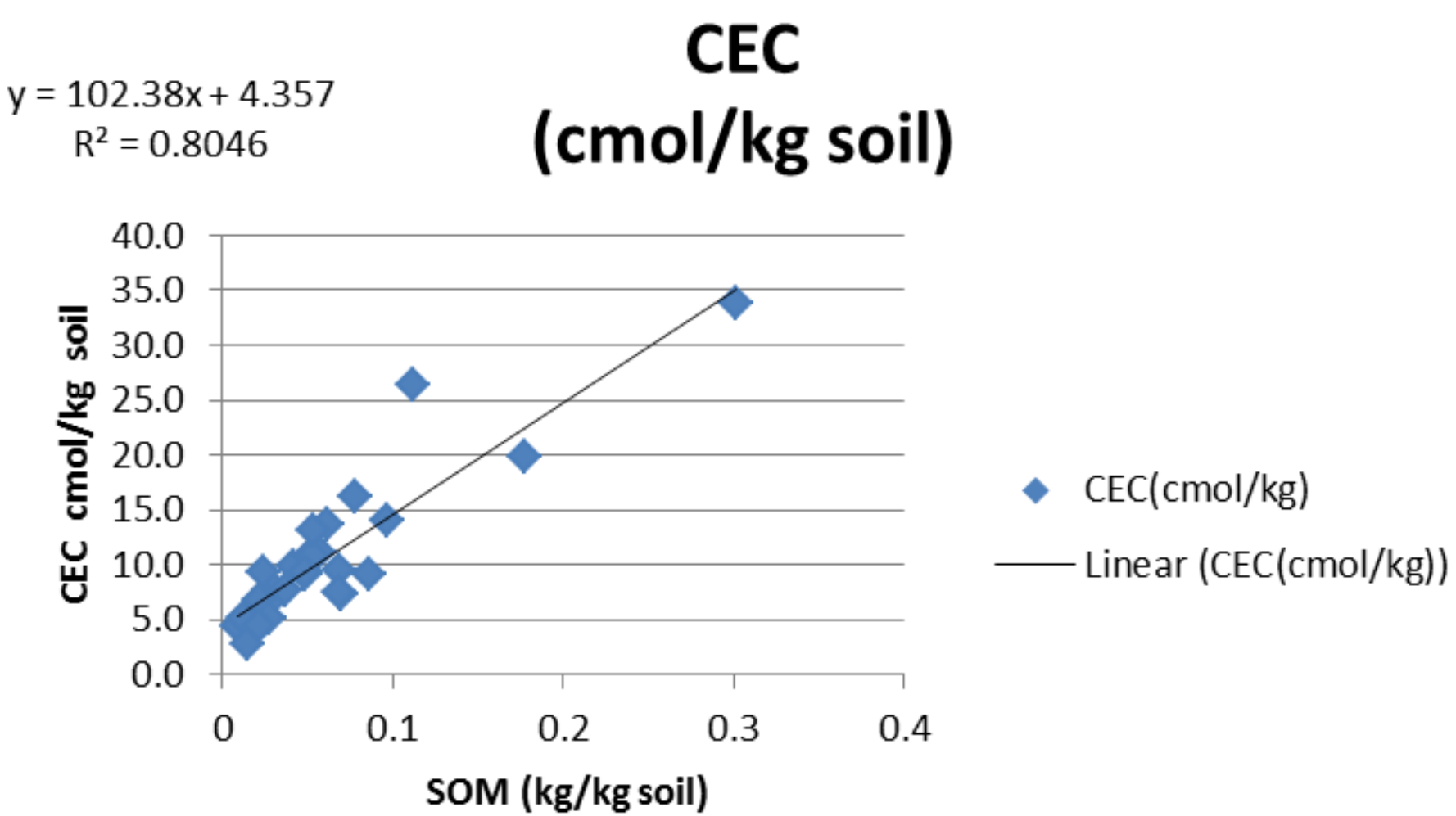
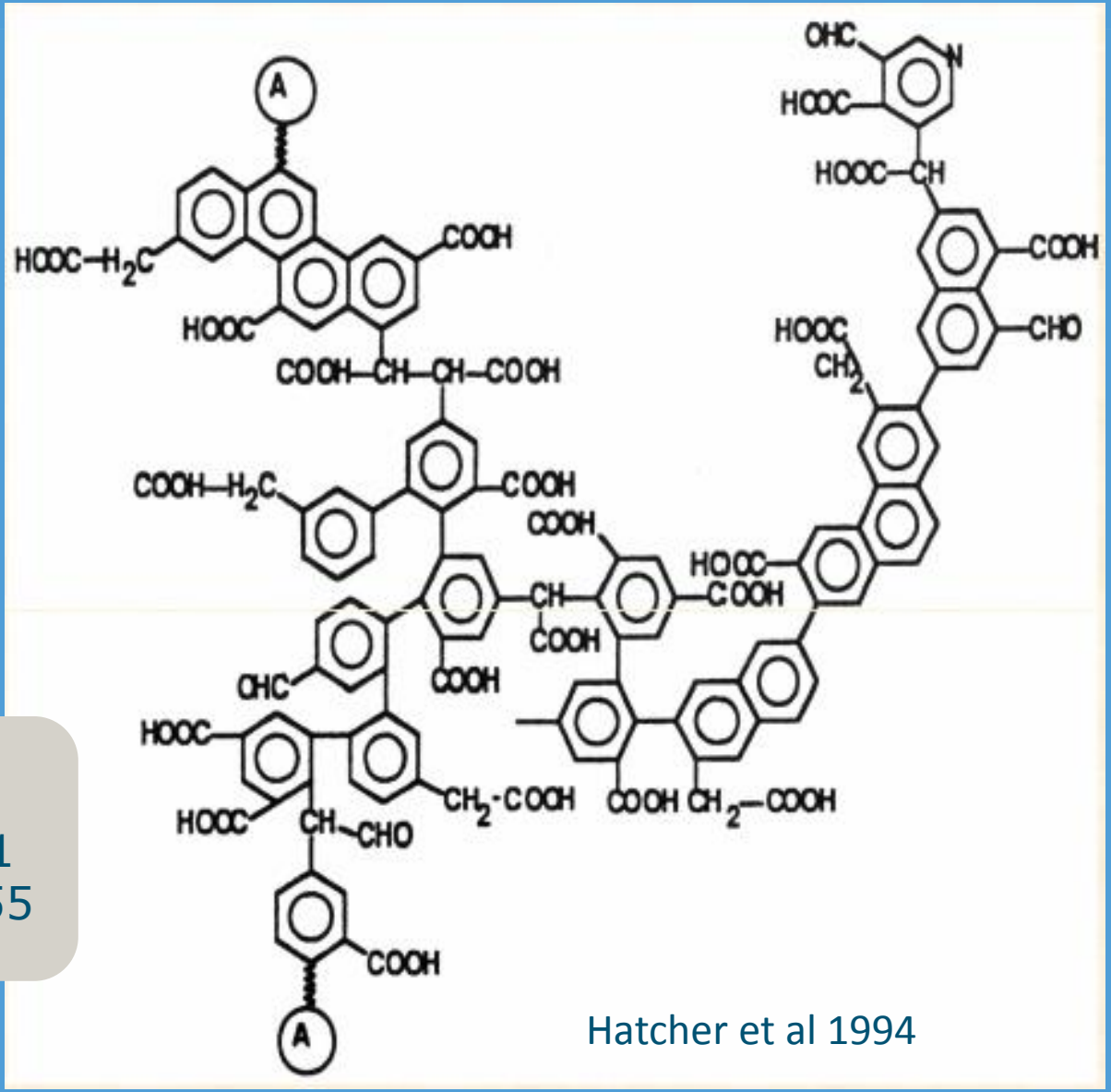
Streubel et al, 2011, JSSSA, 75:1402-1413

CEC reclaimed peat soils



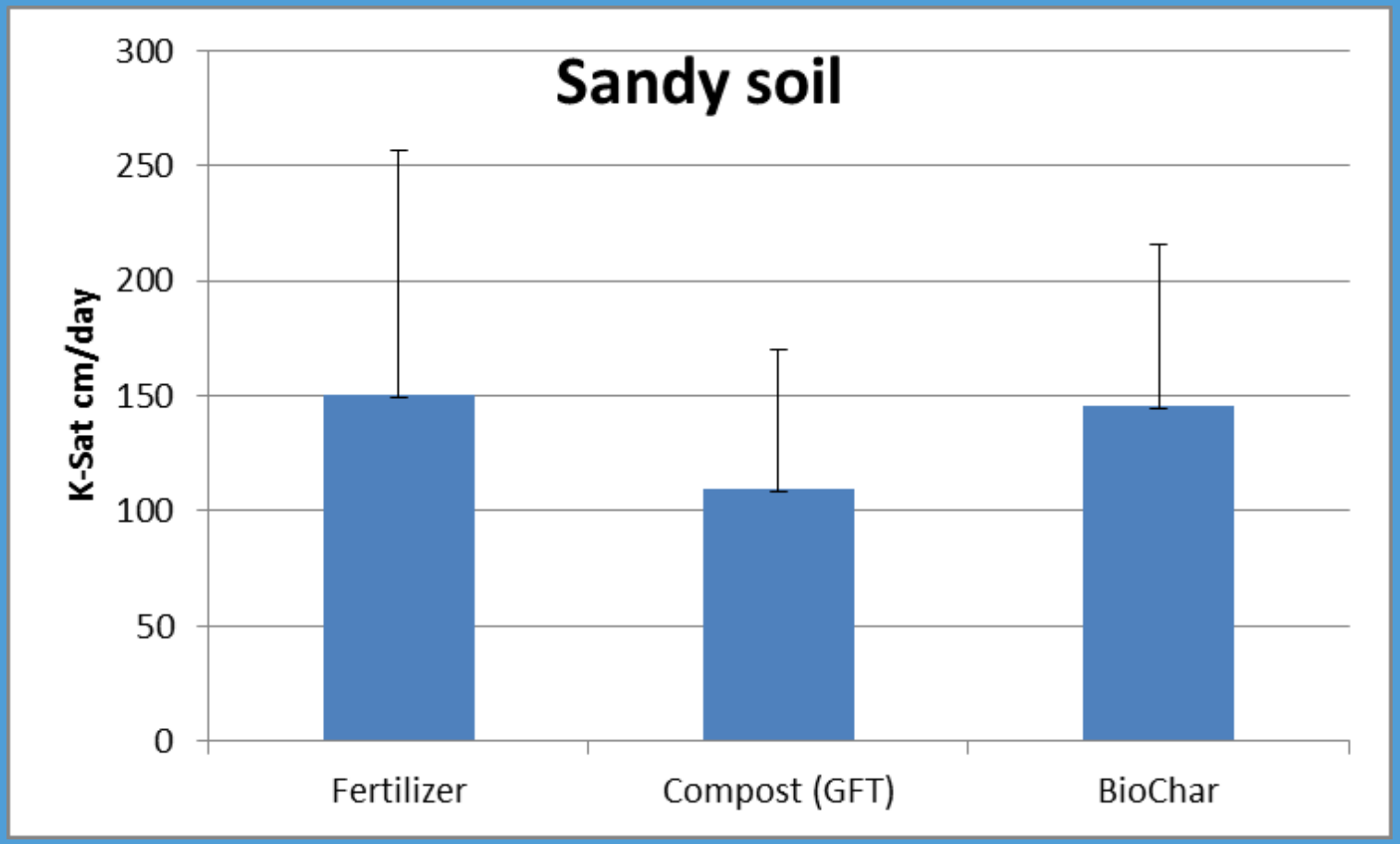
Humic Acid structure



Hatcher et al 1994

C:O
Fulvic acids: 1
Humic acids : 0.55

Water infiltration Interreg Biochar Project



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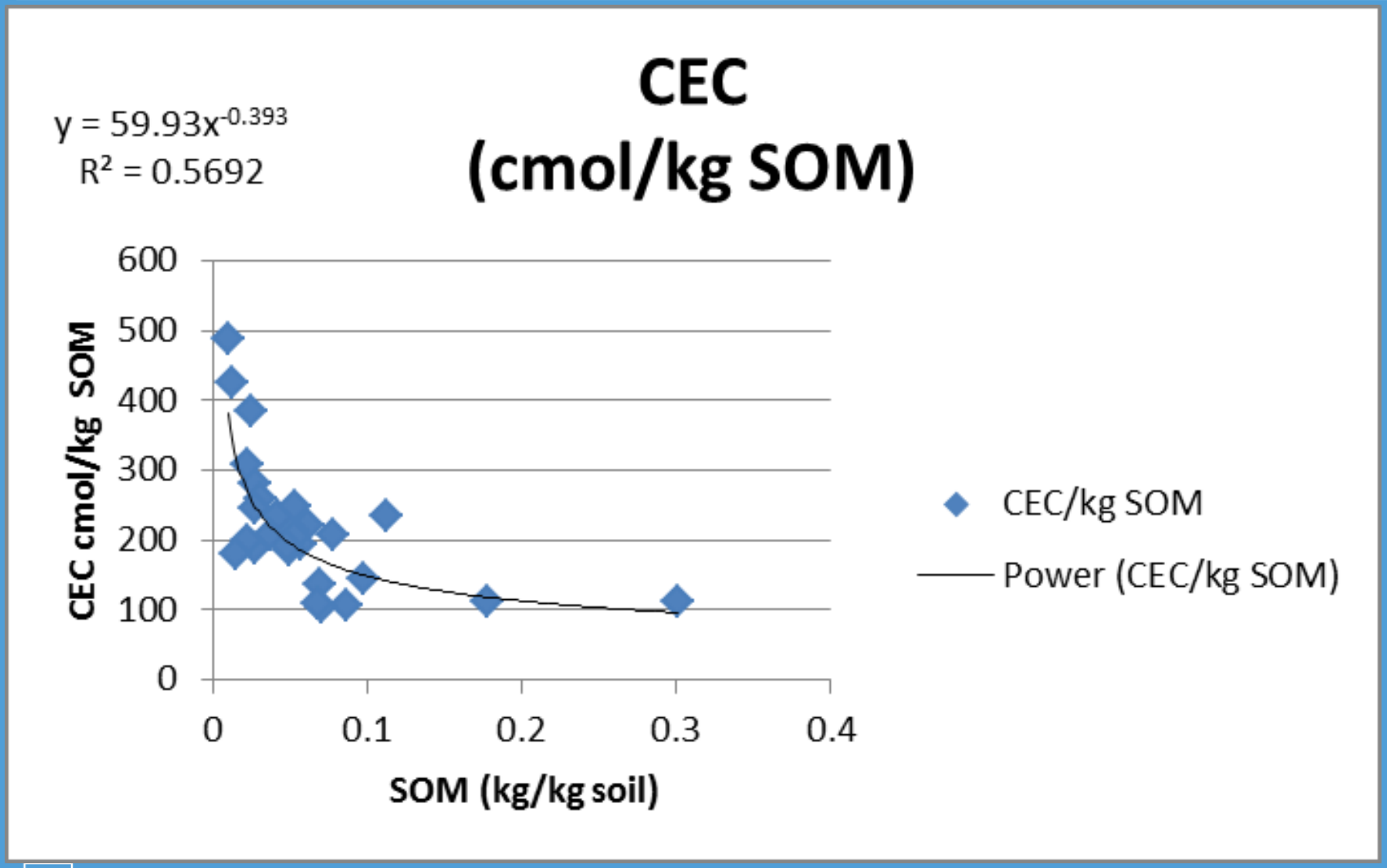
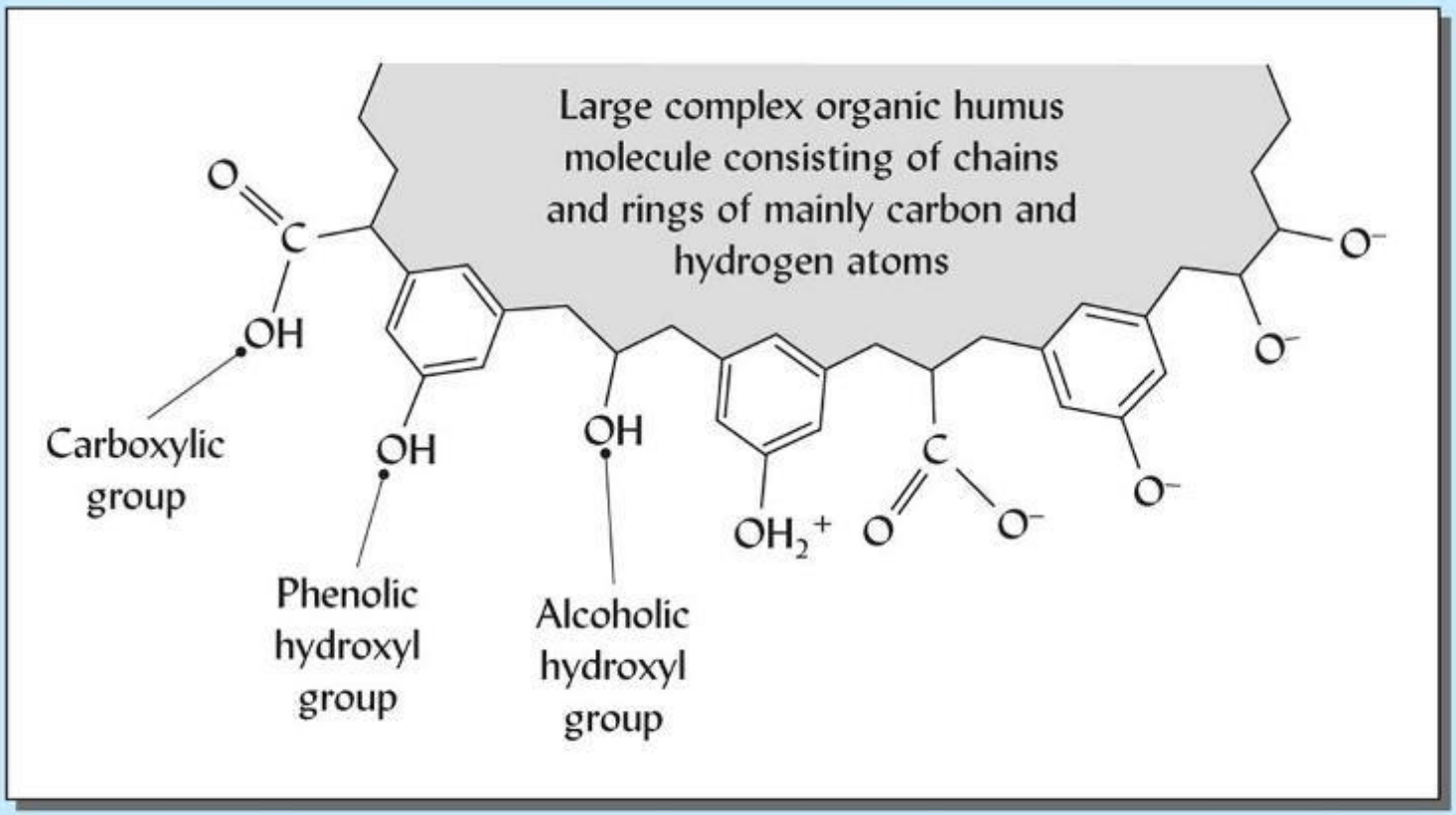
CEC reclaimed peat soils




Large complex organic humus molecule consisting of chains and rings of mainly carbon and hydrogen atoms
O
C
OH
Carboxylic group
OH
Phenolic hydroxyl group
OH
Alcoholic hydroxyl group
OH_2^+
C
O
O⁻
O⁻
O⁻
O⁻