Household biochar production and use by smallholder farmers in Kenya

Cecilia Sundberg, KTH Royal Institute of Technology

James K Gitau, University of Nairobi

Mary Njenga, World Agroforestry Centre

Thomas Kätterer, Swedish University of Agricultural Sciences

Ruth Mendum, Penn State University

Kristina Roing de Nowina, CGIAR

Funded by Swedish research councils VR and Formas

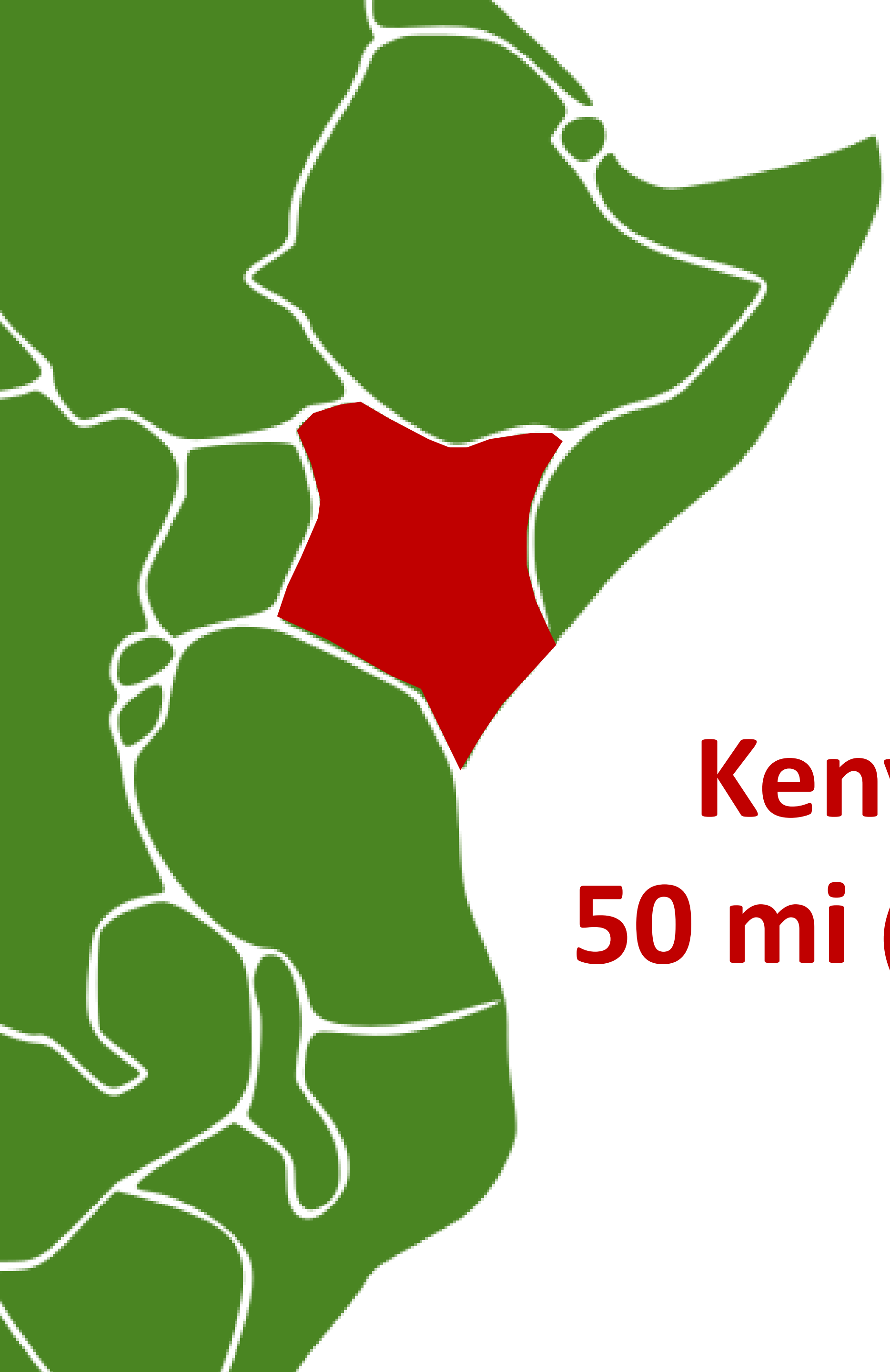
”Strikers are calling on people all over the world to join a week of escalated climate action

Why: To show solidarity with the youth-led strike, shine light on the failures and demand immediate climate action from all governments and corporations”

54 countries

Population
1.3 billion (2019)
4 billion (2100)

Challenges ahead…



Kenya
50 mi (2019)

Research project

- 3 sites * 50 households
- 2006 - 2014 - 2019


Cookstove design & supply
Climate change mitigation
Biochar quality
Fuel use
Indoor air pollution
Cookstove usage
Maize & kale yield

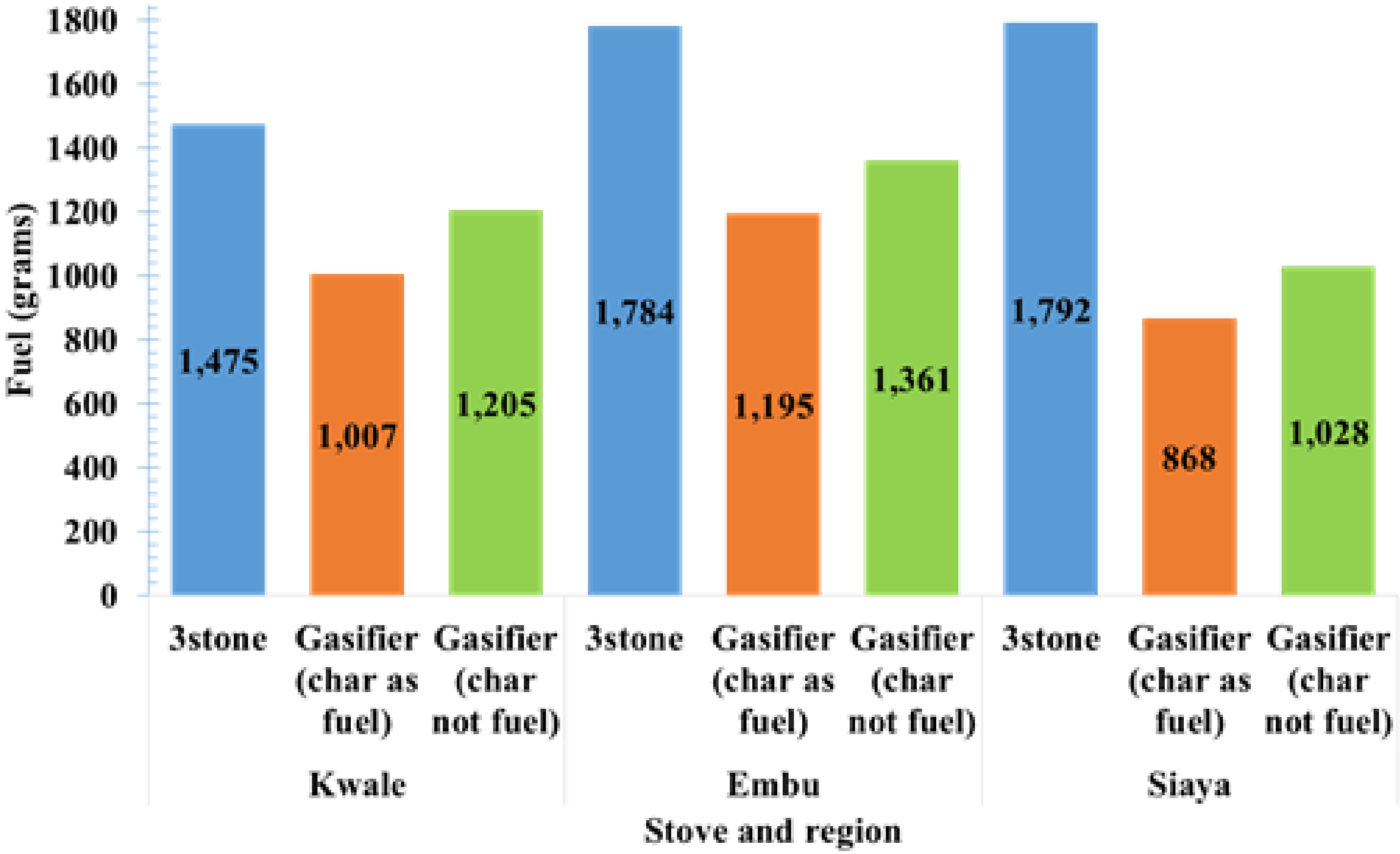
Fuel use

Wood fuels – large variety

- Large variation of wood fuels and sources
- Trees on farms (prunings) dominant source
- 1-2 dominant species in each site
  - Siaya: *Markhamia lutea*
  - Embu: Grevillea, Coffee
  - Kwale: Neem, Casuarina
- Agricultural residues for fuel:
  - Coconut husks
  - Potentially coffee husks

Fuel use efficiency

Fuel use



Indoor air pollution

Reduced indoor air concentrations of $PM_{2.5}$ and CO

Concentrations measured in the kitchen during cooking

1.5 m above ground, 1 m from stove

	$PM_{2.5}$ (μg/m³)	CO (ppm)	CO_2 (ppm)
Embu	320 ± 410	9.9 ± 8.4	590 ± 63
Siaya	160 ± 170	8.5 ± 8.3	619 ± 70
Kwale	290 ± 950	7.5 ± 10.4	601 ± 253

Kitchen concentrations during cooking compared to open fire:

- CO reduced by 57 - 95% in the three sites
- $PM_{2.5}$ reduced by 79 - 97%

CO concentrations are below WHO guidelines 1 h exposure

Biochar production

Biochar quality

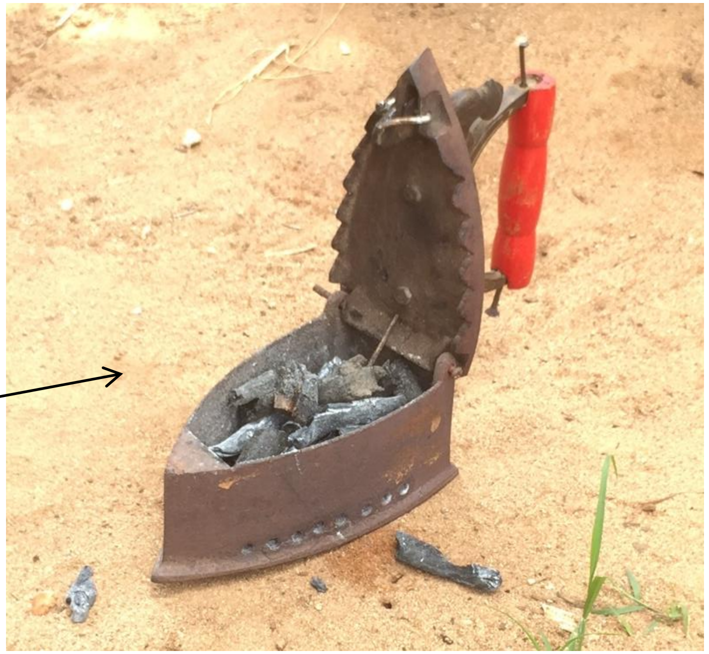
- Average 200 g produced per meal
- Biochar yield 16.5 % of fuel mass

	Biomass				Biochar					
Tree species	Ash 550°C (% dw)	VM (% dw)	Fixed carbon (% dw)	Calorific value (MJ/kg)	Ash 550°C (% dw)	VM (% dw)	Fixed carbon (%dw)	Calorific value (MJ/kg)	pH	BET Surface area m^2/g
Mucuca	0.6	83.1	16.3	17.8	4.1	9.5	86.4	29.9	9.0	254
Muriru	0.7	82.9	16.4	17.9	2.4	10.2	87.5	30.9	8.9	293
Coffee	1.7	80.6	17.7	18.2	3.9	9.8	86.4	30.1	8.6	143
Macadamia	1.1	81.1	17.8	17.8	3.1	10.3	86.6	30.6	8.7	257
Grevillea	0.8	81.7	17.5	18.2	3.1	8.7	88.2	30.1	8.3	135
Neem (n=10)	2.2±0.3	79.4±0.6	18.4±0.4	18.4±0.1	4.8±0.3	10.4±0.5	84.8±0.6	32±0.1	-	-
Casuarina (n= 9)	1.4±0.1	81.4±0.3	17.2±0.3	18.4±0.1	3.4	10.9±0.7	87.5	32.4±0.2	-	-

Cookstove design & supply

The cookstove functions well, but

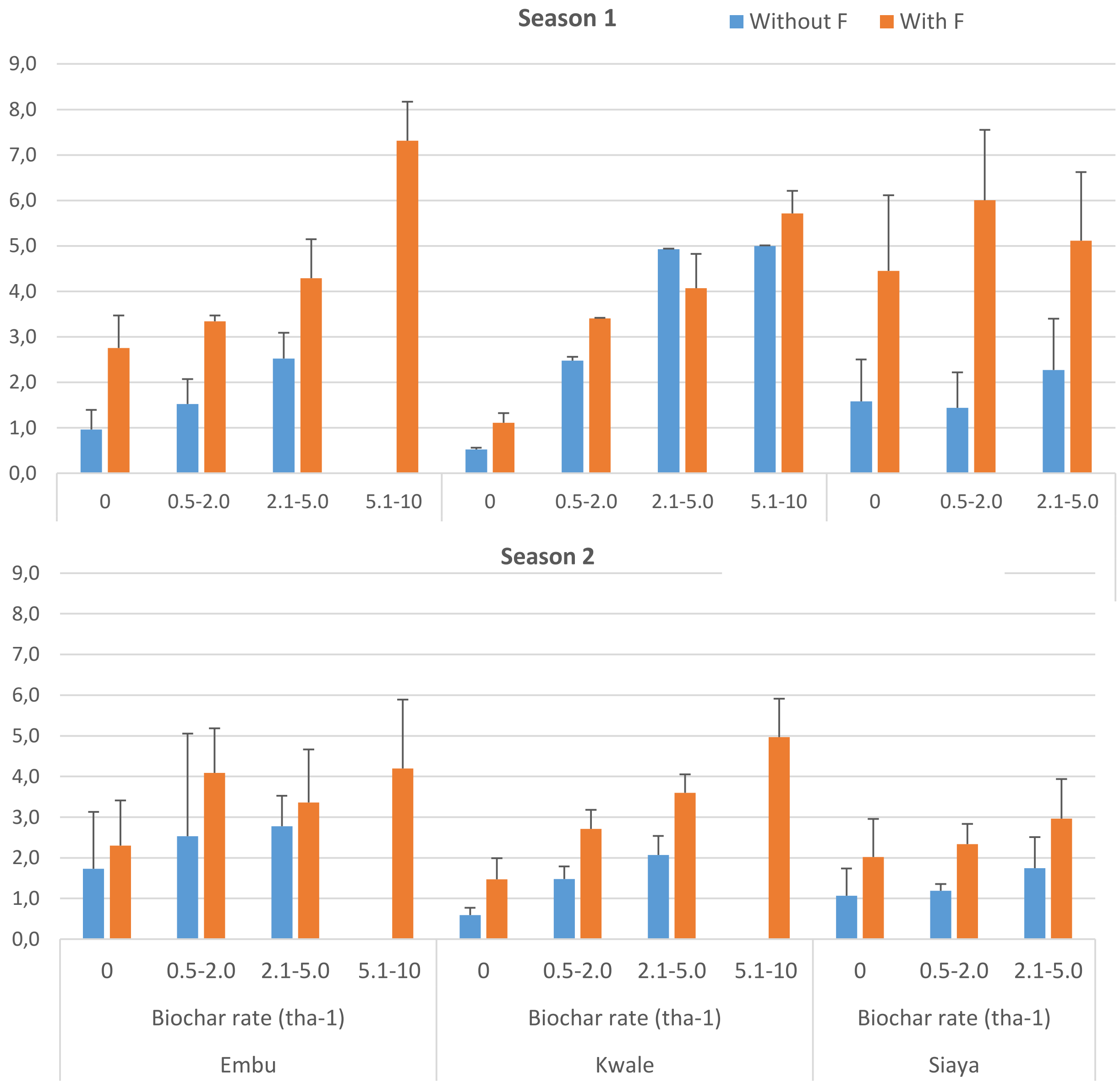
Challenges:
- Lighting
- Refilling
- Cutting wood
- Learning to cook various meals
- Saving biochar to planting season



Most families use the gasifier stove , but most of them don’t use it every day

Maize yield

- field trials comparing biochar to normal farming practices
- farmers used biochar from cookstoves
- biochar doses 1-10 tonnes/ha
- biochar applied in furrows
- hybrid seeds provided
- 2 seasons



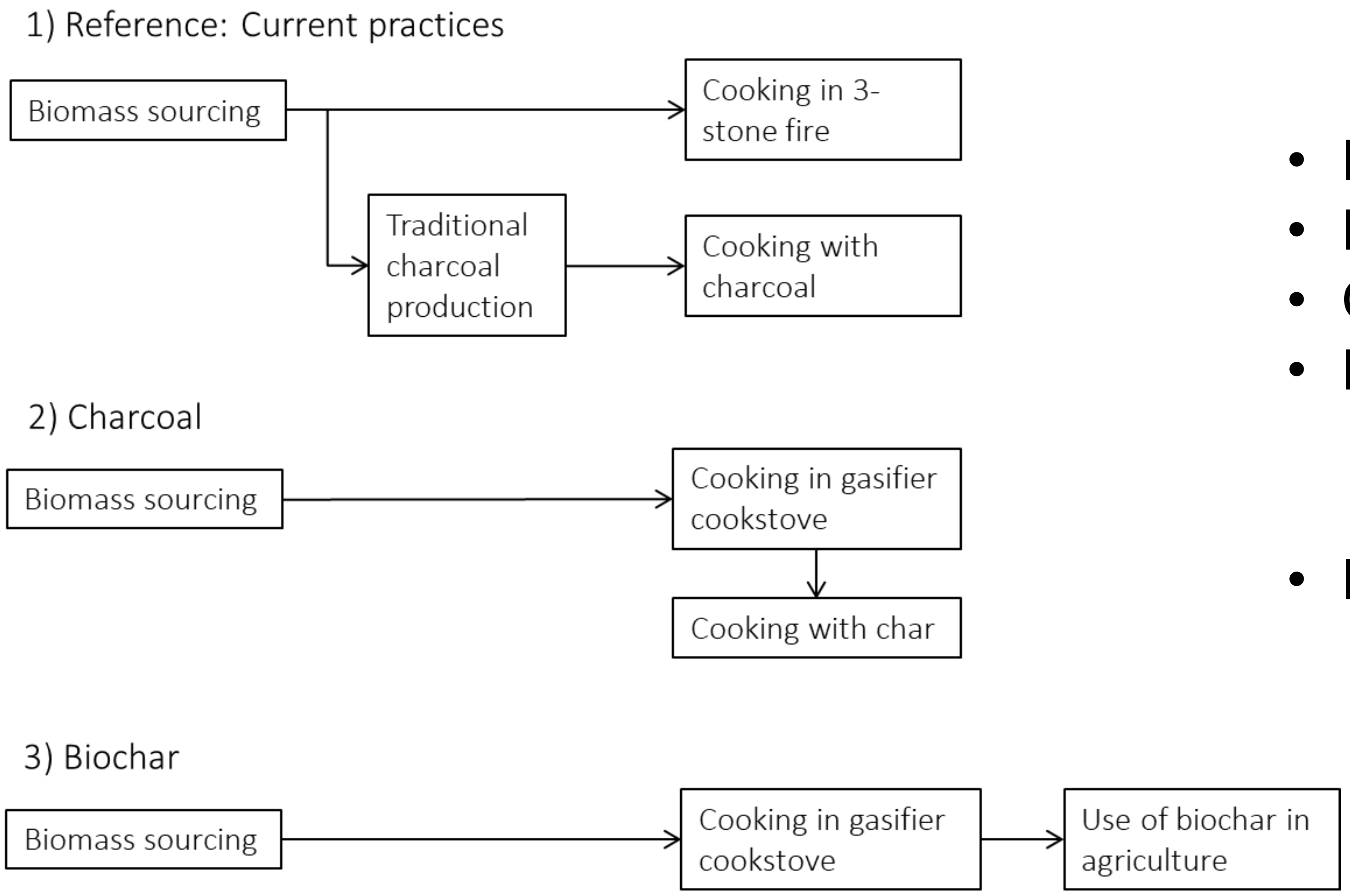
Maize & kale yield

Kale yield

- 2 sites, 1-2 seasons
- Large variability
  due to variable rainfall
- Average yield increases observed

Climate impact – Greenhouse gas balance (LCA)

Climate change mitigation

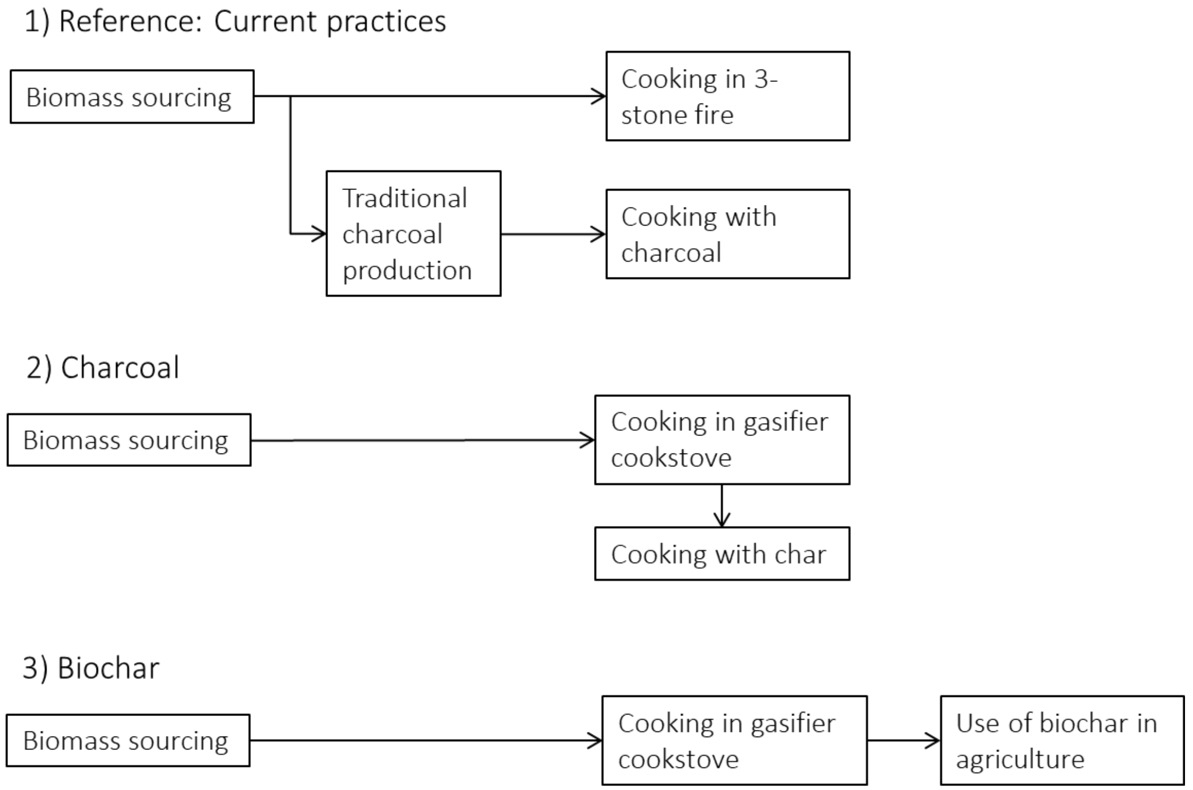


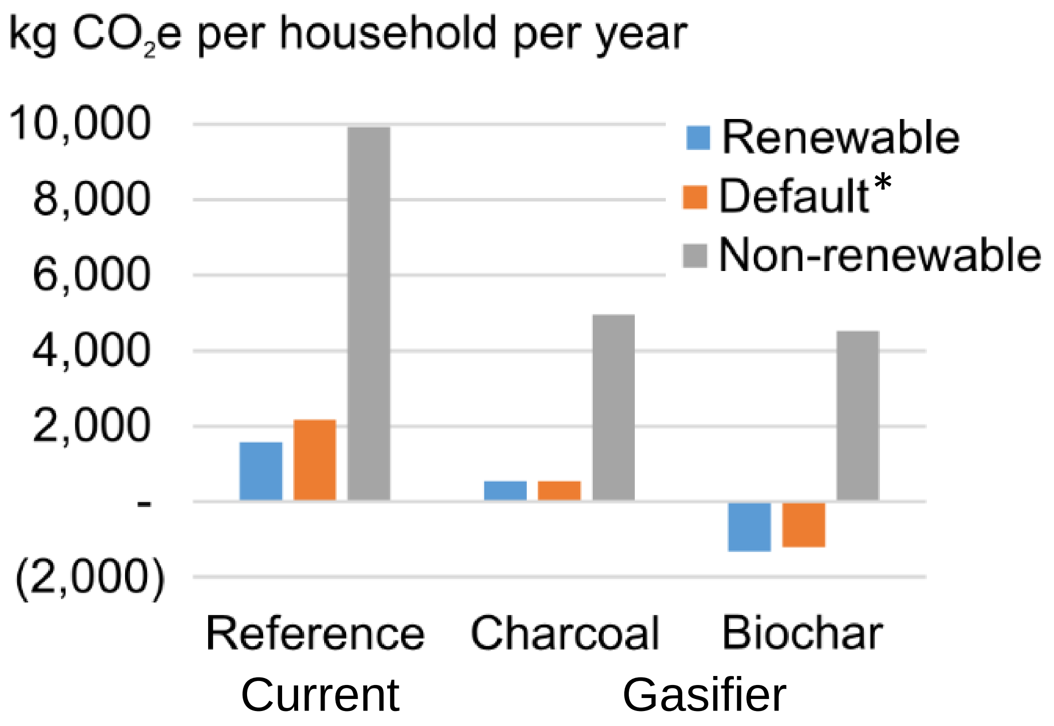
- From fuel to biochar
- Biochar C sequestration
- CO_2, CH_4, N_2O
- Effects of increased agricultural yield not included

- Functional unit: cooking for one household for one year

Climate impact – Greenhouse gas balance

Climate change mitigation





*mostly renewable, minor share non-renewable

Conclusions

Biochar production in cookstoves can provide multiple benefits:

- Reduced fuel use
- Reduced indoor air pollution
- Less drudgery for women
- Increased crop yields
- If non-renewable biomass fuel: large GHG emission reductions
- If renewable fuel: net negative GHG emissions

Publications (more upcoming)

Papers in peer-reviewed scientific journals

- Gitau, K. J.; Mutune, J.; Sundberg, C.; Mendum, R.; Njenga, M. Factors Influencing the Adoption of Biochar-Producing Gasifier Cookstoves by Households in Rural Kenya. *Energy Sustain. Dev.* **2019**, *52*, 63–71; DOI .
- Kätterer, T.; Roobroeck, D.; Andrén, O.; Kimutai, G.; Karltun, E.; Kirchmann, H.; Nyberg, G.; Vanlauwe, B.; Röing de Nowina, K. Biochar Addition Persistently Increased Soil Fertility and Yields in Maize-Soybean Rotations over 10 Years in Sub-Humid Regions of Kenya. *F. Crop. Res.* 2019, *235*, 18–26
- Gitau, J.K., Mutune, J., Sundberg, C., Mendum, R., Njenga, M. 2019. Implications on Livelihoods and the Environment of Uptake of Gasifier Cook Stoves among Kenya's Rural Households. *Applied Sciences. 9*, 1205.
- Njenga, M, Mahmoud Y, Mendum R, Iiyama M, Jamnadass R, Roing de Nowina K, Sundberg C. 2017. Quality of charcoal produced using micro gasification and how the new cook stove works in rural Kenya. Environmental Research Letters. 12(9),095001
- Njenga M, Iiyama M, Jamnadass R, Helander H, Larsson L, de Leeuw J, Neufeldt H, Roing de Nowina K, Sundberg C. 2016. Gasifier as a cleaner cooking system in rural Kenya. Journal of Cleaner Production. 121, 208-217.

Book chapters

- James K. Gitau, Ruth Mendum and Mary Njenga. 2018. Gender and Improvement of Cooking Systems with Biochar-producing Gasifier Stoves. In: Njenga, M.; Mendum, R. (Eds.). 2018. Recovering bioenergy in Sub-Saharan Africa: gender dimensions, lessons and challenges. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). (Resource Recovery and Reuse: Special Issue). doi: 10.5337/2018.226

Thank you!

Cecilia Sundberg

Associate Professor

Dept. Sustainable Development, Environmental Science and Engineering

KTH Royal Institute of Technology

Stockholm

Sweden

www.biochar.abe.kth.se

Don´t forget!

Funded by Swedish research councils VR and Formas