XXXIV CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO
28 de julho a 2 de agosto de 2013 | Costão do Santinho Resort | Florianópolis | SC

Synthesis and characterization of Biochar (Pyrogenic Carbon)

Etelvino Henrique Novotny (*et al*., many *alii*…)

Embrapa 40 anos

Soil, Biochar and Ecosystem Services

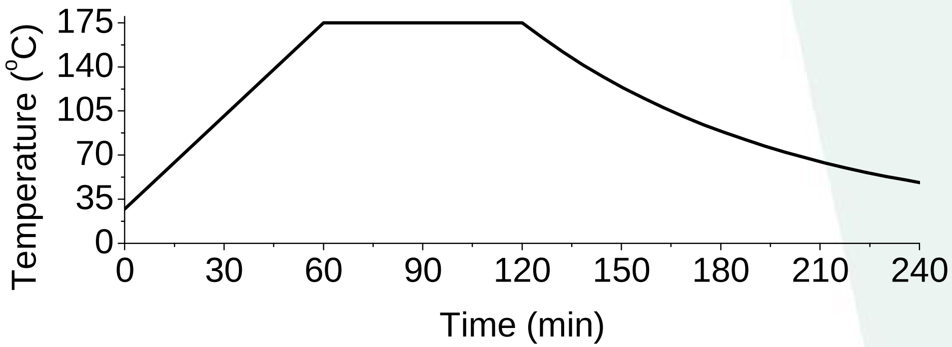
What for?

- GGE $\Rightarrow$ Climate regulation
- Primary production (Beáta Madari)
- Water regulation and purification
- Nutrient cycling
- Residues use (bones; sewage sludge...)

For who?

Acid Hydrolysis

300 g of biomass
2.5 L of water
150 mL H_2SO_4 0.5 mol L^{-1}



What for?

Renewable and Sustainable (soil) biofuels

FP7 – DIBANET Project

Acid Hydrolysis

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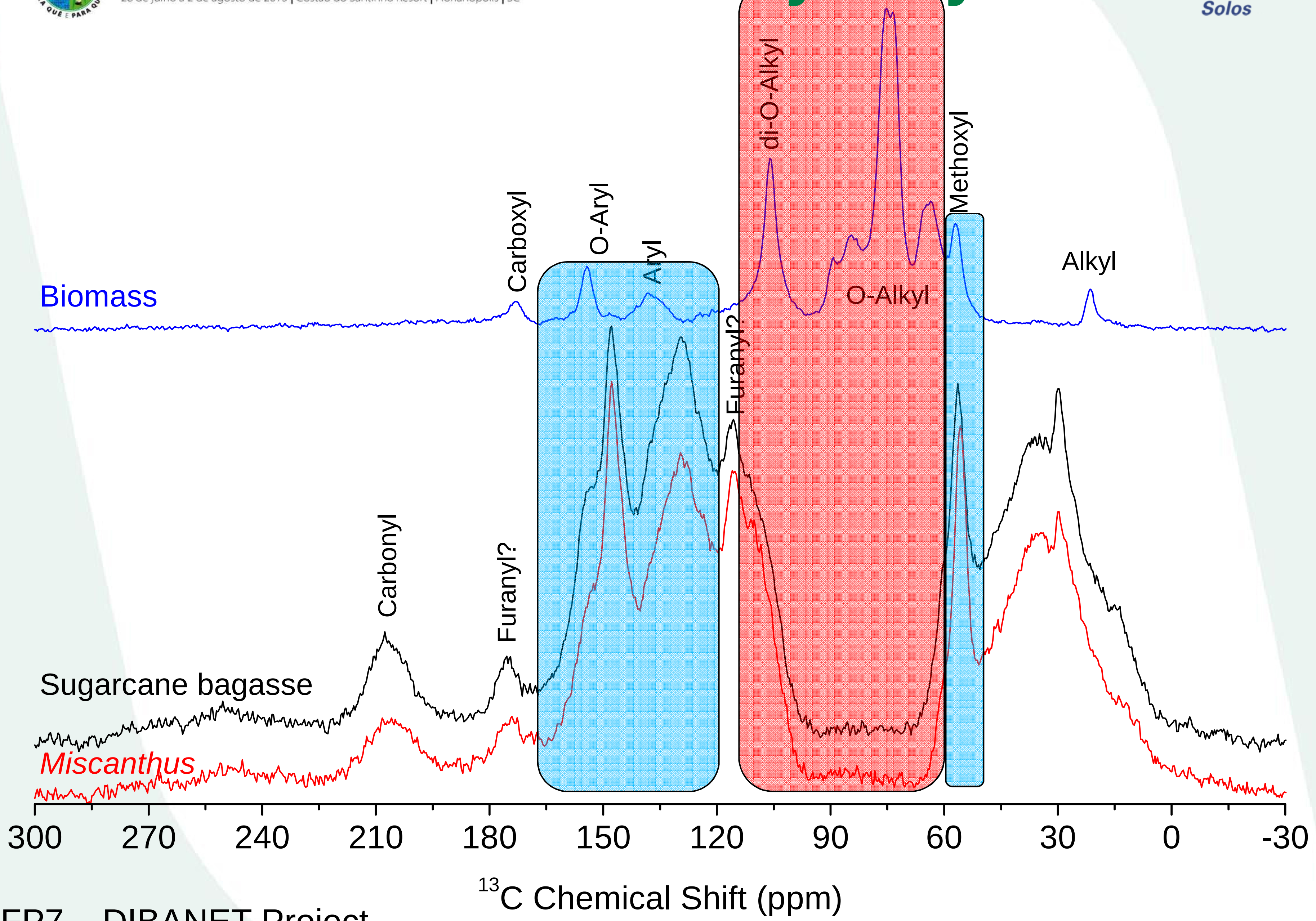
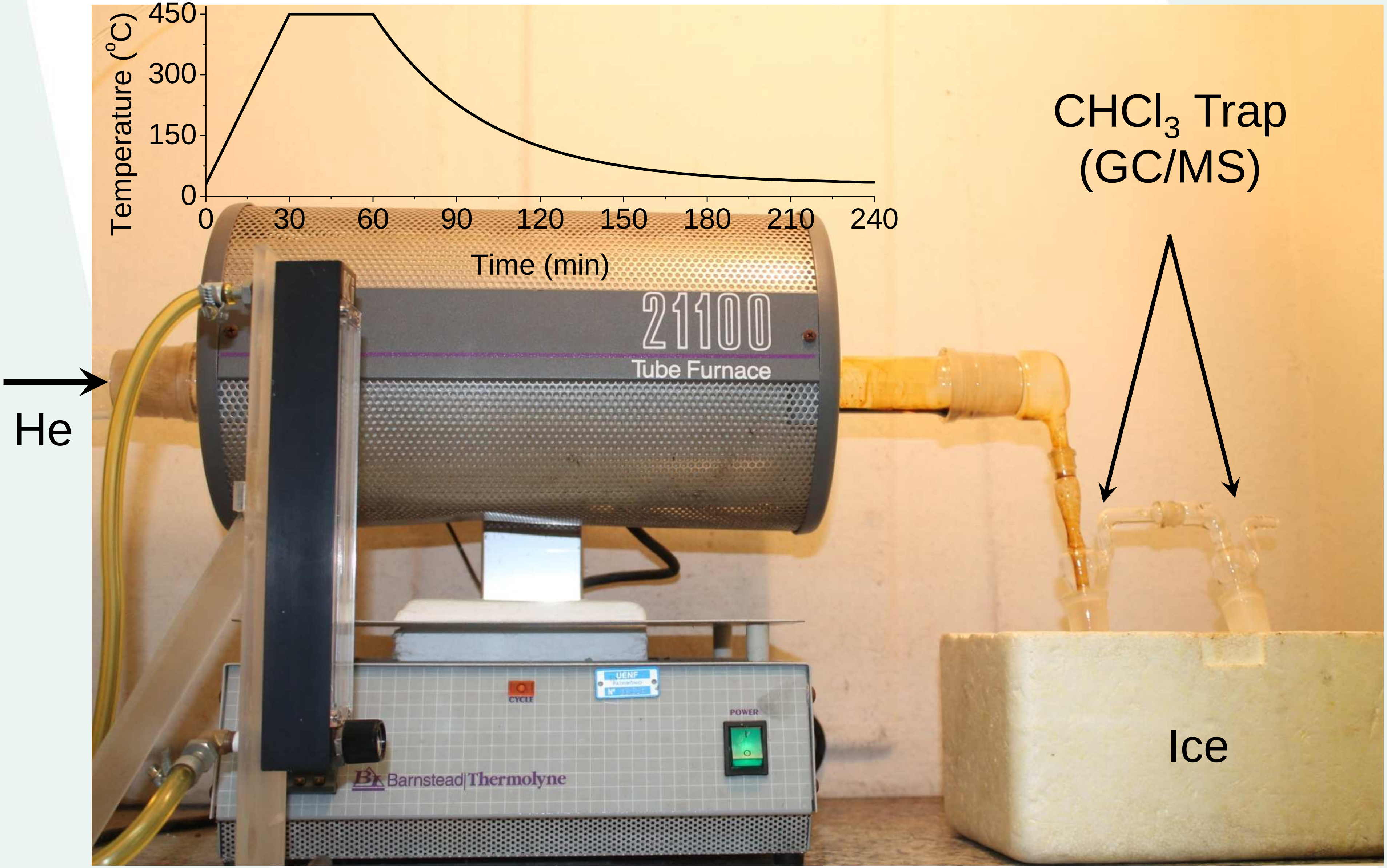
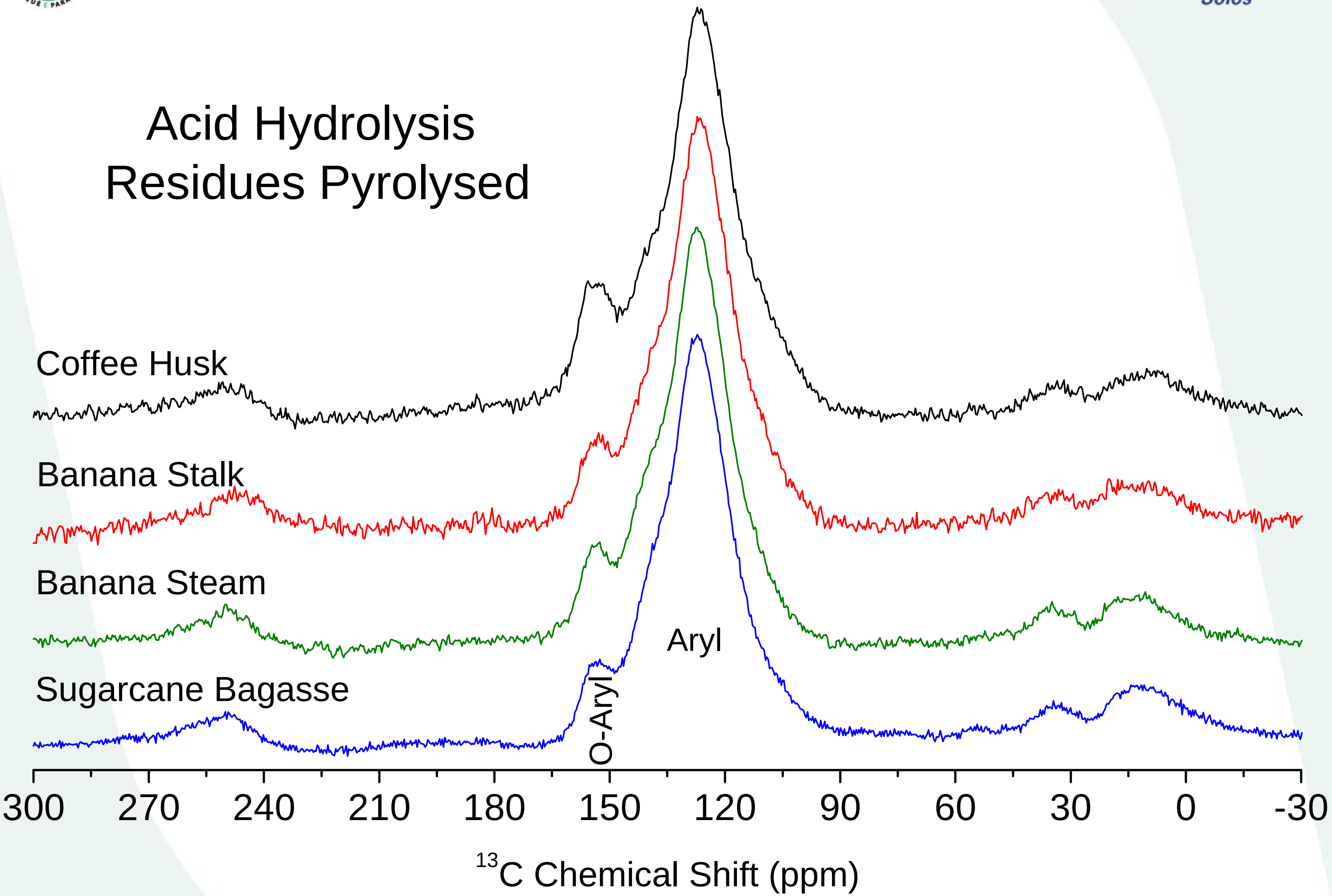


FP7 – DIBANET Project

Slow Pyrolysis



Slow Pyrolysis



Rambo et al. FP7 – DIBANET Project

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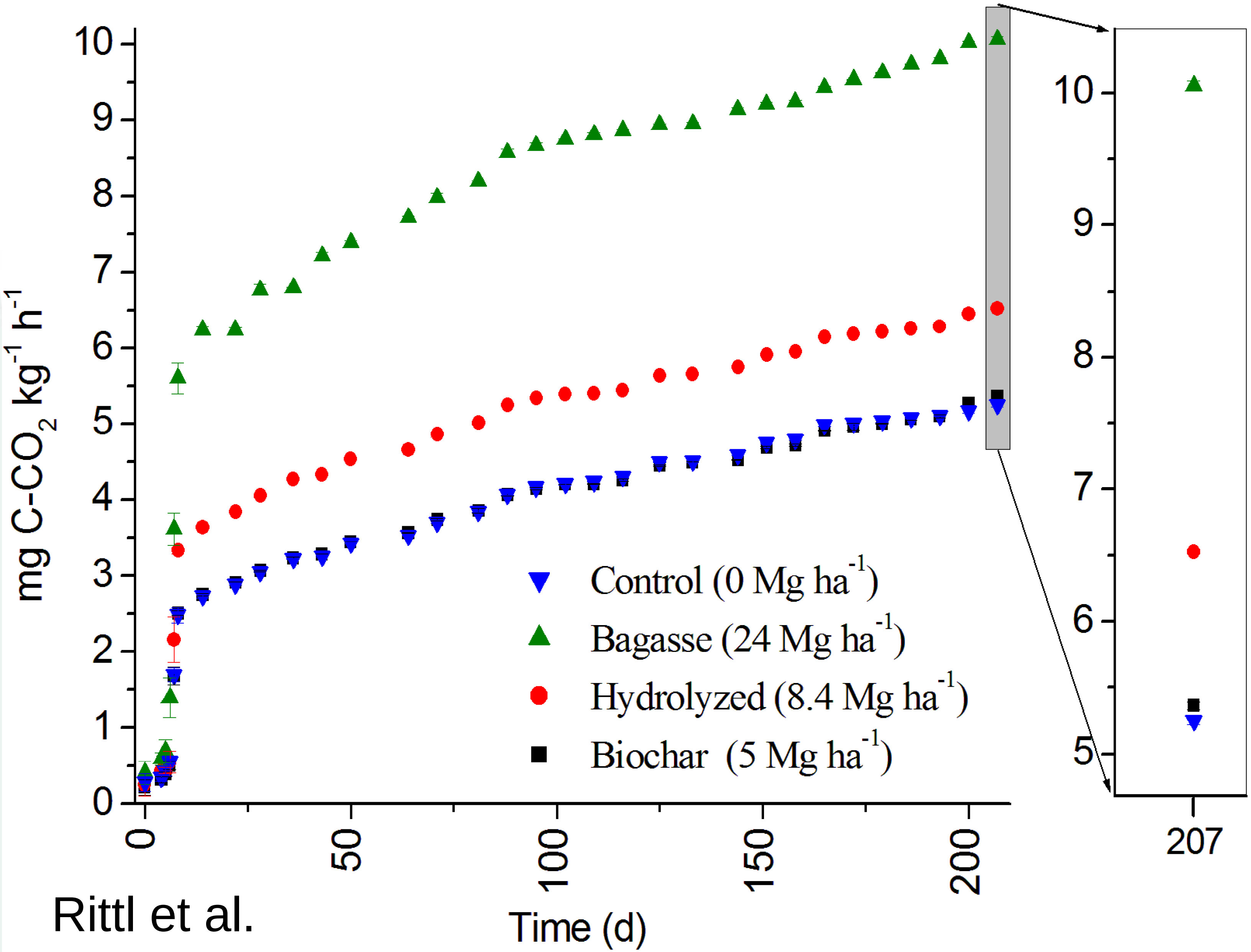
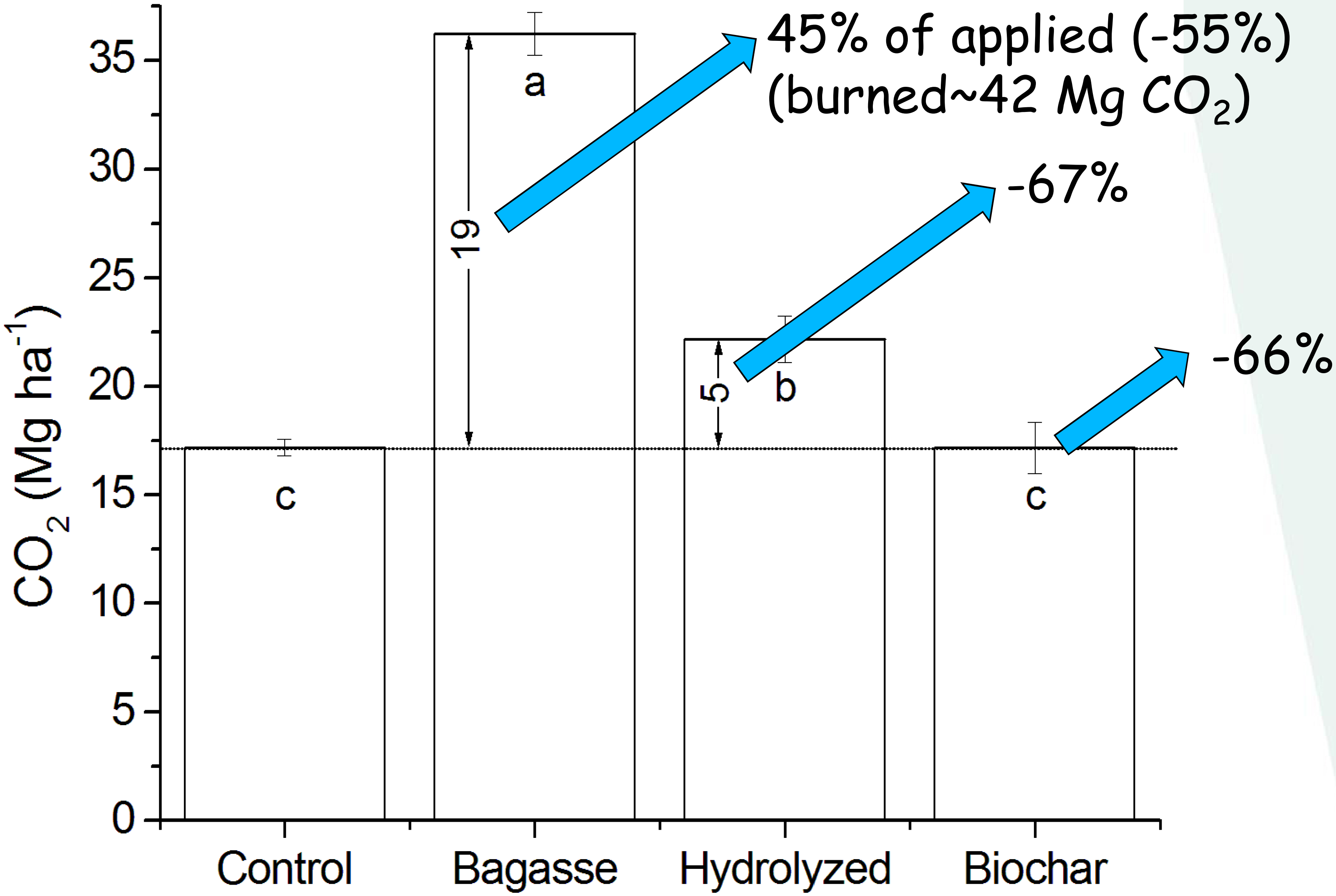
GGE ⇒ Climate regulation

Embrapa Solos



Rittl et al.

GGE ⇒ Climate regulation

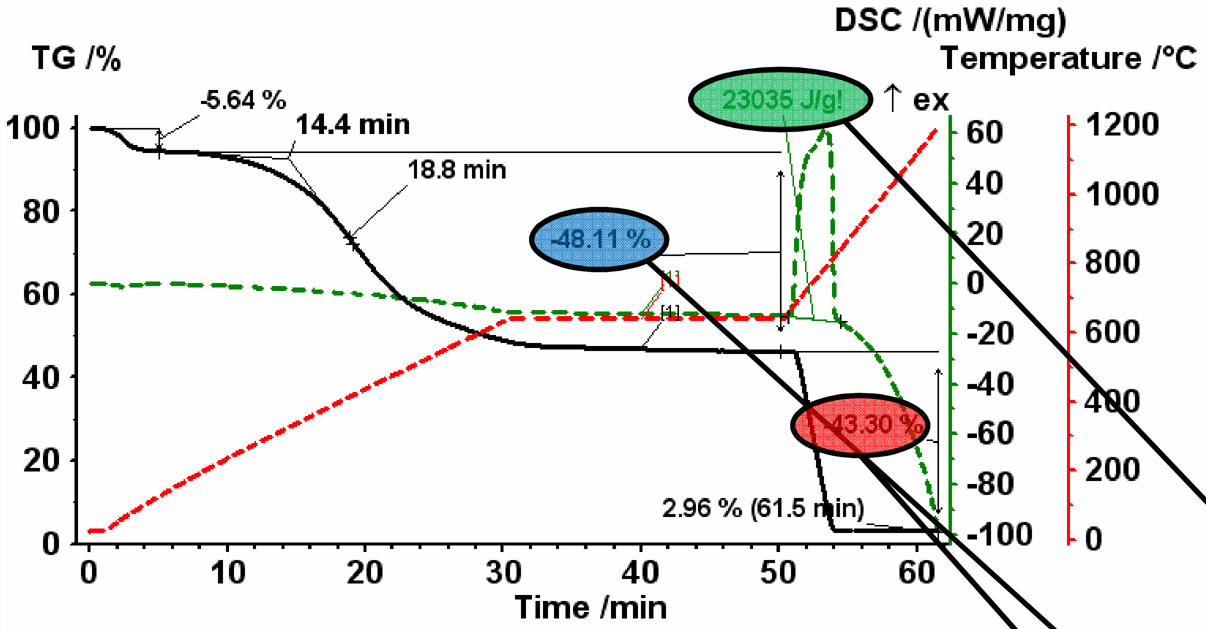


Rittl et al.

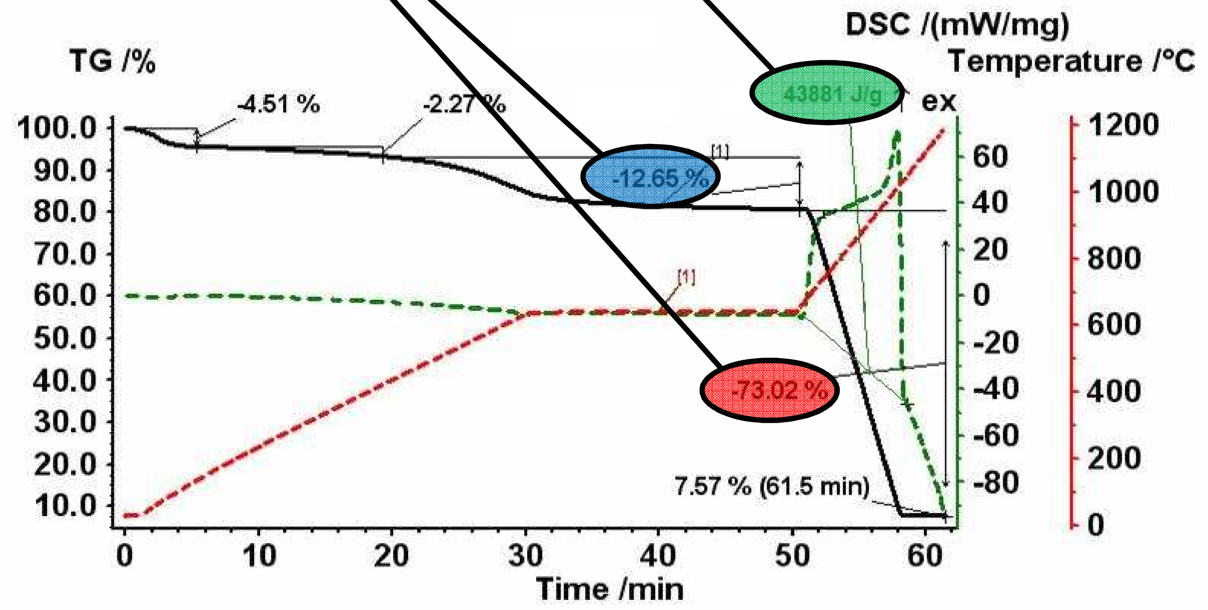
TGA/DSC

Embrapa Solos

Hydrolyzed



Biochar



What for?

Estimate stability;

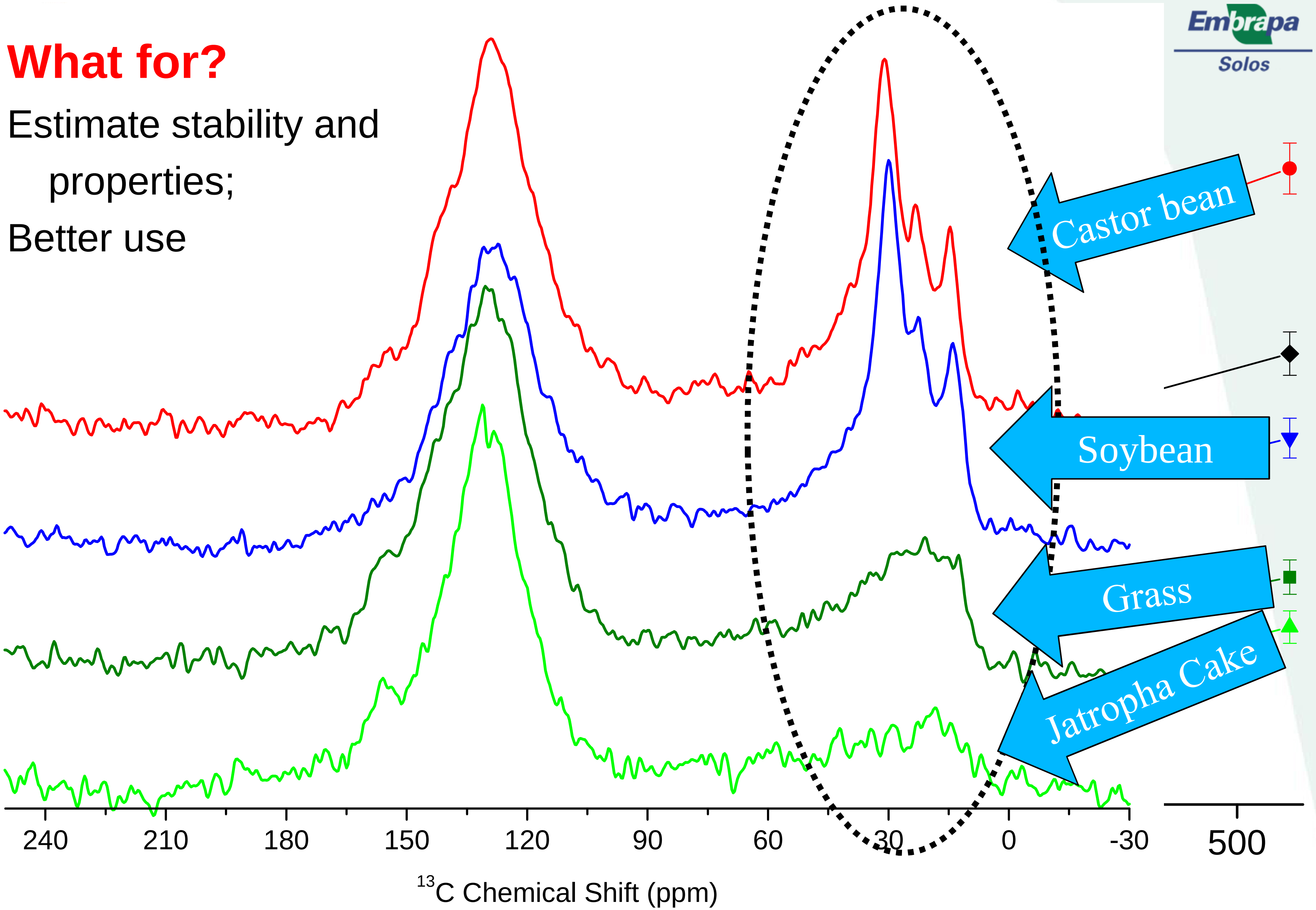
Better use

Rittl et al.

What for?

Estimate stability and properties;

Better use



Rittl et al.

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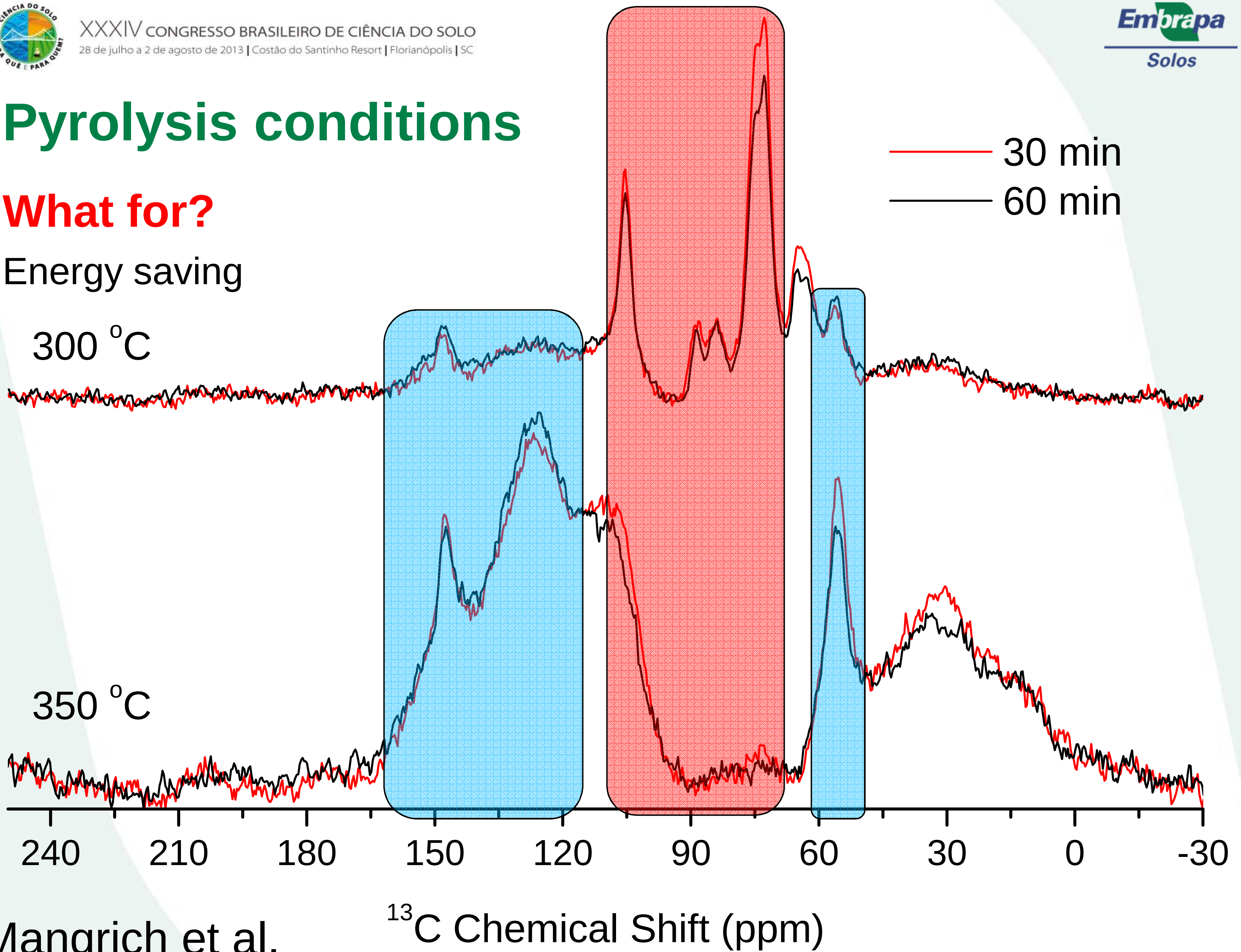
Embrapa Solos

Pyrolysis conditions

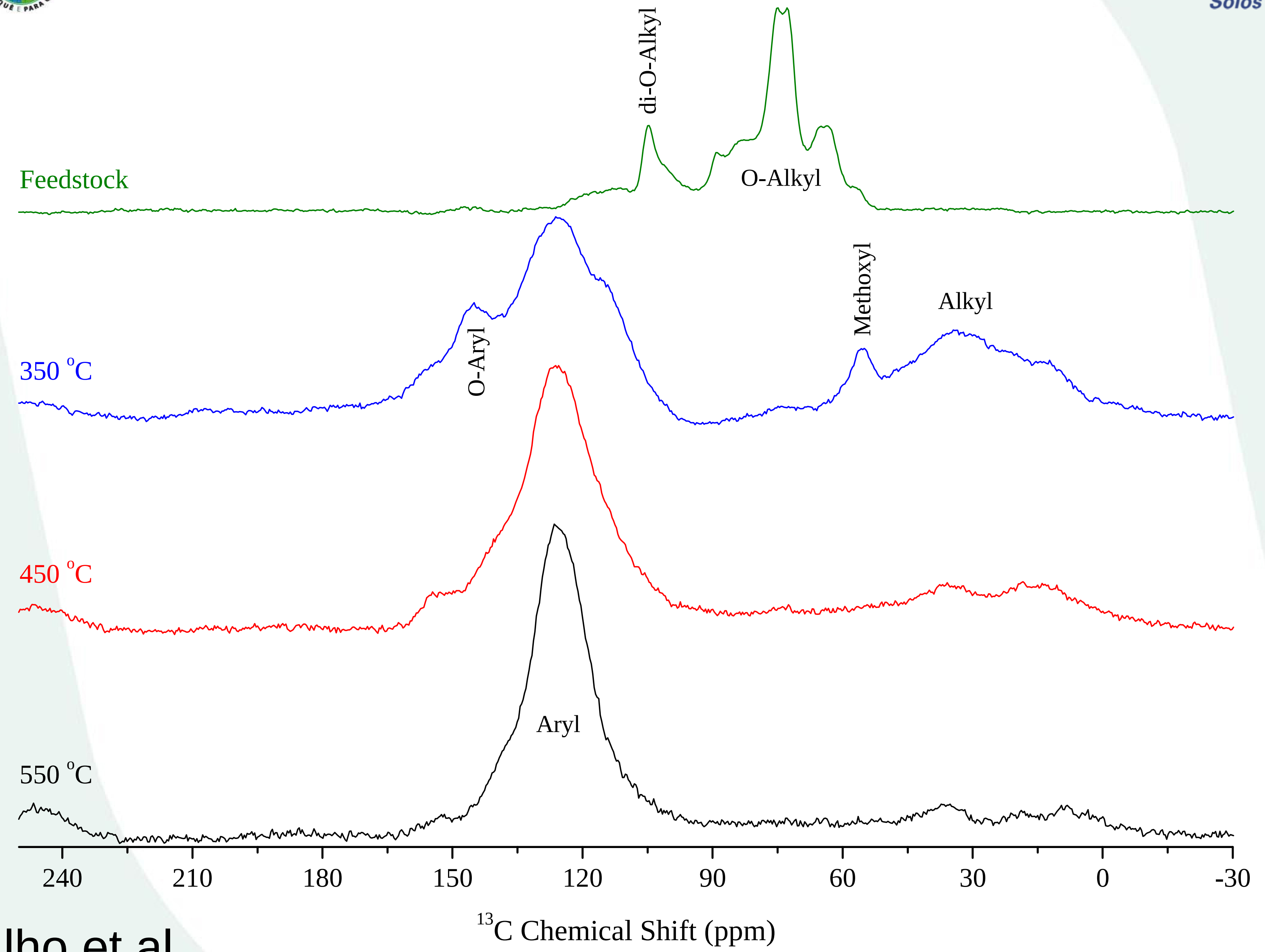
What for?

Energy saving



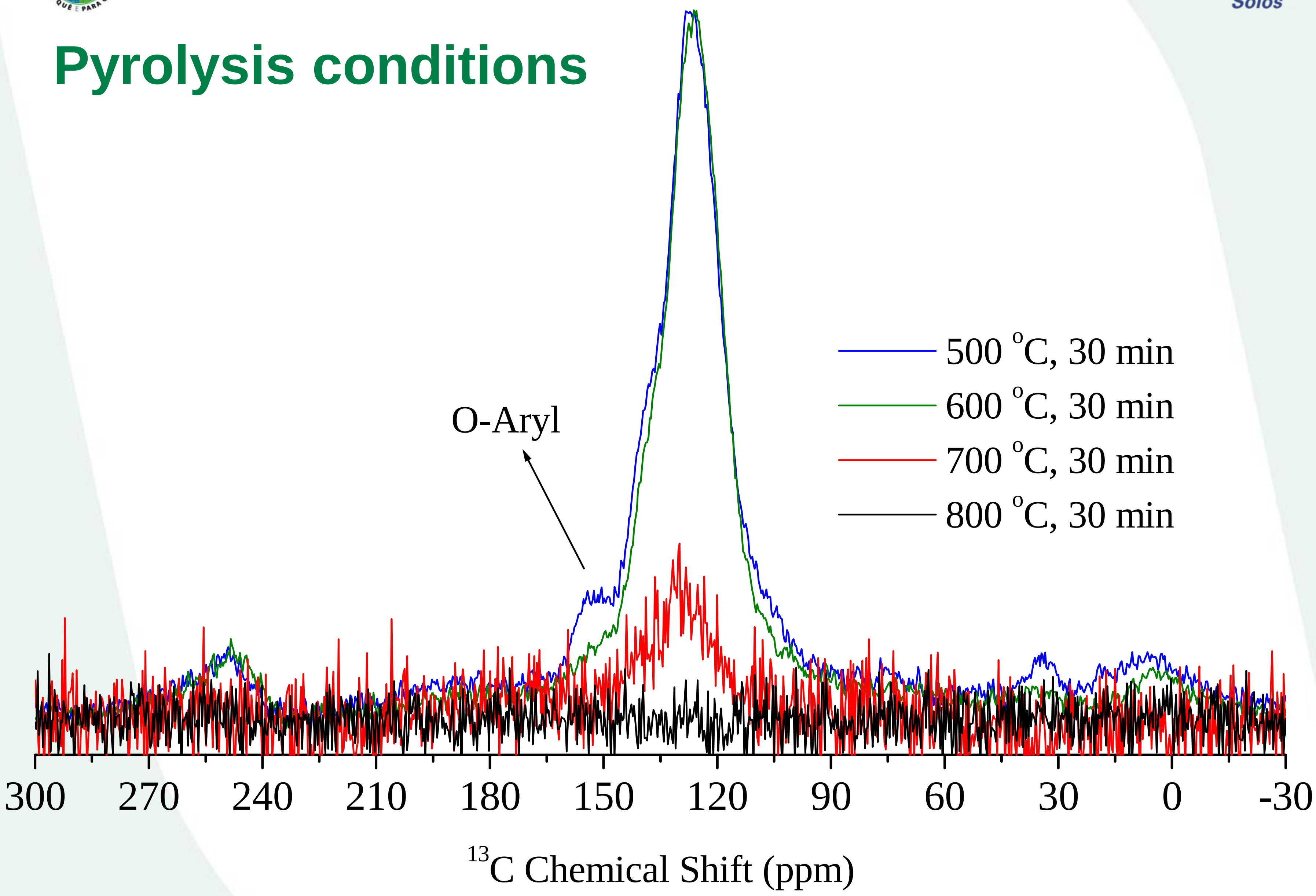
Mangrich et al.

^{13}C NMR



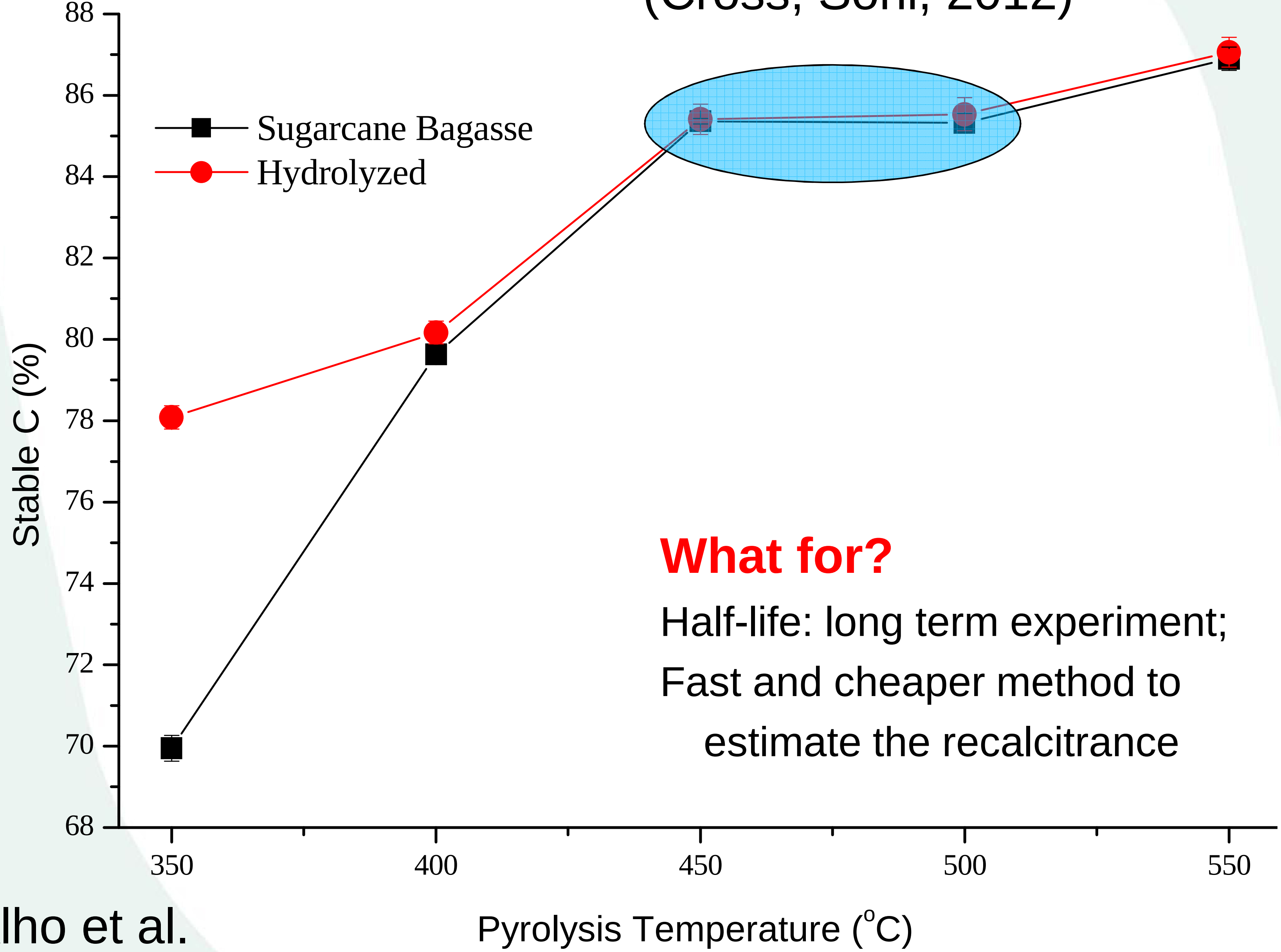
Alho et al.

Pyrolysis conditions



Thermochemical oxidation

(Cross; Sohi, 2012)



What for?

Half-life: long term experiment;

Fast and cheaper method to estimate the recalcitrance

Alho et al.

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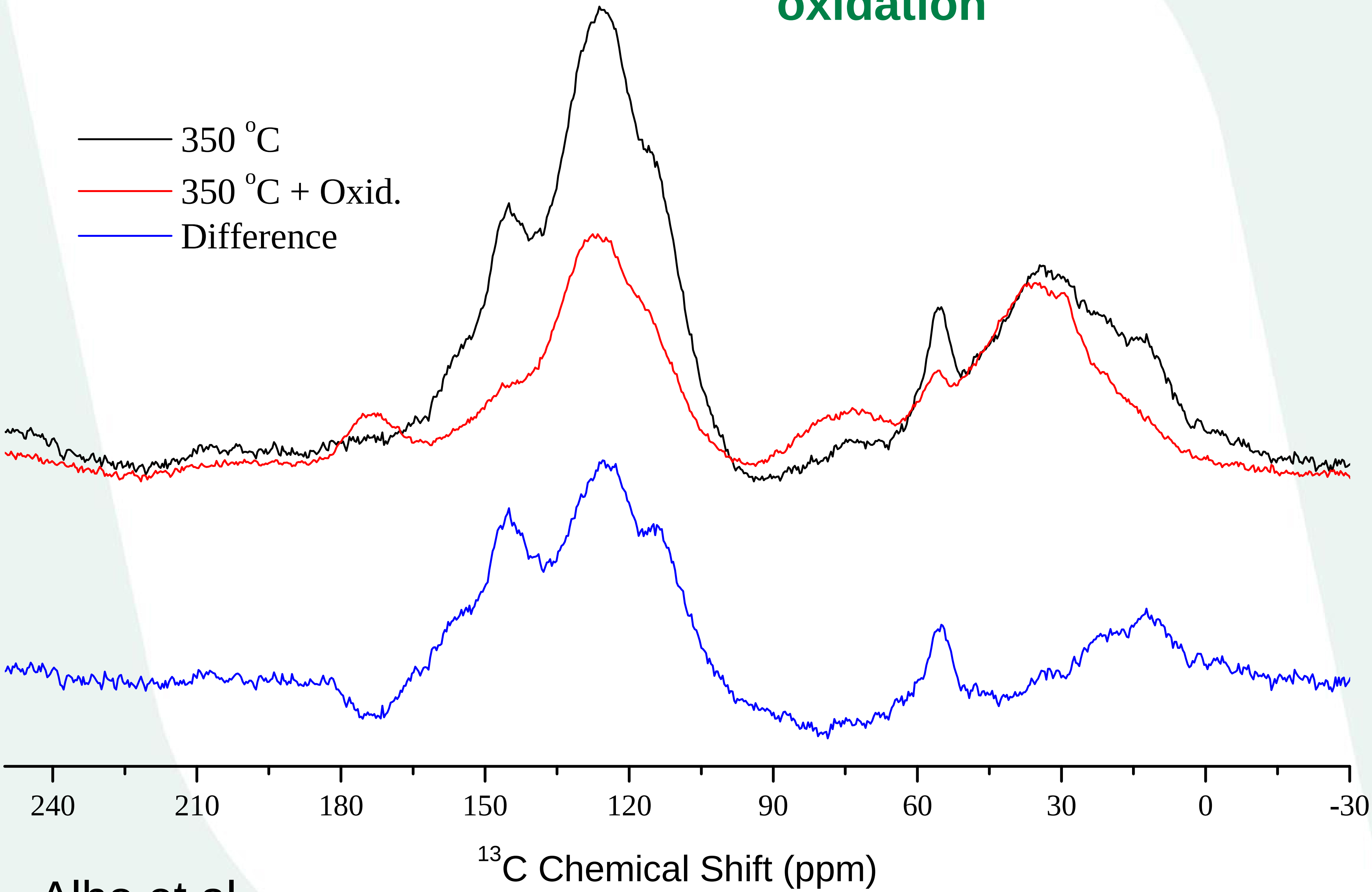
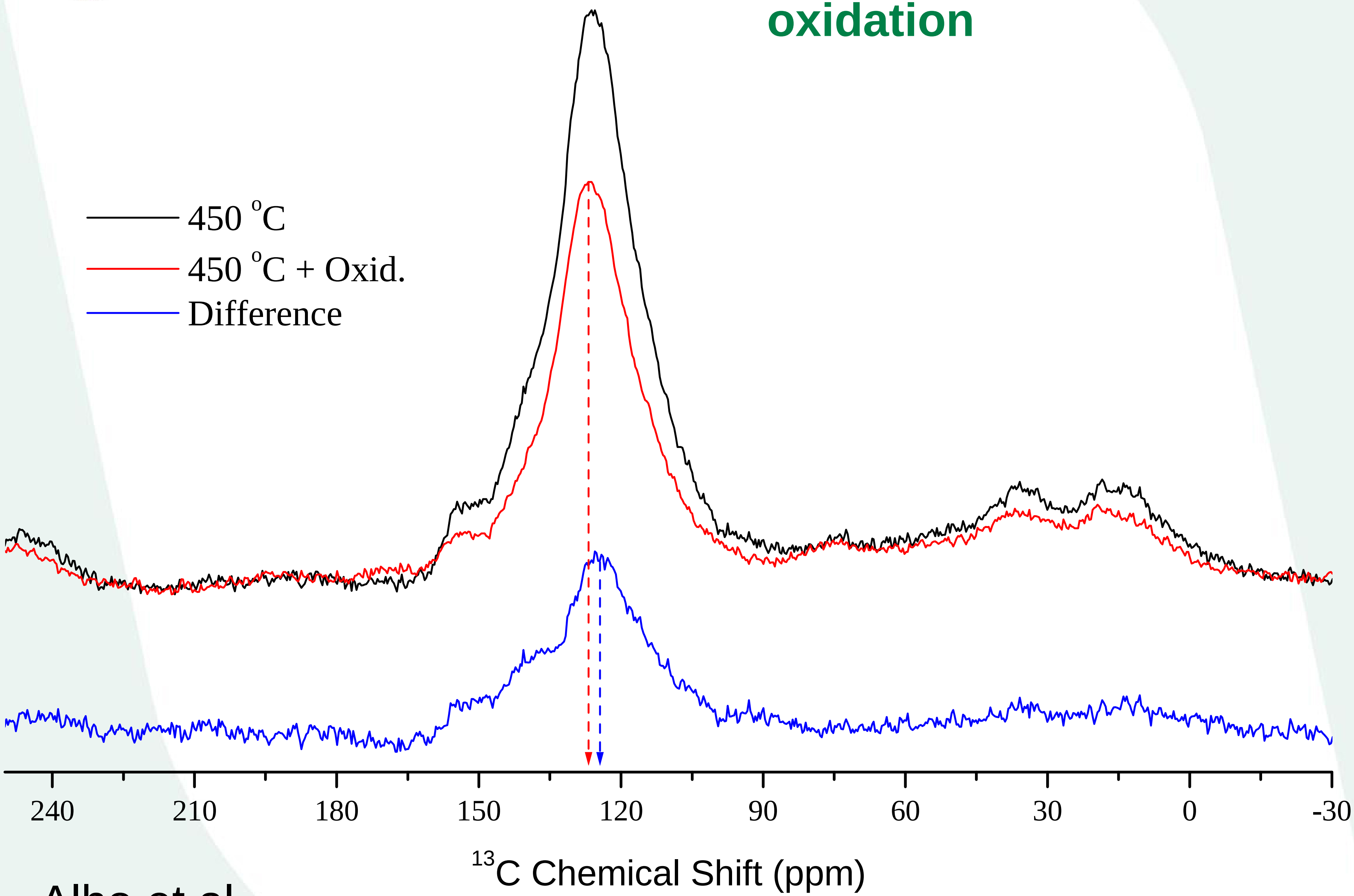
NMR after Thermochemical oxidation

Embrapa Solos



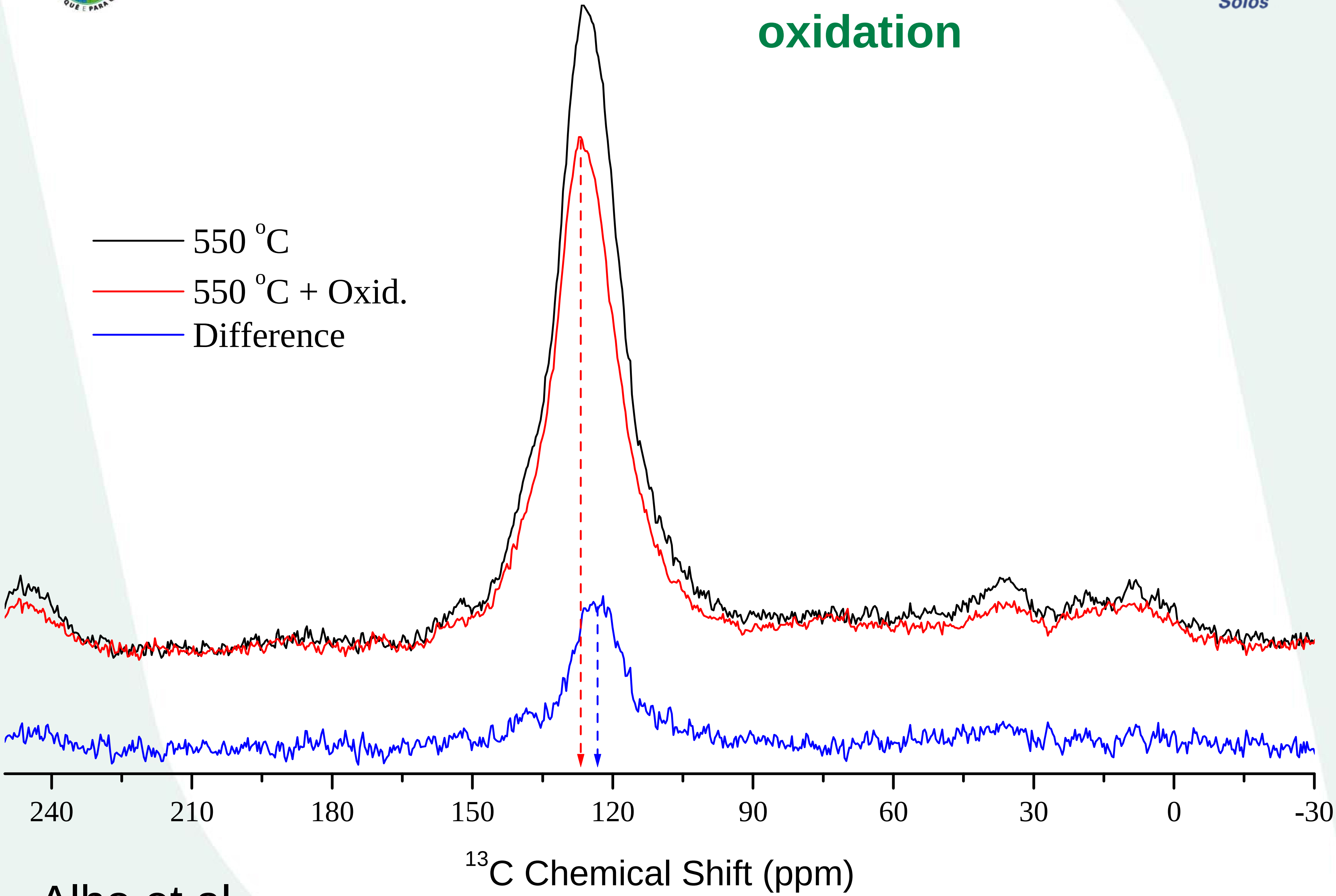
Alho et al.

NMR after Thermochemical oxidation



Alho et al.

NMR after Thermochemical oxidation



Alho et al.

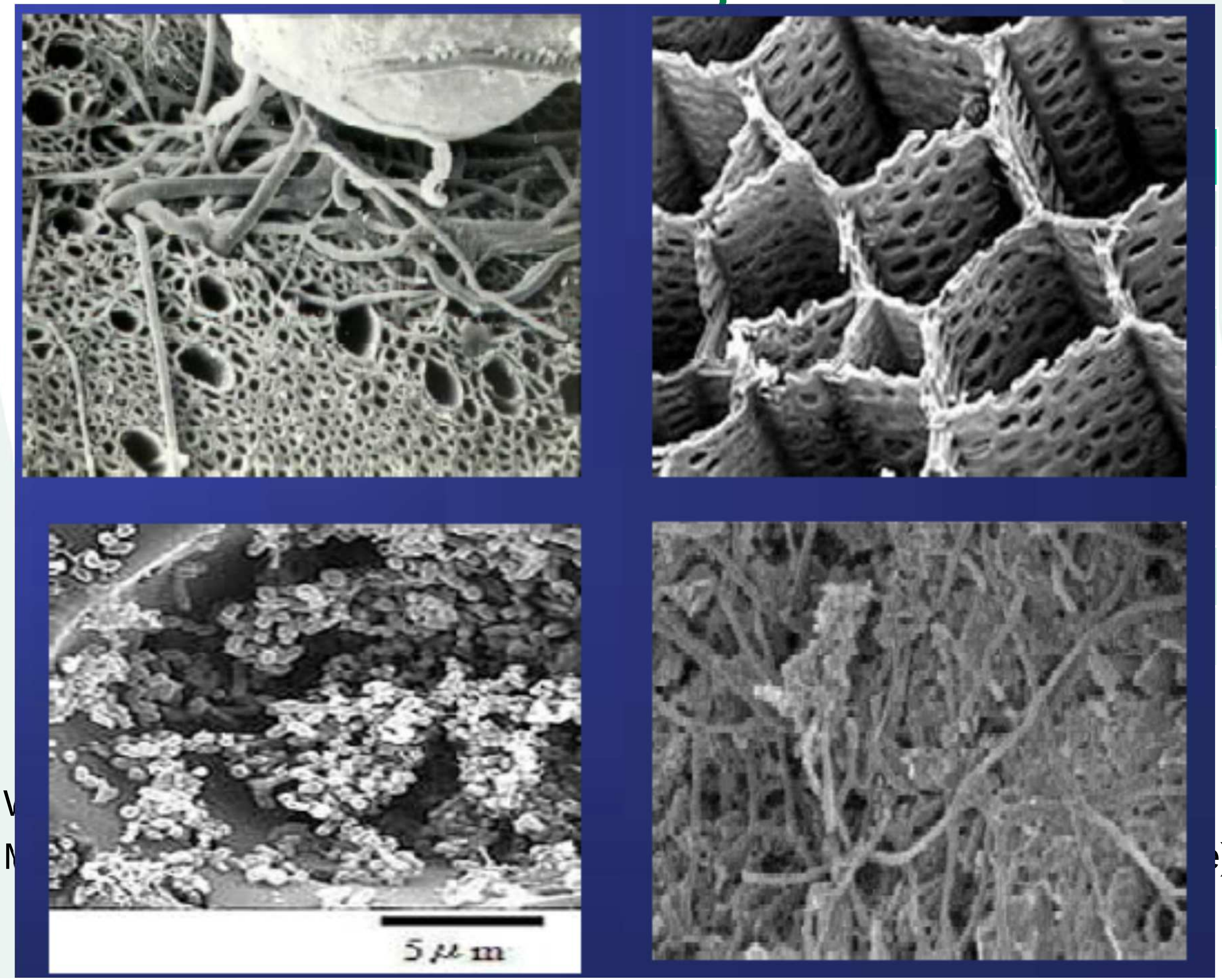
Water regulation and purification

Surface Area and Porosity

Material	Minimum	Average	Maximum
	Specific Surface Area ($m^2\ g^{-1}$)		
Biochar (n=33)	0.4	31	222
Activated Charcoal (n=33)	55	631	1287

Kadirvelu et al., 2005; Brum et al., 2008; Nabais et al., 2008; 2010; 2011; 2013; Brewer et al., 2009; 2011; Novak et al., 2009; Carrier et al., 2010; Song and Guo, 2011; Kim et al., 2012; Anderson et al., 2013

Water regulation and purification



- V
- M e)

Primary production; Water; Nutrient cycling

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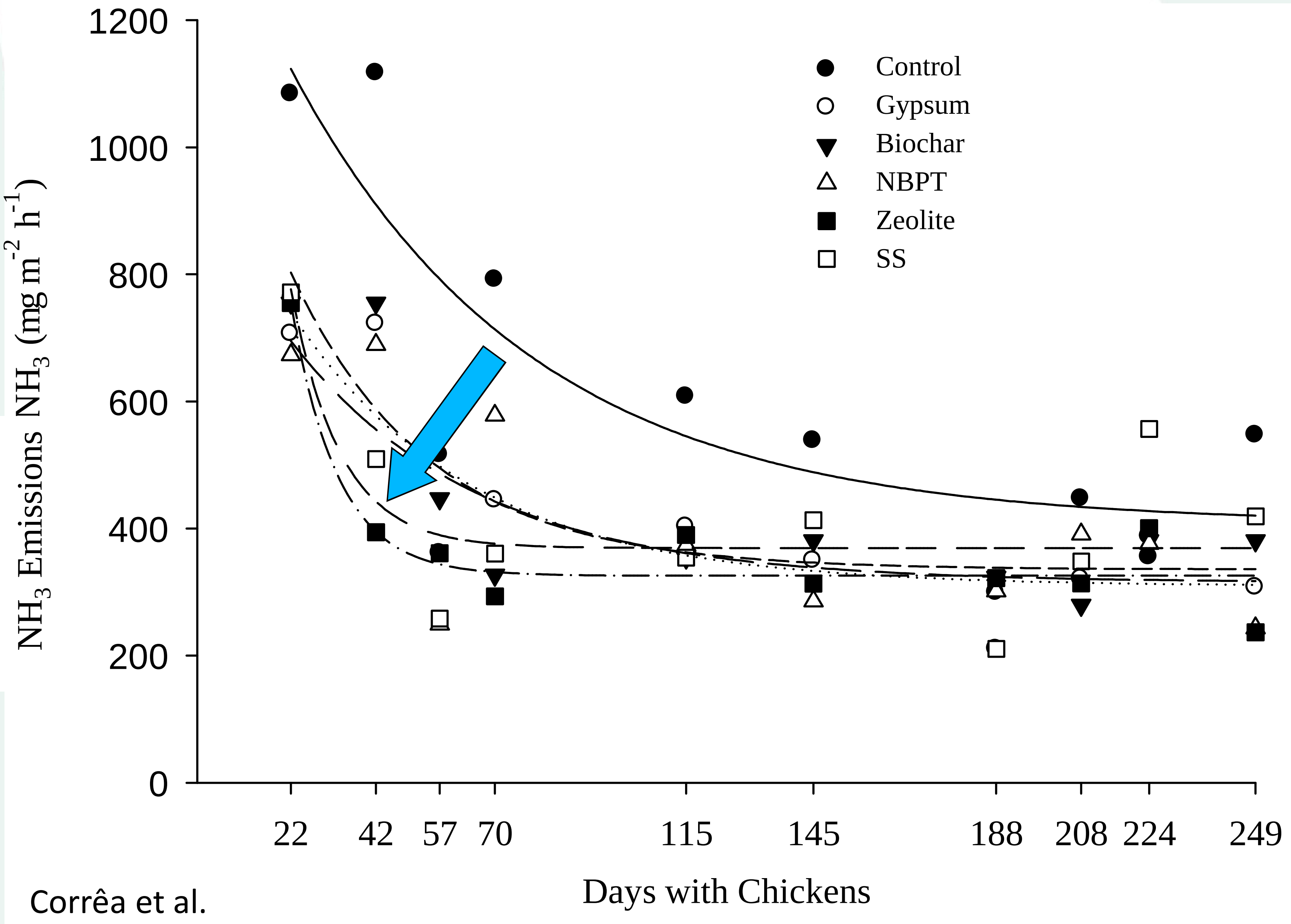
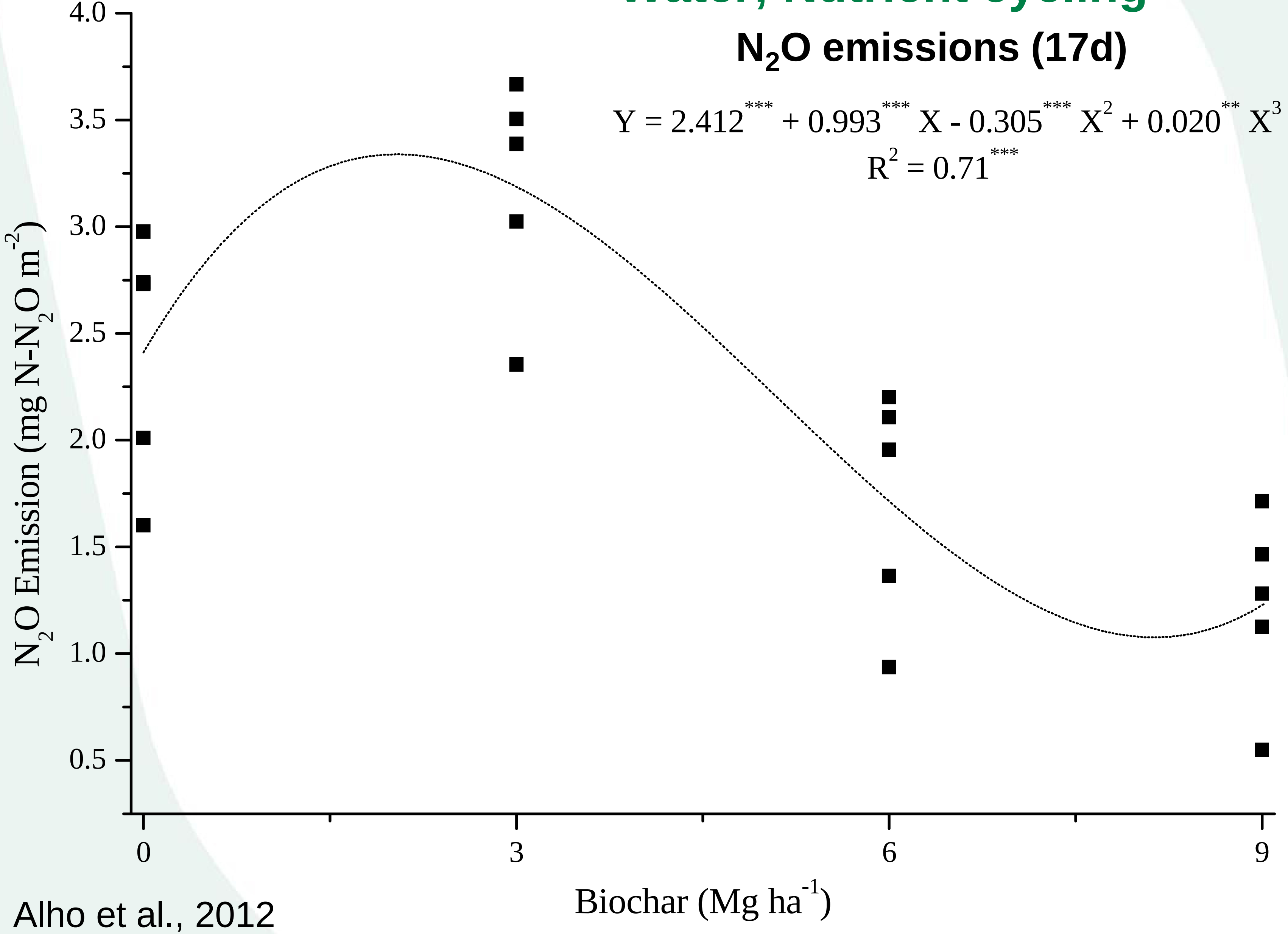
NH_3 emission



Corrêa et al.

GGE ⇒ Climate regulation; Water; Nutrient cycling

N_2O emissions (17d)



Alho et al., 2012

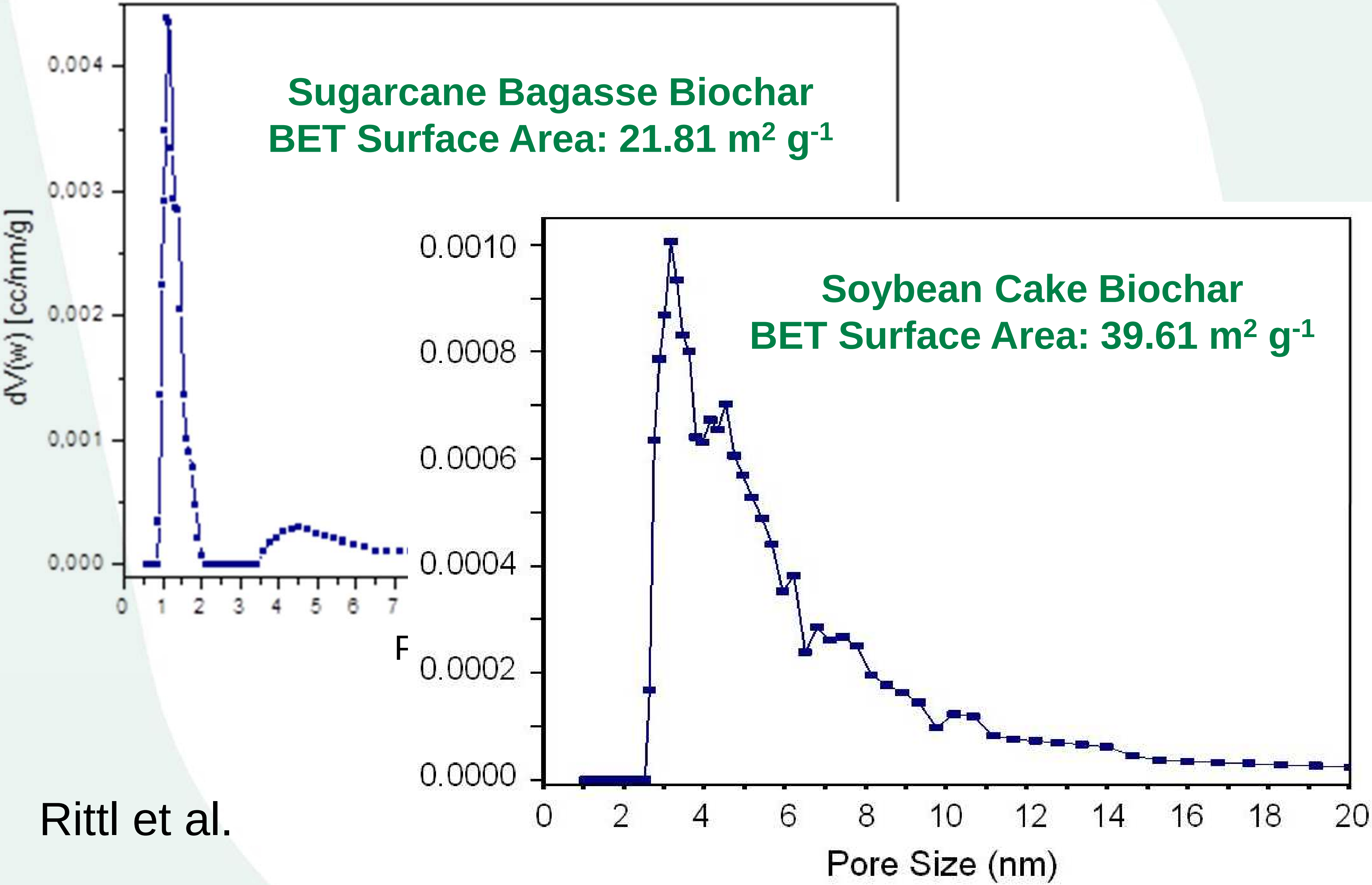
GGE ⇒ Climate regulation; Water; Nutrient cycling

N_2O emissions (complete cycle – 108d) *Oryza sativa*

Charcoal Mg ha^{-1}	Total Emission. g $N\text{-}N_2O$ m^{-2}
0	39.61 b
8	81.40 ab
16	62.41 b
32	114.40 a
F	11.34
CV (%)	37.94

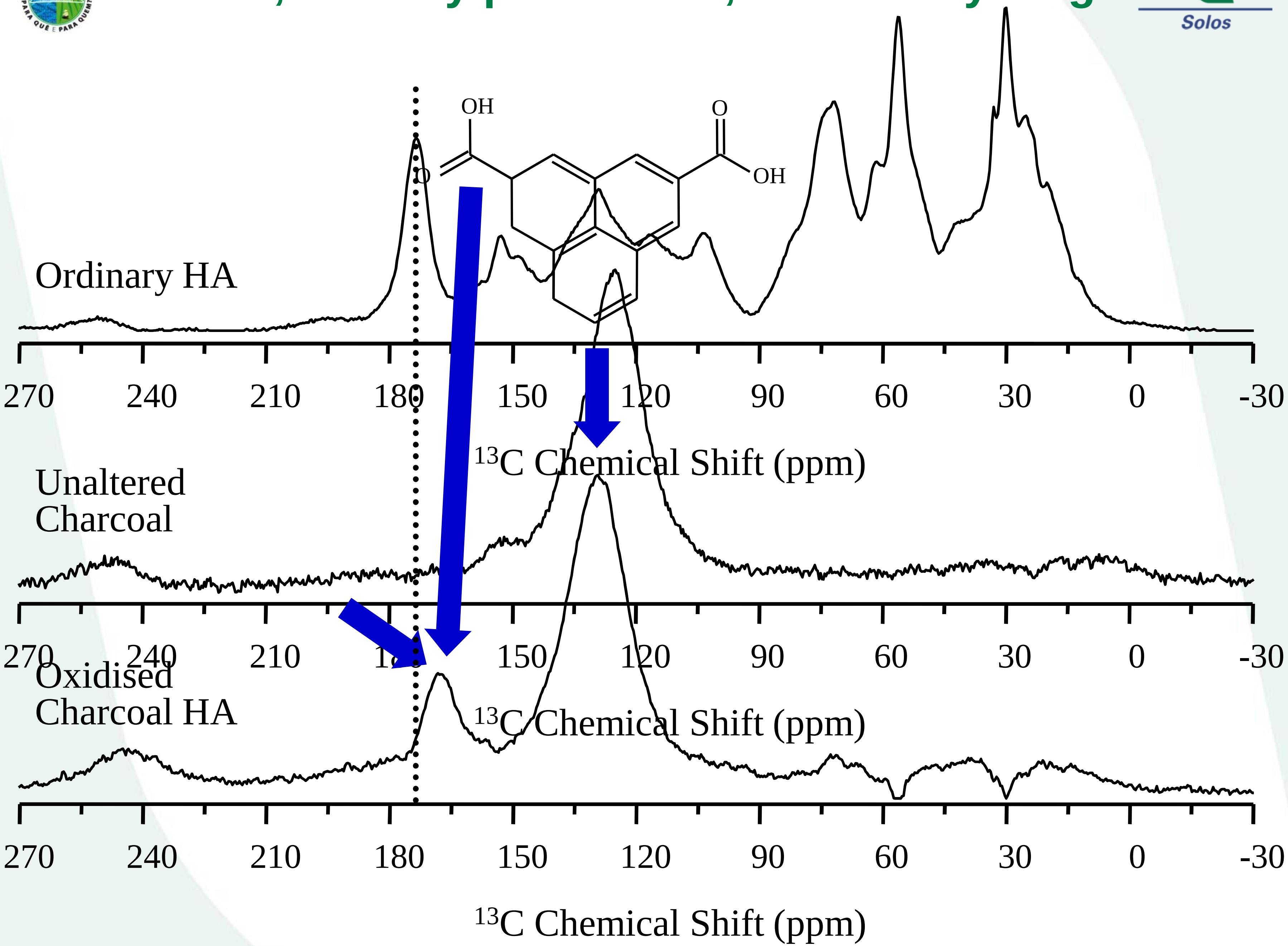
Madari et al., 2010

Pore size distribution



Rittl et al.

Water; Primary production; Nutrient cycling



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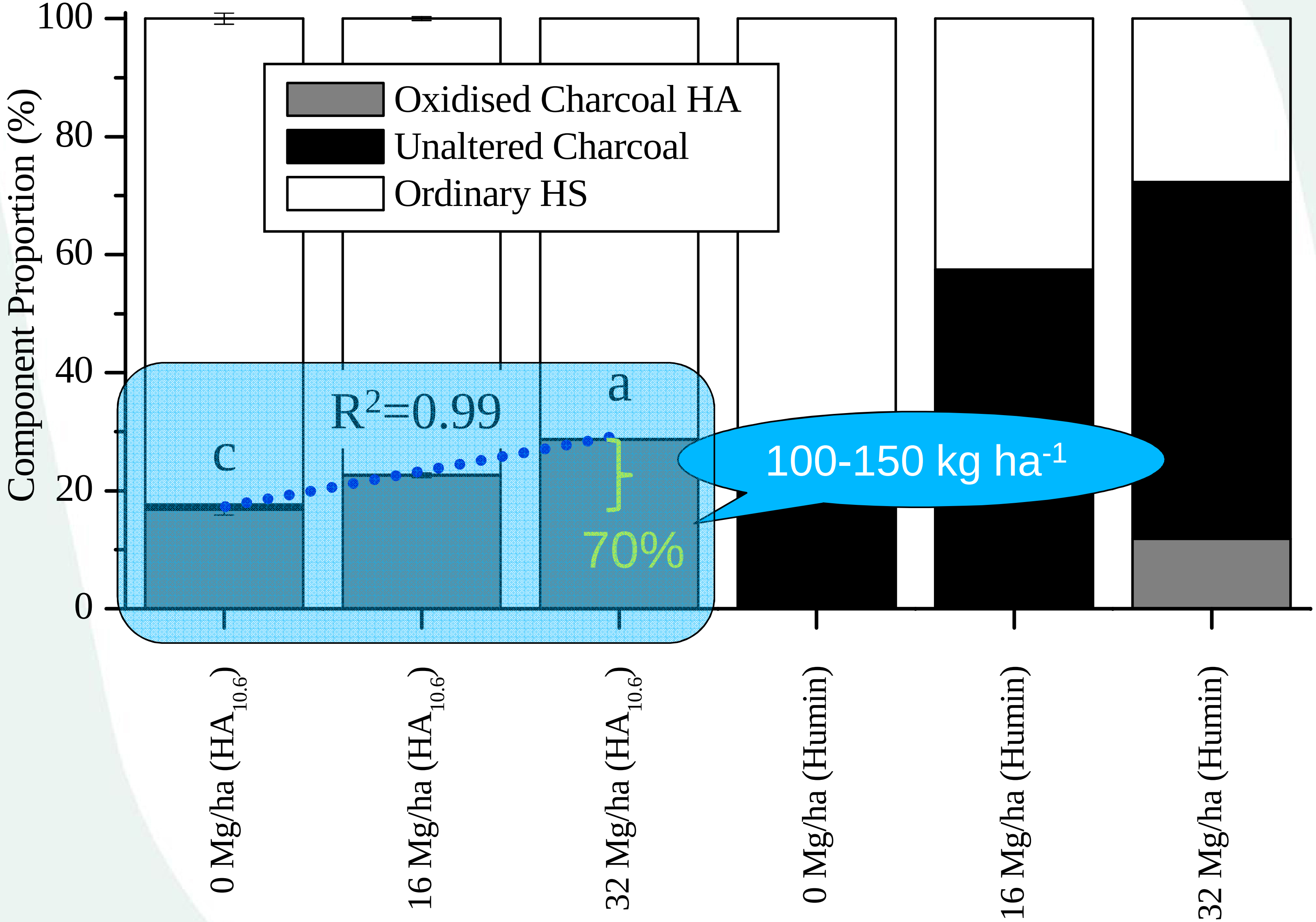
Natural oxidation (2 y)

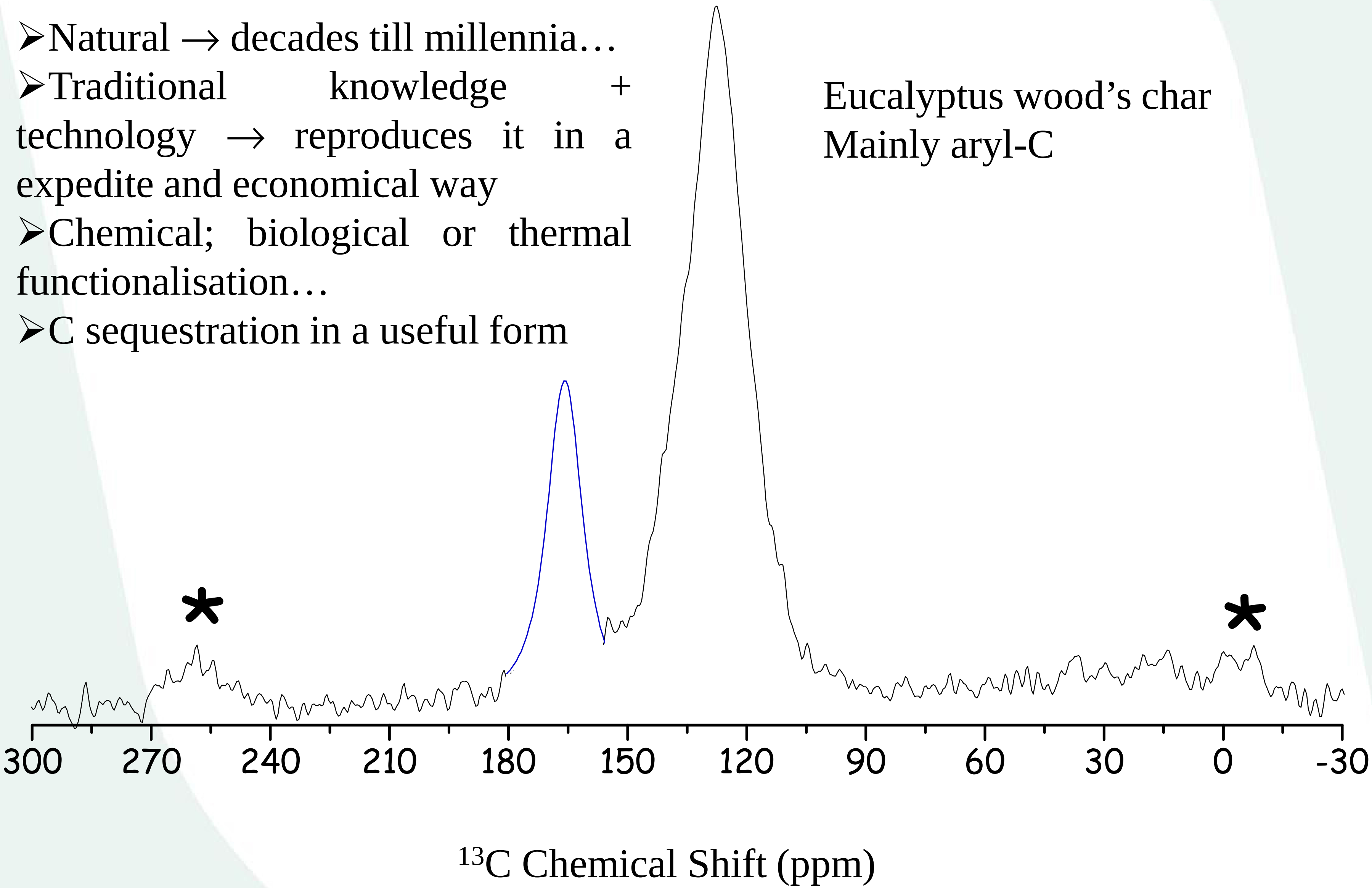
Embrapa Solos



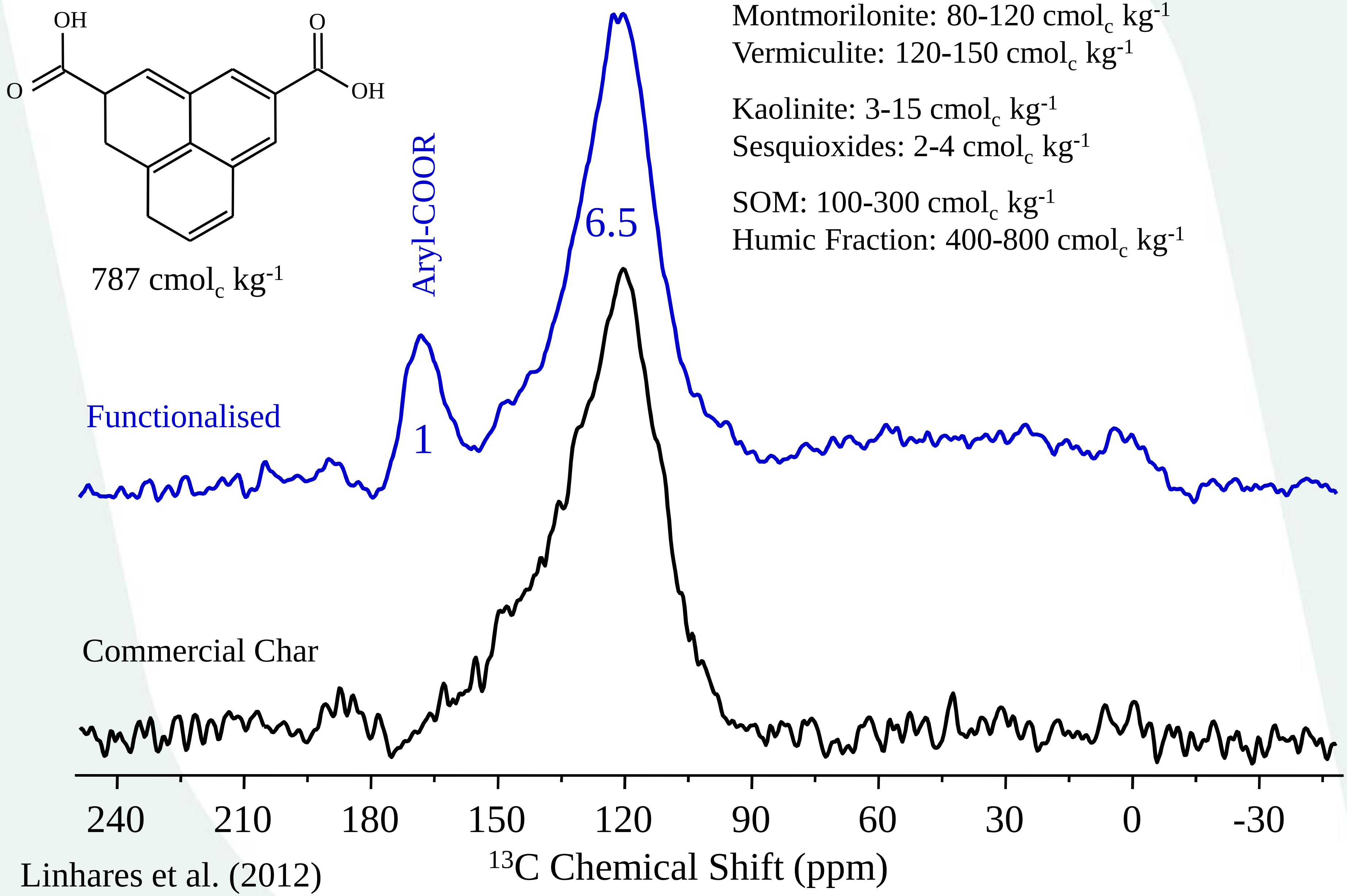
Madari et al.

Model

- ➢Natural → decades till millennia…
- ➢Traditional knowledge + technology → reproduces it in a expedite and economical way
- ➢Chemical; biological or thermal functionalisation…
- ➢C sequestration in a useful form



Chemical Functionalisation



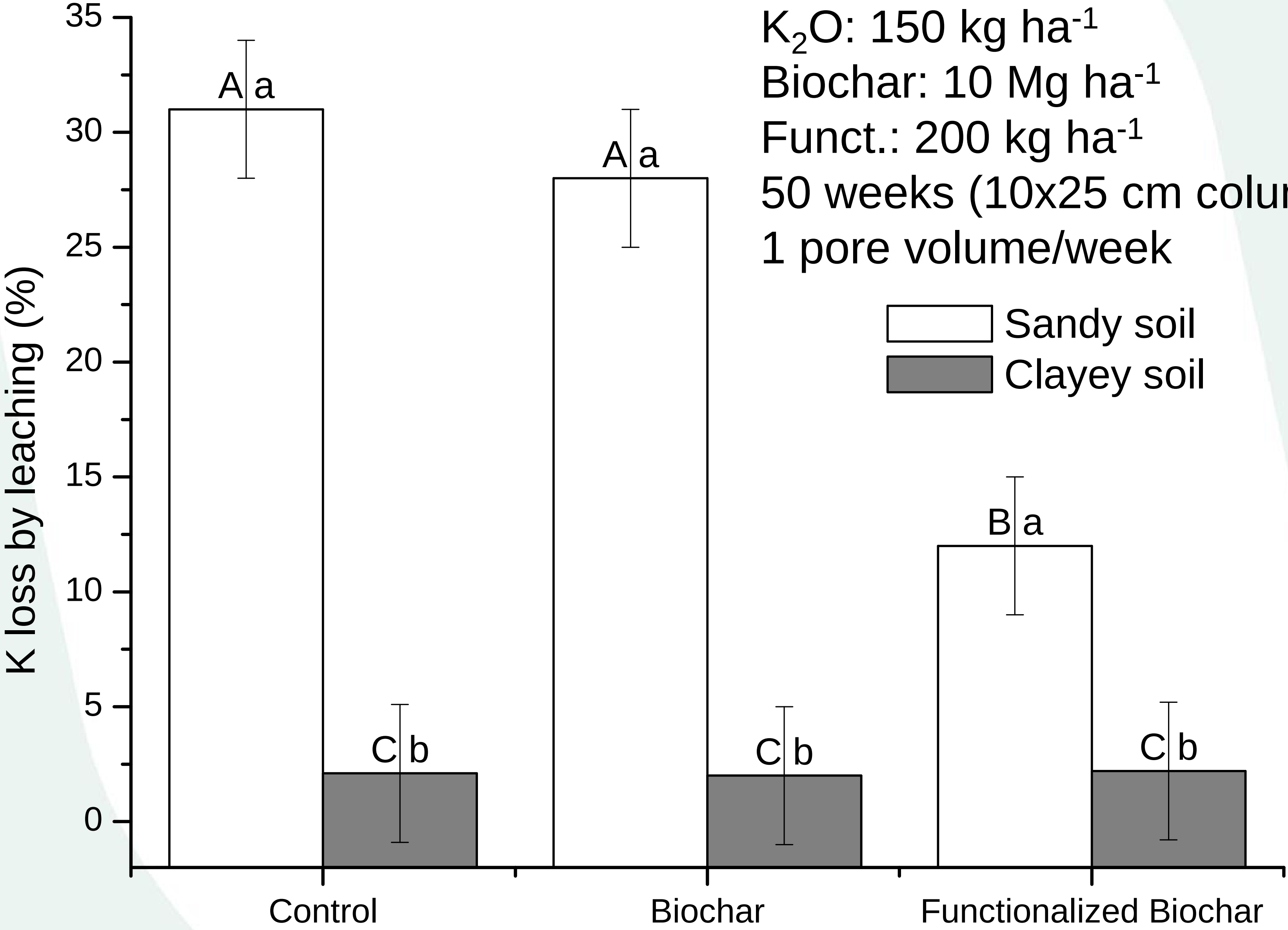
Montmorilonite: 80-120 cmol$_c$ kg^{-1}
Vermiculite: 120-150 cmol$_c$ kg^{-1}

Kaolinite: 3-15 cmol$_c$ kg^{-1}
Sesquioxides: 2-4 cmol$_c$ kg^{-1}

SOM: 100-300 cmol$_c$ kg^{-1}
Humic Fraction: 400-800 cmol$_c$ kg^{-1}

Linhares et al. (2012)

Water; Primary production; Nutrient cycling



K_2O: 150 kg ha^{-1}
Biochar: 10 Mg ha^{-1}
Funct.: 200 kg ha^{-1}
50 weeks (10x25 cm column)
1 pore volume/week

Brazilian nut shell

Paiva et al.

Charring at field scale

Retort kiln (Adapted Adam Retort)

Paiva et al.

Biomass Composition and Pyrolysis Yield

Sample	Lignin (%)	Extrative (%)	Holocellulose (%)
Epicarp	37.67	4.49	57.84
Mesocarp	31.87	2.06	66.07

	Solid (%)	Condensable (%)	Volatiles (%)
350 ° C			
Epicarp	58.70	17.78	23.52
Mesocarp	41.59	45.35	13.06
450 ° C	Solid (%)	Condensable (%)	Volatiles (%)
Epicarp	50.15	18.04	31.81
Mesocarp	32.64	49.74	17.62
550 ° C	Solid (%)	Condensable (%)	Volatiles (%)
Epicarp	44.89	28.06	27.06
Mesocarp	30.94	48.52	20.54

Paiva et al.

Biomass and char composition

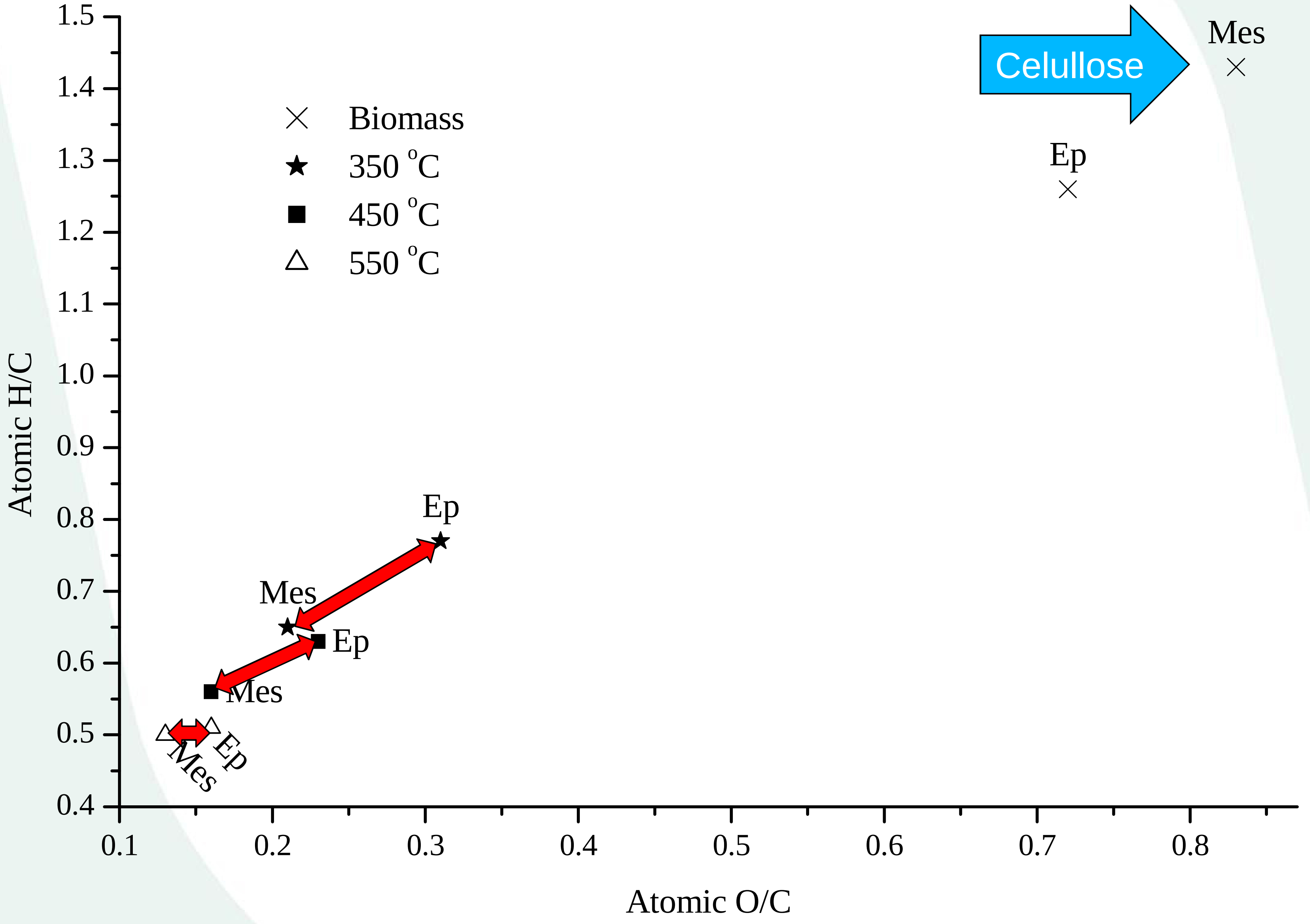
Treatment	Moisture (%)	Ashes (%)	Volatiles (%)	Fixed C (%)	pH	Conductivity
Epicarp						
350° C	2.35	11.85	33.08	55.07	8.32	1.49
450° C	3.83	13.18	23.67	63.16	9.99	2.17
550° C	0.95	15.22	14.44	70.35	10.06	2.57
Mesocarp						
350° C	0.10	1.94	30.06	68.00	7.43	0.17
450° C	0.01	2.26	23.89	73.86	7.86	0.19
550° C	0.23	2.52	18.09	79.39	8.04	0.25

Paiva et al.

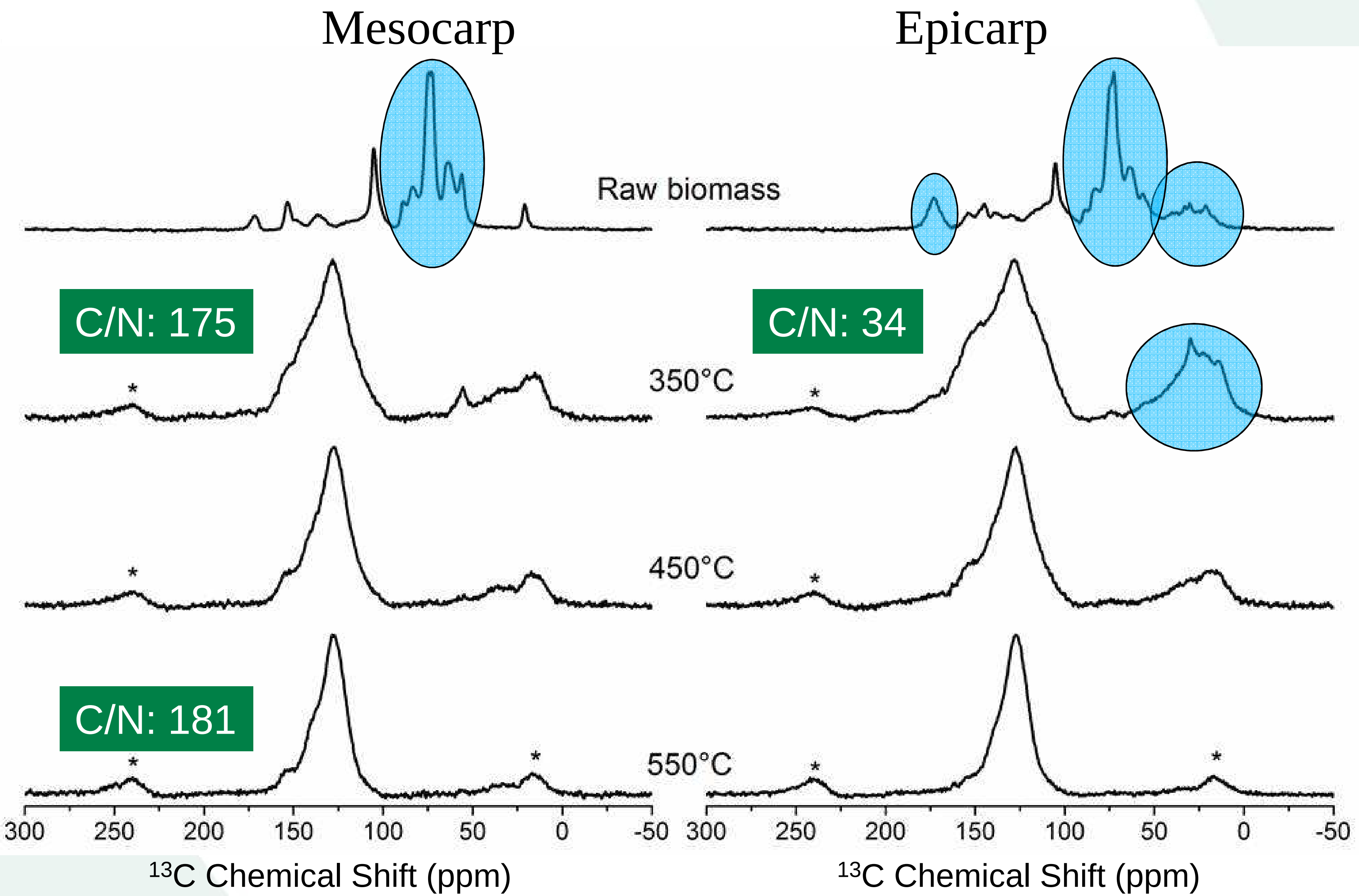
Biomass and char composition

Treatment	C%	H%	N%	O%	C/N	H/C	O/C
Epicarp tissue							
In natura	47.54	5.01	1.73	45.72	32.06	1.26	0.72
350 ° C	66.30	4.24	2.30	27.16	33.63	0.77	0.31
450 ° C	72.09	3.78	2.26	21.87	37.21	0.63	0.23
550 ° C	77.78	3.29	2.21	16.73	41.06	0.51	0.16
Mesocarp tissue							
In natura	44.84	5.34	0.47	49.35	111.30	1.43	0.83
350 ° C	74.94	4.06	0.50	20.50	174.86	0.65	0.21
450 ° C	78.80	3.66	0.53	17.00	173.46	0.56	0.16
550 ° C	82.12	3.43	0.53	13.92	180.77	0.50	0.13

Paiva et al.


Celullose
Mes
Ep
Biomass
350 °C
450 °C
550 °C
Ep
Mes
Ep
Mes
Ep
Mes
Atomic H/C
Atomic O/C
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

^{13}C-NMR



Paiva et al.

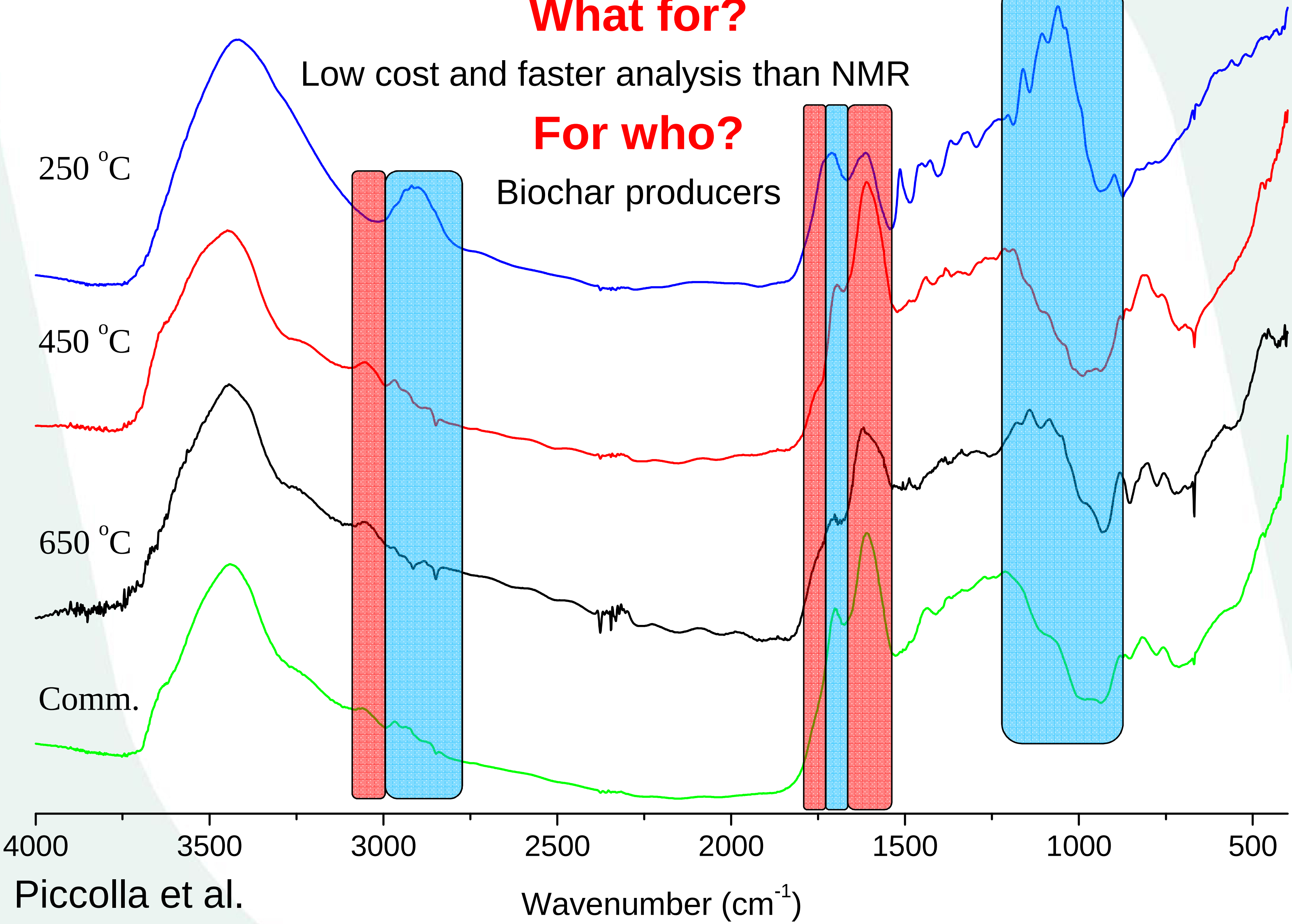
Mid Infrared

What for?

Low cost and faster analysis than NMR

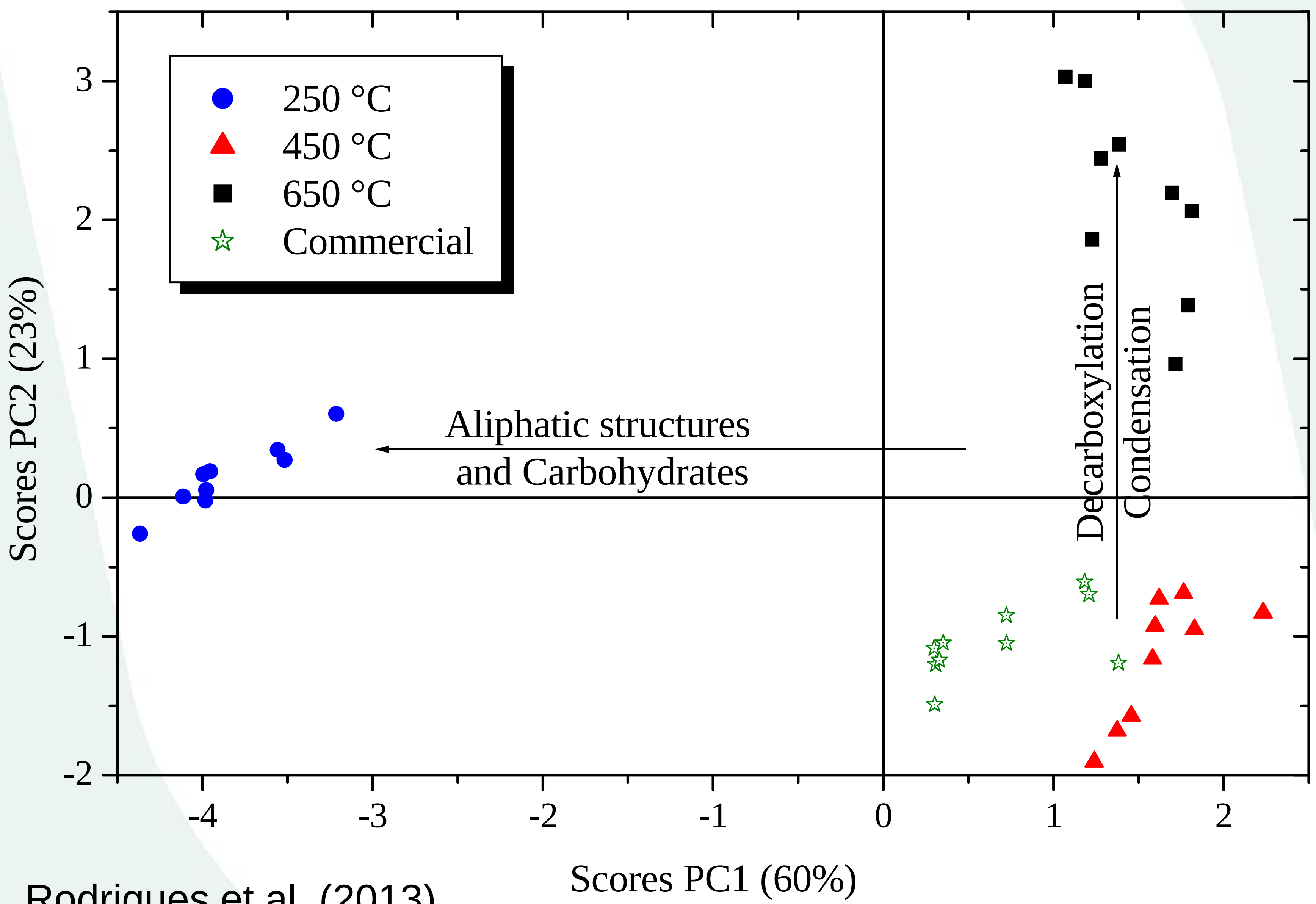
For who?

Biochar producers



Piccolla et al.

Principal Component Analysis



Rodrigues et al. (2013)

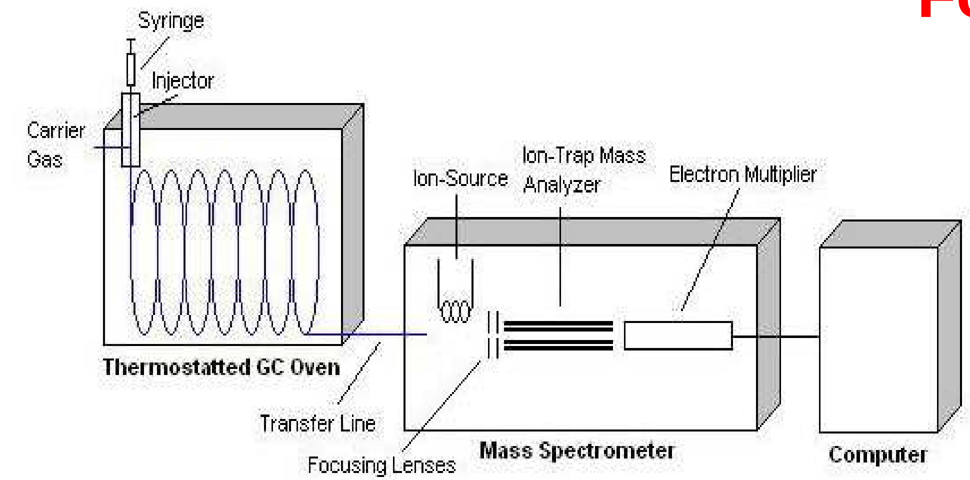
Pyrogenic carbon quantification: BPCA method (Glaser)

Gas-Mass cromatography

What for? Green chemistry;

For who? Worker, environment

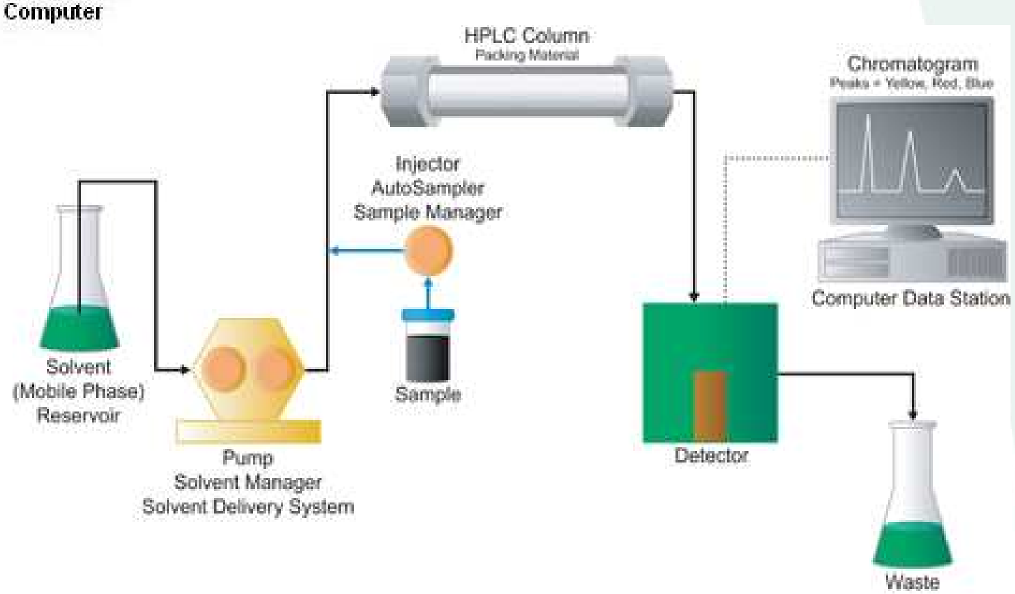
Specific C_{py} markers



- Difficulty to separate all BPCA

- 10 more steps for sample preparation;
- More expensive;
- Time consumer;
- Pyridine.

UV-High performance liquid cromatography



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