Xylofutur
Produits et Matériaux des Forêts Cultivées

Production et caractérisation de biochars produits à partir de différentes matières premières par différentes technologies thermochimiques et applications potentielles en agronomie

La contribution du projet Européen MOBILE-FLIP

SPIRE
Sustainable Process Industry through Resource and Energy Efficiency

MOBILE FLIP

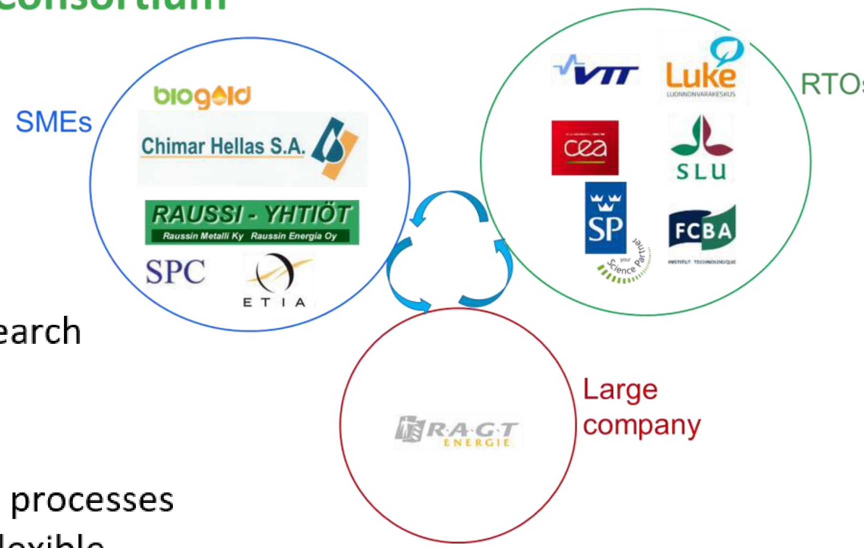
Denilson da Silva Perez – FCBA (FR)

Xylo Dating

Mobile Flip in figures

- Budget: 9.70 million euros
- Resources: 716 Person months
- Duration: 4 years (2015 – 2018)
- Partners: 1 large company, 5 SMEs and 6 research institutes & universities
- From 5 EU member countries
- Programme SPIRE-02-2014 Adaptable industrial processes allowing the use of renewables as flexible feedstock for chemical and energy applications

Consortium



Funding

Sustainable Process Industry through Resource and Energy Efficiency

Main objectives

- Develop and demonstrate technologies for simple and robust processes that are applicable to small scale / mobile unit :
  - biomass pre-treatment steps (comminution, drying, fractioning)
  - hydrothermal treatment and saccharification
  - hydrothermal carbonization
  - torrefaction
  - slow pyrolysis
  - pelletizing and briquetting

Matières premières

Procédés thermochimiques

Torrefaction tests in TORNADE

- Sample mass: ~ 200 mg
- Temperature : 300°C
- Residence time (at 300°C): 45 min
- Gaseous atmosphere: N_2
- Gas flow: 1 $NL.min^{-1}$

Slow pyrolysis bench scale tests

- Sample capacity: 5 kg (wood)
- Temperature : 475°C
- Gaseous atmosphere: N_2

Hydrothermal carbonization tests

- Volume: 2L
- Residence time: 6h
- T: 260°C
- Acidic conditions

Conditions d'obtention des biochars

Raw material	Process	T (°C)	Abbreviation
Norway spruce (*Picea abies*)	Torrefaction	280	TOR-SPR
Scots pine bark (*Pinus sylvestris*)	Pyrolysis	375	SP-SPB-L
Scots pine bark (*Pinus sylvestris*)	Pyrolysis	475	SP-SPB-H
Scots pine forest residue (*Pinus sylvestris*)	Pyrolysis	475	SP-SPFR
Willow (*Salix ssp.*)	Pyrolysis	475	SP-WILL
Wheat straw (*Triticale ssp.*)	Pyrolysis	475	SP-WS
Scots pine bark (*Pinus sylvestris*)	HTC	260	HTC-SPB
Willow (*Salix ssp.*)	HTC	260	HTC-WILL
Coffee cake (*Coffea arabica*)	HTC	260	HTC-CC
Brewery residues	HTC	260	HTC-BRE

Biochars – composition chimique

	Ash	C	O	H
	%	%	%	%
TOR-SPR	0.6	54.9	41.8	6.0
SP-SPB-L	3.1	76.4	16.3	3.8
SP-SPB-H	3.5	83.7	9.3	3.0
SP-SPFR	4.8	84.1	7.2	3.0
SP-WILL	4.5	83.5	8.0	3.1
SP-WS	19.7	69.9	7.3	2.5
HTC-SPB	1.8	70.7	21.1	5.0
HTC-WILL	0.7	72.5	20.9	5.3
HTC-CC	0.1	74.7	15.7	7.8
HTC-BRE	3.0	72.4	14.5	6.9

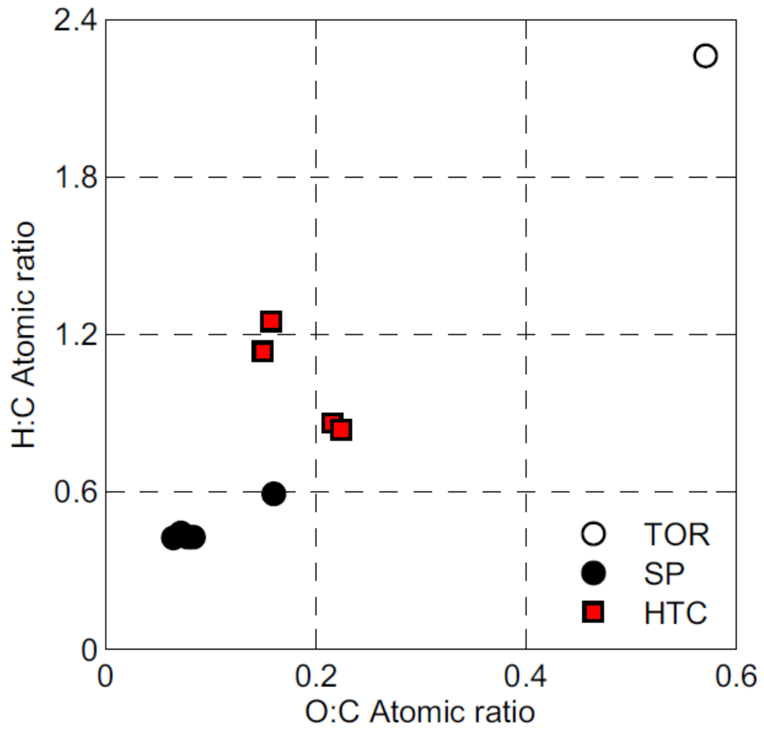


Fig. 1. Van Krevelen diagram of elemental ratios for biochars studied in the experiment (TOR = torrefaction, SP = slow pyrolysis, HTC = hydrothermal carbonization).

Biochars – caractérisation

	Peak area	EC	pH	CEC	Ca
	cm^{-1}	µS/cm		mmol/kg	mg/kg
TOR-SPR	0.43	117 ± 6f	5.2 ± 0.2f	81 ± 3b,c	866 ± 13f
SP-SPB-L	0.09	165 ± 5e	8.0 ± 0.1d	136 ± 6a,b,c	1783 ± 44e
SP-SPB-H	0.06	190 ± 4d	8.4 ± 0.1c	20 ± 2d	4789 ± 27b
SP-SPFR	0.05	318 ± 8c	9.0 ± 0.1b	16 ± 2d	3834 ± 80c
SP-WILL	0.08	462 ± 10b	9.3 ± 0.1b	34 ± 1d	9203 ± 83a
SP-WS	0.08	1520 ± 26a	10.0 ± 0.1a	88 ± 1b,c	3377 ± 45d
HTC-SPB	0.38	105 ± 4f	4.1 ± 0.0g	278 ± 31a,b	362 ± 6h
HTC-WILL	0.50	59 ± 4h	5.1 ± 0.0f	138 ± 6a,b,c	732 ± 16g
HTC-CC	3.13	56 ± 1h	4.0 ± 0.0g	91 ± 20b,c	48 ± 4i
HTC-BRE	0.62	83 ± 4g	5.6 ± 0.0e	8 ± 5e	398 ± 10h

Conditions expérimentales

Soil

- LUKE Kotkanoja long-term field experiment (Jokioinen, Finland).
- Vertic Stagnosol, post-glacial clay soil (64.8% clay, 30.5% slit, 4.7% sand)
- Topmost 10 cm layer of annually ploughed plots in spring 2016.
- Soil air-dried and sieved (5mm mesh size).

Biochar-soil preparation

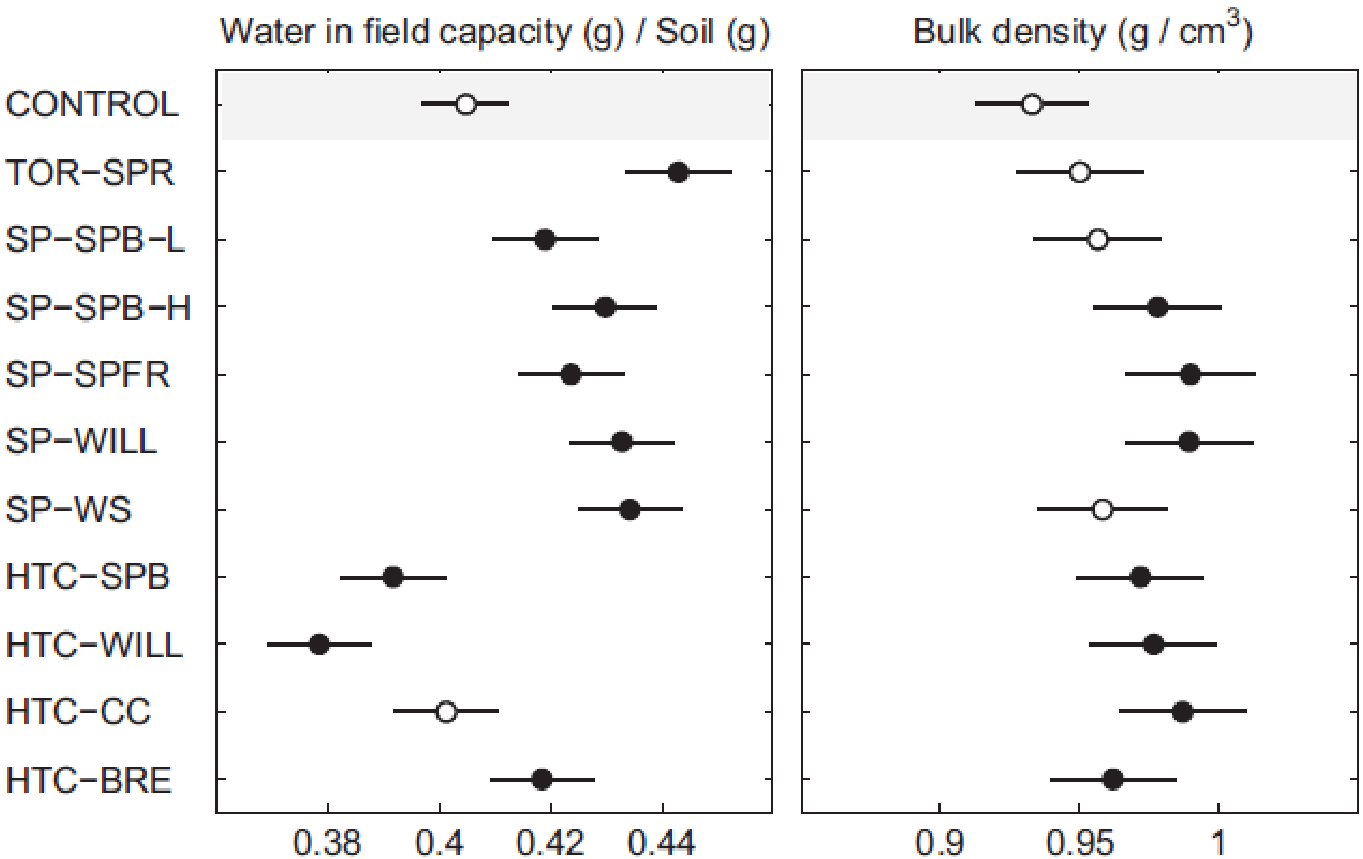
- Dry biochar (94 to 99 % solids content) crushed and sieved (0.2 mm) mixed with dry soil (96 % solids content)
- 190 cm^3 metal cylinders filled with soil only or 2% (dry weight basis) mixture with biochar and compacted under 10 kg press
- 72 packed cylinders prepared (12 controls and 6 samples for each biochar type)
- Soil samples saturated with deionized water (7 weeks), equilibrate in a sandbox (2 weeks) and incubated for 8 weeks
- Water content determined, cylinders unpacked and characterized

Characterisation methods

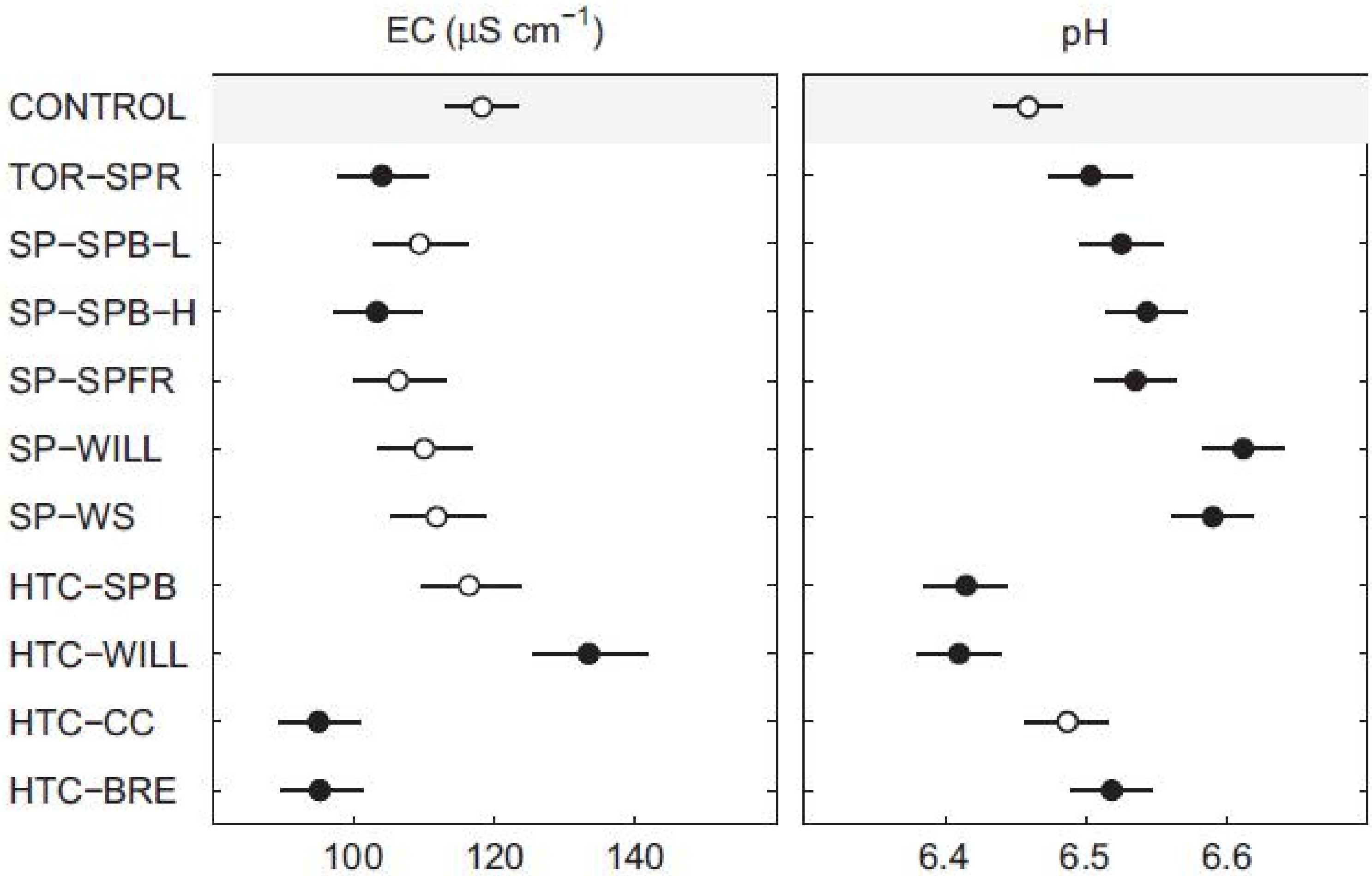
- pH (SFS-EN 13037)
- Electrical conductivity (SFS-EN 13038)
- Ash content (SFS 3008)
- Cation exchange capacity (CEC) and and easily available cations
- Hydrophobicity (IR alkyl peaks surface)
- X-ray tomography
- Image analysis

- Water content
- Bulk density
- Aggregate stability testing (< 2 mm, 2–5 mm, >5 mm)
- Turbidity

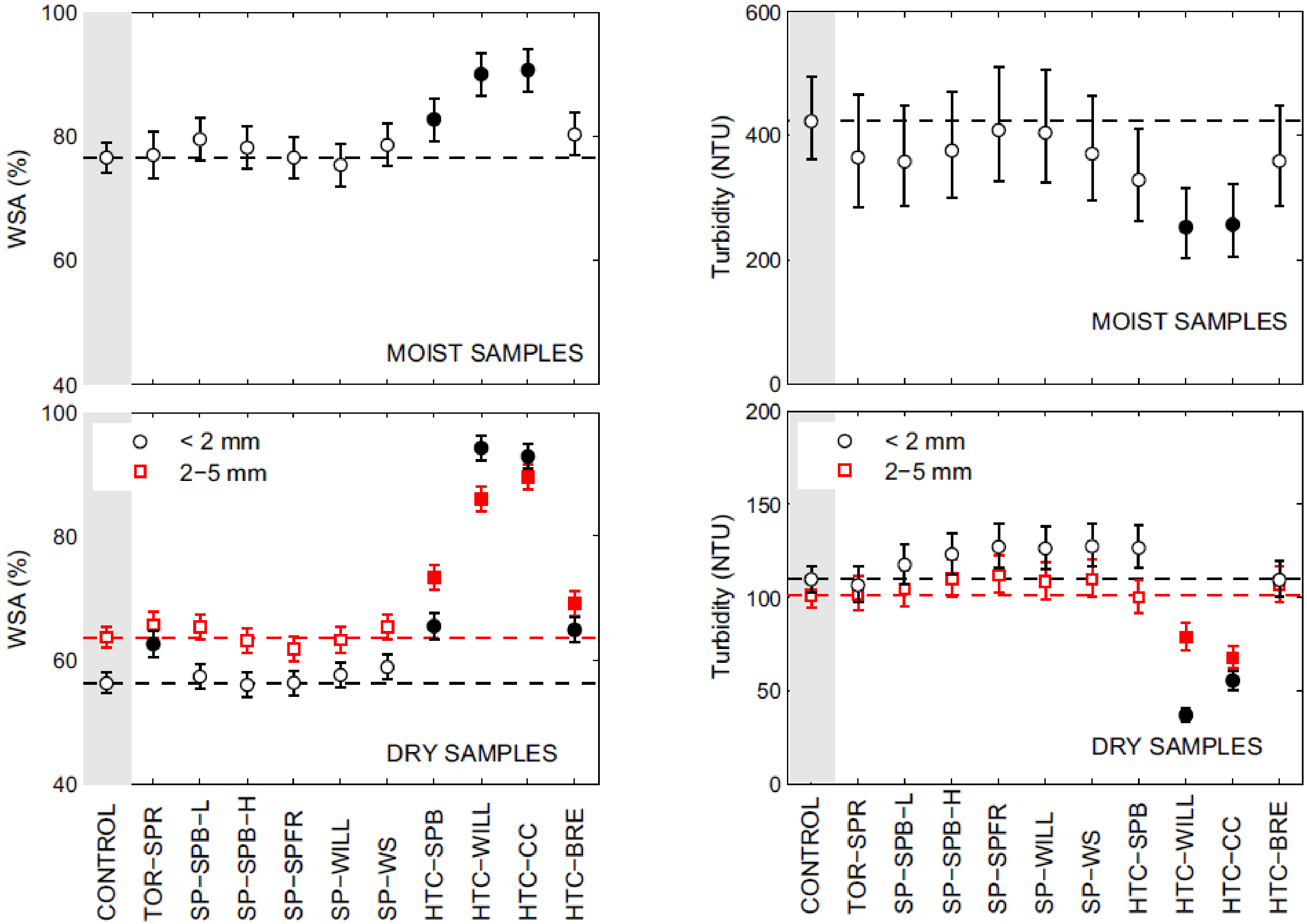
Rétention d'eau et densité



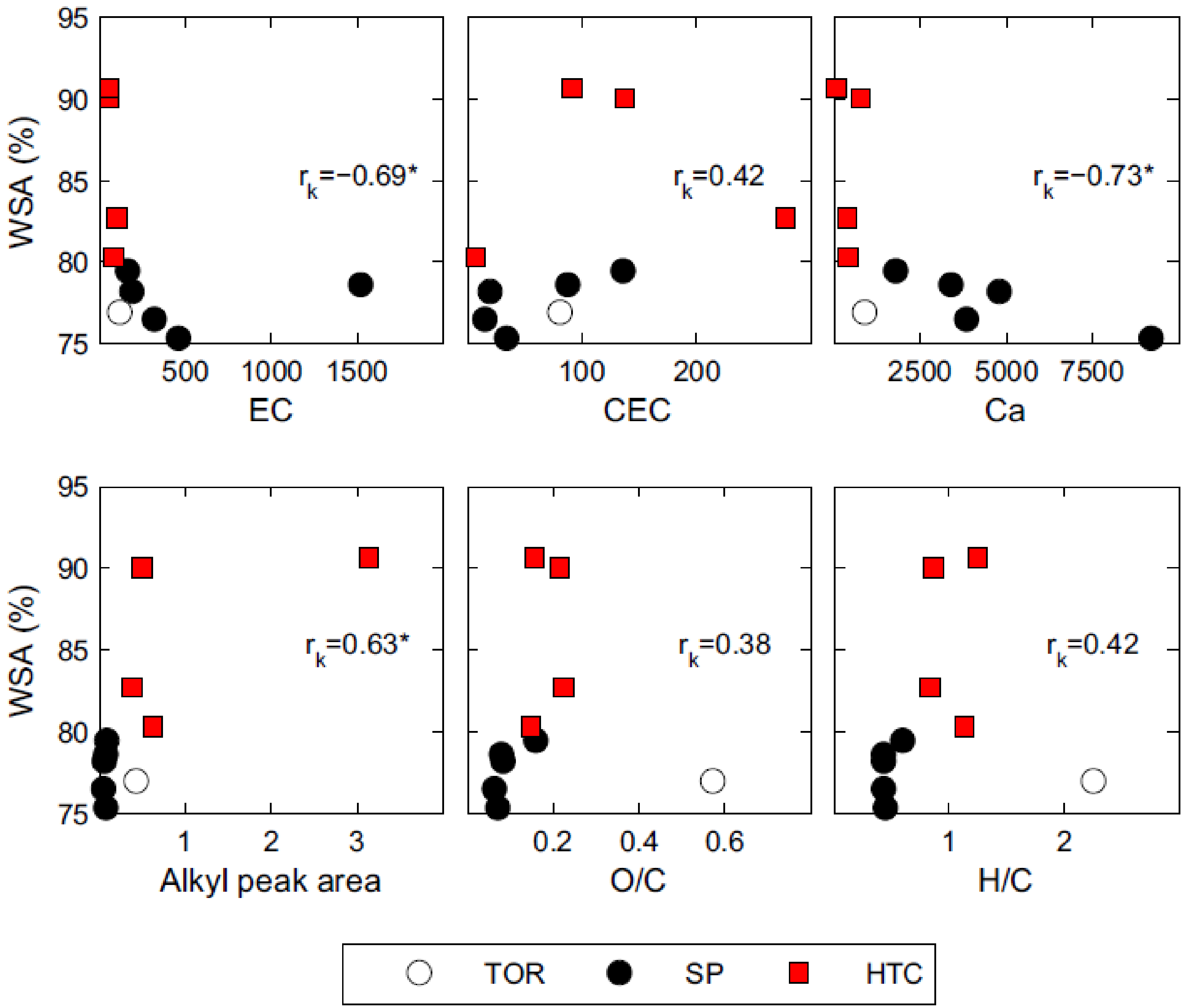
Conductivité et pH du sol

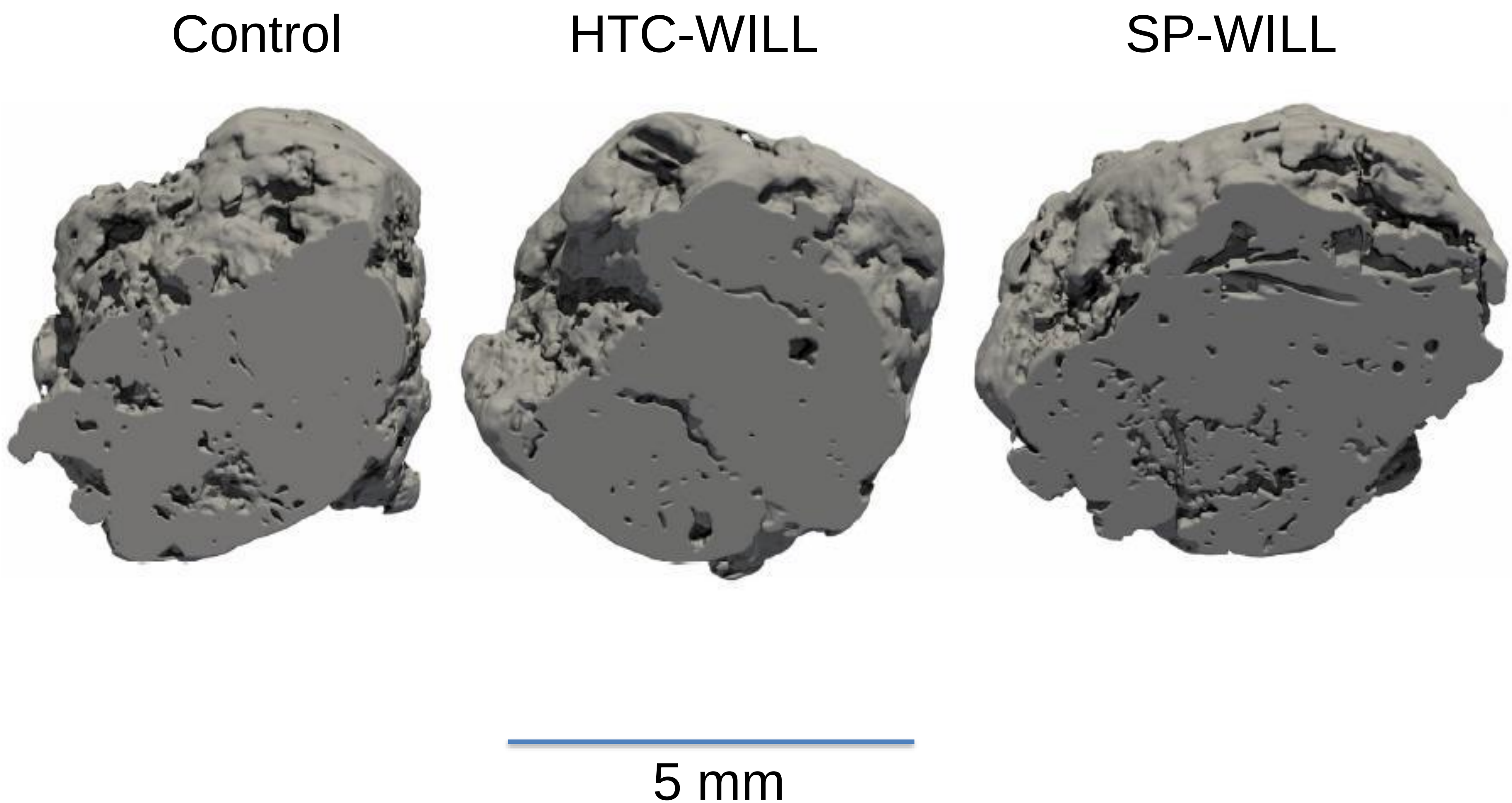


Agrégation des sols et turbidité



Corrélations entre les propriétés des biochars et les effets sur la rétention d'eau au sol




Control
HTC-WILL
SP-WILL
5 mm

Observations/conclusions principales

- The effect of biochar on soil physical is strongly dependent on the biochar properties (raw materials and thermochemical process)
- Slow pyrolysis (and one torrefied) biochars have lower potential to improve soil aggregate stability than HTC ones.
- Hydrophobic and hydrophilic functional groups at the biochar surfaces govern aggregate stability and colloid detachment
- Slow pyrolysis biochars increased the soil volumetric water content at field capacity, while HTC could even reduce it
- The hydrophobicity of HTC biochars may offset their beneficial effects on soil structure and aggregate stability.

Publications Mobile Flip sur le sujet

Geoderma 344 (2019) 40–49

Contents lists available at ScienceDirect

Geoderma

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

Possibilities to improve soil aggregate stability using biochars derived from various biomasses through slow pyrolysis, hydrothermal carbonization, or torrefaction

Jaakko Heikkinen[a,*], Riikka Keskinen[a], Helena Soinne[a], Jari Hyväluoma[a,1], Johanna Nikama[a], Hanne Wikberg[b], Anssi Källi[b], Virpi Siipola[b], Thierry Melkior[c], Capucine Dupont[d], Matthieu Campargue[e], Sylvia H. Larsson[f], Markus Hannula[g], Kimmo Rasa[a]

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Biomass and Bioenergy 119 (2018) 346–353

Contents lists available at ScienceDirect

Biomass and Bioenergy

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

Research paper

How and why does willow biochar increase a clay soil water retention capacity?

Kimmo Rasa[a,*], Jaakko Heikkinen[a], Markus Hannula[b], Kai Arstila[c], Sampo Kulju[a], Jari Hyväluoma[a]

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Journal of Analytical and Applied Pyrolysis 134 (2018) 446–453

Contents lists available at ScienceDirect

Journal of Analytical and Applied Pyrolysis

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

Effects of pyrolysis temperature on the hydrologically relevant porosity of willow biochar

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Industrial Crops & Products 166 (2021) 113475

Contents lists available at ScienceDirect

Industrial Crops & Products

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

Quantitative analysis of feedstock structural properties can help to produce willow biochar with homogenous pore system

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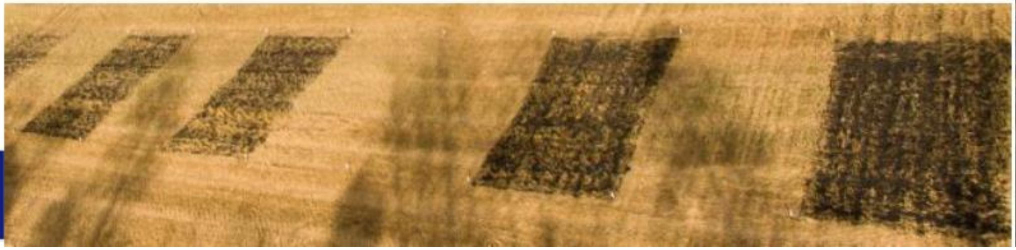
Biochar and soil structure – Field scale

- Field experiment established 2016
  - 5 plots with, 5 plots without biochar amendment
  - Forest residue biochar derived from Raussi's device version 1.0
- Rain-fall simulation test, soil erosion
  - Minor effects in the first year
  - Additional analysis including microbiology at 2nd year
- Research platform for future projects
  - Long term effects, financing needed



LES PÔLES DE COMPÉTITIVITÉ

Xylofutur

TRL élevés (7-8) (démonstration en situation réelle) :

- Capacité de production de quantités importantes (> 100 kg voire tonnes) de biochars
- Suivi pluriannuel d'essais sur différentes qualités de sols et en présence de cultures agricoles et/ou forestières

TRL élevés (4-6) (R&D appliquée et démonstration pilote) :

- Utilisation de biomasses secondaires et effluents contenant charge organique importante; mélange de biomasses
- Valorisation des co-produits (fractions liquides, condensables etc)
- Autres voies de valorisation des biochars

TRL élevés (1-3) (R&D fondamentale) :

- Modélisation, prédiction du comportement du biochar issue de différentes biomasses par différents traitements thermochimiques
- Compréhension des phénomes physico-chimiques ayant lieu pendant les procédés de conversion et sur sol

- **En terme de partenariat industriel :**
  - Producteurs de biomasse(s)
  - Industriels de la conversion de la biomasse
  - Utilisateurs potentiels des biochars et co-produits
- **En terme de partenariat de recherche :**
  - Académiques / Centres de Recherche / Industriels
  - Recherche privée
  - Région / France / Europe / International
- **En terme de partenariat financier :**
  - Fonds publics pour projets collaboratifs (co-financement) (Départements/Régions, France, Europe, fondations, etc)
  - Fonds privés industriels/professions pour la consultance, la recherche privée, transfert industriel, prestations, etc)

MERCI DE VOTRE ATTENTION

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