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The effects of biochar interpores and intrapores on soil-gas transport

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Gas transport and biochar

- In many soils, biochar enhances water retention.
  - This could reduce gas transport, as more water is held in pores.

- If gas diffusion can be maintained, this is beneficial for agriculture industry & waste minimization industry

✓Gas diffusion can minimize CH_4

✓Gas diffusion increases plant growth w/ enhanced water retention

✓Gas diffusion increases microbial respiration

Gas transport and biochar

- Past work:
  - Biochar increases gas diffusion [Sun, 2013]
  - Biochar decreases gas diffusion [Arthur, 2017]
  - Biochar has no affect on gas diffusion [Amoakwah, 2017]
- Fundamental understanding of the mechanism is needed

The effects of biochar on soil-gas transport

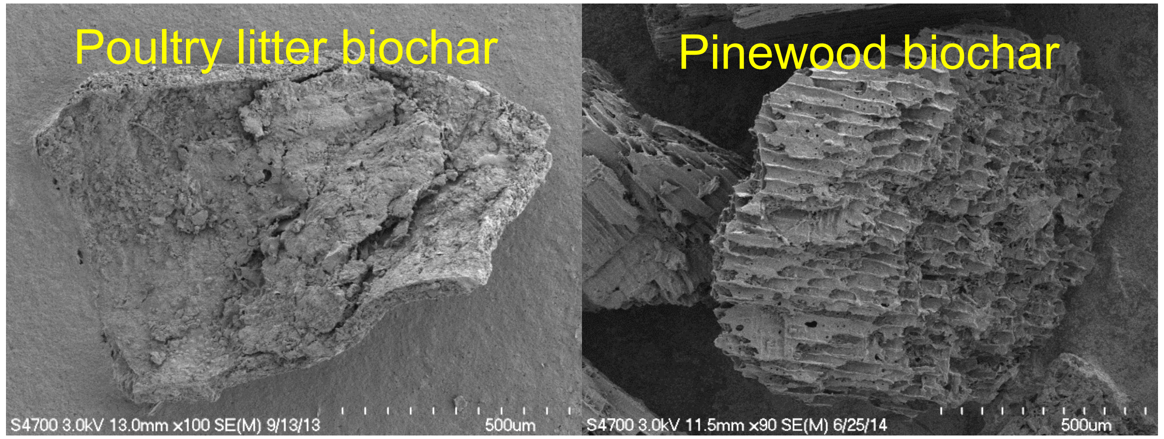
Biochars change pore characteristics of soils.

Biochars have intrapores that vary with feedstock and pyrolysis conditions.

Biochars can affect interpores that change

pore throat sizes

Air filled porosity describe gas properties.



Hypothesis:

<u>Gas diffusion is controlled by air filled interporosity.</u>

Even if air-filled interporosity is the same, biochar particles are more angular increasing tortuosity

Materials

Media

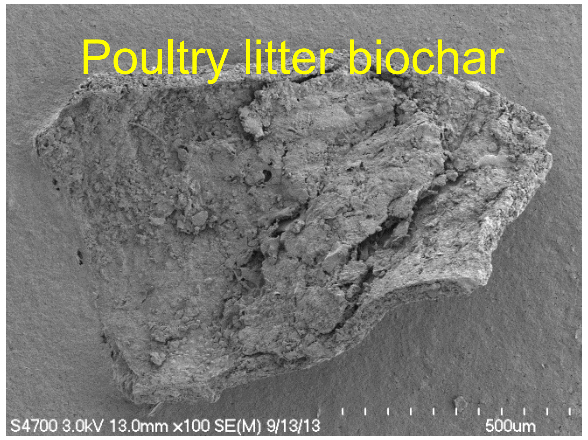
Sand
0.5 mm < d_p < 0.595 mm

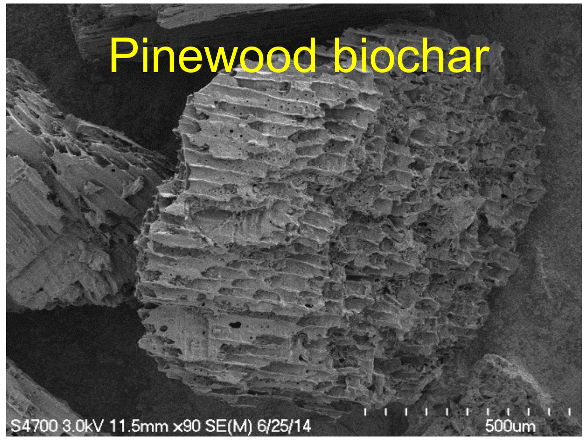
Sandy Loam
0.02 mm < d_p < 9.5 mm

Biochars

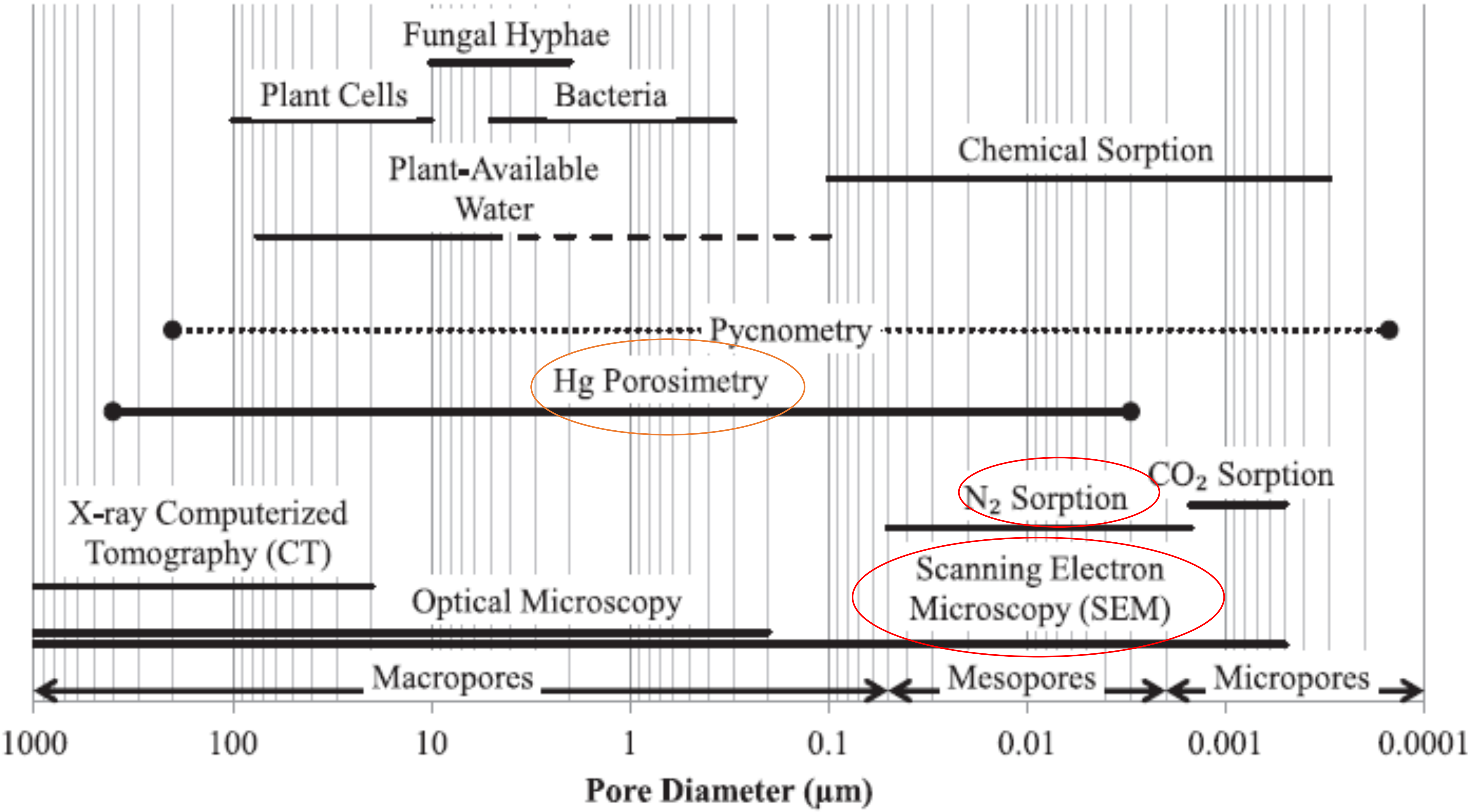
Poultry Litter Biochar (PLBC)
300°C
0.5 mm < d_p < 0.595 mm

Soil Reef (pinewood) Biochar (SRBC)
550°C
0.5 mm < d_p < 0.595 mm

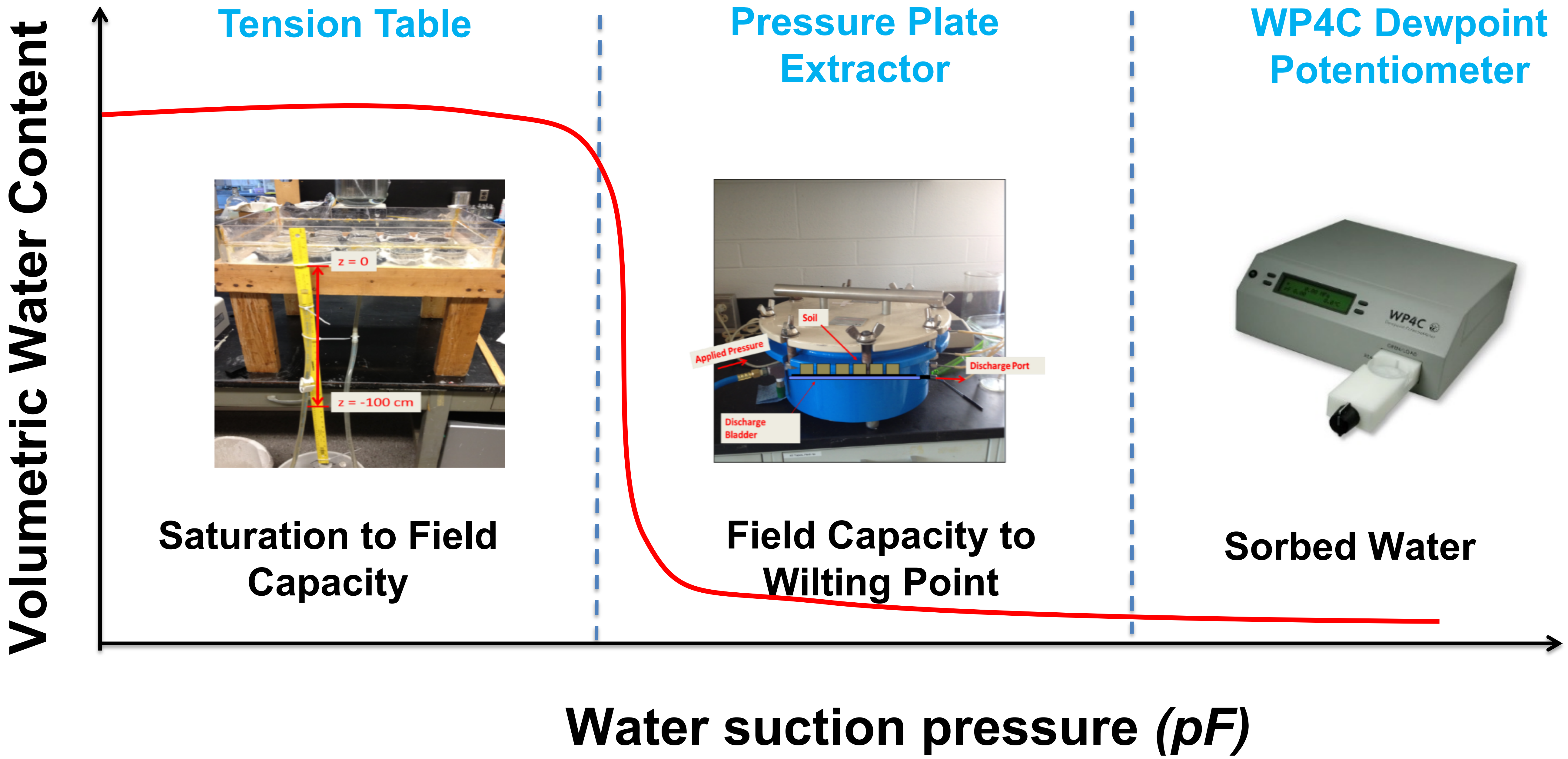




Intrapore Size Determination Techniques



Methods

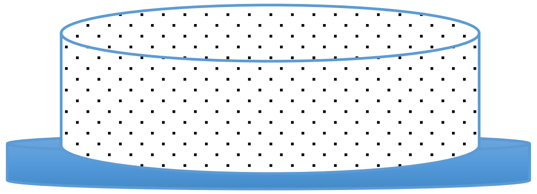

Volumetric Water Content
Tension Table
Pressure Plate Extractor
WP4C Dewpoint Potentiometer
z = 0
z = -100 cm
Soil
Applied Pressure
Discharge Port
Discharge Bladder
WP4C
Saturation to Field Capacity
Field Capacity to Wilting Point
Sorbed Water
Water suction pressure *(pF)*

Fick's law of diffusion

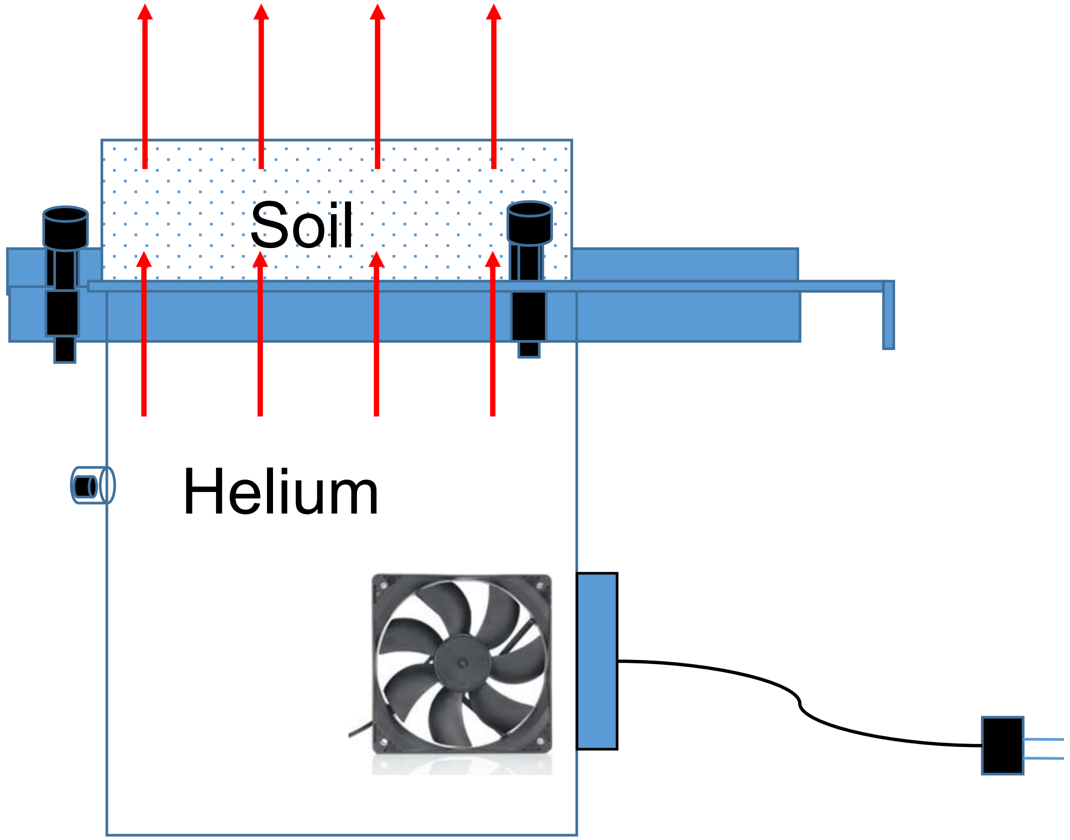
$$J = -D_p \nabla C_g$$

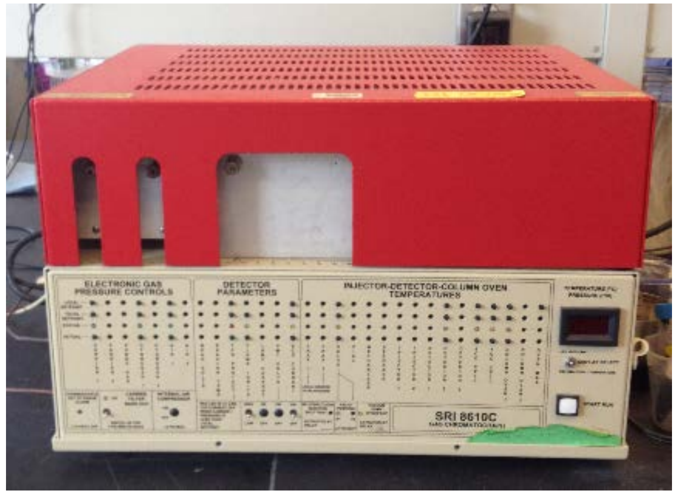
- J = diffusion flux
- D_p = diffusion coefficient
- ∇ = gradient operator
- C_g = concentration of gas

Methods - Diffusion cell

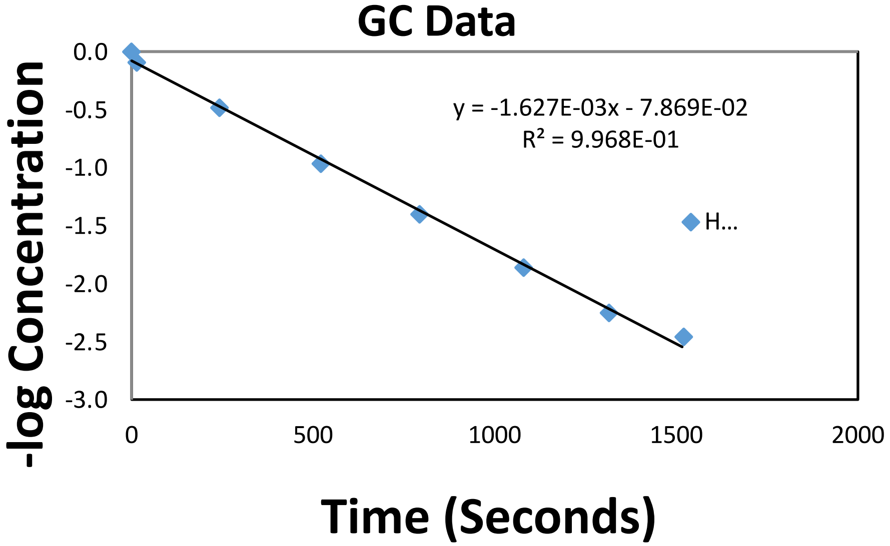


Packed sample
(Control, Control + 7%BC)





Gas Chromatograph



$$D_p = -\ln C_r\, \varepsilon / \alpha_1^2$$

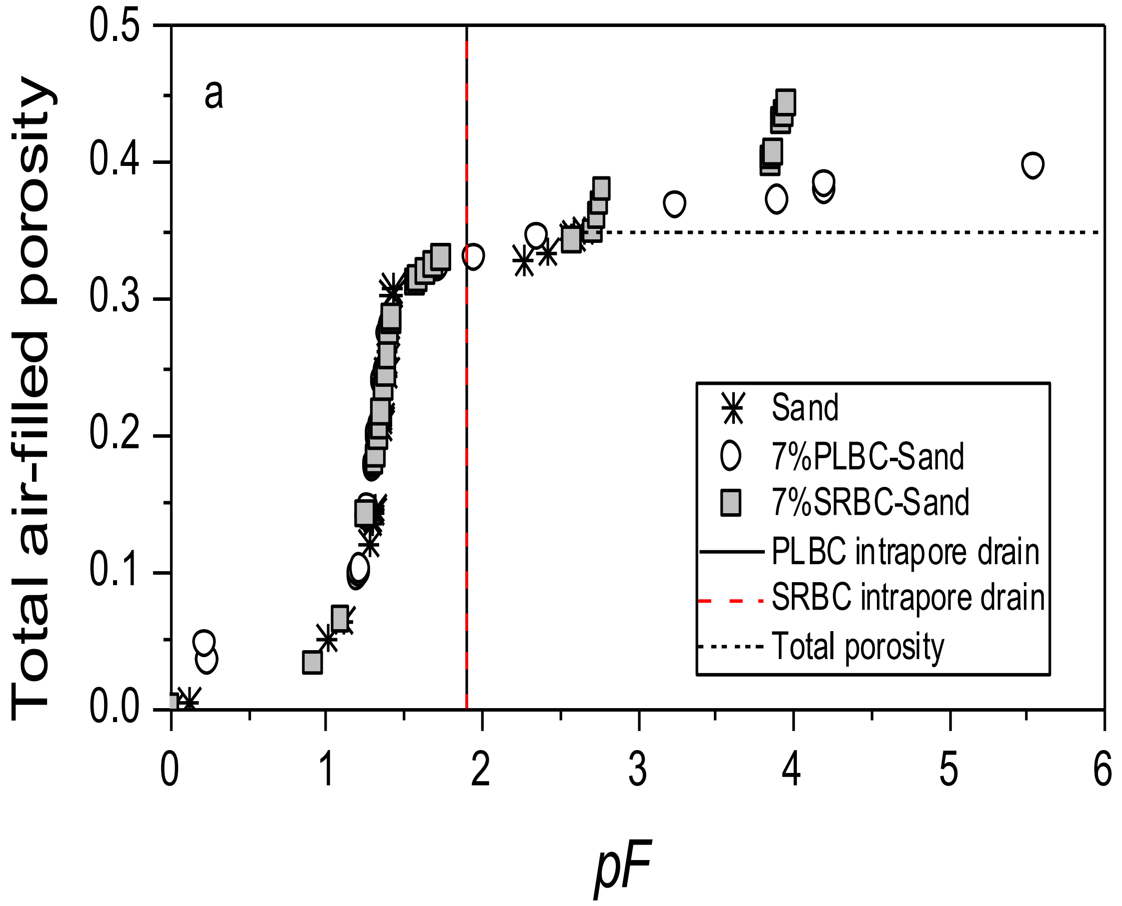
Results

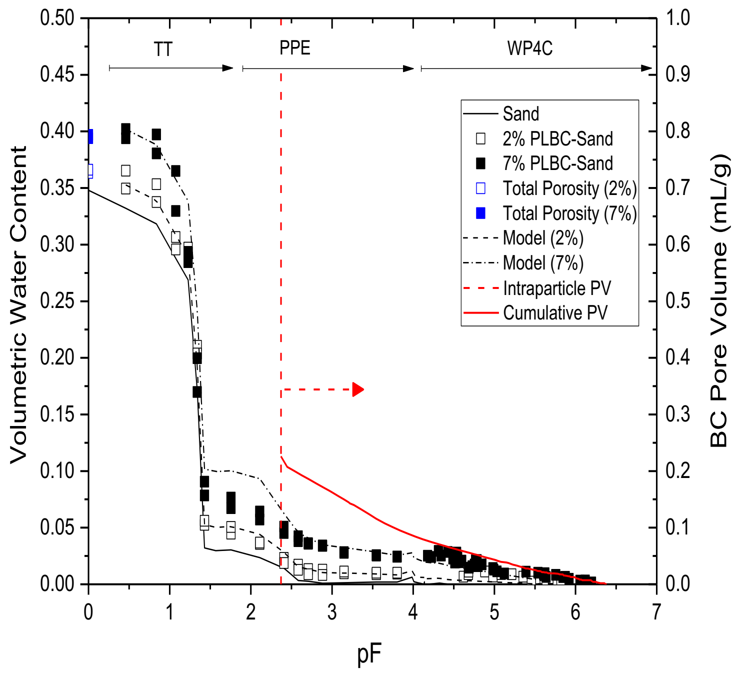
Sample type	*SSA[a]* *$m^2\ g^{-1}$*	*Intrapore volume* *$mL\ g^{-1}$*	*Biochar air entry pressure* *$pF = \log(-h, cm\text{-}H_2O)$*
Poultry litter biochar	1.53 ± 0.15	0.23 ± 0.01	1.9 ± 0.1
Pinewood biochar	350 ± 30	0.83 ± 0.01	1.9 ± 0.1

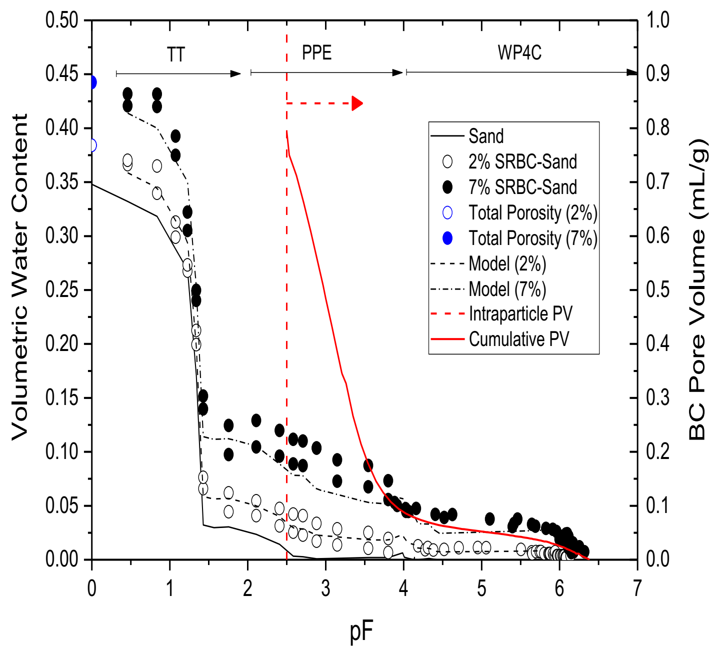
[a] **specific surface area**
[b] **standard error**

Gas diffusion at the same matric potential

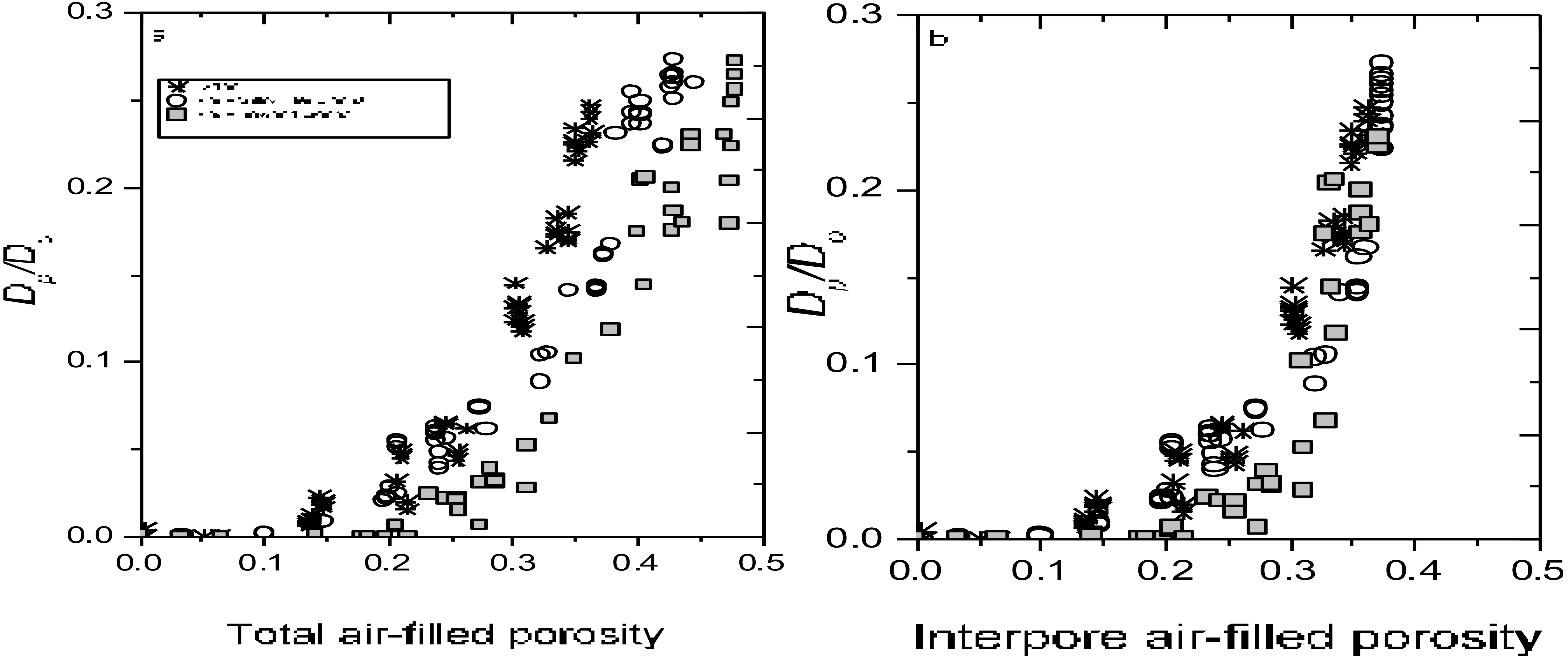
- The total air filled porosity doesn’t increase with biochar
- This is from water held in pores despite higher total porosity
- At the same *pF* values around 1.5, biochars have lower diffusivity than sand
- PLBC = poultry litter biochar
- SRBC = pinewood biochar





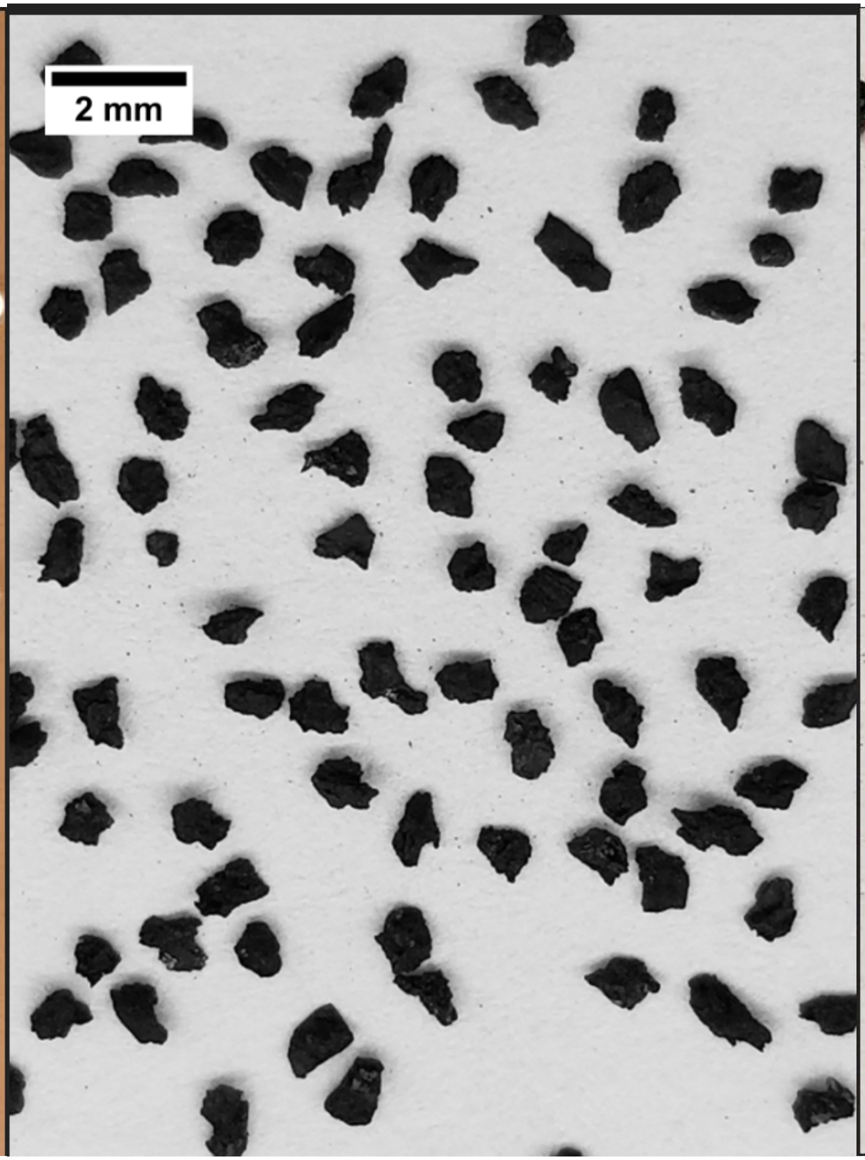


Results –Relative gas diffusion (sand)



Geometric characteristics of sand & biochar

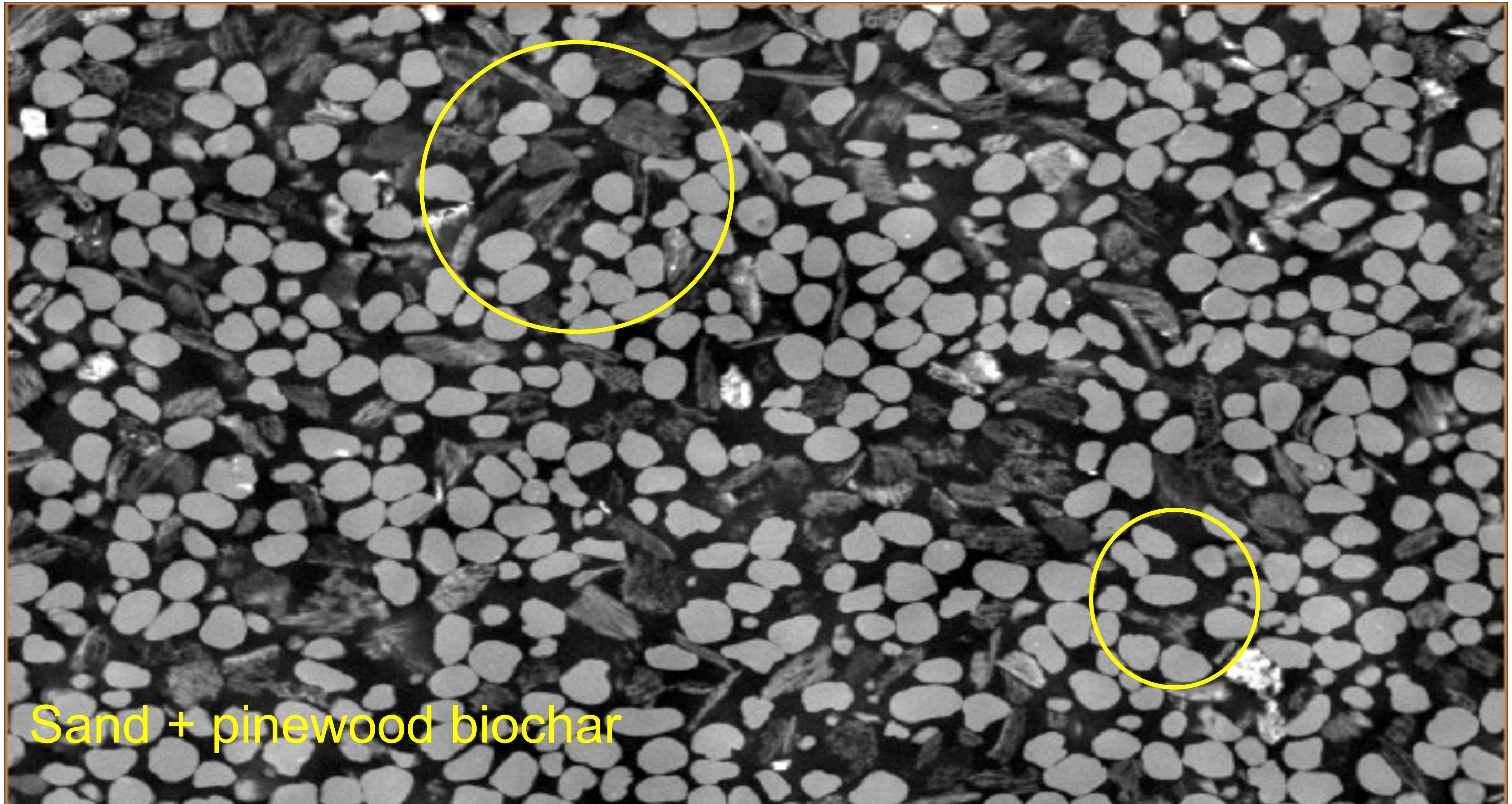
Sand



Poultry litter biochar

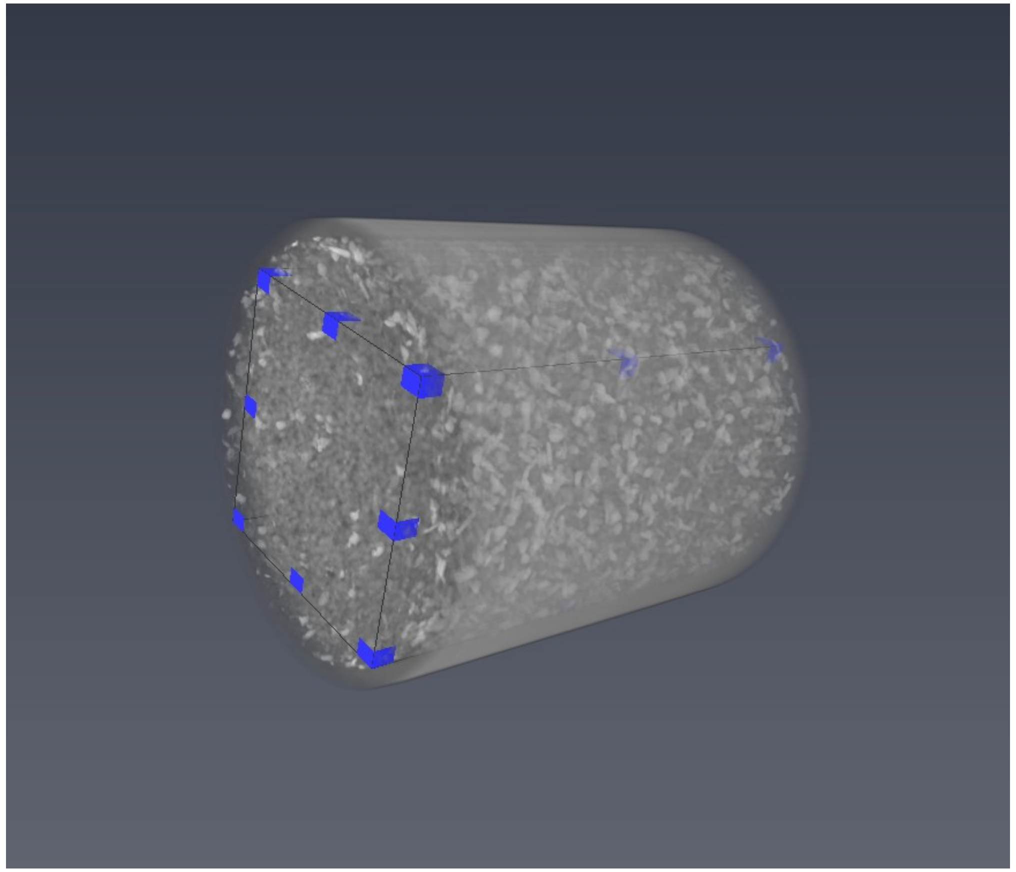
Pinewood biochar

X-ray tomography image (Mills et al, 2018)

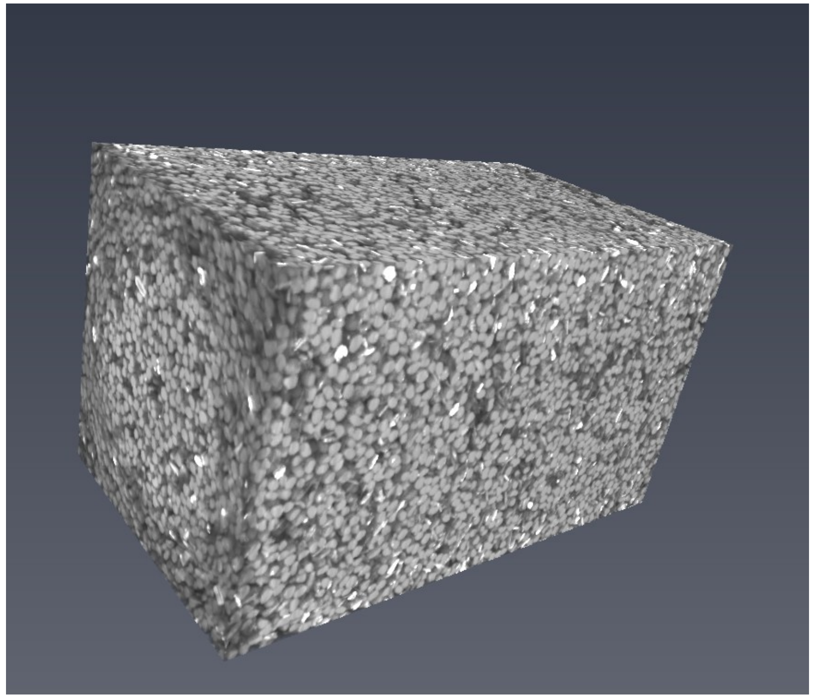


X-ray tomography study (Mills et al, 2018)

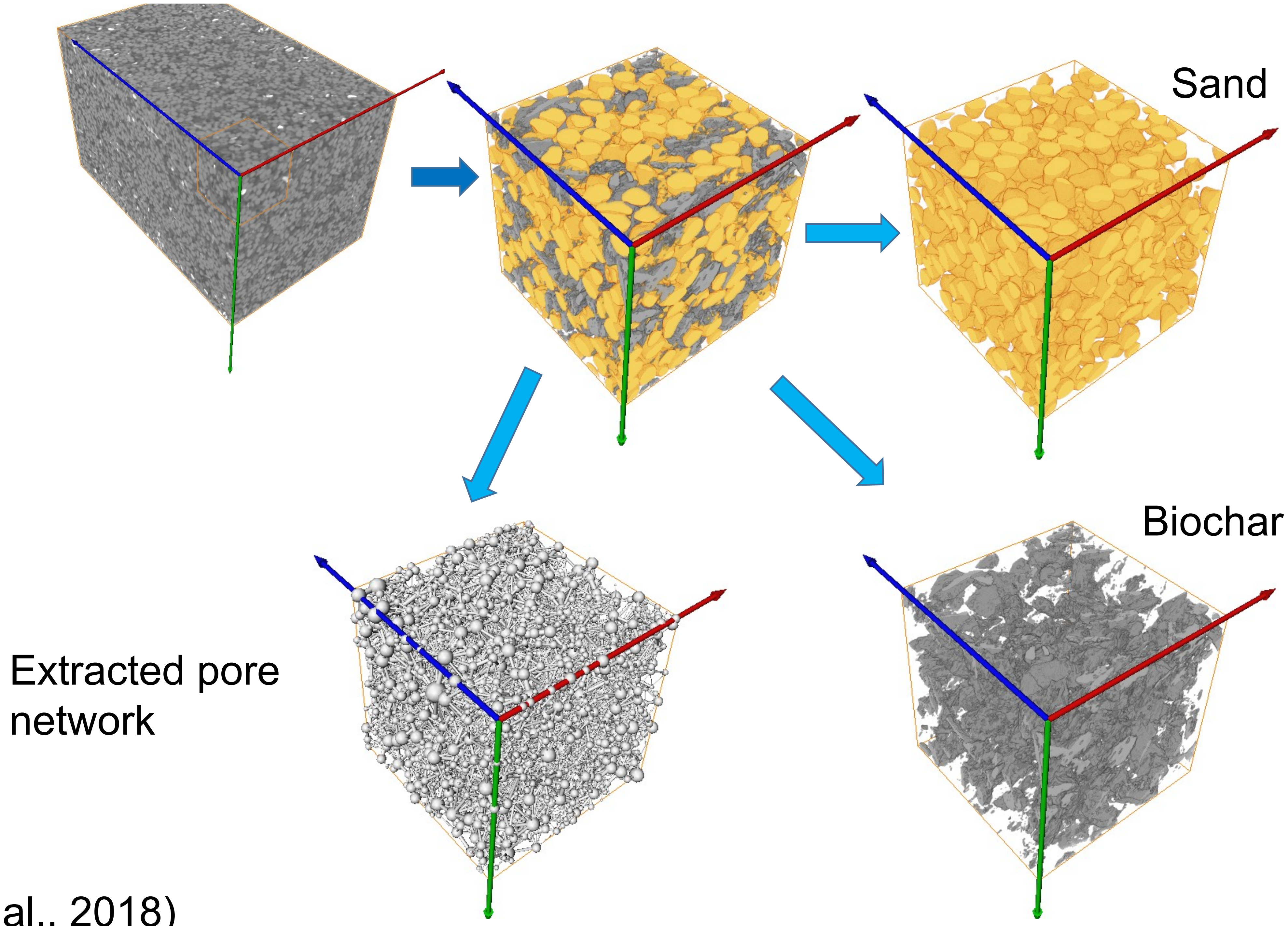
3D Volume



3D Cropped Volume



Sand+Pinewood Biochar: extracted segmented volume (4.9 x 4.9 x 4.9 mm³)



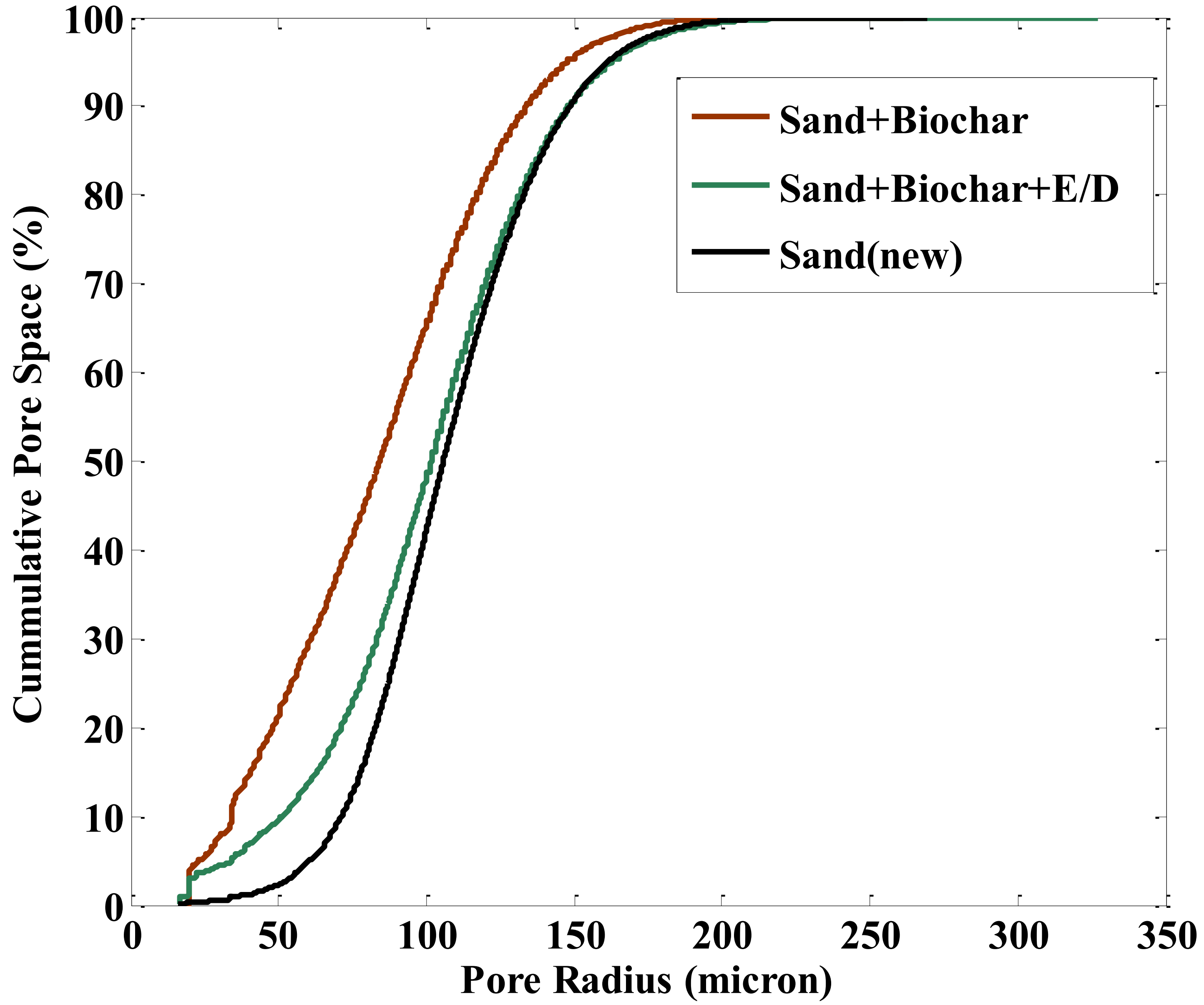
(Mills et al., 2018)

Percentage Phase Composition (Mills et al., 2018)

Sample	Sand(new): % volume	Biochar: %volume	Void: %volume
Sand + Biochar (X-ray)	38.2	12.24	49.5
Pure Sand (X-ray)	59.4	0	40.6
Sand + Biochar (EXP)	**39.86**	**12.94**	**47.20**
Pure Sand (EXP)	**61.73**	**0**	**38.27**

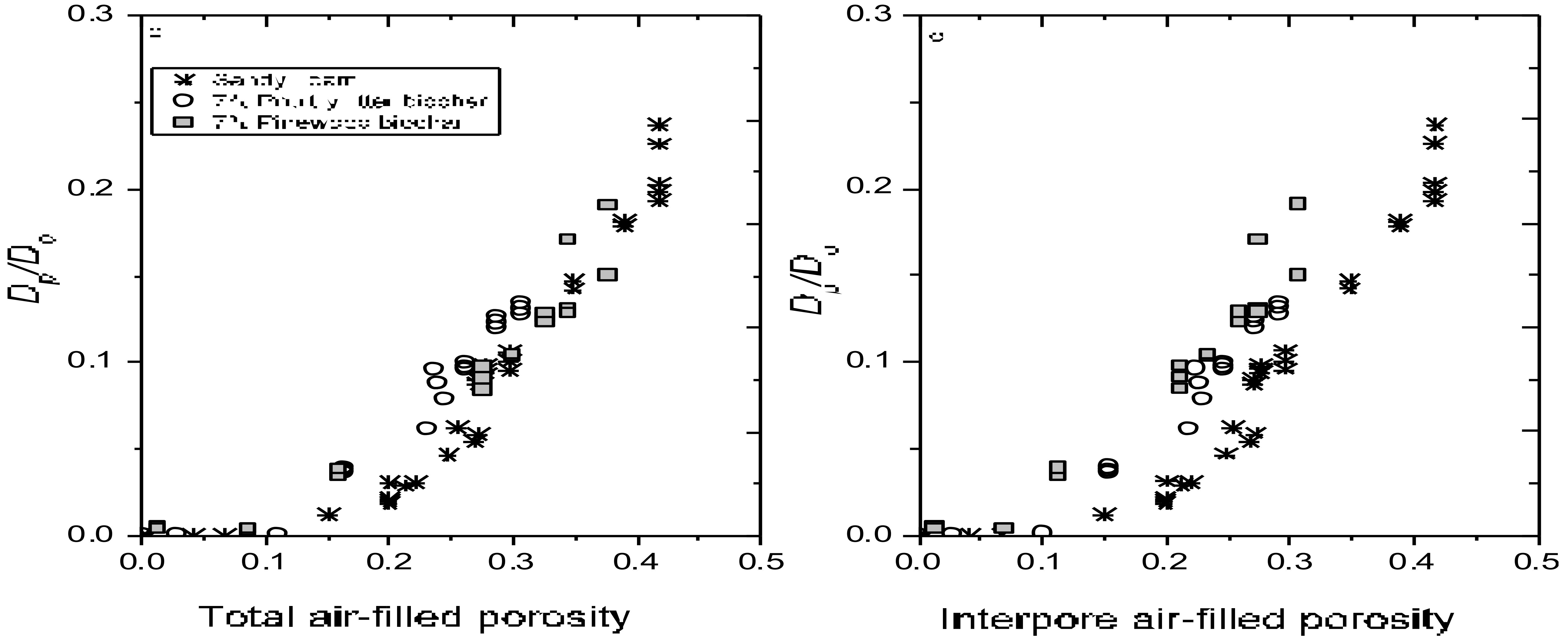
- Sand has lower total (entire volume) and effective (multiple sub volumes) porosity compared to the Sand + Biochar data sets
- The experimental and simulated porosity values are approximately equal.

The effect of biochar on pore radii



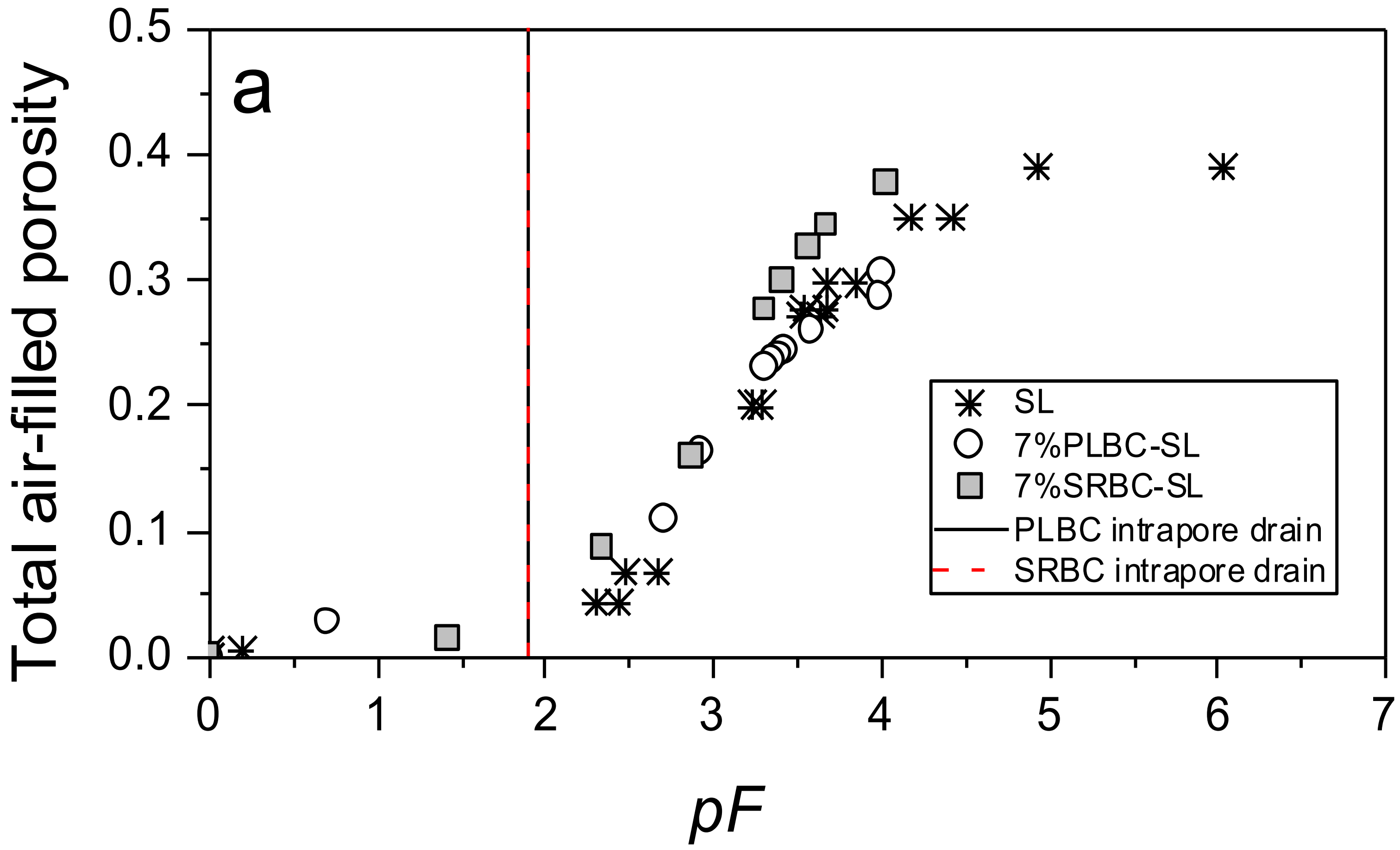
(Mills et al., 2018)

Results – Relative gas diffusion (sandy loam)



Gas diffusion at the same matric potential

- The total air filled porosity was not improved
- This is from water held in pores despite higher total porosity
- Biochars have similar diffusivity than sandy loam
- Biochars did not decrease in diffusivity unlike sand



Summary

- **In Sand:**
  - Particle sizes were sieved to the same size
  - Biochar shapes were not uniform
    - Interpores were reduced with biochar, which reduced diffusion in sand.
    - Intrapores stored water, reduced diffusion
    - Biochar increases tortuosity
- **In SL:**
- Biochars shift the particle size distribution increasing air-filled interpores
  - Biochars (~0.5mm)
  - SL (74% particles > 0.075 mm, 13% particles 0.005-0.05 mm, 13% (<0.005 mm)
- Biochar alters both interpore and intrapores
- Intrapores reduce gas diffusion from the particle geometry. Increase particle size of BC to increase gas diffusion to control pore sizes
- Adding biochar may not increase gas transport at the same air-filled porosity
- Lower diffusivity may imply lower GHG emissions from soil

Acknowledgements

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THANK YOU!

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X-ray tomography study (Mills et al, 2018)