Sequestration Potential of Biochar Amendments

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California Energy Commission
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Can Biochar Sequester Carbon?

James Lovelock:

"There is one way we could save ourselves and that is through the massive burial of charcoal."

James Hansen:

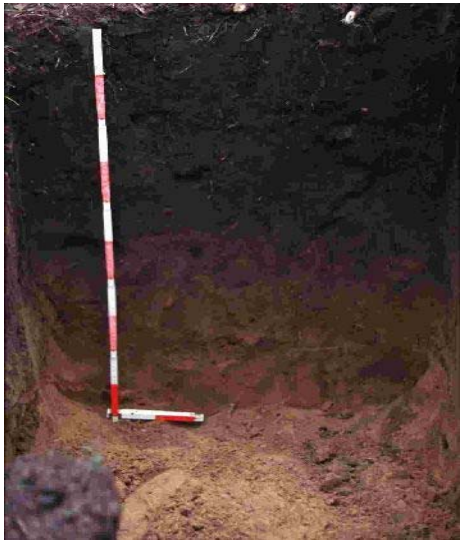
"Biochar … can be used to restore soil fertility while storing carbon for centuries to millenia."

Tim Flannery:

"Biochar may represent the single most important initiative for humanity's environmental future."

Terra Preta

Fertility from sequestration



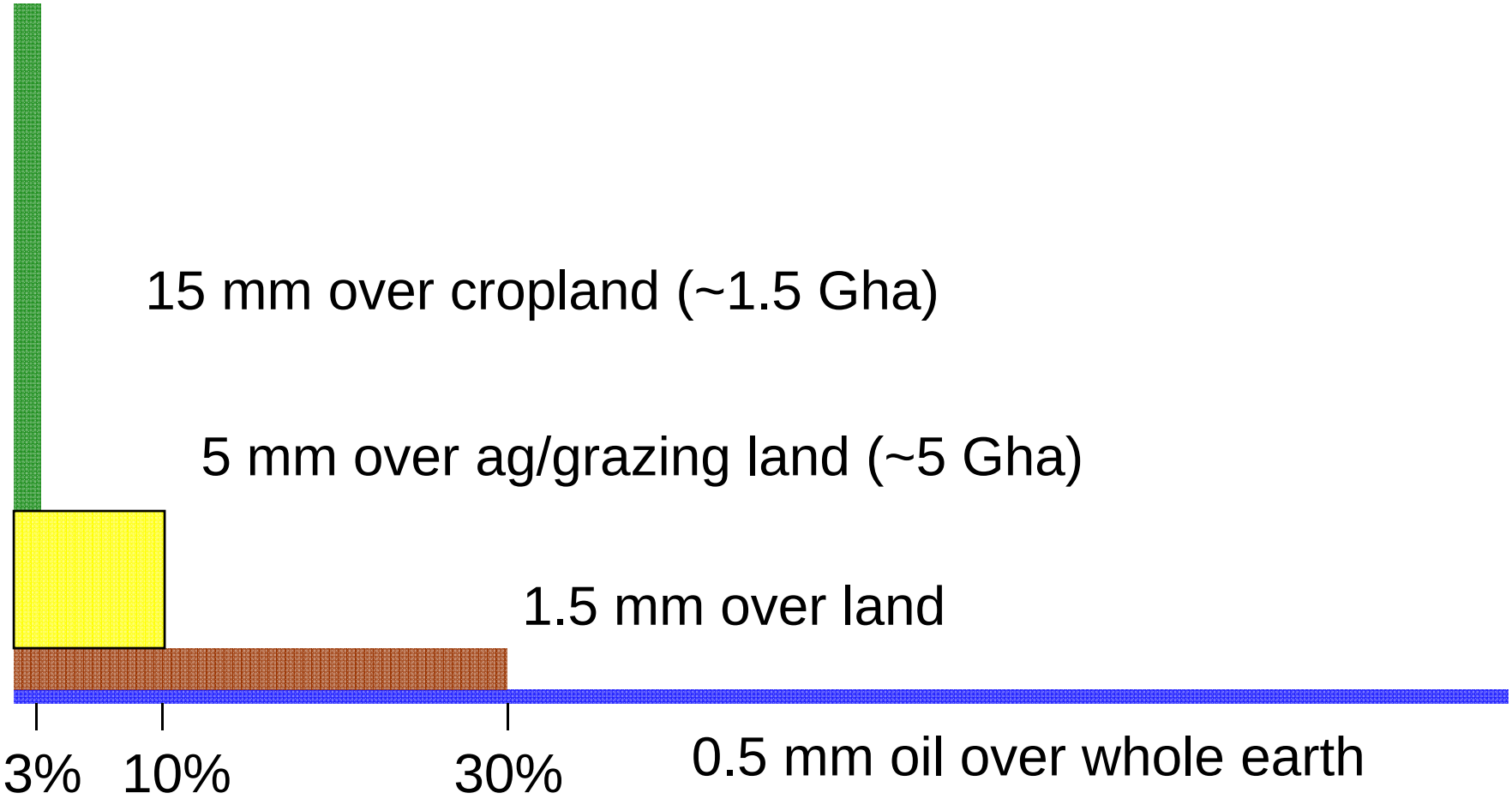
500-8000 years after biochar and nutrient additions

(Central Amazon, Brazil)

‘normal’ soil

“Terra Preta”

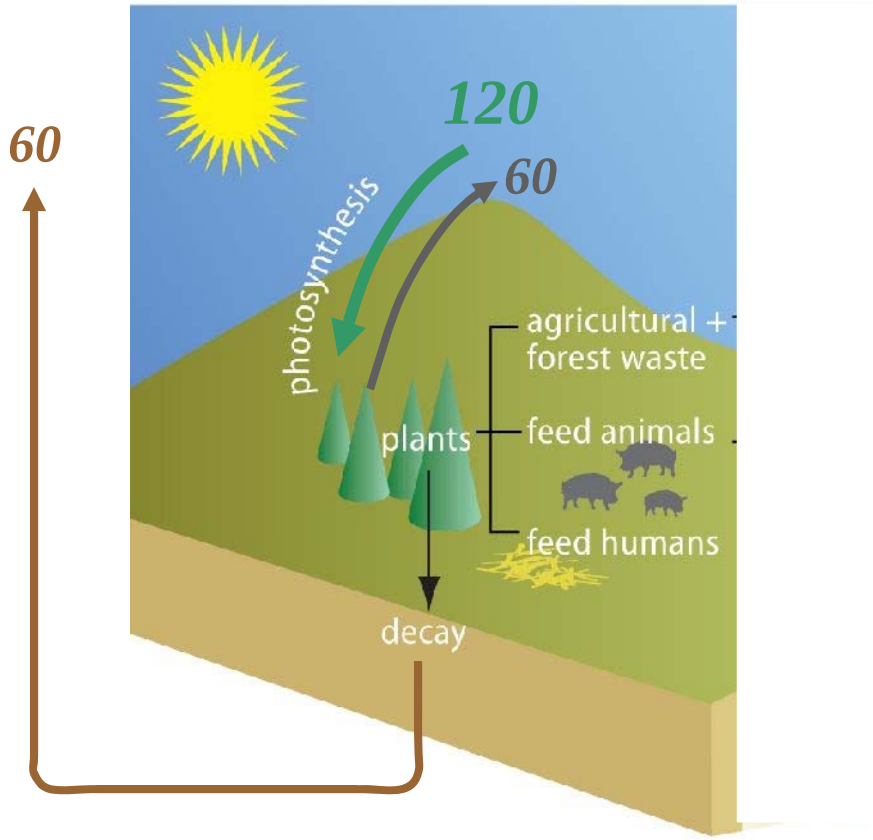
How deep is 100 ppm CO2 (240 Gt C)?



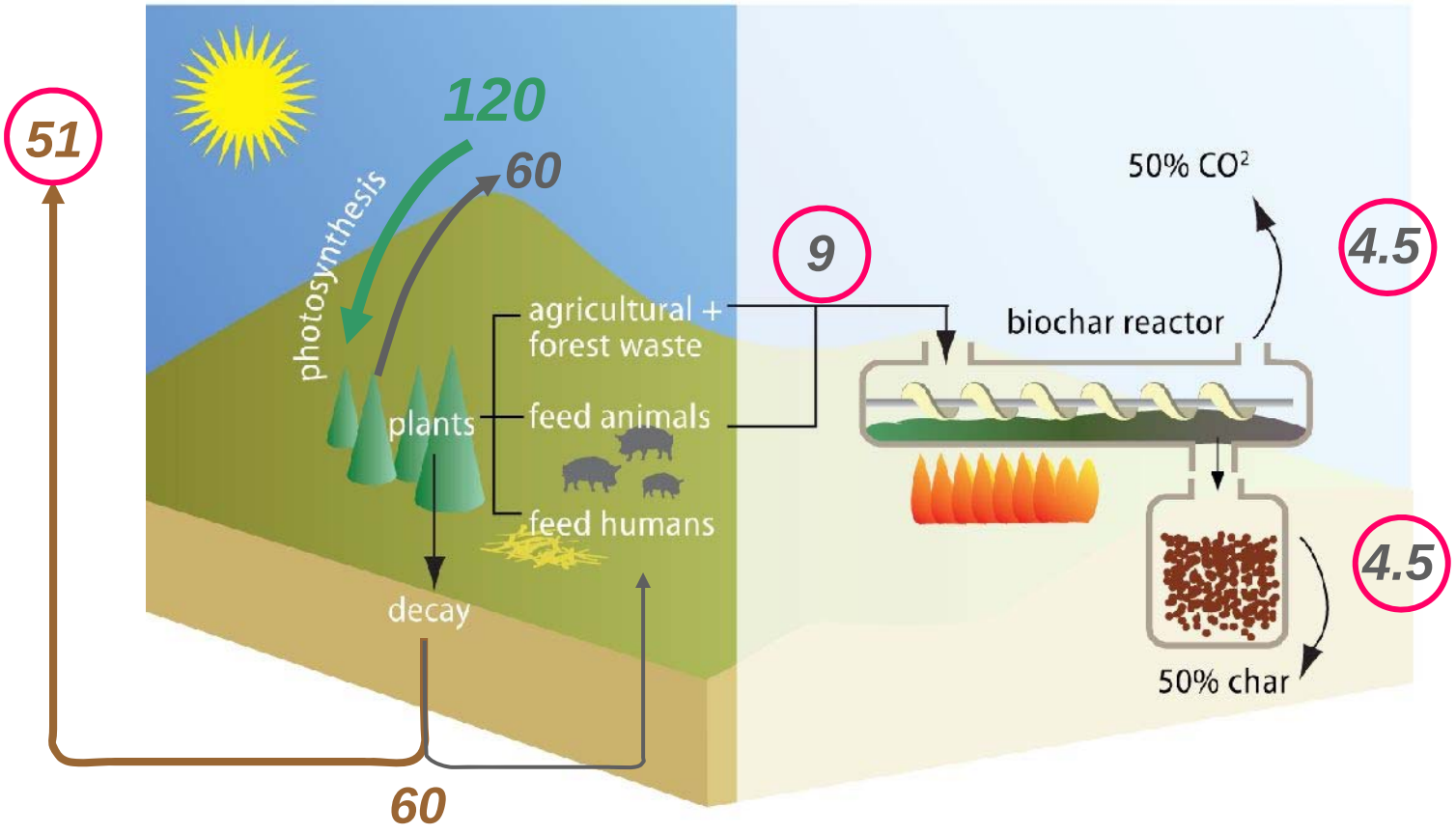
How Fast Could Biochar Sequester all the Excess Carbon?

- 15 mm ~ 150 tons / ha
- ~ 3 t / ha for 50 years
- 4.5 Gt / yr over 1.5 Gha cropland
- Terra Preta cultivation may have exceeded this rate

Carbon Flux
(in Gigatons C per year)



Carbon Withdrawal as Char
(in Gigatons C per year)



How much Biomass Yearly?

- Biomass is ~1/3 carbon
- Biochar captures 50% C
- Need 18 t/ha to capture 3 t/ha

How much Biomass Yearly?

- 20 t / ha in tropical forest
- 12 t / ha in temperate forest
- 6 t / ha in typical cropland
- 30 t / ha in miscanthus

Tropics are self-sufficient

Add waste streams elsewhere

An Assessment of Biomass Resources in California, 2007

The California ENERGY COMMISSION

Table S.2. Resources and generation potentials from biomass in California, 2010

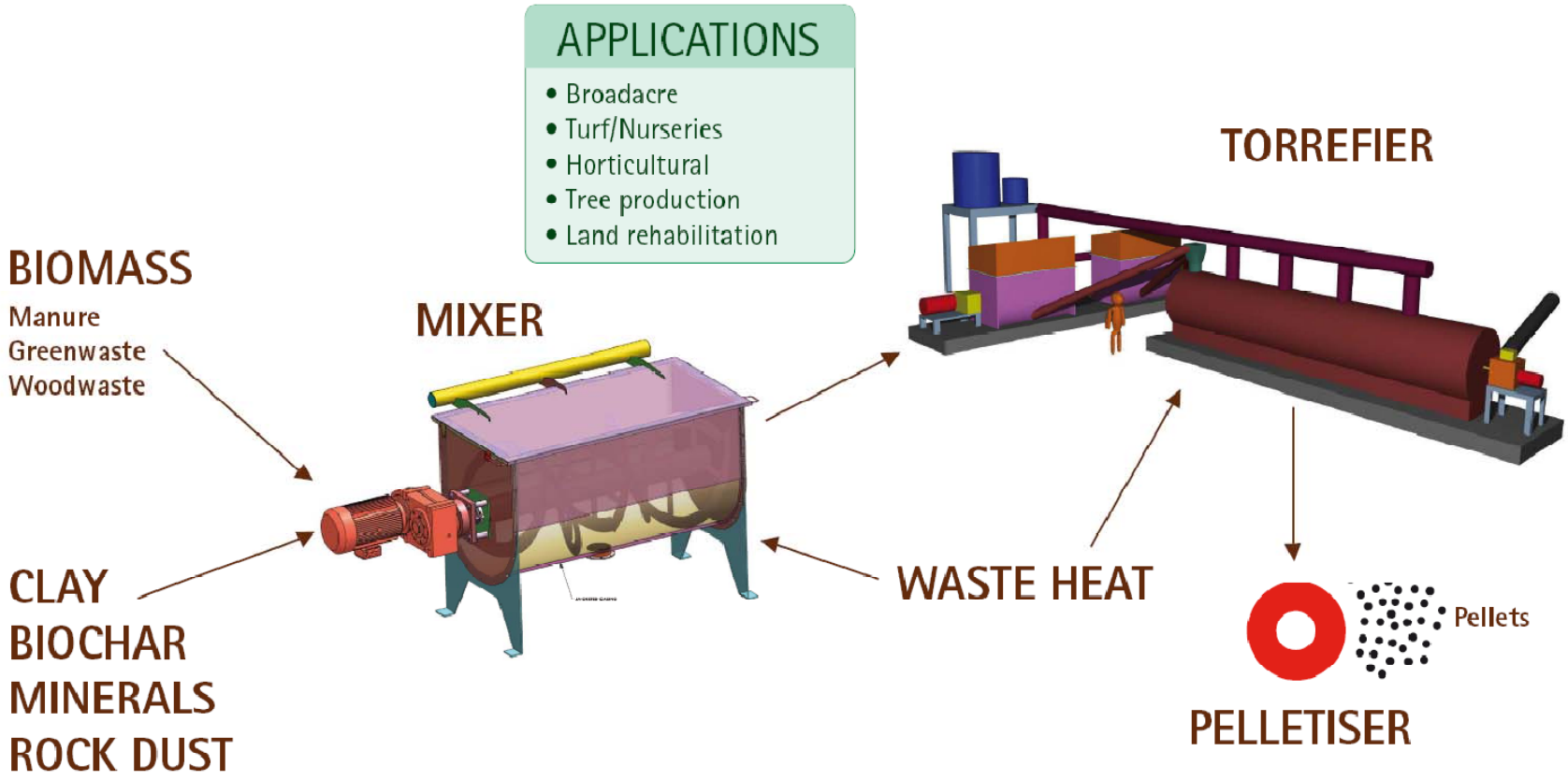
Category	Units	Agriculture	Forestry	Municipal Wastes	Dedicated Crops	Total
Gross Resource	Million BDT/y	22	27	38	2.3	89
Technical Resource	Million BDT/y	9	14	10	2.0	36

Table S.4. Resources and generation potentials from biomass in California, 2020

Category	Units	Agriculture	Forestry	Municipal Wastes	Dedicated Crops	Total
Gross Resource	Million BDT/y	25	27	42	5.0	98
Technical Resource	Million BDT/y	10	14	11	4.5	40

- Cropland = 8.46 M acres = 3.5 Mha
  Gross Biomass ~ 25 T / ha
  Sustainable Biomass ~ 10 T /ha

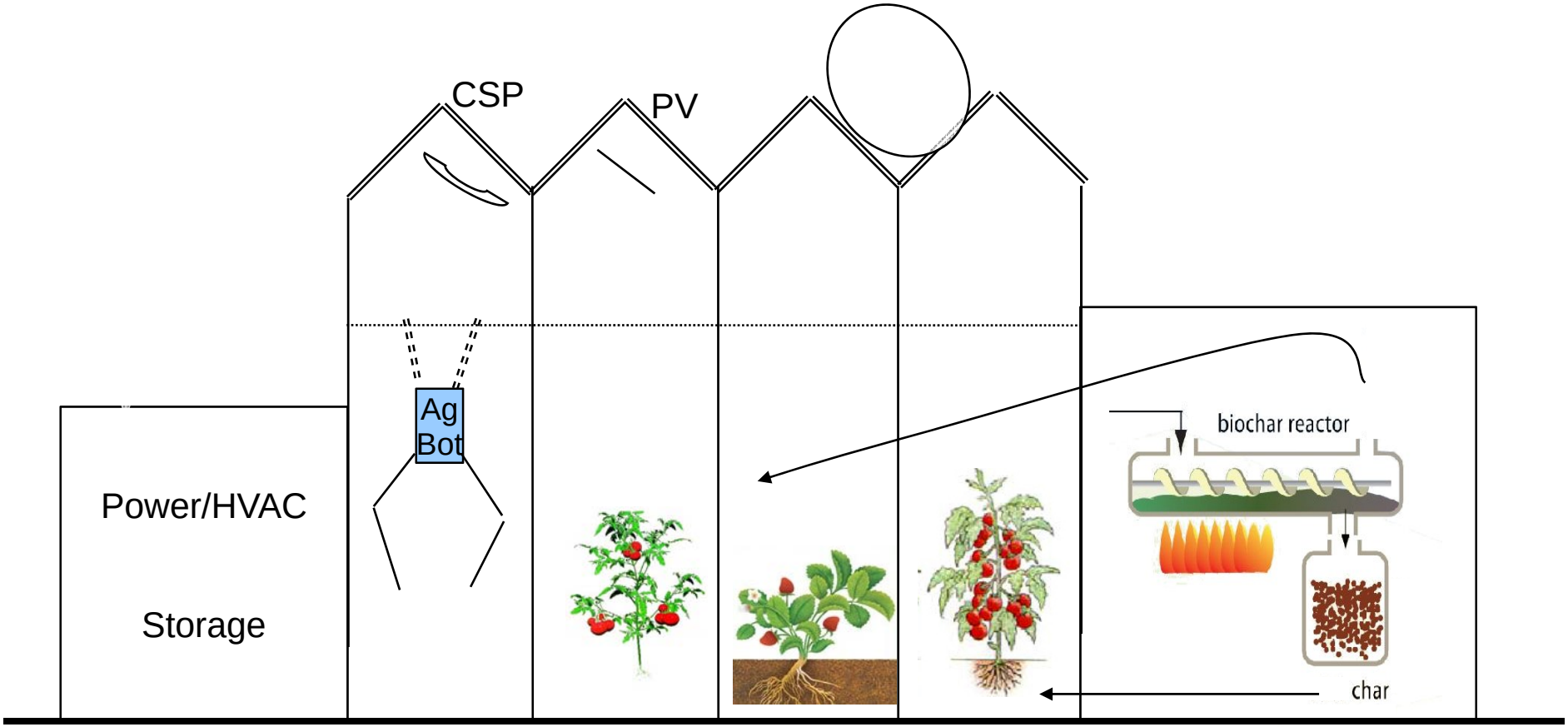
Biochar-Mineral Complexes



Clays improve carbon capture

Biochar-Mineral Bricks

Solar Biochar Greenhouses



Solar Biochar Greenhouses

Greatest biomass in CA in regions of high direct sunlight: best sites for solar greenhouses

Figure S.2. Estimated total biomass (gross BDT/y) in California, 2007.

Other Upside Factors

- Biochar applicable to non-crop lands
  - grasslands, wetlands, forests, reclamation
  - greenroofs, gardens
  - golf courses, parks, lawns
- Biochar increases water retention
- Biochar improves animal feeds
  - improves animal health, productivity
  - reduces methane, NH3, NOx emissions
- Biochar enhances soil biodiversity
  - restores microbial carbon capture
  - ~ 1 T/ha/yr carbon from char < 0.1 T/ha char!?

Biochar Storage Time

About 30 to 100 times longer than uncharred biomass

Mean residence time in soil: ~1000+ years

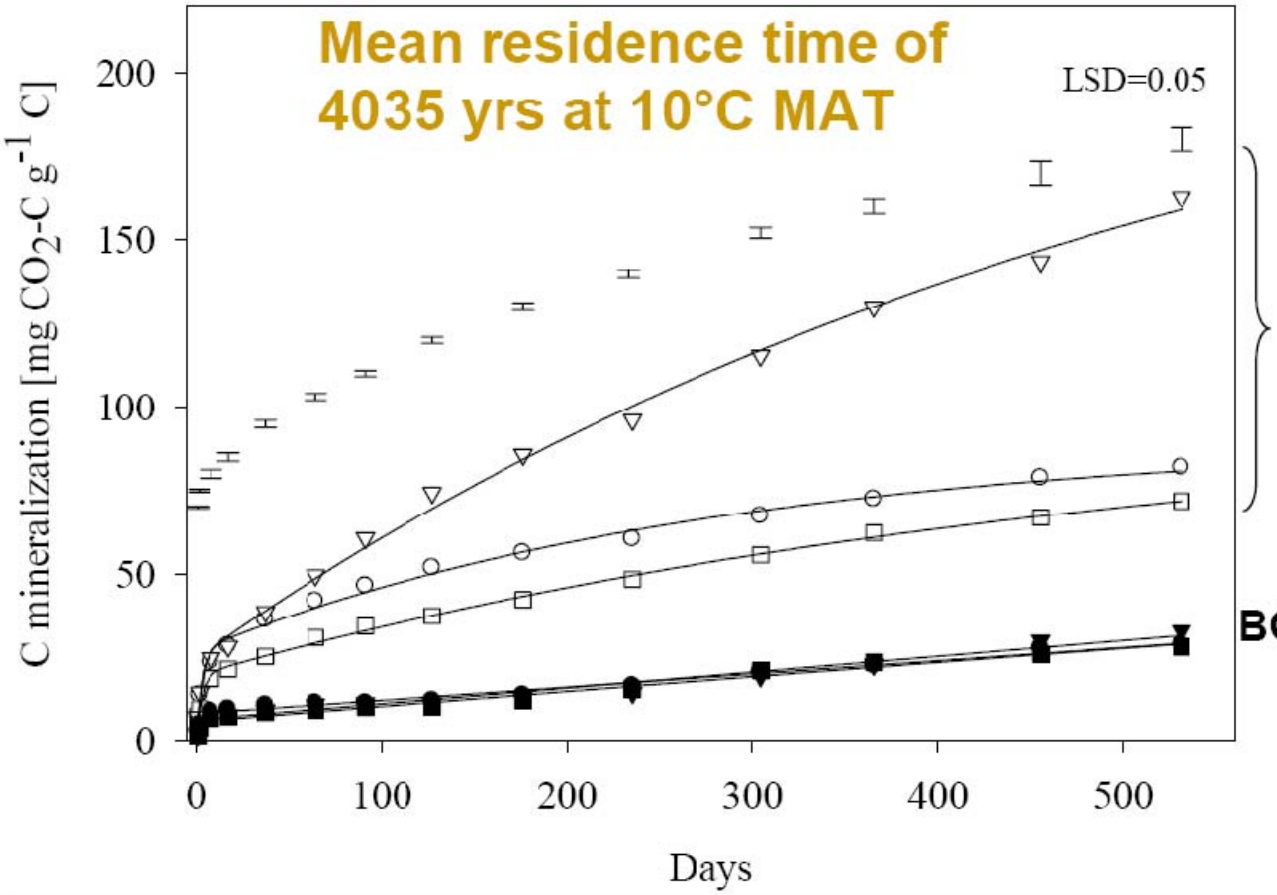
(regionally different dependent on temperature and moisture)

Lehmann et al, 2008, *Nature Geoscience* 1, 832 - 835
Liang et al, 2008, *Geochimica et Cosmochimica Acta* 72, 6096-6078
Cheng et al., 2008, *Journal of Geophysical Research*, 113, G02027
Baldock and Smernik, 2002, *Organic Geochemistry* 33, 1093-1109
Kuzyakov et al., 2009, *Soil Biology and Biochemistry* 41, 210-219

Biochar Stability

Highly Aged Biochar

(Terra Preta Central Amazon Defined period of BC accumulation)



BC-poor soils

BC-rich soils

(N=3; BC age ranges from 800 to 7,000 years)

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

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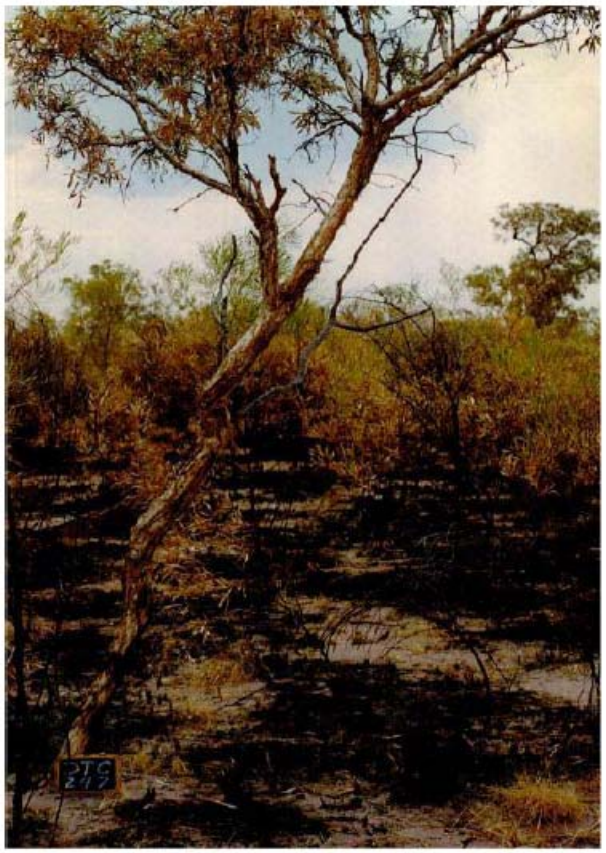
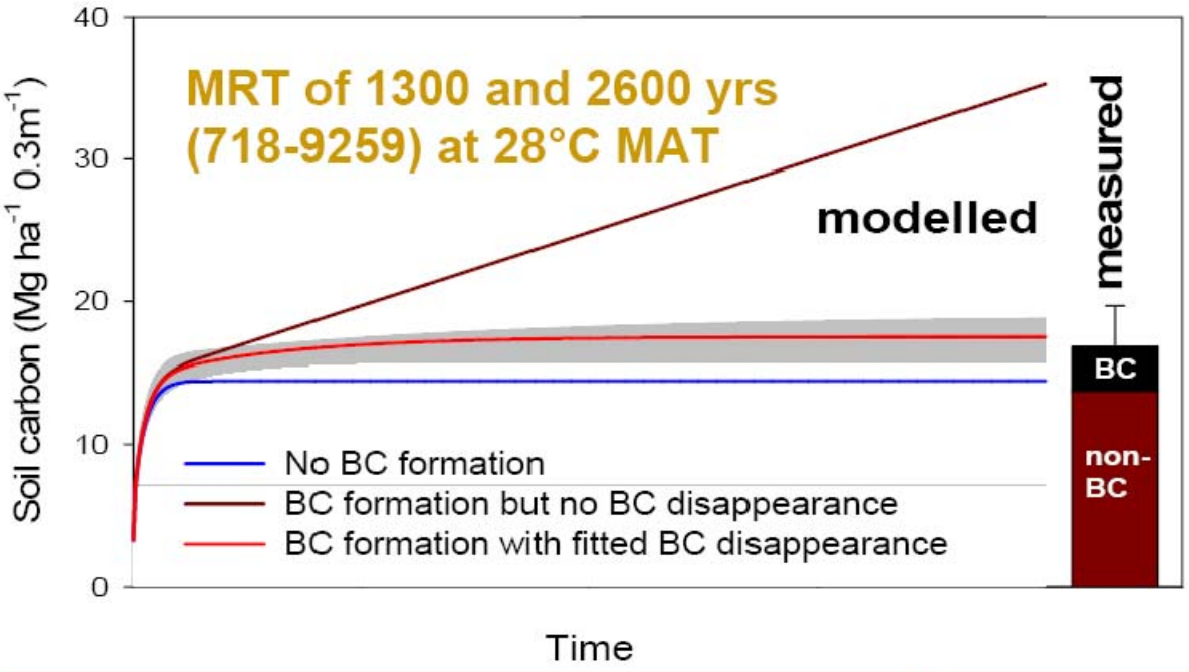
Biochar Stability

Fresh Grass Biochar



Inceptisols (Northern Territory, Australia)
13 and 15 profiles
27°C MAT, 887 mm MAP
Grass vegetation under varying assumptions of burning severity and BC formation
Model run to equilibrium (for BC MRT to 1m)



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

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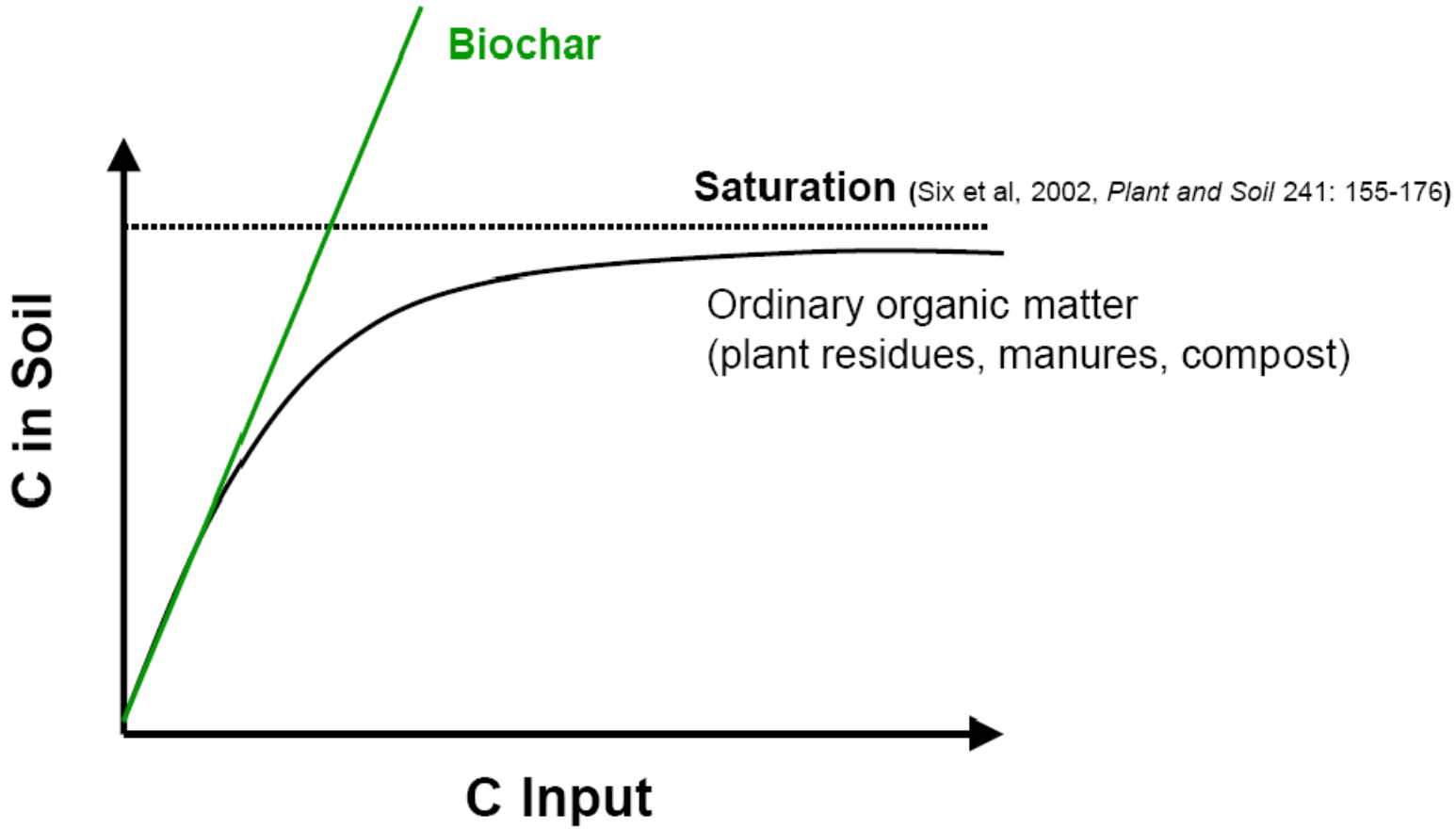
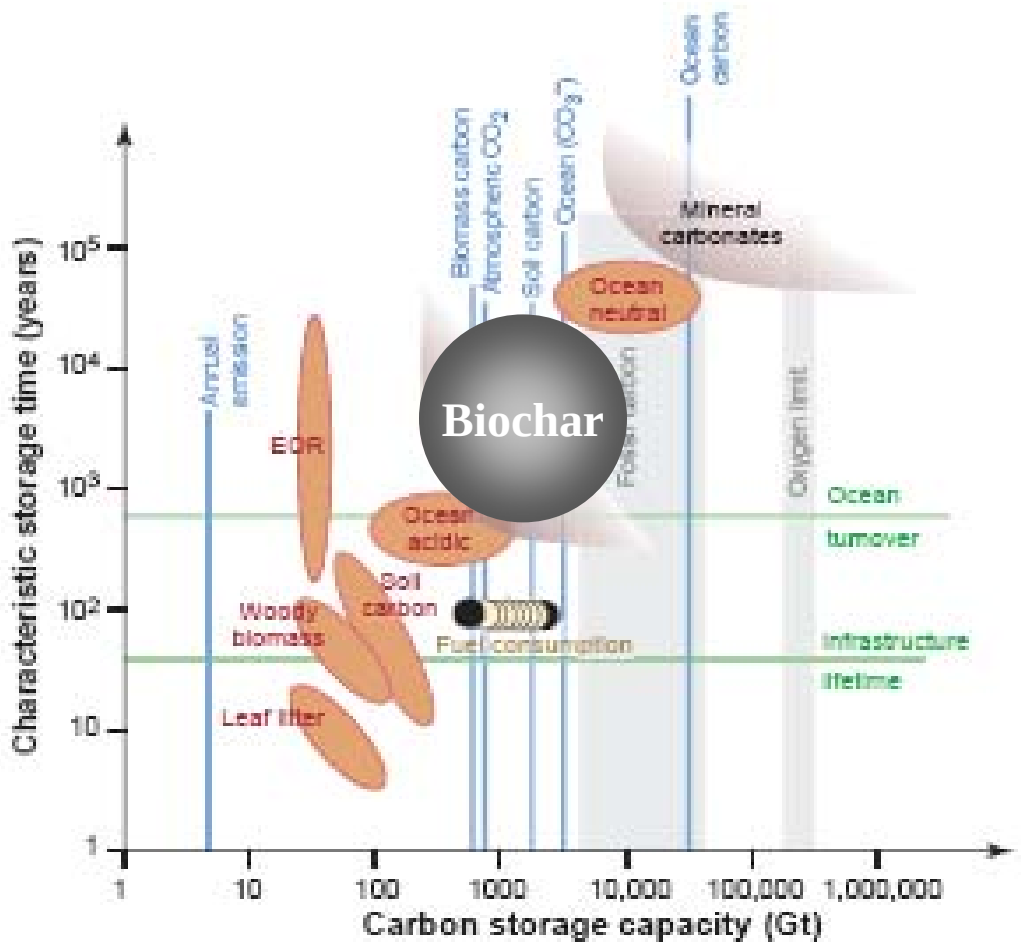
Biochar Stability and Stabilization



Carbon withdrawal from the atmosphere



Lackner, 2003, *Science* 300: 1677-1678

Biochar Carbon Accounting

Paraguay

Copenhagen Draft Negotiating Text May 19

UNITED NATIONS

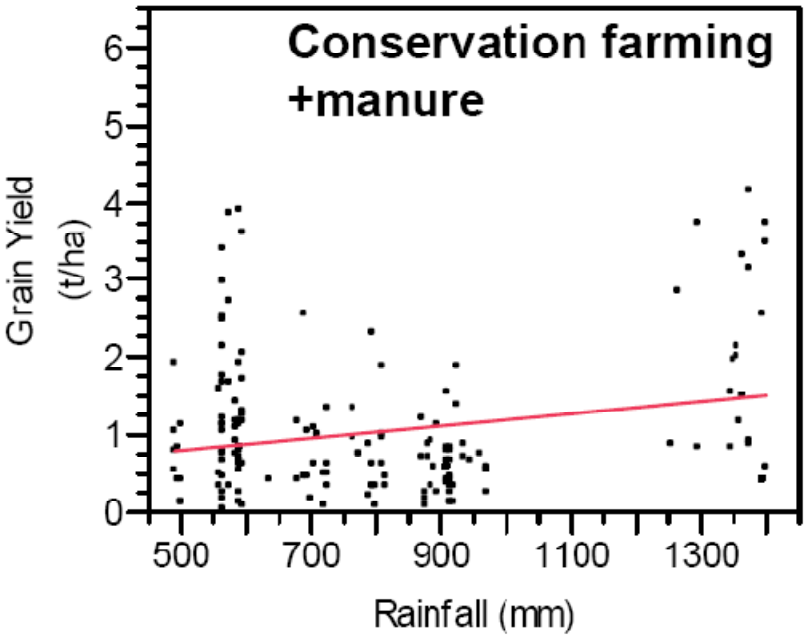
UNFCCC Framework Convention on Climate Change

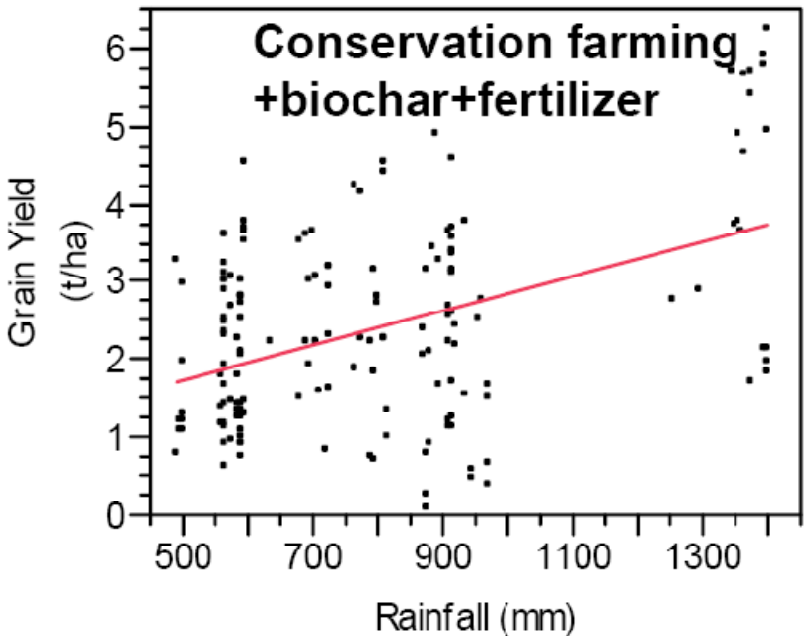
Agriculture

134. "Parties shall cooperate in R&D of mitigation technologies for the agriculture sector, recognizing the necessity for international cooperative action to enhance and provide incentives for mitigation of GHG emissions from agriculture, in particular in developing countries. Consideration should be given to the role of soils in carbon sequestration, including through the use of ***biochar*** and enhancing carbon sinks in drylands."

Agronomic Value

Spatial variability





Eastern Zambia,
280 farmers
Rice husk biochar

Gatere et al., unpubl. data

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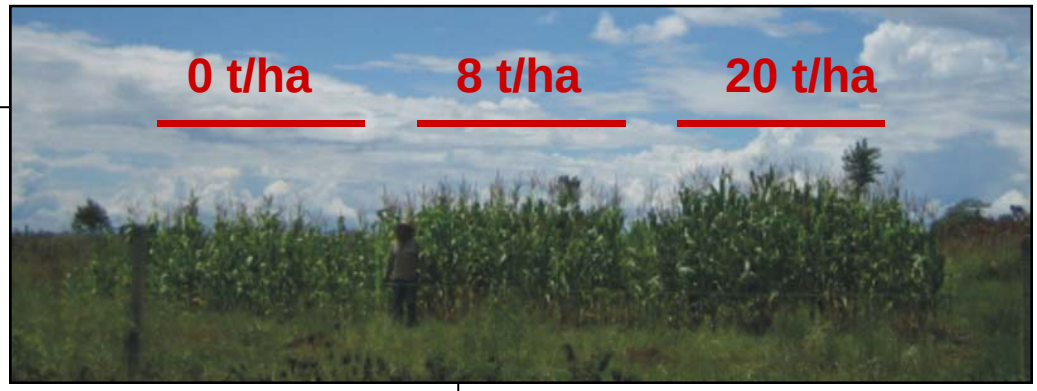
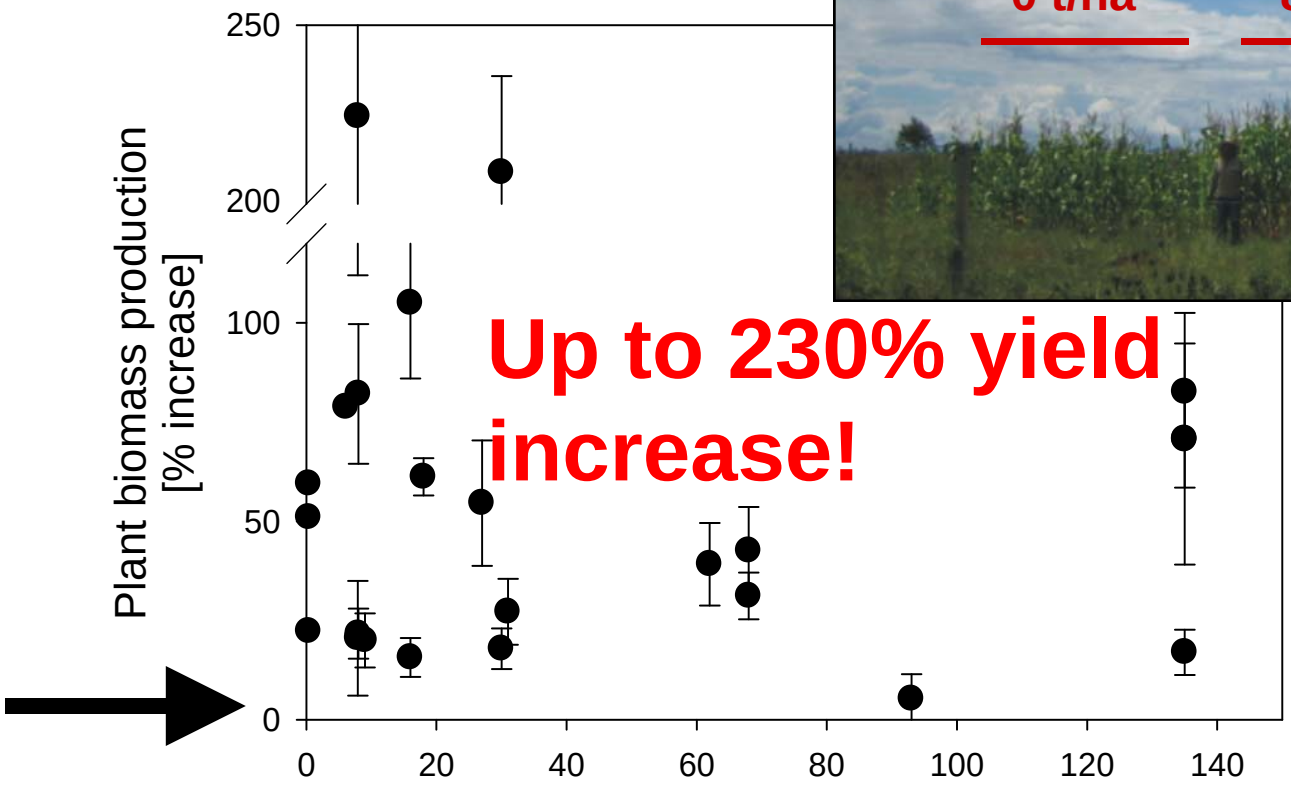
JM1

Biochar Increases Yield





Up to 230% yield increase!

Results from 24 experiments and 10 different crops

Without Biochar using best management

Lehmann and Rondon, 2006, *Bio-char Soil Management on Highly Weathered Soils in the Humid Tropics .* Francis and Taylor, FL, pp. 517-530

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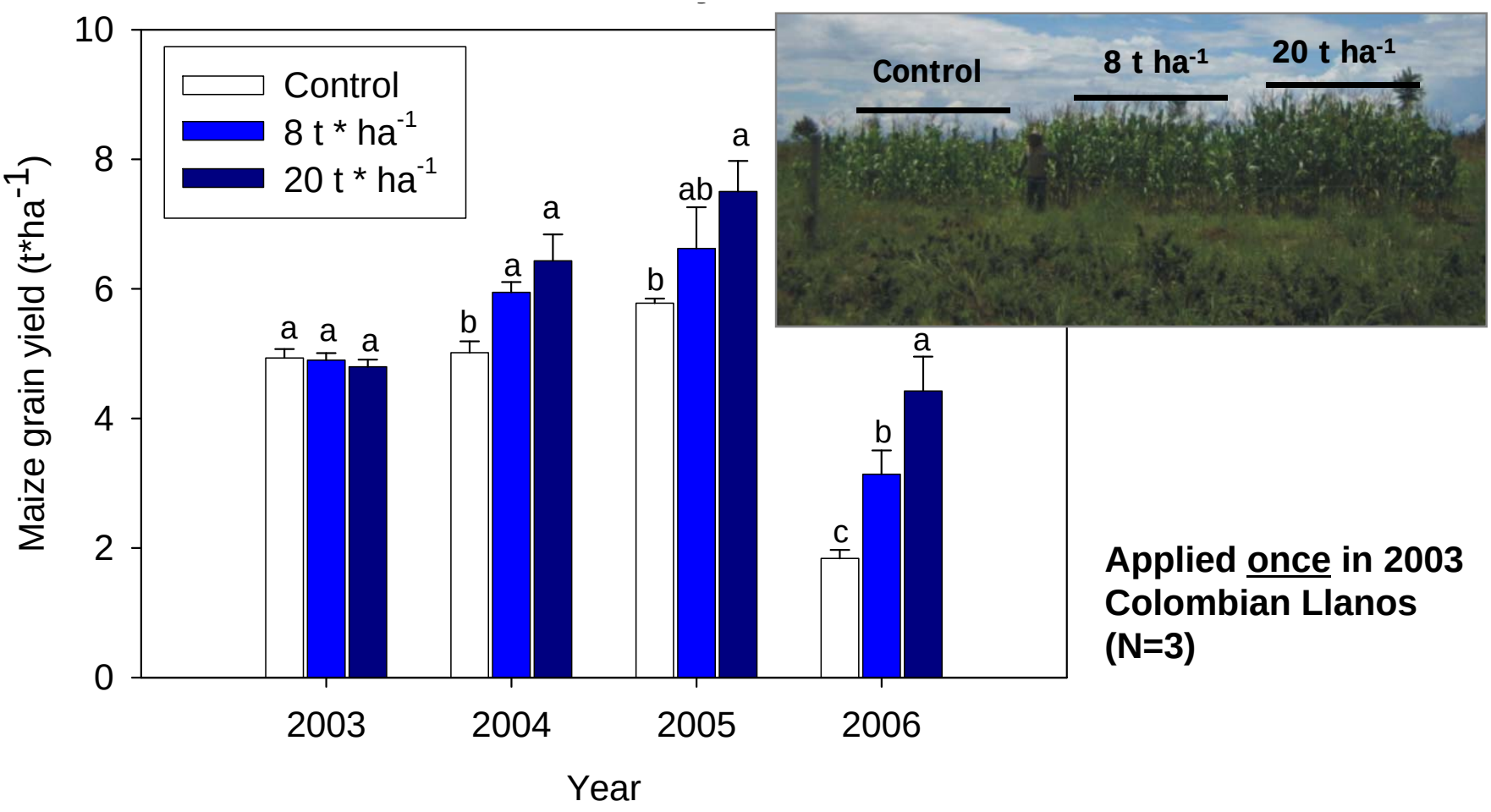
Slide 24

JM1 Biochar has been widely found to benefit crop yields including for field and horticultural crops and trees. All results presented here are for yields with biochar compared to optimally managed controls. At the 0% increase line, crops growing where biochar was added did not do any better than controls. Since all points are above this line, all biochar-amended crops did better than controls, and up to 230% better. This graph shows that application rates of around 20 t/ha gave very good results. The picture shows corn plots in Colombia, and the height of the crop is clearly greater with greater biochar application.

Julie Major, 1/16/2009

Enduring Soil Improvements



Applied <u>once</u> in 2003
Colombian Llanos
(N=3)

Major, Lehmann, Rondon, unpubl. data

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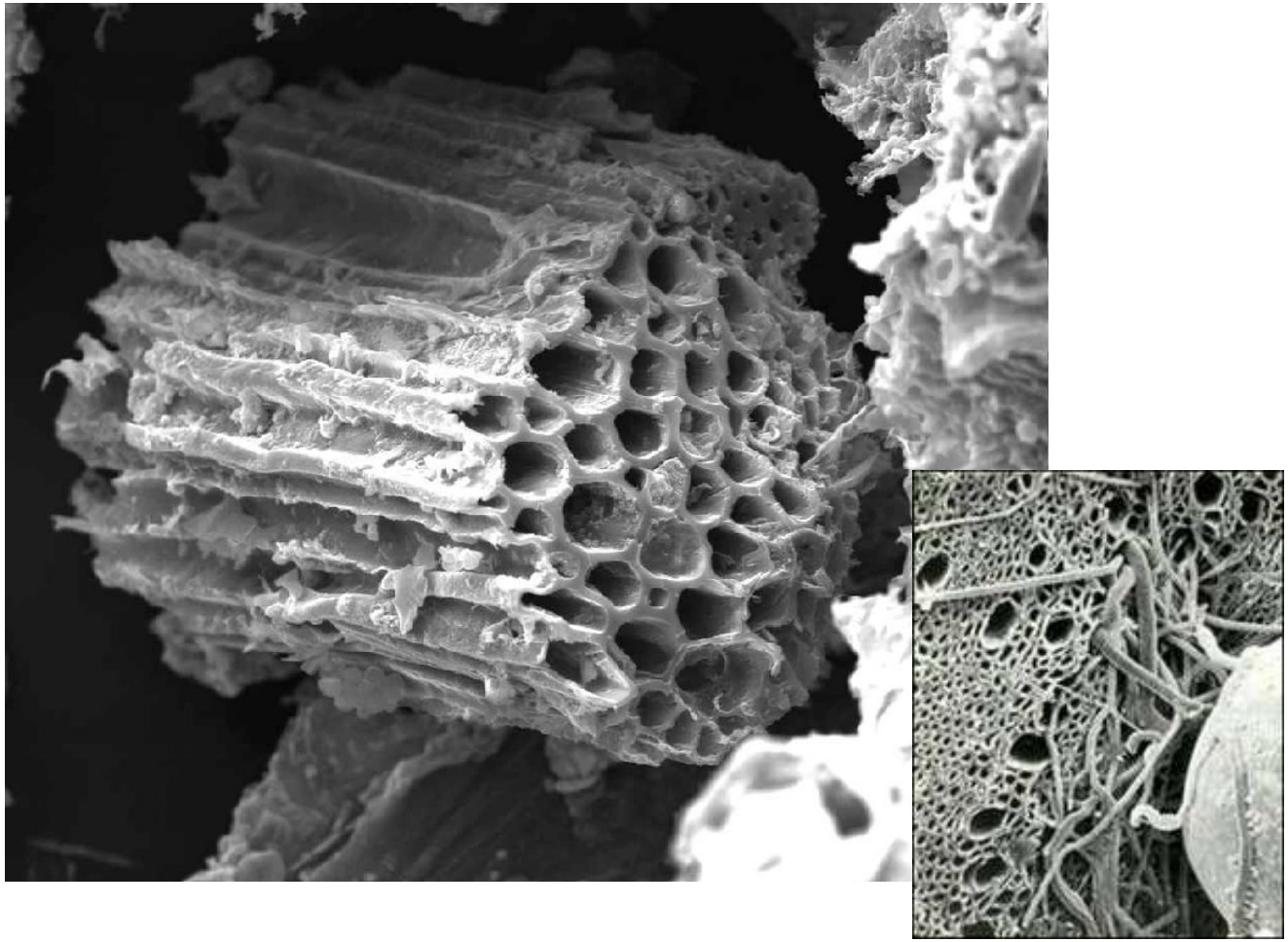
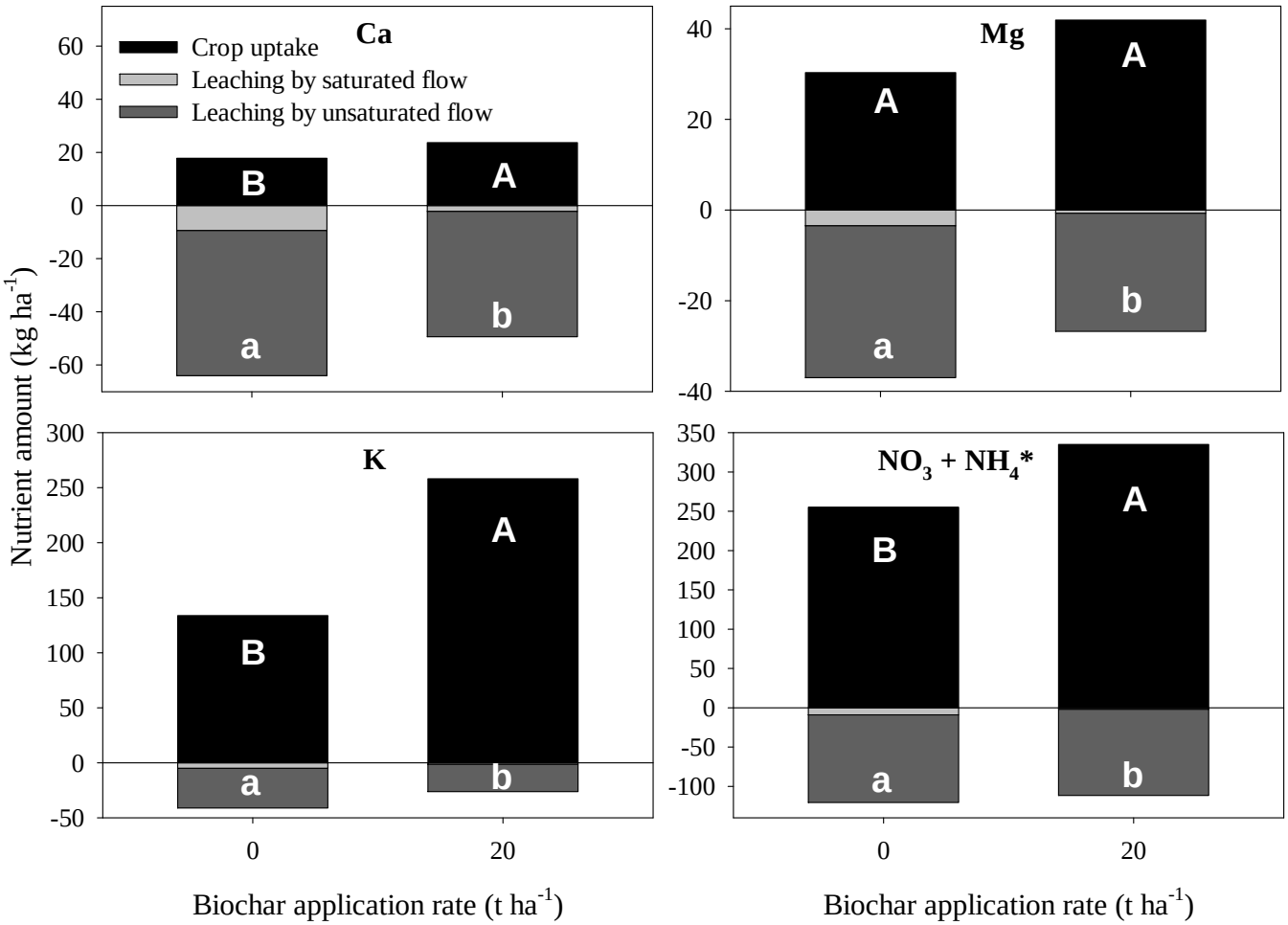
Biochar Enhances Soil Biodiversity



Biochar Soil Improver
= Lower leaching, better crop nutrition



Biochar applied once
Total over 2 years
Colombia (n=3)

Major et al, unpubl. data

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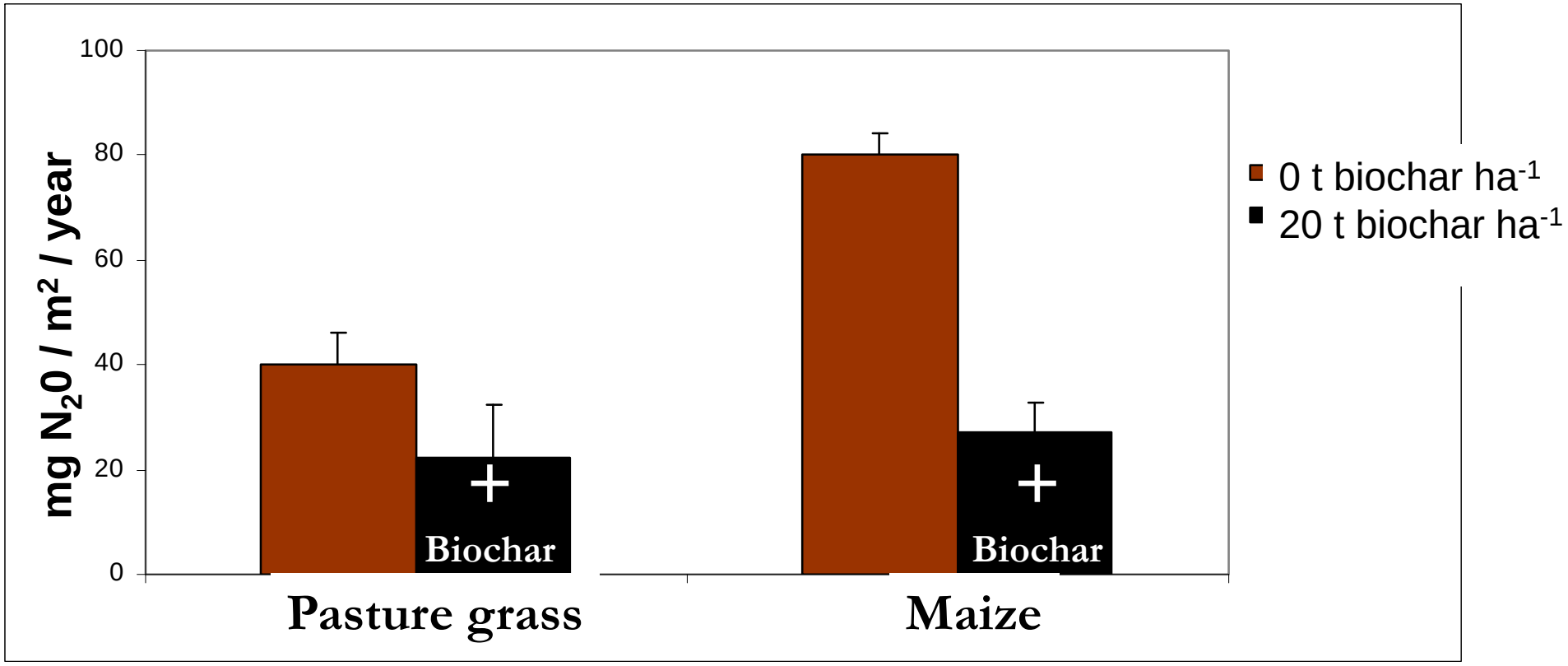
JM4

Other benefits of Biochar

Reduction in nitrous oxide emission from soil



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M. Rondon, unpubl. data

Slide 28

JM4 These are results from field plots in Colombia. Similar behavior was observed for methane. Biochar reduced soil emissions of both of these potent GHGs. However, more field data must be generated in different regions to produce a better understanding of biochar's effect on soil GHG emissions.

Julie Major, 1/16/2009

Kilns and Stoves

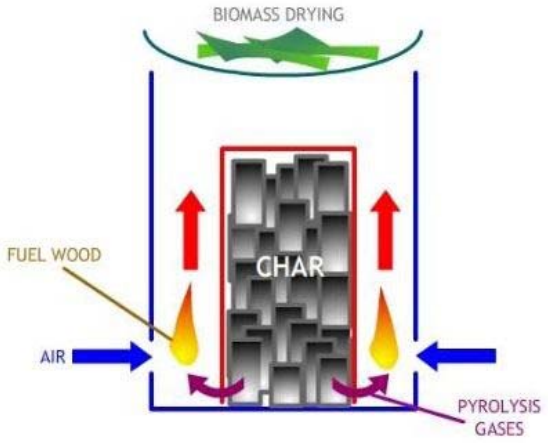
Chilean Kiln

Bolivian Kiln

Portable Kiln for Residues

Kenyan ceramic biochar stove

“Barrel-in-a-barrel”



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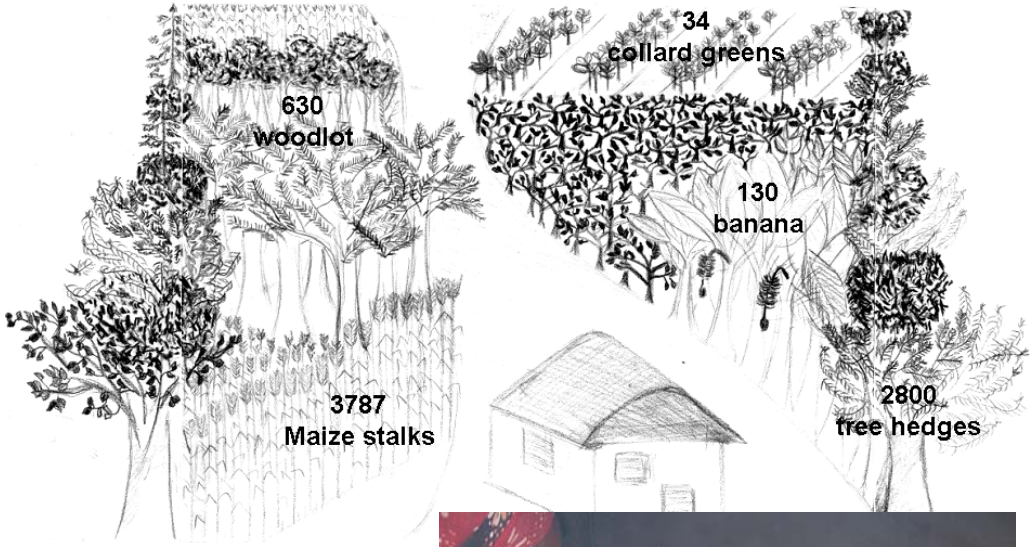
Biochar Systems



(kg/yr)

Smallholder Agriculture in Kenya

7.5 kg/day dry wood (2700 kg/yr)

0.5 t/ha/yr biochar

25-67% increase maize grain yields (8 t/ha)

Torres and Lehmann, 2009, in: EarthscanKimetu et al, 2008, *Ecosystems*

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Chinese Biochar Production Systems

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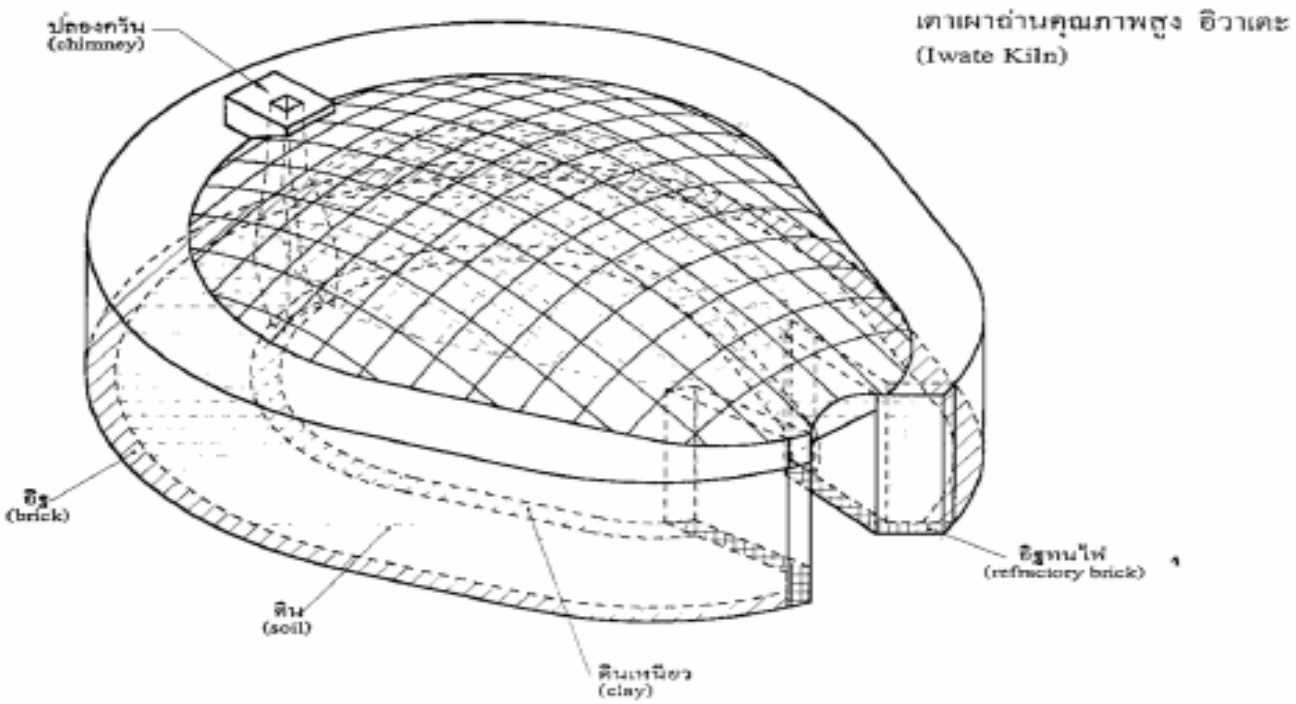


	Charring time -hrs.	Temperature -C	Remarks
Iwate kiln h1xw4.3xL5.4	140-240	400-700	Japanese Traditional style

Japanese Flat Bed Kiln

	Charring time -hrs.	Temperature -C	Remarks
Flat bed h1xw1.8xL3.6	72	350-500	For saw dust, bark

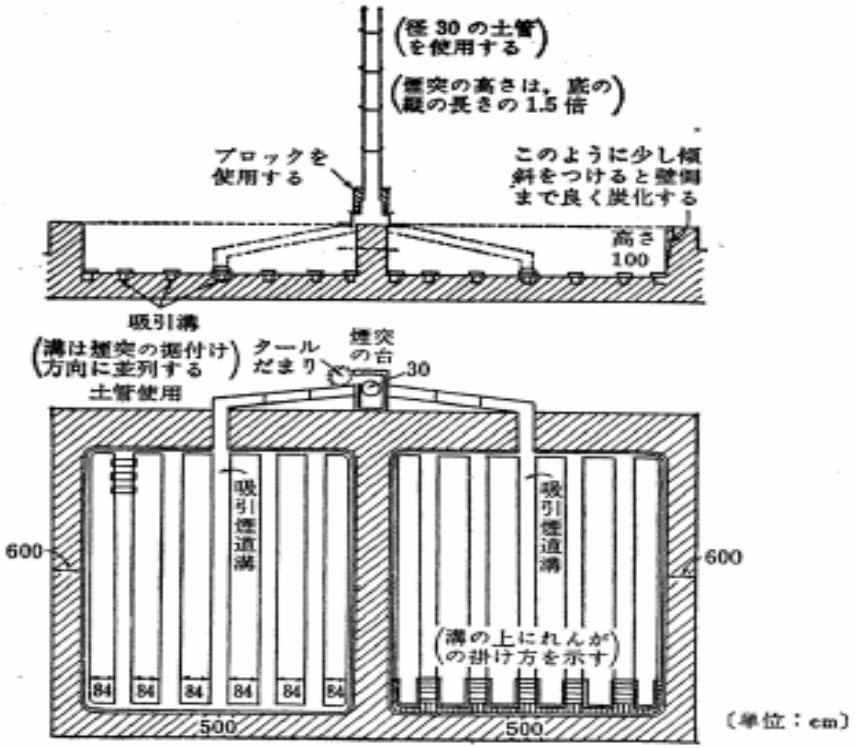
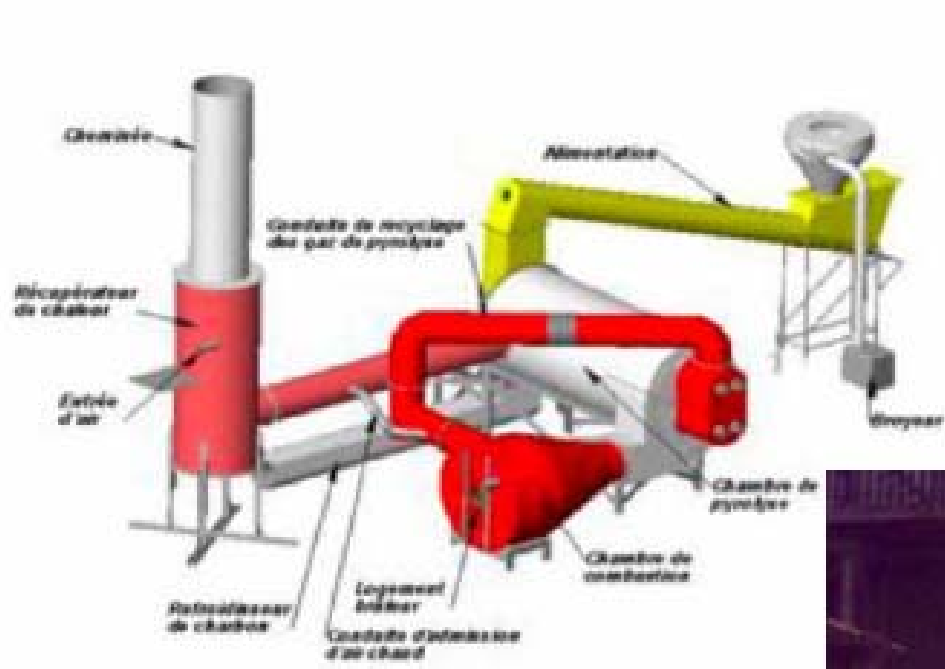


図 11　平窯（チップ，樹皮廃材用）[1]

South African Built Rotary Charcoal Kiln



Biochar Production Systems

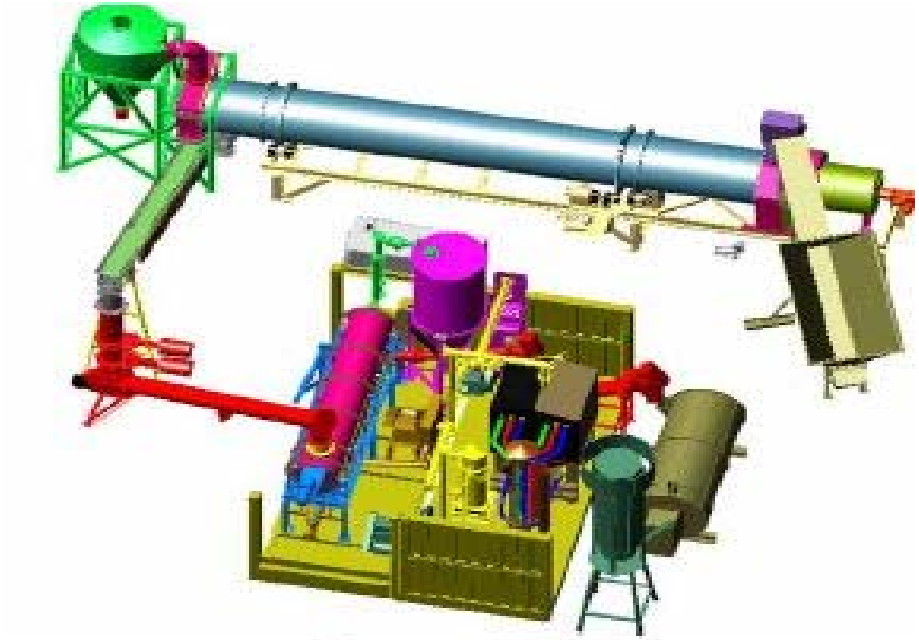
3R Vacuum Pyrolysis Kiln

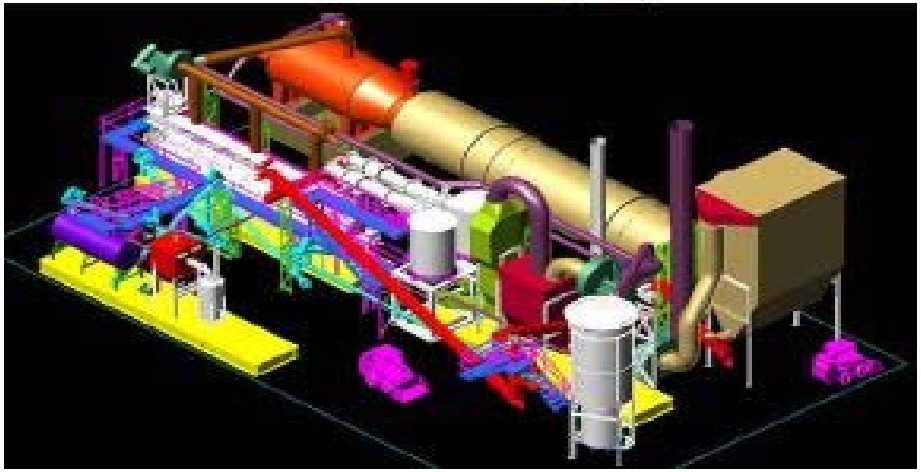
Gasifier modified to produce biochar from chicken manure

Kansai Kiln for Rice Husks and Sawdust

Dynamotive
Fast Pyrolysis
Plant Ontario
Canada

BESTEnergies Demonstration and Commercial System





- **Throughput 300 - 500kg/hr**
- **Yield of Char 30-35%**

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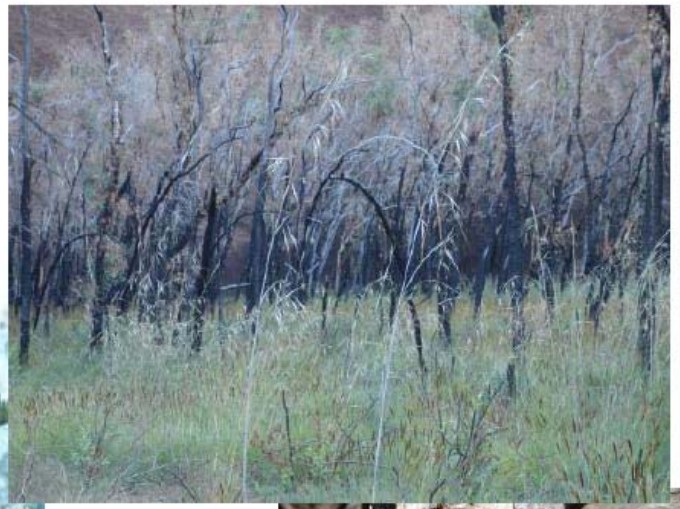
Natural Occurrence



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Conclusion

Biochar is an excellent mitigation strategy for:

- long term carbon sequestration
- reduction of atmospheric carbon levels
- reduction of other GHG emissions

Biochar participation in cap and trade

- will meet scoping plan requirements
- quantifiable, measurable, stable