Northern Minnesota Closed Cycle Biochar Pilot 2023-2025

Funded by USDA Forest Service *An Equal Opportunity Provider*

Goal: Demonstrate the Soil health impact of biochar applied to crop and pasture fields on sandy, clay, and loam soils.

Project Scope: Through field scale applications of biochar only and biochar mixed with on farm manure supplies, this project will explore all aspects of planning, and implementing the U. S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) 336 Soil Carbon Amendment practice.
The project found farmer partners in Carlton County MN that had hay, pasture, and crop fields on sandy, clay, and loamy soils.

Sites: Site 1. S&K Ranch is a 310 acres farm raising row crops, hay and utilizing pasture to support a 40 cow/calf pair beef herd. Soil type on project fields is Ahmeek-Normanna-Canosia complex – loamy soils.

Site 2. Rob and Laura Sandstrom farm 26 acres as sheep pasture along with chickens in the farmstead.
Soil type in project pasture area is Omega loamy sand.

Site 3. This 310 acre property consists of hay fields and woodlands. The property is owned by Minnesota Power and the hay land is cropped by contract with local farmers. The project field has not seen any soil amendments for over 10 years including not ever being reseeded in at least that time period. Soil type is Cloquet fine sandy loam.

Site 4. Heikes Farms operates 917 acres on their home farm and another 600 acres of cropland in the surrounding area of Holyoke, MN and Foxboro, WI. This 1500 acres supports a 130 cow calf pair beef herd along with 40 feeders. In addition, Heikes Farms supplies straw products to various erosion control companies and hay products to a wide variety of livestock operation in the region. Soil types on the home farm are Ontonagon and Bergland Clay, while on the WI project field 7 miles away the soil type is Manitowish sandy loam.

Field Assessments: Using the NRCS In Field Soil Health Assessment Tool all project fields were assessed for Resource Concerns related to soil health. Soil samples were collected from each field and submitted to 2 separate independent labs for their soil health suite analysis plus water holding capacity, soil respiration, organic matter, and aggregate stability. This sets the existing soil conditions.

Biochar: Biochar was purchased from Terra Char. The original batch IBI was done in 2015 so a new IBI was run to document current biochar parameters. The biochar was order wetted to allow easier handling on the farm and reduce product loss from handling an outside storage. Delivery was made in early October by 3 separate semi pulled dump trailers from Missouri. Moisture stated on the IBI was 62%. The particle size was small with 31% < 0.5mm, 26% 0.5 - 1mm, and 21% 1 - 2mm.
Dump sites were located at 3 of the 4 participating farms. Sites 2 and 3 shared one load.

Biochar-Manure Mixing: Site 1 mixed the biochar with beef manure by tractor and bucket. Piles for each plot were made separately and each pile was mixed once in the 16 day inoculation period.
Site 2 mixed the biochar with Sheep manure with a skid steer bucket. The pile sat for 5 months over winter and was mixed before being spread in the spring.
Site 3 only used biochar.

Site 4 mixed the biochar with beef manure by loading a large manure spreader with tractor and loader and then running the spreader to mix and offload into a pile. The pile sat for 31 days from mid-December through mid-January.
All project sites used a 40% biochar – 60% Manure mix ratio consistent with one of the MN NRCS cost share scenarios. All three mixes were sampled and submitted for a standard manure analysis plus soil respiration, organic matter.

Demonstration Plot Design: The project sought input from University of MN regional Extension Educators on plot design. All crop plots in the demonstration contained these same trials.

Plots were adjusted to the acreage available at the farm.

		Volumes in cu. yds.			
Farm	Plot	Biochar	Manure	Acres	# of trials
Risacher	Hay	13.6	18.4	8.3	7
	Bale Graze	8.0	0.0	2	2
	Farm Total	21.6	18.4		
Sandstrom	Pasture	6.8	9.2	3.5	7
	Farm Total	6.8	9.2		
Hikes	Hay	27.2	36.8	14	7
	Pasture	13.6	18.4	7	7
	Rye	27.2	36.8	14	7
	Farm Total	68.0	92.0		
MP	Hay	48.0		8	5

Site 1 also implemented a biochar only demonstration on 2 acres of bale grazing pasture.
Site 3 had no access to manure, so biochar only was applied at 4, 8 and 12 cu. yds./ac. rates.

Application: Biochar/manure mixes were applied to plots using manure spreaders supplied by the farmers.

Follow up testing:

<u>Soils:</u>
Soil samples from each of the projects 42 trials will be collected annually for 3 years (2024, 2025, 2026) and submitted to the lab for the exact same analysis as were done in the pre application stage.

<u>Forage:</u>
Forage volumes will be collected from each of the 42 trials for the same 3 years to document any changes in forage production.

Field Days: Field days will be coordinated on all 4 sites in the late summer after the first crop hay has been harvested. Field days will be held in 2024 and 2025.

PLACE-BASED BIOCHAR PRODUCTION

~Oregon Kiln~

- Flame Capped unit
- DIY or $<2000 locally
- Blueprints available on-line
- 1.5 cubic Yard capacity

by Harry Groot

~Ring of Fire~

- Flame Capped unit
- DIY or $<3500 from Wilson Biochar Associates
- ~ 3 cubic Yard capacity

courtesy of USBI

~Big Box Kiln~

- Flame Capped unit
- DIY or <$5,000 local shop
- up to 20CY capacity

by John Webster

~Closed Retort~

- Various designs on line for purchase (COZ or Exeter design shown)
- DIY to $20,000
- ~1.5 CY capacity

by Harry Groot

~Char Boss Jr~

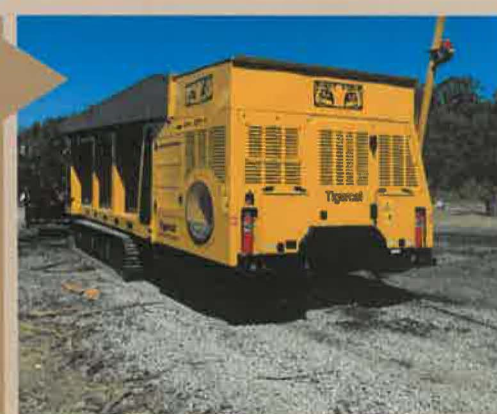
- Air Curtain/Flame Capped unit
- $150,000 by Air Burners, Inc.
- ~5% biochar from processing
- 2-3 Tons/hour of operation

by Harry Groot

~Carbonator~

- Air Curtain/Flame Capped unit
- $750,000 by TigerCat
- ~5% biochar from processing up to 20 Tons/hour

by EarthFounderies, Inc.



Place Based Kiln Comparisons

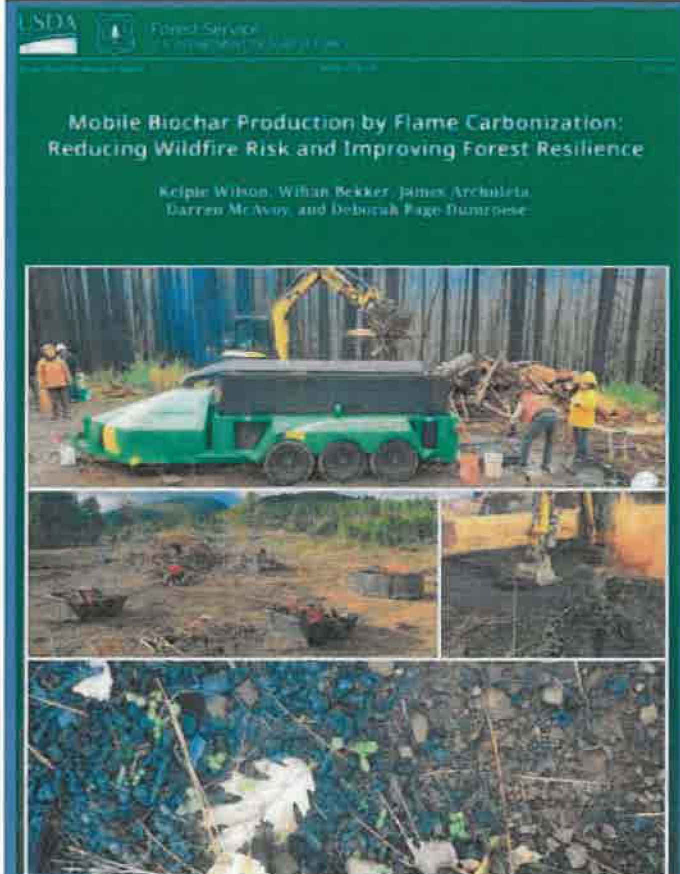


Table 9—Emission factors (grams per kilogram dry biomass) for wildfires, burn piles, flame-cap kilns, and air curtain burners.

Type	PM10	PM2.5	Nitrous oxide (NOx)	Methane (CH4)	Carbon dioxide (CO2)	Carbon monoxide (CO)	Source
Wildland fire	—	23.2	2.00	7.3	**1,600**	**135.0**	**Urbanski 2014**
Burn pile, flaming	4.0	—	—	1.0	—	28.0	Springsteen et al. 2011
Burn pile, smoldering	7.0	—	—	8.5	—	116.0	Springsteen et al. 2011
Burn pile, dry	—	4.5	—	1.1	1,785	29.0	Aurell et al. 2017
Burn pile, wet	—	18.0	—	5.7	1,689	82.0	Aurell et al. 2017
Slash pile burn	4.4	3.9	2.30	4.5	1,690	65.3	Puettmann et al. 2020
Flame-cap kiln	1.3	—	0.14	2.6	780	2.6	Puettmann et al. 2020
Large air curtain burner	—	0.6	—	0.7	1,808	1.3	Susott et al. 2002
BurnBoss® air curtain burner	2.1	—	1.00	0.3	—	7.1	Montrose Air Quality Services 2023

— Indicates no data.

Table 6—Biochar productivity comparison (based on one 8-hour shift).

Technology type	Typical scenario	Hand crew per shift	Machine operator for loader per shift	Biomass processed per shift by dry mass, tons (metric tonnes)	Biochar production per shift by volume, cubic yards (cubic meters)	Total water required per shift, gallons (liters)
Conservation burn pile (CBP)	Hand piles (150 piles)	5	N/A	22 (20)	11 (8)	1,000 (3,800)
	Machine piles (30 piles)	4	1	99 (90)	27 (21)	9,000 (34,000)
Flame-cap kiln (FK)	Ring of Fire Kiln® (4 kilns)	5	N/A	8 (7)	12 (9)	600 (2,300)
	Oregon Kiln (6 kilns, 2 batches)	5	N/A	8 (7)	12 (9)	600 (2,300)
	Big Box Kiln (2 kilns)	2	1	11 (10)	16 (12)	600 (2,300)
Air curtain burner (ACB)	BurnBoss® (1 unit, 2 batches)	1	1	12 (11)	6 (5)	500 (1,900)
	CharBoss® (1 unit, continuous)	2	1	5 (4)	6 (5)	300 (1,100)
	Tigercat 6050 (1 unit, continuous)	2	2	56 (51)	16 (12)	3,000 (11,300)

Table 8—Recommended feedstock size limits for optimizing biochar production. Larger material can be processed, but will have lower biochar yields.

Biochar production method	Seasoned feedstock diameter or thickness inches (cm)			Acceptable average moisture content percent		Green feedstock diameter or thickness inches (cm)			Green feedstock diameter or thickness feet (m)		
	4 (10)	12 (30)	18 (46)	25	50	3 (8)	6 (15)	12 (25)	6 (1.8)	10 (3)	20 (6)
Hand pile	X	—	—	X	—	X	—	—	X	—	—
Machine pile	—	X	—	X	—	—	X	—	—	—	X
Oregon Kiln	X	—	—	X	—	X	—	—	X	—	—
Ring of Fire Kiln®	X	—	—	X	—	X	—	—	X	—	—
Big Box Kiln	—	X	—	X	—	—	X	—	—	X	—
BurnBoss®	—	X	—	—	X	—	X	—	—	X	—
CharBoss®	—	X	—	—	X	—	X	—	—	X	—
Tigercat 6050	—	—	X	—	X	—	—	X	—	—	X

— Indicates no data.

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Biochar Production Variables

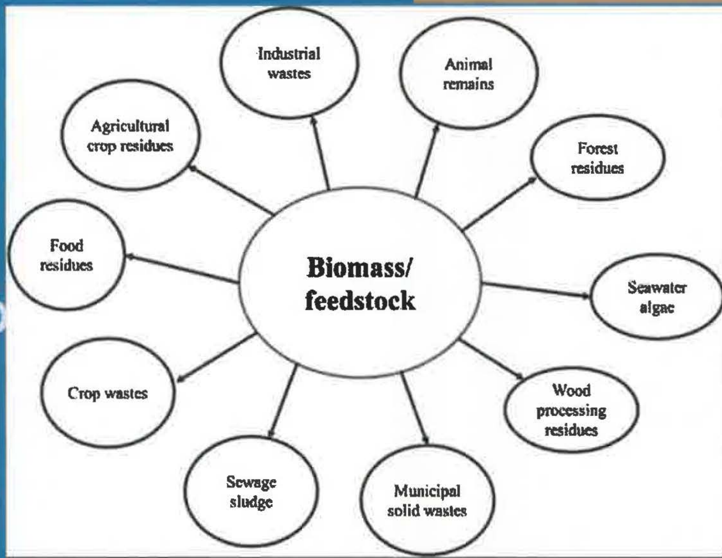

Figure 1

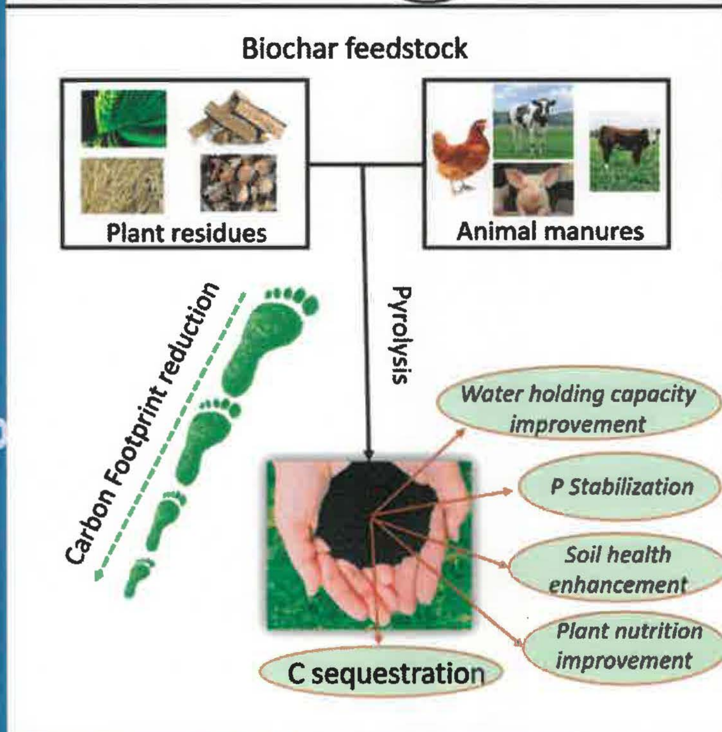

Figure 2

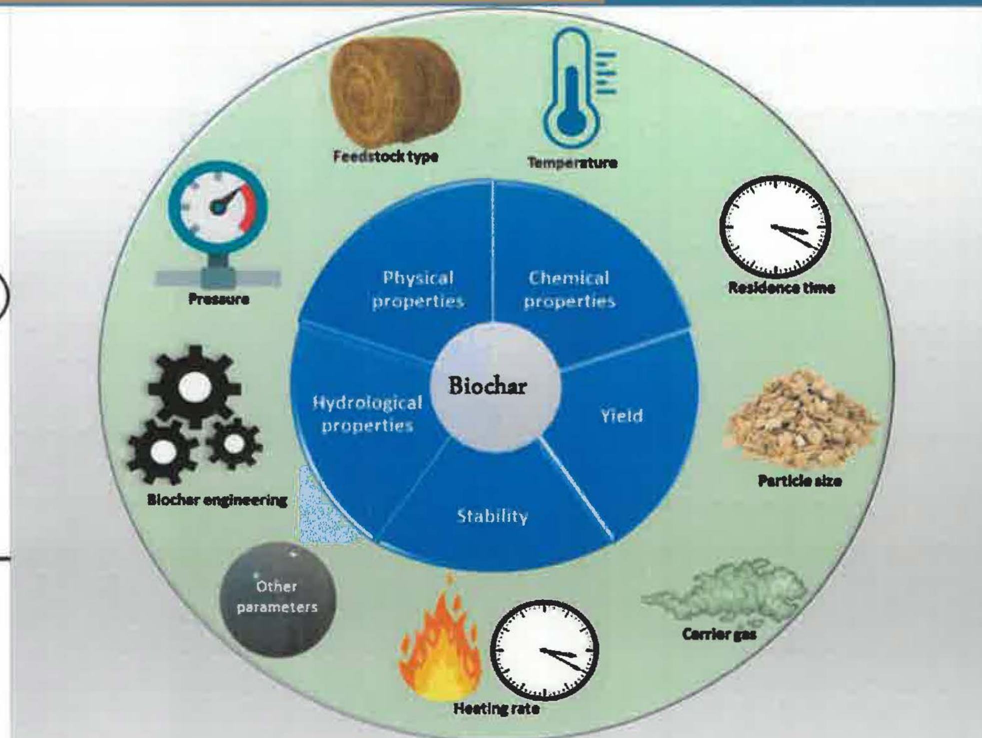

Figure 3

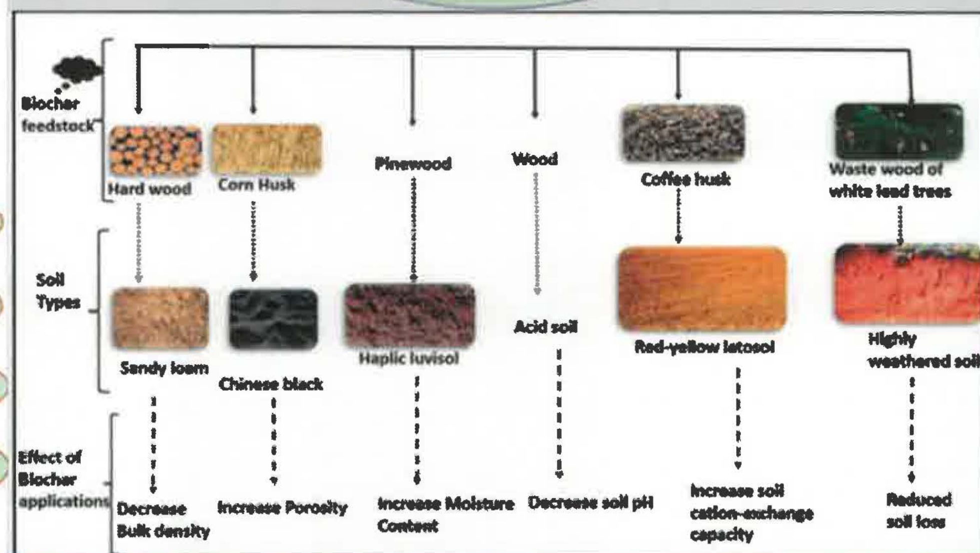

Figure 4

Credits

Figure 1: Wani, Insha & Kushvaha, Vinod & Garg, Ankit & Kumar, Rakesh & Naik, Sambit & Sharma, Prabhakar. (2022). Review on effect of biochar on soil strength: towards exploring usage of biochar in geo-engineering infrastructure. Biomass Conversion and Biorefinery. 1-32. 10.1007/s13399-022-02795-5.
Figure 2: Nair VD, Mukherjee A. The use of biochar for reducing carbon footprints in land-use systems: prospects and problems. Carbon Footprints 2023; 2(1): 6. http://dx.doi.org/10.20517/cf.2022.13
Figure 3 Fawzy, S., Osman, A.I., Yang, H. et al. Industrial biochar systems for atmospheric carbon removal: a review. Environ Chem Lett 19, 3023–3055 (2021). https://doi.org/10.1007/s10311-021-01210-1
Figure 4 Alex P., Mohammed Ismail KP, Meenatchisundaram N, Ramanathu P, Sai Bharadwaj AVSL. Agricultural Biomass Waste to Biochar: A Review on Biochar Applications Using Machine Learning Approach and Circular Economy. ChemEngineering 2023, 7(3):50. https://doi.org/10.3390/chemengineering7030050

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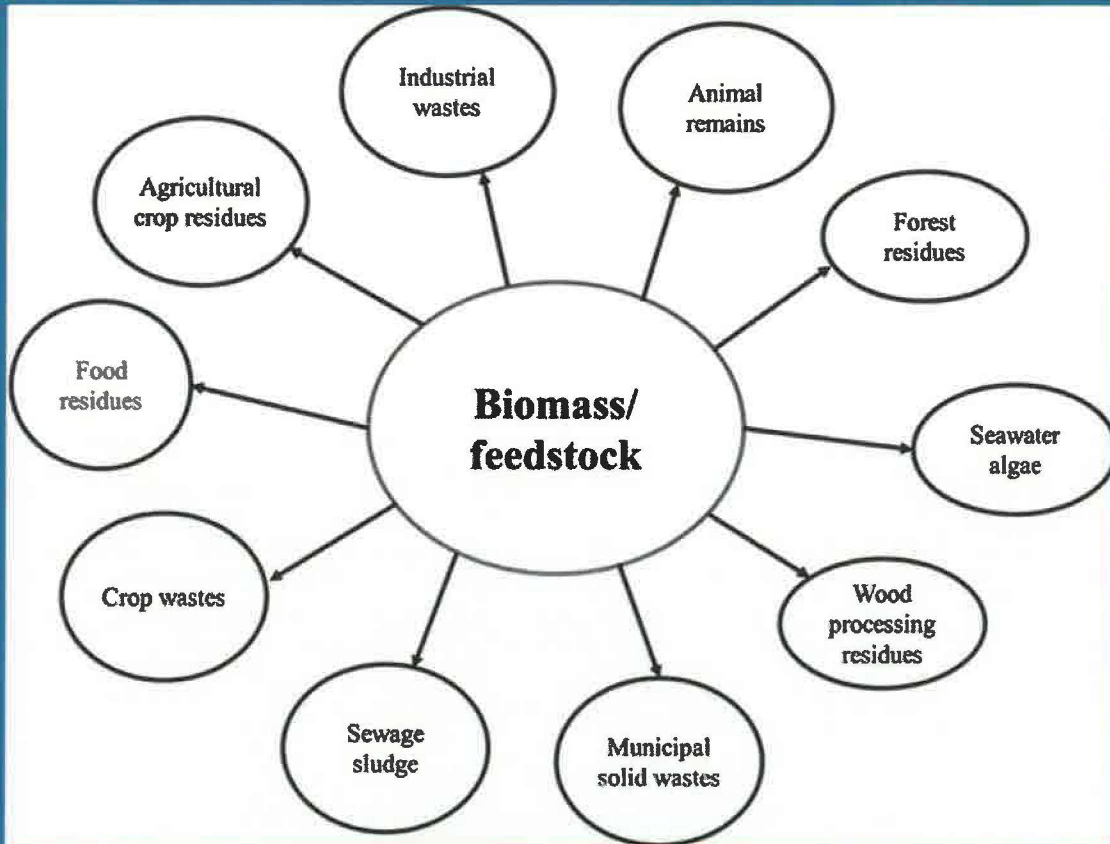

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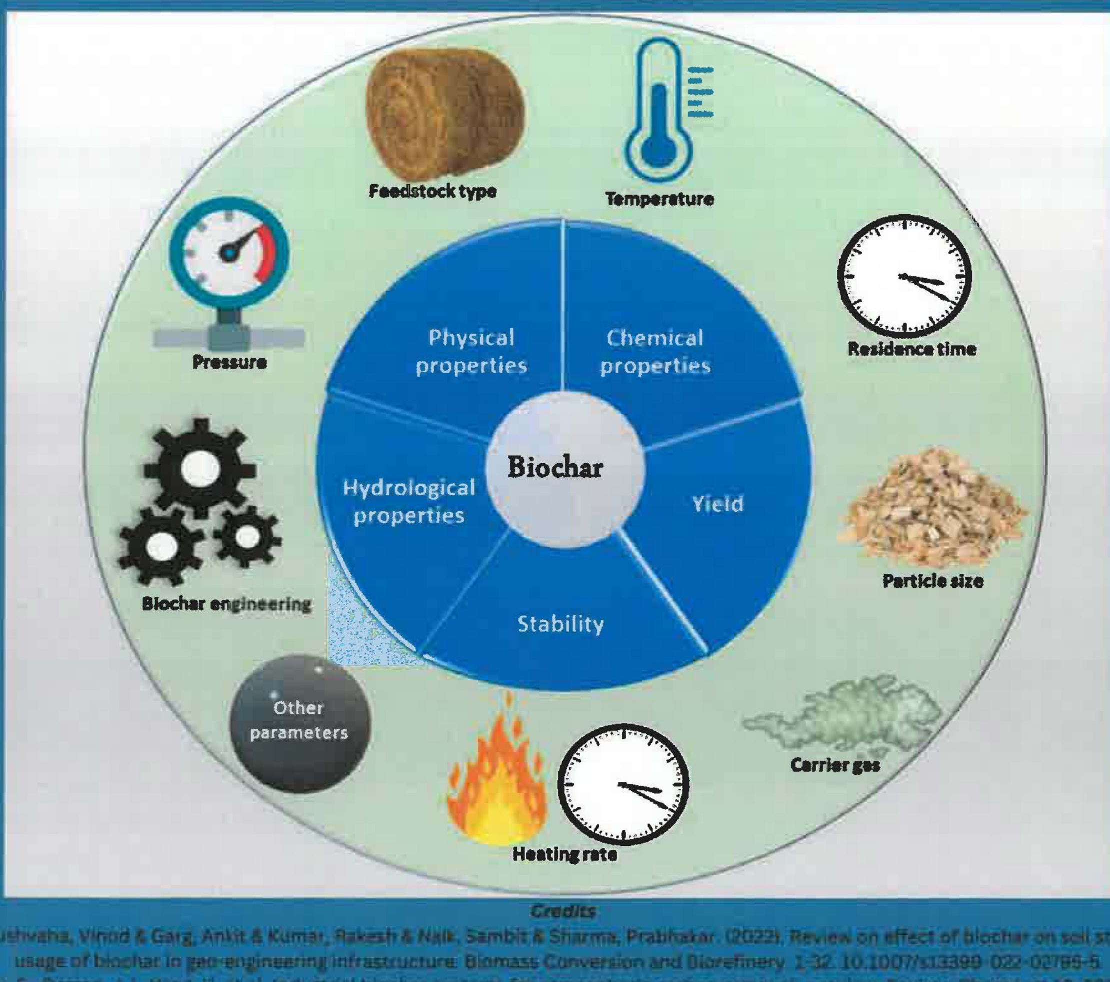

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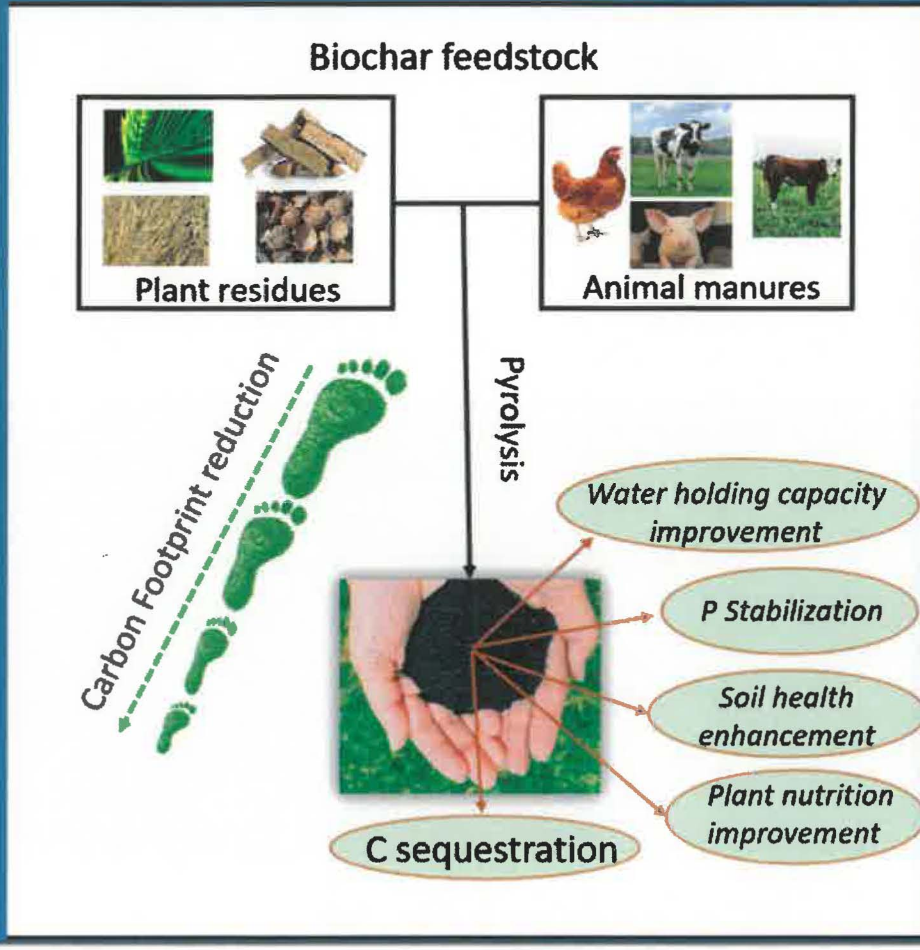

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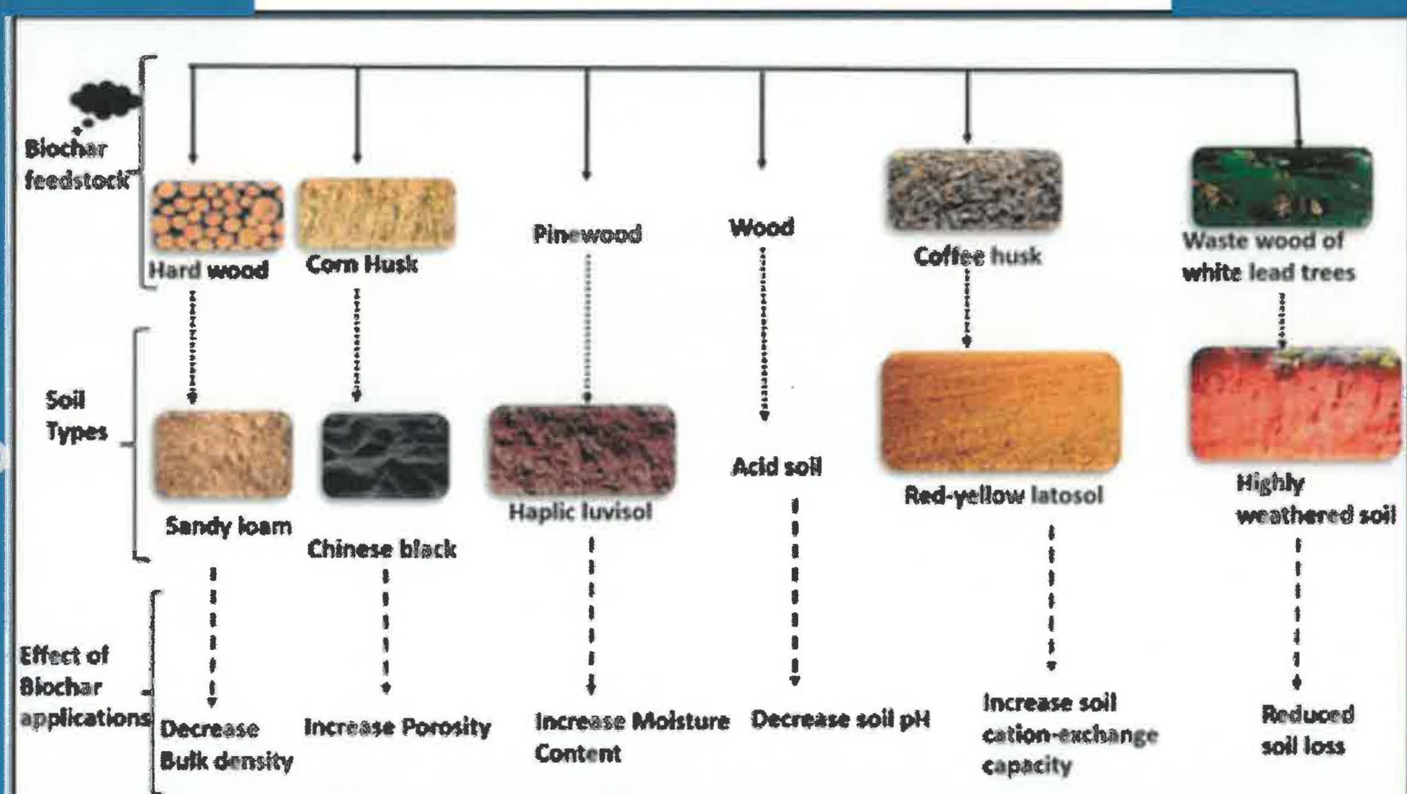

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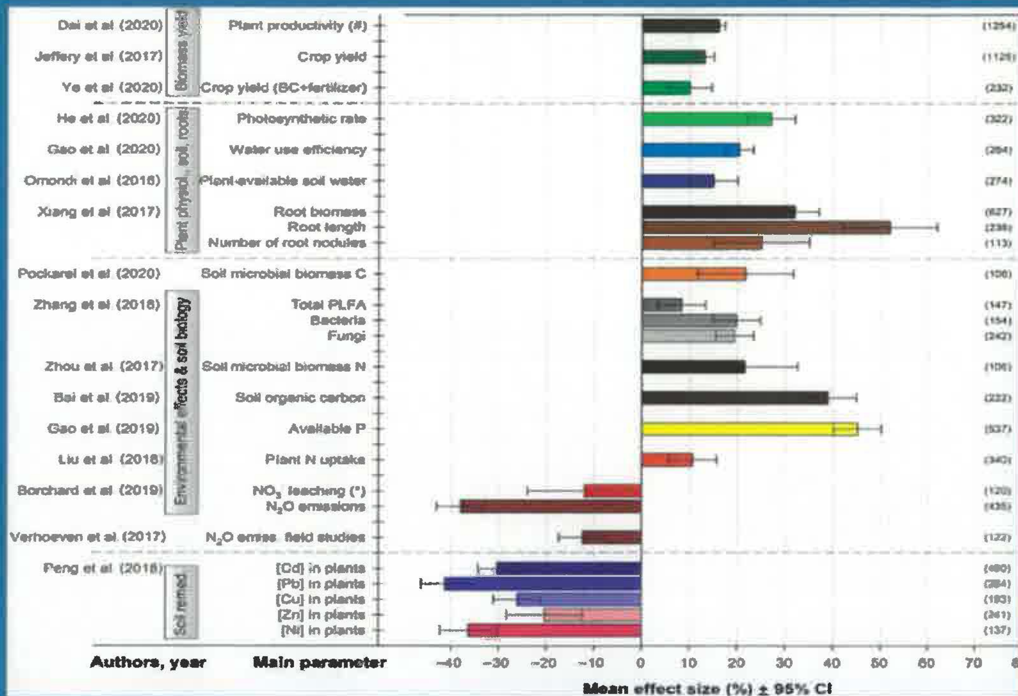
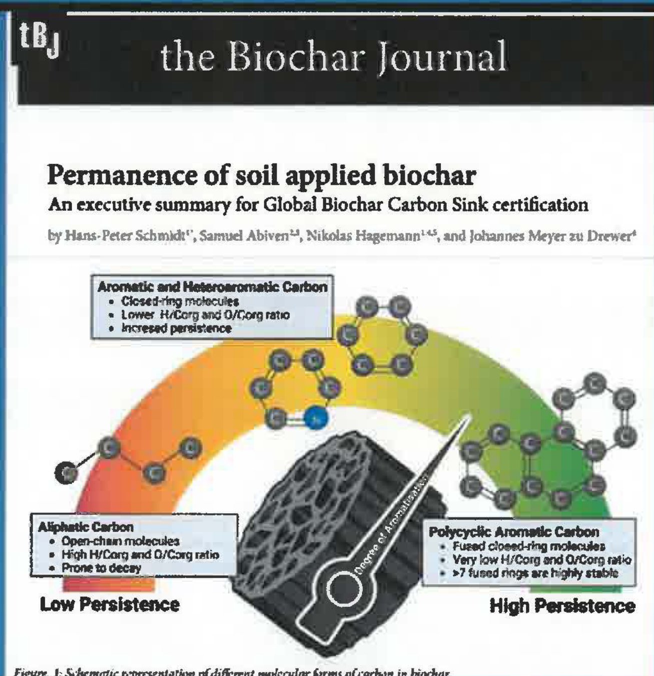
Useful Biochar References

Biochar in Agriculture

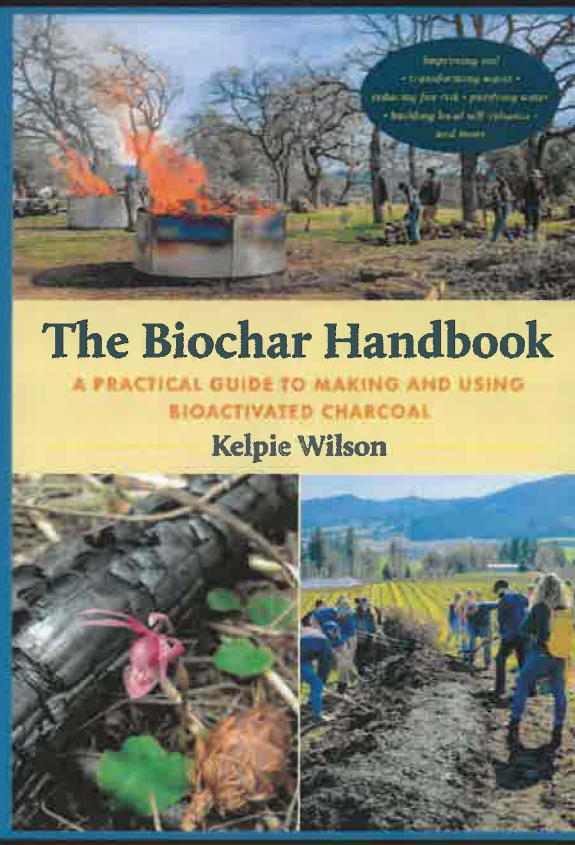
Credit: Biochar in agriculture –A systematic review of 26 global meta-analyses; Schmidt et al. 2021



Hans-Peter Schmidt; Kammann, Claudia; Hagemann, Nikolas; Leifeld, Jens; Bucheli, Thomas D ; et al. Global Change Biology. Bioenergy; Oxford Vol. 13, Iss. 11, (Nov 2021): 1708-1730. DOI:10.1111/gcbb.12889



Schmidt HP, Abiven S, Hageman N, Meyer zu Drewer J: Permanence of soil applied biochar. An executive summary for Global Biochar Carbon Sink certification, the Biochar Journal 2022, Arbaz, Switzerland, www.biochar-journal.org/en/ct/109, pp 69-74



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