ILLINOIS SUSTAINABLE TECHNOLOGY CENTER
PRAIRIE RESEARCH INSTITUTE

Simultaneouly strengthening of carbon sequestration and heavy metals immobilization in soil via biochar modification

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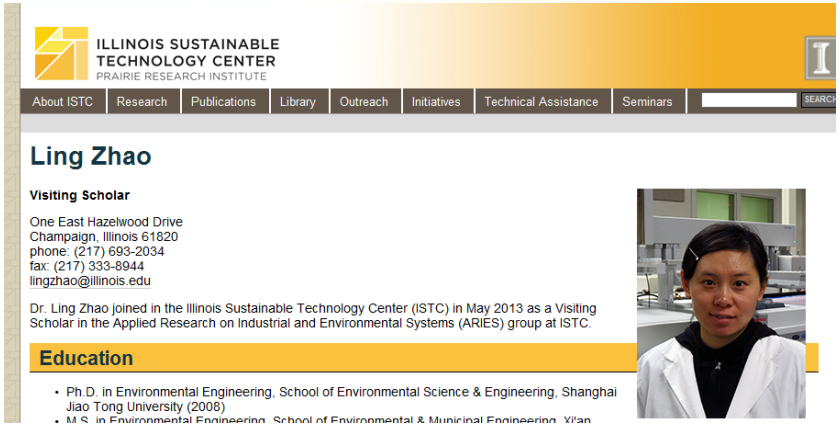
Introduction of myself

Ling Zhao

Visiting Scholar



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Outline

- Backgrounds and aims
- Study methods
- Some results
- Conclusions and implications
- Study progress

Backgrounds

Problems

Biochar: A tool for long-term carbon sequestration in soil

During biochar generation from biomass, a fair amount of carbon loses (about 50%) , which causes biochar to be controversial as a carbon sequestration strategy.

Biochar: A tool for heavy metals immobilization in soil

However, due to the variety of biomasses and soils, the immobilization efficiency was not stable, even questionable.

Aims of this study

- Using chemical additives to pre-treat biomasses, and then reduce C loss in pyrolysis.
- The biochar products stability is enhanced.
- After a relative long time in soil, the total C remaining is increased.
- The modified biochars' capability to immobilize heavy metals in contaminated soil is strengthened.

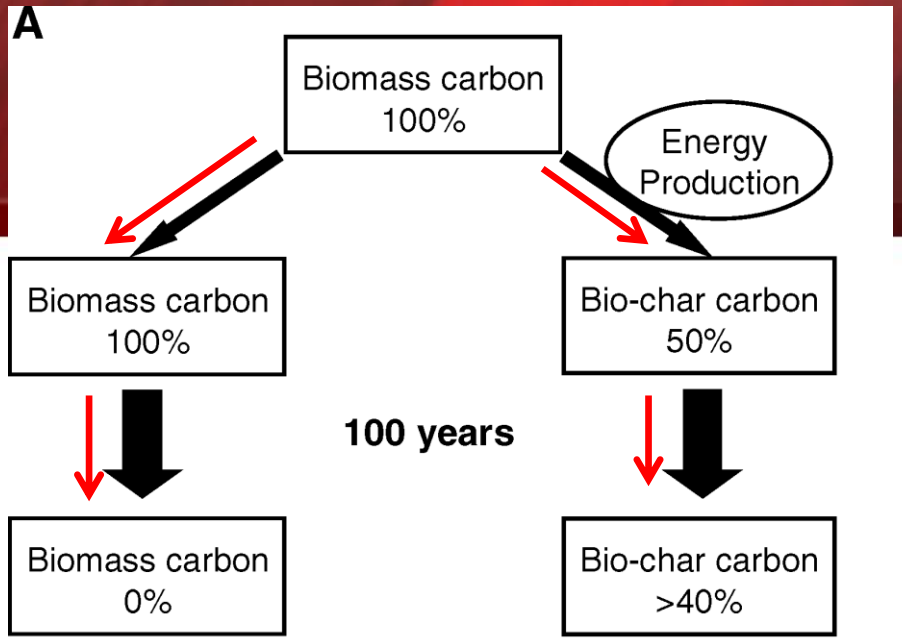
Backgrounds

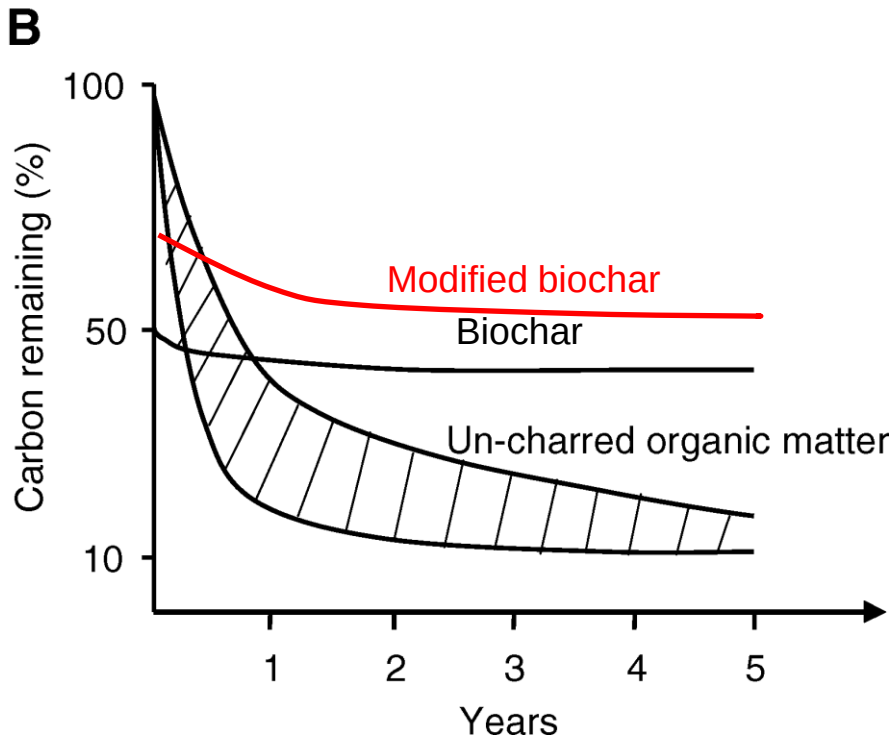
How long for keeping C in biochar

Figure A:
C remaining from biomass decomposition after 100 years;
C remaining after charring or pyrolysis;
Bio-char C remaining after decomposition.

Figure B:
Range of biomass C remaining after decomposition of crop residues and estimation of bio-char.

From: Lehmann et al. 2006 in *Mitigation and Adaptation Strategies for Global Change*





Study methods

Chemical additives

Phosphoric acid

P-containing fertilizer

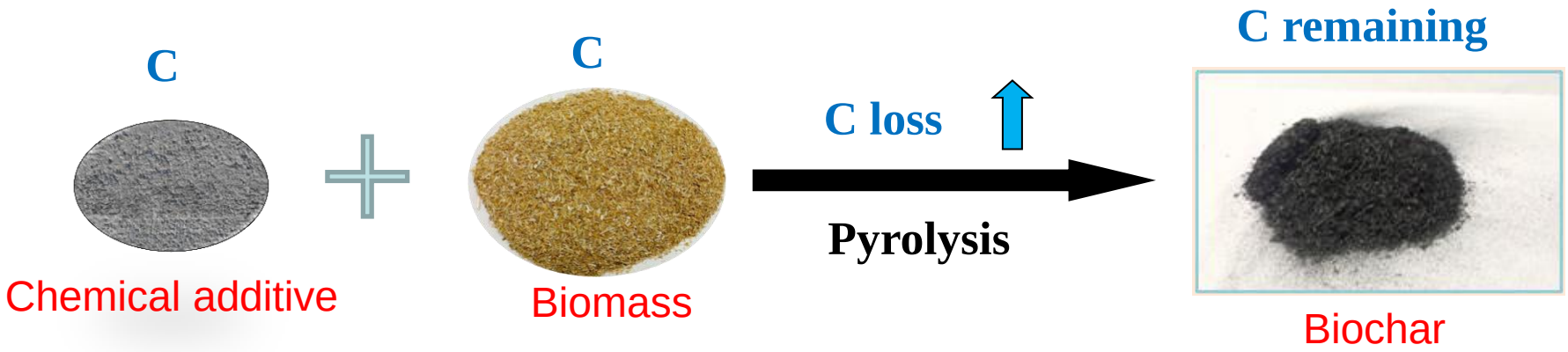
P-containing mineral

P or Ca containing biomass

……

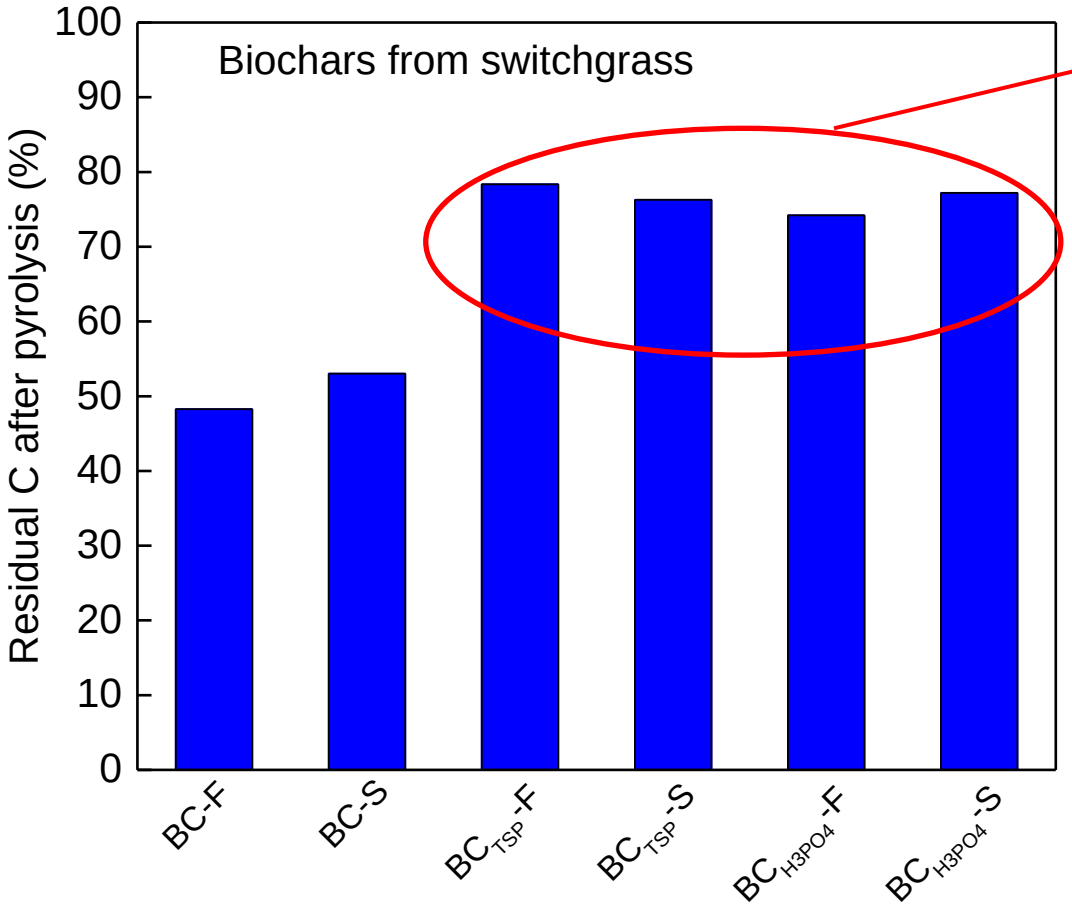
Low-cost and environmentally friendly material

Calculation of residual C



$$\text{Residual C (\%)} = \frac{TC_{biochar} * W_{biochar}}{TC_{biomass} * W_{biomass} + TC_{additive} * W_{additive}}$$

Some results



Modified biochars

BC-F: Fast pyrolysis

BC-S: Slow pyrolysis

BC$_{TSP}$-F: TSP modified

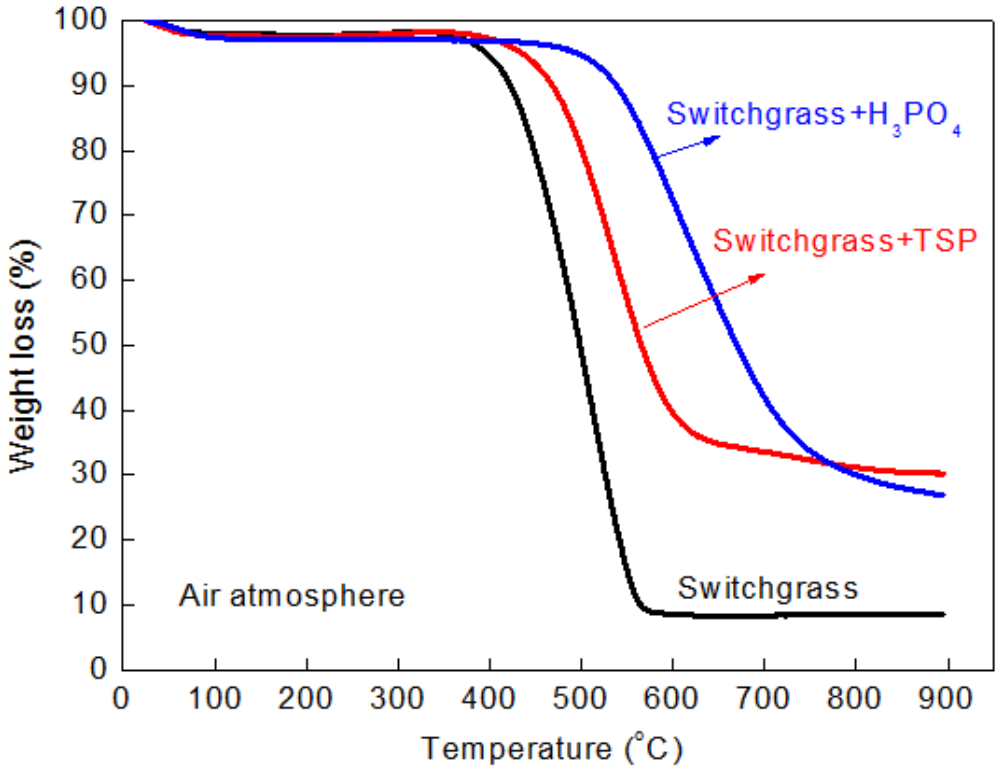
BC$_{TSP}$-S: TSP modified

BC$_{H3PO4}$-F: H_3PO_4 modified

BC$_{H3PO4}$-S: H_3PO_4 modified

Some results

Biochar Oxidation Stability: TGA curve under air atmosphere



O.R. Harvey, L.J. Kuo, A.R. Zimmerman, P. Louchouarn, J.E., Environ. Sci. Technol. 46 (2012) 1415−1421.

Biochar mineralization

Method

CO_2 emission from biochar and soil incubation

Soil + Biochar (5% addition by weight).

50-60% of soil field moisture capacity.

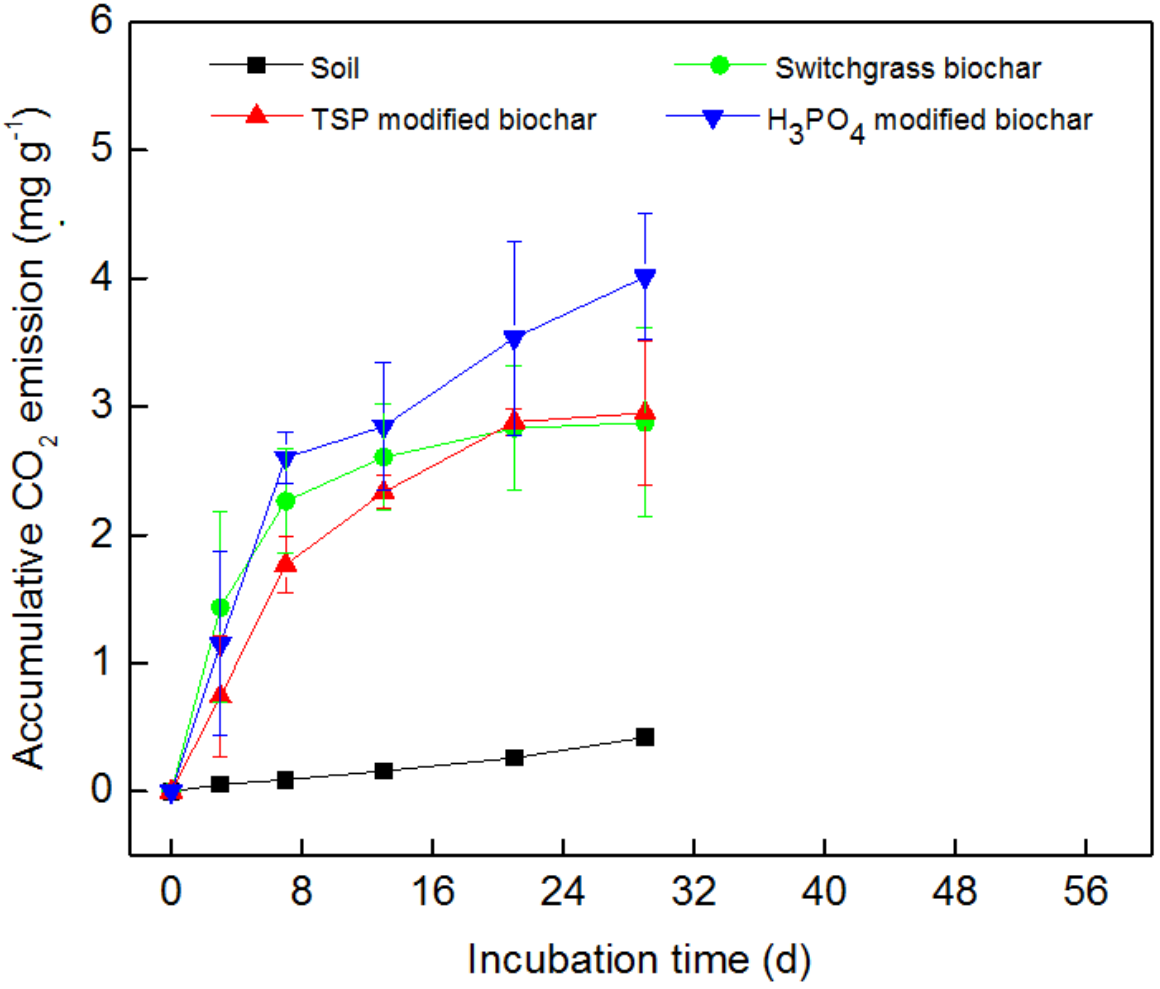
Samples taken in an increasing time interval: 0 d, 3 d, 7 d, 13 d, 21 d……

Samples were prepared in triplicate.

Sampled with 50-100 ul syringe.

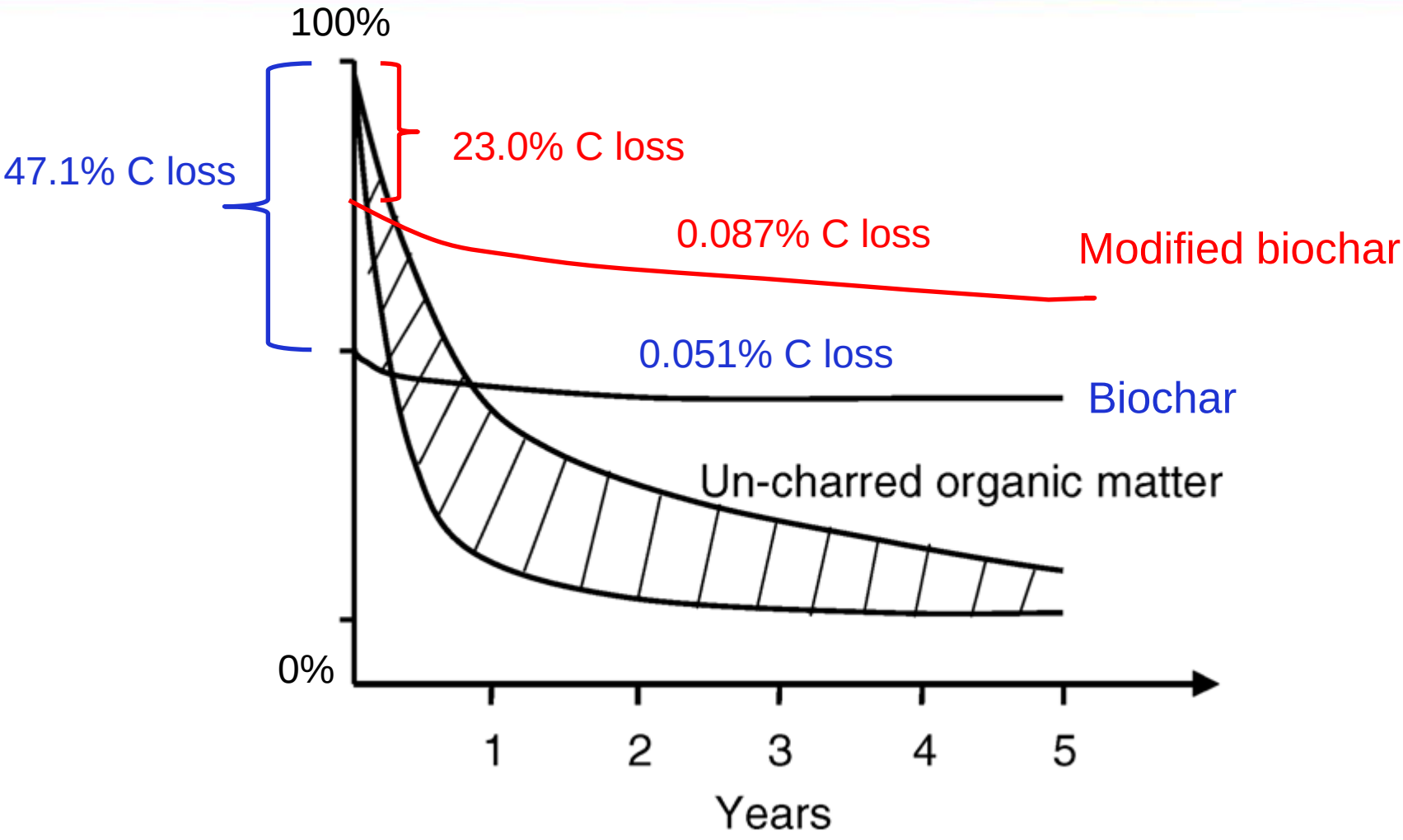
Instrument: GC-5890 Series II

Some results



Accumulative CO_2 emission from biochar and soil incubation

Calculated C loss based on our experiments

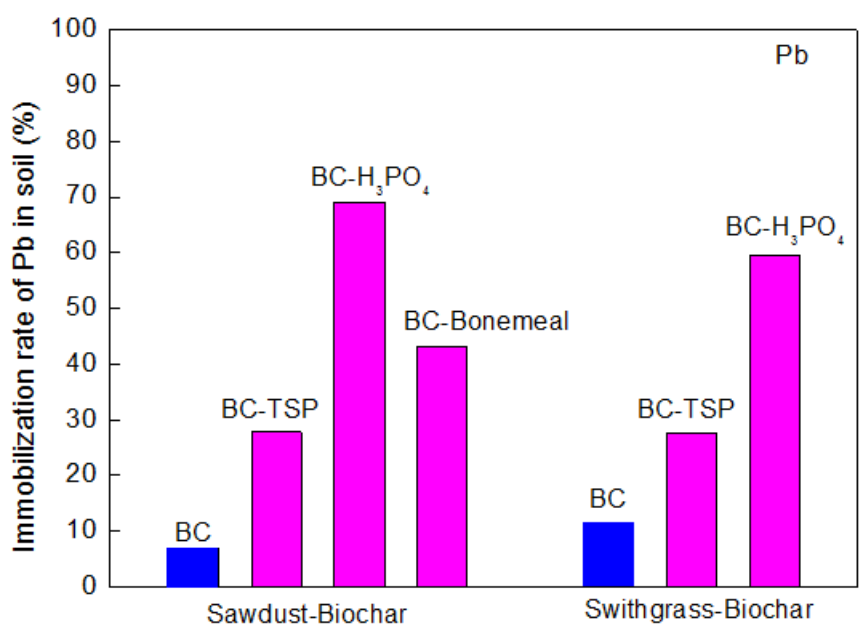


Switchgrass + Additive, Slow pyrolysis, 500°C

Another benefit

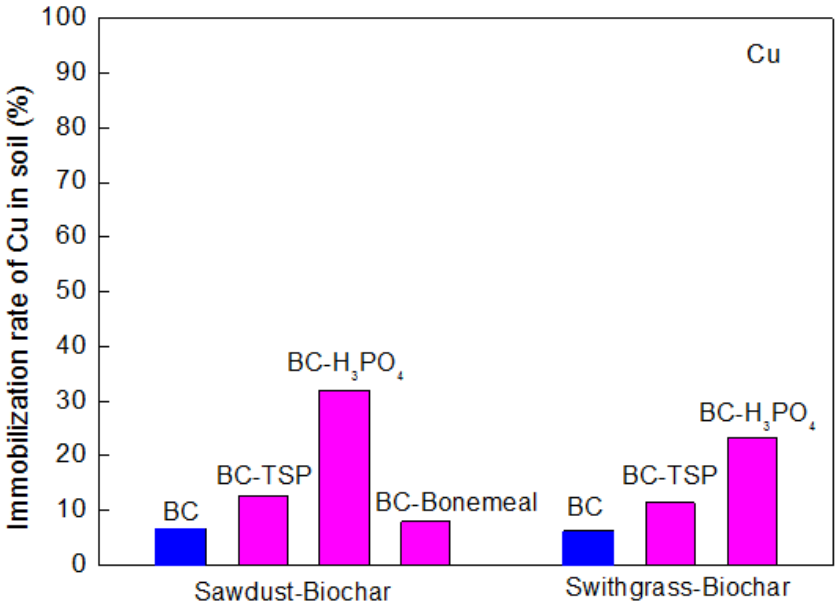
These modified biochars were observed to be enhanced their capability of immobilizing heavy metals in soil.

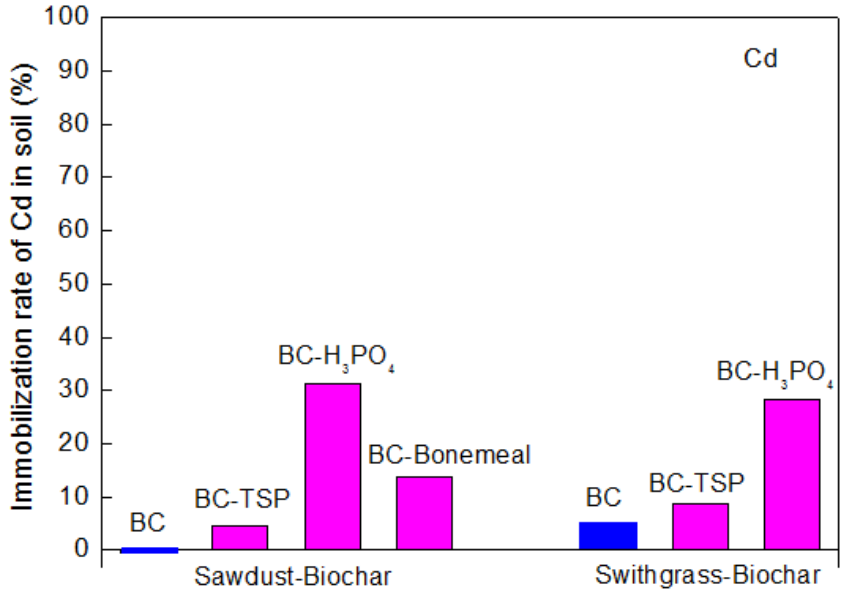
Soil heavy metals immobilization



Pb, Cu, Cd contaminated soil

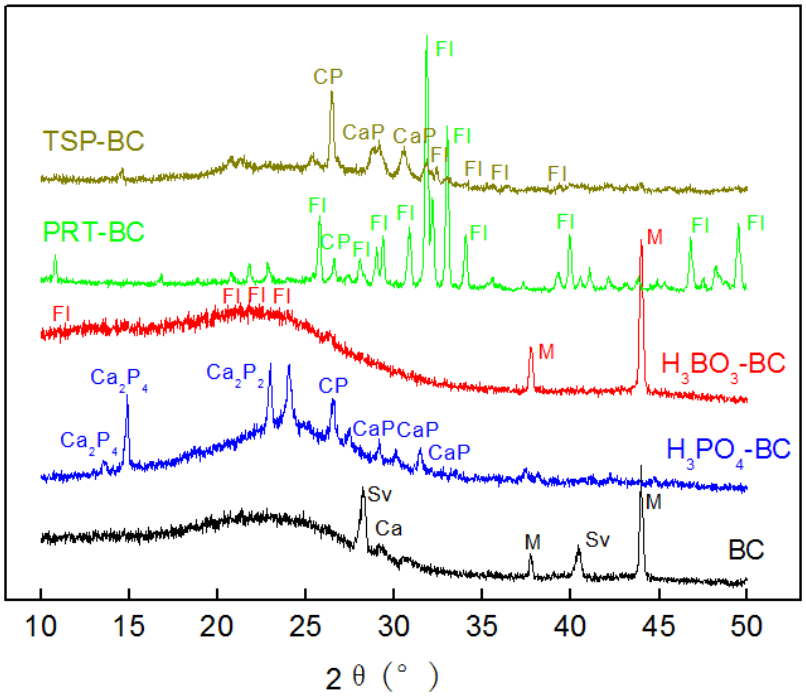
Toxicity characteristic leaching procedure (**TCLP)**

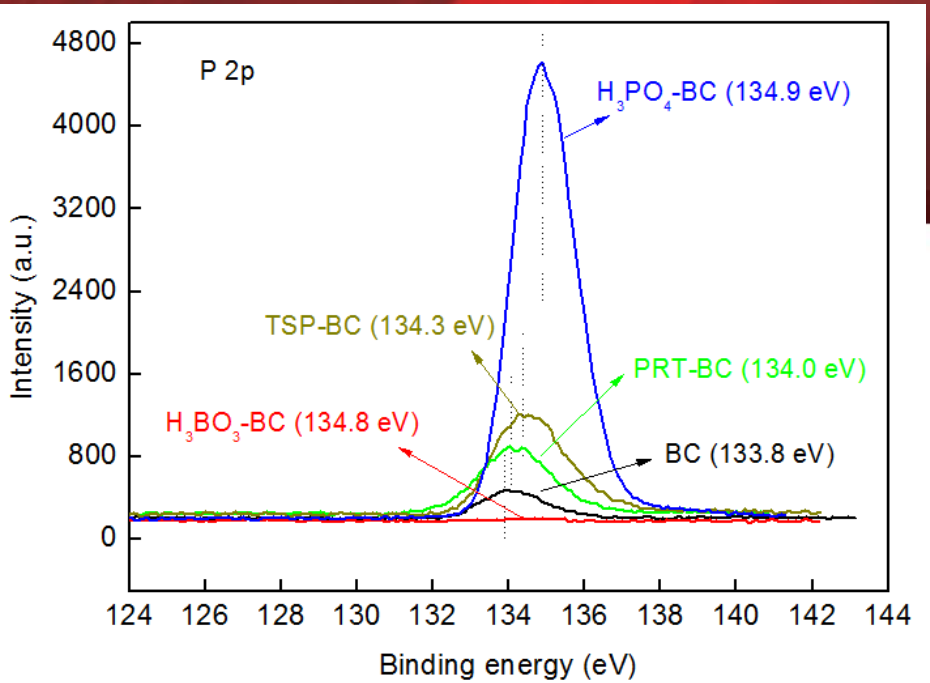


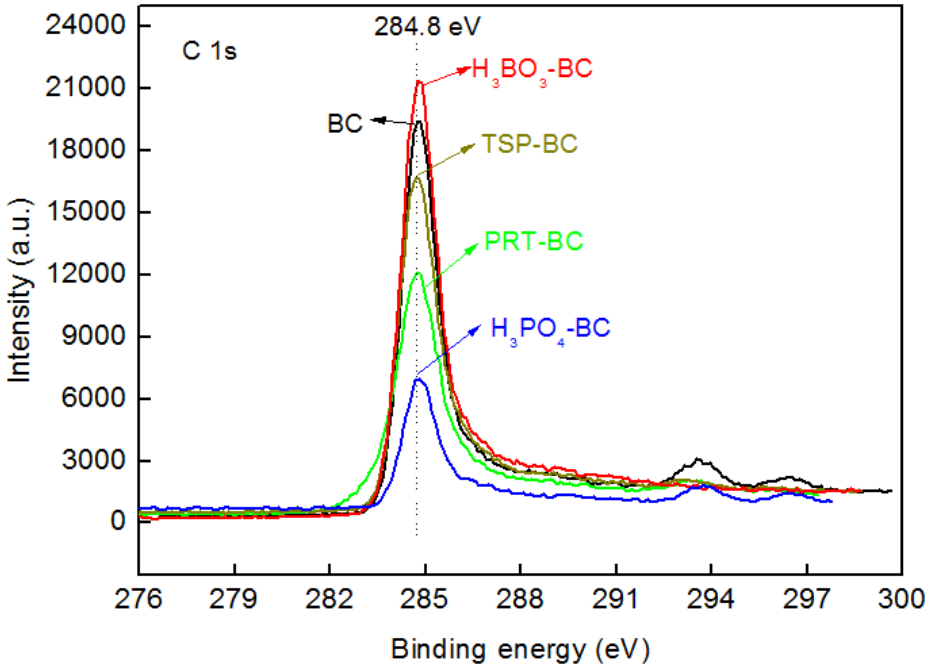


Some results

Possible mechanisms







Possible formation of P-C compounds such as $C–O–PO_3$

Conclusions

- Some P-containing materials have potential to reduce C loss during pyrolysis as passivators.
- As an additional benefit, modified biochar can strengthen its capability of immobilizing heavy metals.
- The efficiency is expected to be improved through the regulation of process conditions and type of additives.

Implications

- Biochar's primary and main significance has always been carbon sequestration.
- A novel idea that "high-carbon-sequestration-capacity" biochar can be designed during the charring process.
- Modifications might change biochar's physicochemical properties. These changes may have additional benefits to soil.

Study progress

What we did:

- Effect of different biomasses
- Effect of different additives
- Effect of pyrolysis conditions
- Part of instrumental characterization: TGA, XPS, XRD.

Ongoing work

- The CO_2 emission of soil incubation is still in monitor
- Effect of pyrolysis conditions
- Characterization of modified biochars including physicochemical properties and instrumental characterization such as FTIR, BET and SEM.

Thanks

Questions?

Ling Zhao
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03/10/2014