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Influence of feedstock and operational conditions on bio-chars derived from the pyrolysis of selected biomasses

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Authors

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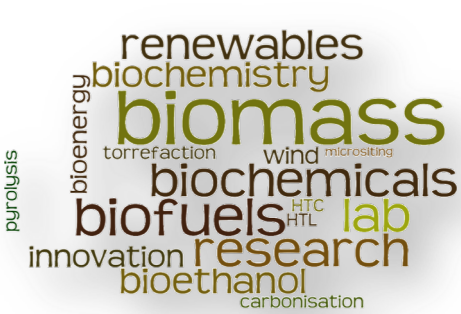

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Outlook

- **Main goals**
  - ✓ *To investigate (lab.scale) biochar properties versus feedstocks and pyrolysis conditions*
  - ✓ *To consider biochar porosity and CEC for use as soil amendment*
- **Feedstock**
  - ✓ *Pinus nigra (softwood)*
  - ✓ *Poplar (hardwood)*
  - ✓ *Willow (hardwood)*
- **Methodology**
  - ✓ *Slow pyrolysis in macro-TGA*

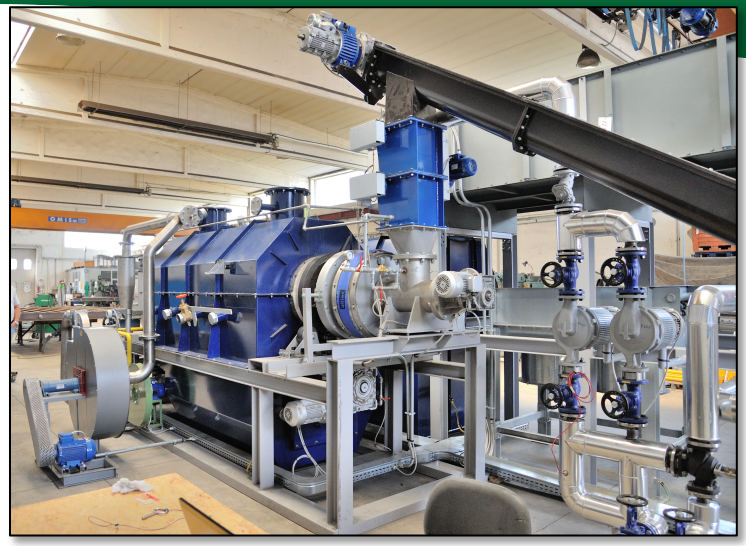
Pyrolysis PDU units at RECORD

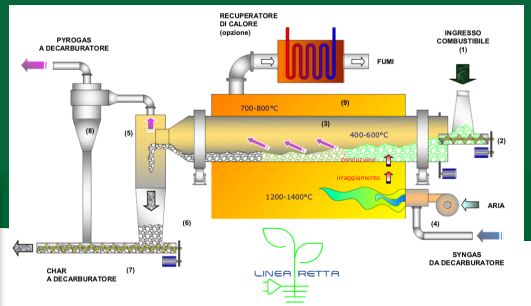
(in-house developed technologies)

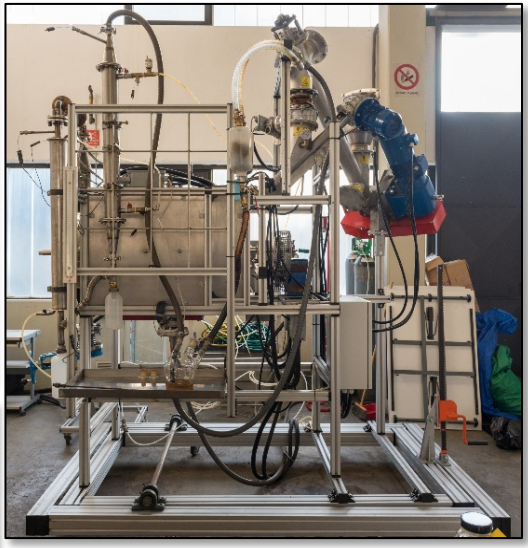
Rotary Kiln

Slow pyrolysis of biomass & waste to fuels and products

- Solid (as fuel or amendment) + high T heat
- Integration in large-scale Advanced Biofuel supply chain
- IN=100 kg/h





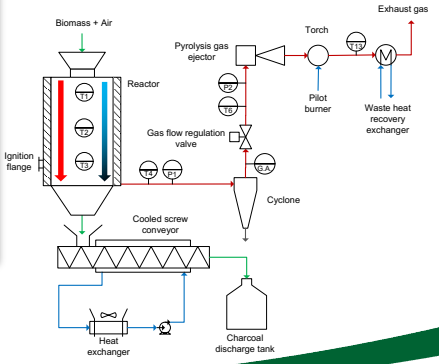


CARBON

Slow pyrolysis of biomass for charcoal and biochar making.

- Fixed bed, Open-top Oxidative Reactor (Autothermal)
- Designed and developed for small farmers
- Continuous operation.
- IN=50 kg/h. OUT=12kg/h (ηc = 24 wt.%)

Intermediate pyrolysis Pilot Unit



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Feedstocks and process conditions

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SOFTWOOD

Pine

Poplar

HARDWOOD

Willow

- *Drying*
- *Grinding to 2 mm*

TGA Leco 701

Temperature [°C]	Heating rate [°C/min]	Plateau [h]	N flowrate [l/min]
400	20	2	10
550	20	2	10
650	20	2	10

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Specific surface, water retention….

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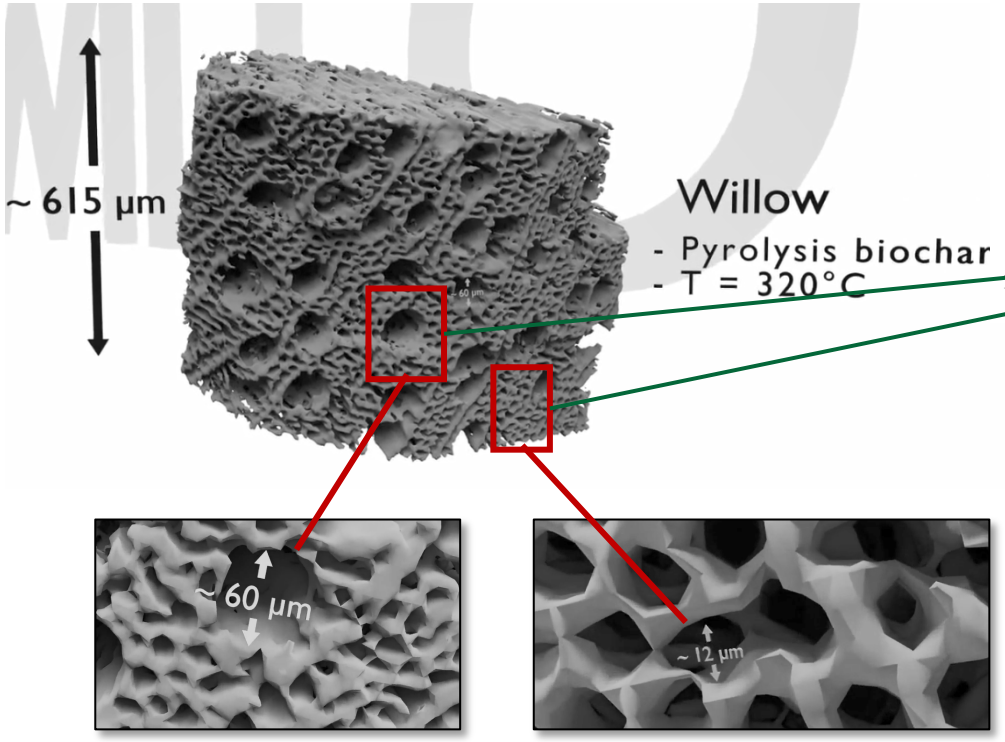
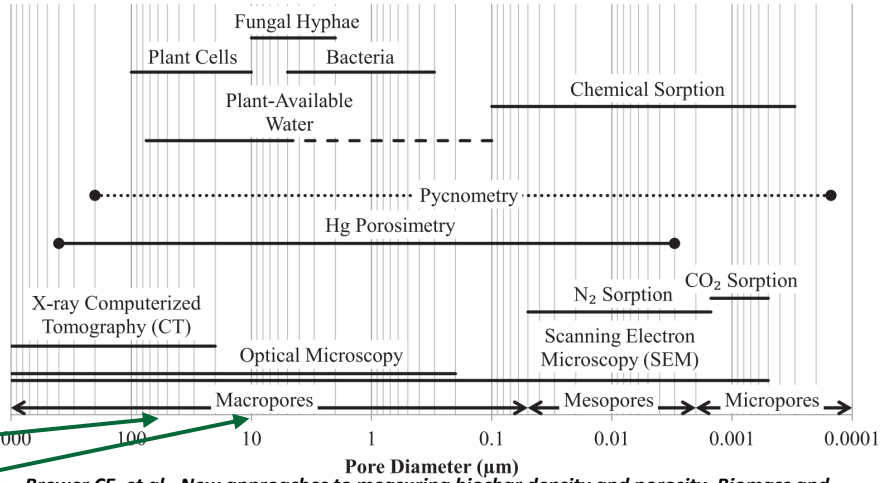
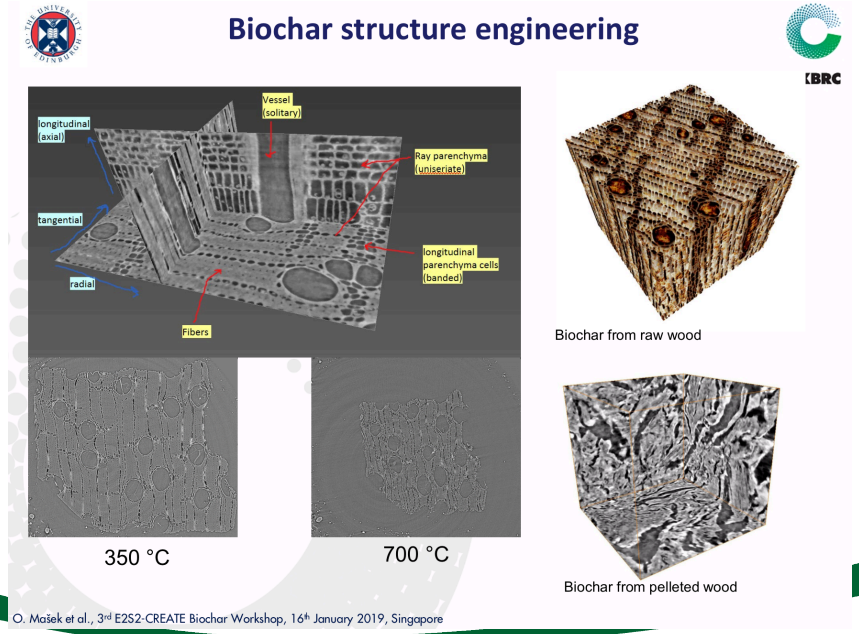
Source: Luke, Finland. X-ray tomographic reconstruction of a willow biochar sample pyrolysed at temperature 320 ° C. Image resolution is 1.14 µm. Camera moves through pores relevant for water retention (approx. 10 and 50 µm in diameter). **https://www.youtube.com/watch?v=xZeu8mNlxZQ**





Brewer CE, et al., New approaches to measuring biochar density and porosity, Biomass and Bioenergy (2014), http://dx.doi.org/10.1016/j.biombioe.2014.03.059



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Wood structure: Hardwood/Softwood

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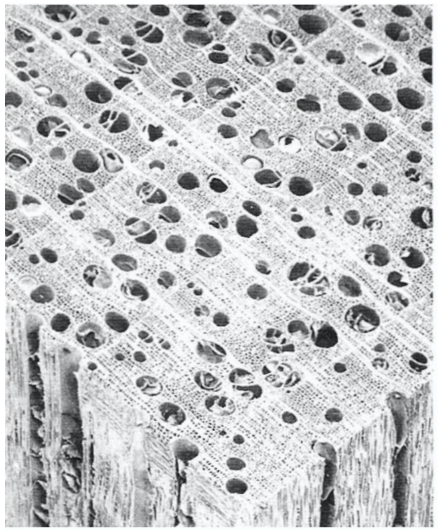
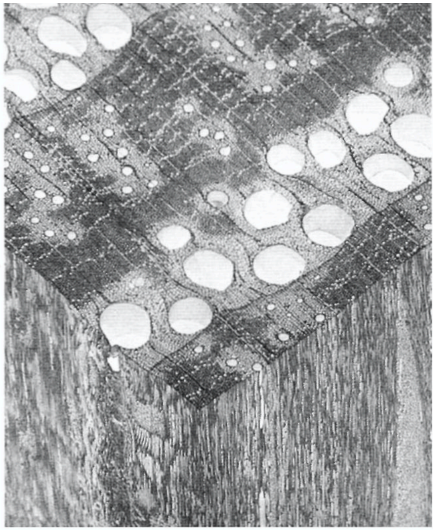
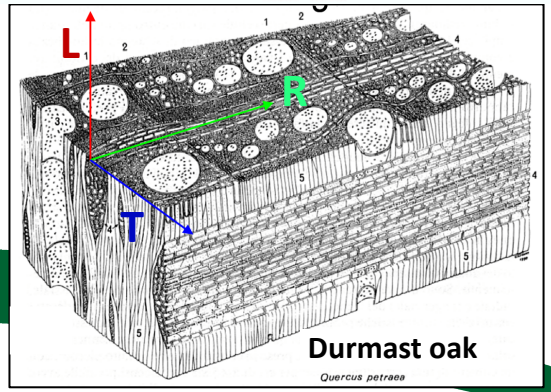
Hardwood *Angiosperms-Monocotyledons*



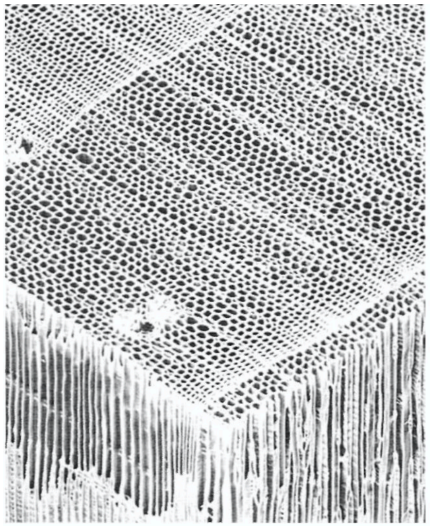
BLACK WALNUT



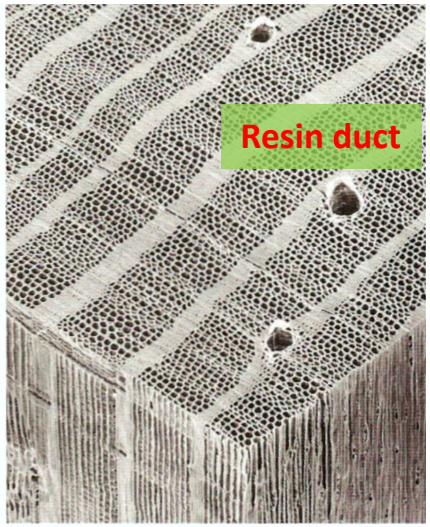
RED OAK



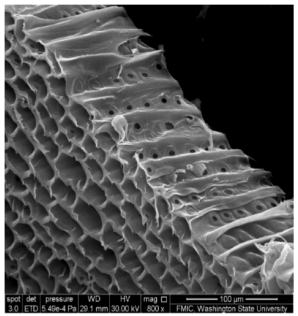
Softwood *Gymnosperm-Coniferous*



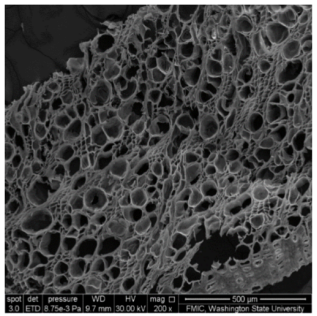
EASTERN WHITE PINE



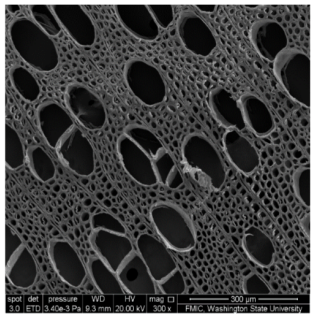
SOUTHERN YELLOW PINE



Pine wood biochar
mag. 800X



Pine bark biochar
mag. 200X



Poplar wood biochar
mag. 300X

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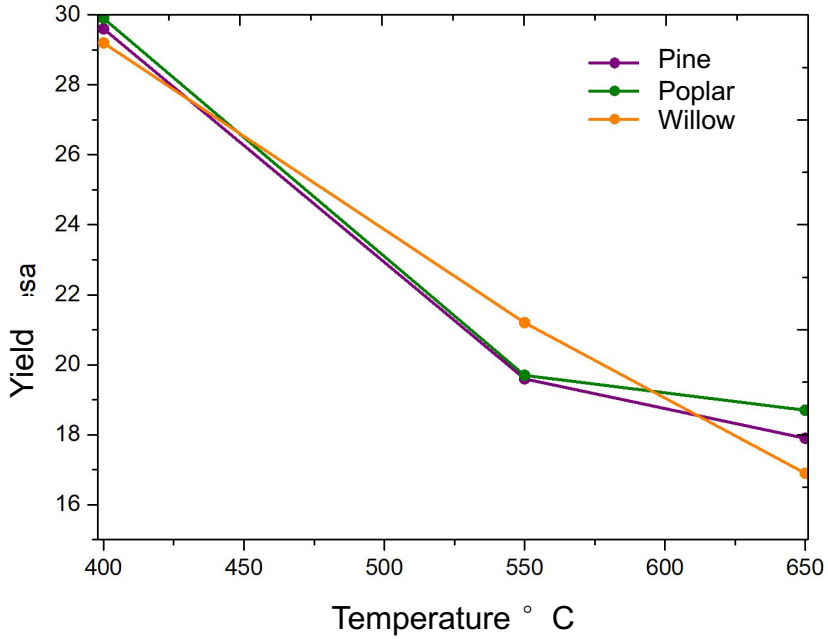
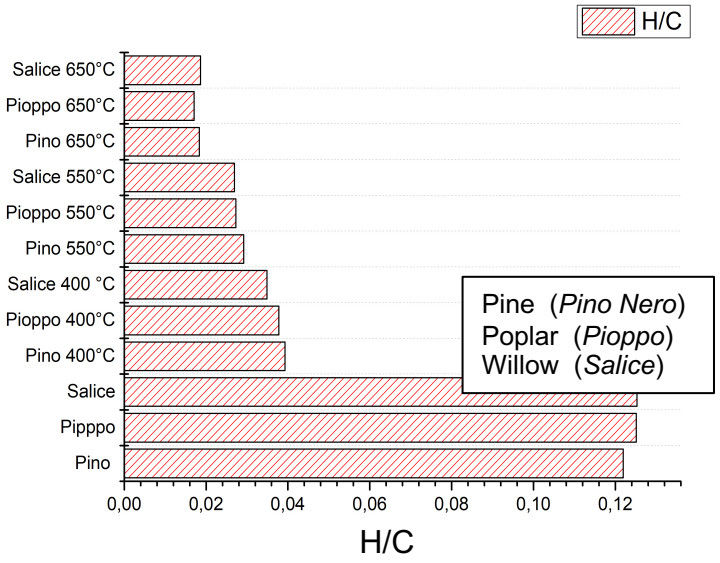
Suliman WSO, Harsh J,Abu-Lail N, Fortuna A-M, Dallmeyer I, Garcia-Perez M: Influence of Feedstock Source and Pyrolysis Temperature on Biochar Bulk and Surface Properties. *Biomass and Bioenergy*, Volume 84, **2016,** pp 37-48

Yields and elemental composition

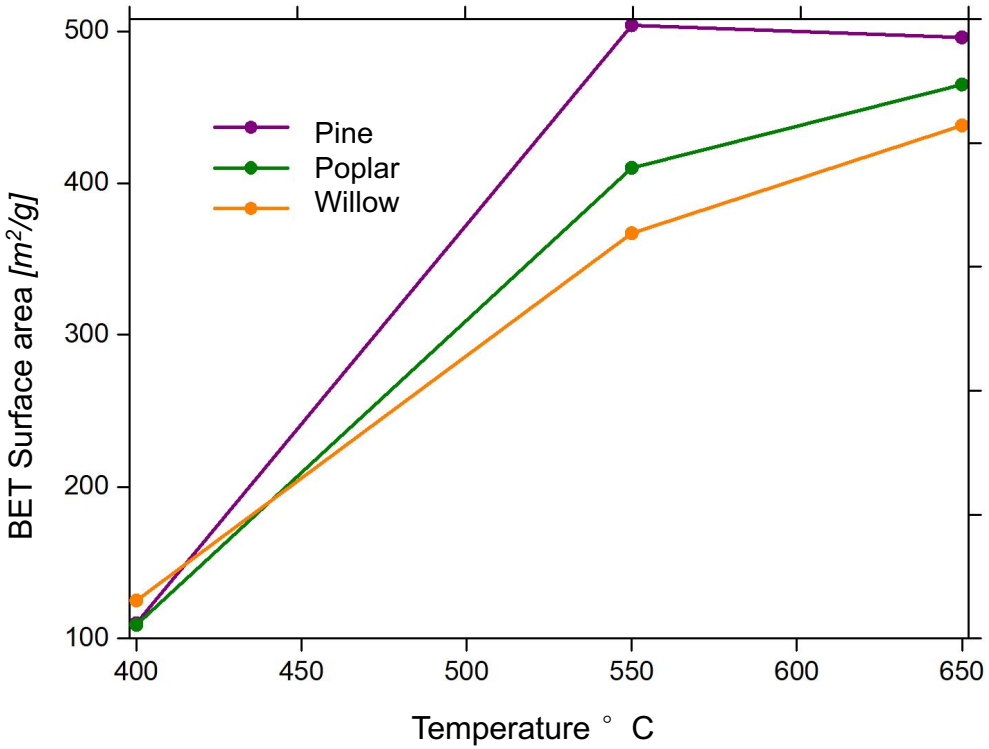


H/C ratio decreasing with carbonization T



	Biomass			Biochar								
	Pine	Poplar	Willow	Pine 400°C	Poplar 400°C	Willow 400°C	Pine 550°C	Poplar 550°C	Willow 550°C	Pine 650°C	Poplar 650°C	Willow 650°C
Moist. %	28,5	39,4	40,2	-	-	-	-	-	-	-	-	-
Yield % w/w	-	-	-	29,6	29,9	29,2	19,6	19,7	21,2	17,9	18,7	16,9

BET



Softwood biochar (pine) shows higher BET values at 550 ° C and 650 ° C

Mercury porosimeter

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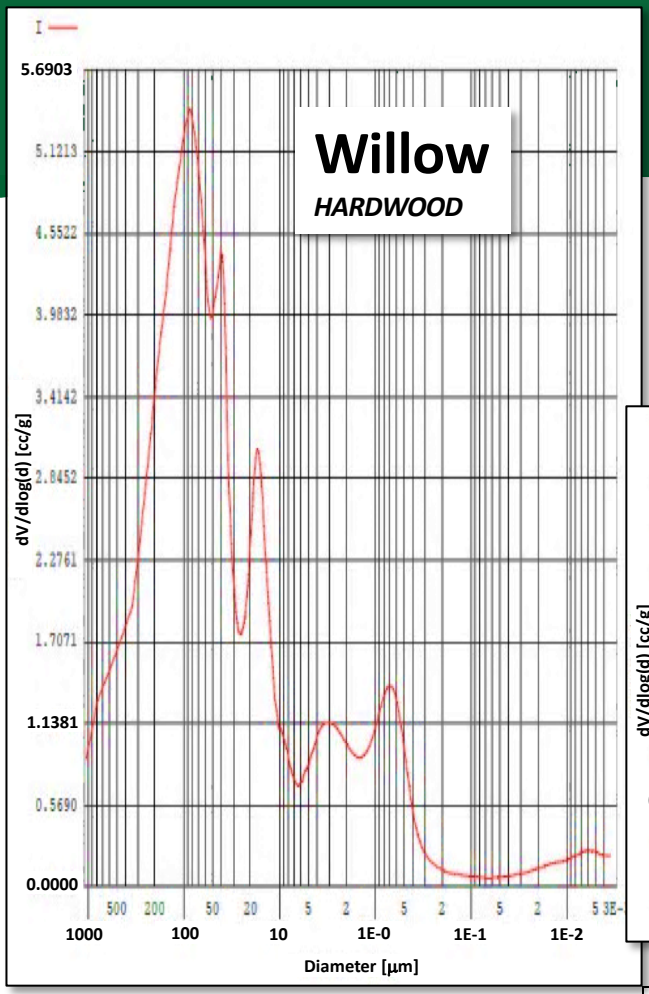

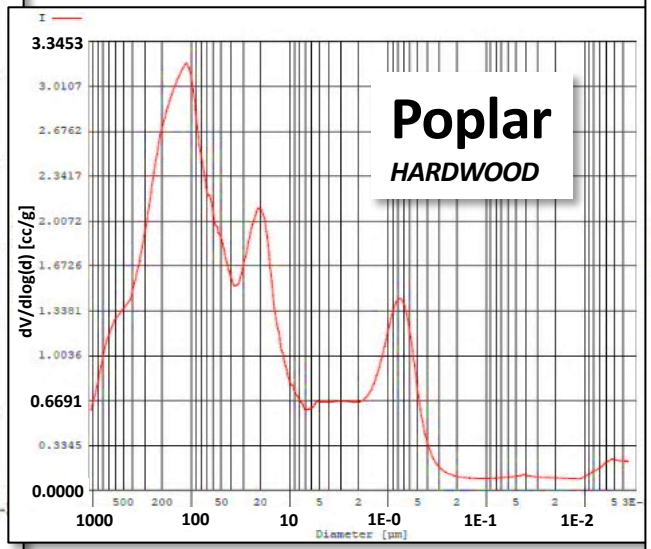

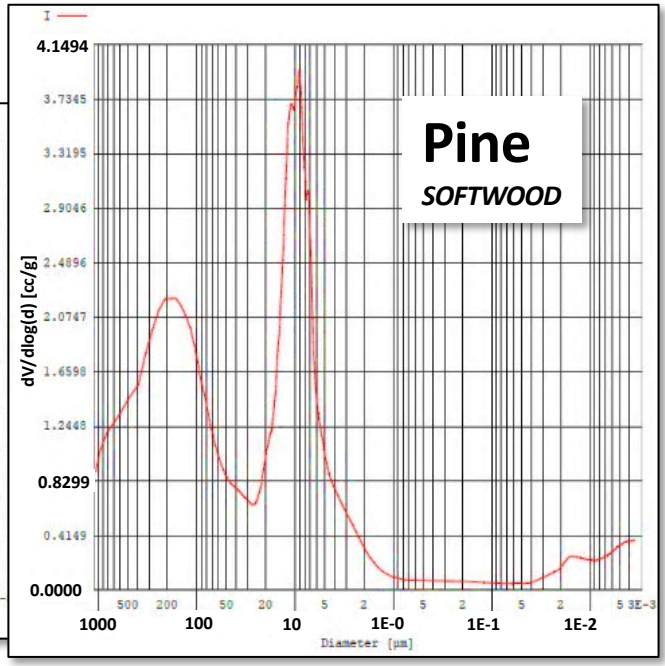

Wood	BET - Specific Surface (m2/g)	Mercury Porosimeter - Surface Area (m2/g)	Mercury Porosimeter -Total Intruded Volume (cc/g)
Willow	367	97.16	7.69
Poplar	410	78.85	5.33
Pine	504	126.86	4.53

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Density vs superficial area - char produced at 550° C

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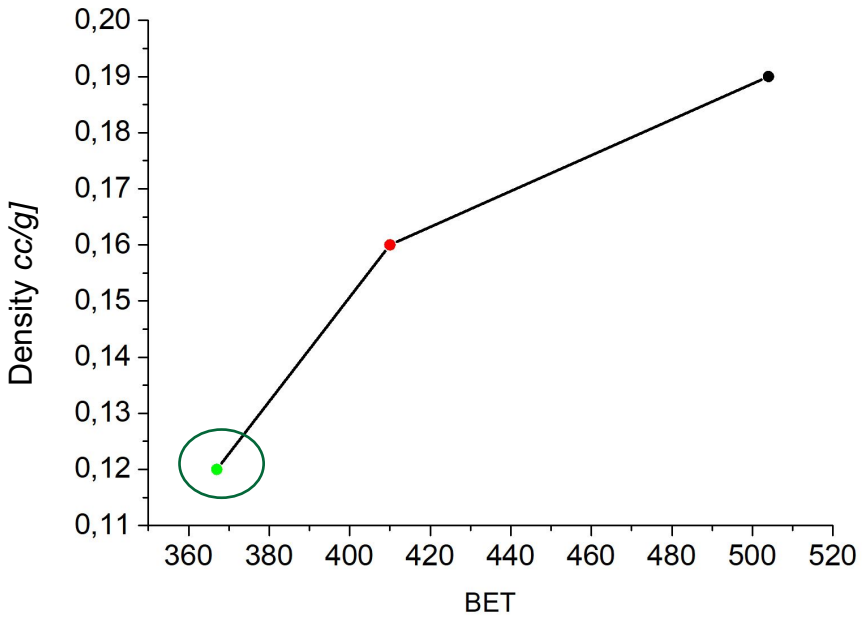
Biochar 550° C	Total Porosity [%]	Density [g/cc]	Total intruded volume Hg [cc/g]
Pine	86	0,19	4,5
Poplar	86	0,16	5,3
Willow	91	0,12	7,6



I biochar a 550 ° C sono: Pino nero (●), Pioppo rosso (●), Salice verde (●).

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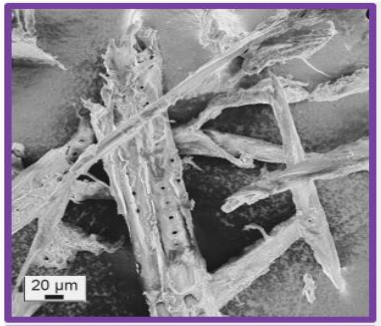
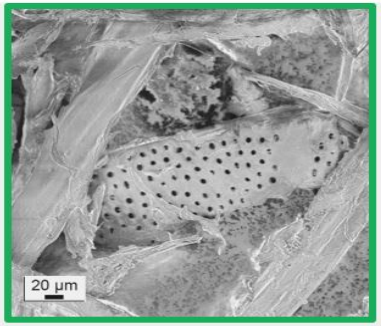
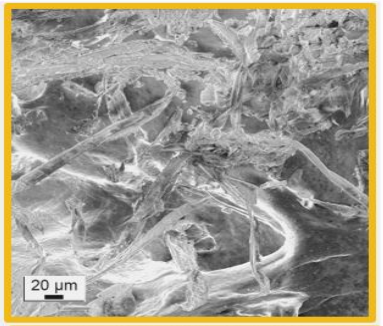
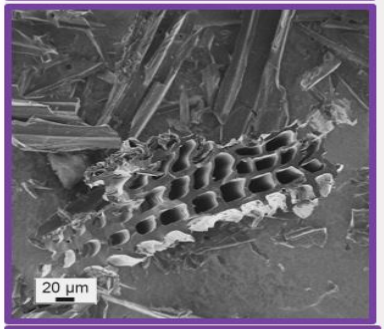
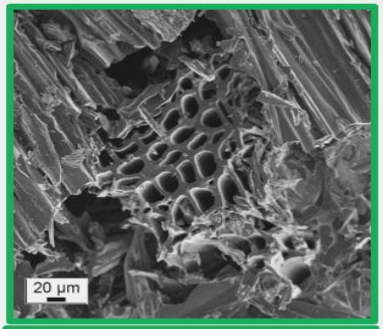
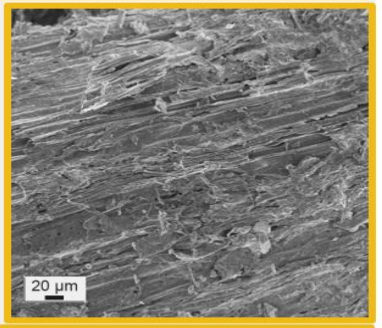
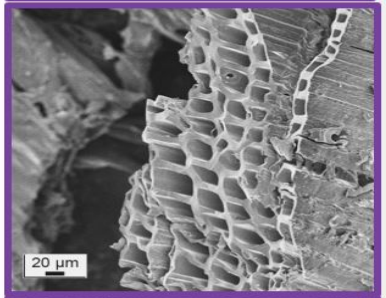
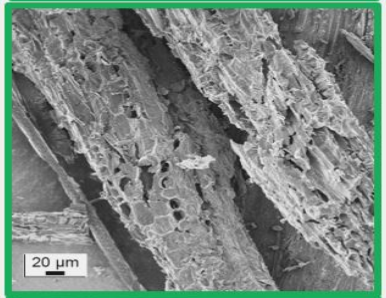
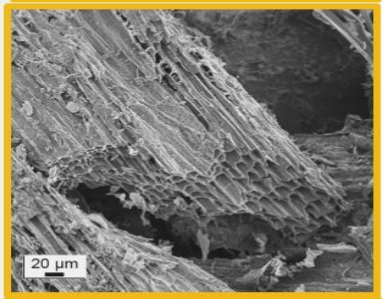
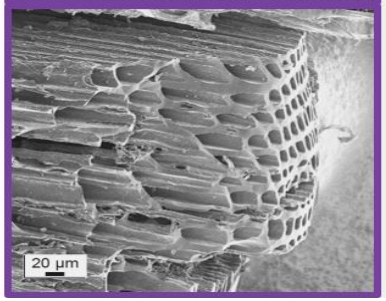
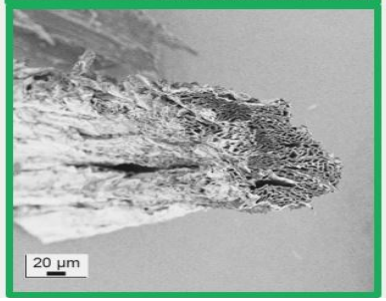
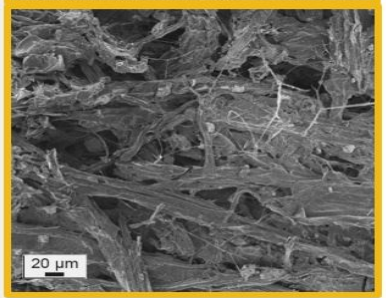
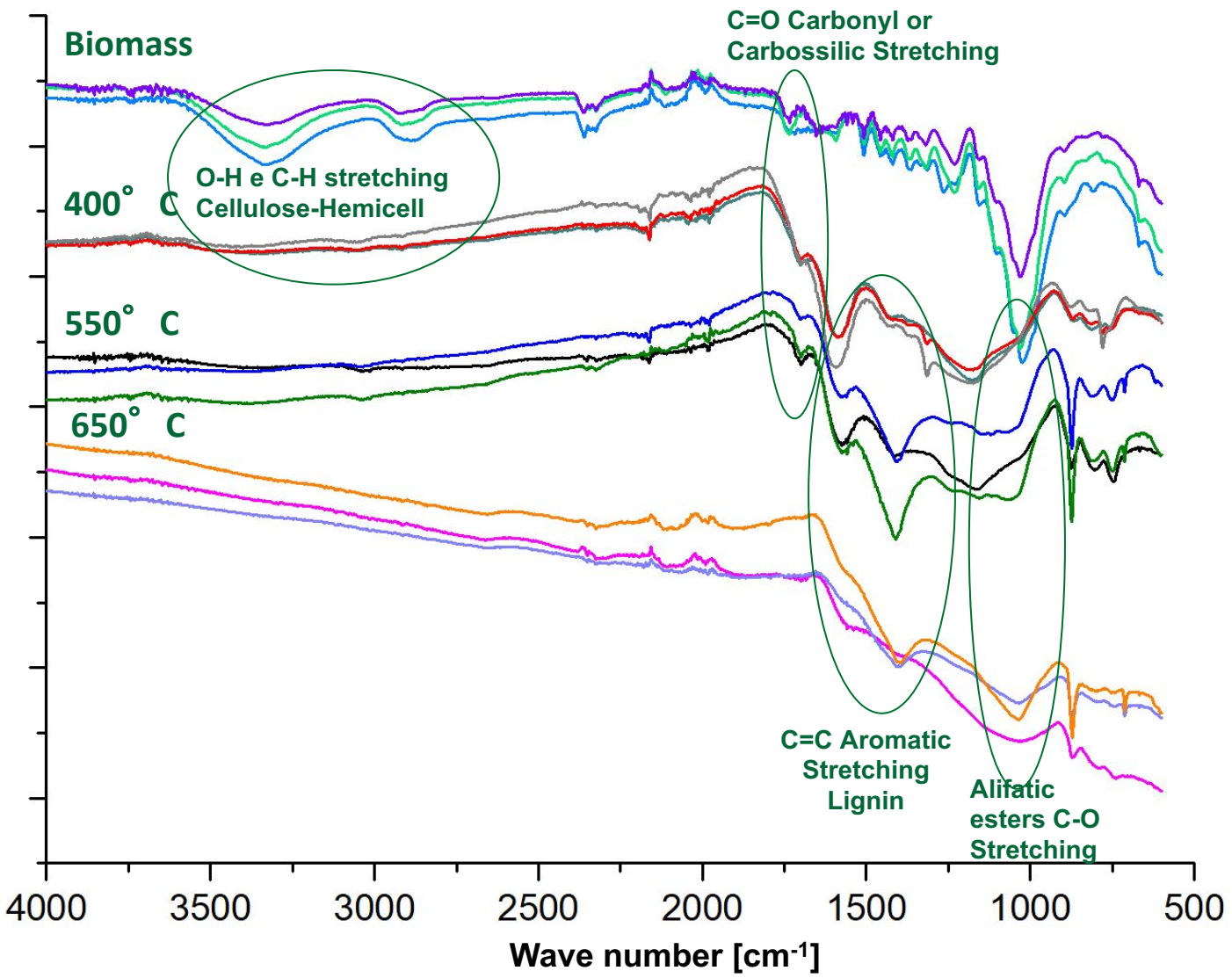
SEM analysis

	Pine	Poplar	Willow
Biomass			
400°C			
550°C			
650°C			

FT-IR



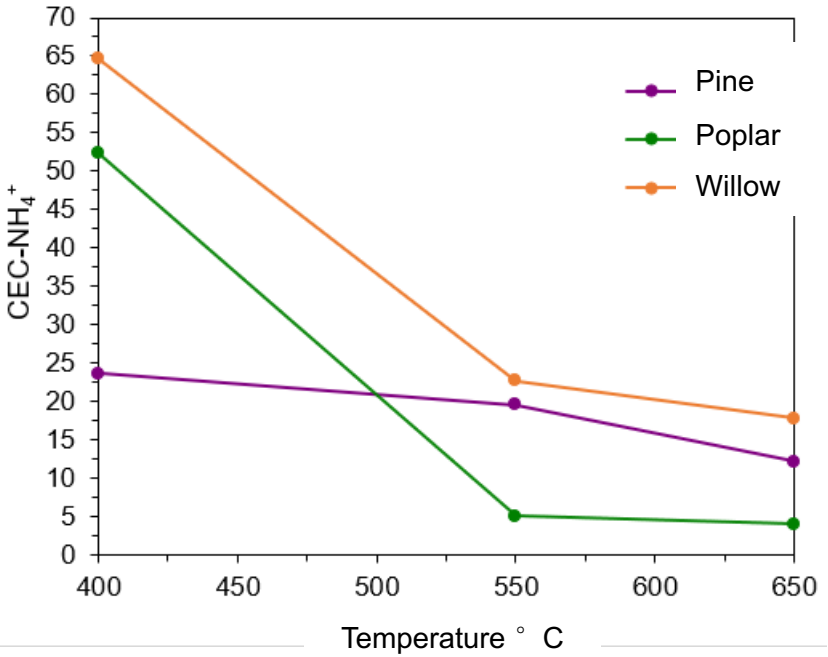
Broad bands at ~3400 cm^{-1} in the feedstock, together with bands at ~2900–2800 cm^{-1}: they refer to cellulose and hemicellulose (due to the stretching vO-H and vCH).

These signals disappear increasing pyrolysis T.

The signal at 1730 cm^{-1}, probably due to the hemicellulose (C = O), gradually disappear from 400 to 650 ° C.

Some bands at ~1600-1500 cm^{-1} attributed to aromatic group (C = C) both in biomass and in biochar; an increase in the intensity of aromatic CH at 870-850 cm^{-1} probably due to graphitic structures

CEC – NH_4^+



Sample	CEC-NH_4^+
Pine 400°C	23,7
Pine 550°C	19,6
Pine 650°C	12,2
Poplar 400°C	52,3
Poplar 550°C	5,1
Poplar 650°C	4,1
Willow 400°C	64,7
Willow 550°C	22,7
Willow 650°C	17,8

Criteria for assessment	CEC cmol(+)/Kg
High	> 20
Average	10-20
Low	< 10

Willow, 400 ° C: highest CEC-NH_4^+. Trend in agreement with the reduction of oxygenated functional groups with temperature

Conclusions

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Results in good agreement with literature and expectations:

- ***Softwood*** **: higher BET surface (550° C).**
- ***Hardwood:*** **more macropores (consistent with wood structure). Better feedstock for plant water available water.**
- **CEC max at 400° C, decreasing with T (less oxygenated functional groups)**

Ongoing R&D work

- **Investigation of fresh and aged or partially oxidated biochar, both at lab and pilot scale**
- **Assessment of biochar characteristics vs plant and soil**
- **Final goal: framing process conditions and feedstock selection in the industrial scale of biochar production**

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Thanks for the attention

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