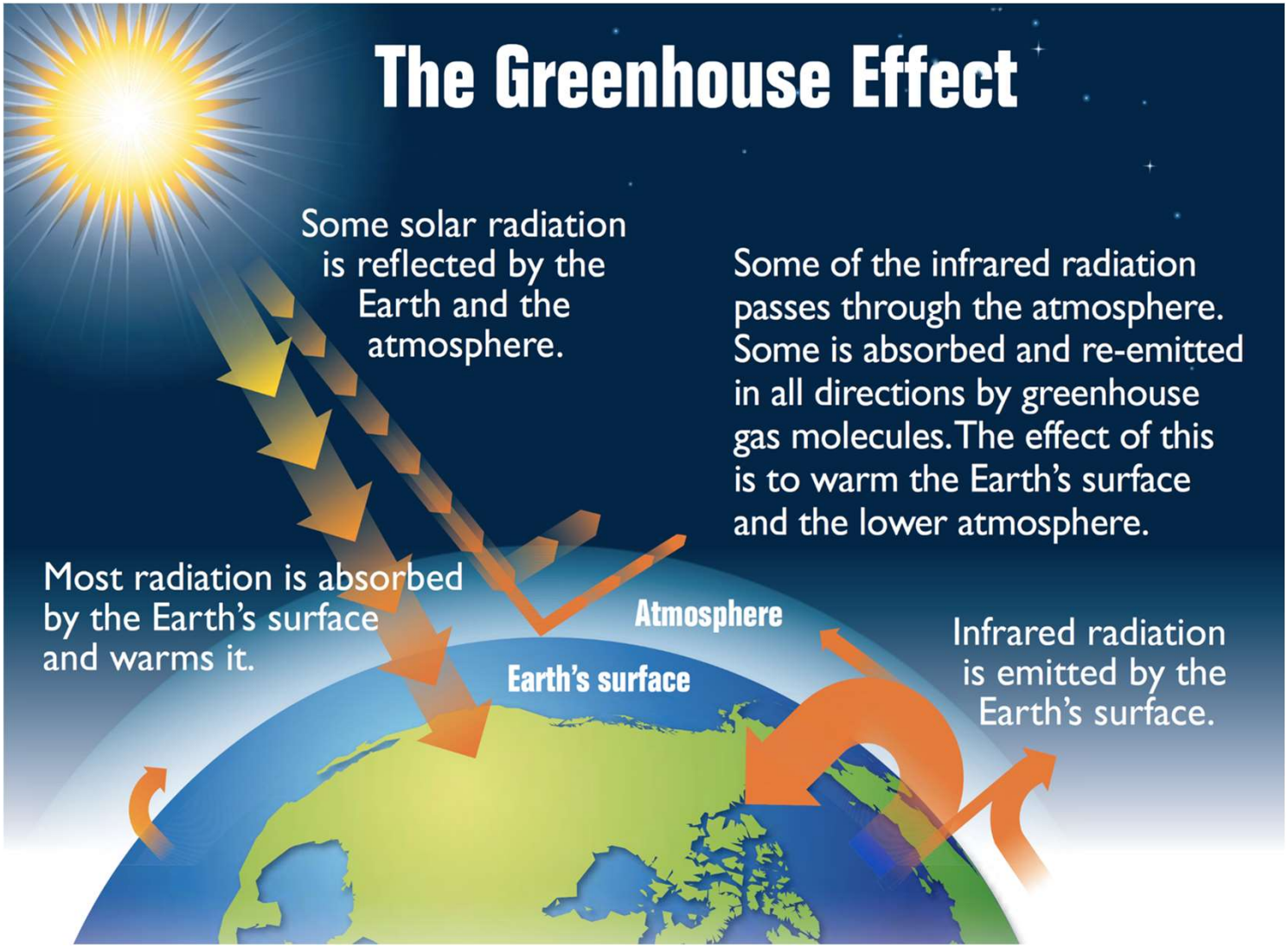
Biochar: a carbon negative technology and nature based solution


The Greenhouse Effect
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere. Some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Most radiation is absorbed by the Earth's surface and warms it.
Atmosphere
Earth's surface
Infrared radiation is emitted by the Earth's surface.

Biochar is carbon negative

To the Editor: The editorial "Half-hearted engineering" and the commentary "Ranking geo-engineering schemes" in *Nature Geoscience*[1,2] discuss various schemes for addressing the issue of climate change. We would like to draw attention to the production and burial of biochar as an additional scheme that allows the sequestration of carbon in the soil at the same time as providing fertilizer.

Carbon sequestration through biochar involves pyrolysis or gasification of organic material in low-oxygen conditions from plant waste[3]. The resulting char can be mixed with existing soil, acting as a fertilizer[4] and sequestering carbon with a mean residence time of about 2,000 years[5]. Biochar production and burial removes carbon dioxide directly from the atmosphere through uptake by plants, allowing, in principle, an actual reduction of atmospheric carbon dioxide levels.

By contrast, conventional carbon capture and storage reduces the carbon dioxide concentrations from exhaust fumes, therefore at best preventing atmospheric carbon dioxide levels from rising further. In addition, it will take at least another decade or so before power plants with carbon capture and storage can be implemented on a large scale. Making biochar is a low-tech process that could be started right now, given the political will.

Based on European emissions of about 1.1 gigatonnes of carbon per year, we estimate that biochar could offset around 9% of Europe's emissions. We suggest that biochar should be added to the climate change toolkit of renewables, energy saving, and carbon capture and storage. ❐

References

1. *Nature Geosci.* **1,** 719 (2008).
2. Boyd, P. M. *Nature Geosci.* **1,** 722–724 (2008).
3. Harris, E. *Nature* **442,** 624–626 (2006).
4. Glaser, B. *Phil. Trans. R. Soc. B* **362,** 187–196 (2007).
5. Kuzyakov, Y., Subbotina, I., Chen, H., Bogomolova, I. & Xu, X. L. *Soil Biol. Biochem.* doi:10.1016/j.soilbio.2008.10.016 (2008).

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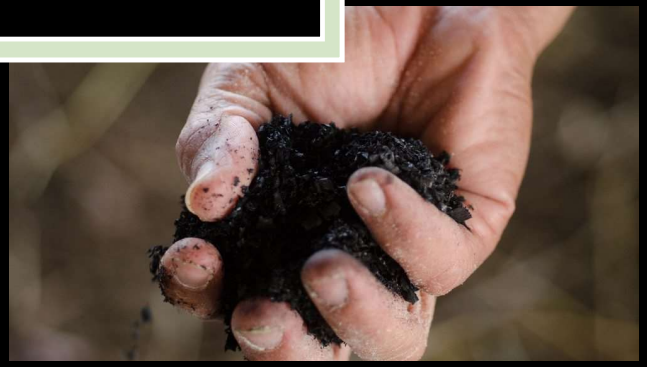
Glaser, B., Parr, M., Braun, C. *et al.* Biochar is carbon negative. *Nature Geosci* **2**, 2 (2009). https://doi.org/10.1038/ngeo395

Biochar and Sustainability

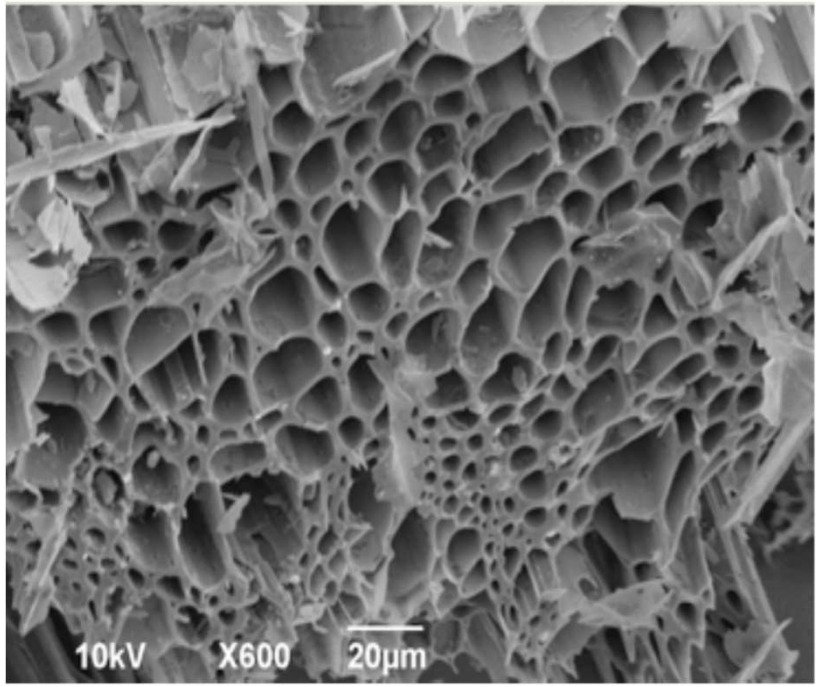


- What is biochar
- 50 uses of biochar
- Biochar as soil amendment
  - Potential for better water retention and nutrient retention. Environmental impact?
  - What biochar for what plant?
  - acidic biochar and urban farming
  - Green roofs, green walls?
- Beyond agriculture
  - Functionalized biochars
  - CO2 absorption
  - Heavy metal absorption
  - …

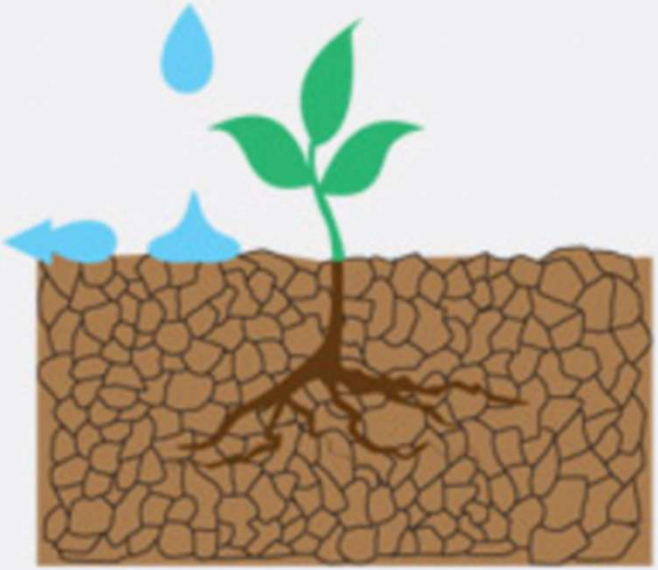
Terra Preta


Amazonian dark earth - *terra preta*
Left a nutrient-poor *oxisol*; right an oxisol transformed into fertile *terra preta* - photo courtesy of Bruno Glaser

Biochar



Biochar is loosely defined as a powder like carbon material thermally produced with very low oxygen content, aka, pyrolysis.

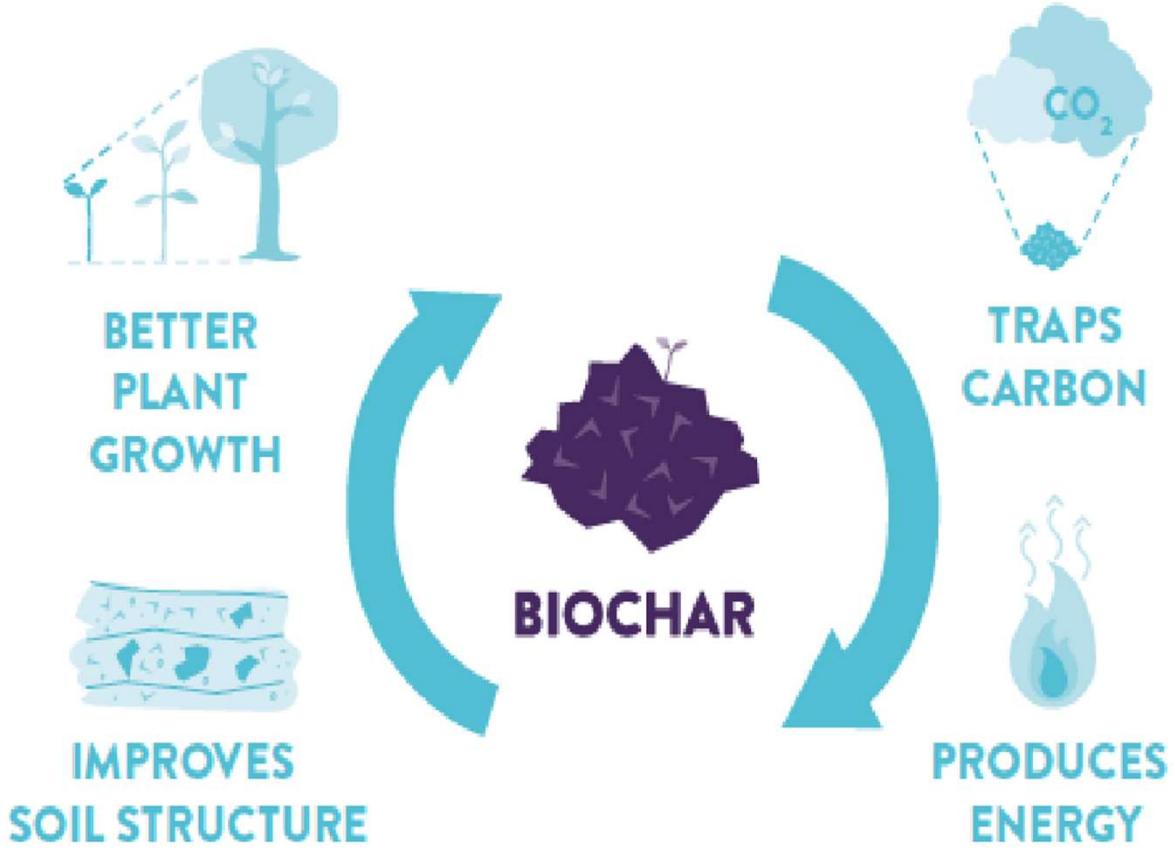


CHEMICAL SOIL

ORGANIC SOIL

RAISING ORGANIC MATTER 1% WILL RETAIN AN EXTRA 20,000 GALS OF WATER PER ACRE

Biochar to Improve Resource Base



- Water retention,
- N, P (nutrient) retention
- Host microbes

→ plant specific, biochar specific

4 PER 1000
CARBON SEQUESTRATION IN SOILS FOR FOOD SECURITY AND THE CLIMATE

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt

The quantity of carbon contained in the **atmosphere** increases by **4.3** billion tons every year

+4.3 bn tons carbon / year

CO_2 emissions

Forests ⊖⊖
Oceans ⊖⊖
Human activities ⊕⊕⊕⊕
Deforestation ⊕

⊖ absorption ⊕ emission

The world's **soils** contain **1 500** billion tons of carbon in the form of organic material

absorption of CO_2 by plants

storage of organic carbon in soils

1500 bn tons carbon

If we increase by 4‰ (0.4%) a year the quantity of carbon contained in soils, **we can halt the annual increase in CO_2 in the atmosphere,** which is a major contributor to the greenhouse effect and climate change

increased absorption of CO_2 by plants :

farmlands, meadows, forests…

+4‰ carbon storage in the world's soils

= more fertile soils
= soils better able to cope with the effects of climate change

HOW CAN SOILS STORE MORE CARBON?

The more soil is covered, the richer it will be in organic material and therefore in carbon.
Until now, the combat against global warming has largely focused on the protection and restoration of forests.
In addition to forests, we must encourage more plant cover in all its forms.

Never leave soil bare and work it less, for example by using no-till methods

Introduce more intermediate crops, more row intercropping and more grass strips

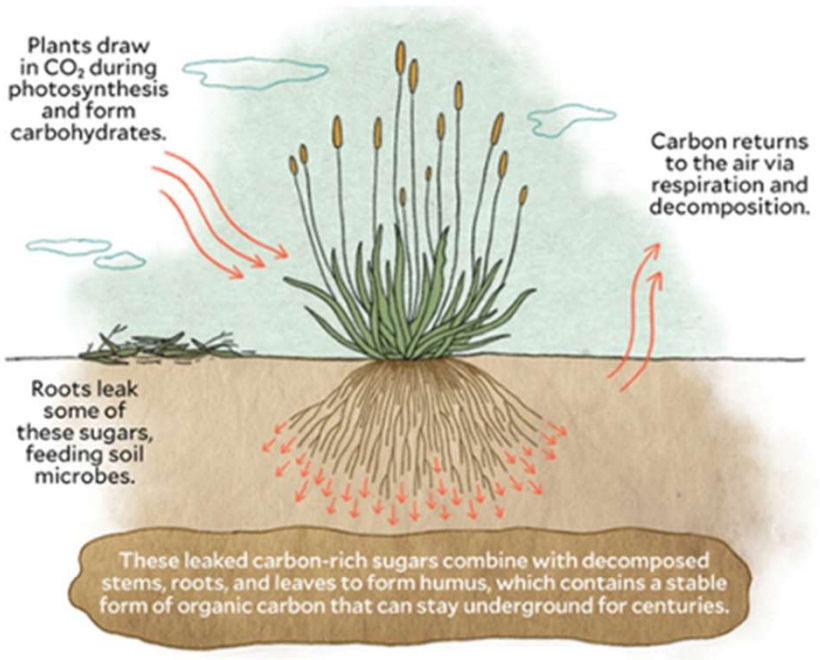
Add to the hedges at field boundaries and develop agroforestry

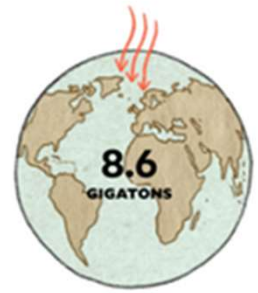
Optimize pasture management – with longer grazing periods, for example

Restore land in poor condition e.g. the world's arid and semi-arid regions

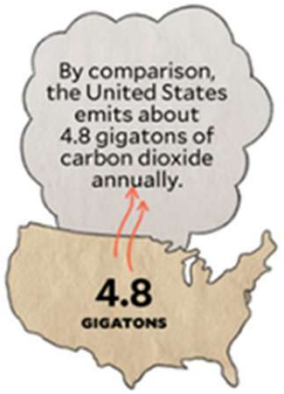
*"This international initiative can reconcile the aims of **food security** and the **combat against climate change,** and therefore engage every concerned country in COP21."*

Stéphane Le Foll, French Minister of Agriculture, Agrifood and Forestry



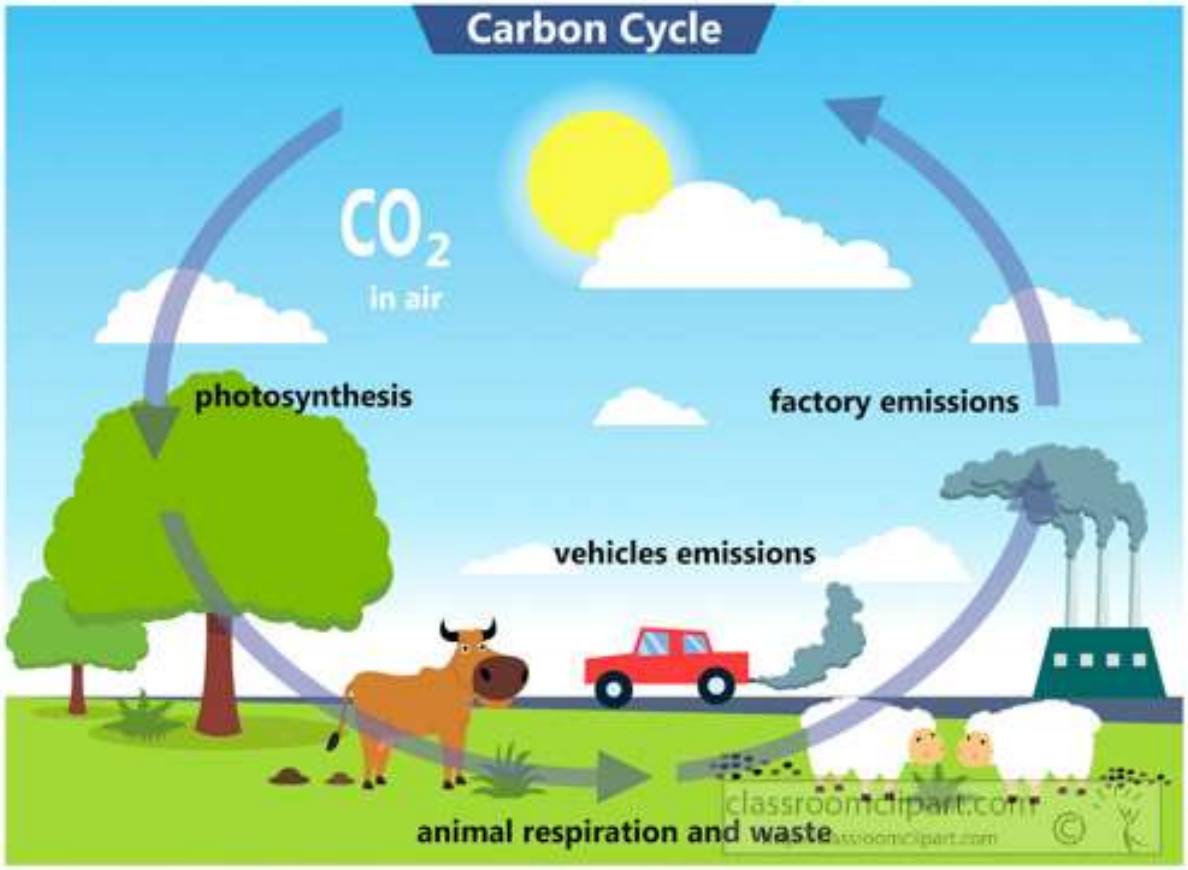


Scientists say we could stash as much as an extra 8.6 gigatons of carbon dioxide annually in the world's soils.



By changing their agricultural practices, US farmers could capture up to an additional quarter of a gigaton of carbon dioxide each year.

The carbon cycle
Where does CO_2 come from and where does it go?



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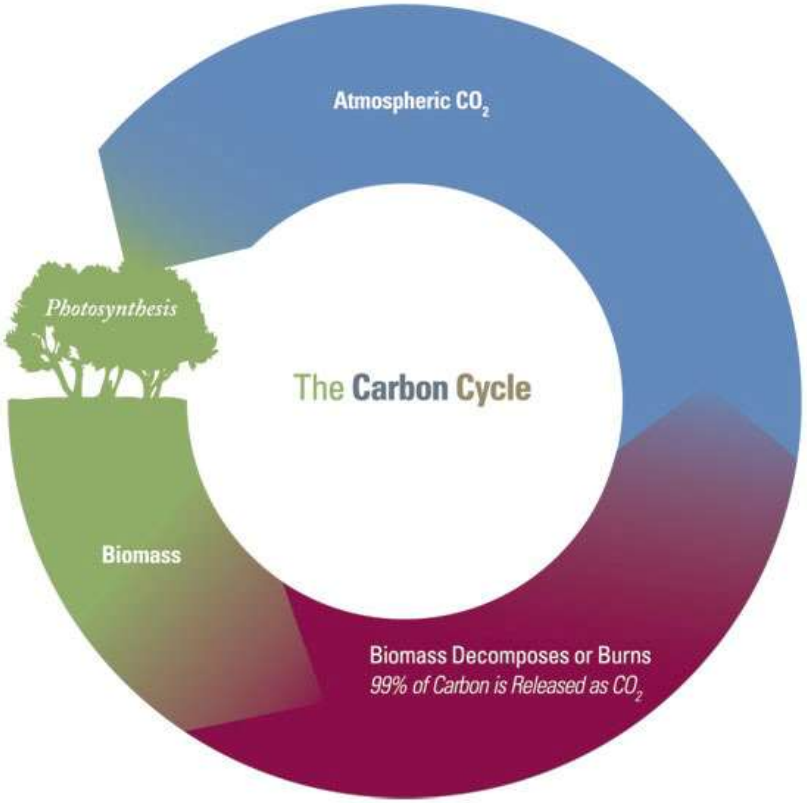
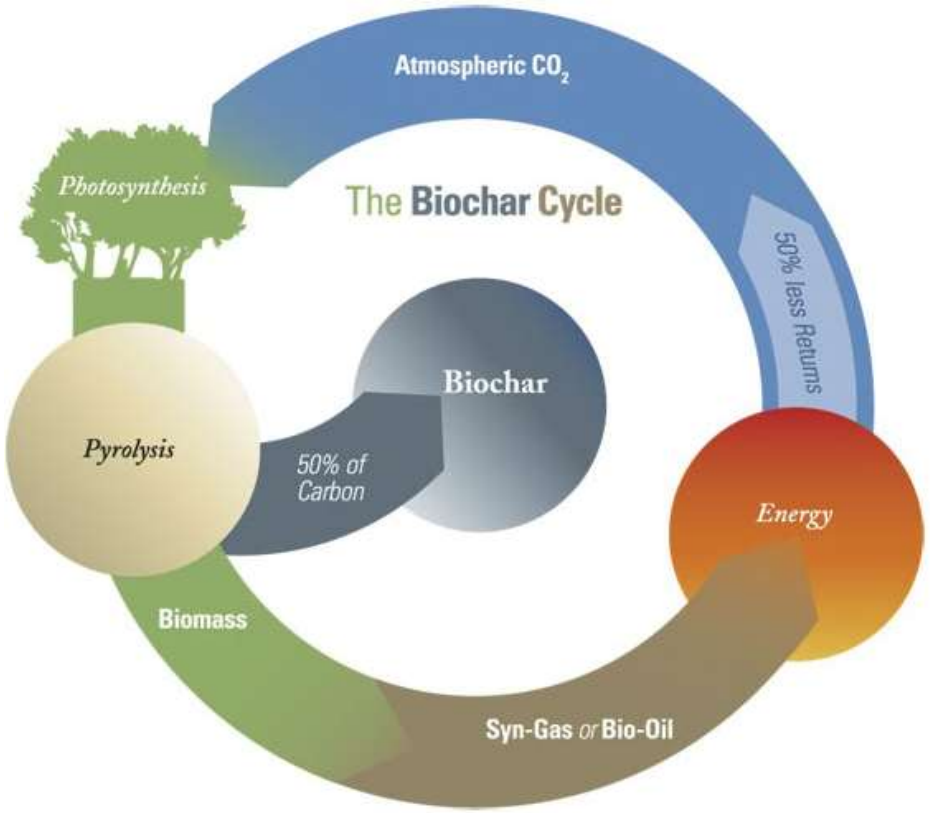
The carbon cycle with and without biochar

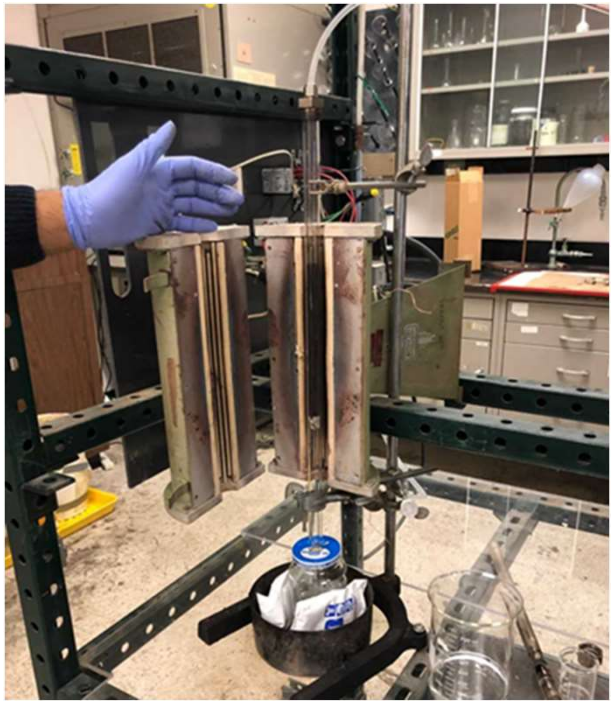
Without

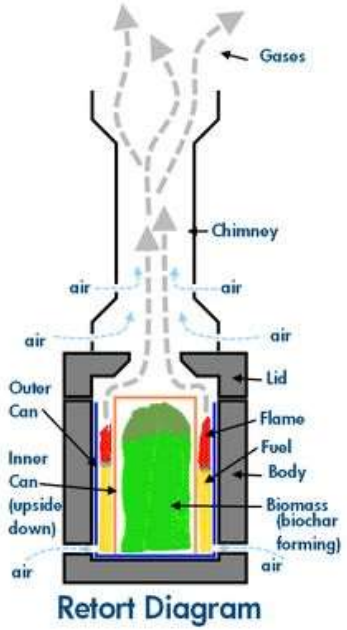


With



How is biochar made?





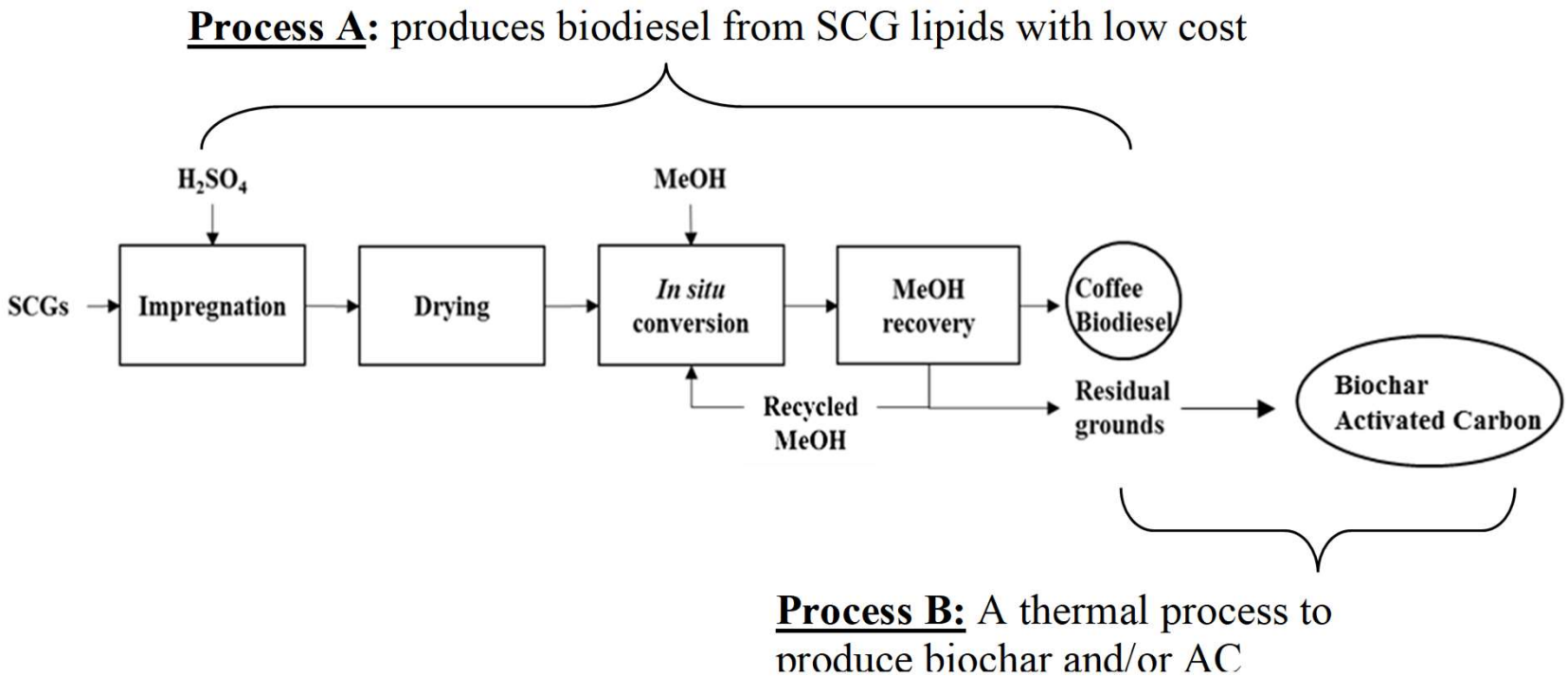
Retort Diagram

Feedstocks

Agricultural waste, sewage sludge, paper sludge, cow manure, poultry manure, poultry litter, leaves sugarcane, rice, bark, pecan shells, corn hulls, peanut hulls, hardwoods, switch grass, pig manure, wood waste, straw, maize stover, stripped cobs, oil seed husks, jatropha, prosopsis, albizzia, babassu

→ biomass residuals and other wastes. Low cost; waste diversion; reduce carbon foot print

Pathway of SCG upcycle

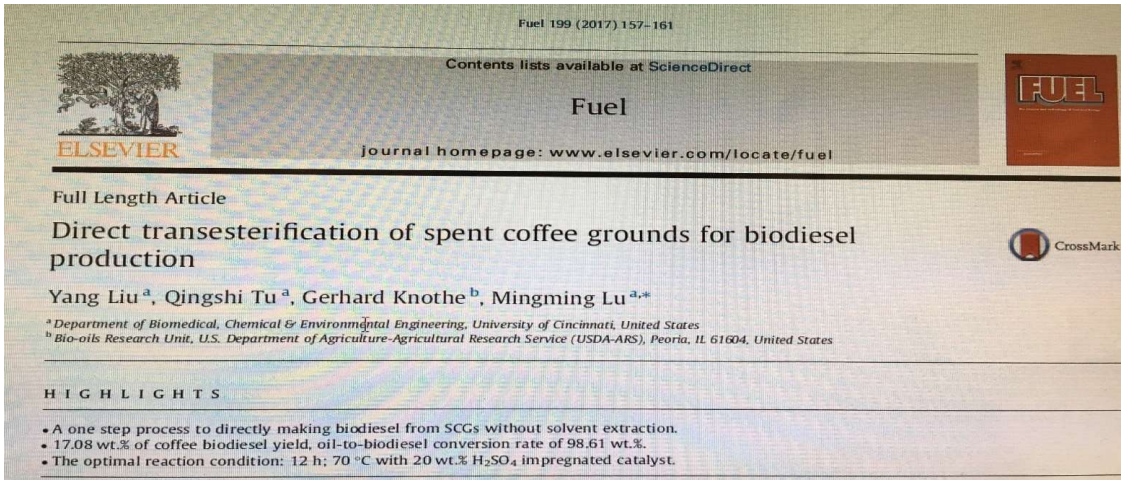


Biochar functionalization

- Alkaline biochar
- Acidic biochar
- Biochar with other functions
- New products, unique applications

SCG biodiesel

- A patent pending process without solvent extraction, simpler one step reaction, easier to recycle solvents → lower cost and more environmentally friendly
- Increased biochar yield, reduced tar formation
- Produced an acidic biochar, more suitable for urban farms, especially higher valued acid-loving fruits and vegetables



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journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Direct transesterification of spent coffee grounds for biodiesel production

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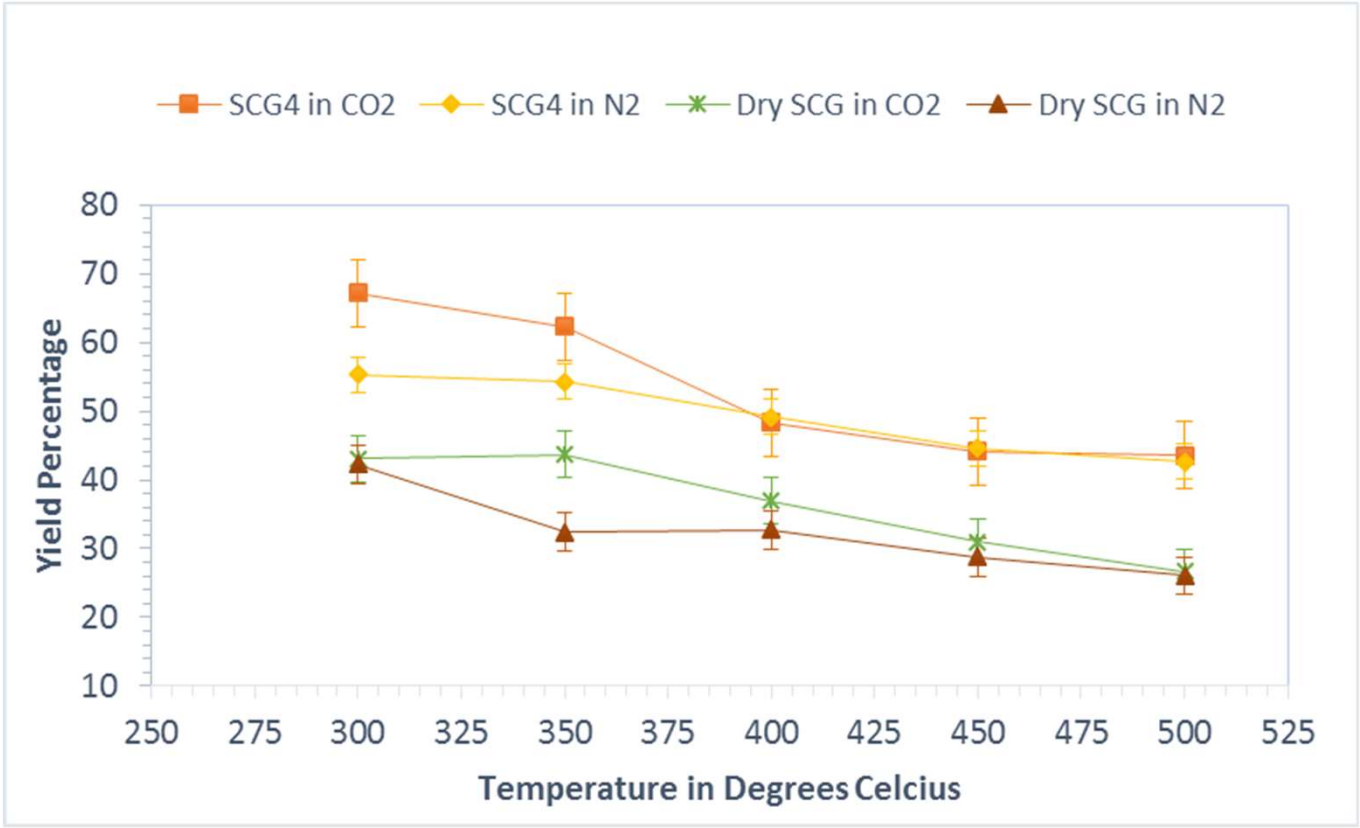
[b] Bio-oils Research Unit, U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS), Peoria, IL 61604, United States

HIGHLIGHTS

- A one step process to directly making biodiesel from SCGs without solvent extraction.
- 17.08 wt.% of coffee biodiesel yield, oil-to-biodiesel conversion rate of 98.61 wt.%.
- The optimal reaction condition: 12 h; 70 °C with 20 wt.% H_2SO_4 impregnated catalyst.

Research and commercial opportunities

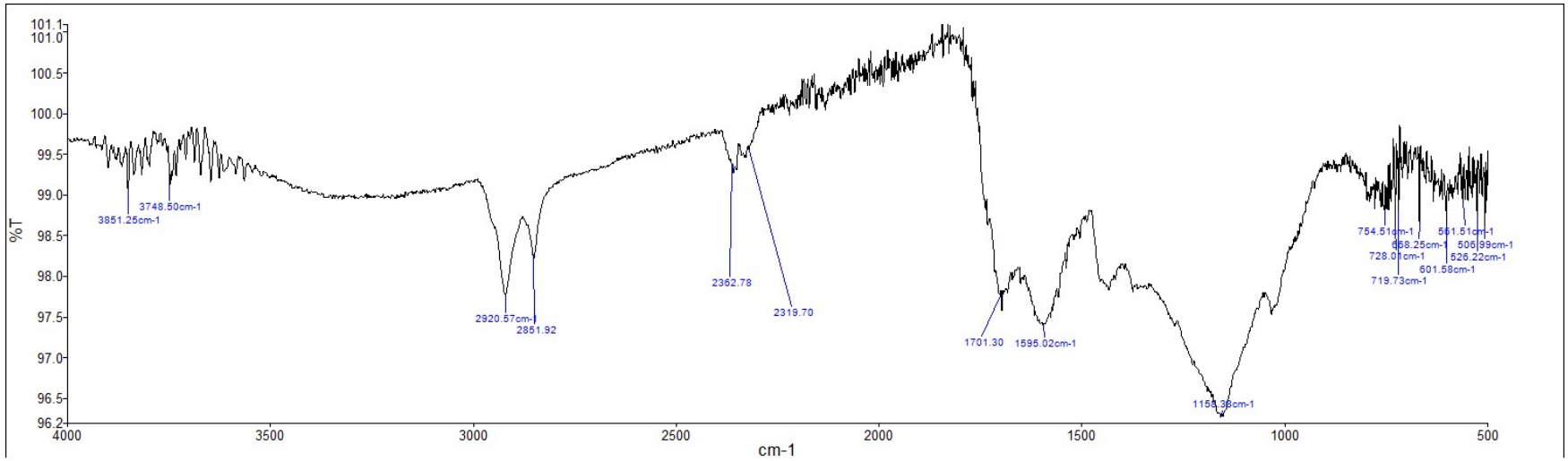
- Biochar as soil amendment
  - What biochar for what plant?
  - acidic biochar and urban farming
  - Green roofs, green walls?
- Beyond agriculture
  - Functionalized biochars
  - CO2 absorption
  - Pollutant fixing in soils
  - Heavy metal absorption
  - Methane reduction from cows
  - …

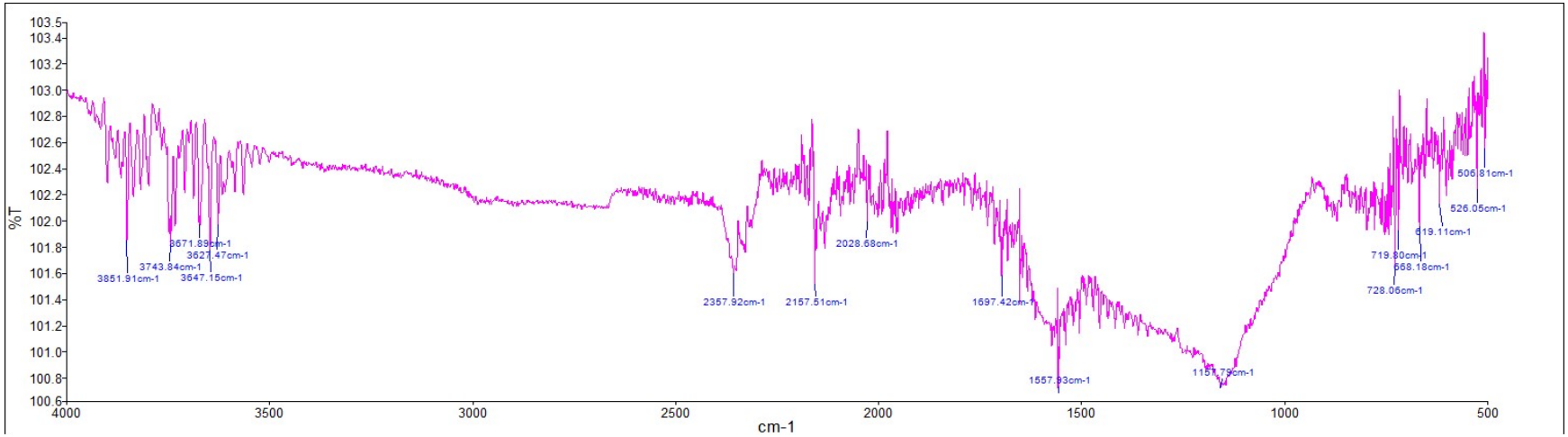

SCG4 in CO2
SCG4 in N2
Dry SCG in CO2
Dry SCG in N2
Yield Percentage
80
70
60
50
40
30
20
10
250
275
300
325
350
375
400
425
450
475
500
525
Temperature in Degrees Celcius

pH of biochar

- Raw biochar: (SCG0) pH 6-9 like other biochars.
- Our biochar is treated to be acidic.

SCG4 Wash-water pH					
Temperature	300	350	400	450	500
SCG4-N2	5.4	4.28	4.07	6.55	7.05
SCG4-CO2	3.15	3.85	7.04	6.98	7.08

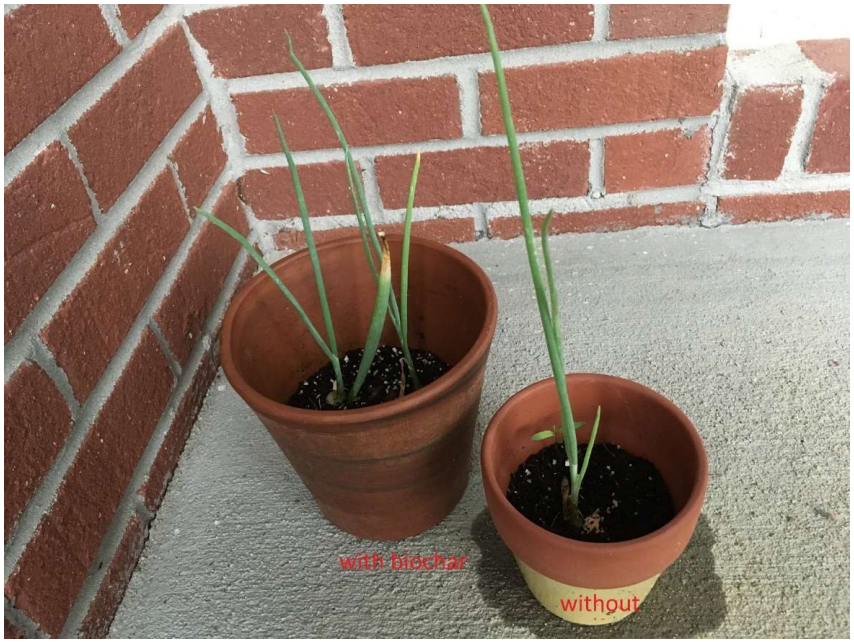

%T
cm-1
3851.25cm-1
3748.50cm-1
2920.57cm-1
2851.92
2362.78
2319.70
1701.30
1595.02cm-1
754.51cm-1
728.01cm-1
719.73cm-1
668.25cm-1
601.58cm-1
561.51cm-1
526.22cm-1
506.99cm-1


%T
cm-1
3851.91cm-1
3743.84cm-1
3671.89cm-1
3627.47cm-1
3647.15cm-1
2357.92cm-1
2157.51cm-1
2028.68cm-1
1697.42cm-1
1557.93cm-1
1151.79cm-1
719.80cm-1
728.06cm-1
668.18cm-1
619.11cm-1
526.05cm-1
506.81cm-1

SCG biochar applications

- Growth test
- Metal removal from aqueous phase
- Phosphorous absorption
- …

Tomato seeds and Chinese Onion tests

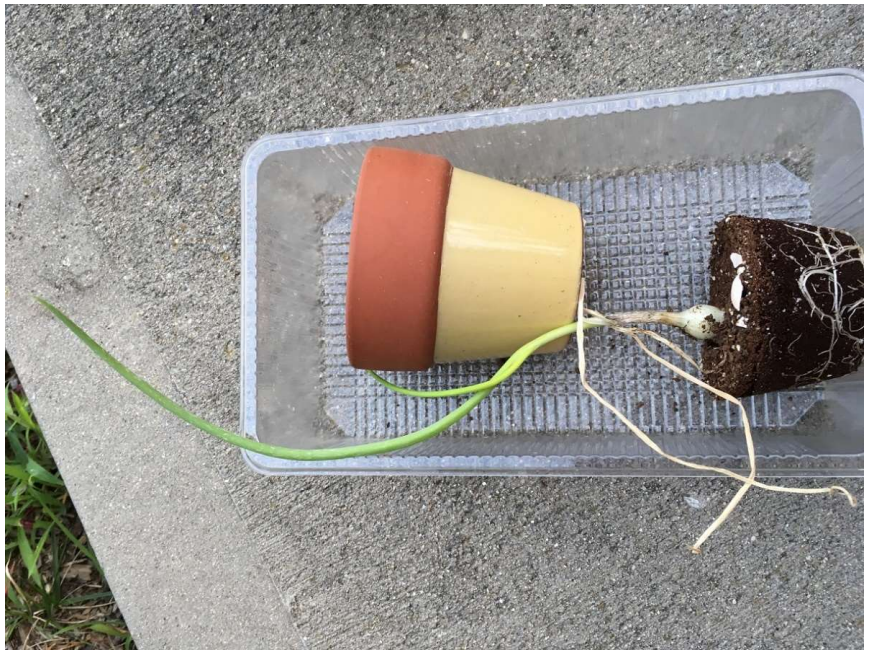


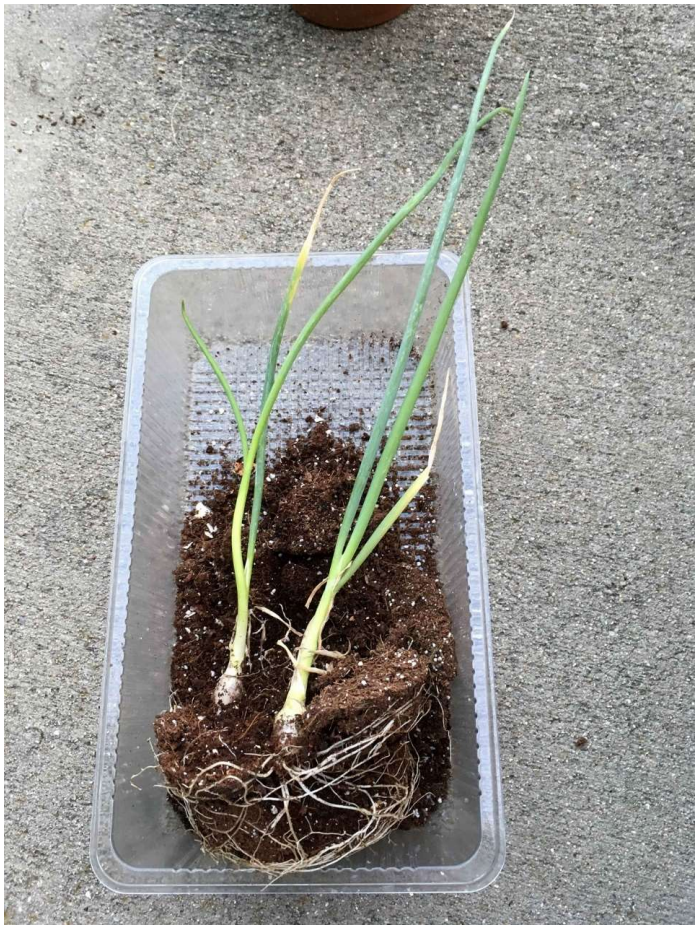
Two weeks of drought test

- The biochar pots clearly doing better, non-biochar tomato did not produce sprouts, 7/12

Results observed 2

Before moving into the garden, 7/27





Results and analysis

- Biochar onion survived in the garden (2 on the left), the non-biochar one (right) did not.
- Biochar may be very helpful in water retention. Offer better buffer conditions for changing conditions.
- Glass jar is NOT the best for growth, did not drain well.
- The clay soil in the garden can be a challenge
- Need to charge the biochar first
- A lot I need to learn

Biochar resources

- Many research articles
- IBI, USBI

African relevance

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Review on the Extent of Acid Soil in Ethiopia, Its Impact and Management Methods

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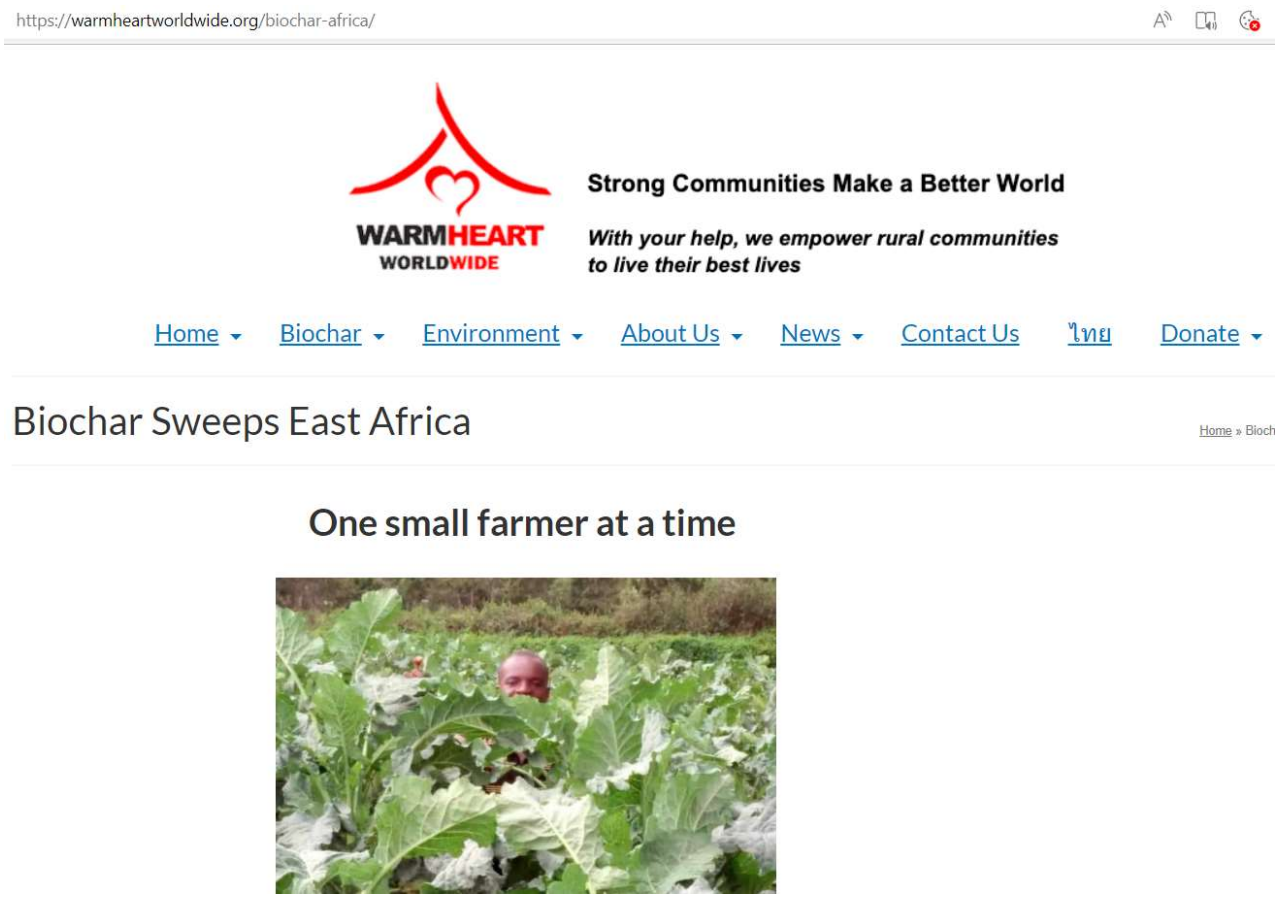
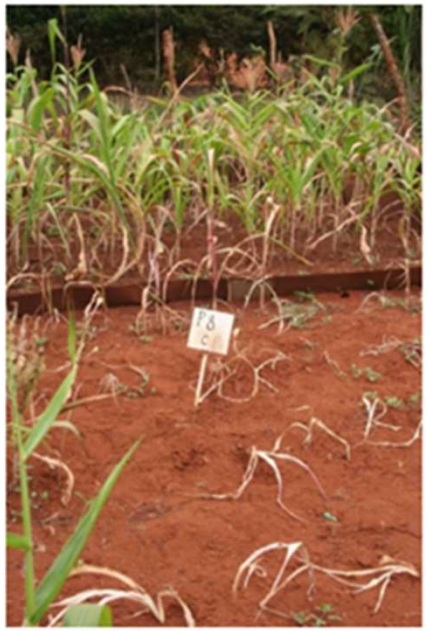
Abstract

Soil degradation is a global threat. Developing countries are more severely affected by soil degradation than developed countries. Ethiopia, one of the developing countries in eastern Africa, is highly threatened by soil degradation problems. Soil acidity is one of the main factors that limit and prevent profitable and sustained agricultural productivity in many parts of the world . The objective of this paper is to review the extent of acid soil distributions in Ethiopia, its impact on crop production and management practices. About 40.9% of the total arable land of Ethiopia is affected by soil acidity, from these 27.7% moderately to weak acids with pH 5.8-6.7 and 13.2% covered by strong to moderate acidic soils with pH less than 5.5. According to Ethio SIS, (2014) about 43% of the Ethiopian arable land is affected by soil acidity of these about 28.1% of soils in Ethiopia are dominated by strong acid soils (pH 4.1-5.5). Most of investigators confirmed that the two fundamental factors that limit the fertility of acid soils are: nutrient deficiencies, e.g. phosphorus (P), calcium (Ca) and magnesium (Mg) and the presence of phytotoxicity substances, e.g. soluble aluminium (Al) and manganese (Mn). To overcome these problems, different acid soil management has been implemented in the country. Thus many

https://warmheartworldwide.org/biochar-africa/



One example: Corn grown with and without biochar



Crop only

Crop +biochar

Crop + fertilizer

Crop+fertilizer+Biochar

Application in Botswana

- A large parts of Botswana's soil is sandy, which are low in nutrients and organic matter, and have poor water holding capacity and thus not so fertile for plants.
- Acid mine drainage
- Pollutant remediation, e.g. heavy metals

Bloomberg Philanthropies Allocates $2.8M For Biochar Project To Reduce Emissions

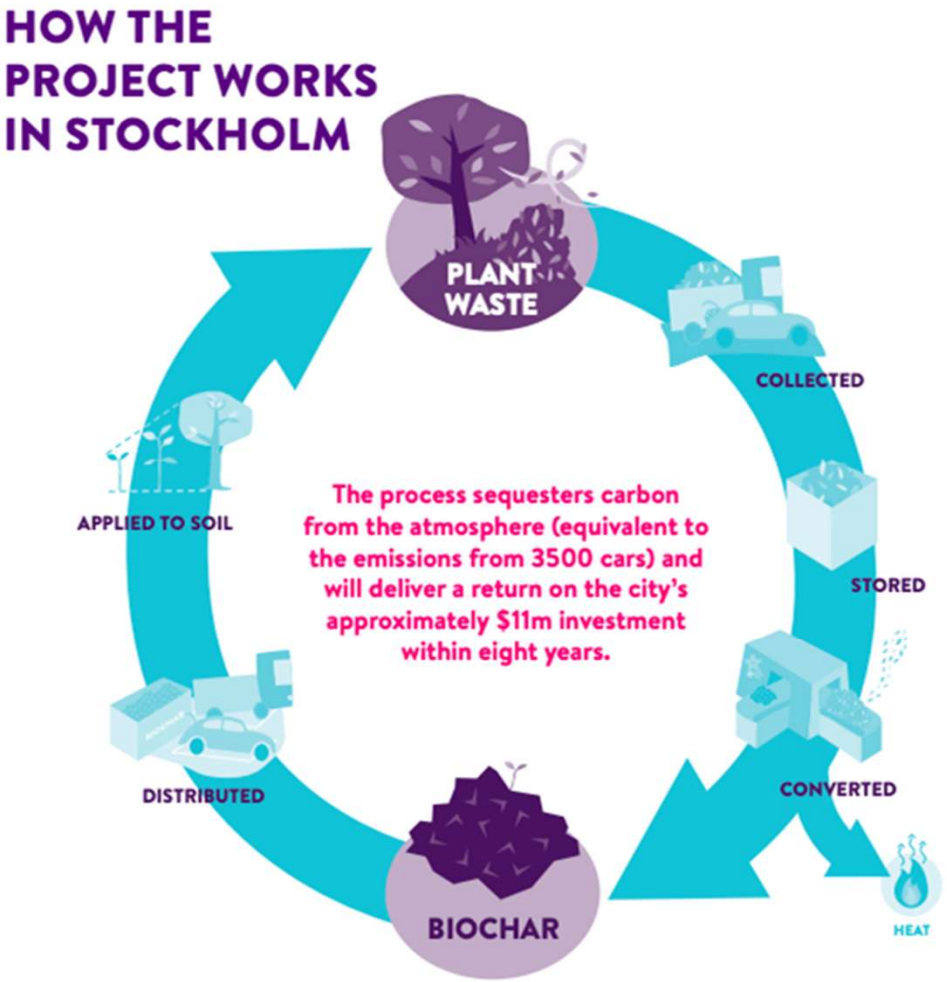
by **Petya Trendafilova** · August 15, 2022 · 2 minute read

Bloomberg Philanthropies – the organization aiming to create lasting change, announced on June 28th that it has chosen seven cities from the US and Europe to receive support to develop city-wide biochar project and engage residents in the fight against climate change.

The cities will each receive up to $400,000 in funding, along with implementation and technical support from Bloomberg Philanthropies. The cities are as follows: Lincoln in Nebraska; Minneapolis, Minnesota; Darmstadt, Germany; Helsingborg, Sweden; Sandnes, Norway; Helsinki, Finland; Cincinnati, Ohio.

Bloomberg Philanthropies Allocates $2.8M For Biochar Project To Reduce Emissions (carbonherald.com)
https://carbonherald.com/bloomberg-philanthropies-allocates-2-8m-on-biochar-project-to-reduce-emissions/

Stockholm Biochar Project



COLLECTED

NO ADDITIONAL FINANCIAL OR CARBON COST

Both citizens and the city already deliver park and garden waste at a network of waste management centers across Stockholm.

STORED

NO ADDITIONAL FINANCIAL OR CARBON COST

These waste management centers already have plant waste storage facilities.

CONVERTED

HIGH ADDITIONAL FINANCIAL COST

The project requires an upfront capital investment, both to purchase the plant and prepare the site. Plant waste also needs to be chipped before it can be used in the plant.

NEW REVENUE

As well as turning plant waste into biochar, the carbonization process produces heat which is sold into the grid in order to heat local homes.

DISTRIBUTED

NO ADDITIONAL FINANCIAL OR CARBON COST

Citizens and city gardeners pick up biochar from waste management centers when they are dropping off their plant waste.

NEW REVENUE

Biochar is sold to the open market and to the the city's traffic adminstration team (the department that manages the city's trees). It will be gifted to citizens.

APPLIED TO SOIL

NO ADDITIONAL FINANCIAL OR CARBON COST

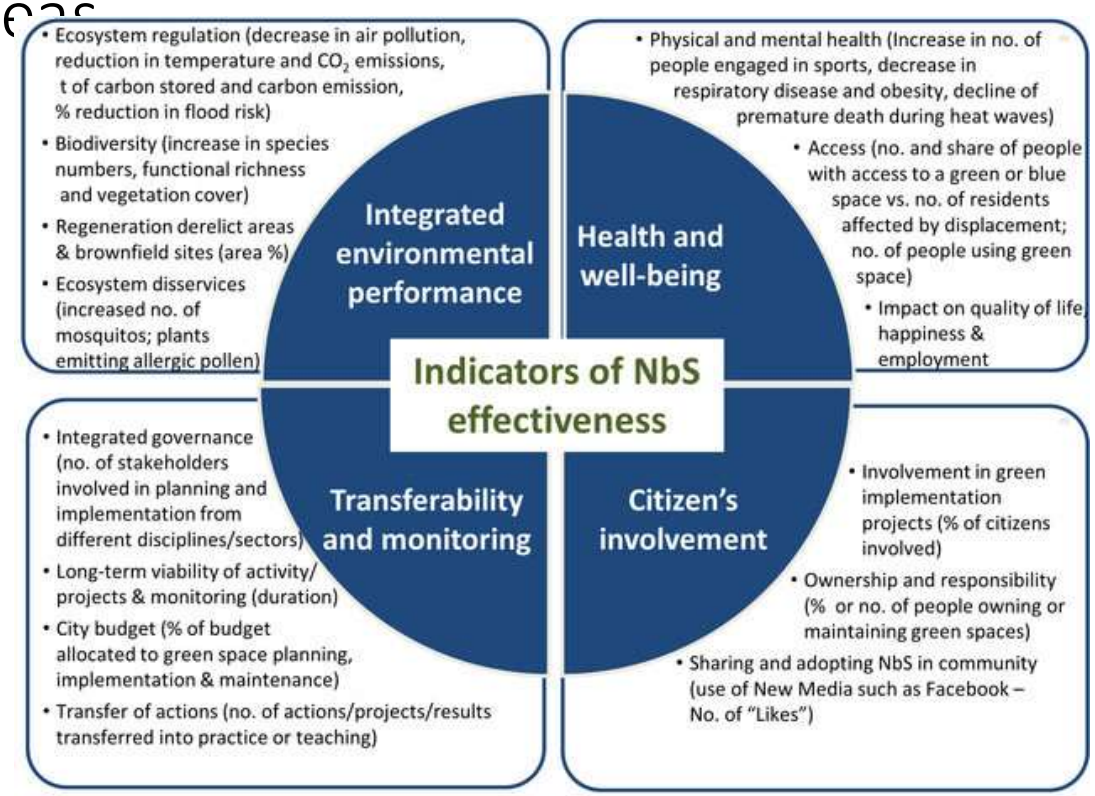
City gardeners and citizens apply biochar to their parks and gardens in the course of their regular activity.

NEW CARBON SAVING

When planted with trees or plants biochar increases growth while sequestering carbon dioxide from the atmosphere.

Nature-Based Solutions in Urban areas

Integrating nature into cities can provide citizens with urban cooling, cleaner air, regulated water supplies, food security, flood protection, and a greater sense of emotional, mental, and spiritual well-being.



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- Ecosil LLC: Dr. Maggie Zhu and Art Helmstetter
- Carbon Harvest LLC :Sam Dunlap
- Students: Dr. Qingshi Tu, Yang Liu, Suhas Srivastava, Garrett Schwein, Elizabeth Williams, Deshui Xu, Jinqi Liu, Alessia Torboli, Omer Alomari …

Thank you.

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