

Generating Biochars from Biomass Residues: Impacts on Compost, Soil, and Plants

EUBCE side event: Biomass residue valorisation in the Global South



Jindo Keiji

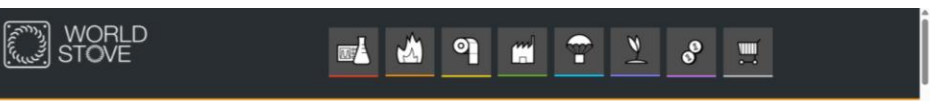
Wageningen University and Research, The Netherlands

22 May, 2026 Den Haag

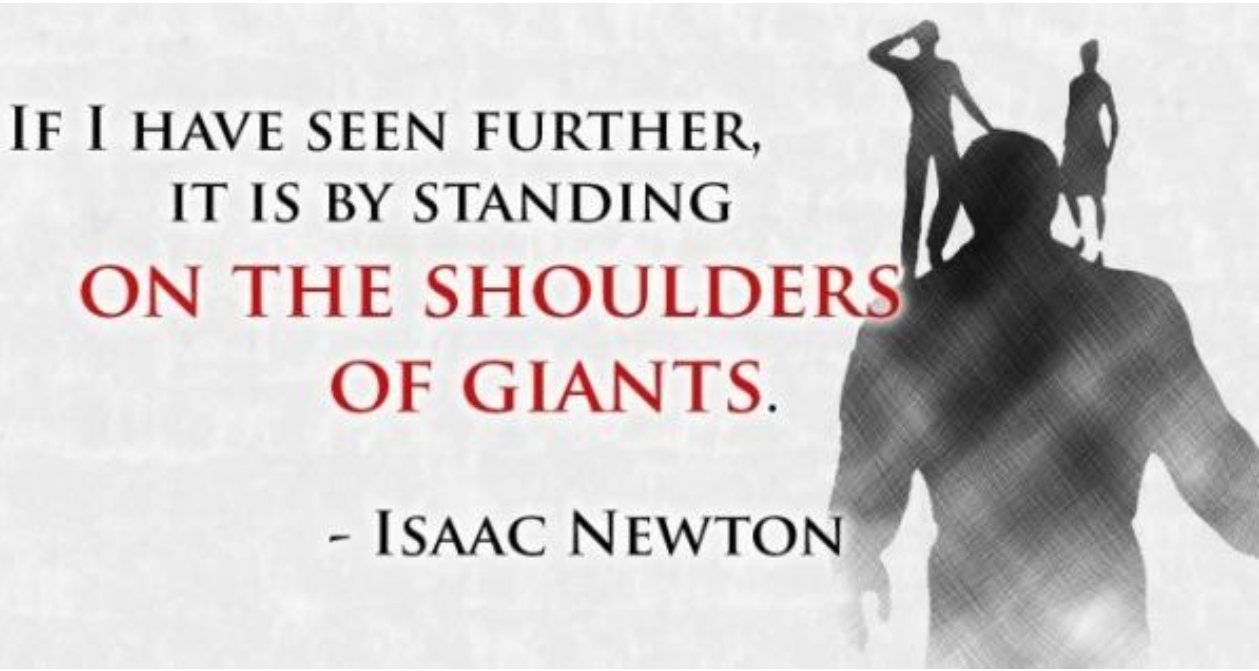
Pioneers of biochar in the Global South:




“Worldstove Lucia” (18-20 years ago) (Ethiopia, Zambia, and Sierra Leone, and Haiti) DOI: 10.1201/b13788-13



Stoves



Paper about *Terra Preta do indio* in 2003 (23 YEARS AGO)

 *Plant and Soil* **249**: 343–357, 2003.
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Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments

Johannes Lehmann^{1,2,4}, Jose Pereira da Silva Jr.³, Christoph Steiner², Thomas Nehls², Wolfgang Zech² & Bruno Glaser²

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Social concern about Climate change



<http://www.g-green4good.org/services.htm>



<http://blogs.saschina.org/aplangpd/category/recycling/>







Photos taken in Paraguay



Typical low cost carbonization kiln made of a standard drum in Botswana

(source: Prof. Akashi)

Photos taken in Paraguay

Biochar of Rice husk in Africa (Benin)





Application of biochar (derived from cocoa residue) in Liberia





Crop Diversification in Brazil

Grilicidia (legume plant) & pineapple





Fertilization for agroforestry



Biochar



Pruned material



Poultry manure

1 : 7 : 1



2m



Variety of Biochar



Japanese oak (*Quercus serrata*), φ 8 cm



Rice straw







Apple tree (*Malus pumila*), φ 1-2 cm



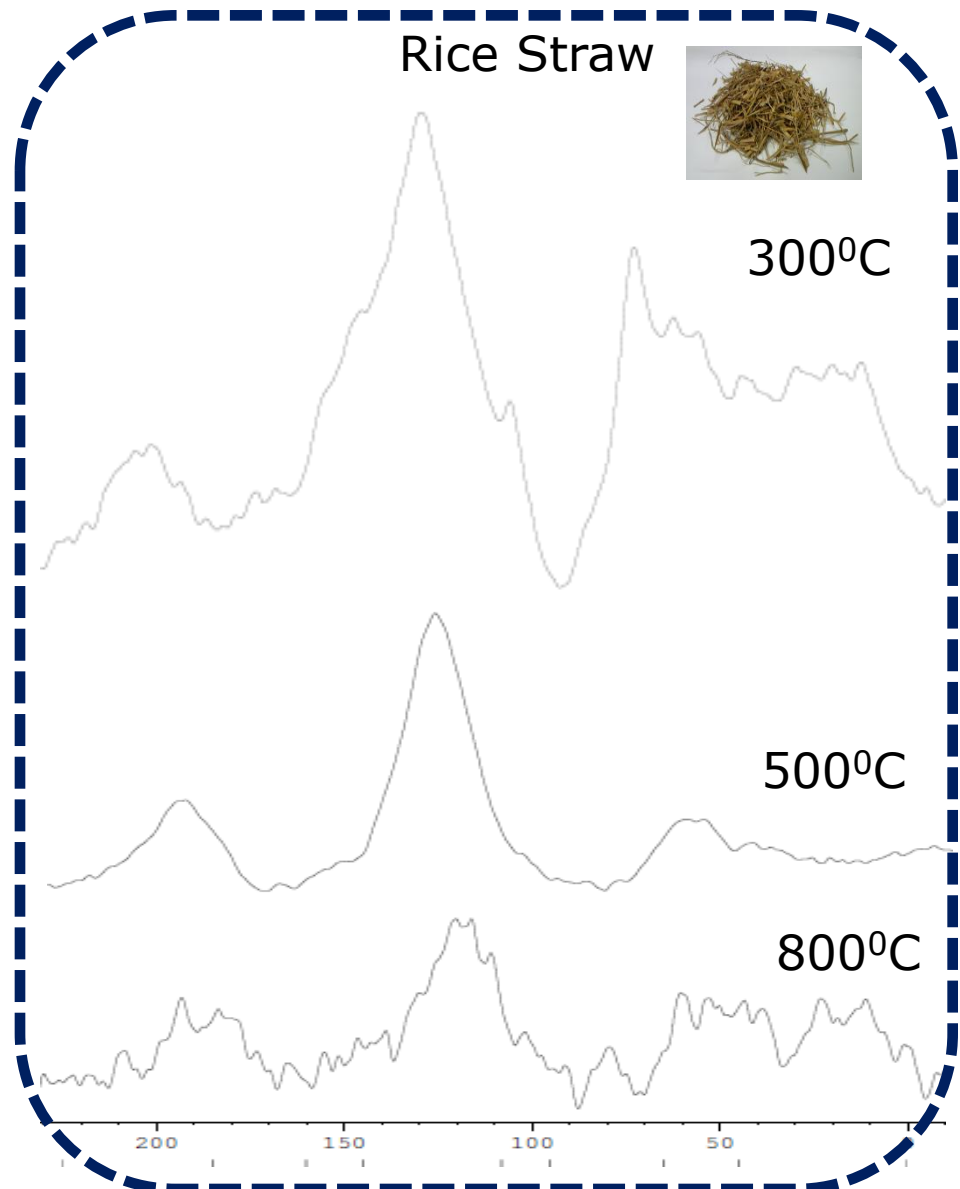
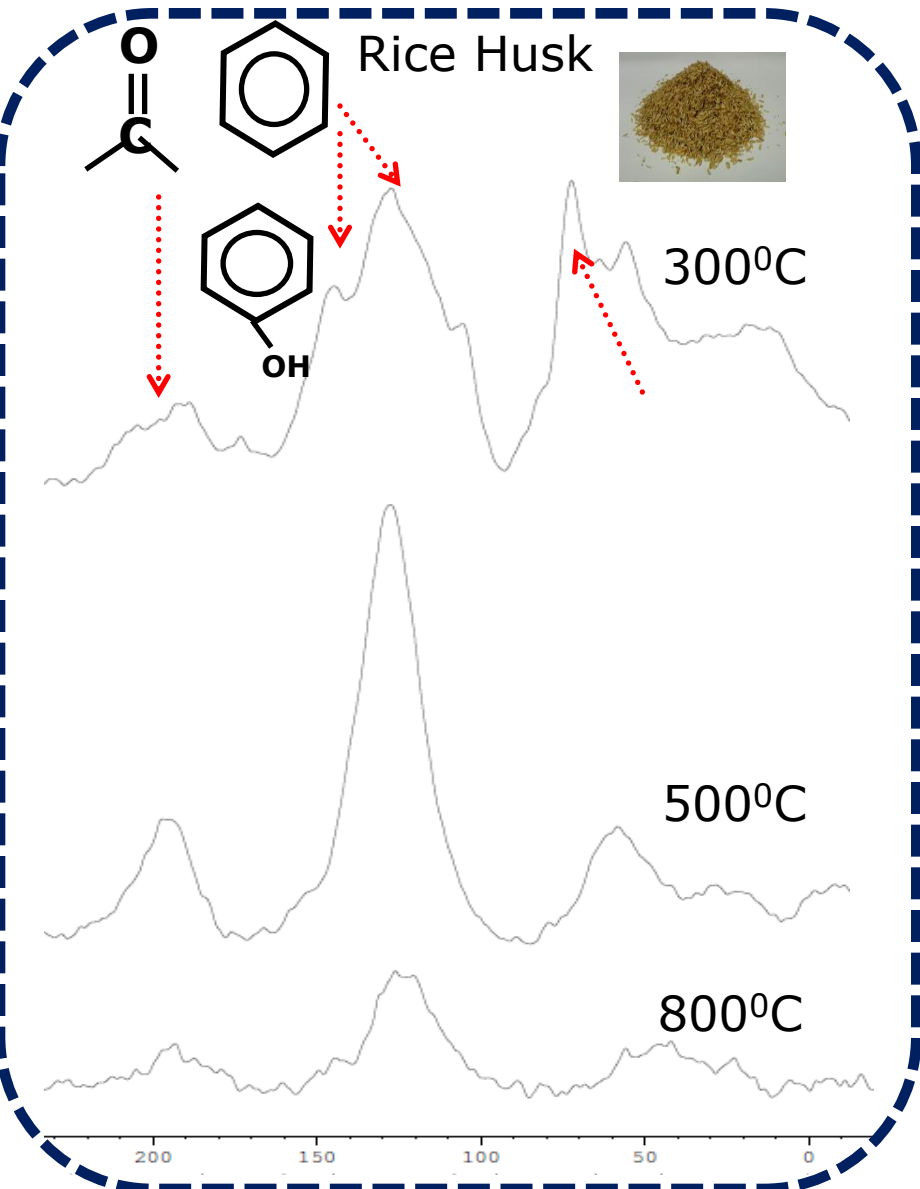
Rice hush



Physical Property of different biochars

Feed stocks	Temperature (°C)	Hold time (h)	Yield (%)	pH		MB adsorption/gDW		I ₂ adsorption (mg/gDW)		Surface
				Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.
Quercus serrata <i>(Oak tree)</i> 	400	10	35.8	6.43	0.04	3.90	0.28	38.66	0.04	5.60
	500	10	28.6	8.10	0.12	5.59	0.47	91.74	0.06	103.17
	600	10	22.0	8.85	0.07	5.51	0.39	131.27	1.47	288.58
	700	10	20.0	9.54	0.00	17.06	0.16	212.79	0.09	335.61
	800	10	19.1	9.68	0.03	29.38	0.47	250.28	1.40	398.15
Malus pumila <i>(Apple tree)</i> 	400	10	28.3	7.02	0.08	4.36	0.21	44.96	2.61	11.90
	500	10	16.7	9.64	0.07	12.04	0.38	97.87	2.65	58.6
	600	10	16.6	10.64	0.02	5.65	0.39	122.05	1.53	208.69
	700	10	15.8	10.03	0.02	10.63	0.67	208.28	1.50	418.66
	800	10	15.5	10.02	0.02	51.79	0.58	298.51	1.70	545.43
Rice Husk 	300	10	63.6	5.52	0.03	1.41	0.93	39.82	8.45	-
	400	10	48.6	6.84	0.03	2.91	0.75	44.07	1.55	193.70
	500	10	42.4	8.99	0.04	9.72	0.37	75.38	1.58	262.00
	600	10	37.3	9.41	0.00	13.50	0.21	68.95	3.13	243.00
	700	10	32.8	9.52	0.02	13.88	0.99	121.02	1.58	256.00
	800	10	32.0	9.62	0.01	34.06	0.34	174.40	3.07	295.57
Rice Straw 	300	10	53.4	6.13	0.02	19.72	9.73	84.19	4.15	-
	400	10	39.3	8.62	0.03	29.32	2.40	74.66	2.64	46.60
	500	10	32.6	9.82	0.01	29.58	2.81	95.94	1.52	59.91
	600	10	23.4	10.19	0.01	33.65	4.93	85.57	1.58	129.00
	700	10	18.4	10.39	0.03	40.45	3.02	100.55	1.52	149.00
	800	10	18.3	10.47	0.04	82.61	2.02	190.21	1.31	256.96

Chemical Property (carbon) different biochars (C^{13} -NMR)





Terra Preta do Indio



Oxisol



Terra Preta

<http://en.wikipedia.org/wiki/Biochar>

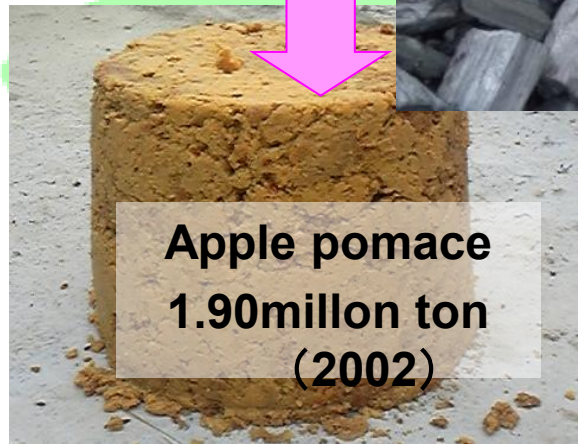
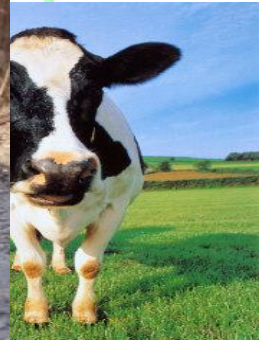
JAPAN



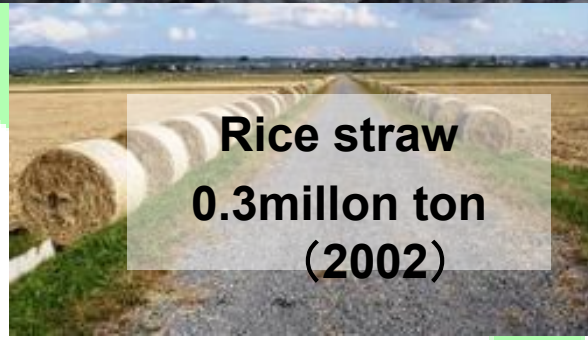
“After charring all waste concentrated excretions should be mixed with it and stocked from a while. When you apply this manure to the field, it is efficient for yielding any crop.”

(Miyazaki 1697, *Nogyo zenshu* [Encyclopedia Agriculture])

Organic Residues in Aomori



Apple pomace
1.90million ton
(2002)



Rice straw
0.3million ton
(2002)



Manure
1.9million ton
(2002)

Compost + Biochar



Poultry Manure + Biochar



Poultry Manure



Cow Manure + Biochar

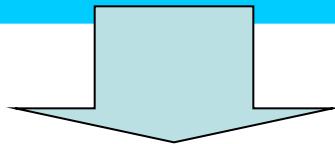


Cow Manure

WHY BIOCHAR IN COMPOST?

1. Improvement of Compost Quality

2. Reduction of gas emission during process



1. Volatilization of N-NH₄ (Strong Odor)

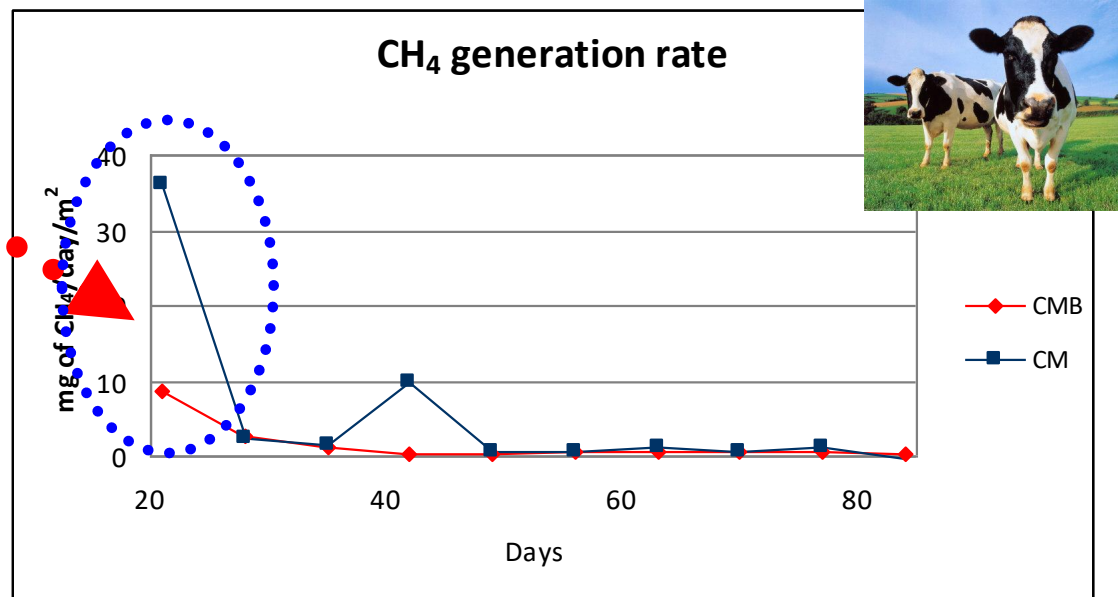
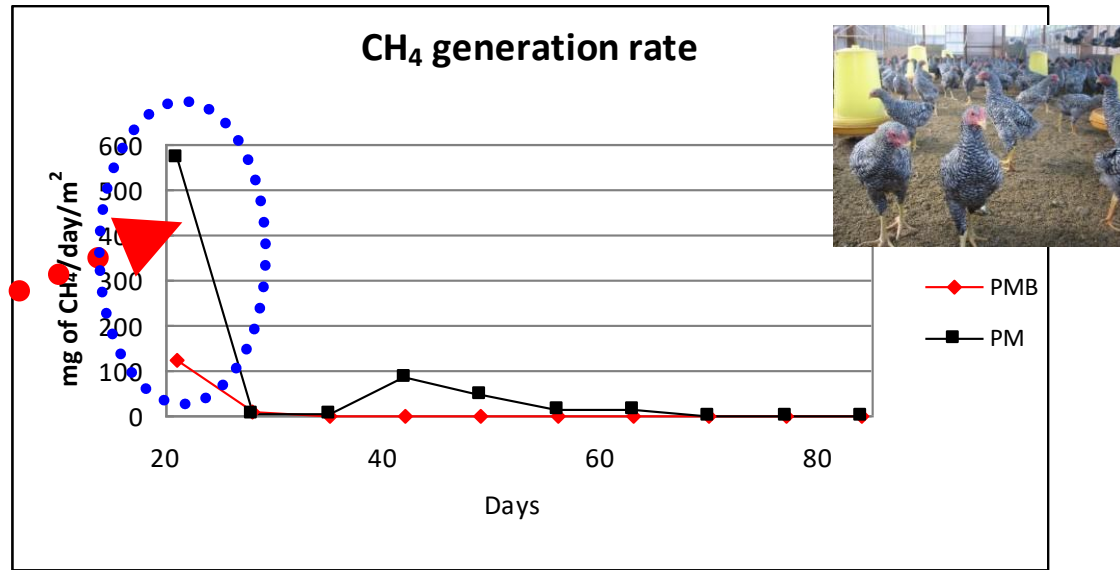
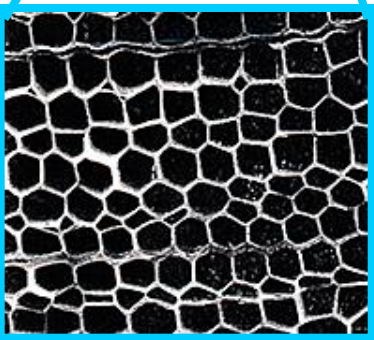
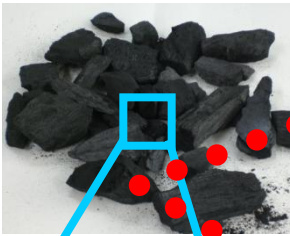
2. Production of CH₄ (= x25 CO₂ for Global warming)

Composting process



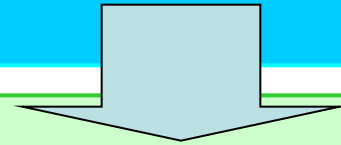
GHG emission

A decrease of methanogens (*mcrA*) and an increase of methanotrophs (*pmoA*) by biochar



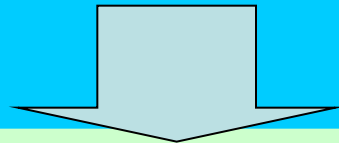
WHY BIOCHAR IN COMPOST?

1. Improvement of Compost Quality

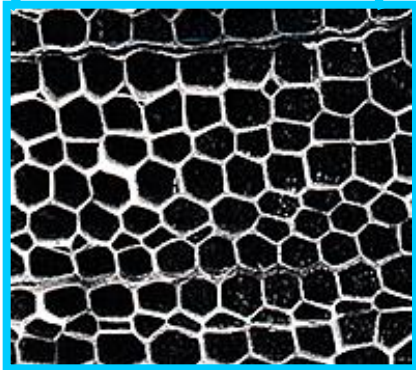


HOW?

2. Reduction of gas emission during process



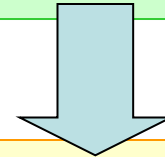
1. N-NH_4 (Strong Odor)
2. CH_4 (= x25 CO_2 impact for Global warming)



1.Higher Porosity (Lower Density)

Effect:

Increase aeration in composting pile



1.More space and more air

2.Inhibition of anaerobic condition



More Space!
More Aeration!

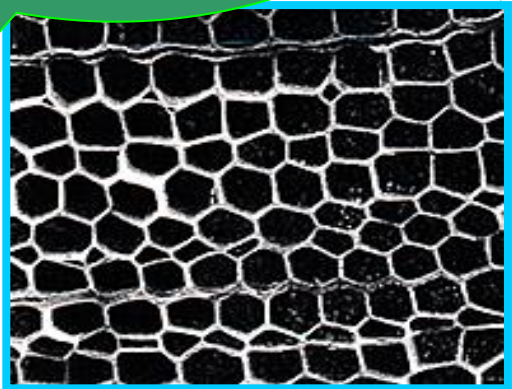
Composting time

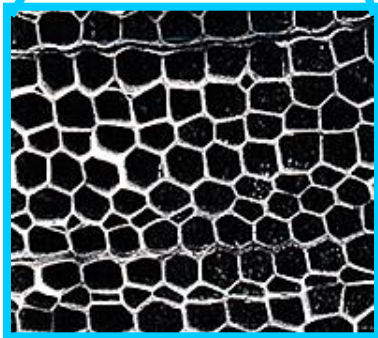
BD
(g cm⁻³)

12 weeks

PM
PMB
CM
CMB

0.81d
0.57b
0.65c
0.55a

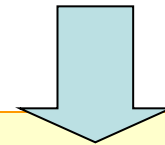




2. Long stability as bulk agent

Effect:

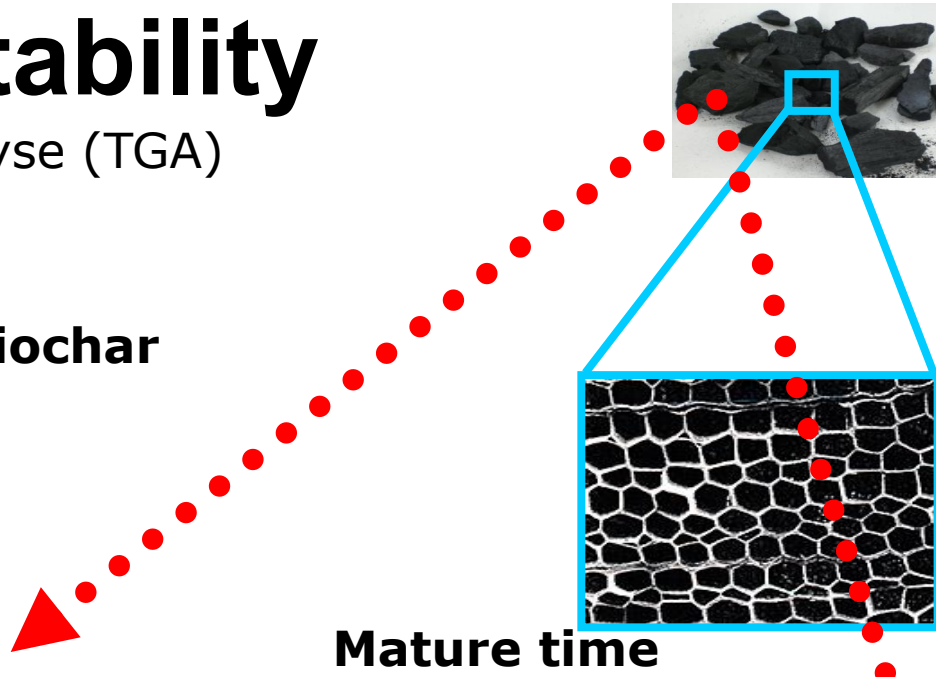
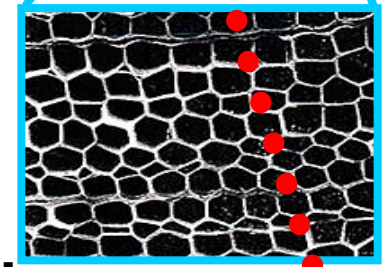
No decomposition



Maintain Fix Carbon

Long Stability

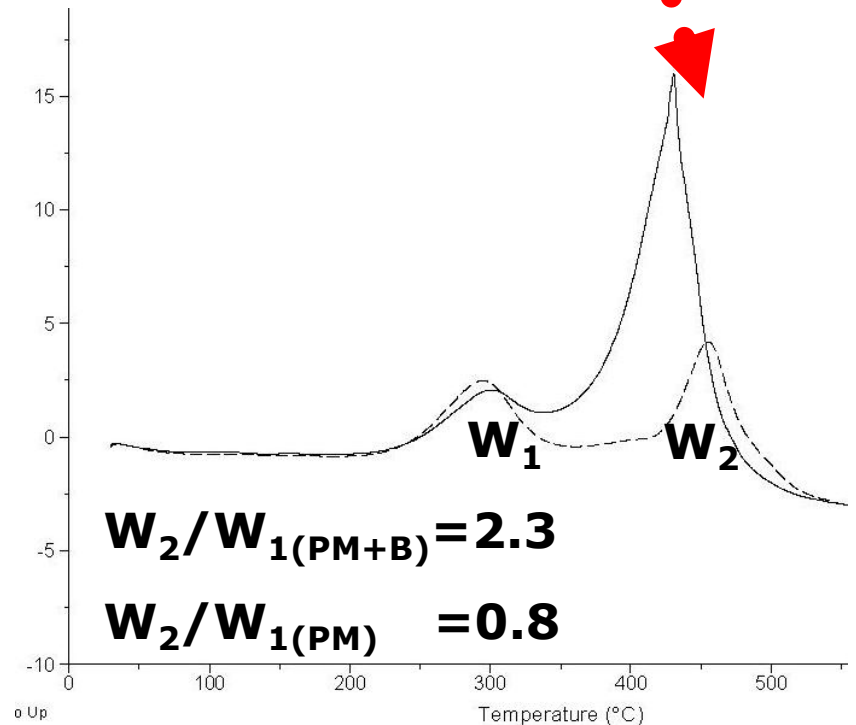
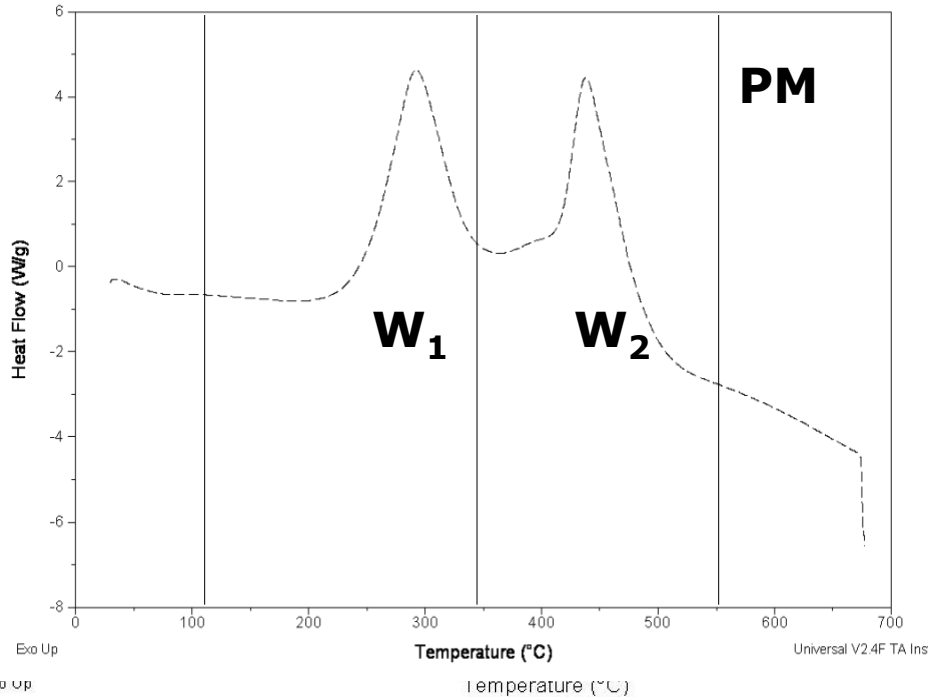
thermogravimetrische analyse (TGA)



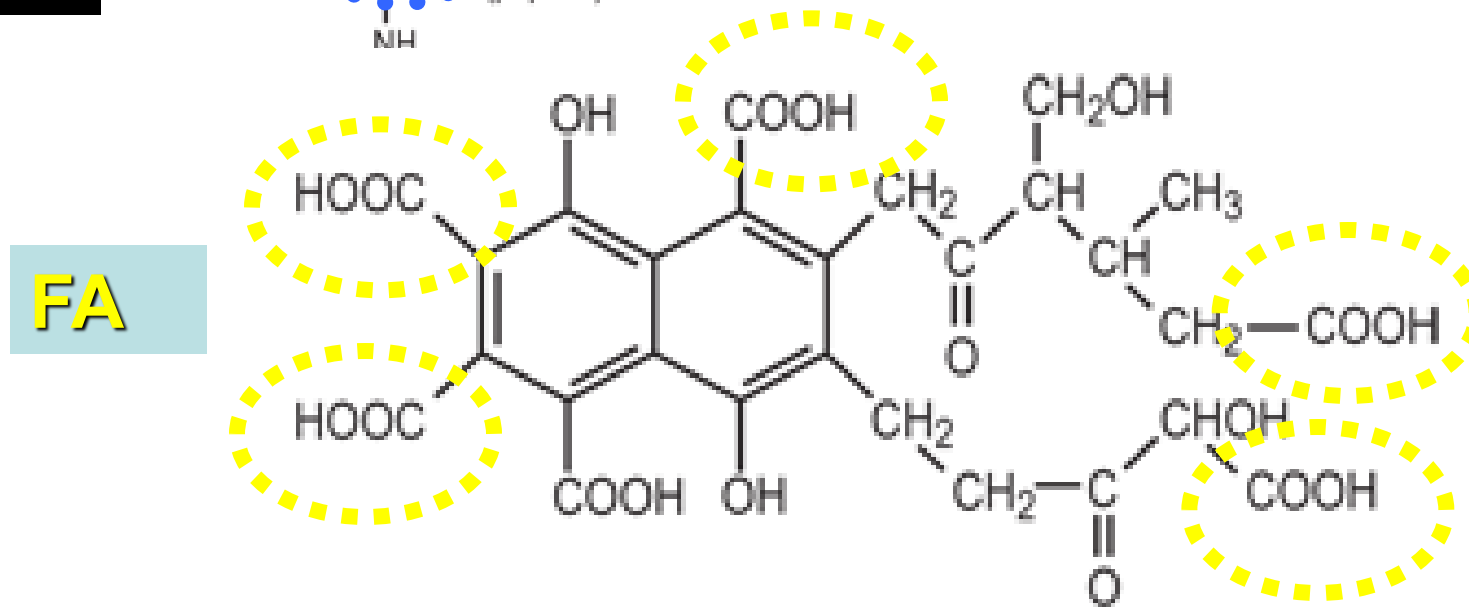
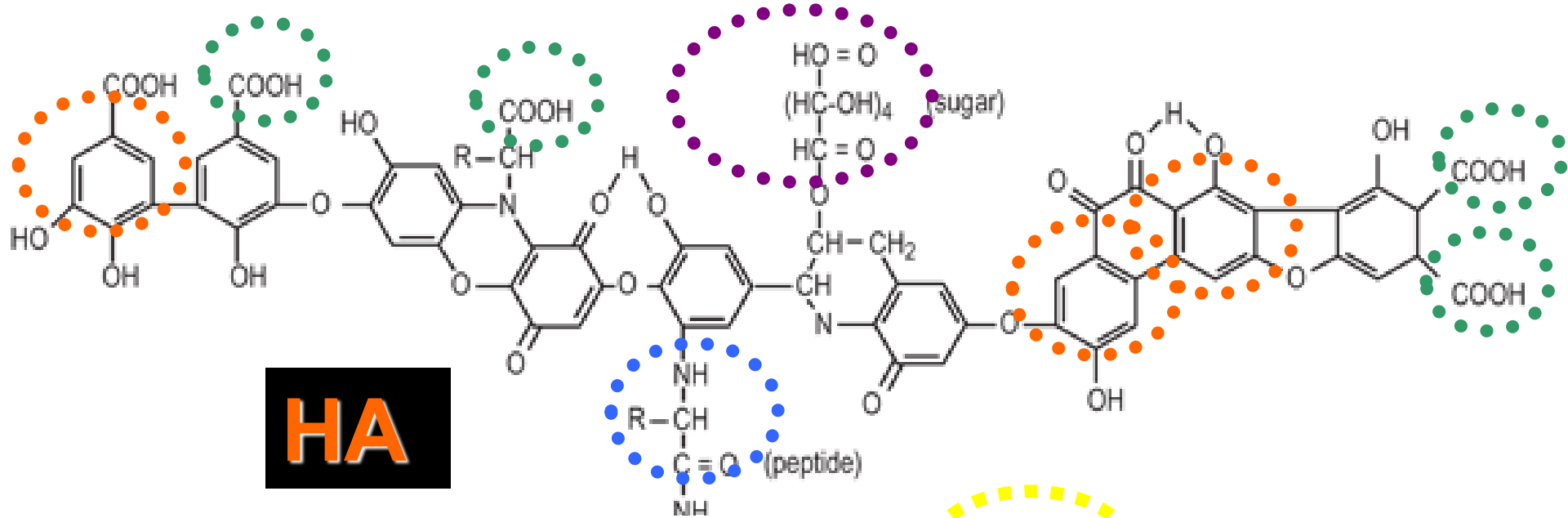
— PM+Biochar
 - - - PM

Initial time of composting

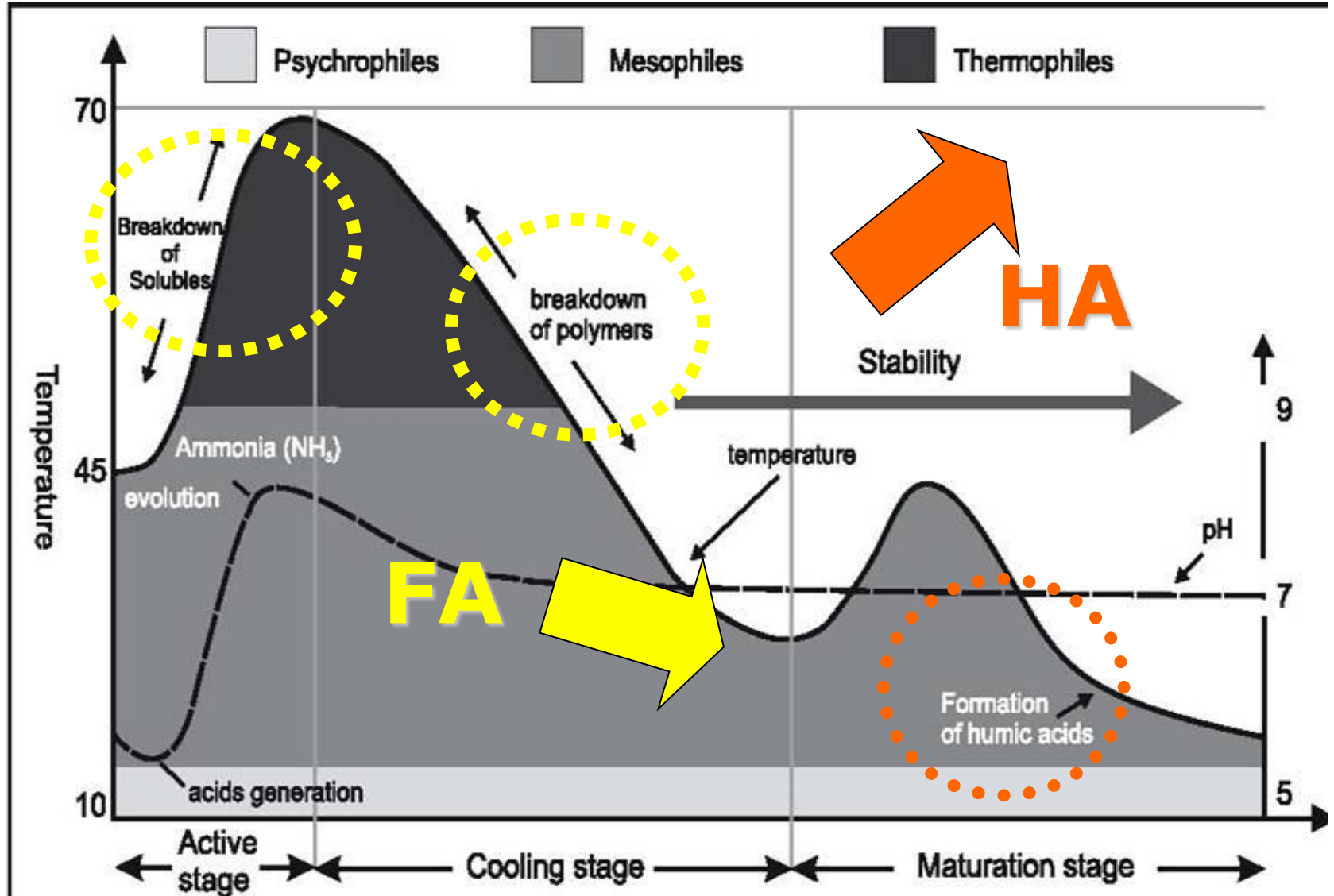
Mature time



Chemical Structure of **Fulvic acid** and **humic acid** in carbon



COMPOSTING PROCESS



Elemental Analysis and TGS of extracted humic acid and fulvic acid

Origin

Humic acids

Fulvic acids

Mass / %

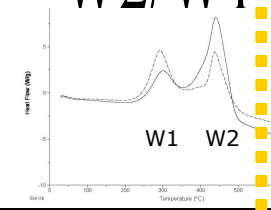
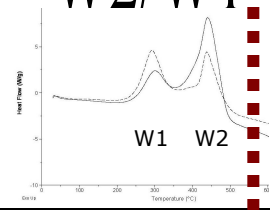
Mass / %

W2/W1

W2/W1

C H N

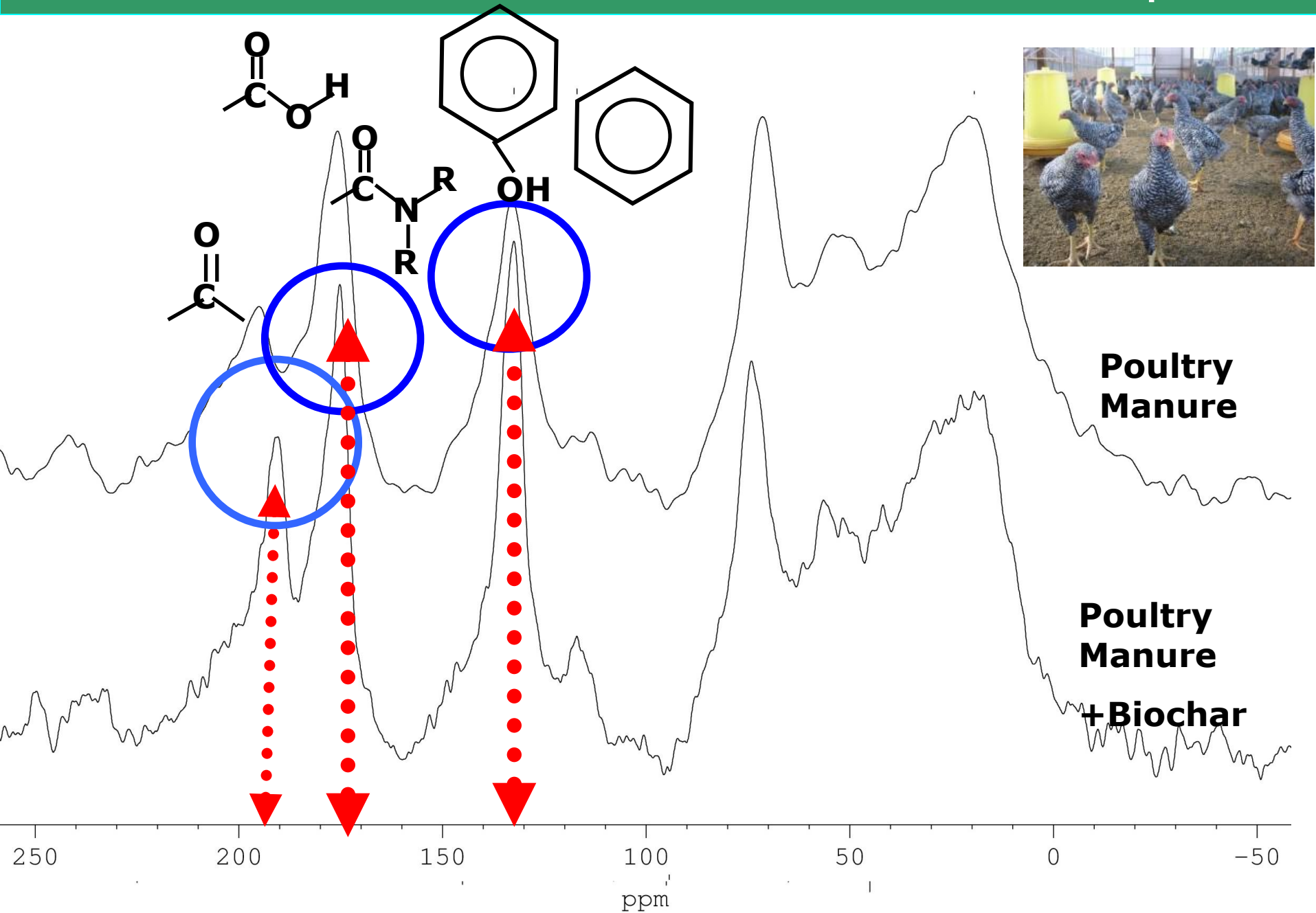
C H N



	C	H	N	W2/W1	C	H	N	W2/W1
PM	53.5	6.4	6.7	0.95	36.4	2.9	4.5	0.77
PM+B	57.4	6.5	7.0	1.13	37.5	3.7	4.1	0.79
CM	64.7	7.8	6.2	0.95	34.8	2.8	4.1	0.67
CM+B	68.0	8.1	6.3	0.97	39.4	3.7	3.5	0.88



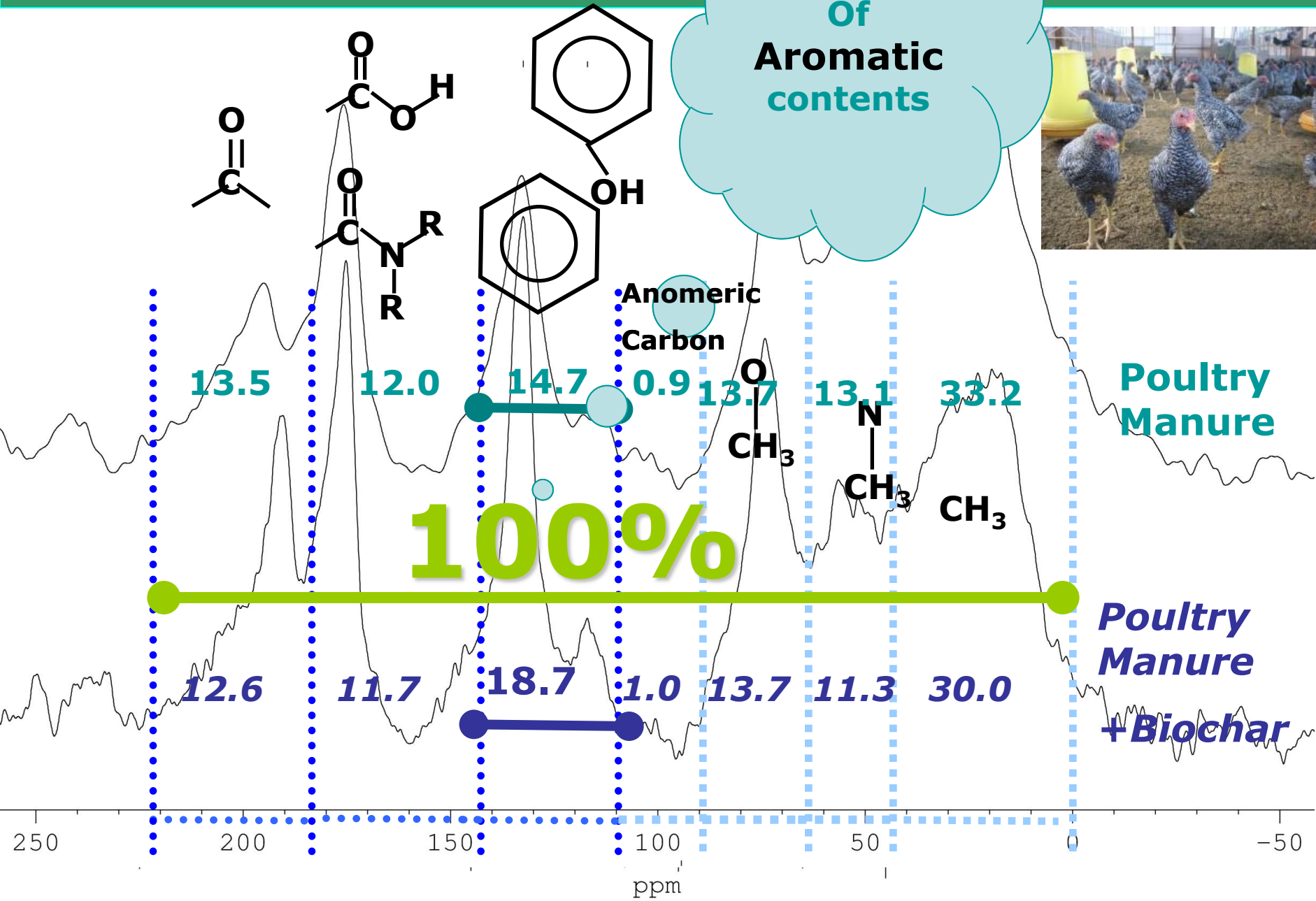
^{13}C -NMR of extracted **FA** from mature composts



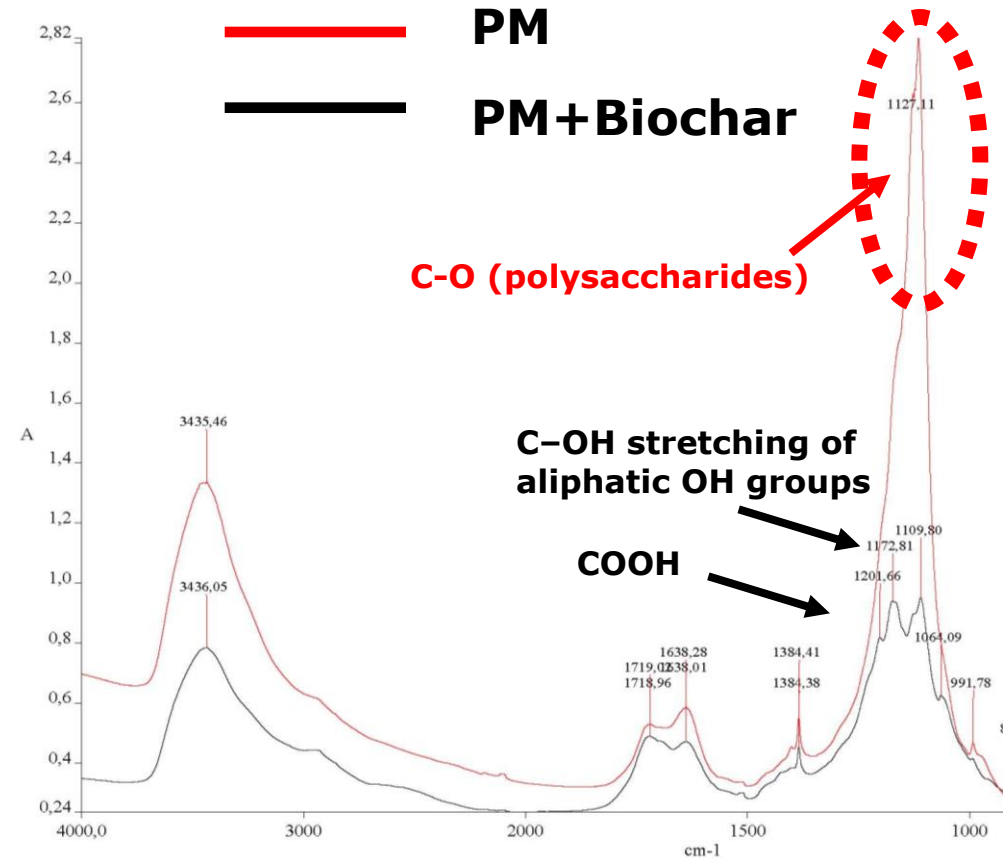
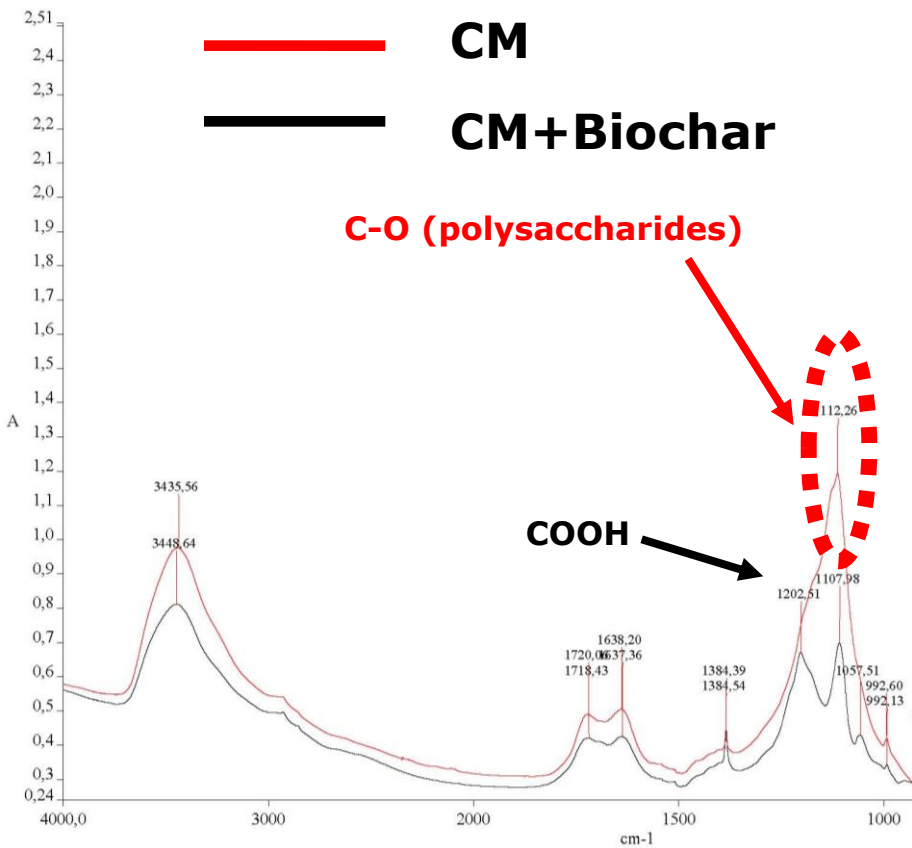
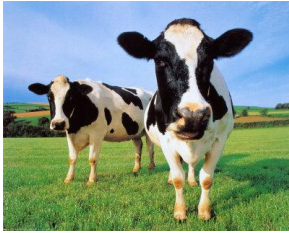
¹³C-NMR of extracted FA

Increasing Of Aromatic contents

composts



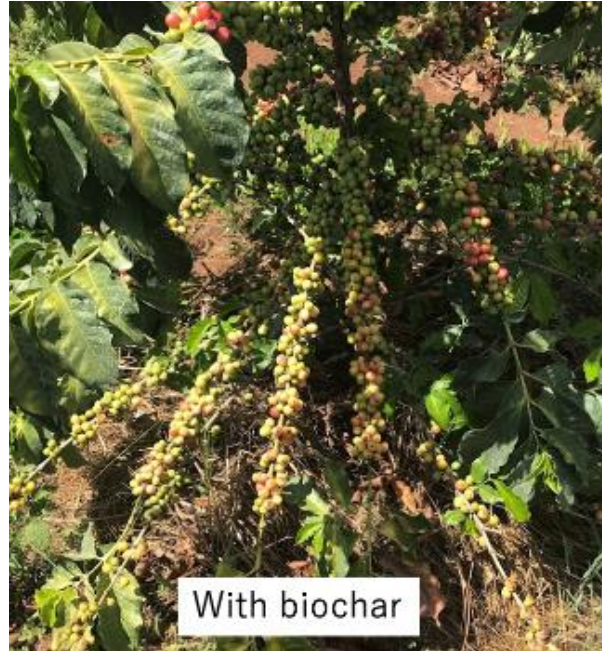
IR spectra of extracted **FA** from mature composts



Biochar derived from local residues in Kenya



Pile of pruned branches



With biochar



Without biochar



Demonstration of pyrolysis of dried sludge by Meiwa Co., Ltd.



Without biochar

With biochar

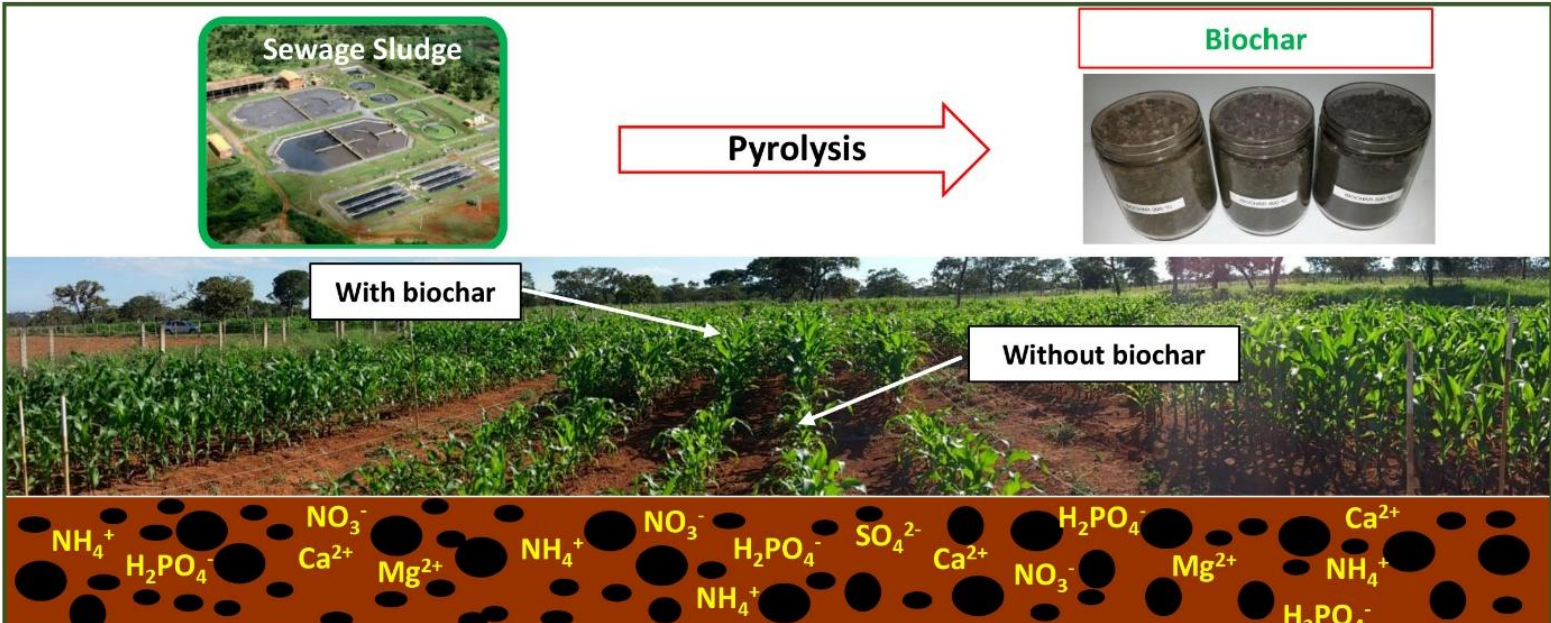
Effect of biochar on coffee trees by water & nutrient retentions in dry season

Long-term experiment (9 years) on the effect of sewage sludge biochar as a slow-release fertilizer in maize field, Cerrado region, Brazil (weathered acidic soil)



Biochar: Additional P + increasing pH + water-holding capacity

Yield  SOC  Heavy metal : Immobilized by biochar

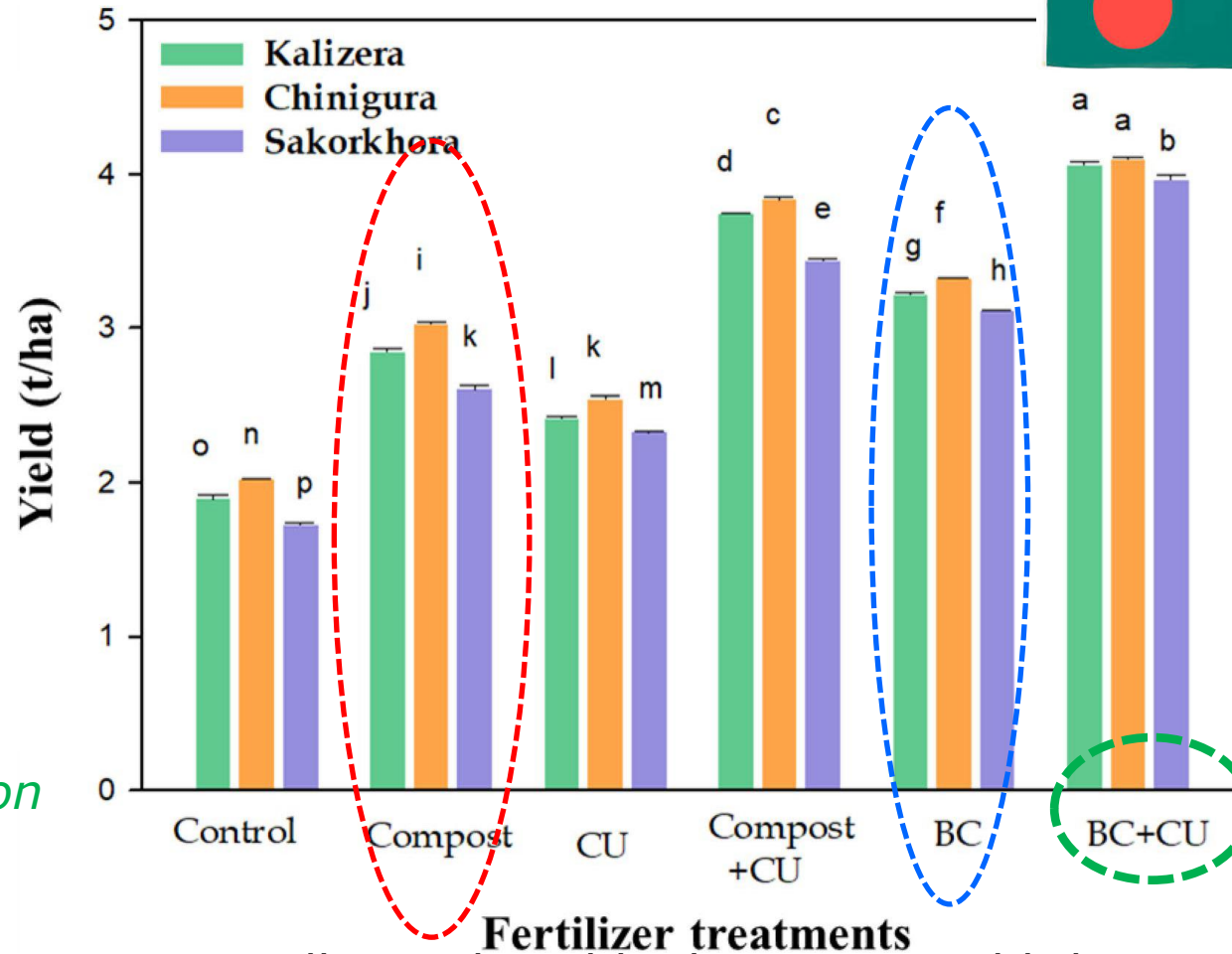


Grain yield of three rice cultivars in costal area (Bangladesh) under different amendment treatments



(BC and CU indicate biochar-compost and cow urine, respectively)

- Soil Salinity
- Monsoon-induced waterlogging
- Nutrient losses via runoff



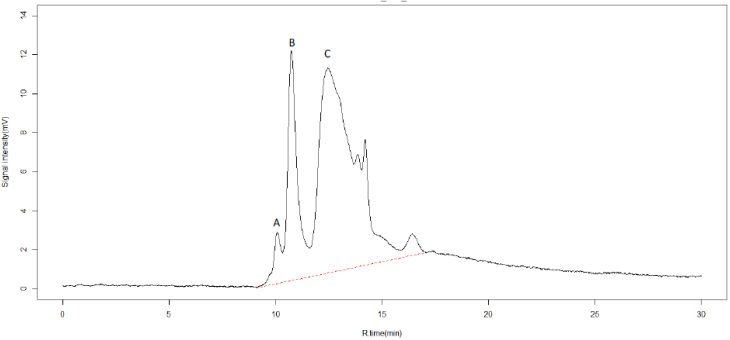
-Higher N concentration in rice grain under **BC + CU treatment** due to combined fast and slow N cycling

-Biochar enhances retention of urine-derived nitrogen.

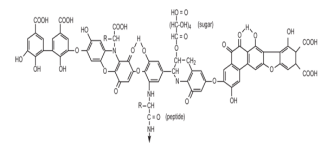
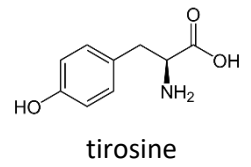
- Biochar-compost treatments generally produced higher grain yield than **compost**-only treatments.
- The combined application of **biochar-compost and cow urine (BC + CU)** resulted in the highest productivity across cultivars.



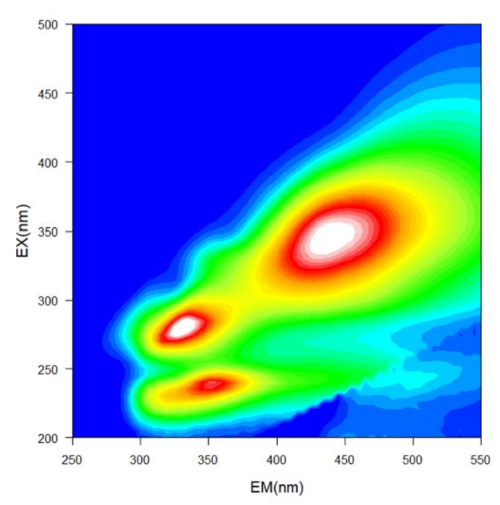
Wood vinegar ("Pyroligneous acid" or "bio-oil") application for Spinach growth



Different compounds identified by high-performance liquid chromatography (HPLC)



Fulvic acid



Excitation-Emission Matrix (EEM) spectrometric analysis. Colors indicate relative fluorescence intensity (RFI, QSU). Peaks indicate:

- (1) protein/tryptophan-like compounds (Ex/Em = 230/350 nm),
- (2) aromatic amino acid-like compounds (280/335 nm)
- (3) Fulvic acid (340/430–450 nm).

Major compounds detected by ion chromatography in pyroligneous acid (4100 mg 100 mL⁻¹.)

Name	Molecular Formula	Molecular Weight (g mol ⁻¹)	%
Acetic Acid	C ₂ H ₄ O ₂	60.05	73.86
Pyruvic acid	C ₃ H ₄ O ₃	88.06	23.42
Succinic acid	C ₄ H ₆ O ₄	118.09	1.98
Malic acid	C ₄ H ₆ O ₅	134.0874	0.74



Pyroligneous Acid Dilution Rate	Chemical Fertilizer Concentration			
	100%	75%	50%	0%
Water (control)	Fresh Weight (g)			
800	19.9 ab	18.9 ab	18.9 a	9.4 bc
200	14.2 b	12.7 b	15.5 a	14.2 a
	18.8 ab	19.7 a	18.0 a	13.2 ab


Effect of pyroligneous acid on growth of Japanese spinach (komatsuna) compared to water

Farmmaps for carbon estimation

Somewhere in Dutch field

BODEMCOOLSTOF

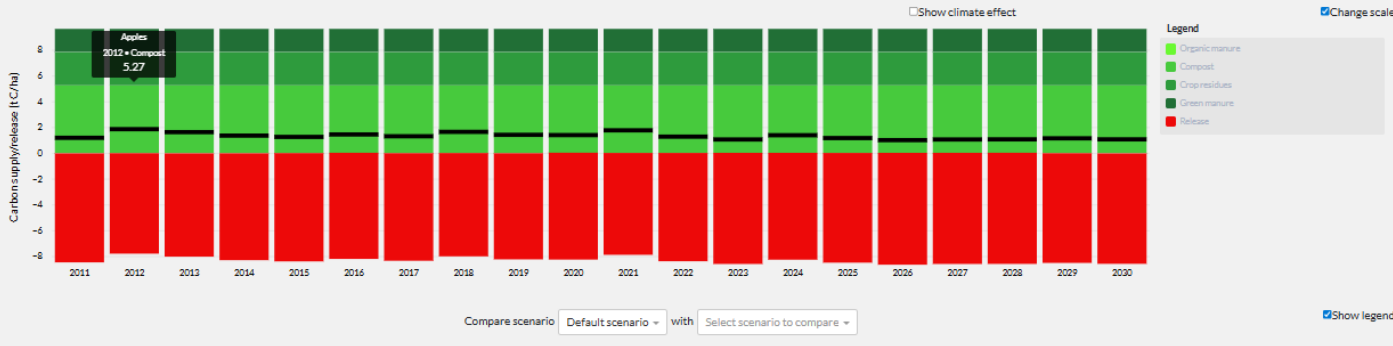
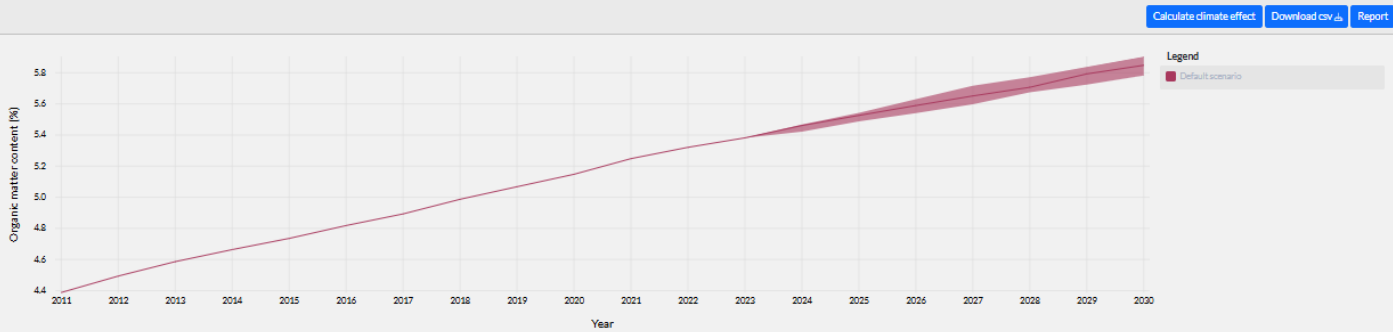
PROGRAMMA SLIM LANDGEBRUIK (WAG)



Contact: Chantal Hendriks
E-mail: chantal.hendriks@wur.nl
Website: www.slimlandgebruik.nl/themas/monitoren-van-de-voortgang-richting-05-mton/projecten/praktijktoel-bodemcoolstof
Link naar appstore: farmmaps.eu/nl/editor/plan
Prijs: €0

Calculation model: 2025

Farm results are available using the button at the bottom of the screen



Perceel 1

Input Default scenario Result

Organic manures Common data

Area: 0.15

Soil: Sand

Clay content (%): 4

Organic matter (%): 2011

Soil sample taken at depth: 25cm

Scenario	CO2 sequestration (t CO2/ha/year)	Carbon balance (t C/ha/year)
Default scenario 2011 - 2011	4.43	1.21
Default scenario 2012 - 2030	4.97	1.36

Buttons: Show farm result

Year	Crop	Yield (ton/ha)	Green manure	Period green manure	Organic manure (ton vers/ha)
2011	Apples		African Marigold	Enter search text	Click on button to add or edit organic manure

Options for bioslurry, compost, biochar

Organic manure

Enter search text

- Compost
- Thin fraction of digestate
- Thick fraction of digestate
- Mineral concentrate
- Digestate
- Champost
- Sheep/goat manure

Quantity (ton vers/ha): 29

Buttons: +, -

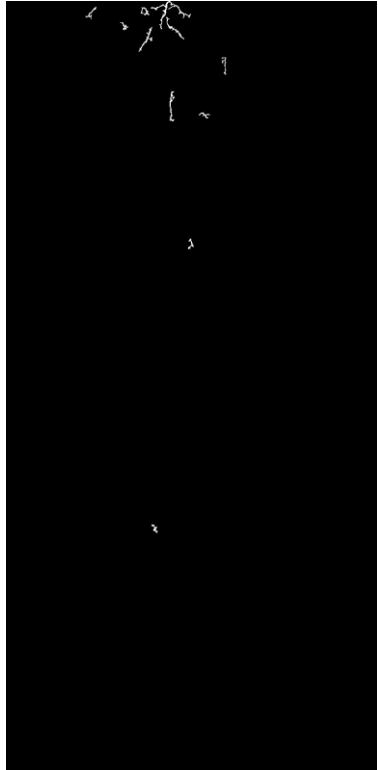
Straw withdraw

Crops in standard rotation

Testing your biochar and bioslurry in NPEC? (Netherlands Plant Eco-phenotyping Centre) <https://www.npec.nl/virtual-tour/>



Digitally phenotype facilities for
research and industry



Clockwise:

(top right) Screening tomato varieties for drought tolerance under simulated climates

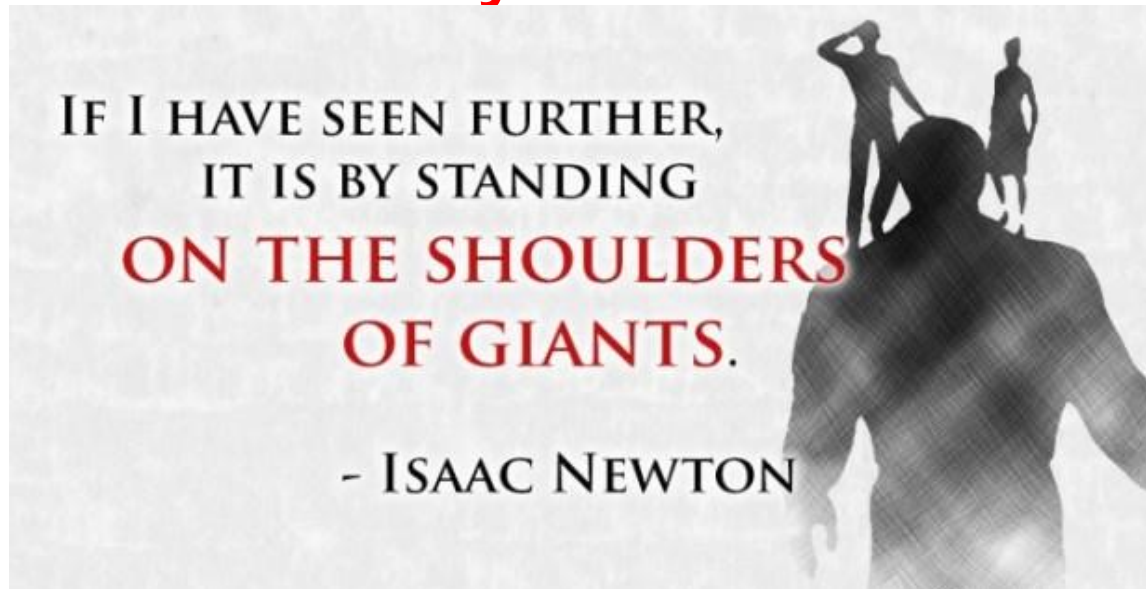
(bottom right) Screening potato collections for fungal disease resistance

Screening quinoa for salt and drought tolerance in controlled-environment agriculture

Take home messages

- Not “biochar,” but “**biochars**” — properties vary widely.
- Biochars are **not a silver bullet**.
- Biochar performance is **context-dependent**.
- Selection should match:
 - soil type (pH, texture),
 - climate,
 - crop system, and
 - management goals.
- Different goals require different biochars:
 - compost additive,
 - soil conditioner,
 - nutrient retention,
 - carbon sequestration

Thanks for your attention



27 Sustainable Applications of Biochar for Environmental Control and Promotion of the Circular Economy

Keiji Jindo, Yuki Audette, Cicero Célio de Figueiredo, Leônidas Carrijo Azevedo Melo, Carlos Alberto Silva, Fábio Satoshi Higashikawa, Kinya Akashi, Takafumi Konaka, Adrián Malo Sanz, Takeo Tokunari, Emmanuel O. Oyelude, Shamim Mia, and Miguel Angel Sánchez-Monedero

27.1 INTRODUCTION

Biochar's global adoption in agriculture has increased due to its multi-beneficial properties for agro-ecosystem sustainability. It sequesters carbon in soil [1] offsets up to 12% of CO₂ emissions, enhances soil fertility, improves nutrient use efficiency, and boosts crop productivity while reducing nutrient losses [2].

In developing countries, traditional biochar production methods (e.g., pit kilns, ground pit kilns, clay pot kilns) are more prevalent among smallholder farmers [3] (Figure 27.1). Limited investment and operating costs hinder the adoption of modern pyrolysis plants, making traditionally produced charcoal the main source of biochar for smallholder farmers at the household level (not at the community level) in rural areas of developing countries. Several studies showed that the biochar produced in traditional kilns from wooden feedstocks increased the yield of different crops under different agroclimatic conditions, varying from Colombian Savanna Oxisol [4], highlands of Western Kenya [5], Brazilian savannah woods [6] and Alfisol from Nigeria [7]. Kimetu et al. [5] found that adding biochar to degraded soils doubled corn yield. Major et al. [4] demonstrated that a