
Biochar: A Solution to Improve Soils around the World?

Johannes Lehmann

Department of Crop and Soil Sciences

Cornell University

Biomass – Opportunities and Constraints

Food

Bioenergy

Bioproducts

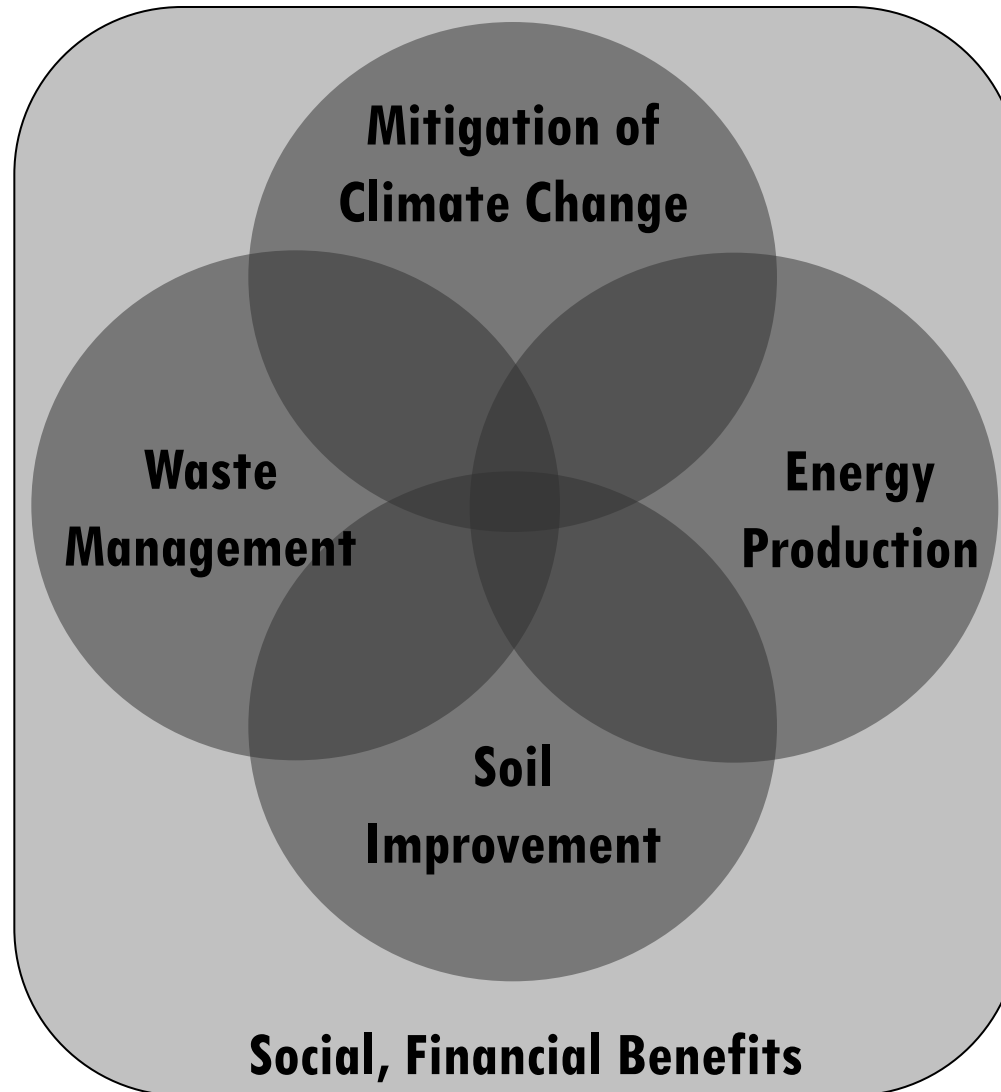
**Soil health (soil protection,
soil organic matter, nutrients)**

**Climate forcing (carbon dioxide, methane, nitrous
oxide, black carbon)**

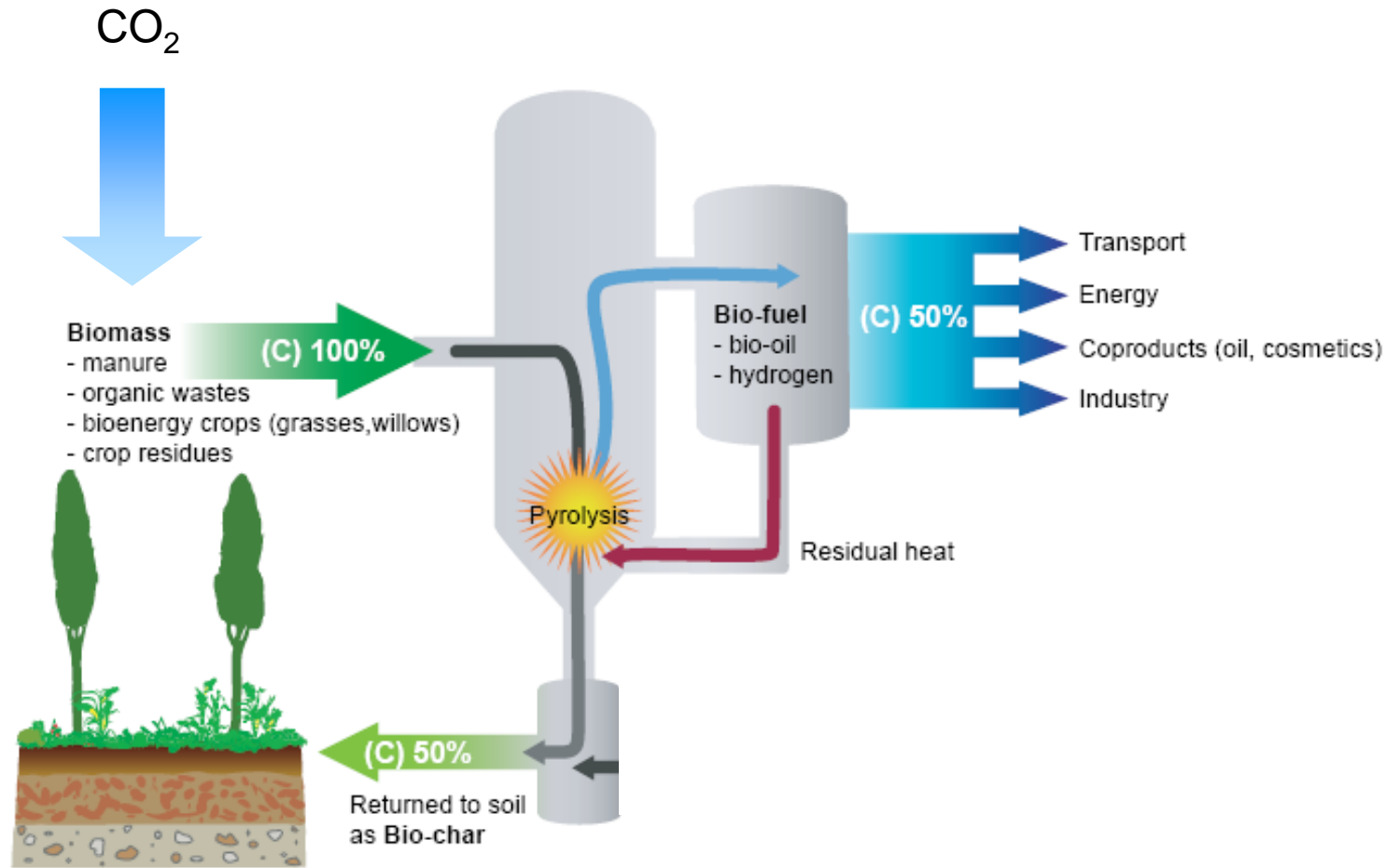
**“Waste” (agriculture, forestry, invasive species, pine
bark beetle, municipal yard wastes etc)**



Biomass Systems – Trade-offs and Synergies



Biochar System – Core Principle



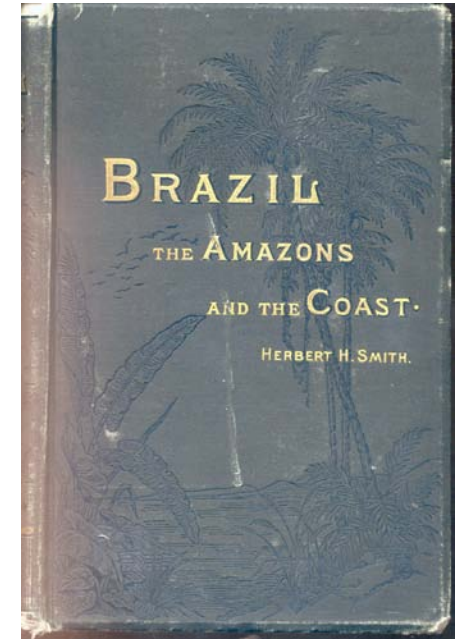
Terra Preta as Biochar Legacy



'normal' soil



"Terra Preta"



**500-8000 years old
(Central Amazon, Brazil)**

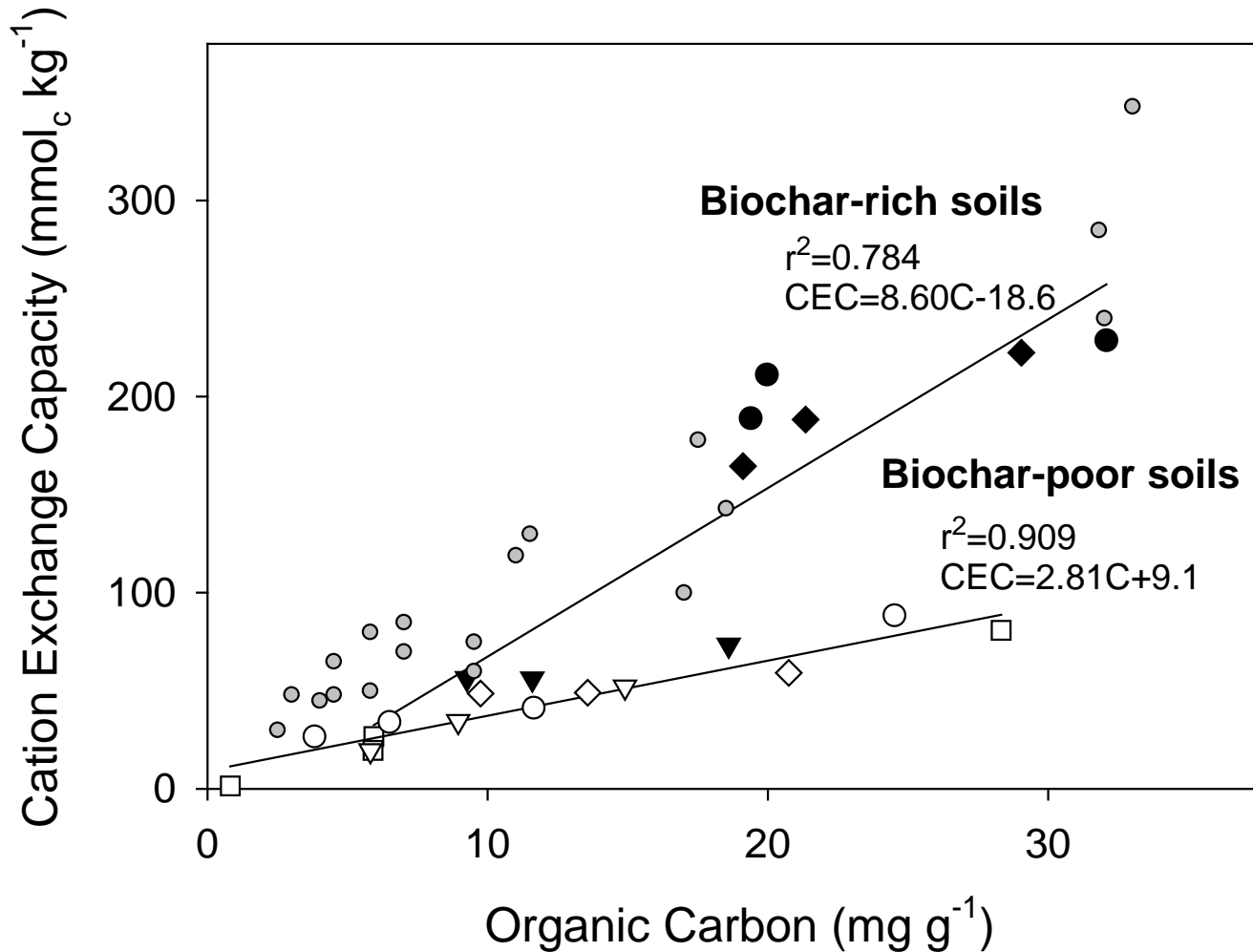


The Value of Terra Preta

Terra Preta mining



Biochar Soil Improvement

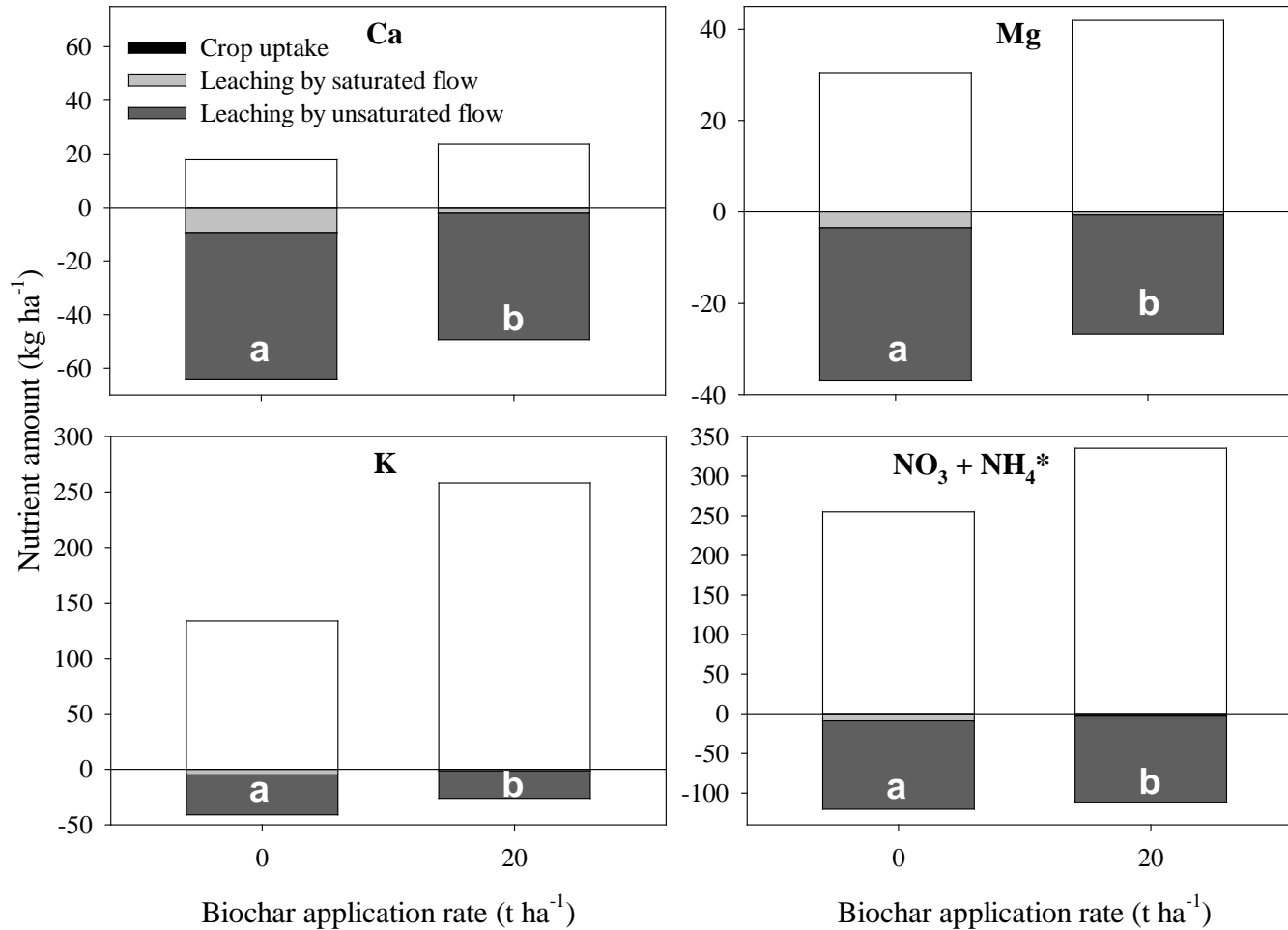


Biochar Benefits to Soil

- **Nutrient retention**
- **Soil reaction, pH**
- **Soil structure and soil water relations**
- **Effects last longer due to greater stability of charred organic matter**
- **Soil microbial ecology?**



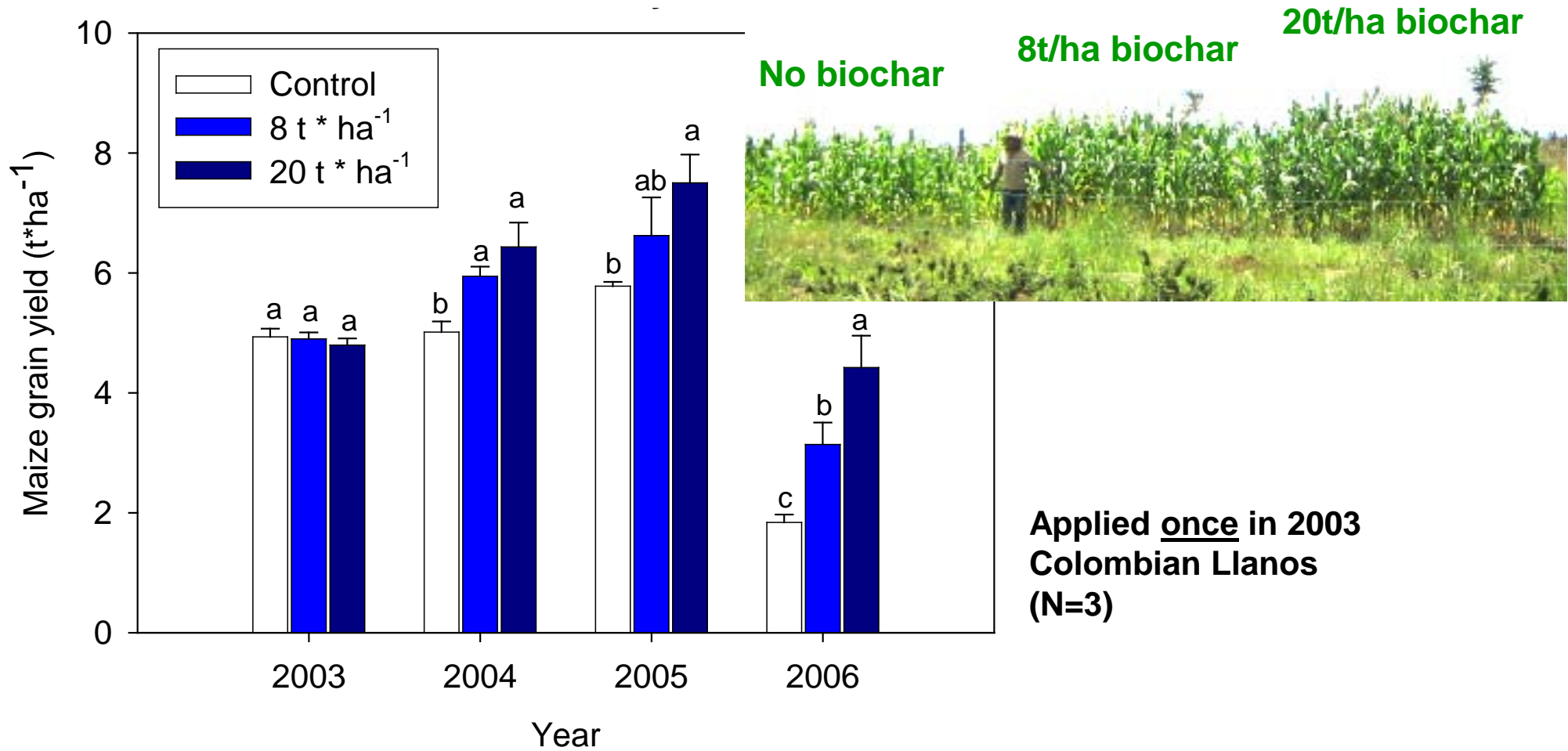
Nutrient Retention



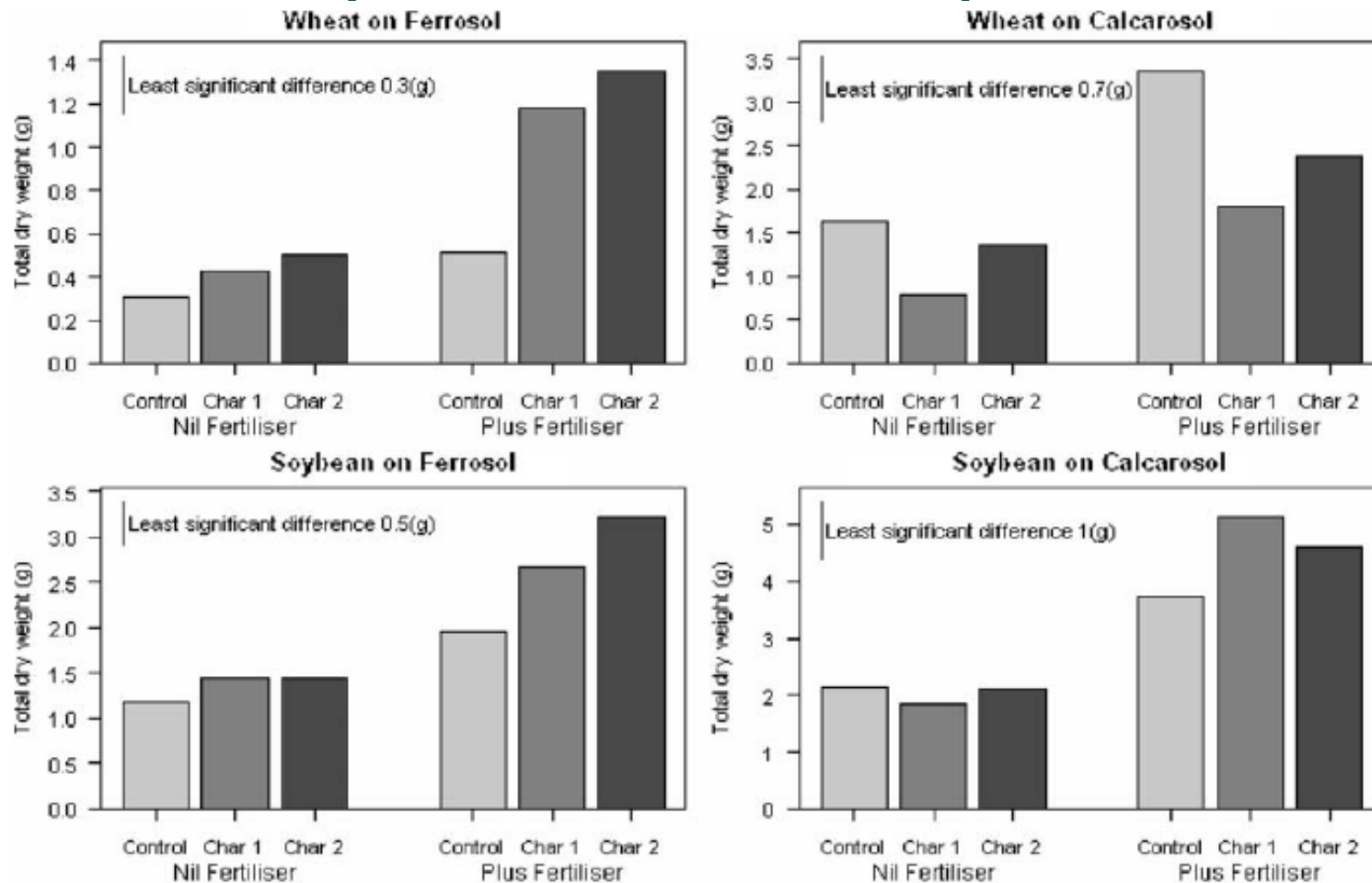
Improved nutrient uptake and crop yield

**Applied once in 2003
Colombian Llanos
(N=3)**

Yield Response

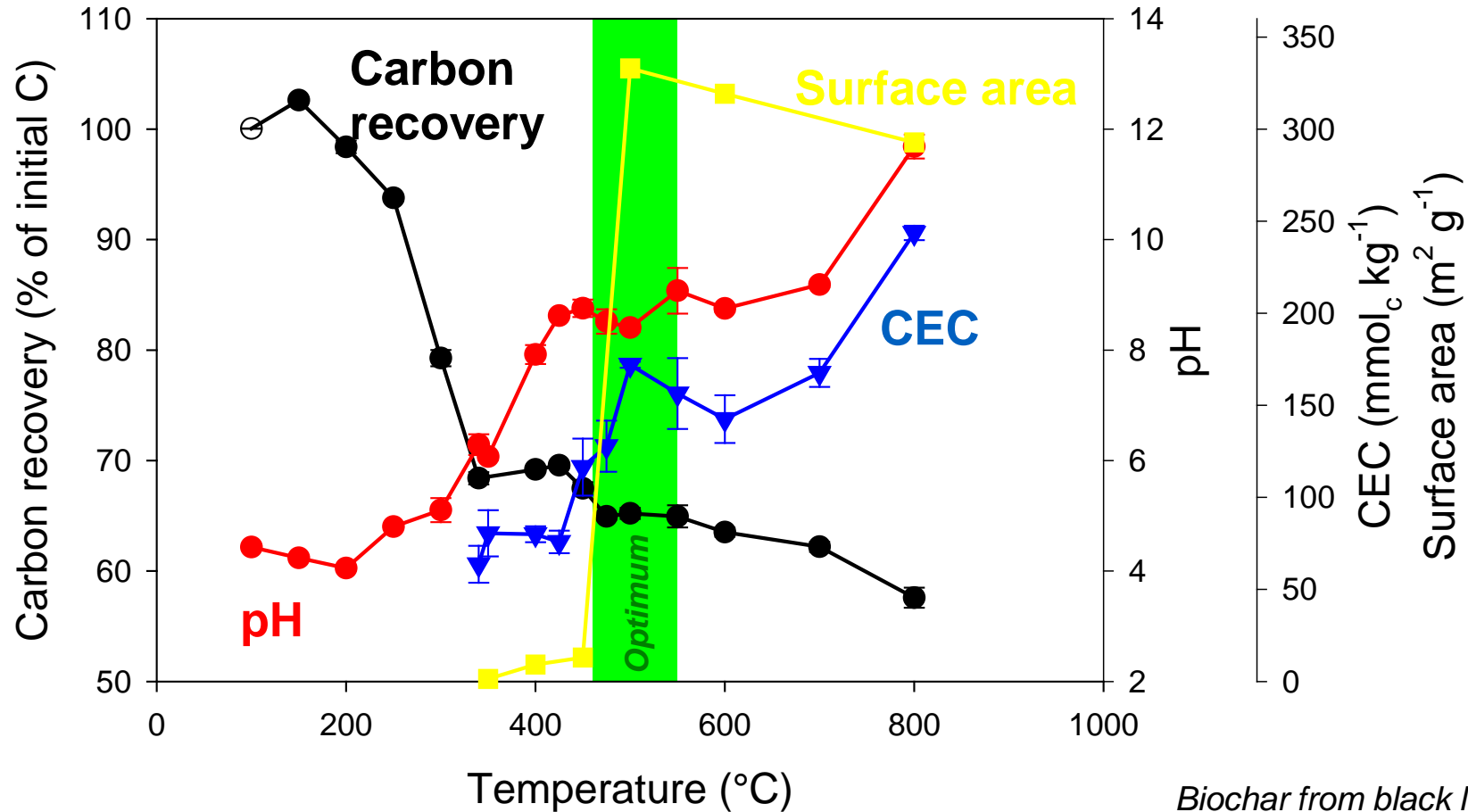


Soil Fertility Benefits Dependent on Soil Properties and Crop



10 t/ha biochar from paper mill waste+ wood chips (550°C; pH 9.4; 8.2)

Biochar Properties

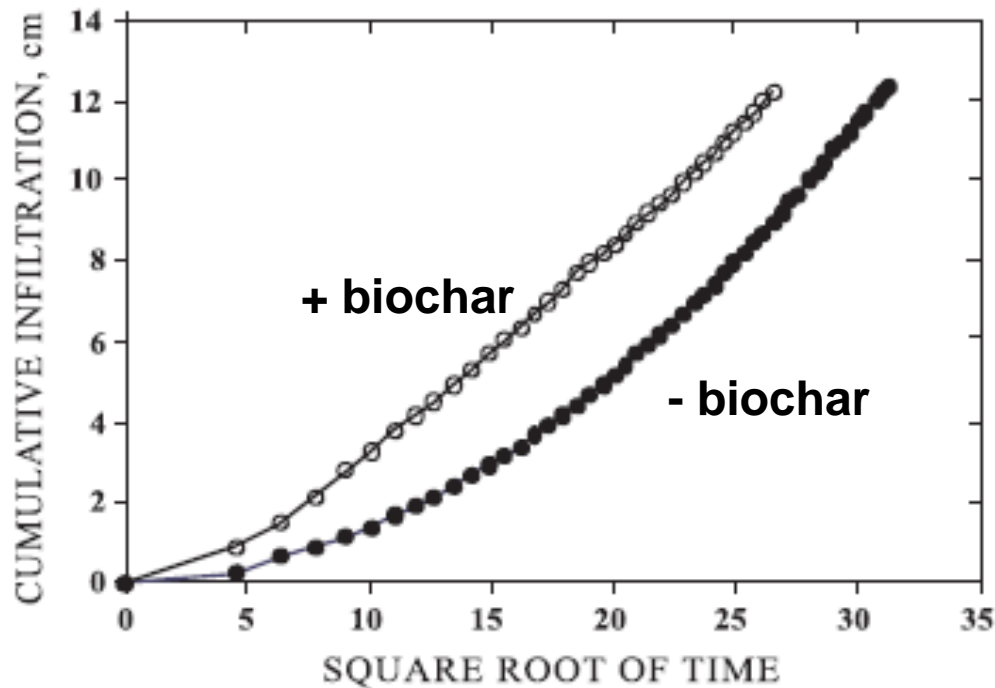


Biochar from black locust
(N=3)

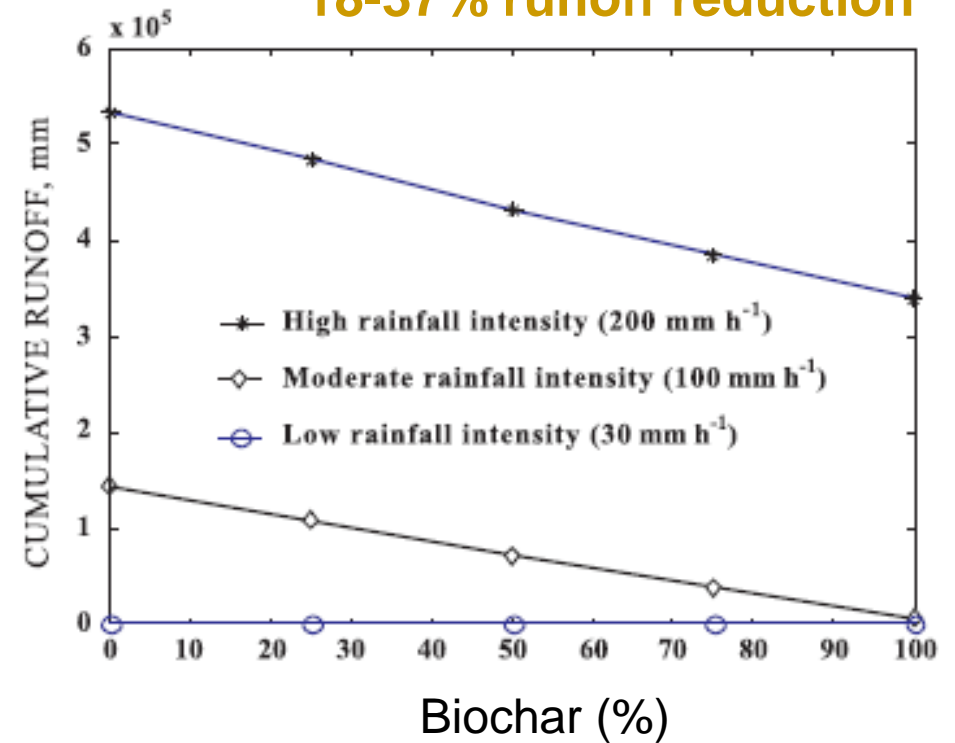
Soil Physical Properties

Emerging information

88% infiltration increase



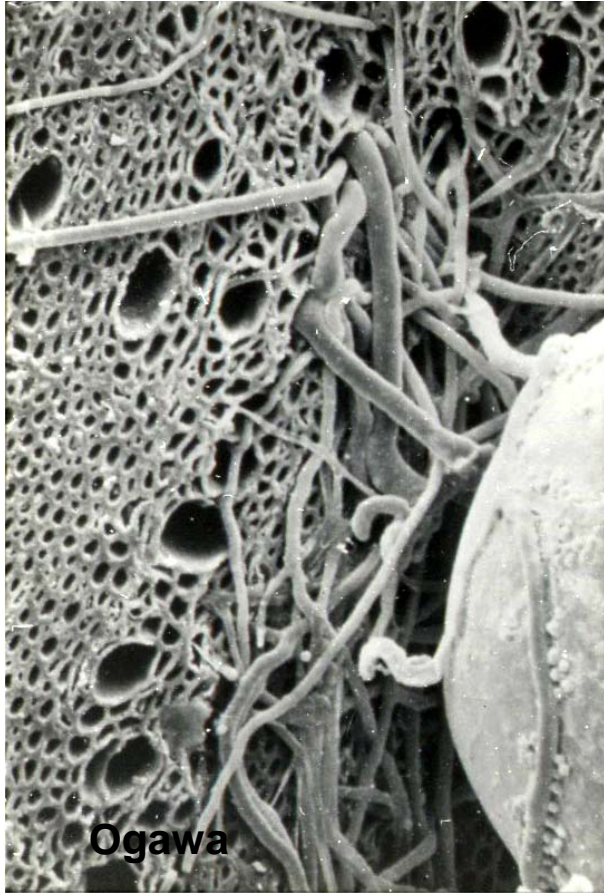
18-37% runoff reduction



Charcoal production sites
Ghana

Soil Biological Properties

Insufficient and emerging information



Biochar Stability

About 1.5 to 2 orders of magnitude greater than uncharred biomass

Mean residence time in soil: ~1000 years (at 10°C)

Baldock and Smernik, 2002, *Organic Geochemistry* 33, 1093-1109

Bruun et al., 2008, *Organic Geochemistry* 39, 839-845

Cheng et al., 2008, *Journal of Geophysical Research*, 113, G02027

Lehmann et al., 2008, *Nature Geoscience* 1, 832 - 835

Liang et al., 2008, *Geochimica et Cosmochimica Acta* 72, 6096-6078

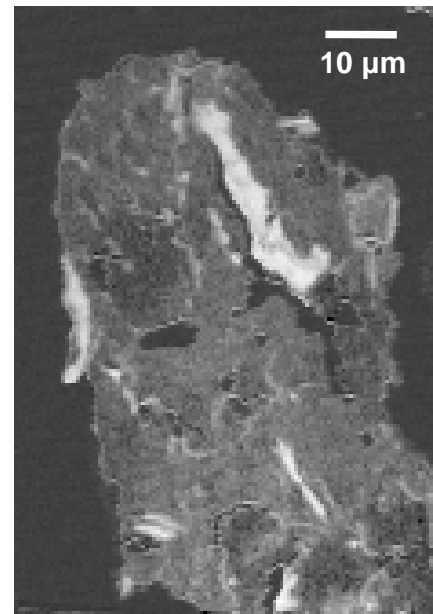
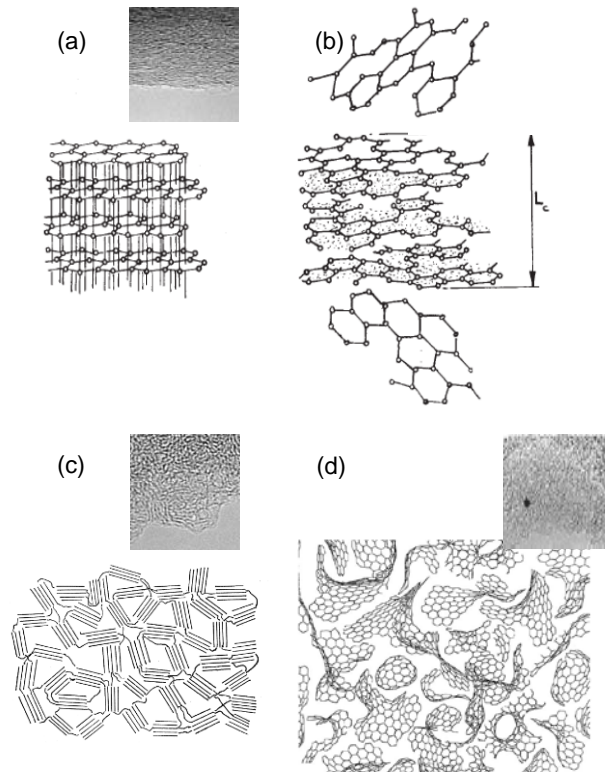
Kuzyakov et al., 2009, *Soil Biology and Biochemistry* 41, 210-219

Major et al., 2009, *Global Change Biology*, doi: 10.1111/j.1365-2486.2009.02044.x

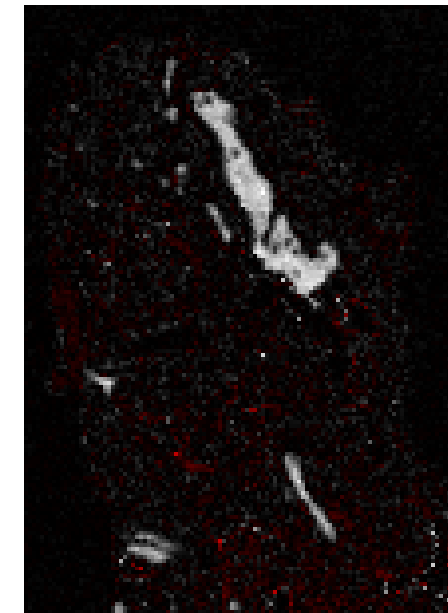


Biochar Stability and Stabilization

Chemical stability + particulate nature

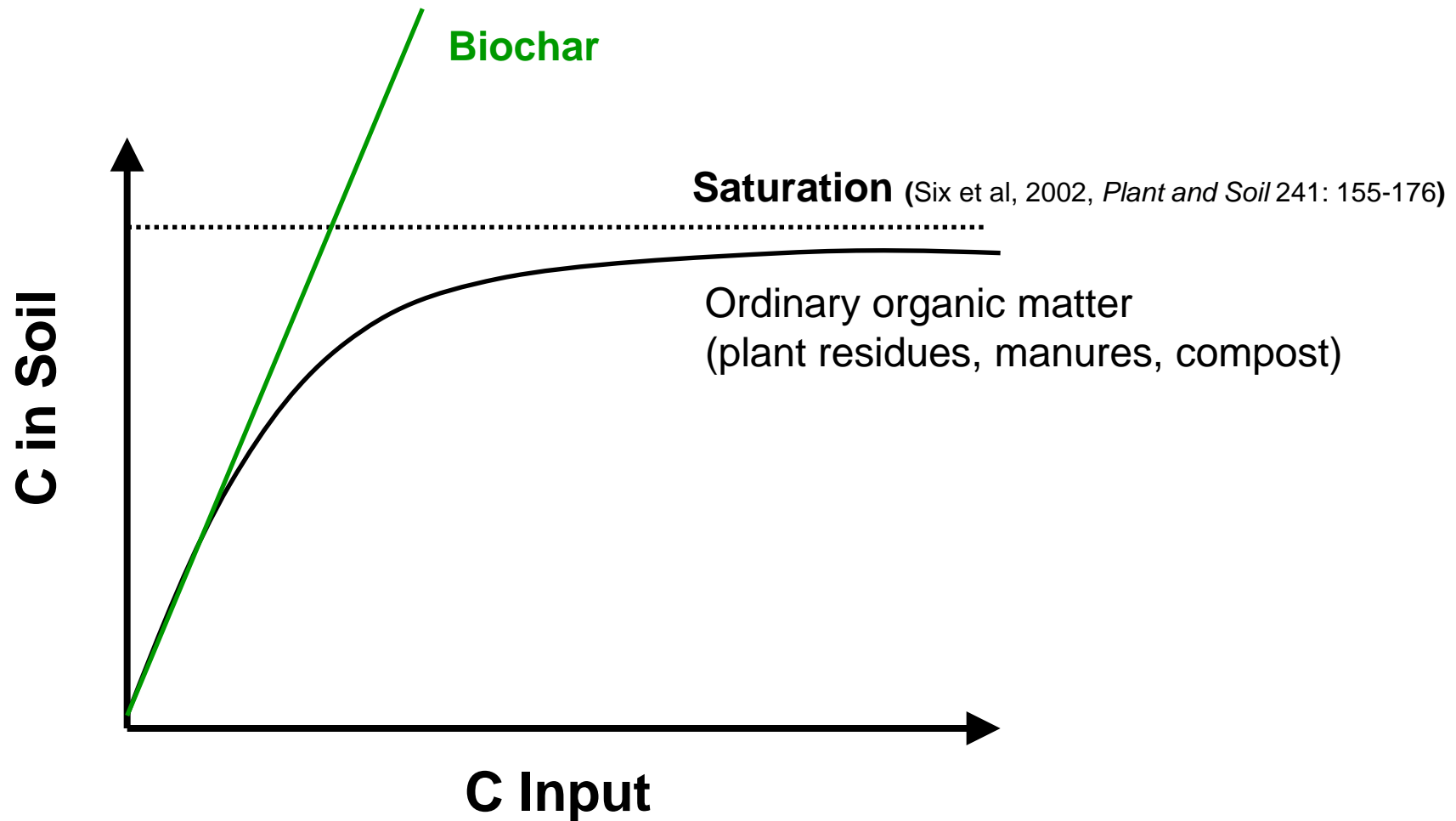


Total Carbon

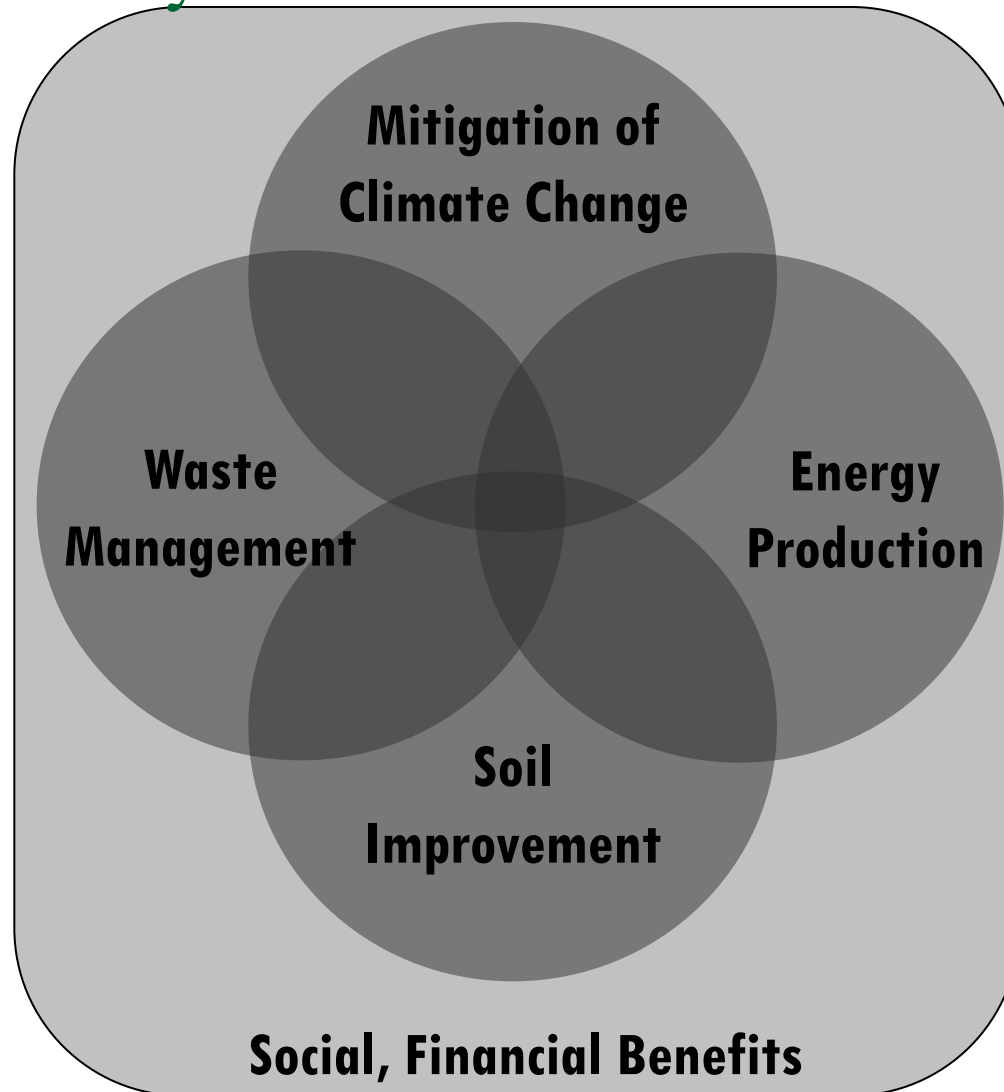


Black Carbon

Biochar Stability and Stabilization



Biochar Systems



Biochar Systems - Motivation

What was or could be your primary motivation to explore pyrolysis/biochar?

A: no interest in biochar

B: soil fertility improvement

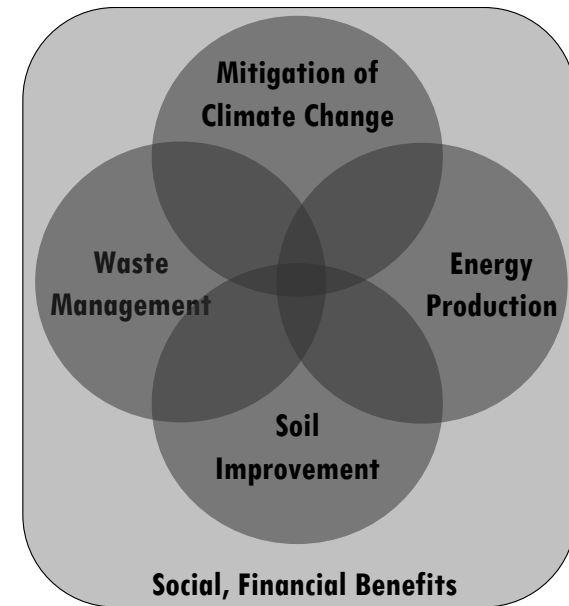
C: bioenergy, bioproducts

D: mitigation of climate change

E: carbon trading

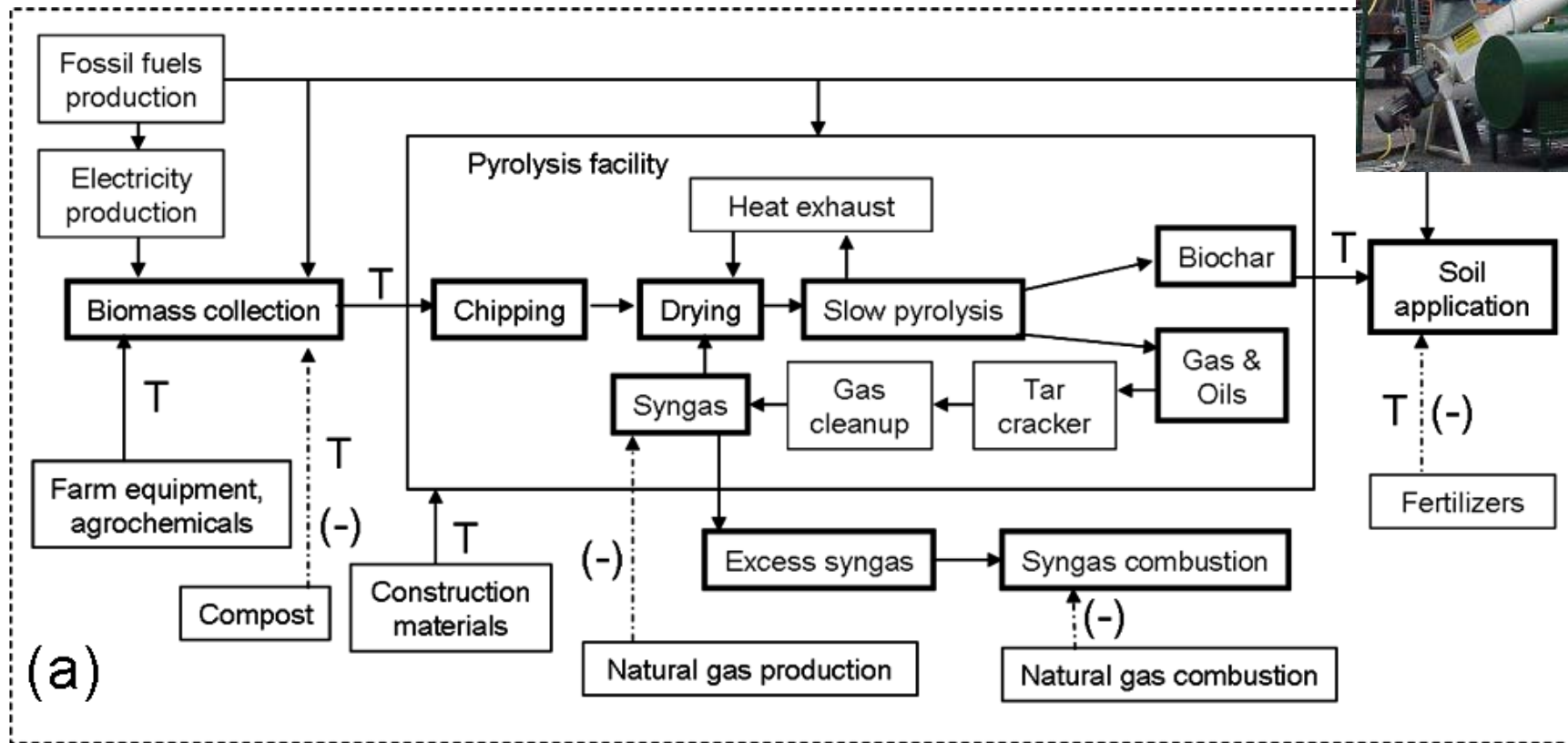
F: management of wastes

G: systems approach to biomass management



Biochar Systems View

Life-cycle energy and emission balances



Life-Cycle Energy and Emissions



Life-Cycle Energy and Emissions



Economic Analysis



Sensitivity Analysis

Stover collection energy sensitivity: <2%

Stover collection emissions sensitivity: <12%

Biochar yield emissions sensitivity: <13%

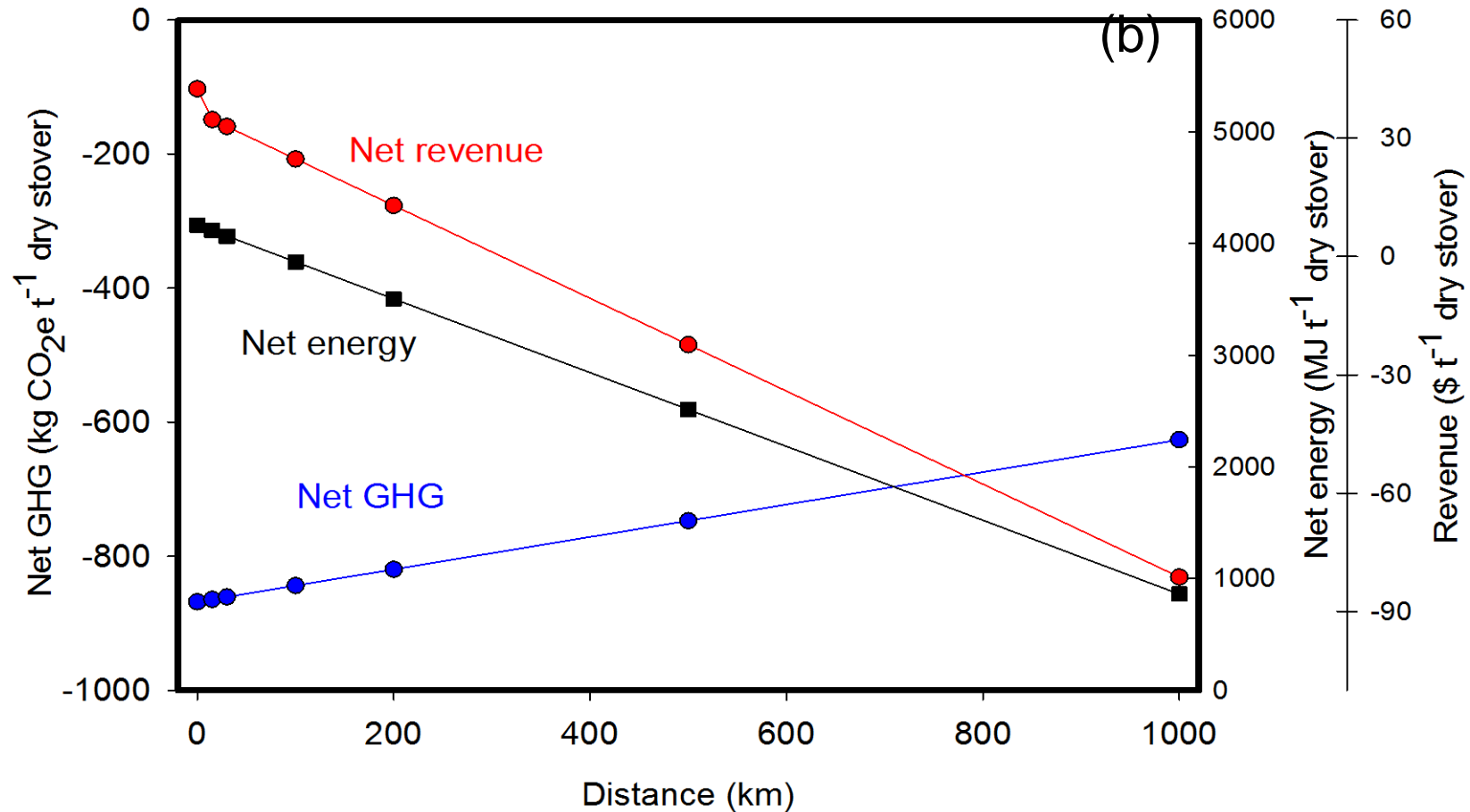
Stable C emissions sensitivity: <25%

Syngas energy sensitivity

Energy yield input	50% of baseline	(baseline)	150% of baseline
Net energy (MJ)	1509	4116	6722
% change	-63%	0%	63%
Net CO ₂ e (kg)	-703	-864	-1025
% change	-19%	0%	19%

Sensitivity Analysis

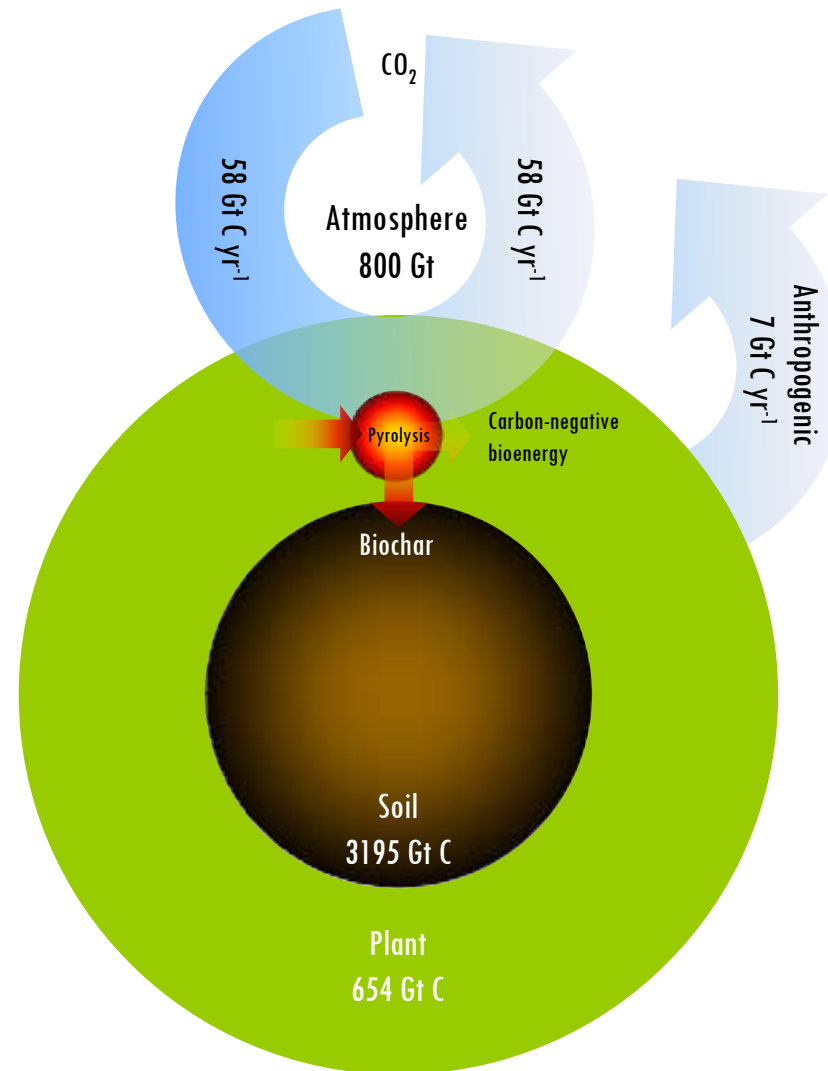
Transportation distance



Energy vs Soil Amendment

Biochar as fuel	-617 kg CO₂e t⁻¹ dry stover	
Biochar as soil amendment	-864 kg CO₂e t⁻¹ dry stover	+29%

Global Biochar Systems



Fuel Efficiency – Cook Stoves

Case Study Kenya

Lower indoor pollution = lower respiratory
+ eye infections



Fuel Efficiency

Case Study Western Kenya (Kakamega)

Fuel reduction:

- Fuel security
- Lower fuel acquisition time
- Lower pressure on natural resources

Distance per headload: 2.1 km (0.1-6.3)

Wood saved: 4.9 t/household/year (0.9-19.2)

Time saved: 6.2 hours/household/week (0.5-32)
(30 households)



Biochar Systems Analysis

Case Study West-Virginia



West Virginia Poultry Farm

99,000 chickens
125-600 t/yr poultry litter

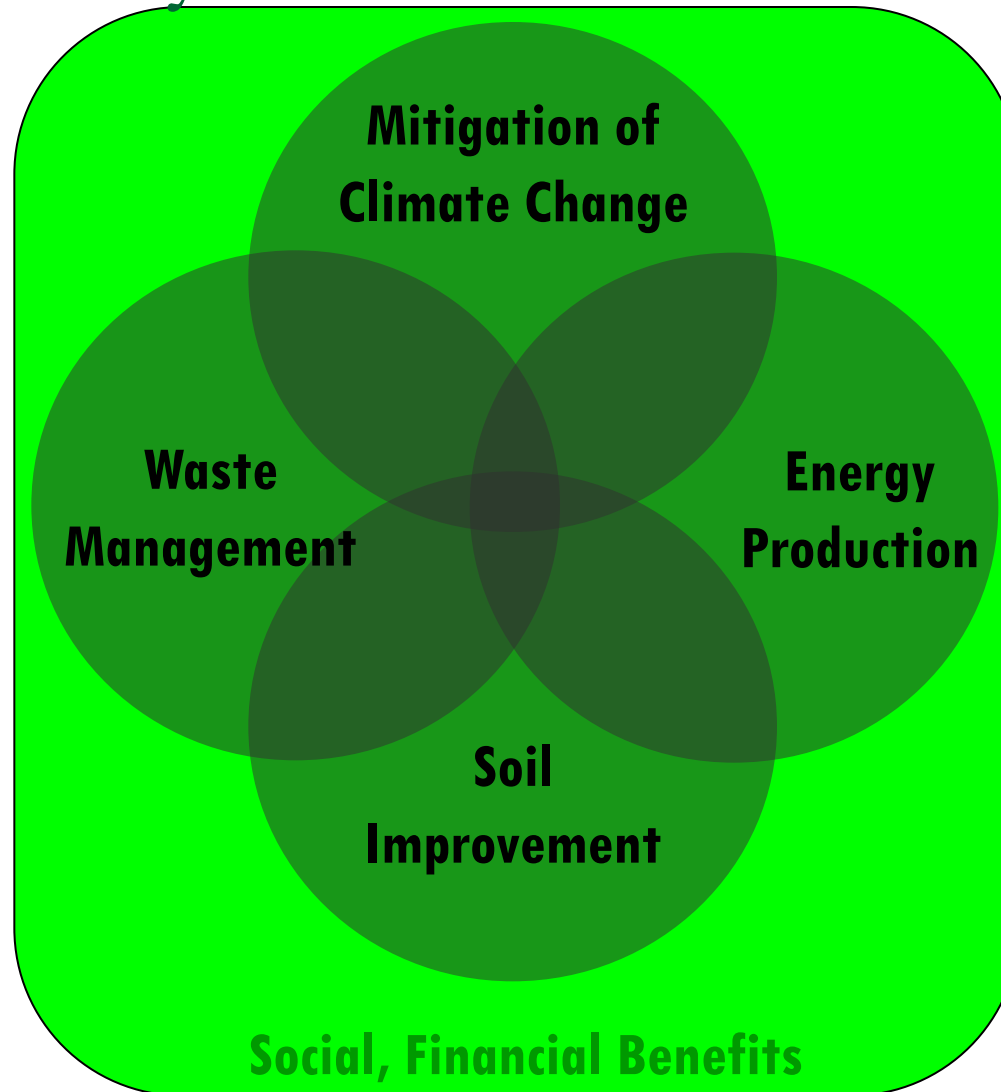
Pyrolysis of 300 kg/hr dry litter
(at 500°C)

Off-sets 114,000L propane gas
US\$66,000 /yr

25-120 t/yr biochar



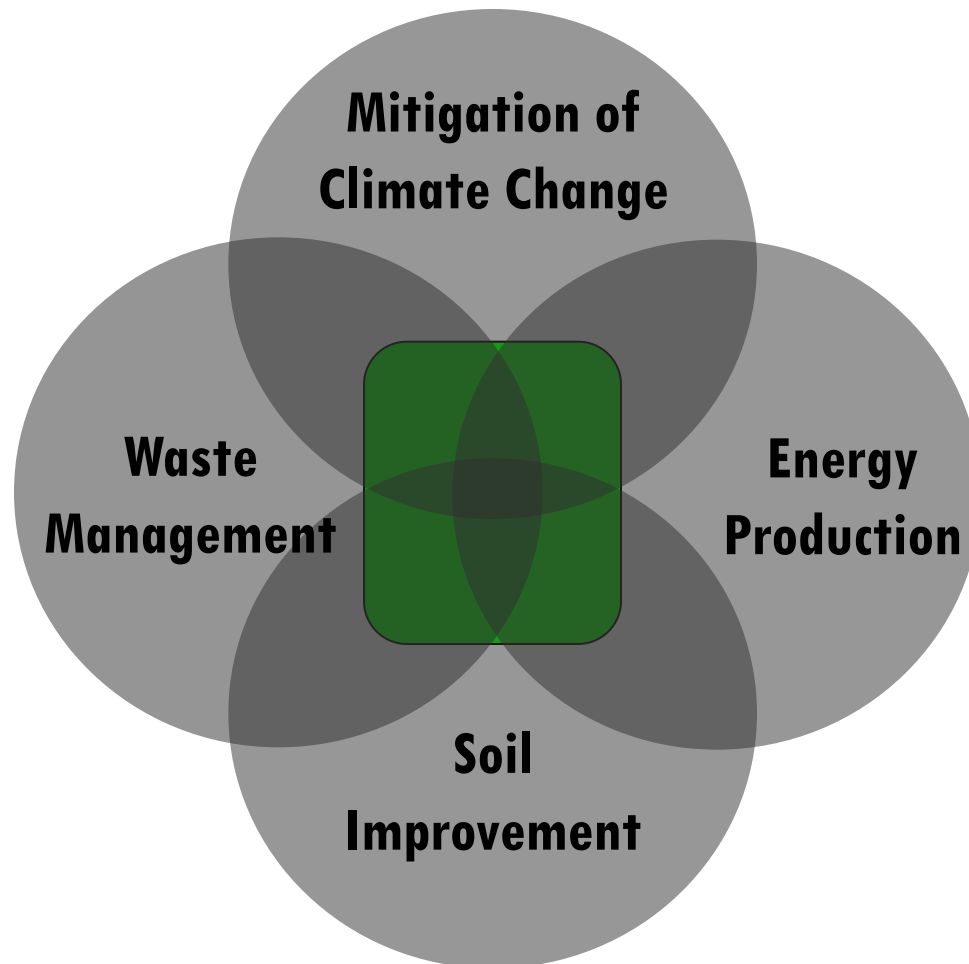
Biochar Systems



What systems benefits have to be harnessed?



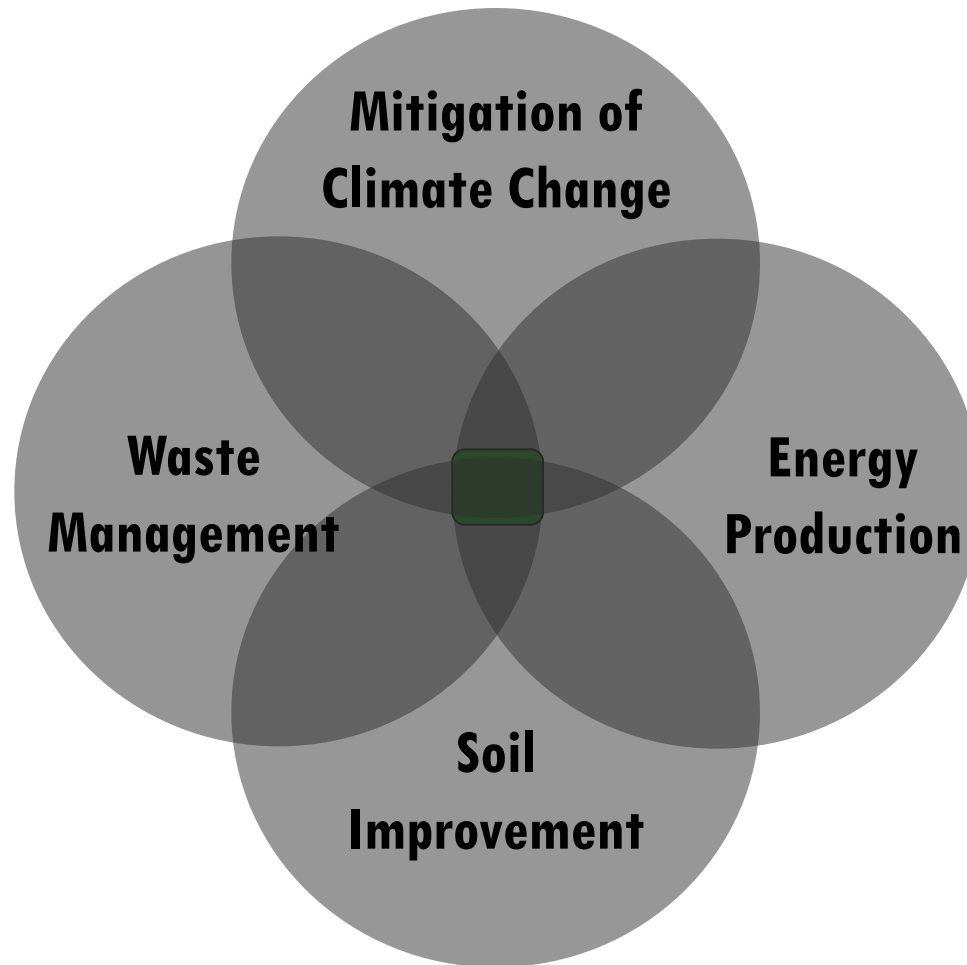
Biochar Systems



Social, Financial Benefits



Biochar Systems



Social, Financial Benefits

How many opportunities exist?



Biochar – The Way Forward

Not “WHETHER”, but “WHERE”



Biochar – The Way Forward

Based on solid science

Taking a “systems perspective”

**R&D alongside implementation where
we know enough**

