Bioenergy-Biochar climate smart systems

Mary Njenga*, Cecilia Sundberg, James K. Gitau, Ruth Mendum, Erik Karltun, Thomas Kätterer, Dries Roobroeck, Geoffrey Kimutai,Gert Nyberg, Yahia Mahmoud, Kristina Roing De Nowina, Miyuki Iiyama, Mehmood Hassan

Contact:
M.Njenga@cgiar.Org*

Transforming lives and landscapes with trees

CTCN Capacity Development Workshop for NDE from Africa Jointly with ICRAF 12-14/12 2018

What is biochar?

https://nature4climate.org/science/n4c-pathways/grasslands-and-agricultural-lands/biochar/

Biochar is charcoal **used** as a soil amendment

Charcoal is **used** for heating and cooking

Charcoal is made through burning biomass under controlled oxygen

Biochar application is an ancient practice

- Ancient South American cultures used biochar from burning agricultural waste and covering it in soil 1500 years ago to increase soil productivity
- The term Biochar wasn't coined until Peter Read did so in 2005 (Godbey 2016)

700 year-old fertile soil technique could revolutionise farming across Africa

A farming technique practised for centuries by villagers in West Africa, which converts nutrient-poor rainforest soil into fertile farmland, could be the answer to mitigating climate change and revolutionising farming across Africa.

A global study, led by the University of Sussex, which included anthropologists and soil scientists from Cornell, Accra, and Aarhus Universities and the Institute of Development Studies has for the first-time identified and analysed rich fertile soils found in Liberia and Ghana.

They discovered that the ancient West African method of adding charcoal and kitchen waste to highly weathered, nutrient poor, tropical soils can transform the land into enduringly fertile, carbon-rich black soils that the researchers dub 'African Dark Earths'.

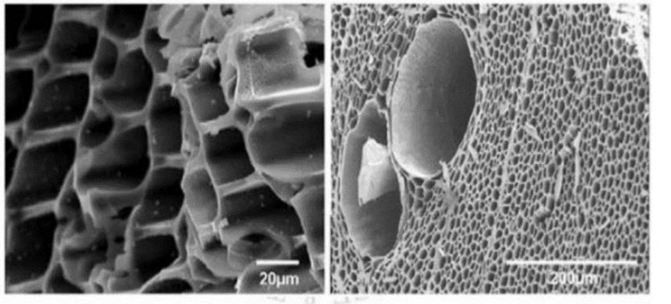
From analysing 150 sites in northwest Liberia and 27 sites in Ghana researchers found that these highly fertile soils contain 200-300 percent more organic carbon than other soils and are capable of supporting far more intensive farming.

Why biochar now ?
Qualities for improved soil fertility

High stability – provides permanent sequestration of C in soil.

High specific area and porosity – improved water-holding capacity mitigates drought effects hence a climate smart agriculture

Improves plant nutrient retention – mainly through absorption of soil solution, efficiency in fertilizer use

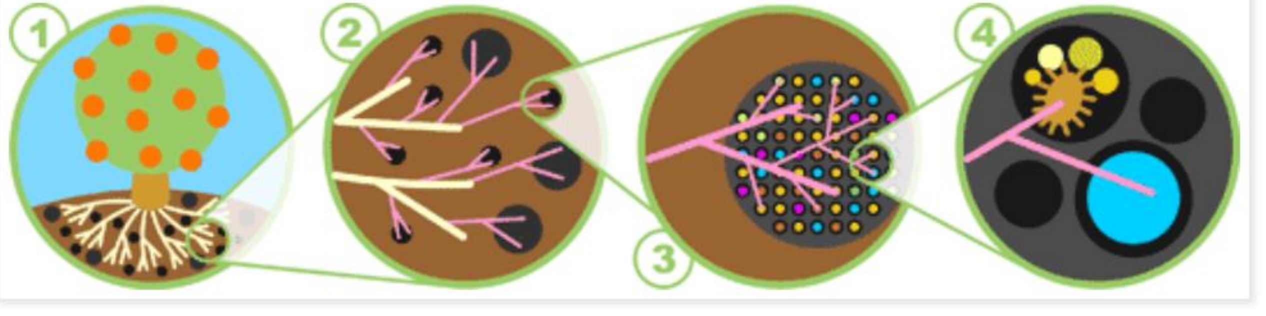


20µm 200µm

Lehmann and Joseph (2009)

High pH – alleviates acidity and Al toxicity in acid soils

Attractive surfaces for plant-microbe interaction – positive effects on many microbiological processes in soil and root growth



www.

Biochar partnerships in Africa

The Africa Biochar Partnership (ABP) which is an open continental platform for advancing the cause of Biochar Systems in Africa was launched on March 1st, 2016 in Nairobi - Kenya at the International Workshop on Biochar Systems for Africa, organized by the “Biochar Plus” project in collaboration with “Biochar for Sustainable Soils” project.http://www.ecreee.org/news/launch-africa-biochar-partnership-0

The **sub Saharan African Soil Regeneration Initiative (ASRI)** aims to scale up regenerative, climate smart agriculture (CSA) and grazing practices across Africa with emphasis on the smart use of biomass and nutrients.

Internatonal Biochar Initiative (IBI) provides a platform for fostering stakeholder collaboration, good industry practices, and environmental and ethical standards to support biochar systems that are safe and economically viable. https://biochar-international.org/

Examples on biochar use

Example i: Low-Cost Biochar Application in Tanzania

Plots treated with biochar resulted in 10 to 43 times more cherry production volume than a plot treated with traditional NPK fertilizer treatments alone.

Example ii: Charcoal makes African soil more fertile and productive (Liberia, West Africa)

http://sciencenordic.com/charcoal-makes-african-soil-more-fertile-and-productive

https://dailycoffeenews.com/2017/07/18/low-cost-biochar-application-in-tanzania-shows-astounding-increases/)

Example iii: Case of Belize, Central America

- Using a biochar/fertilizer blend of Carbon Gold (UK producer) improved germination of cacao seedlings and increased production of cacao fruit

- Seedlings growing in soils that received biochar survived a recent water shortage, while large numbers of seedlings in untreated soils perished during the drought.

World Atlas

https://nature4climate.org

Chocolate.org

Example iv: Biochar production and use among small-scale farmers in Kenya

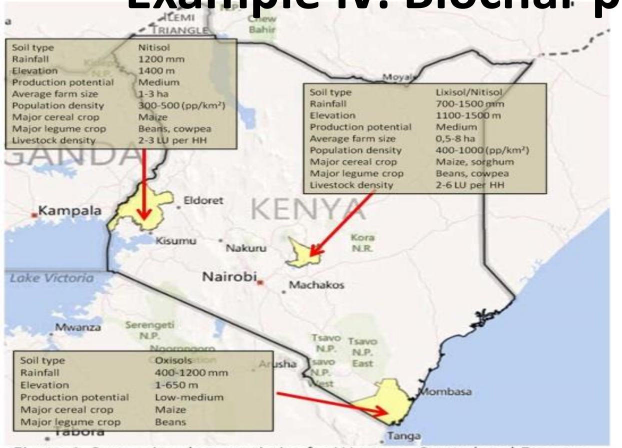


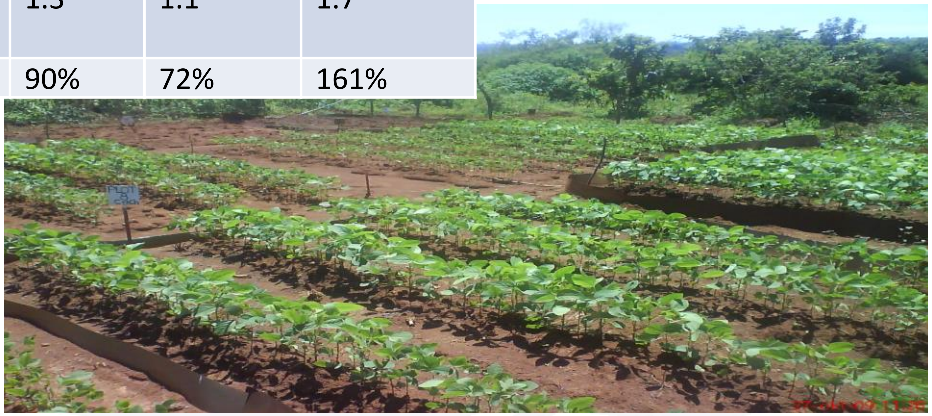
Figure 1. Some site characteristics for Western, Central and Eastern Kenya benchmark areas.

	Control	Biochar	Fertilizer	Biochar+ Fertilizer
Maize (ton/ha)	1.4	3.1	2.5	4.3
Increases		133%	89%	237%

	Control	Biochar	Fertilizer	Biochar+ Fertilizer
Soybean (ton/ha)	0.7	1.3	1.1	1.7
Increases		90%	72%	161%

Grain yields were persisted 2006-2016 (10t/ha of biochar) (Kätterer et al., forthcoming)

Kale and maize yield increased by 33% and 398% from biochar produced using pyrolytic cooking systems. Rates 1-10t/ha depending on amounts produced



Control


Biochar

Fertilizer

Fertilizer+Biochar

Biochar application rates and for particular soils, risks are research gaps

Example v: Biochar use for wastewater filtration for urban agriculture in W. Africa

irrigation water with locally produced corn con and rice husk biochar was developed. This water treatment system allowed a reduction of hazardous bacteria by 99.9% and organic substances by 90.0% and improved irrigation water quality to a normal surface water level in Tamale. Thereby, essential plant nutrients such as nitrogen and

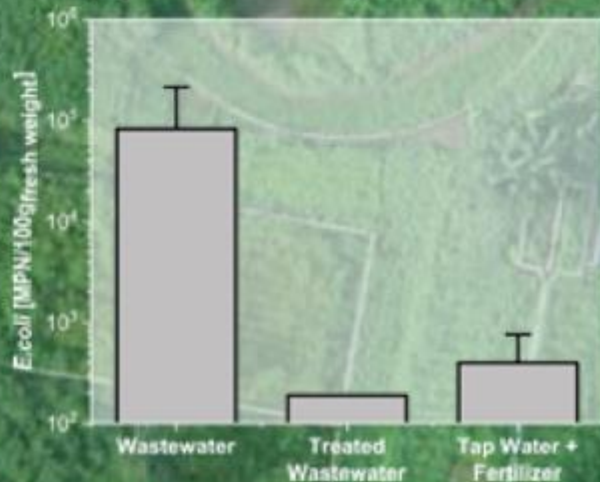


Figure 2.13. *E. coli* contamination of jute mallow (*Corchorus spp.*), irrigated with wastewater, treated wastewater and tap water with commercial fertilizer (NPK).

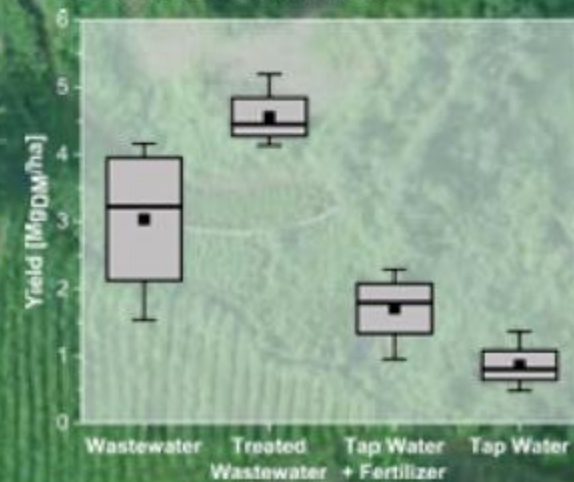


Figure 2.14. Yield of jute mallow (*Corchorus spp.*) in kg dry matter per hectare irrigated with wastewater, treated wastewater and tap water with commercial fertilizer (NPK) and without fertilizer.

Further work as a filter

- Cost of the filtering system
- Effectiveness of biochar compared to other filters like fine sand

Further work on soil amendment

- Performance of biochar on different soils (does it work or failure)

Manka'abusi et al., Submitted. Agronomic effects of biochar application and wastewater irrigation in urban vegetable production in Ouagadougou, Burkina Faso. Akoto-Danso et al., 2018. Agronomic effects of biochar and wastewater irrigation in urban crop production of Tamale, northern Ghana. *Nutrient Cycling in Agroecosystems* 543(295): 1–17.

http://www.iwmi.cgiar.org/publications/other-publication-types/books-monographs/atlas-of-west-african-urban-food-systems/

Production of charcoal/biochar

a. Pyrolytic cooking systems

Two-chamber gasifier

Case study i: Two-chamber gasifier in Uganda

uses 36% (RH) to 40% (CS) less wood than

emits 24% (CS) to 33%(RH) less CO_2 than

emits 67% (CS) to 82% (RH) less PM than

emits 8%(CS) to 28% (RH) less CO than

Three-stone fire

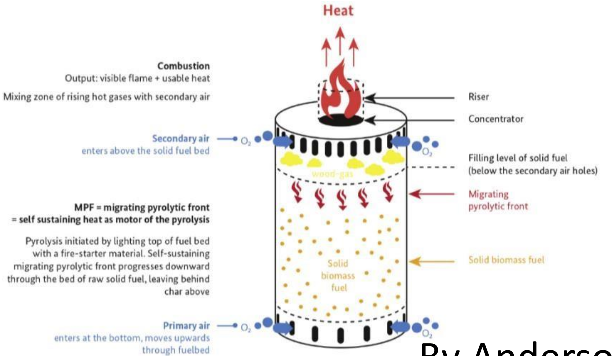
	MASS BALANCE	Gasifier x Rice Husks (n=6)	Gasifier x Coconut shells (n=6)	Three-stone (n=4)
IN	Firewood (g)	2412 ± 162	2229 ± 244	3771 ± 297
IN	Crop residue (g)	600	1500	NA
OUT	Biochar yield (g)	342 ± 15 *(55 - 60%)*	555 ± 61 *(33 - 41%)*	NA

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

AUSTRIAN DEVELOPMENT COOPERATION

Pyrolytic cooking systems

Case study ii: TLUD Gasifier improves livelihoods of 150 farmers in rural Kenya



By Anderson and Reed, 2004

Top Lit Updraft (TLUD) Gasifier

Reproduced by KIRDI

uses 43% less wood than (net)

uses 32% less wood than (gross)

emits 41% less CO_2 than

emits 79% less PM2.5 than

emits 57% less CO than

Three-stone open fire

	MASS BALANCE	GASTOV (n=5)		Three-stone (n=5)
IN	Firewood (g)	1007 ± 17*a	844.56±174.6*b	1475 ± 159.9
OUT	Biochar yield (g)	198 ± 32.24 *(16.4%)*	*NA*	NA

a gross firewood used with Gastov, b net (if energy is used after food is ready) firewood for cooking a meal used with Gastov

Pyrolytic cooking systems Bioenergy-biochar nexus

Type of biomass has an effect on quality of charcoal and biochar

(TLUD) Gasifier

Firewood from Kwale (Coast)	Moisture, 105°C (%)	Ash, 550°C db (% ts)	Volatile matter (% ts)	C-fix (% ts)	Net cal. value Const press db (kJ/g)
Neem	9±0.2	2.18±0.3	79.42±0.6	18.41±0.4	18.38±0.1
Casuarina	8.7±0.1	1.37±0.1	81.41±0.3	17.22±0.3	18.44±0.1
Charcoal as fuel					
Neem	8 ±0.2	4.8±0.3	10.4±0.5	85.8	32±0.1
Casuarina	7.5±0.3	3.4	10.9±0.7	87.5	32.4±0.2

Biochar	Ph	P (mg/g)	B (mg/g)	Zn (mg/g)	Cu (mg/g)
Neem	>8	122.31	2.04	1.43	0.11
Casuarina	>8	217.11	1.71	0.38	0.02

Biochar

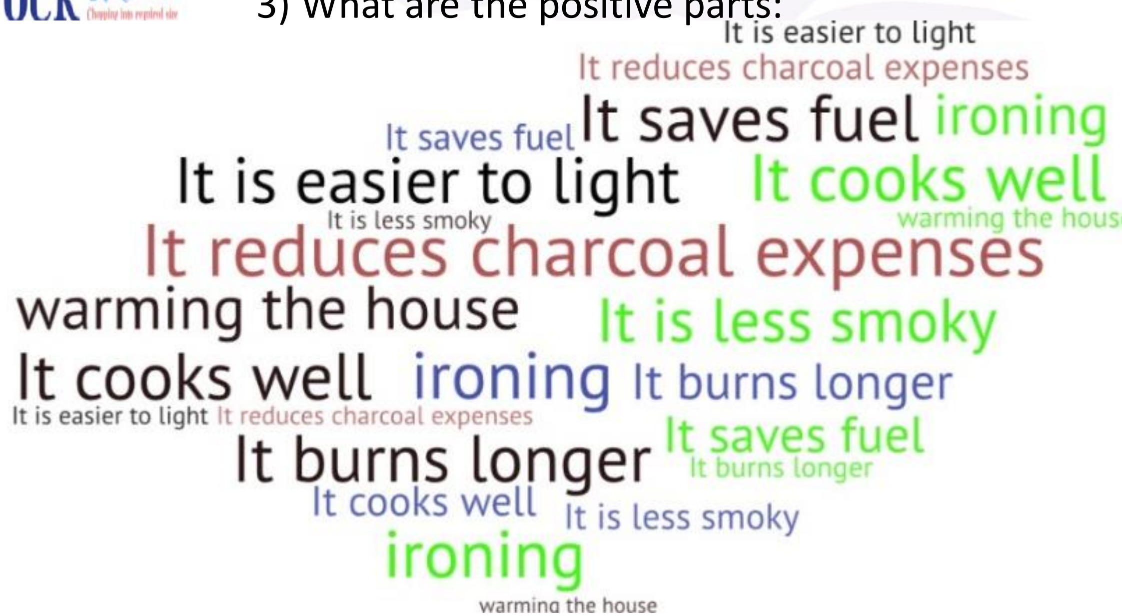
Cooking

Experiences with Gastov pylorytic cooking systems in Kenya

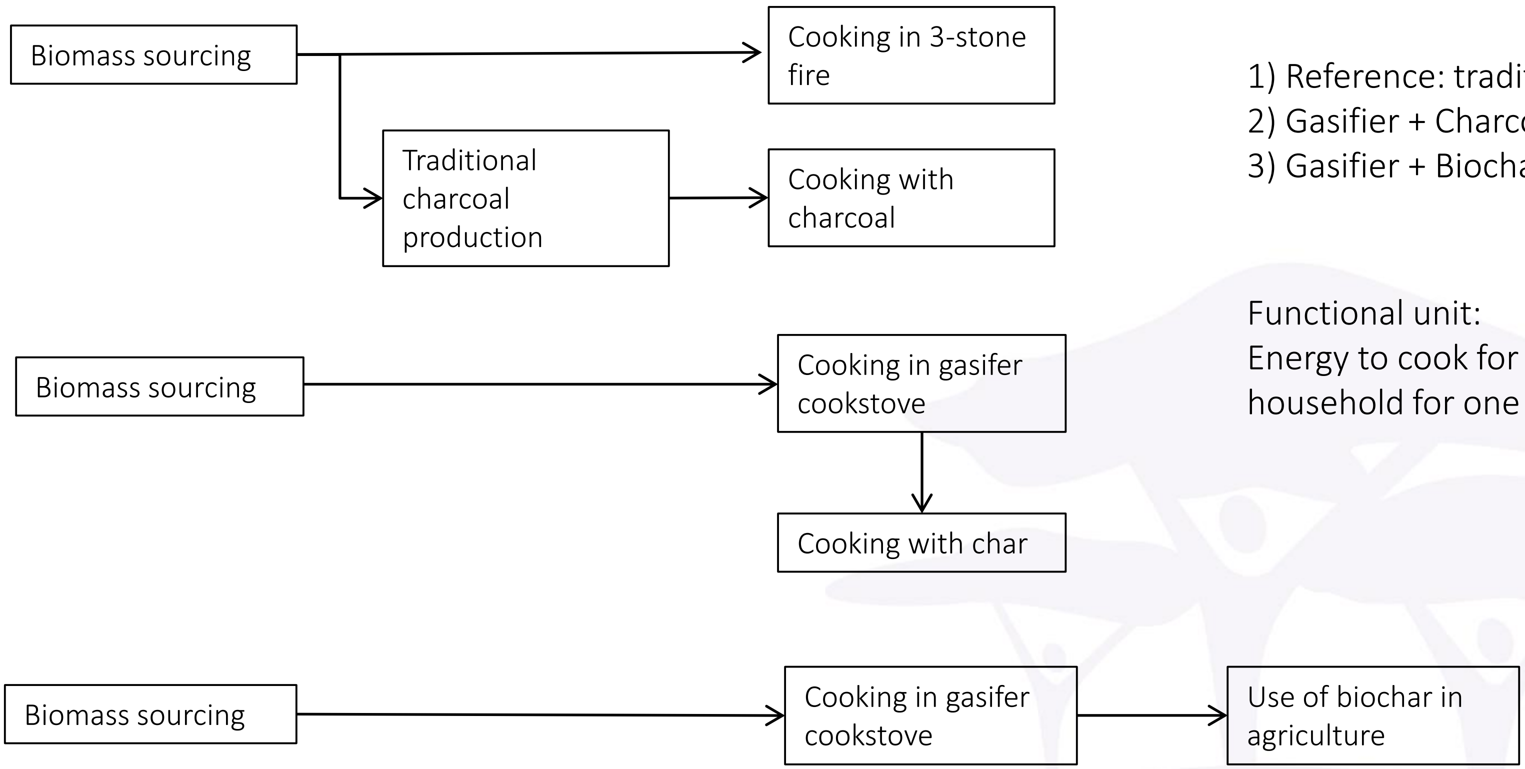
1) What are the most difficult parts of producing biochar?

2) What are the easiest parts:

3) What are the positive parts:



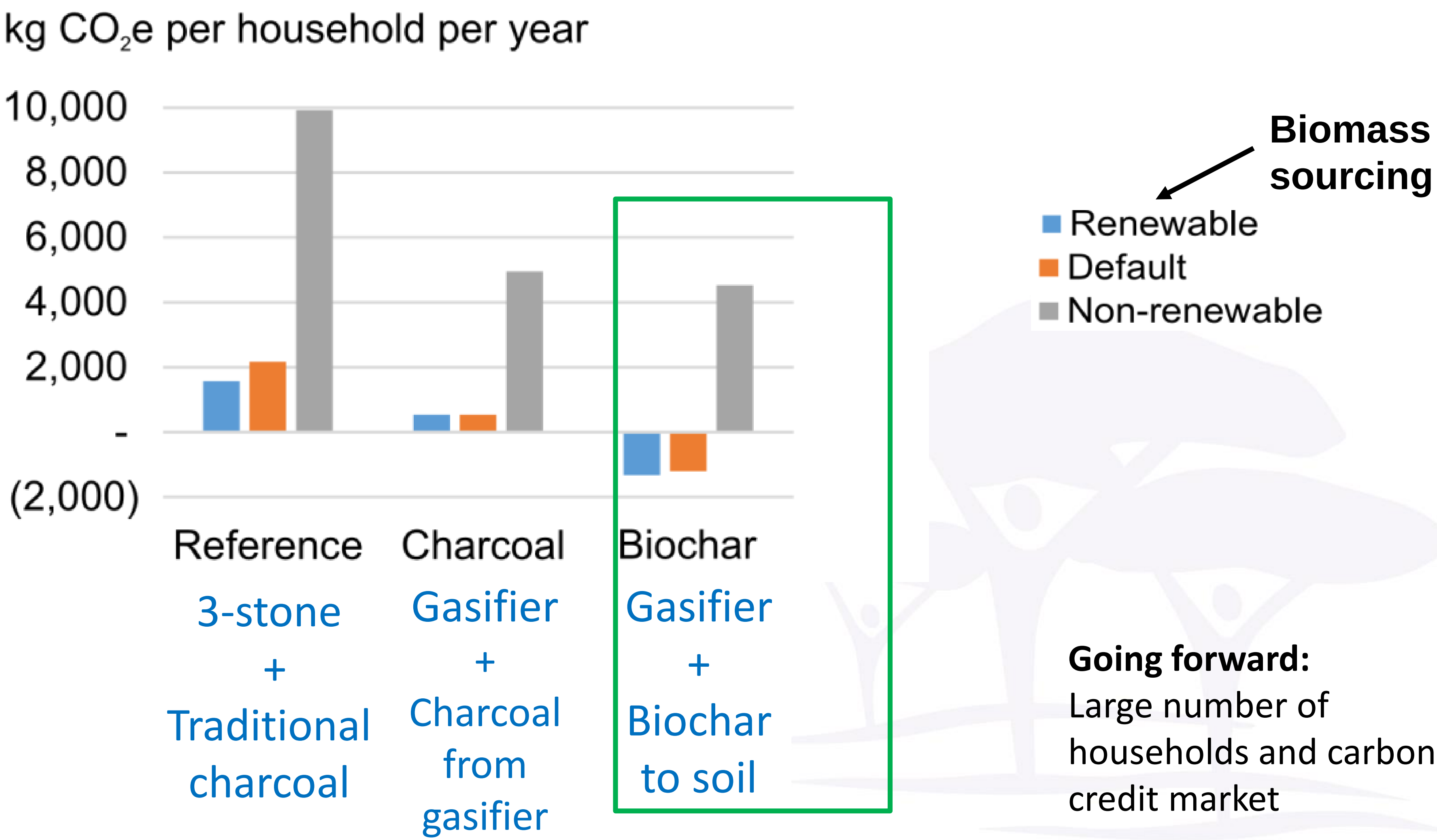
Bioenergy-Biochar Climate Impact
Life Cycle Assessment (LCA)



1) Reference: traditional
2) Gasifier + Charcoal
3) Gasifier + Biochar

Functional unit:
Energy to cook for one household for one year

Global warming potential (GWP100) pyrolytic cooking systems



Going forward:
Large number of households and carbon credit market

Sundberg et al, CO_2-Negative Cooking and Cultivation in Smallholder Farms in Africa - the Potential Role of Pyrolysis and Biochar , forthcoming

Biochar: A Win^{4}Resilient Landscapes

Mary Njenga*,
Kristina Roing de Nowina,
Cecilia Sundberg
Email: M.Njenga@cgiar.org*
K.RoingdeNowina@cgiar.org,
Cecilia.Sundberg@abe.kth.se

World Agroforestry Centre

CIFOR 25th ANNIVERSARY FORESTS MATTER

KTH VETENSKAP OCH KONST

Win-Win-Win-Win

IITA Transforming African Agriculture

SLU

LUND UNIVERSITY

Global Landscape Forum, 2018

b. Biochar production in the field

Biochar Maker at Field Scale – Semi gasifier

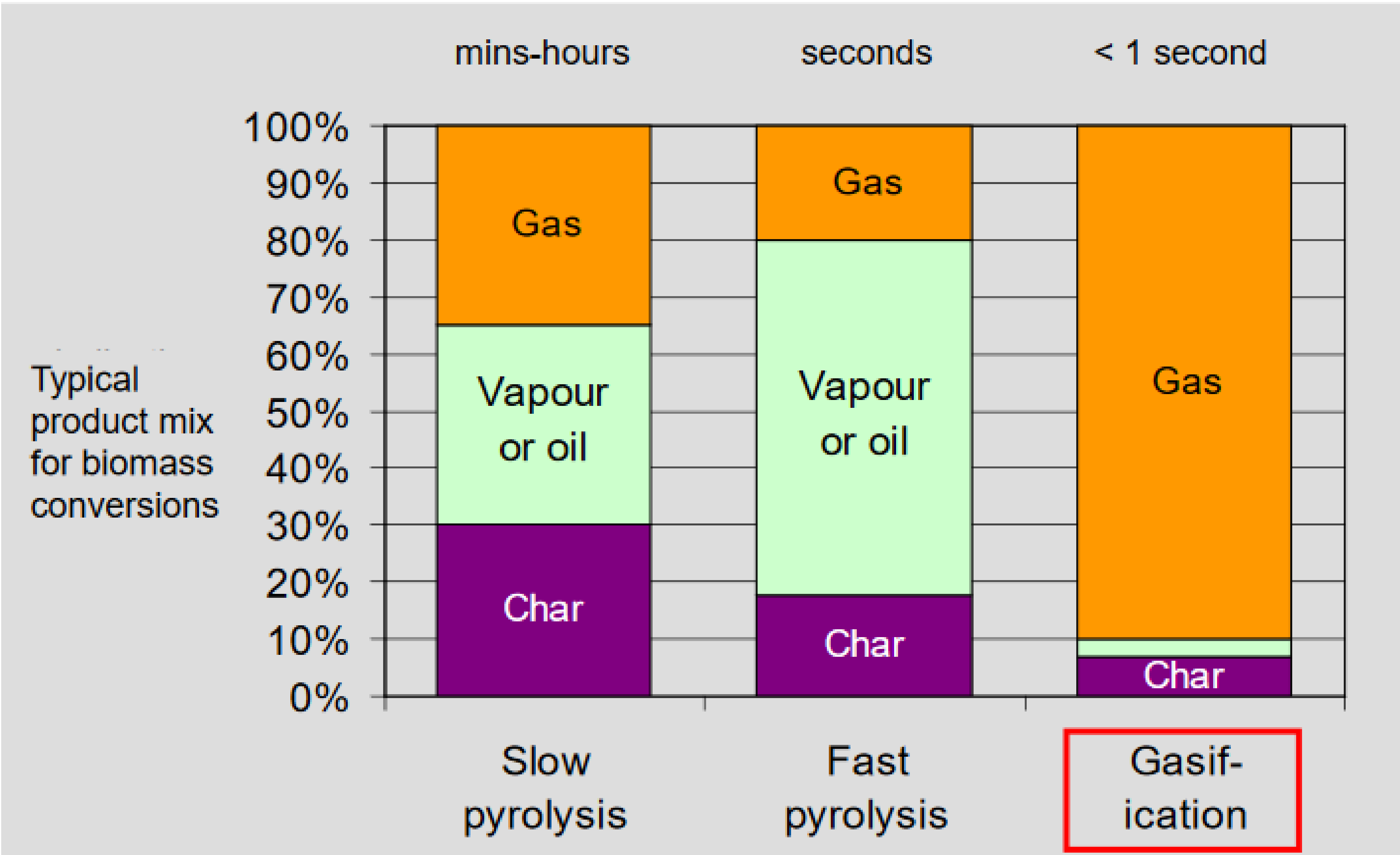



The feeding rate is 100kg per hour



https://www.biochar-international.org/wp-content/uploads/2018/04/SDC_July_2015.pdf

Conversion process has an effect



UK Biochar Research centre

Charcoal production

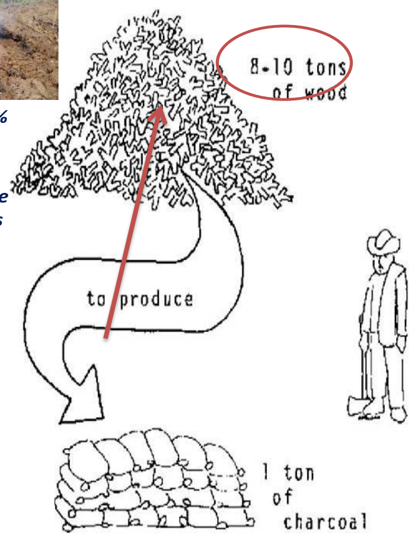
Business-as-usual → **Green charcoal systems**

Selective one-off cutting of live hard wood species, leading to degradation & biodiversity loss

Earth Kiln – efficiency ±10% low capital, skills required, done on site

Earth Kiln – 10%

- ***Extremely inefficient***
- ***Done on site where trees are cut***



Inefficient stoves, waste wood & cause smoke in kitchen

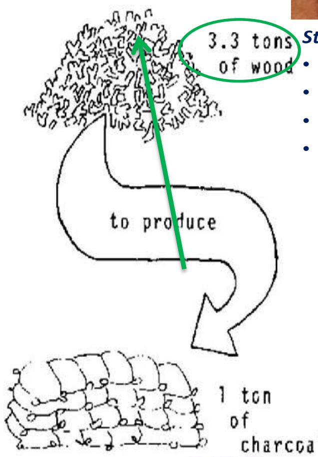
Farmer managed natural (assisted) regeneration

Domestication of preferred Acacia trees (Photo by KEFRI)

Tree nursery in refugee settlement in Uganda. ICRAF

Stationary Kiln -30%+?

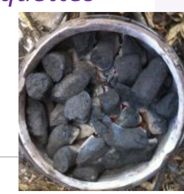
- ***Efficient***
- ***Capital intensive***
- ***Need skills***
- ***Inmobile***

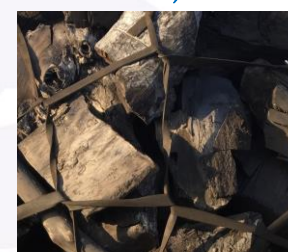


Sustainable harvest of wood on farm ex. agroforestry, reducing pressures on forests

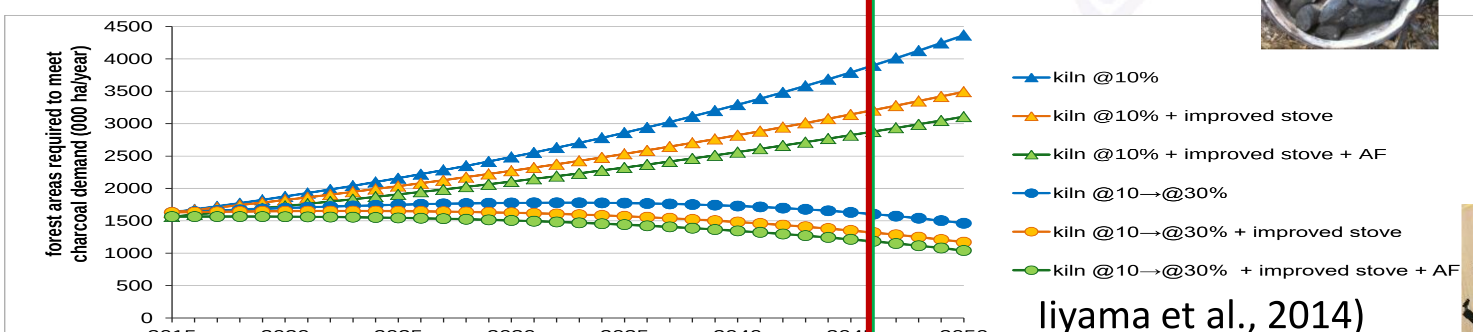
Efficient kilns– efficiency ±30% but capital intensive, need skills,

Alternative biomass fuel from organic waste- briquettes

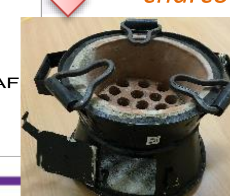




Improved stoves, reduce demand for charcoal



Iiyama et al., 2014)



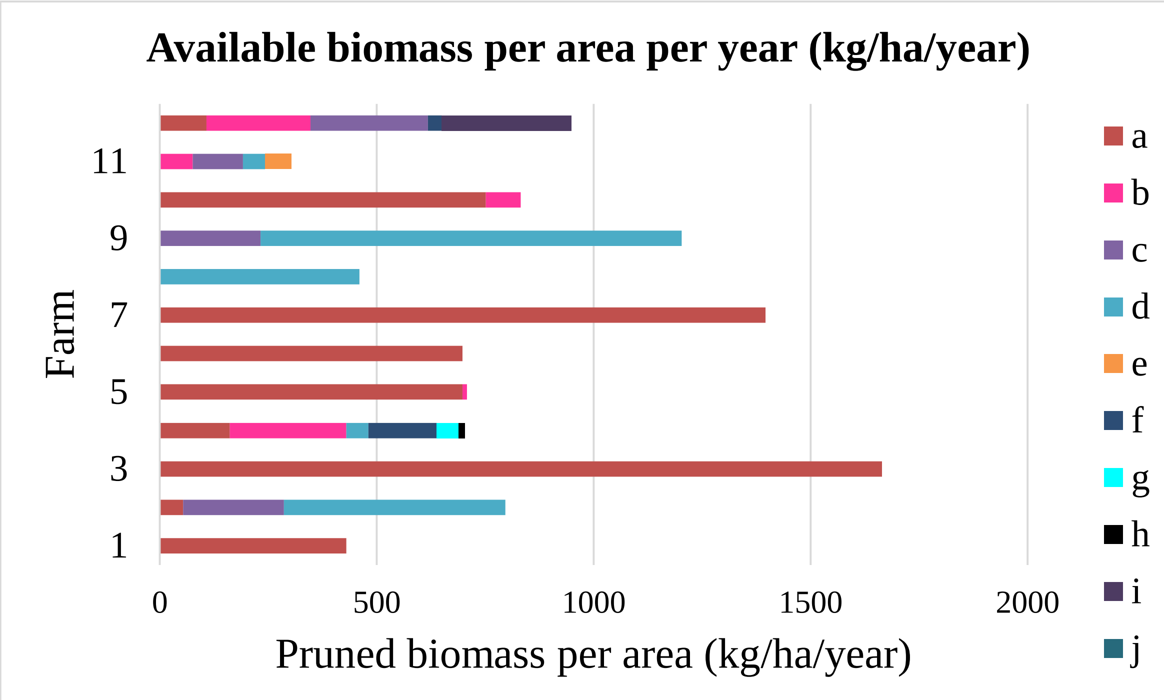
Charcoal

Biochar

1kg charcoal=6-9kg CO_2 eq (FAO 2017)

-80% GHG FAO 2017

Sustinable biomass production for bioenergy or biochar is critical



Trees on the farms at Kwale, Kenya			
Swahili name	**Common name**	**Binomial name**	**Assigned name**
	Neem	*Azadirachta indica*	A
	Casuarina	*Casuarina equisetifolia*	B
	Mango	*Mangifera indica*	C
	Cashew Nut	*Anacardium occidentale*	D
	Leucaena	*Leucaena leucocephala*	E
Mkilifi	Chinaberry	*Melia azedarach*	F
Mrabai		*Senna siamea*	G
Mbambakofi		*Afzelia quanzensis*	H
	Soursop	*Annona muricata*	I
Mbokwe		*Annona senegalensis*	J

On farm prunings for firewood and biochar production in Kwale

Household using three stone open fire need 1460-1825kg with consumption of 4 - 5kg/day

This firewood if used on pyrolytic cooking systems yields 292-365kg of biochar as a by-product. Land size on use depends on application rate

Sujessy, 2018. MSc thesis, KTH Royal Institute of Technology

Biomass production through agriculture with trees (agroforestry)

Acacia species +livestock+bee

Coppicing Acacia

6 years rotation

Half orange kiln

KEFRI, Western Kenya. Oduor et al., 2012. Supported by DFID

Production system	Tree species	Density Number /ha	Wood (t/ha)	Production cycle (yrs)
Boundary	*Acacia polyantha*	2500	4.41	3-5
Woodlots	*Grevillea robusta*	2500	2.64	3-5

Tanzania ICRAF; Kimaro et al., Supported by GIZ/BMZ, USAID

Yield depend on carbonization efficiency and wood

Sustainable wood and efficient conversion can reduce GHG in charcoal by 80% (FAO, 2017)

Plantations with right species, right place; higher inputs, monoculture

Sustainable biomass production through improved fallows (IF)

Drum kiln recovering smoke for vinegar By Cookswell Jikos

Photos: one year improved fallow with *Sesbania sesban*, Kitale ,Kenya

- Double yields for (at least) 2 subsequent harvests*
- 15-20 ton dry stem-wood /ha in 2 years*
- 10-15 ton branches/ha in 2 years*
- Increases soil organic matter (SOM)
- Fixes 300 kg N/ha in 2 years*

➢ Sale of stem-wood for bio-energy could be incentive to farmers to establish IF

➢ Branches can be used for household cooking in improved stoves

➢ IF thinned regularly produce fodder

Biomass production under evergreen agriculture with fertilizer trees

Maize growing under a Faidherbia canopy of trees in Tanzania . Photo: World Agroforestry Centre

EVERGREEN AGRICULTURE

"Evergreen agriculture allows us to glimpse a future of more environmentally sound farming where much of our annual food crop production occurs under a full canopy of trees."

Dr Dennis Garrity, World Agroforestry Centre

Community based forest/woodland management for biomass production

Conserve native species, mark those need to be protected, low inputs

Improved earth kilns

Tanzania Forest Conservation Group

Supported by Swiss Agency for Development and Cooperation

TFCG, 2017	Year 1 2015/16	Year 2 2016/17
Production (tonnes)	324	1391
Community revenues (fees) US$	21,830	85,917
Producer incomes US$	22,746	86,787
Number of producers	308	1053
Villages	8	13

Farmer managed natural regeneration (FMNR) by ICRAF in various places

Sustainable wood production can eliminate GHG emission and result into net sequestration

Climate smart charcoal private company business model

Out grower scheme from small scale farmers +

Plantations by the company

Poles after 12 years

Thinning's every 3 years

Mobile container kiln 33% conversion. Gaseous energy used for drying wood and indirectly heating wood into charcoal

60% lump charcoal

40% smaller charcoal pieces into briquettes

Biochar ???: a possibility

Darrin: Darrinjd825@gmail.com, New Forests Company Ltd, Rwanda, Uganda, Tanzania http://newforests.net/

Stakeholder approach to sustainable woodfuel systems in Coastal regions in Tanzania supported by CTCN-UNEP

Activities:

- Literature **synthesis**
- Context analysis, priority interventions **by stakeholders**
- Capacity development (TOT= 16 men and 5 women, Grassroots trainings 76 males; 42 females) **Co-learning**
- **Co-designing** a proposal for scaling up business models

Acknowledgement: 2017-2018

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- Mathew, John, Denis, Emma -TAREA
- Gerald, Harun, COSTECH

World Agroforestry Centre (ICRAF) **Implementing organization**

Request by Tanzania Renewable Energy Association (TAREA) **Proponent**

Tanzania Commission of Science and Technology (COSTECH) **NDE**

Co-designing for cleaner inclusive bioenergy/biochar systems: Transdisciplinary processes

Preferred tree production systems

Participatory kitchen laboratory

Users needs and preferences

Users

Industry

Researchers

→ Co-learning, Co-designing

Farmer managed planned comparisons

Women friendly portable metal steel rings kiln in Turkana Kenya. Invasive *Prosopis juliflora* Photo by J. Owino (KEFRI) FAO/KEFRI/ICRAF

Adaptive technology development increase adoption

KIRDI (Kenya Industrial Research Institute)(NDE) Reproducing Biochar producing GASTOV

Transdisciplinary team:

- Farmer/women researchers
- Bioenergy, Environment, Soil
- Engineering and design
- Gender
- Government
- Funders

Saraswati S. M. 2018. Design improvements for TLUD biochar producing gasifier stove in Rural Kenya from the user's perspective. Masters Thesis. Sustainable Development. Uppsala University, Uppsala Sweden.

Lessons

- **Bioenergy-biochar systems have multiple benefits**: energy security, improved livelihoods and gender equity, resource recovery, improved agricultural productivity and climate change mitigation and adaptation
- **Gender responsive demand driven development** for scaling up existing technologies for sustainable biomass production and efficient processing into charcoal for energy or biochar and use systems.
- **Knowledge and capacity is needed** on charcoal and biochar systems as low carbon emitter and context biochar performance
- **Enabling policy framework** including standards and regulations for climate smart charcoal for energy and biochar

World Agroforestry Centre

The World Agroforestry Centre
United Nations Avenue, Gigiri
P.O Box 30677 Nairobi, 00100, Kenya
Phone: +254 20 722 4000
Fax: +254 20 722 4001
Email: icraf@cgiar.org
Web: www.worldagroforestry.org

Further Learning Resources

- Akoto-Danso, E.K., Makan'abusi, D., Steiner, C., Werner, S., Haring, V., Nyarko, G, Marschner, B,. Drechsel. P., Buerkert, A. 2018. Agronomic effects of biochar and wastewater irrigation in urban crop production of Tamale, northern Ghana. Nutrient Cycling in Agroecosystems 543 (295); 1-17.
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- Njenga. M., Yonemitsu, A., Karanja, N., Iiyama, M., Kithinji, J., Dubbeling M., Sundberg, C and Jamnadass, R. (2013b). Implications of charcoal briquette produced by local communities on livelihoods and environment in Nairobi, Kenya. International Journal of Renewable Energy Development (IJRED). 2 (1) 19-29. Available online. http://www.ijred.com/index.php/ijred/article/view/88/pdf. ISSN 2252-4940

- **Video:** How to make own biochar machine https://youtu.be/YIbGkmt1VdE (5 min 45 sec)

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