ECREEE
TOWARDS SUSTAINABLE ENERGY

Validation Workshop on The ECOWAS Bioenergy Policy
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Biochar Systems for energy, agriculture, health and the environment

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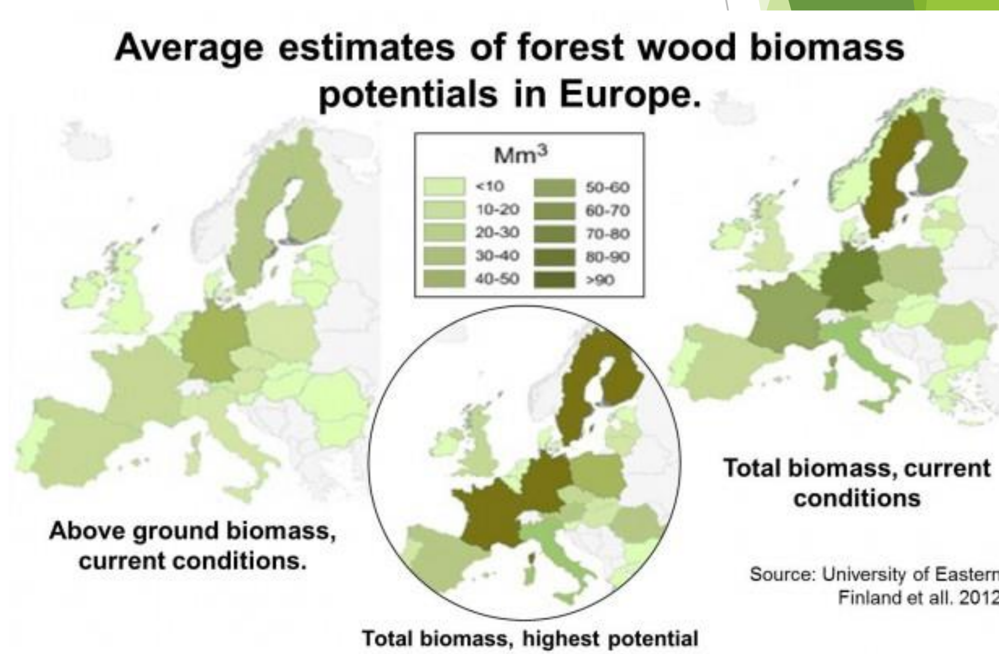
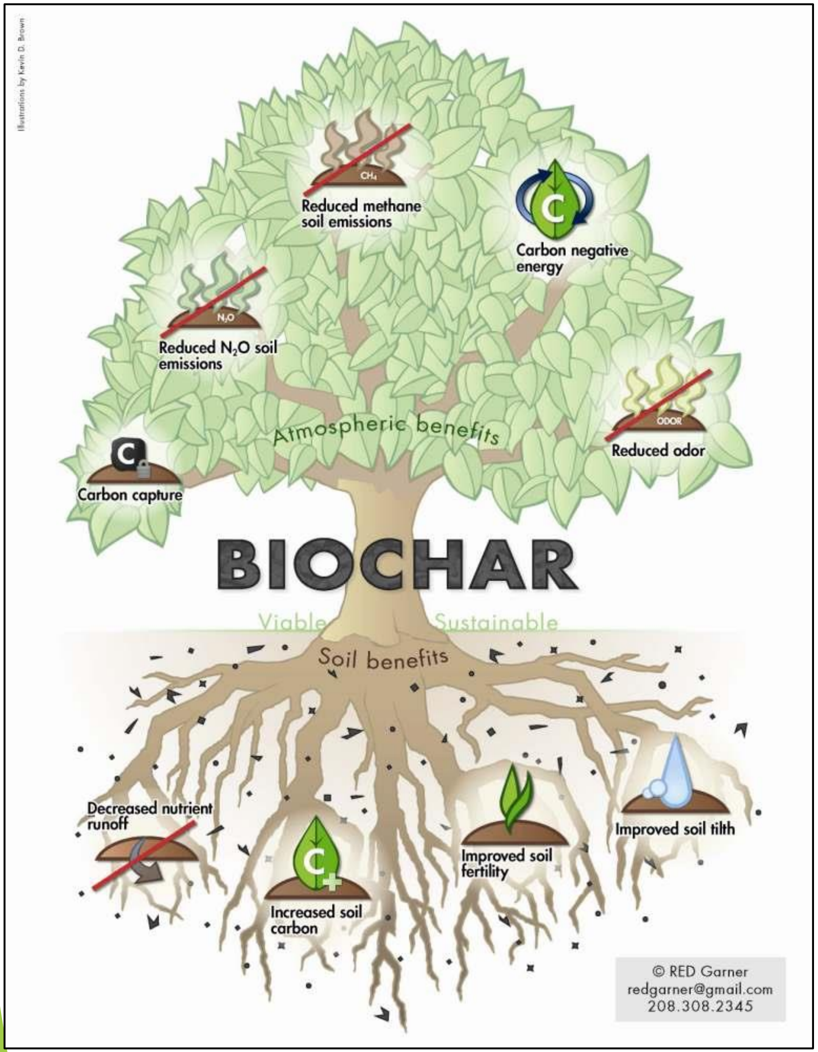
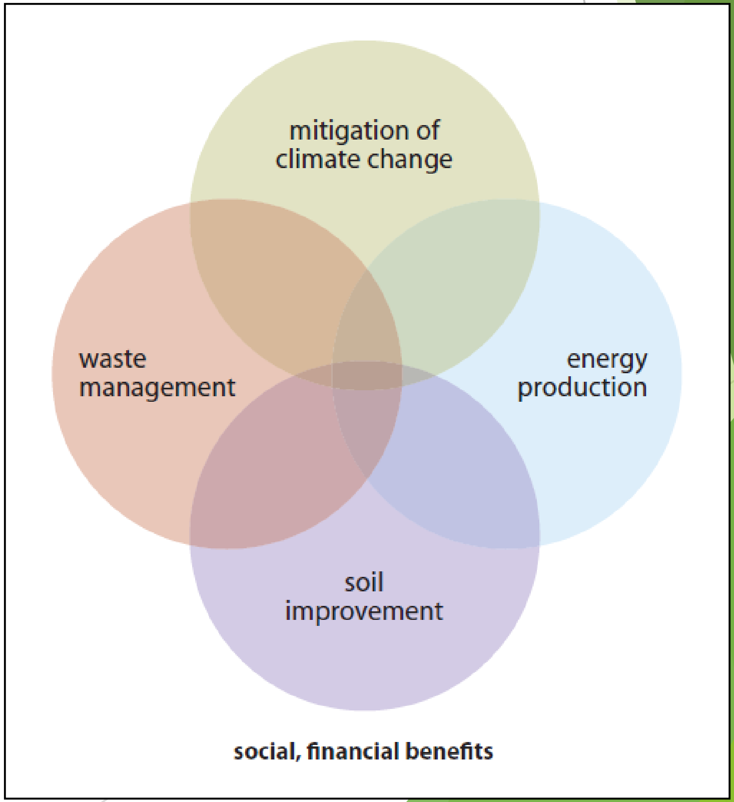
Much of the current scientific debate on the harvesting of biomass for bioenergy is focused on how much can be harvested without doing too much damage





how to design integrated agricultural biomass-bioenergy systems that build soil quality and increase productivity so that both food and bioenergy crops can be sustainably harvested ?

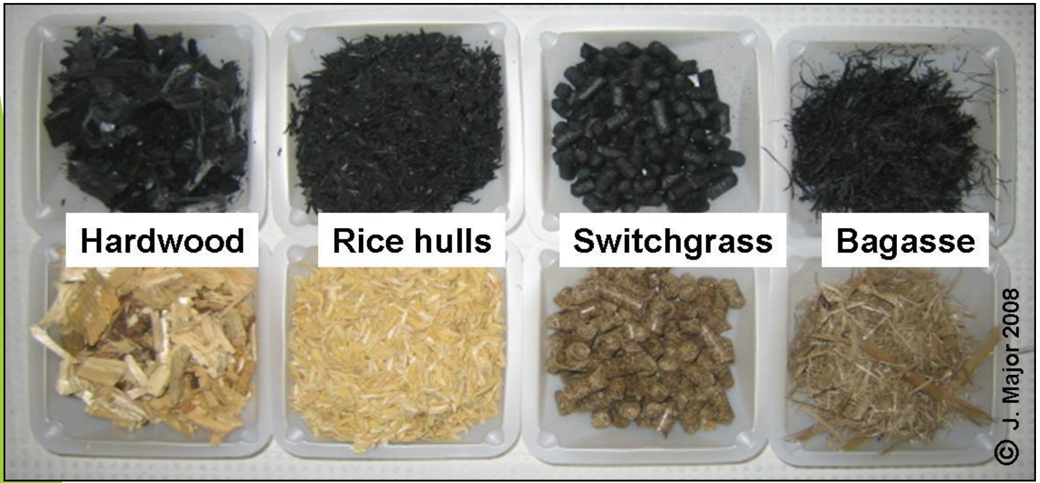
Laird 2008

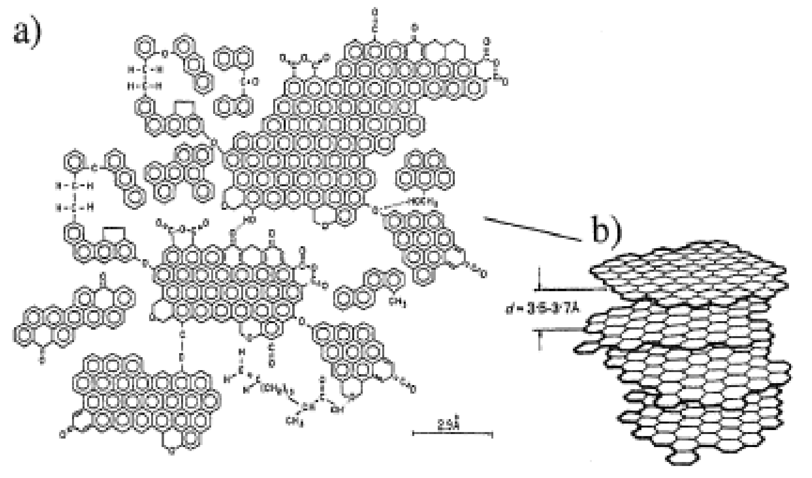


Lehmann and Joseph, 2009

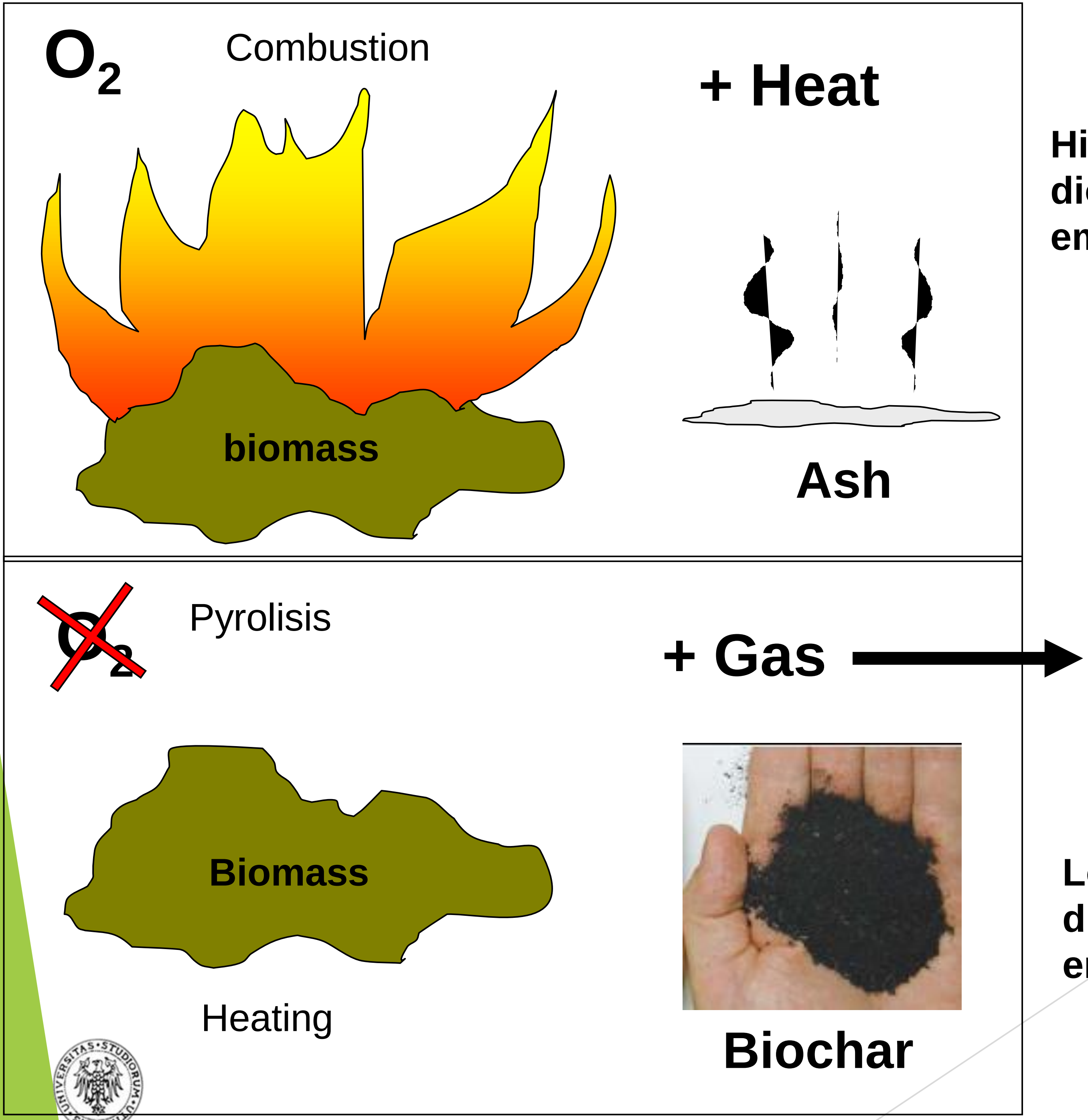
What is biochar ?

- Produced from biomass above 300 ºC, with pyrolysis (low O_2)
- Contains ~ 60-80% C as black C
- Porous low bulk density, large hydrophobic surface area
- Also contains minerals as ashes
- Highly aromatic, strong adsorption of org. compounds





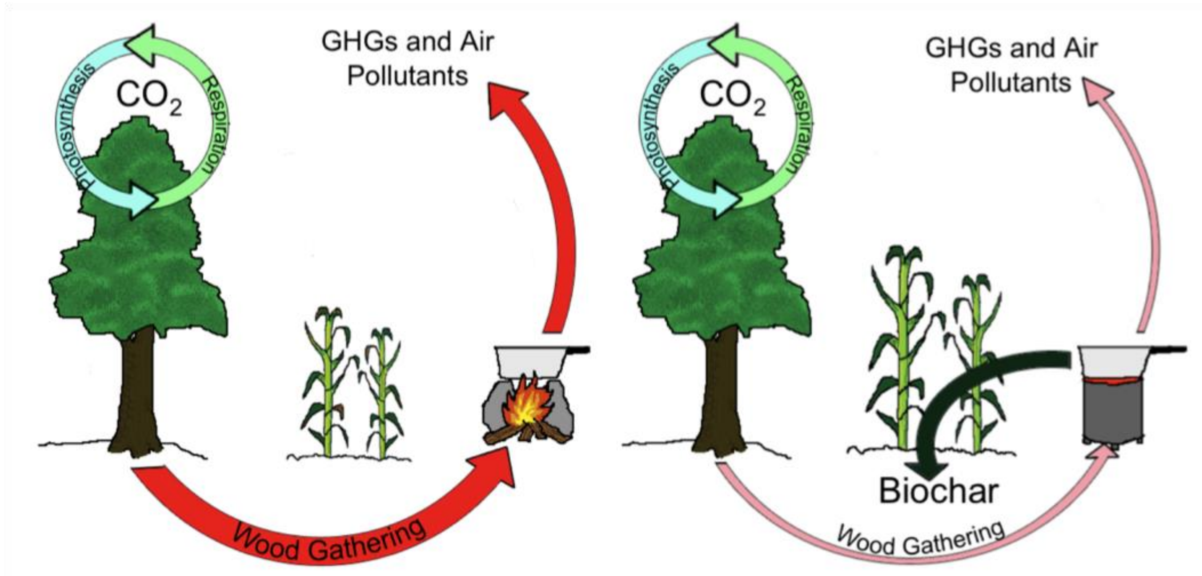
Schmidt and Noack (2000)



Heat or Energy

High particulate and dioxins amospheric emissions

Low particulate and dioxins amospheric emissions

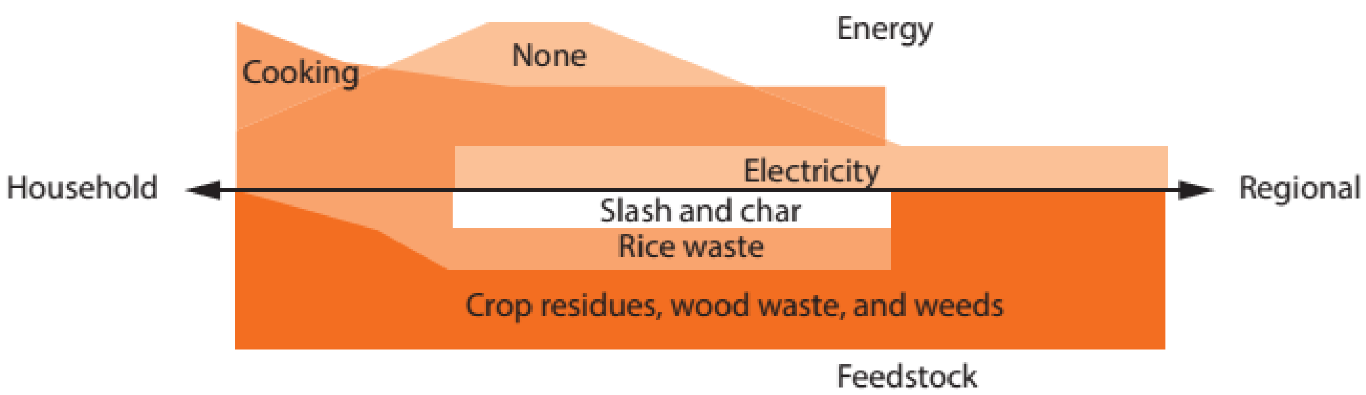


Whitman 2010

Unlike other biofuels and bioenergy, biochar does not necessitate valuable agricultural lands, food crops like corn, nor the deforestation of already valuable ecosystems.

Production and sustainability: how is produced biochar ?

- Pyrolysis can occur on many different scales (from households to energy plants)
- Small-scale pyrolysis plants can be used on-farm or by small industries (feedstock inputs of 50 to 1000 kilograms per hour).
- At a regional level, pyrolysis units can process up to 8000 kilograms of feedstock per hour (Talberg 2009).



Source: World Bank

Production and sustainability: biochar production

- The commercial production of biochar is still very limited today
- The main part of the process aims primarily to produce syngas, a low calorific power mix of CO, CO_2, H_2, CH_4 and N_2, which is used to power an endothermic engine in order to produce electricity and heat.

approach	conditions	liquid (bio-oil) %	solid (biochar) %	gas (syngas) %
Slow	Moderate temperature ~500°C Long vapour residence time ~5–30 minutes	30	35	35
Moderate	Moderate temperature ~500°C Vapour residence time ~10–20 seconds	50	20	30
Fast	Moderate temperature ~500°C Short vapour residence time ~1 second	75	12	13
Gasification	High temperature >750°C Vapour residence time ~10–20 seconds	5	10	85

Source: Brown 2009

Meyer et al., 2011, *Environ. Sci. Tech.*

Stoves

Fuels and cooking

Charcoal (biochar)

Soil improvment

Biochar Plus

value-chain

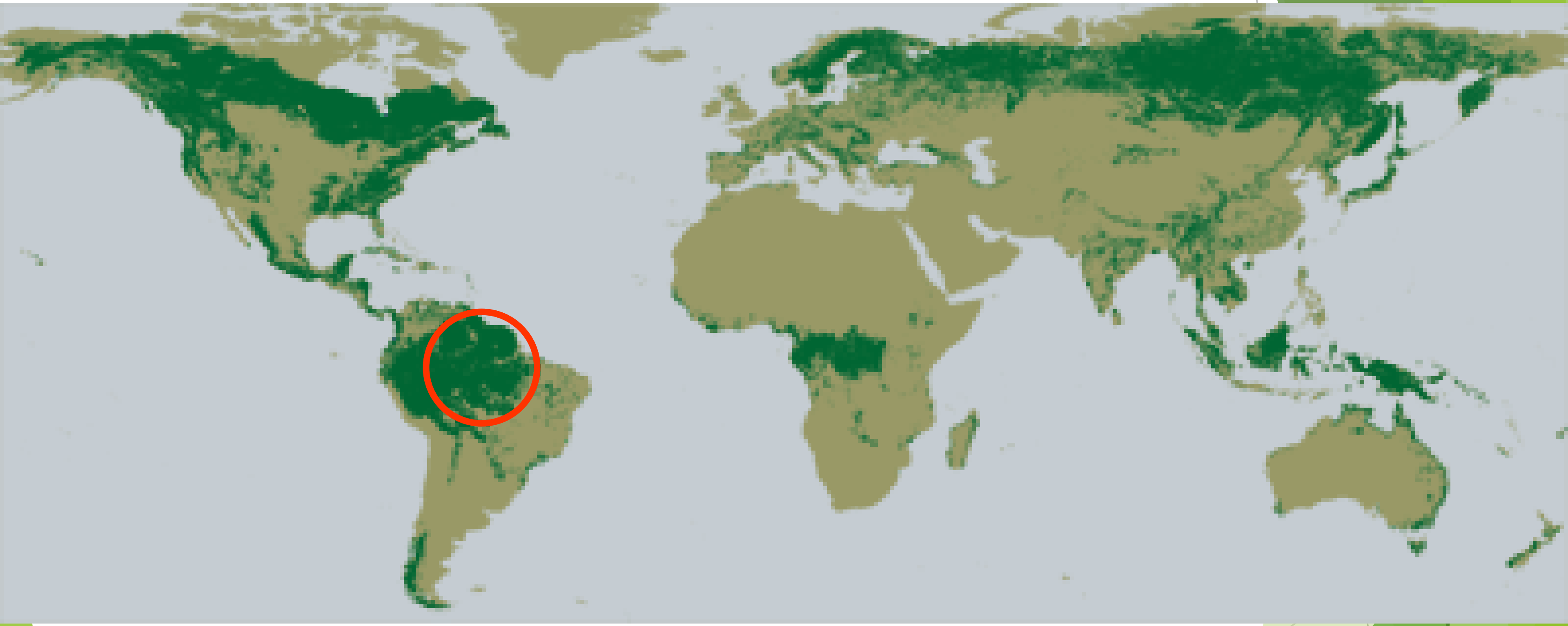
Fuel producer	Farm or Forest	Carbon Market
 Get fuel	Distribute biochar	Sell Carbon Credits

Small Medium Enterprise

Produce stoves	Test fuel	Get biochar
		
Sell stoves	Provide fuel	Burn fuel

Final user

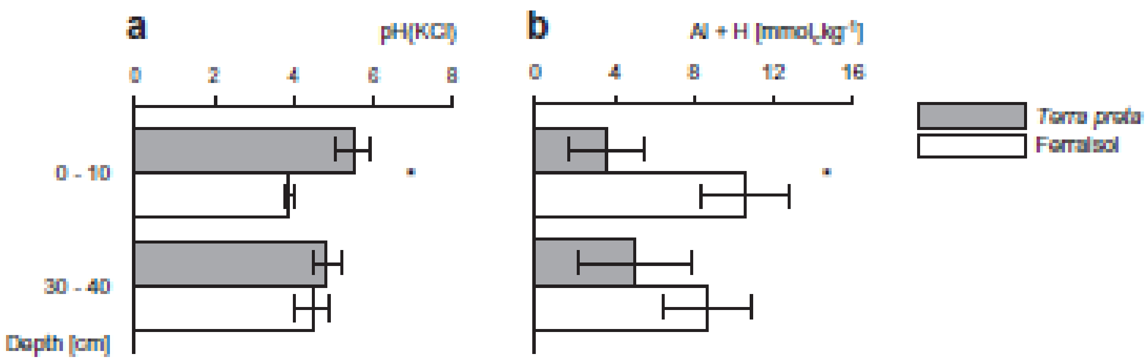
Biochar use in agriculture: some history

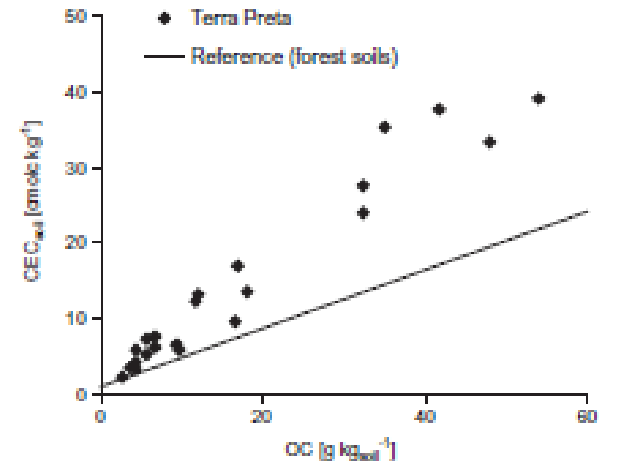


Amazzonia, Manaus Area….

Terra Preta

More fertile soils





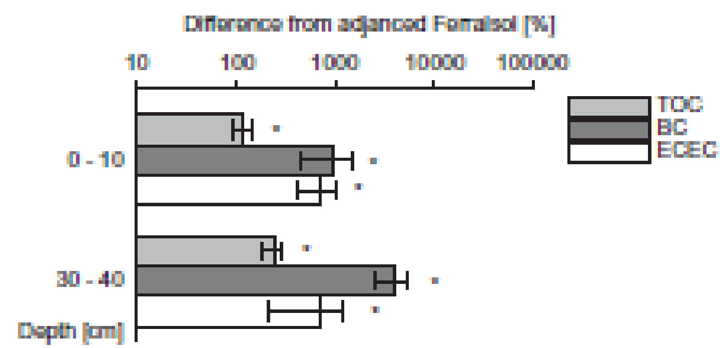
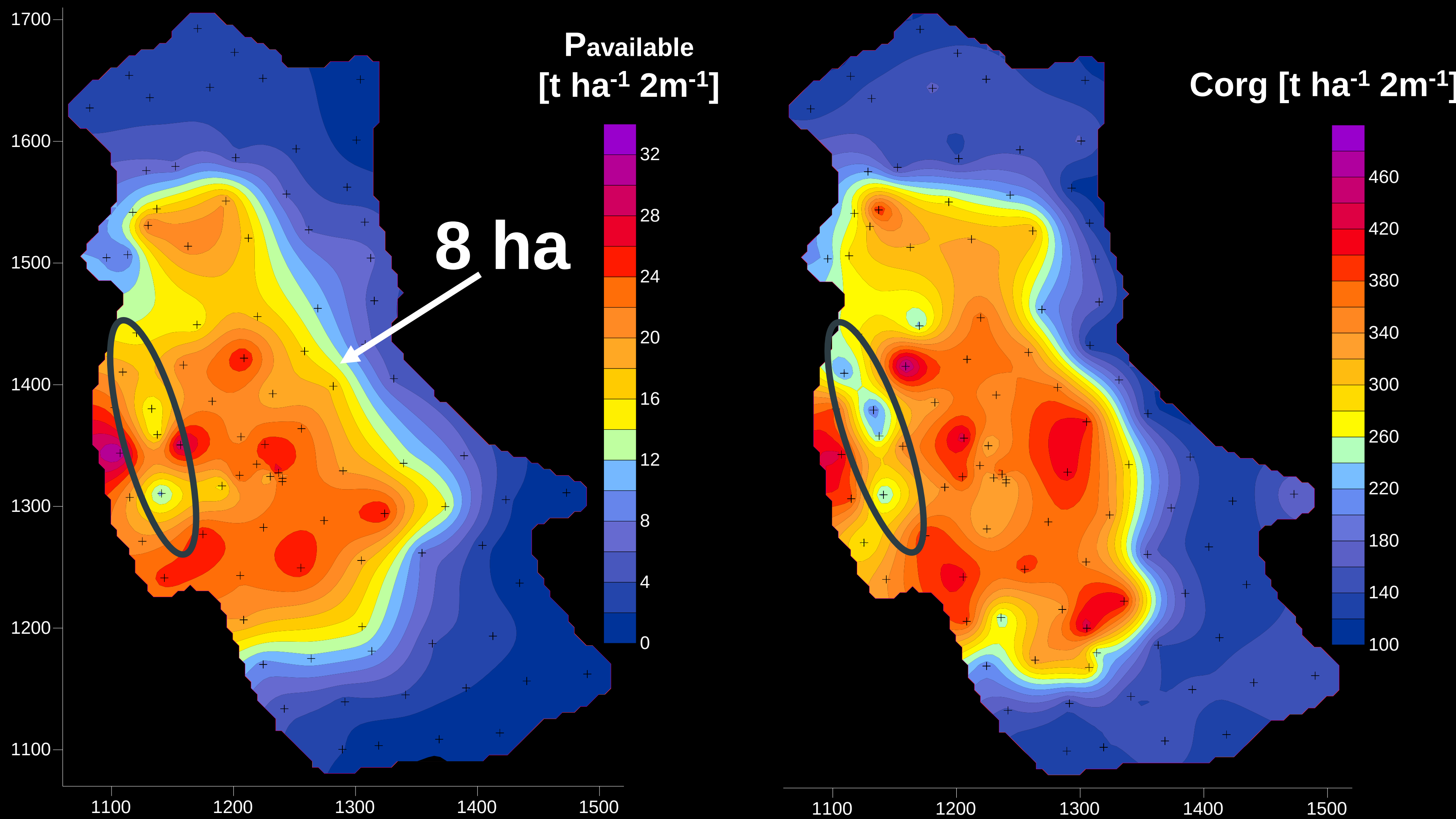


Fig. 6. Cation exchange capacity at soil pH (ECEC), total organic C (TOC) and biochar (BC) concentration of five *terra preta* sites near Manaus and Santarém in comparison to adjanced Ferralsols: $\text{Difference}[\%] = \frac{\text{Value}_{\text{terra preta}} - \text{Value}_{\text{Ferralsol}}}{\text{Value}_{\text{Ferralsol}}} \times 100[\%]$ [data from Glaser et al. (2004a); mean and standard errors; * indicate significant differences ($P < 0.05$) between terras pretas and Ferralsols in pair wise comparisons].

Glaser et al., 2012, *Geochim. Cosmochi. Acta*

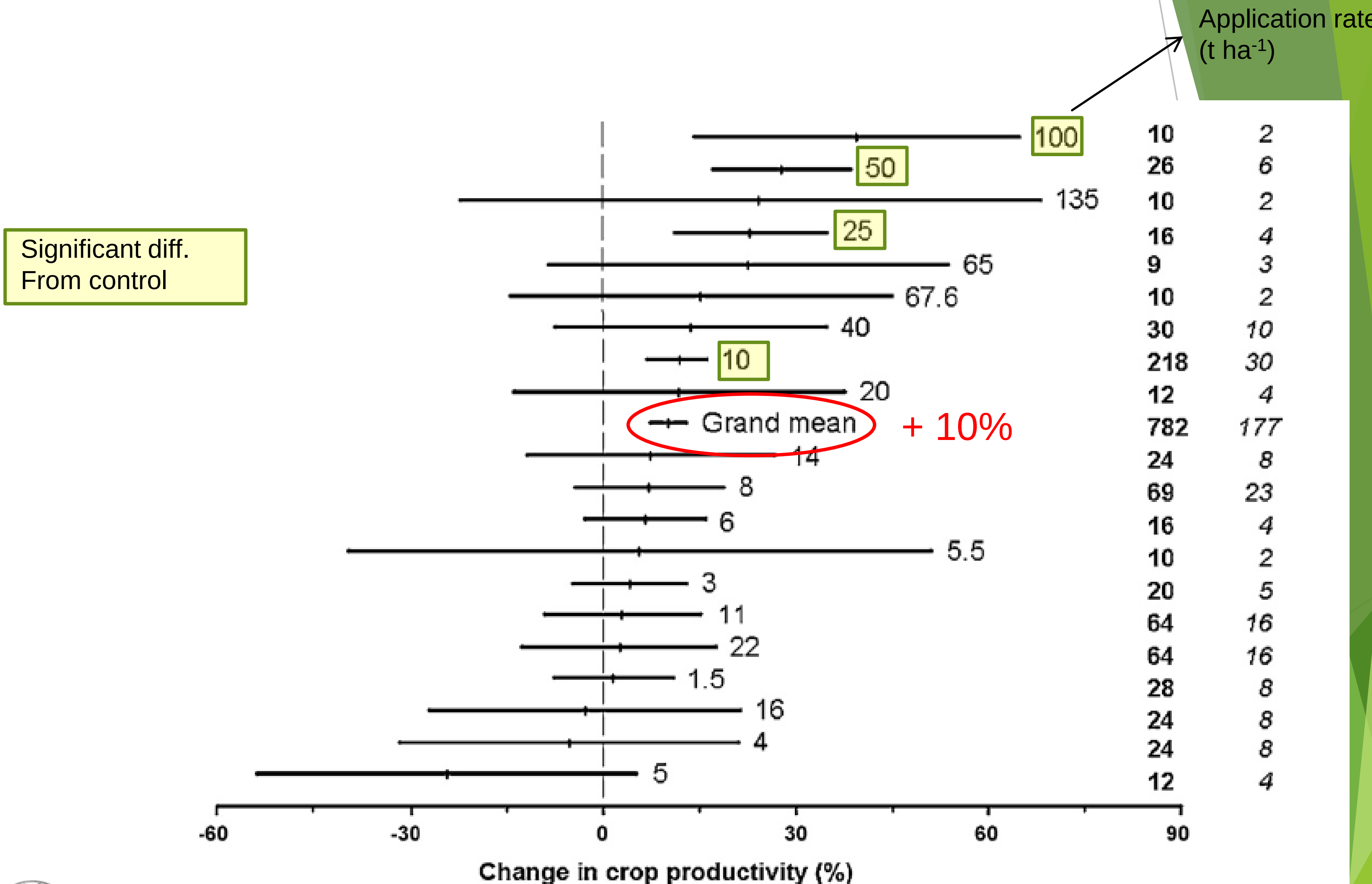
Differences are very clear also today



=> Different P and C pools !!!

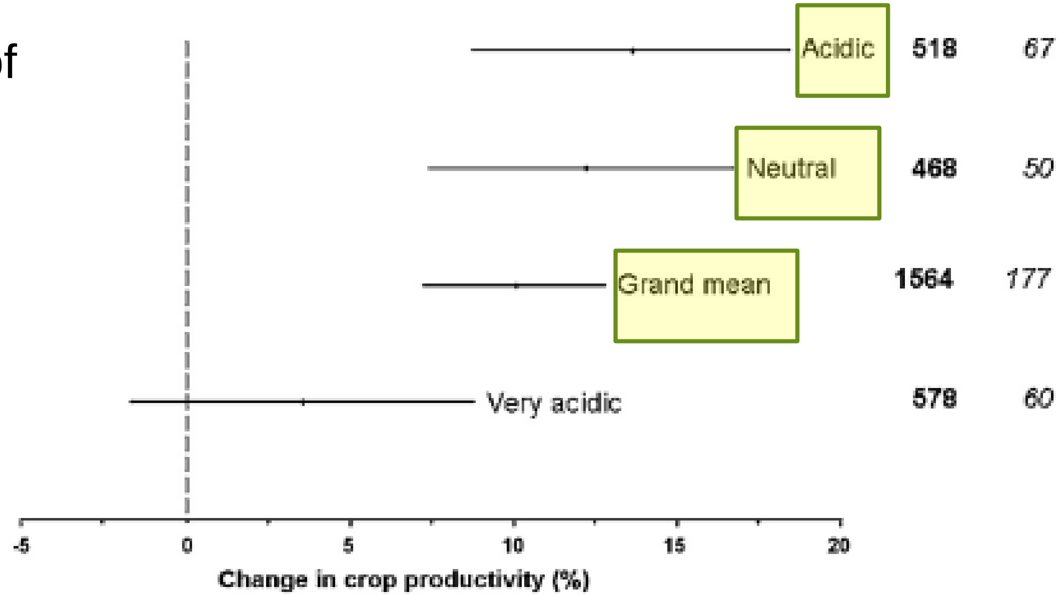
Not only in Amazzonia, but also in Sierra Leone

Is biochar able to increase plant productivity and yield ?



Jeffery et al., 2011, *Agri. Eco. Environ.*

pH ranges of soils

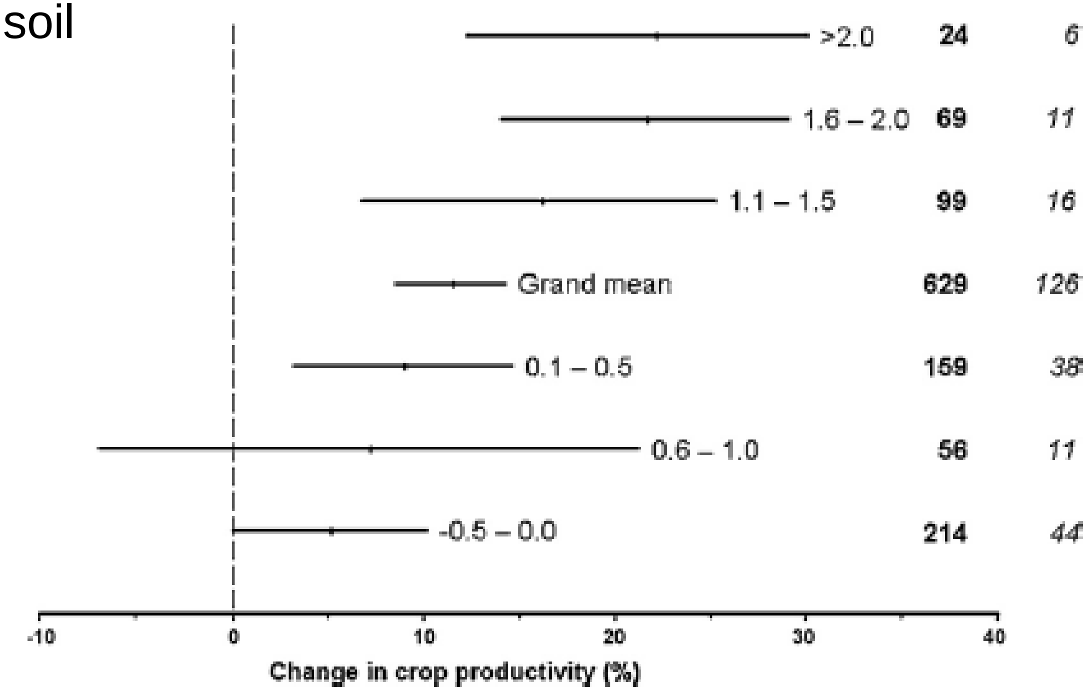


5 < pH < 6

pH > 6

pH < 5

Changes in soil pH



Jeffery et al., 2011, *Agri. Eco. Environ.*

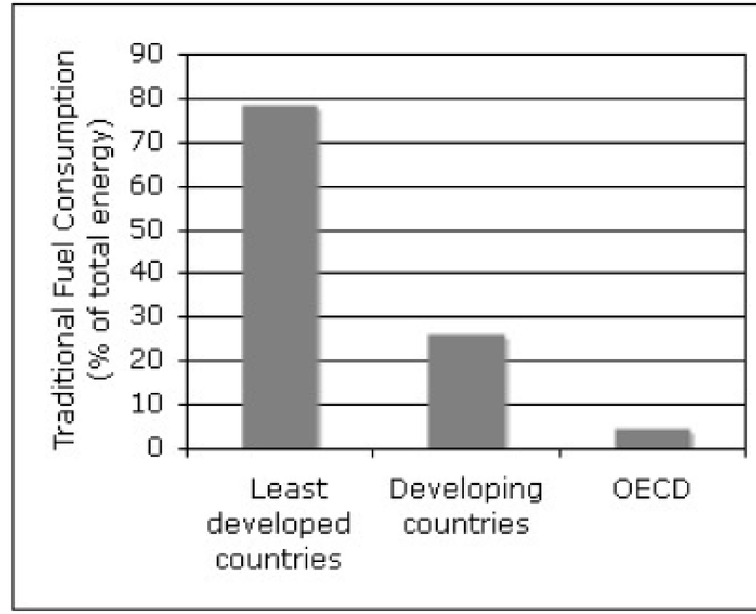
However results have to be handled carefully as:

- Published articles are likely to be drawn from the pool of statistically significant results (papers with no significant findings are often not considered for publication) (Rosenthal and Rosnow, 1991)
- No studies were found with experiments for more than 2 years (90% of studies showed results over 1 growing season)
- Most of the papers are based on trials in tropical and subtropical latitudes

Biochar and health

- Indoor air pollution kills 1.3 million people per year, mostly women and children > than malaria, and almost = tuberculosis and AIDS (WHO, 2006)

- It is the most important cause of death among children under 5 years of age in developing countries (WHO, 2000).



Source: *UNDP Human Development Report 2006*

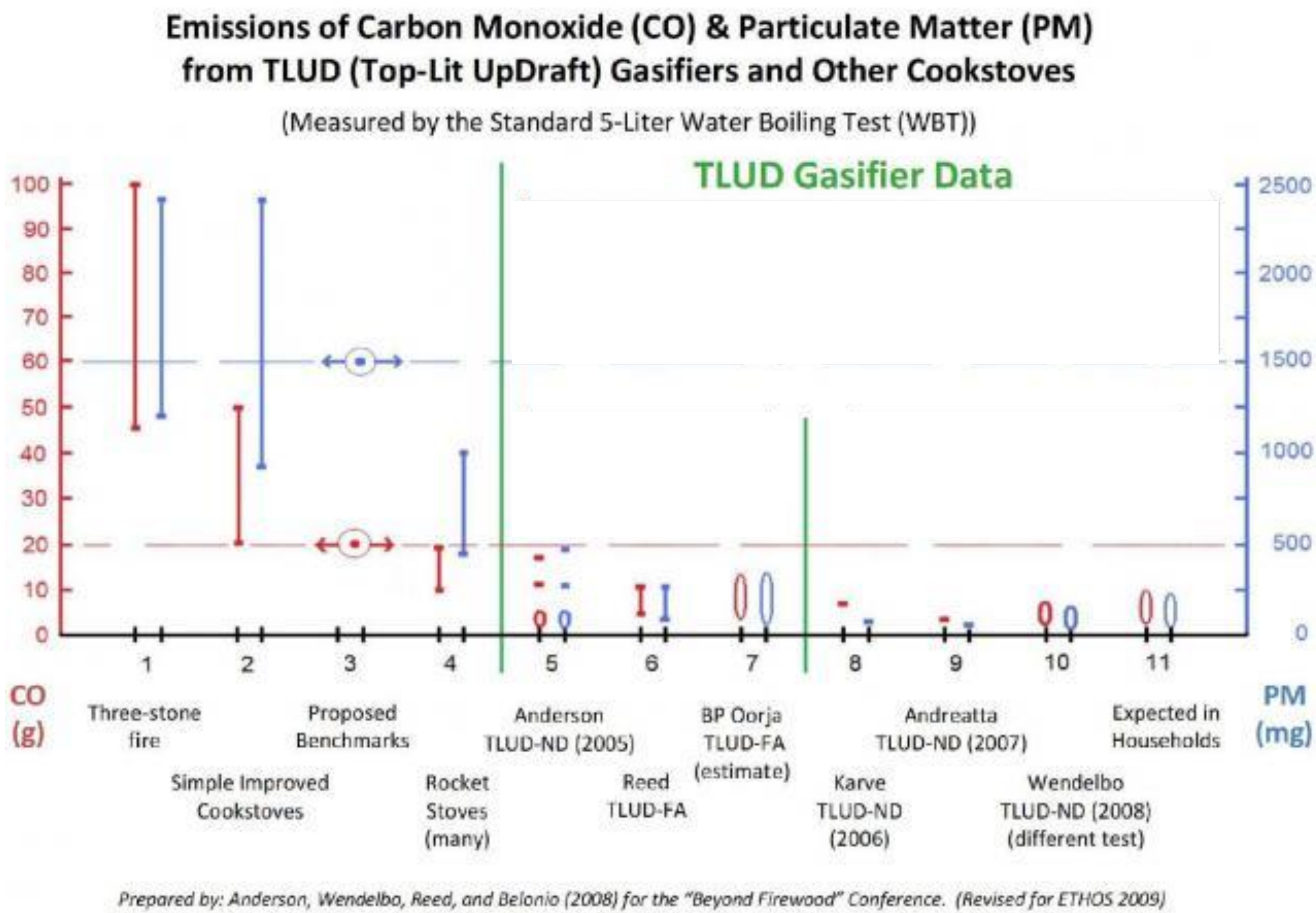
worst

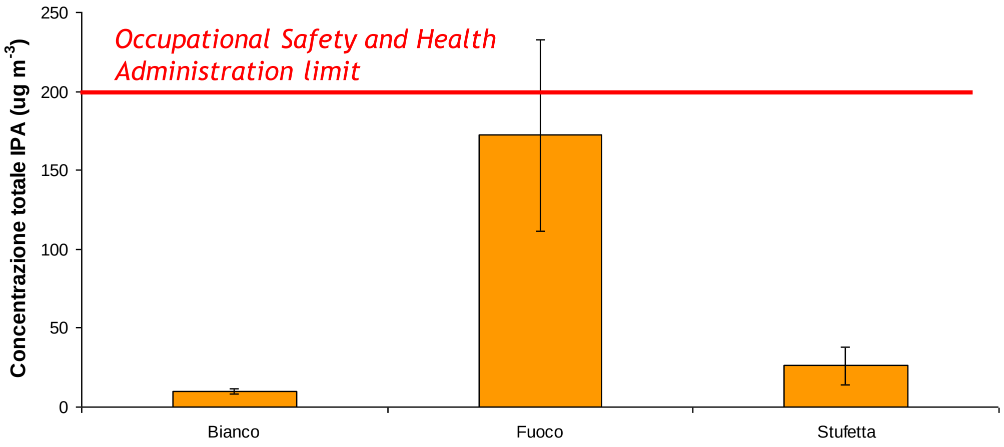
best

Table 2. Indoor levels of pollutants during cooking hours in the houses using different types of fuels

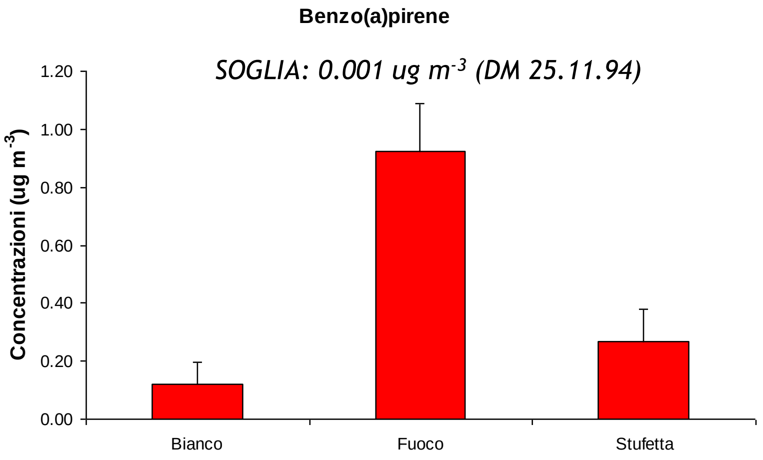
Fuel	N		TSP ($mg\,m^{-3}$) $\bar{X}$	TSP CV	CO ($mg\,m^{-3}$) $\bar{X}$	CO CV	NO_2 ($\mu g\,m^{-3}$) $\bar{X}$	NO_2 CV	HCHO ($\mu g\,m^{-3}$) $\bar{X}$	HCHO CV	SO_2 ($\mu g\,m^{-3}$) $\bar{X}$	SO_2 CV
Cattle dung	20	A	3.47†	0.68	174†	0.80	348†	0.45	1002†	1.02	188†	0.61
		G	2.75†		144†		319†		670†		159†	
Wood	20	A	2.63†	0.94	189†	0.58	344†	0.36	916†	0.99	187†	0.64
		G	1.98†		156†		325†		652†		155†	
Coal	20	A	1.19†	0.35	110†	0.56	165	0.51	165*	1.16	258†	0.76
		G	1.10*		94†		147		109*		185†	
Kerosene	20	A	0.52	0.42	137†	0.72	184	0.82	164*	0.94	121*	0.76
		G	0.46		108†		133		112*		87*	
LPG	20	A	0.50	0.32	24	1.00	183	0.87	87	0.77	65	0.78
		G	0.46		14		124		68		51	

Levels of pollutants are compared with those LPG using houses as control.
$^*P<0.05$; $^†P<0.01$.
N = number of samples/houses surveyed.
A = arithmetic value; $\bar{X}$ = mean; G = geometric value; CV = coefficient of variation.

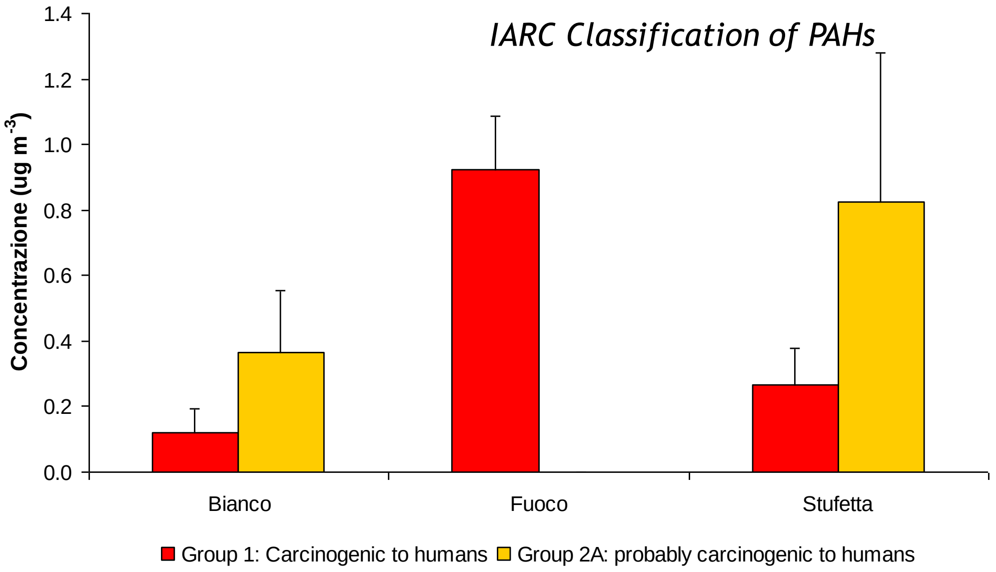

Emissions of Carbon Monoxide (CO) & Particulate Matter (PM)
from TLUD (Top-Lit UpDraft) Gasifiers and Other Cookstoves
(Measured by the Standard 5-Liter Water Boiling Test (WBT))
TLUD Gasifier Data
100
90
80
70
60
50
40
30
20
10
0
2500
2000
1500
1000
500
0
1
2
3
4
5
6
7
8
9
10
11
CO
(g)
Three-stone fire
Simple Improved Cookstoves
Proposed Benchmarks
Rocket Stoves (many)
Anderson TLUD-ND (2005)
Reed TLUD-FA
BP Oorja TLUD-FA (estimate)
Karve TLUD-ND (2006)
Andreatta TLUD-ND (2007)
Wendelbo TLUD-ND (2008) (different test)
Expected in Households
PM
(mg)
Prepared by: Anderson, Wendelbo, Reed, and Belonio (2008) for the "Beyond Firewood" Conference. (Revised for ETHOS 2009)



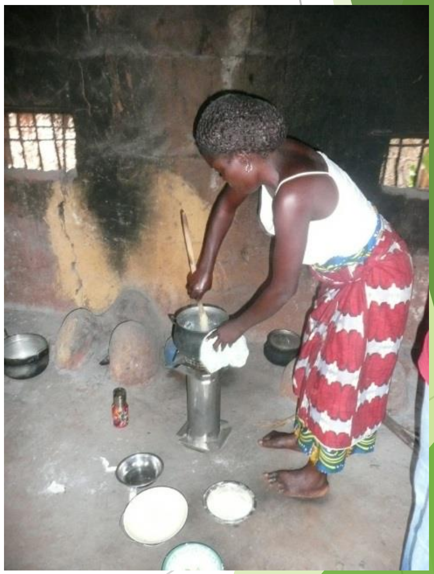
Occupational Safety and Health
Administration limit
Concentrazione totale IPA (ug m-3)
250
200
150
100
50
0
Bianco
Fuoco
Stufetta



Benzo(a)pirene
SOGLIA: 0.001 ug m-3 (DM 25.11.94)
Concentrazioni (ug m-3)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Bianco
Fuoco
Stufetta



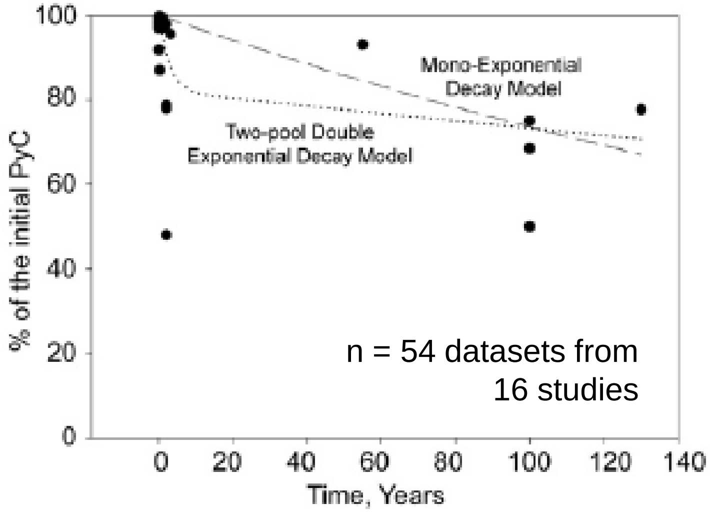
IARC Classification of PAHs
Concentrazione (ug m-3)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Bianco
Fuoco
Stufetta
Group 1: Carcinogenic to humans
Group 2A: probably carcinogenic to humans



Biochar and environment

- Reduced deforestation
- Reduce CO_2 emissions
- Reduced N_2O emissions after soil application
- C storage

Carbon sequestration



Singh et al., 2012, *Biogeosciences*

	Size	Decomposition rate	Mean residence time
Labile C pool	3 ± 0.6%	0.0093% day^{-1}	108 ± 196 days
Recalcitrant C pool	97 ± 0.6%	0.0018% $year^{-1}$	556 ± 483 years

n = 128 datasets from 24 studies

Wang et al., 2015, *GCBB*

- One-pool decay model: **291 years**
- Two-pool model:
  - **3 years** for the fast-cycling pool (C_{fast} = 17 %) and
  - **870 years** for the slow-cycling pool
- The nominal turnover time of biochar is shorter than previously assumed, on order of **hundreds of years**

- Overall mean: **107 years**
- Two-pool model:
  - **108 days** for the fast-cycling pool (C_{fast} = 3 %) and
  - **556 years** for the slow-cycling pool
- The calculated MRTs are much shorter than previously assumed

Future challenges

- Pyrolysis plants are still limited both in EU and Africa
- Most of the efforts aimed to introduce improved and pyrolytic cookstoves in developing countries have not been successful yet as:
  - final users do not perceive indoor air pollution as a high-priority health hazard;
  - non-health considerations dominate household decision-making;
  - stated demand for NTCSs is more price-elastic than stated demand for other essential goods and services.
- Biochar use is still constrained by some knowledge gaps and limitations
- The research on biochar as soil conditioner still needs to be locally implemented, especially in developing countries
- Carbon finance could fund the provision of capital for pyrolysis systems

Thanks for your attention

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This presentation will be available at the website:
https://sites.google.com/site/biocharplusproject/

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