Biochar!

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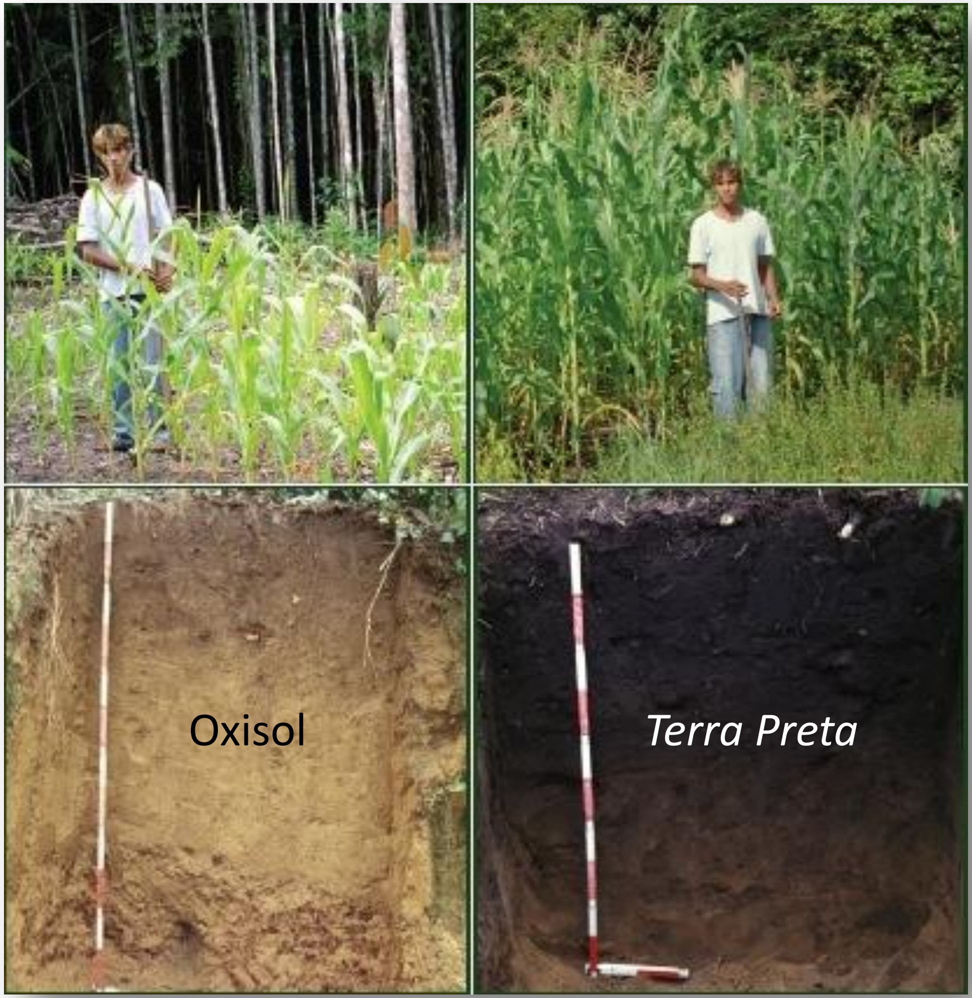
UC DAVIS
BIOCHAR
DATABASE

Origin: *Terra Preta*

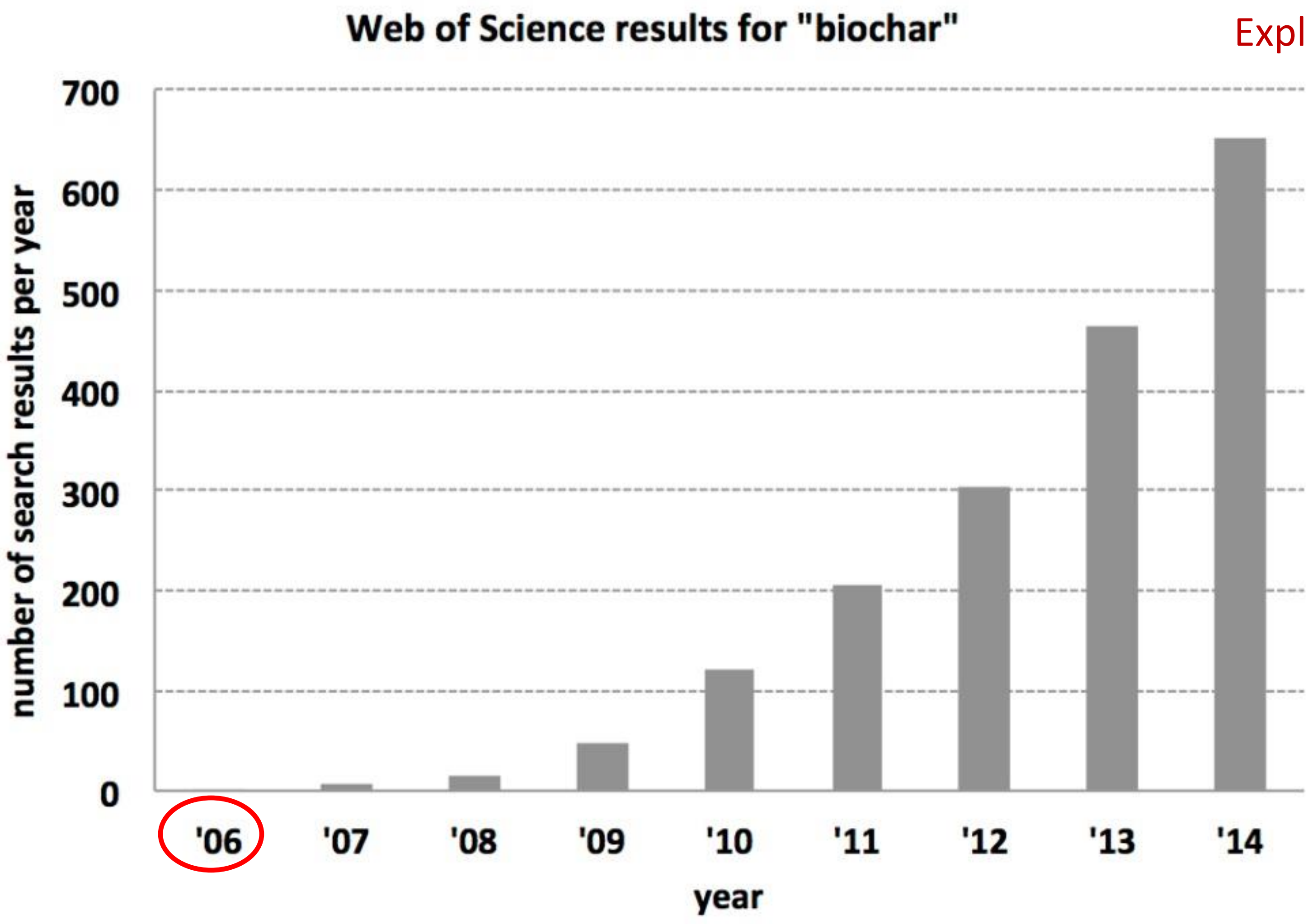
- Dark earth, anthropogenic Brazilian Amazon soils
- Will Sombroek 1966
- Darker, enhanced levels of soil fertility
- High levels of soil organic matter, N, P, K and Ca
- Crops grow three times faster compared to adjacent infertile land
- Soils in Ecuador and Peru, Africa (Benin, Liberia and savanna of South Africa



http://www.biochar-international.org/biochar/soils

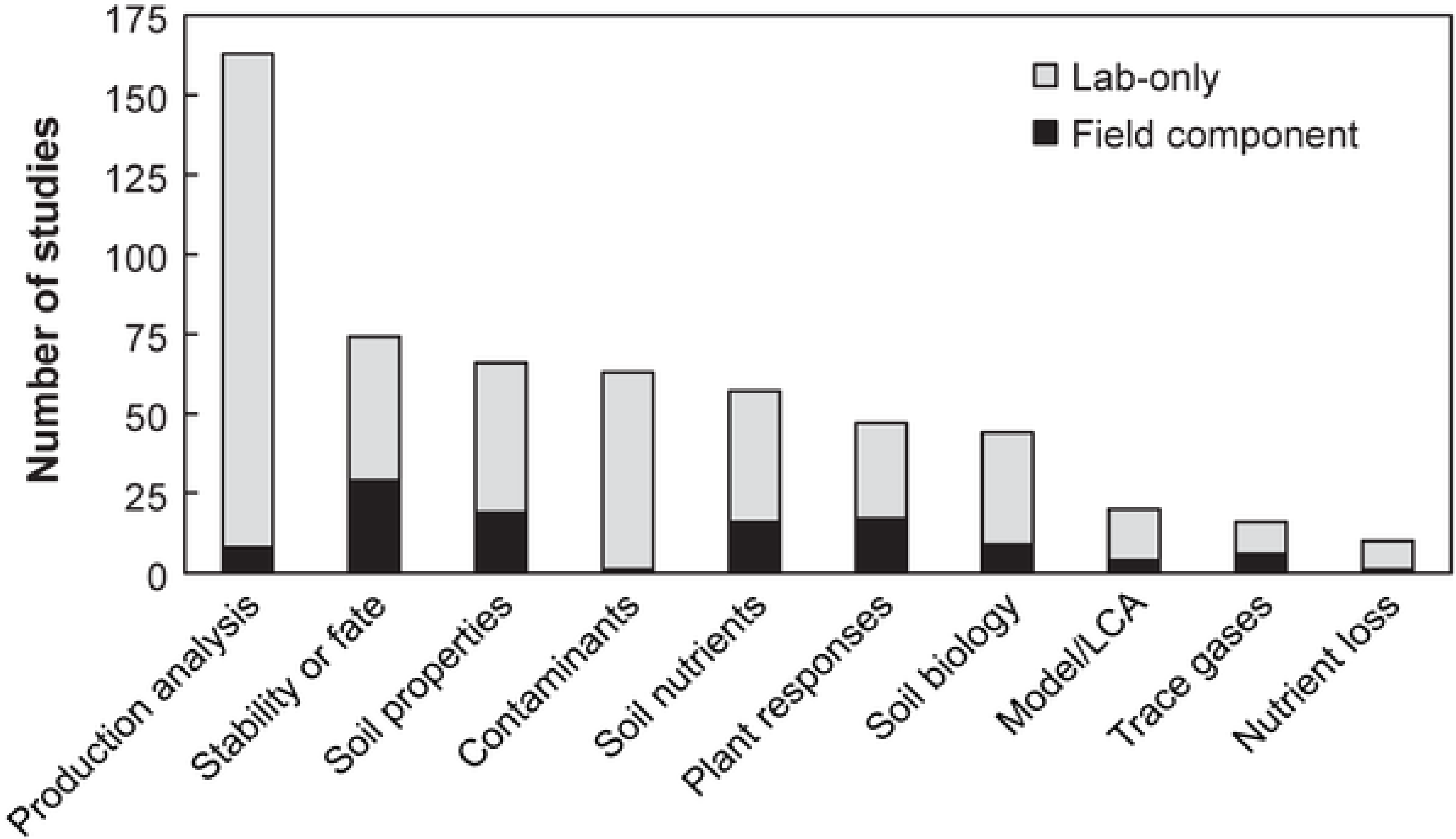
Research

Young field
Explosive research



http://www.aqsolutions.org/?page_id=1430

Figure 1. Number of primary research articles addressing each topic area.

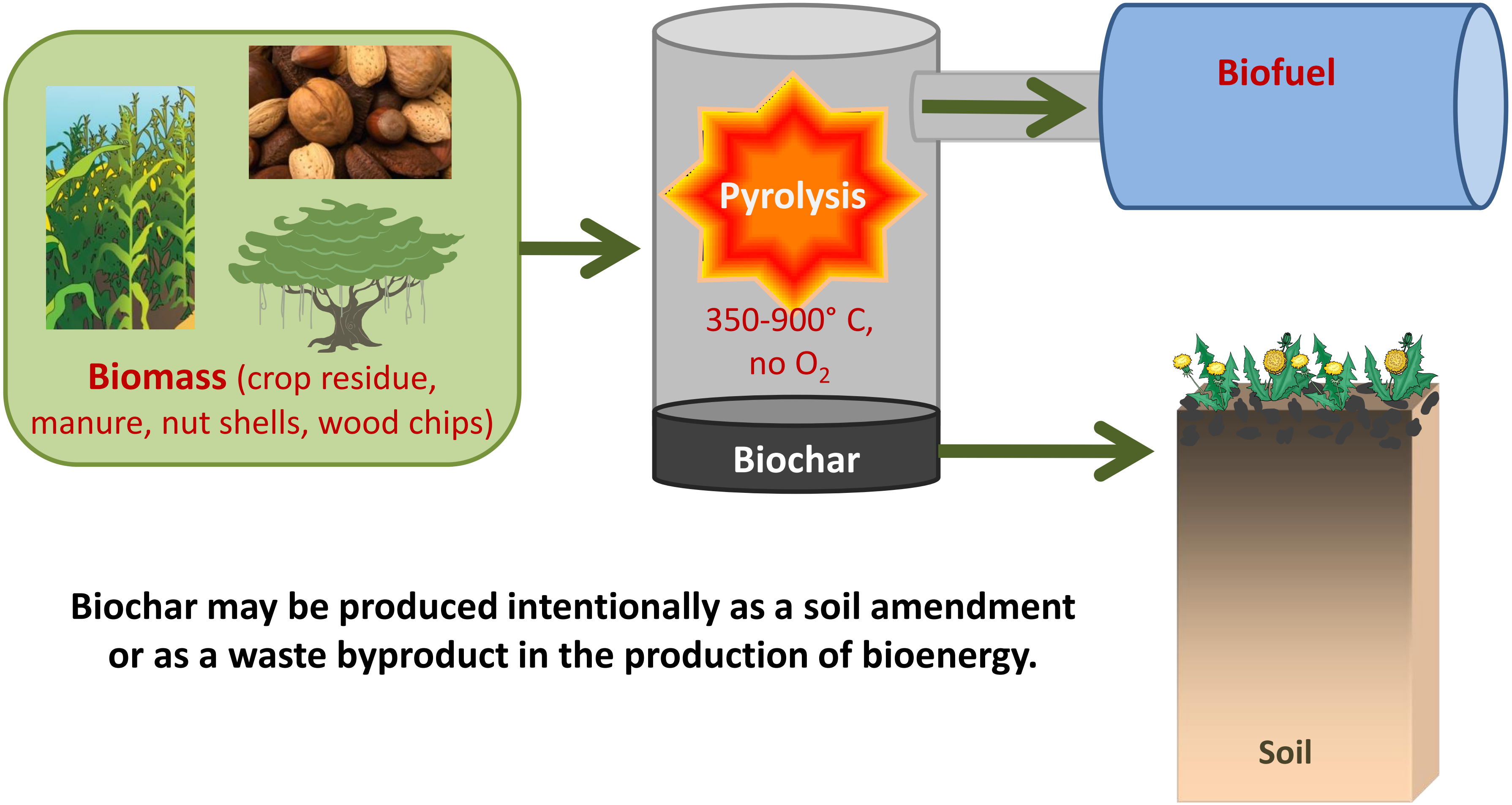


Gurwick NP, Moore LA, Kelly C, Elias P (2013) A Systematic Review of Biochar Research, with a Focus on Its Stability in situ and Its Promise as a Climate Mitigation Strategy. PLoS ONE 8(9): e75932. doi:10.1371/journal.pone.0075932
http://127.0.0.1:8081/plosone/article?id=info:doi/10.1371/journal.pone.0075932

PLOS | ONE

What is Biochar?

Charcoal created from biomass, and differs from charcoal only in the sense that its primary use is not for fuel.



Biochar may be produced intentionally as a soil amendment or as a waste byproduct in the production of bioenergy.

Confusion of terms

Char:

- Solid product from thermal decomposition of any natural or synthetic organic material. e.g. char and soot from forest fire

Charcoal:

- Made from the thermal decomposition of wood and related organic materials
- All heat, gaseous and liquid co-products are lost during the combustion process
- Used as an urban fuel for heating and cooking, but also traditional uses as soil amendment

Activated carbon:

- Made by heating carbonaceous material at a high temperature (above 500°C) and over long (>10 hours) periods of time.
- High adsorptive capacity – due to activation
- Used for cleansing processes, such as water filtration and adsorption of gas, liquid or solid contaminants

Black carbon:

- General term that encompasses diverse forms of refractory organic matter

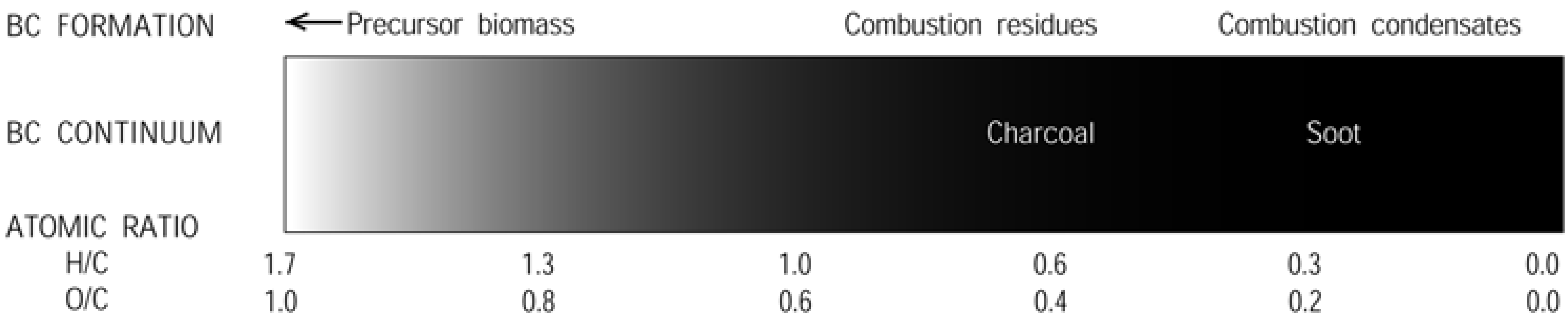
Production

Process	Liquid (bio-oil)	Solid(biochar)(%)	Gas (syngas) (%)
Fast pyrolysis: Moderate temperature (≈500ºC), short hot vapour residence time (<2 s)	75% (25% water	12	13
Intermediate pyrolysis: Low to moderate temperature, moderate hot vapour residence time	50% (50% water)	25	25
Slow pyrolysis: Low to moderate temperature, long residence time	30% (70% water)	35	35
Gasification: High temperature (>800ºC), long vapour residence time	5% tar (5% water)	10	85

Sohi, S.P., Krull, E., Lopez-Capel, E. & Bol, R. 2010. A review of biochar and its use and function in soil. In: *Advances in Agronomy*, Volume 105 (ed. D.L. Sparks), pp. 47–82. Elsevier Academic Press Inc, San Diego, CA.

Biochars are Diverse!

The black continuum



- International Biochar Initiative (2012)
  - Standardized protocols
  - Standardized definitions
  - Biochar certification

International Biochar Initiative

http://www.biochar-international.org/

How do we sort between them?

Characteristics

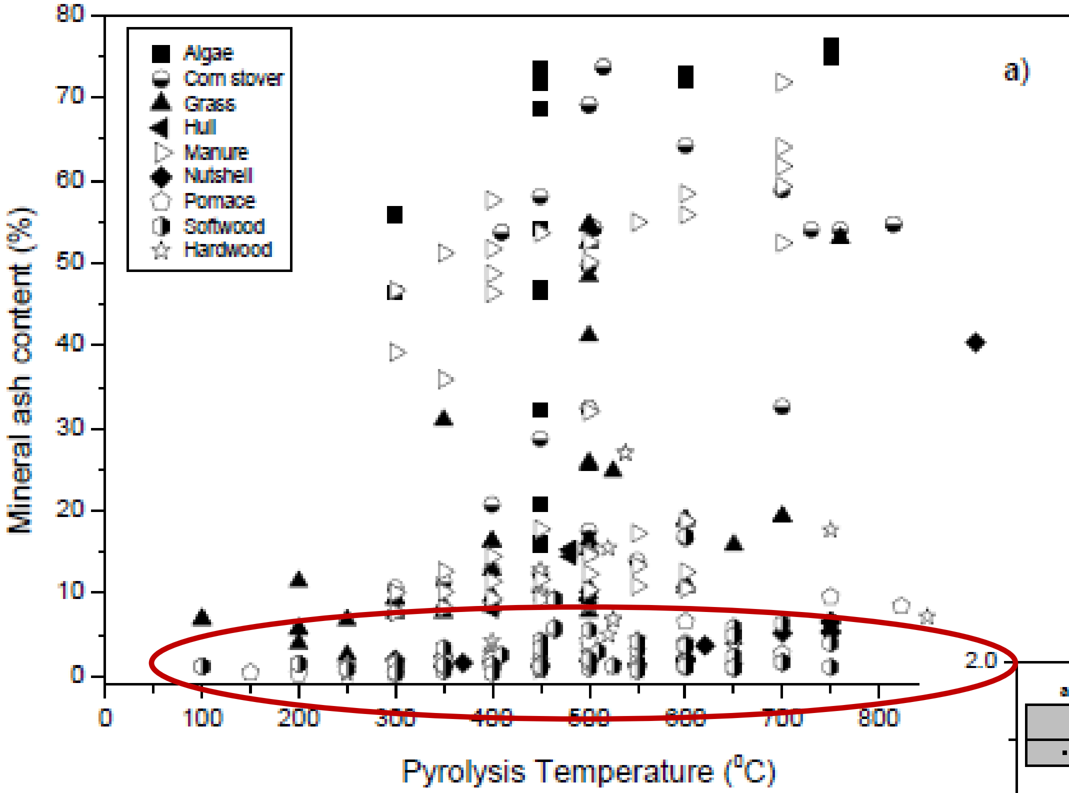
- pH
- Surface area
- Ash content
- Water holding capacity
- Cation exchange capacity (CEC)
- H/C ratio
- C/N ratio

- All a function of pyrolysis temperature (highest treatment temperature-HTT), pyrolysis method, residence time and feedstock

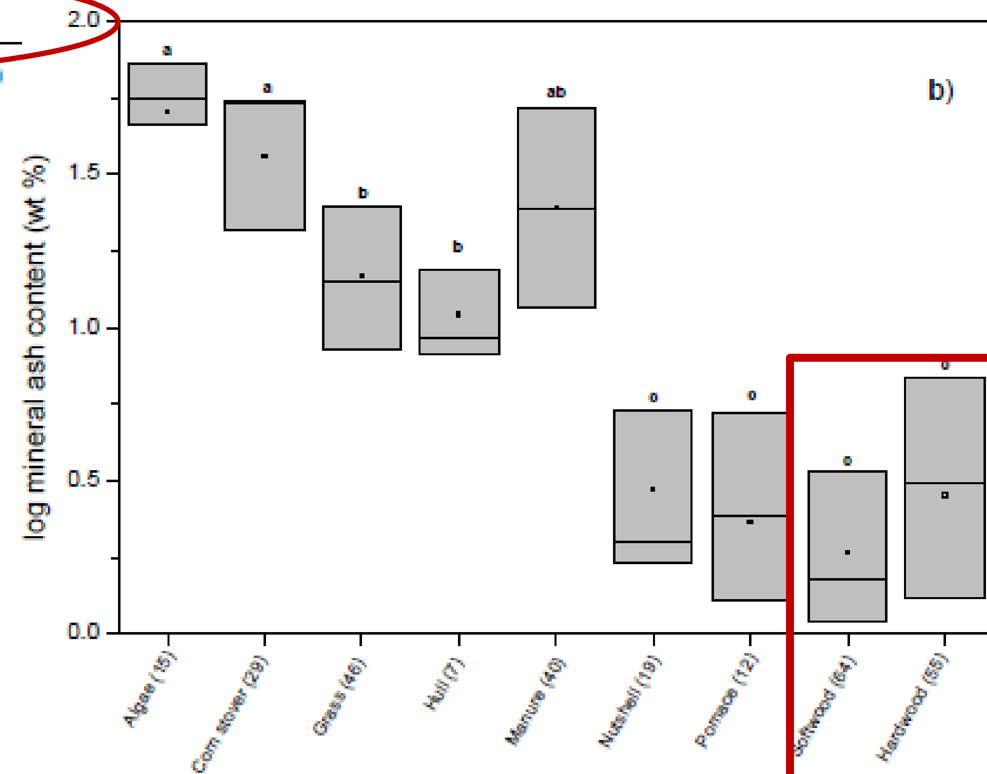
Trends?

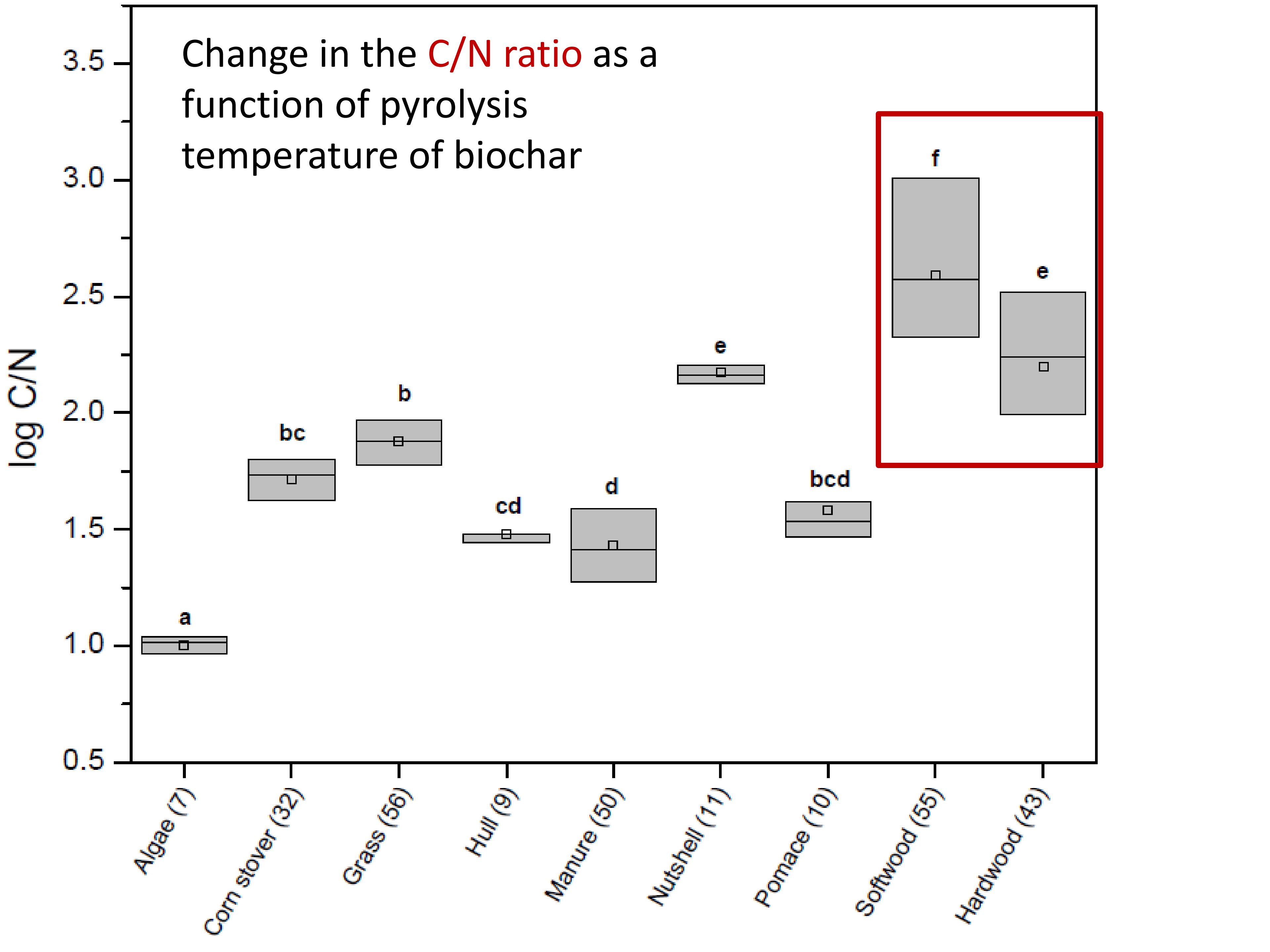
Launched 2013

Over 1000 biochars

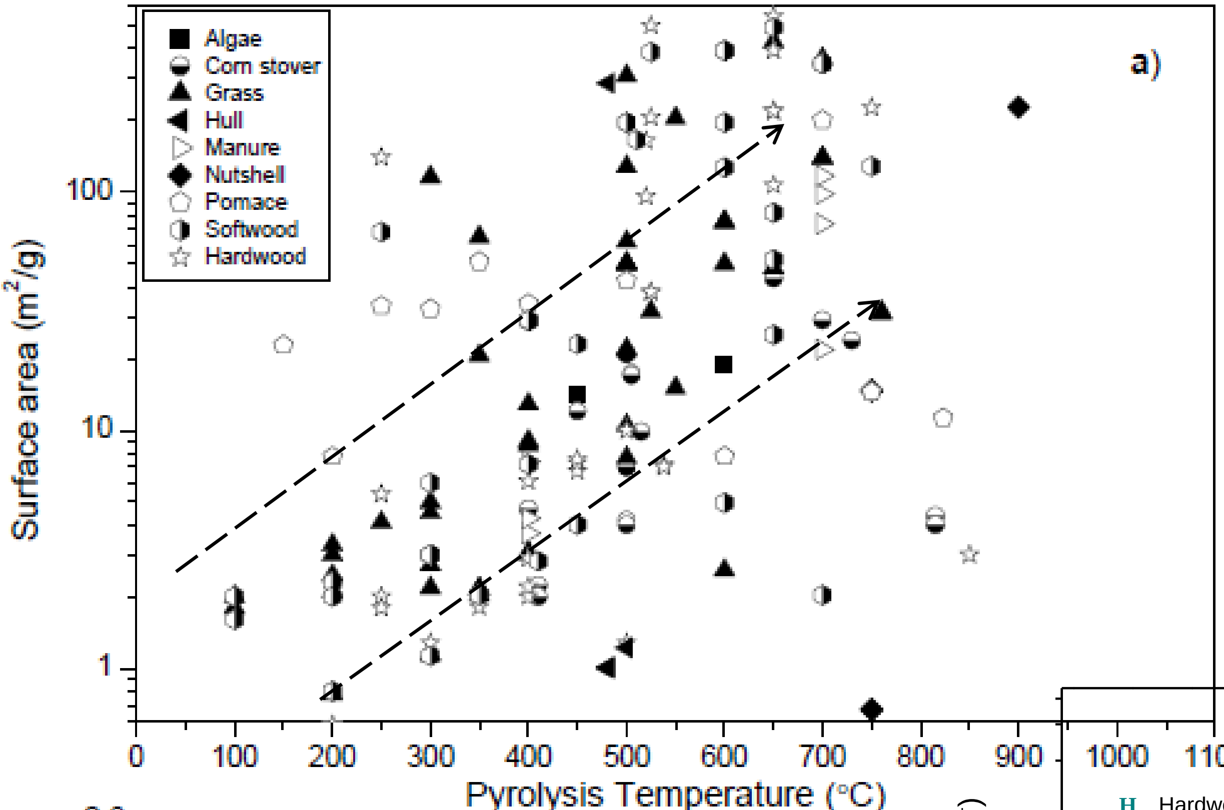


Change in ash content as a function of pyrolysis temperature of biochar



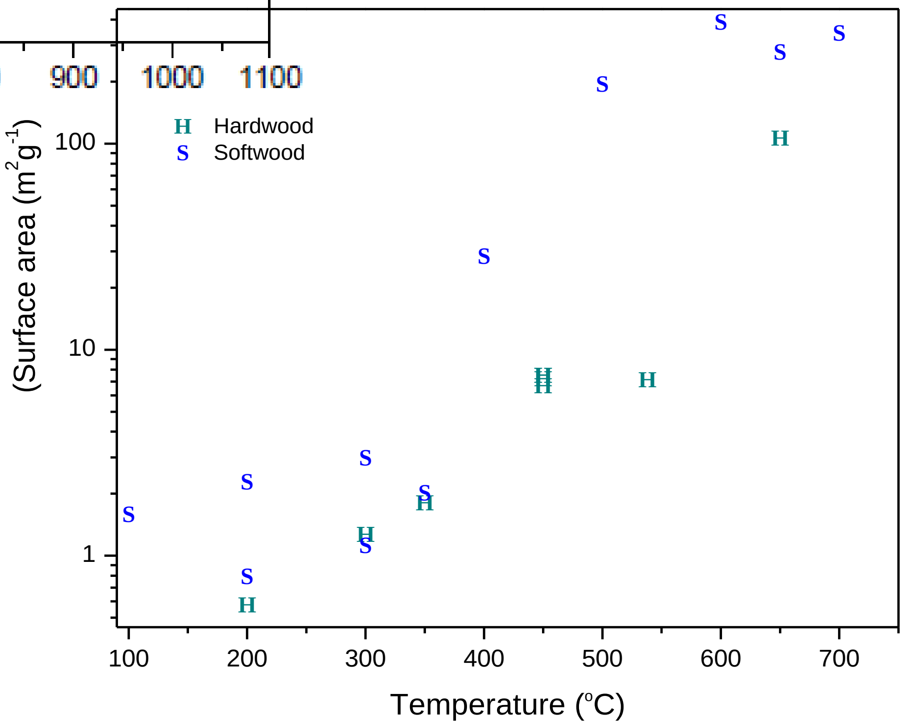


Change in the C/N ratio as a function of pyrolysis temperature of biochar
log C/N
3.5
3.0
2.5
2.0
1.5
1.0
0.5
a
bc
b
cd
d
e
bcd
f
e
Algae (7)
Corn stover (32)
Grass (56)
Hull (9)
Manure (50)
Nutshell (11)
Pomace (10)
Softwood (55)
Hardwood (43)



Change in the surface area as a function of pyrolysis temperature of biochar

Change in surface area as a function of pyrolysis temperature of biochar derived from hard and softwood →



Suggested guidelines

Property	Agroecosystem consideration
Ash content	Hydrophobicity and retention of agrochemicals
C/N ratio	Initial Immobilization of soil N
Surface area	Sorption of pesticides, herbicides and heavy metals, sites for fungal and microbial colonization

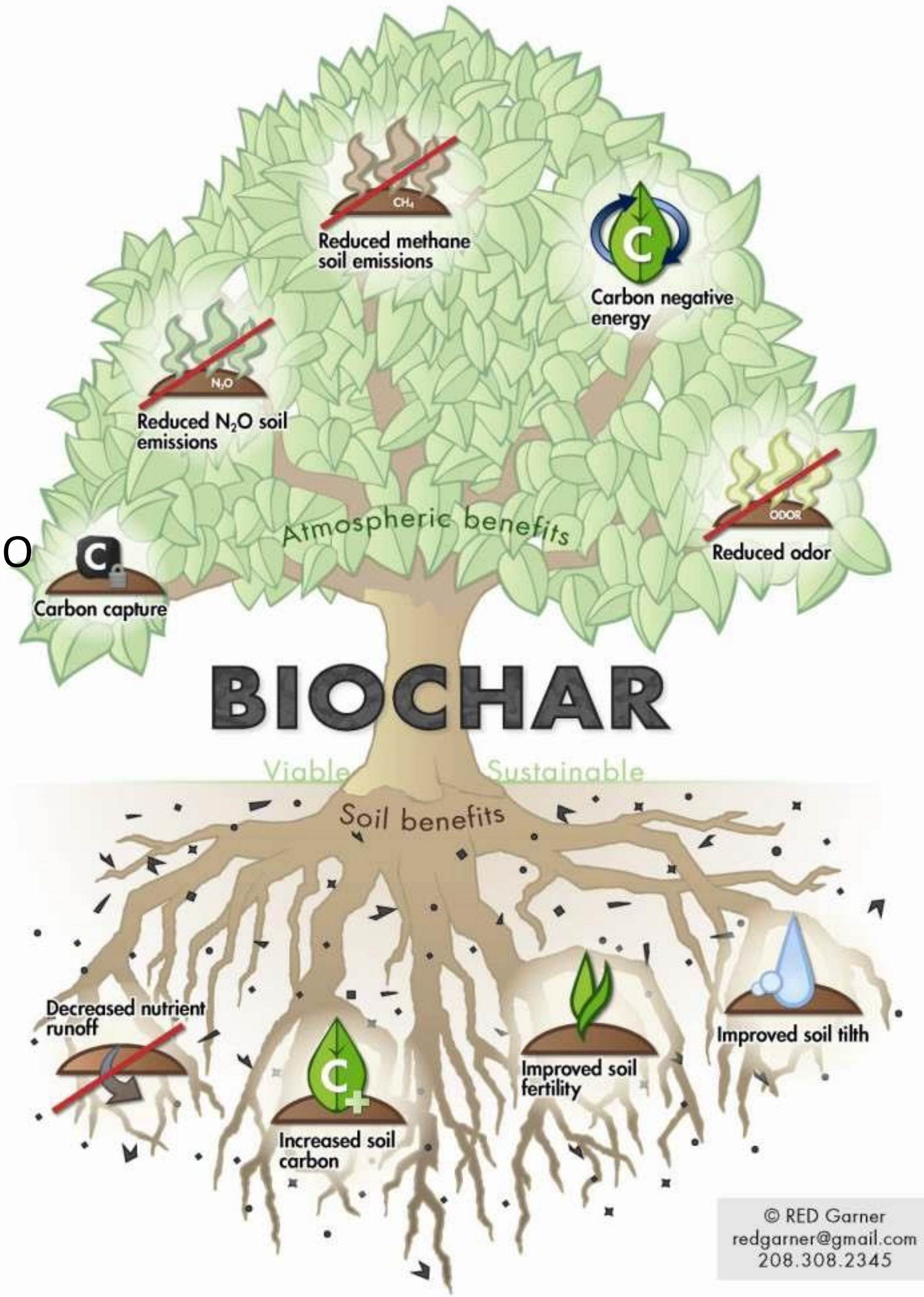
Characteristic	Suggested guideline
Ash content	grass ≈ manure >> nut shells, pomace and wood (hard wood > soft wood)
C/N ratio	wood >> grass> pomace> manure (soft wood > hard wood)
Surface area	soft wood> pomace > grass> hard wood

Mukome, F.N.D., X. Zhang, L.C.R. Silva, J. Six, and S.J. Parikh. 2013. Use of chemical and physical characteristics to investigate trends in biochar feedstocks. J. Agric. Food. Chem. 61:2196-2204.

Potential benefits to biochar soil amendments….

- sequester native/amended C and N – reduce leaching
- reduce greenhouse gas emissions (N_2O & CO_2)
- improve water holding capacity
- increase soil fertility and biomass production
- stimulation of favorable microbial activity

Is Biochar a <u>Real Solution</u> of just <u>Biochar Hype</u>?



The jury is out, but opinions are everywhere!

"The New Black Gold"

Sequestration

Agronomy **2013**, *3*, 462-473; doi:10.3390/agronomy3020462

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agronomy

ISSN 2073-4395

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Review

The Application of Biochar in the EU: Challenges and Opportunities

Luca Montanarella * and Emanuele Lugato

"would require the conversion of 2.2 Gt of C feedstock into biochar every year. "

GHG Emissions

nature COMMUNICATIONS

OPEN

ARTICLE

Received 29 Oct 2009 | Accepted 14 Jul 2010 | Published 10 Aug 2010

DOI:10.1038/ncomms1053

Sustainable biochar to mitigate global climate change

Dominic Woolf[1], James E. Amonette[2], F. Alayne Street-Perrott[1], Johannes Lehmann[3] & Stephen Joseph[4]

"biochar can potentially offset a maximum of 12% of current anthropogenic CO_2-C equivalent (CO_2-C_e) emissions (that is, 1.8 Pectagrams (Pg) CO_2-C_e per year of the 15.4 Pg CO_2-C_e emitted annually), and that over the course of a century, the total net offset from biochar would be 130 Pg CO_2-C_e."

Conflicting data on GHG emission

- Reduced GHG emissions
  - Case et al., 2012; Singh et al., 2010; Yanai et al., 2007
- Increased GHG emissions
  - Novak et al.,2010; Novak and Reicosky, 2009.

  - No consensus

Stability

- Long term stability evidenced in *terra preta* soils and natural fire events
- Charcoal used for C dating and paleo-environmental reconstruction
- Its extraordinary stability means that charcoal particles in soil have been used as a tool for dating and as well as evaluation of cropping practices
- Freshly made char is different and weathers
- Labile and recalcitrant components
- Impacted by climate and soils

Table 1. Field experiments estimating biochar stability.

Study	Location (ecosystem)	Biochar source and application method	Study design	Biochar loss rate (years)
Major et al. [48]	Colombia (savanna)	Charred mango wood disked into soil	Measured soil respiration and leaching for 2 years after biochar addition	MRT 3,624
Haefele et al. [58]	Thailand and the Philippines (rice paddies)	Charred rice husks tilled into soil	Measured biochar C for 3 years after biochar addition	MRT >1,000
Knoblauch et al. [51]	Los Baños, Philippines (rice paddies)	Charred rice husks tilled into soil	Measured soil CO_2 and CH_4 emissions for 3 months immediately and 2 years after biochar addition	MRT ''several hundred if not thousands''
Cheng et al. [68]	Eastern North America (various)	Collected from soils at historic charcoal furnaces	Compared C content of old charcoal to that of charcoal produced in reconstructed furnaces	22% of biochar C lost in 130
Hammes et al. [47]	Russia (steppe)	Naturally-occurring fire	Measured black carbon stocks at a 100-year fire suppression site	Turnover time 293
Bird et al. [50]	Zimbabwe (savanna)	Naturally-occurring fire	Measured charcoal and oxidation-resistant elemental carbon (OREC) abundance at a 50-year fire suppression site	Half-life ''considerably <50 years'' (charcoal) and <100 years (OREC)
Nguyen et al. [49]	Kenya (cropland)	Slash-and-burn conversion from forest to cropland	Measured black carbon stocks along a 100-year chronosequence	MRT 8.3

The locations, methods, and results of the seven experiments that measured or estimated biochar stability in a field setting. MRT is mean residence time. Assuming a steady decomposition rate, the results of Cheng et al. [68] imply a turnover time of 565 years. However, decomposition tends to slow over time, so turnover time is likely longer.

doi:10.1371/journal.pone.0075932.t001

"Variable stability from 8 to 3600 years "

Gurwick NP, Moore LA, Kelly C, Elias P (2013) A Systematic Review of Biochar Research, with a Focus on Its Stability in situ and Its Promise as a Climate Mitigation Strategy. PLoS ONE 8(9): e75932. doi:10.1371/journal.pone.0075932
http://127.0.0.1:8081/plosone/article?id=info:doi/10.1371/journal.pone.0075932

PLOS | ONE

Impacts on soil

- **Range of studies showing benefits:**
  - Increased cation exchange capacity
  - Liming effects
  - Microbial activity and habitats
  - Reduced greenhouse gas emissions
  - Increased soil fertility and water holding capacity

- **Studies showing opposite effects:**
  - Native organic matter priming
  - Microbial quorum quenching (signaling)
  - Increased greenhouse gas emissions
  - None to limited increase in crop yields
  - Elevation of soil pH

Contrasting results linked to the **properties of the biochar** used, application rate, soil type and climate.

Agriculture, Ecosystems and Environment 144 (2011) 175–187

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

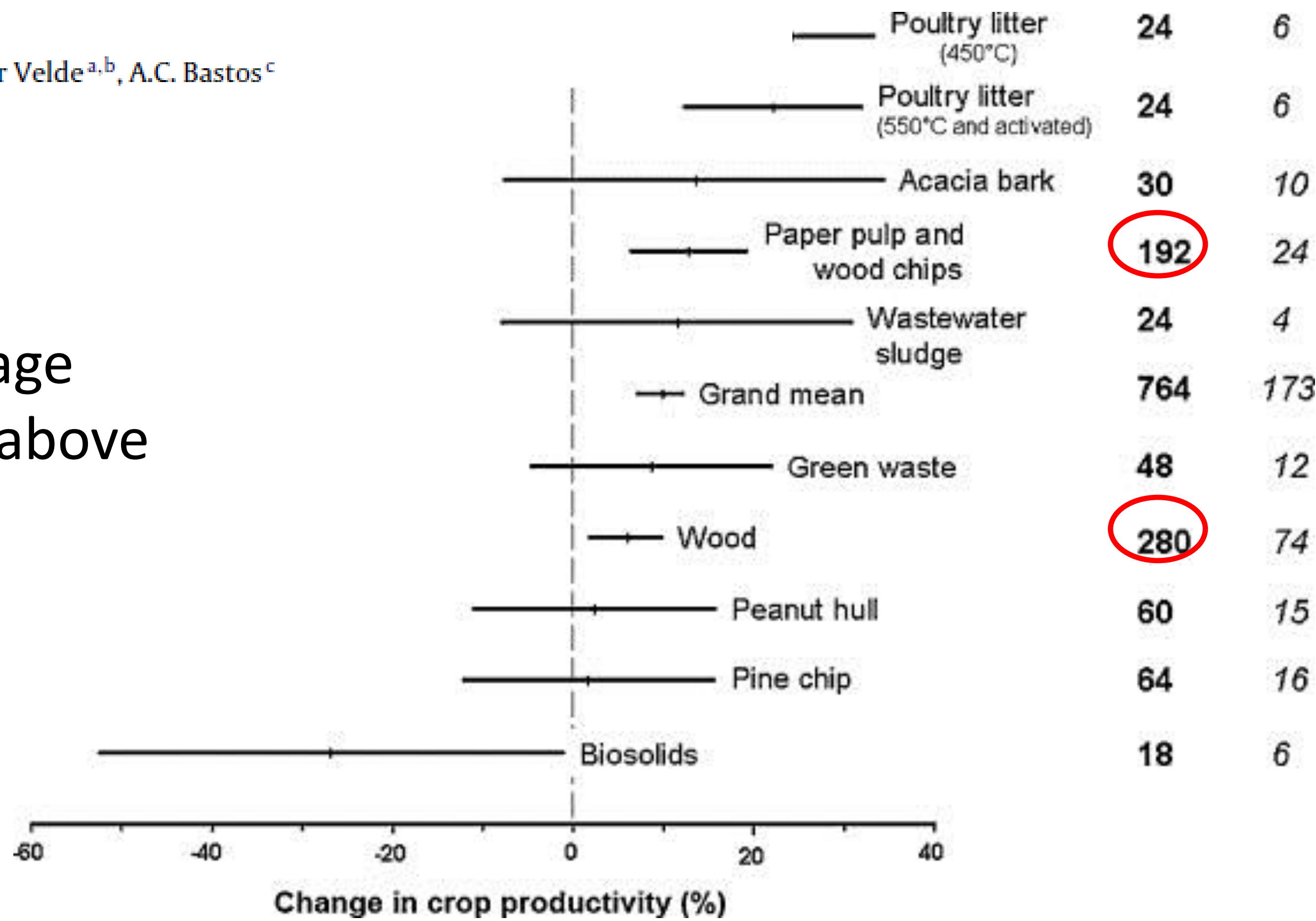
journal homepage: www.elsevier.com/locate/agee

Review

A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis

S. Jeffery[a,*], F.G.A. Verheijen[a,d], M. van der Velde[a,b], A.C. Bastos[c]

Study showed average increase of 10% in above ground biomass



Location of studies: tropical (38%) and subtropical (55%)…temperate?

GLOBAL CHANGE BIOLOGY BIOENERGY
GCB Bioenergy (2014), doi: 10.1111/gcbb.12182

More plant growth but less plant defence? First global gene expression data for plants grown in soil amended with biochar

MAUD VIGER[1], ROBERT D. HANCOCK[2], FRANCO MIGLIETTA[3,4] and GAIL TAYLOR[1]
[1]*Centre for Biological Sciences, University of Southampton, Southampton SO17 1BJ, UK,* [2]*Cell &Molecular Sciences, The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK,* [3]*Institute of Biometeorology (IBIMET), National Research Council (CNR), Via Caproni 8, Firenze 50145, Italy,* [4]*FoxLab, Forest & Wood Science, San Michele All'Adige 38010, Italy*

Poplar wood chips
gasification 1200C
pH 10.6
Ash 15%

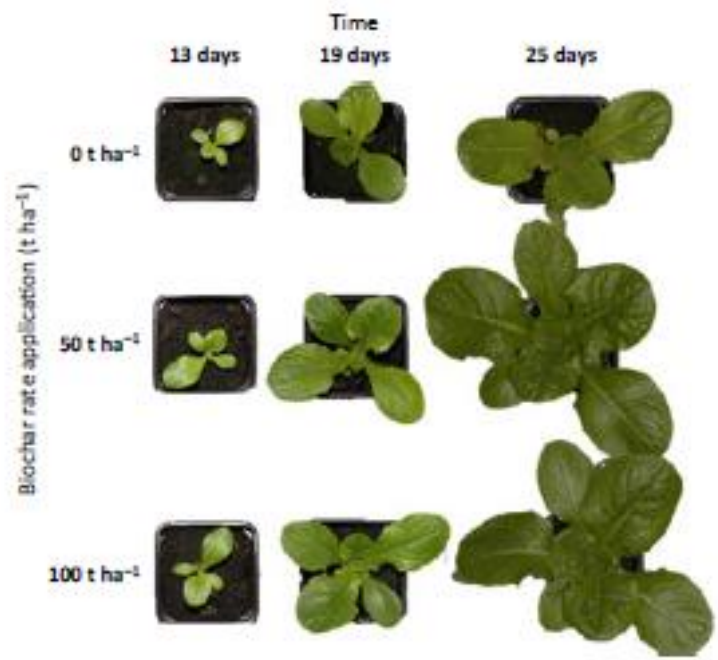


Fig. 3 Lettuce growth over time (13 to 25 days after planting) at 0, 50 and 100 t ha^{-1} equivalent biochar application with fertilizer.

Is it safe

What has been found:

- Heavy metals
- Polyaromatic hydrocarbons (PAH’s)
- Dioxins

-function of production method- high temp and condensation

Gaps:

- Studies on down stream effects eg erosion
- Airborne/ dust products
- Degradation products
- Fate and transport in the environment

Reviews

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GLOBAL CHANGE BIOLOGY
BIOENERGY

GCB Bioenergy (2013) 5, 202–214, doi: 10.1111/gcbb.12037

Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis

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Reviews

CSIRO PUBLISHING

Soil Research, 2014, **52**, 217–230
http://dx.doi.org/10.1071/SR13359

Review

The biochar dilemma

A. Mukherjee[A,B] *and R. Lal*[A]

[A]Carbon Management and Sequestration Center, The Ohio State University, 2021 Coffey Road, Columbus, Ohio 43210, USA.

European Journal of **Soil Science**

European Journal of Soil Science, January 2014, **65**, 22–27 doi: 10.1111/ejss.12127

Guest Editors' Introduction

Biochars in soils: new insights and emerging research needs

Take Home

- Biochar is diverse, function of feedstock and pyrolysis temperature
- Short term observations but projected long term benefits
- Agronomic benefits but not consistent
- No clear “predictive” performance

Take Home

- Still a lot to learn:
  - More research (field) required to confirm current observations (lab)
  - More studies in differing climatic regions e.g. temperate
  - Application rates
  - Mechanisms of action

Questions?

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