Economic Assessment of Pyrolysis Production and Biochar Soil Application

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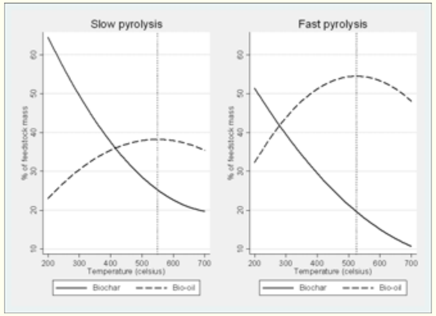
Background of the Study

The study analyzes the production and large-scale application of biochar for market returns. Biochar is found to have potential as a soil amendment for a variety of uses, and its value would likely increase as social and regulatory interest in carbon sequestration increases. Our quantitative analyses focus on using biochar as: an energy source, thereby offsetting the use of fossil fuels for energy; and soil amendment and its potential carbon sequestration benefits for agricultural uses.

In particular, the questions that our study addresses are:

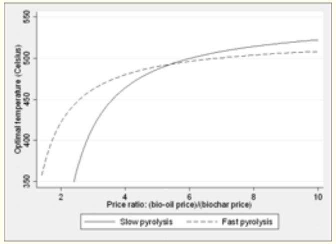
- What are the economic tradeoffs in biochar and bio-oil production?
- Is the production of biochar and bio-oil economically feasible?
- What is the potential economic value of biochar for carbon sequestration?

Economic Tradeoff between Biochar and Bio-oil Production via Pyrolysis



- For any given temperature, slow pyrolysis is estimated to provide more biochar and less bio-oil compared to fast pyrolysis.
- Bio-oil yield increases with temperature for low temperatures, then it hits a peak and begins to decline. Biochar declines over the entire range.
- Tradeoff at low temperatures: biochar yield ↓; bio-oil yield ↑. Optimal temperature depends on the relative prices of the two products.
- At higher temperatures both yields decline. Production at and above the temperature where bio-oil yields begin to decline is uneconomical.

Optimal temperature for Fixed Prices



Optimal temperature increases as bio-oil price increases relative to biochar price. The optimal temperature under fast pyrolysis is higher than for slow pyrolysis at low bio-oil prices, but the opposite is true for high price ratios.

Optimal temperature for Endogenous Prices

When price is a function of quality, which in turn is a function of temperature, the price ratio itself is determined in part by the chosen temperature.

If price increases with temperature, there is an additional revenue gain from each incremental increase in temperature. This means that for otherwise similar circumstances, the incremental price increase will tend to push the optimal temperature higher than if prices were fixed and constant.

Economic Feasibility of Biochar and Bio-oil Production

Case study on forest thinnings as feedstock

Table 1: Break-even (BE) selling prices of biochar and bio-oil

	Biochar ($/metric ton)[a]	Bio-oil ($/gallon)[b]
BE price to cover variable cost	394 - 1,421	0.87 – 2.81
BE price to cover total cost excluding long-haul transportation	614 - 2,114	1.15 – 4.03
BE price to cover total cost including long-haul transportation*	718 - 2,449	1.28 – 4.62

*This assumes the producer will shoulder 100% of the cost of long-haul transportation of bio-oil from forest edge to the end-user.
[a] The base price of biochar is $114.05/metric ton. [b] The base price of bio-oil is $0.52/gallon.

<u>Biochar</u>

- Results show that the base price of biochar ($114.05/metric ton) is less than the break-even price to cover variable costs. This means that it would not be economically viable to produce biochar, even in the short run, because the added costs of production are greater than the added returns.
- If the base price is greater than the break-even price to cover total cost, it means that a profit is earned in addition to covering all costs. However, there is no profit since the total production costs are higher than the estimated economic value of biochar.

<u>Bio-oil</u>

- The base price of bio-oil ($0.52/gallon) is lower than the break-even price to cover variable costs as well as the breakeven price to cover the total cost of production. Results imply that fast pyrolysis is not economically feasible to produce bio-oil at current market conditions.
- If refining bio-oil for biofuels (e.g., ethanol, bio-gasoline) becomes commercially viable, then the value of bio-oil for refining would likely increase, and the break-even price for biochar would decline.

Economic Value of Biochar in Crop Production and Carbon Sequestration

Table 2: Break-even (BE) selling prices of biochar and bio-oil given US$1/metric ton CO_2 offset market price

	Biochar ($/metric ton)[a]	Bio-oil ($/gallon)[b]
BE price to cover variable cost	295 – 1,322	0.75 – 2.64
Difference from Table 1	*-7% to -25%*	*-6% to -14%*
BE price to cover total cost excluding long-haul transportation	515 - 2,016	1.03 – 3.86
Difference from Table 1	*-5% to -16%*	*-6% to -14%*

- Results show that at a carbon market price of $1/metric ton, fast pyrolysis is not economically viable even if the carbon value of biochar amendment is taken into account.
- However, in comparison to the case where the environmental benefits of biochar are excluded, the adjusted break-even prices to cover total cost of production are lower.
- If the prevailing market price of CO_2 offset is US$31/metric ton, our estimates show that fast pyrolysis becomes economically feasible.

Table 3: Comparison of estimated profits from winter wheat production in Eastern Whitman County (US$ per acre)

Scenario	Revenue	Total cost	Cost of lime	Cost of biochar	CO_2 offset value	Profit
1. Without Biochar Application	$694	$228	$133	---	---	$333
2. With Biochar Application, when price of biochar (PB) is...						
PB_1 = $515.36/mt	$694	$228	---	$15,780	$2,799	-$12,515
PB_2 = $114.05/mt	$694	$228	---	$3,506	$2,799	-$241

- A farmer will still gain a profit with the addition of agricultural lime.
- If ag lime is replaced with biochar, the farmer will incur losses at either market price of biochar. Results show that a high market price of biochar outweighs the income from carbon offsets.

Conclusion

- The type of pyrolysis used (fast or slow), final pyrolysis temperature and feedstock type are primary variables that must be considered when maximizing the revenues from the joint production of biochar and bio-oil.
- A case study on fast pyrolysis of forest thinnings shows that production of biochar and bio-oil it is not economically feasible even in the short run, given current market conditions.
- Pyrolysis production can be profitable in the U.S. if: a carbon market exists for avoided emissions and C sequestration due to biochar soil application (necessary condition); and the market price of carbon offset is high enough so that the producer will earn a positive return.
- Under the assumed parameters and current market conditions, income derived from potential carbon offsets of biochar soil application is not adequate to support the adoption of biochar in agricultural production.

Additional Information

Poster is based on Chapters 5, 6 and 7 of the following report:

Granatstein, D., C.E. Kruger, H. Collins, S. Galinato, M. Garcia-Perez and J. Yoder. 2009. “Use of Biochar from the Pyrolysis of Waste Organic Material as a Soil Amendment.” Final Project Report. Center for Sustaining Agriculture and Natural Resources, Washington State University, Wenatchee, WA.

This research is funded by the Washington State Department of Ecology through the Beyond Waste - Organic Waste to Resources project.