

Pyrolysis, Biochar, and Crop Residues: Is this an Economic Proposition?

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Sources of Support

CSiTE and USEPA (for McCarl)

Paper Motivation

For over a decade have been looking at sequestration

At first optimistic, now somewhat pessimistic

Why?

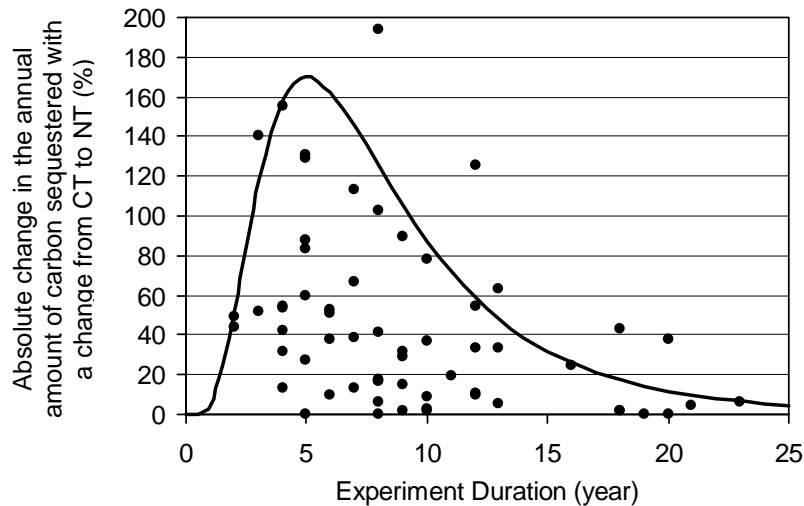
Permanence/Reversibility, Timing

Equilibrium/Saturation, Aggregation, Spatial variation, Monitoring, Facilitation by Policy

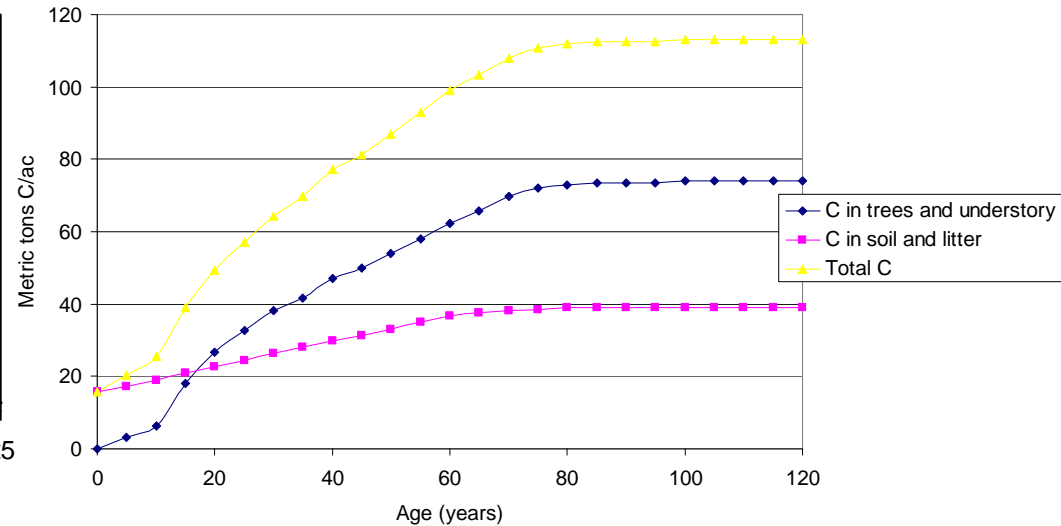
So is there a way around this?

An Elaboration Approach to Equilibrium / Saturation

Absolute Change in the Annual
Rate of Carbon Sequestered
Following a Change from
Conventional Tillage (CT) to No-
Till (NT) - West and Post



Carbon Accumulation on an
Afforested Southeastern Pine
Stand, to Saturation -- Birdsey



Carbon May not be traded at full price

Fungibility

Grading standards

#2 yellow corn, CD plywood,

long staple cotton

Receive a price premium/discount depending upon product characteristics and consumer cost of using

GHG offsets may have consumer cost effects being not fully claimable due to

Permanence

Additionality

Leakage

Uncertainty

I Compute a 50% plus discount for soul

So what can we do

Can we take plant carbon absorbed from the atmosphere and store it in a more permanent form?

In comes biochar which also plays into the energy situation

So Now on to Biochar

Procedures

Application to corn residue case

Fast and Slow Pyrolysis to

Electricity

Biochar to corn application

GHG offset

Sensitivity analysis

Feedstock production

	Corn Stover per ton
Cost of producing	
Assembling	
Moving to loading point	
Bundling for transport	
Pay farmer a labor return	\$13
Replacing lost use	
Add nutrients	\$10
Lower tillage	-\$5.4
Supplier cost	\$27.6

Feedstock hauling

Cost of loading

Distance to transport

Fuel and operating cost

Storage cost of seasonal

Feedstock at supplier

Delivered cost

Plant costing

Amortized fixed cost including return to capital

Operating cost

Three module plant

Feedstock preparation

Pyrolysis

Energy generation

Plant costing

Table 19.4. *Annual costs of raw pyrolysis liquids production – variation with delivered feedstock cost in \$1000 per year*

	Delivered feedstock cost in US\$ t ⁻¹ (dry)			
	33	44	55	66
Annual pretreatment capital cost	367	367	367	367
Biomass pretreatment operating cost	334	334	334	334
Annual cost pyrolysis capital	1080	1080	1080	1080
Feedstock cost	2310	3080	3851	4621
Utilities – water	3867	3867	3867	3867
Labour	900	900	900	900
Maintenance	423	423	423	423
Overhead	423	423	423	423
Annual liquids production cost	5624	6394	7164	7934

This involves the annual use of 70,080 t of feedstock yielding 55,000 tons of bio-oil (including the water)

Plant costing

Table 19.5. *Costs of electricity production – variation with delivered feedstock cost. Net electrical output 12.52 MWe (427.3 US therms)*

	Cost delivered, US\$ t ⁻¹ (dry)			
	33	44	55	66
Capital amortization	978	978	978	978
Labour cost	124	124	124	124
Utilities	1507	1507	1507	1507
Overheads	188	188	188	188
Maintenance	235	235	235	235
Total Electricity Only	3339	3339	3339	3339
Bio-oil cost [from Table 19.4]	5624	6394	7164	7934
Total Cost electricity+bio-oil	9742	10512	11282	12052
Electricity Prod Cost kwh ⁻¹	9.7	10.5	11.4	12.2

Slow vs fast

For the slow plant

More biochar

Less bio-oil

Less preprocessing

Same cost structure otherwise

Syngas provides needed heat

Haul biochar to field

Same hauling distance

**Applied to land where residue
harvested**

No backhauls

**Cost 50% more per ton to haul
flammable product**

Value biochar

Approaches

Observe

Thin markets

Economic engineering

Current use – energy coal eq

\$54.73 per ton today

\$17.70 in Dec 2007

Apply biochar

Yield increase amounts to \$60 per ha per yr

Nutrients, lime and seed replacement amounts to a saving of \$73.4 per ha per yr

Net value \$143.40 per ha per yr

Now for how long we assume forever but a 1 time gain so capitalize at 5% (multiply by 20) but assume char applied 10 times so give twice the gain \$286.8 /ha. - \$57/ ton.

GHG items

Production

- Less sequestration, more input emissions,

- Less tillage emissions

Other use replacement

- Lost nutrient and water holding

Haul Feedstock and Biochar

- Fossil use

Processing plant

- Fossil use

Apply biochar

- Fossil use, Save inputs

- Sequester

Offset fossil energy

- Replace coal based electricity

GHG LCA (CO₂eq/ t feedstock)

Category	Discount	Fast	Slow
Collect feedstock on farm		0.011	0.011
Haul feedstock and biochar		0.002	0.003
Lost nutrients on farm		0.007	0.007
Save fuel in tillage		-0.018	-0.018
Operate pyrolysis		0.033	0.008
Reduce nutrient and seed		-0.004	-0.028
Displace coal electricity		-0.764	-0.191
Sequest. lost with residue	0.5	0.033	0.033
Sequest. gain from biochar		-0.122	-0.963
Net GHG effect		-0.822	-1.137
GHG Efficiency		108	595

Biofuels are big today address GHGs

Offset Rates Computed Through Lifecycle Analysis

Energy Form

Commodity	Crop Ethanol	Cellulosic Ethanol	Biodiesel	Electricity Co-Fire 5%	Electricity fire100
Corn	31				
Sorghum	39				
Sugarcane	65				
Corn Residue		73		93	86
Wheat Residue		73		95	91
SwitchGrass		69		94	90
Energy Sorghum		79		98	96
Sweet Sorghum	61				
Sweet Sorghum Ratoon	63				
Soybean Oil			71		
Corn Oil			55		
Bagasse		90		100	100
Lignin				100	100

Net Carbon Emission Reduction (%)

Crop ethanol < cellulosic < biodiesel < Electricity

Ethanol offsets are in comparison to gasoline Power plants offsets are in comparison to coal.

Value Prospect

(per ton feedstock)

Costs, Benefits	Fast	Slow
Cost of feedstock	-\$59	-\$59
Value of energy created	\$100	\$25
Value of biochar	\$2	\$16
Biochar hauling cost	-\$0.4	-\$3.1
Fixed cost of facility	-\$34	-\$21
Operating cost of facility	-\$56	-\$32
GHG market (\$4 CCX)	\$3.3	\$4.6
Net value	-\$45	-\$70

Sensitivity – Profitability points

	Base	Fast	Slow
Electricity Price (\$/mwh)	\$80	>\$115	>\$304
GHG Price (\$/ton co2eq)	\$4	>\$58	>\$71
Biochar induced Yield increase.	5%	>193%	>43%
Biochar price (\$ / ton)	\$54	>\$450	>\$246
% Reduction in Cap and oper cost	0%	<-49%	--
Feedstock cost (\$ / ton maize stover)	\$60	\$14	(\$11)

Omitted factors

Link with Carbon Capture and Storage
NOX emissions
Value the oil as a product
Multiple feedstocks
Dynamics of biochar use
Leakage – crop byproducts
Differential properties of fast/slow chars
Time to char degradation/GHG release
Marginal effects of repeated applications
Hauling systems

Findings

- Biofuels and pyrolysis possible important part in GHG mitigating world
- Biochar may be LCA > 100
- Today's GHG price in Europe and rising energy makes this near viable
- Biochar is not without its weaknesses
 - Costs too much
 - Flammable burns trucks and fields
 - Can it be used to make Liquid fuel

Big questions

- Will society choose to reward biofuel carbon recycling?
- Will energy prices remain high in short run?
- Will carbon prices take off?
- When will cellulosic ethanol or pyrolysis be producible at scale?
- Is pyrolysis non competitive with food

For more information

<http://agecon2.tamu.edu/people/faculty/mccarl-bruce/biomass.html>

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