Biochar in the Global Sustainability Discussion

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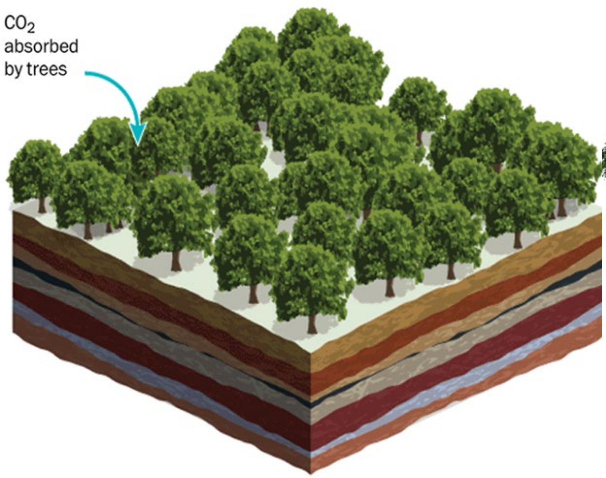
Biochar in Climate Change Mitigation

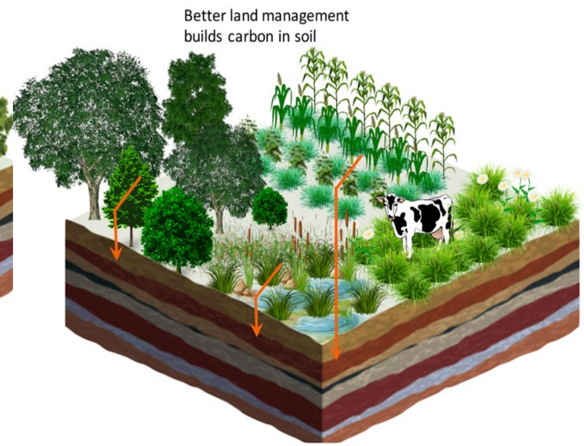
Large U.S. bi-partisan public support for soil organic carbon and biochar sequestration – perceived 'naturalness'

No difference between positive perception of biochar and soil organic carbon

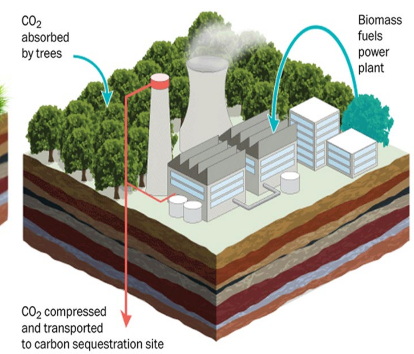
73%



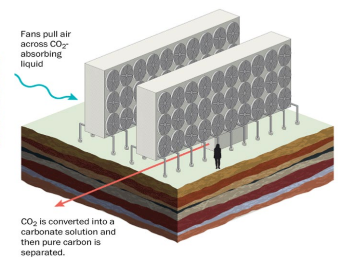
62% soil
55% biochar



32%



25%



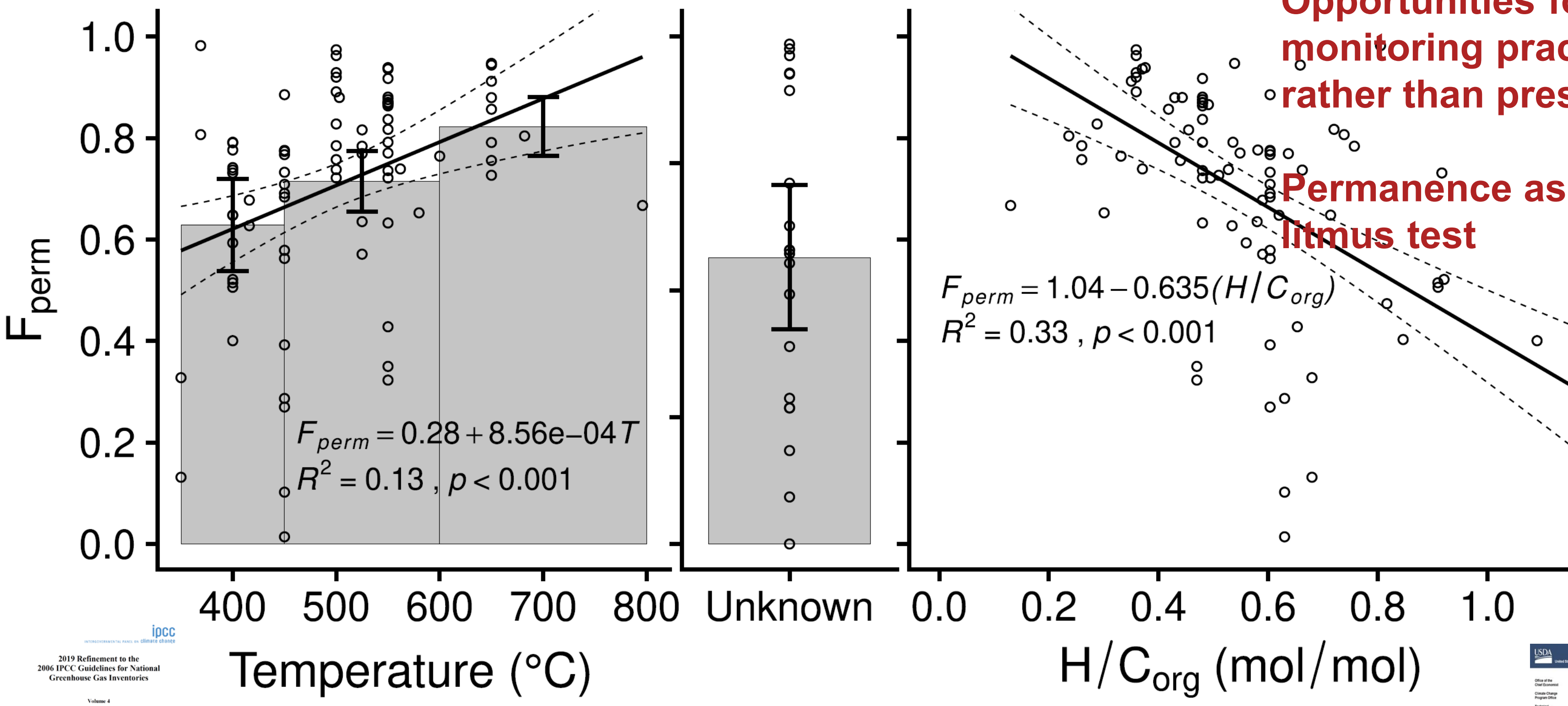
1222 US adults, Oct 2019

Cornell University

Sweet et al., 2020, *Climatic Change* 166, 22

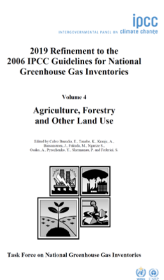
Biochar Carbon Market Methods

Higher pyrolysis temperature ≈ higher condensation



Opportunities for monitoring practice rather than presence

Permanence as litmus test


ipcc
2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Volume 4

Agriculture, Forestry and Other Land Use

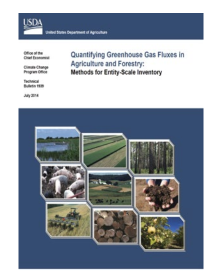
Task Force on National Greenhouse Gas Inventories

CLIMATE ACTION RESERVE

Verified Carbon Standard

puro·earth

Carbonfuture


USDA

Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory

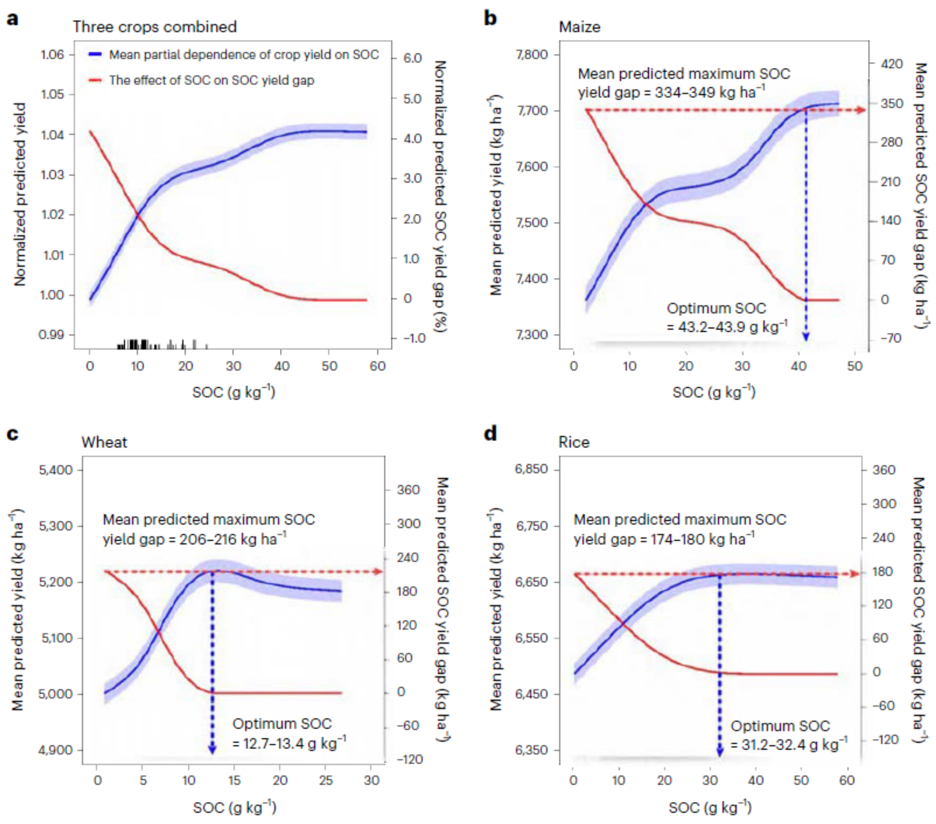
Cornell University

Woolf et al 2021 *Environmental Science & Technology* 55, 14795−14805

(Only experiments longer than one year, 2-pool model, adjustable environment °C)

Climate change mitigation and Land care

No land (crop growth?) benefits = no biochar adoption?

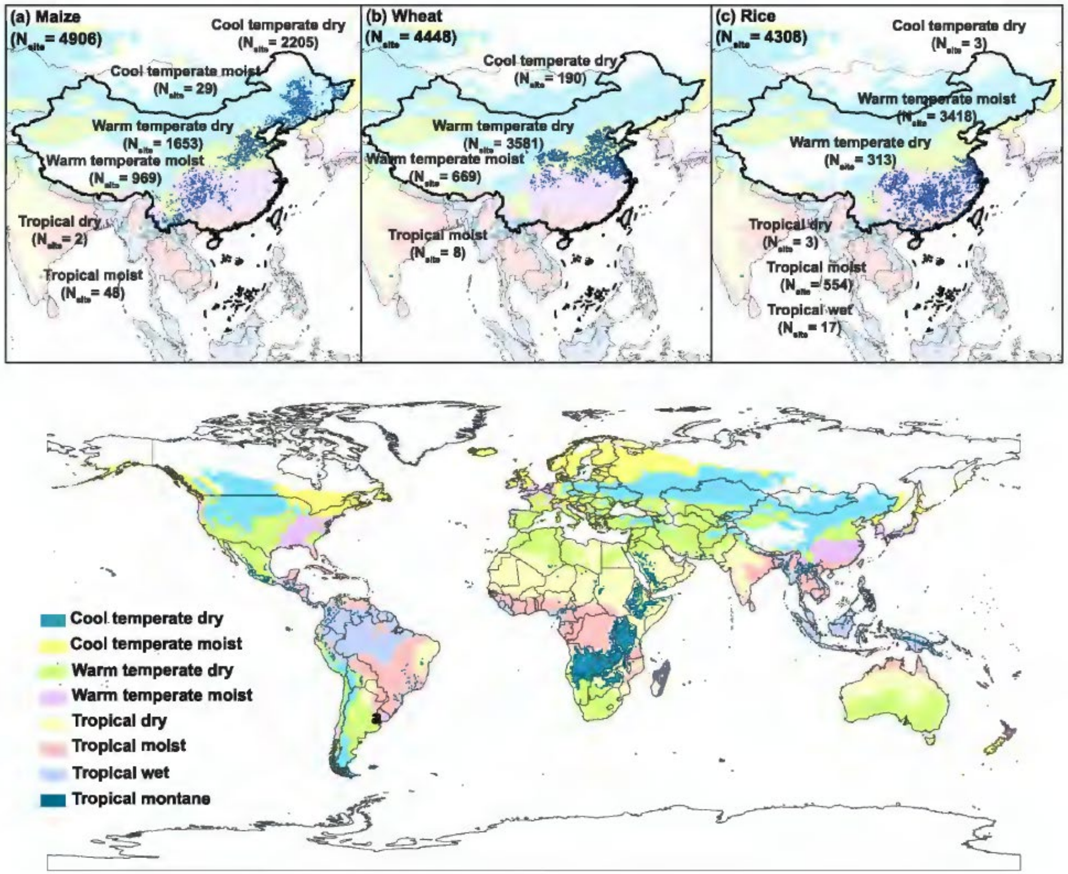


Higher Soil organic C = greater crop growth Average increase is small….

Cornell University

Ma et al., 2023, *Nature Geoscience* 16, 1159-1165

Climate change mitigation and Land care



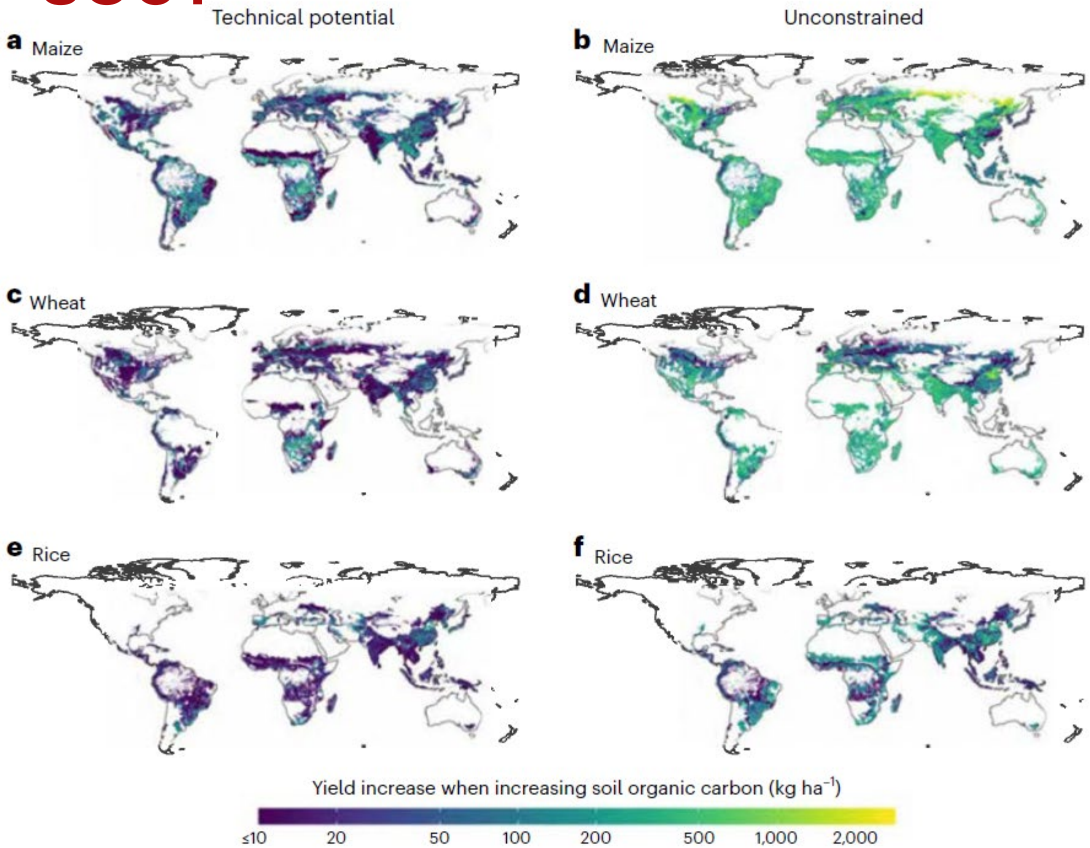
13,662 controlled field trials with 66,593 treatments across a broad range of soils, climates and management practices representing ten of the 12 soil texture classes pH values of 3–9, SOC of 1–58 g kg−1 exceeding the average range observed for global producing regions of these crops

Cornell University

Ma et al., 2023, *Nature Geoscience* 16, 1159-1165

Climate change mitigation and Land care

Regionally different SOC yield gap – redistribution of SOC?



Current technology:
120 million people's cereal need
Unconstrained:
700 million
six times larger than the technical potential

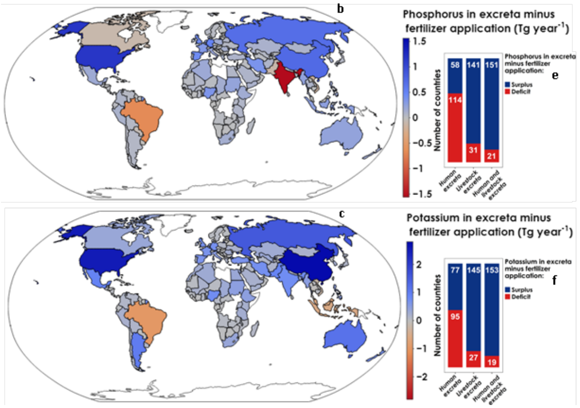
Affordable?
Unintended consequences?
Feasible?
What scale? (regional-global)

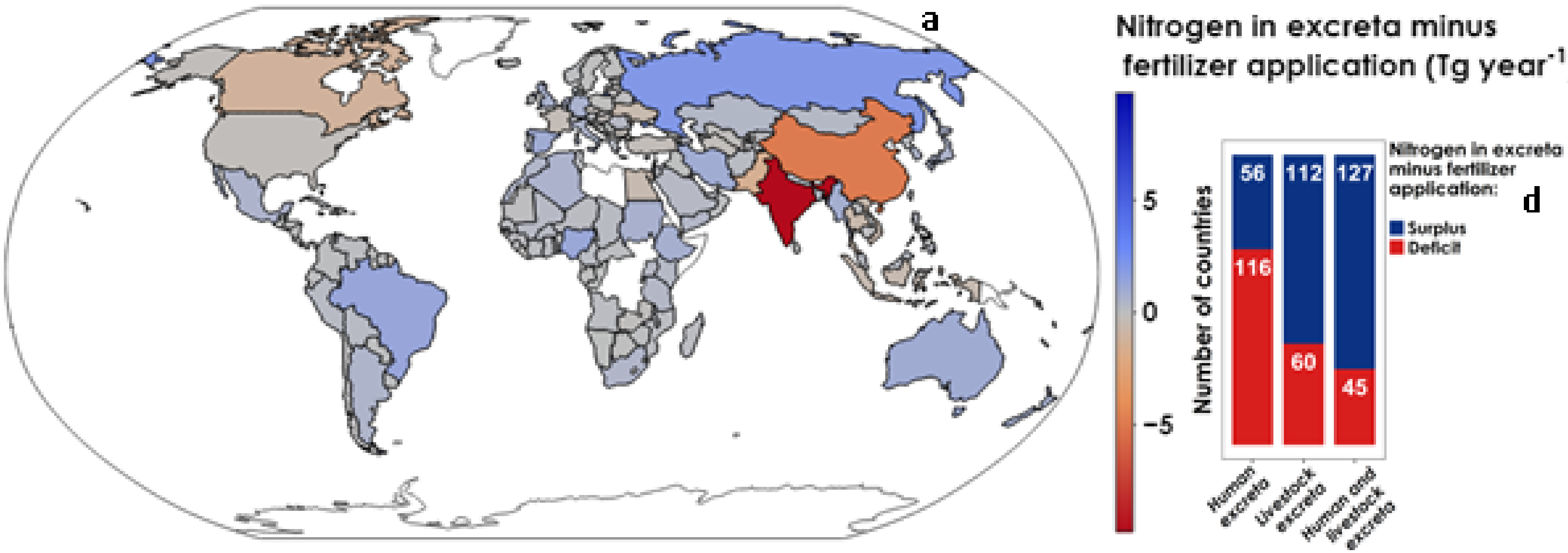
Ma et al., 2023, *Nature Geoscience* 16, 1159-1165

Not just carbon…

More N-P-K flushed down the toilet than added (or imported) as fertilizer for crops

(Nitrogen: in 56 countries, 127 with livestock)



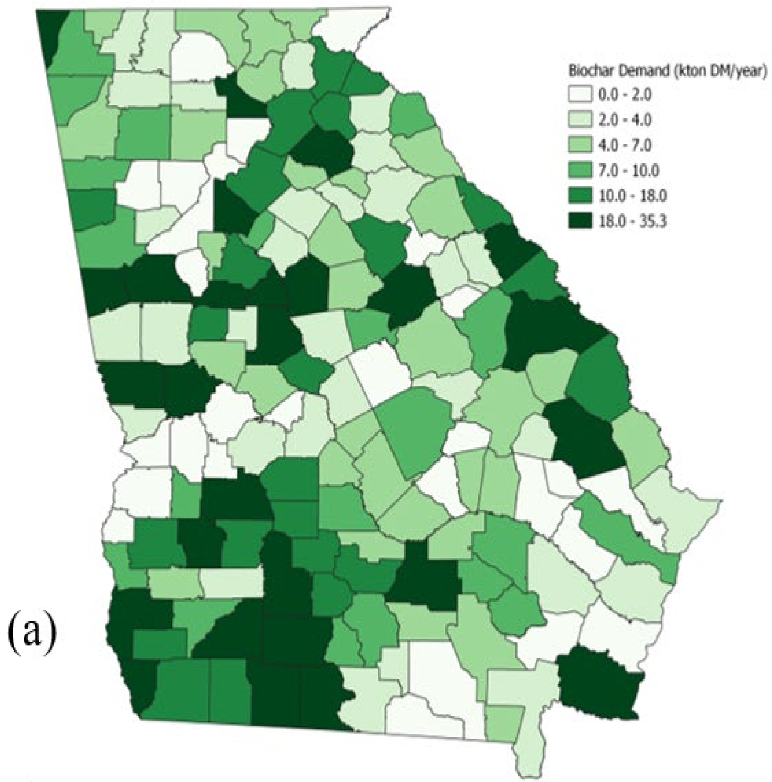


Devault, Lehmann, Woolf, in revision.

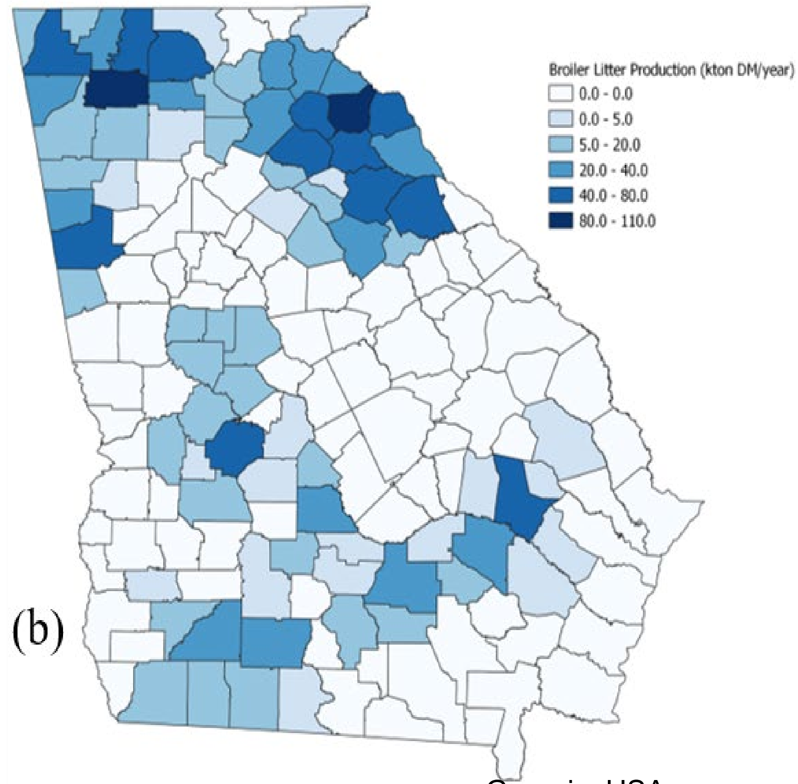
Redistribution – example animal excreta

Regional mismatch of resource and need (causing costs and environmental burden)

Biochar P Demand



Poultry Litter Production



Georgia, USA

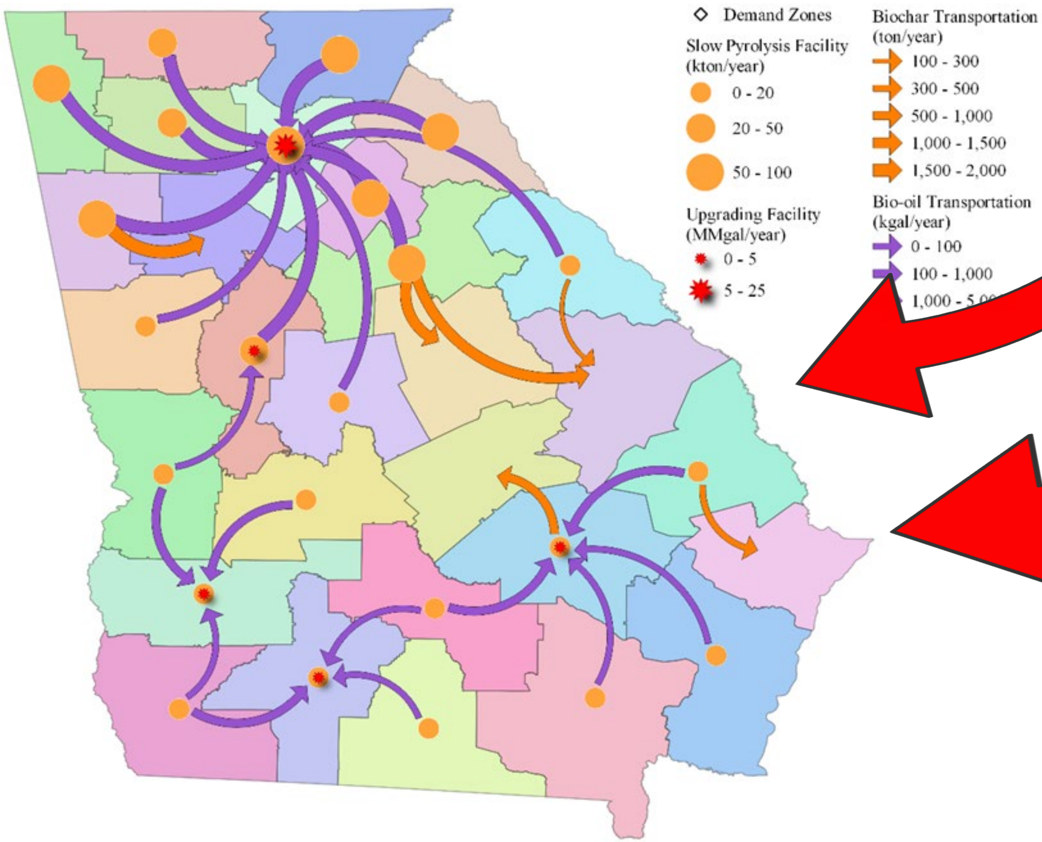
Cornell University

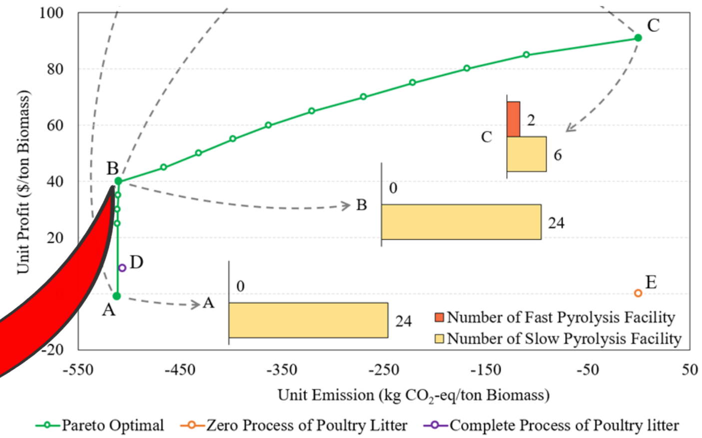
Zhao et al., 2020 *Sustainable Chemistry & Engineering* 8, 4633-4646

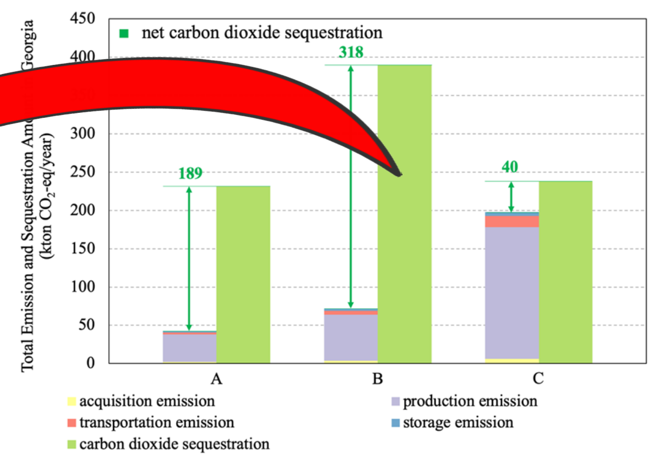
SCWG supercritical water gasification

Spatial Optimization: costs – GHG - CDR

Optimization of pyrolysis locations needed for largest net carbon sequestration







Zhao et al., 2020 *Sustainable Chemistry & Engineering* 8, 4633-4646

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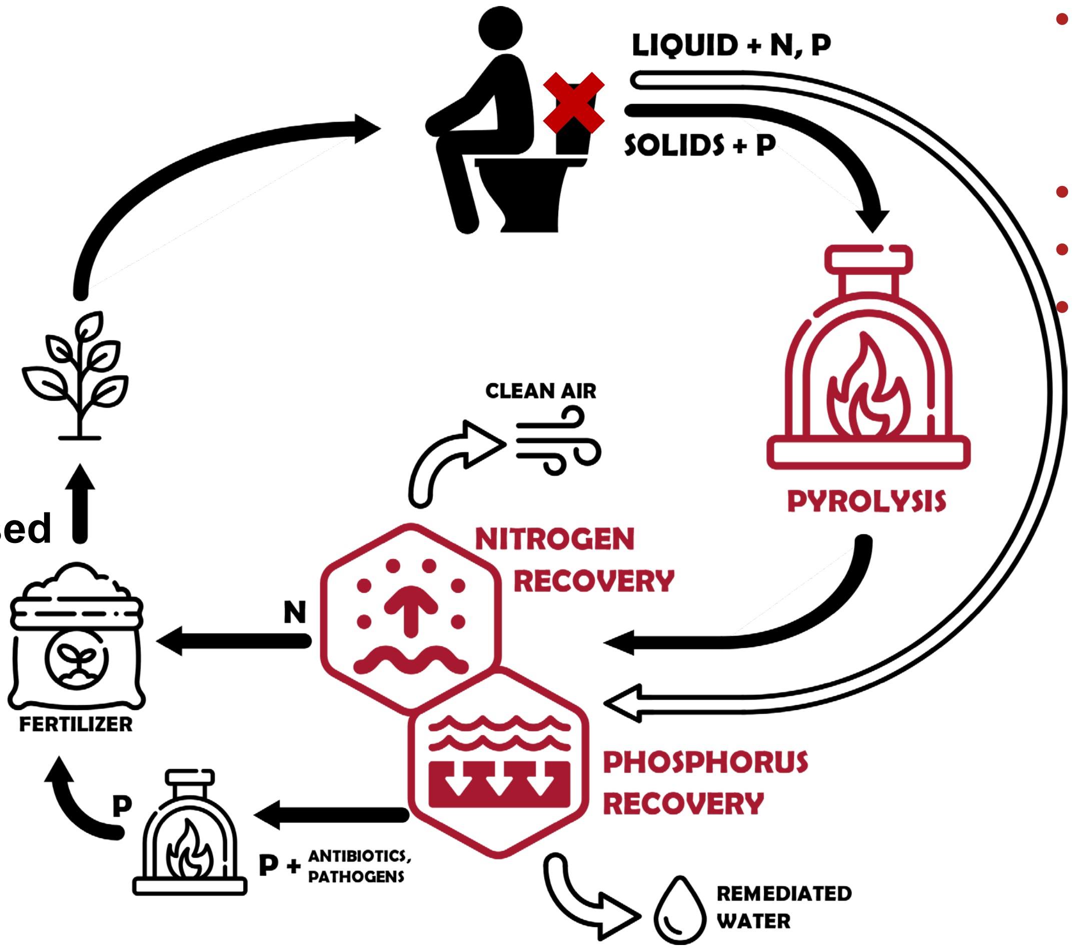
SCWG supercritical water gasification

Circular Bionutrient Economy

- Full sterilization, no hormones & antibiotics (500°C)
- High nutrient content
- Separation of N and P
- All essential nutrients

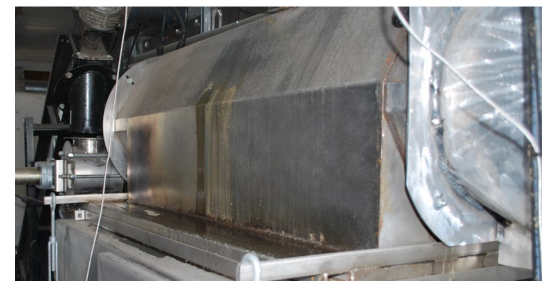
Biochar-based fertilizers in national markets



Feces Pyrolysis

6-fold increase in plant-av. P w/w
4-fold increase in total P w/w

Ballroom A04, 11:10
Lucinda Li



91% reduction in mass

No contaminants (heavy metal, PAH, PCB, dioxin/furans, etc.)
No known pollutants from manure (pathogens, hormones, antibiotic; PFAS and microplastics not analyzed)

Krounbi et al., 2019, *Waste Management* 89, 366–378

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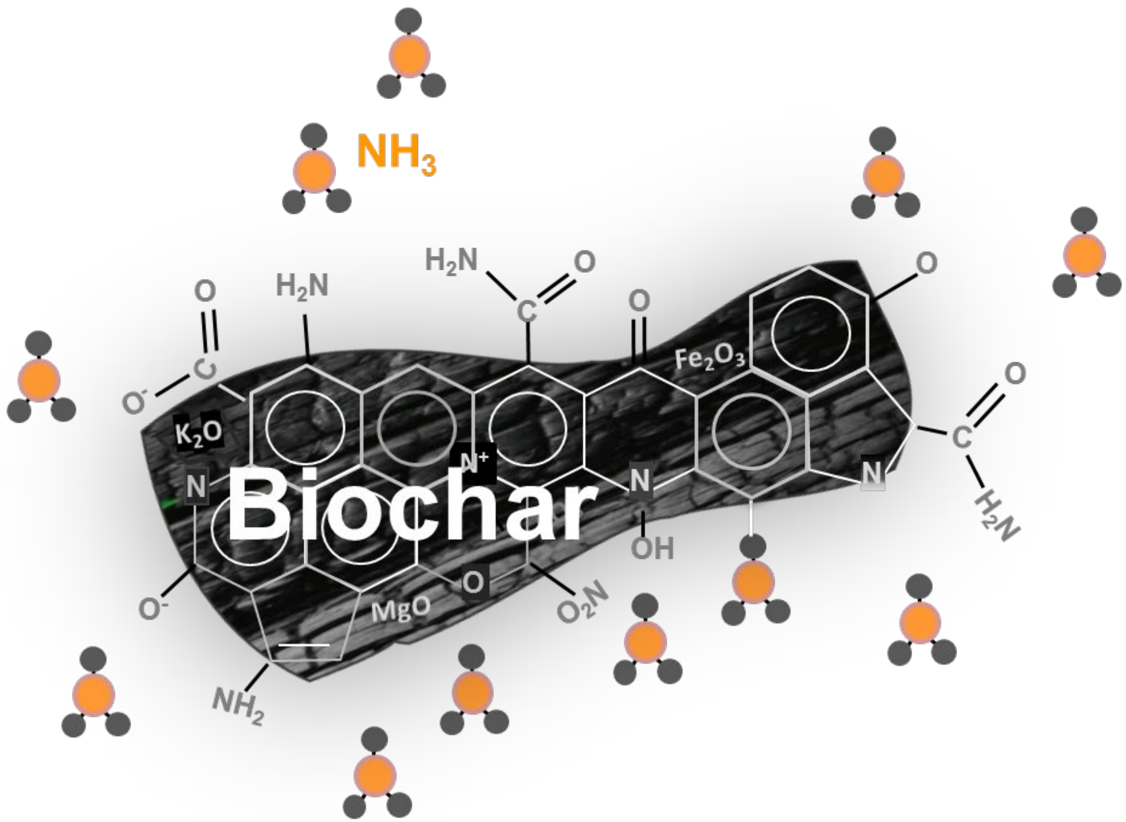
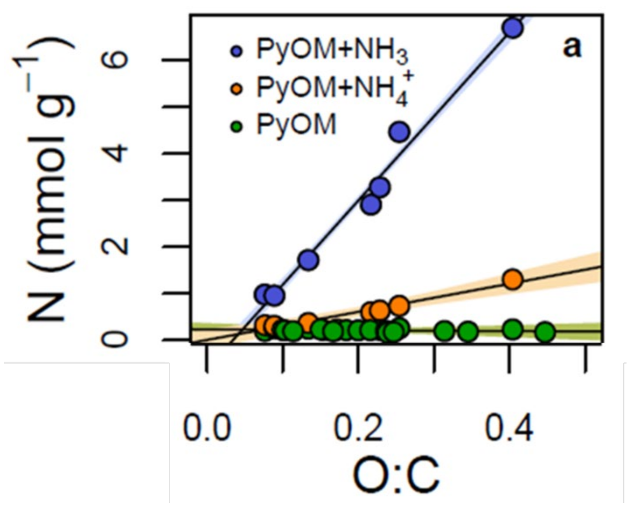
Nitrogen Recovery from Urine – gas phase

Biochar from wood



Up to 18% Nitrogen

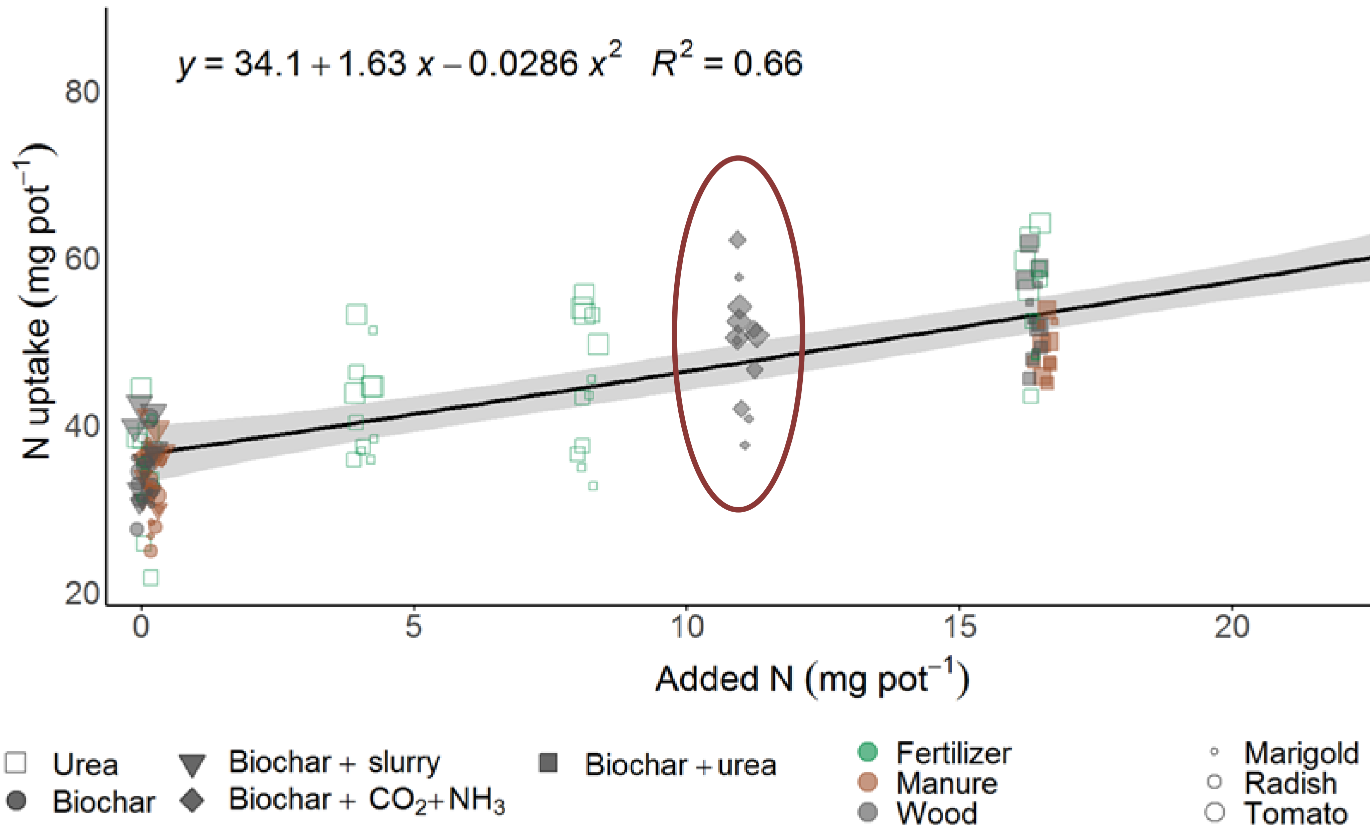
(more than any other organic soil amendment)



Hestrin et al, 2019, *Nature Communications* 10, 664
Hestrin et al, 2020, *Journal of Env Quality* 49, 1690-1702

Biochar Nitrogen Fertilizer Use Efficiency

Similar N uptake between plants treated with biochar exposed to NH_3, compared to conventional N fertilizer



Kroumbi et al. 2021, *Scientific Reports* 11, 15001

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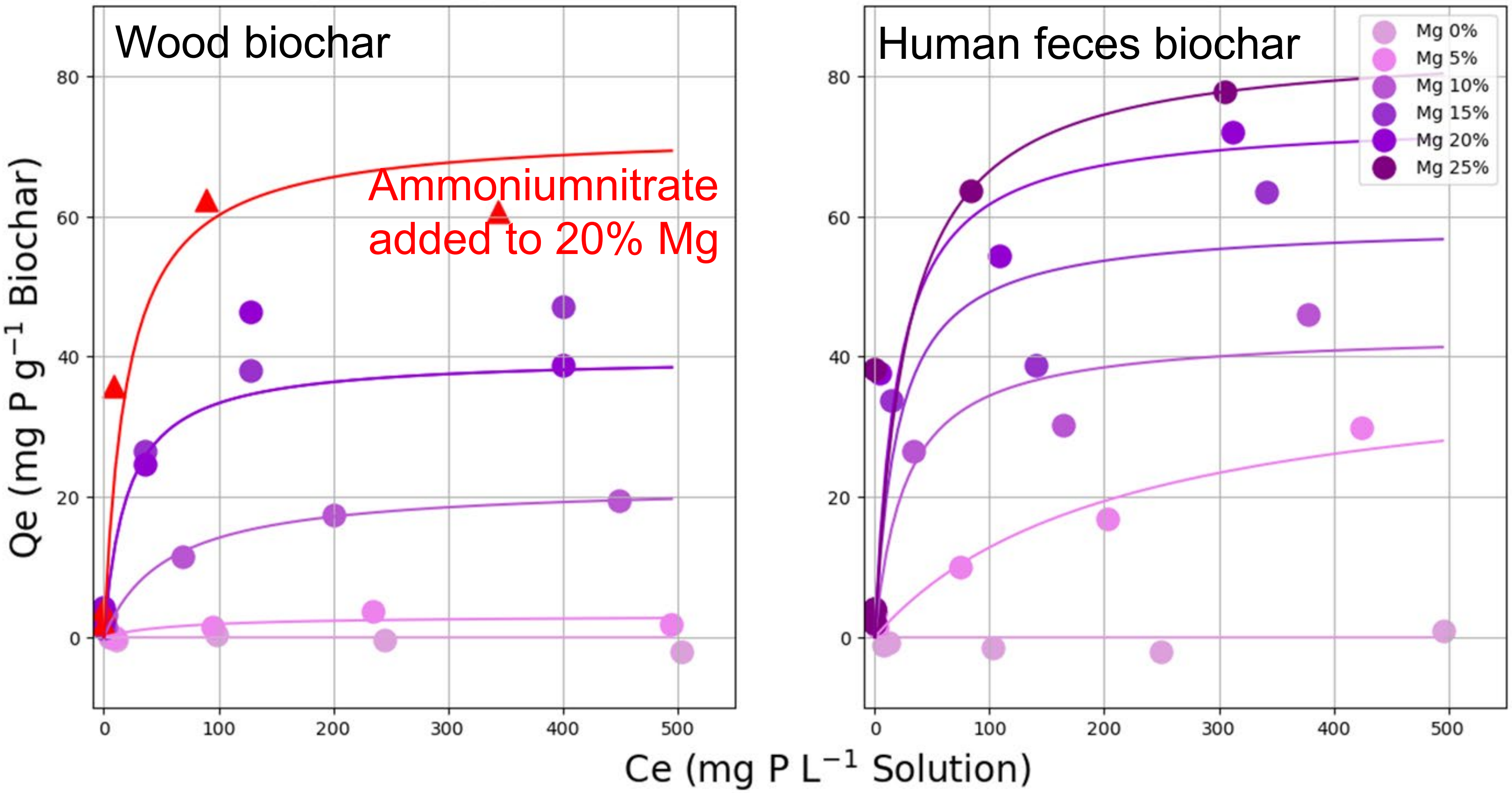
Phosphorus Recovery – old story

Tuscan Grand Duke Peter Leopold's chemistry cabinet (1775-90)

Phosphorus isolation from urine of soldiers in the Belvedere Fortress, Florence

Museo Galileo

Phosphorus Recovery with Biochar - new

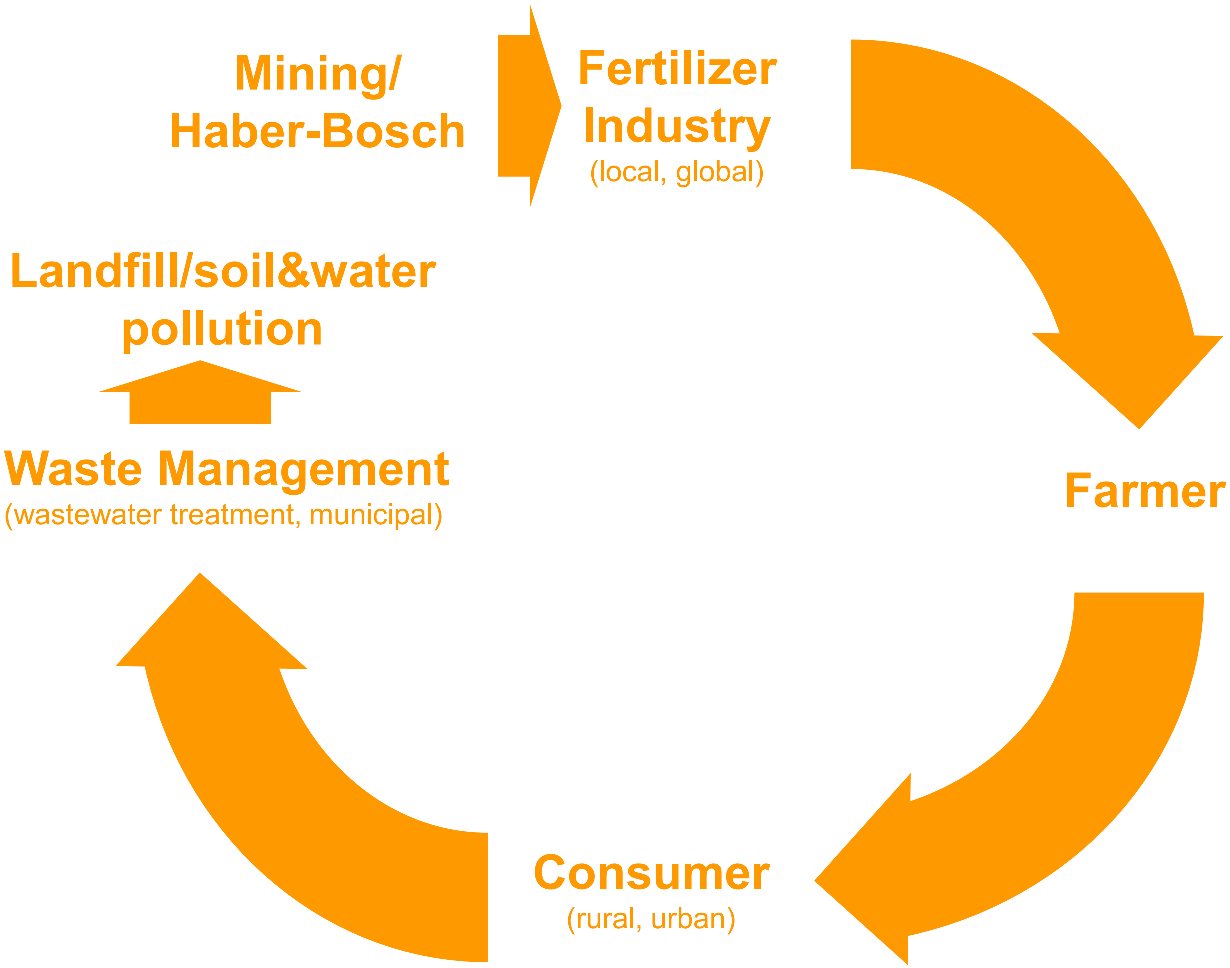


14% N added, 3.2% N in biochar
Oak-ash-maple mix

Pyrolyzed at 600°C

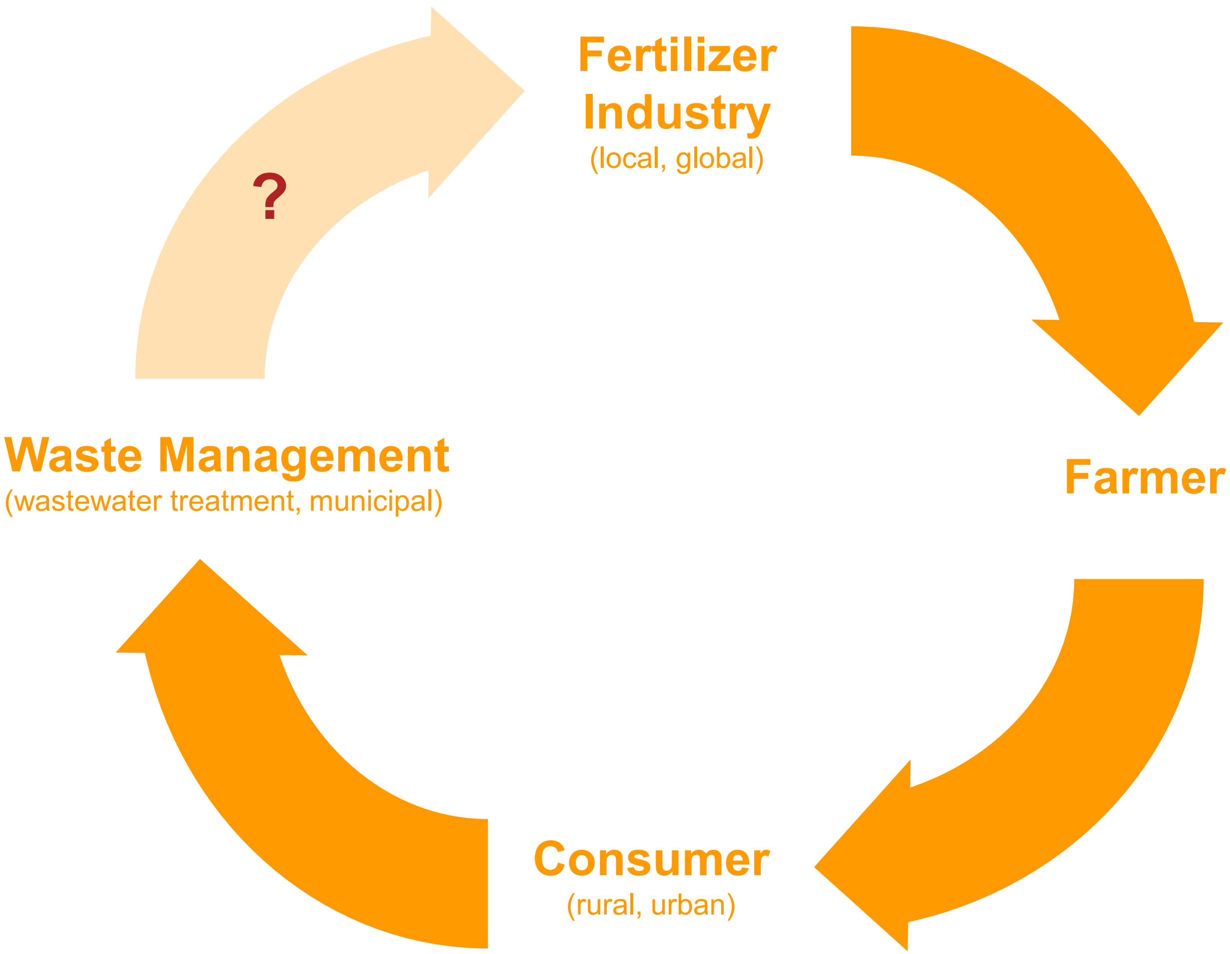
Kim et al, unpublished data

Circular Economy for Nutrients and Carbon



How to close the circle?

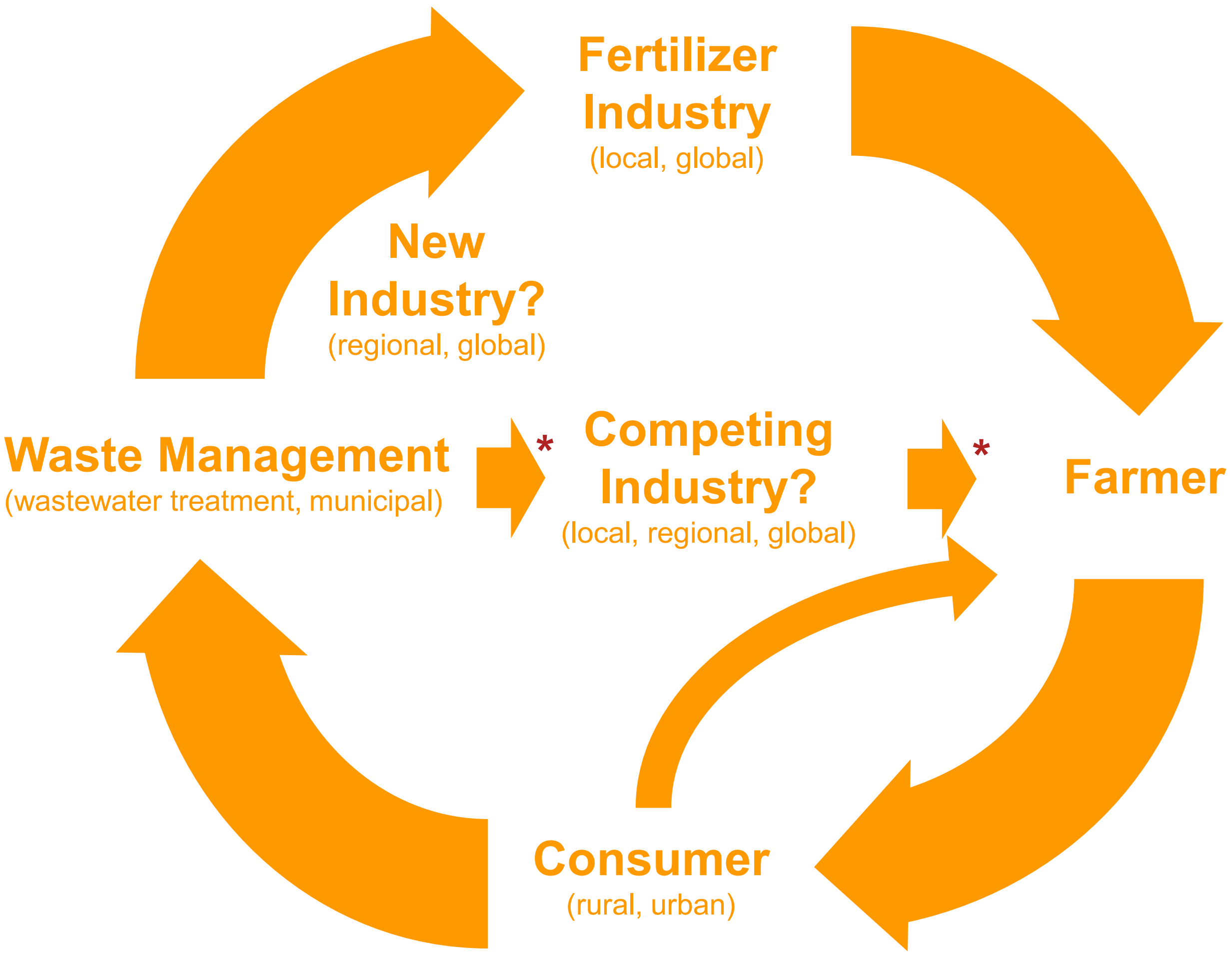
Circular Economy for Nutrients and Carbon



How to close the circle?

Hurdles:
Mismatch in business model
Entrenched revenue stream

Circular Economy for Nutrients and Carbon



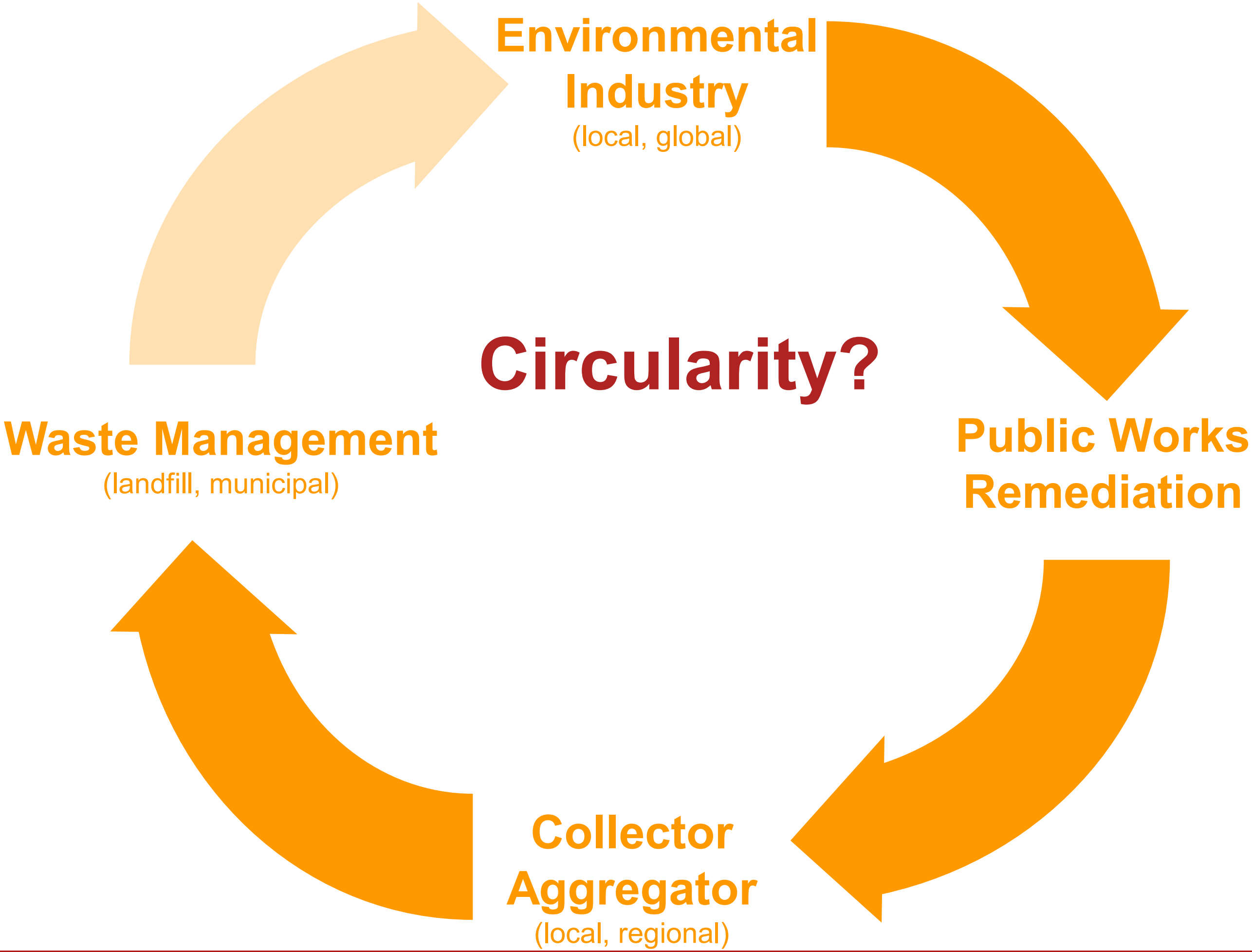
How to close the circle?

New industry + multiple concurrent innovation*biochar

Tesla provocation

Incentives through remediation needs (odor, PFAS etc)

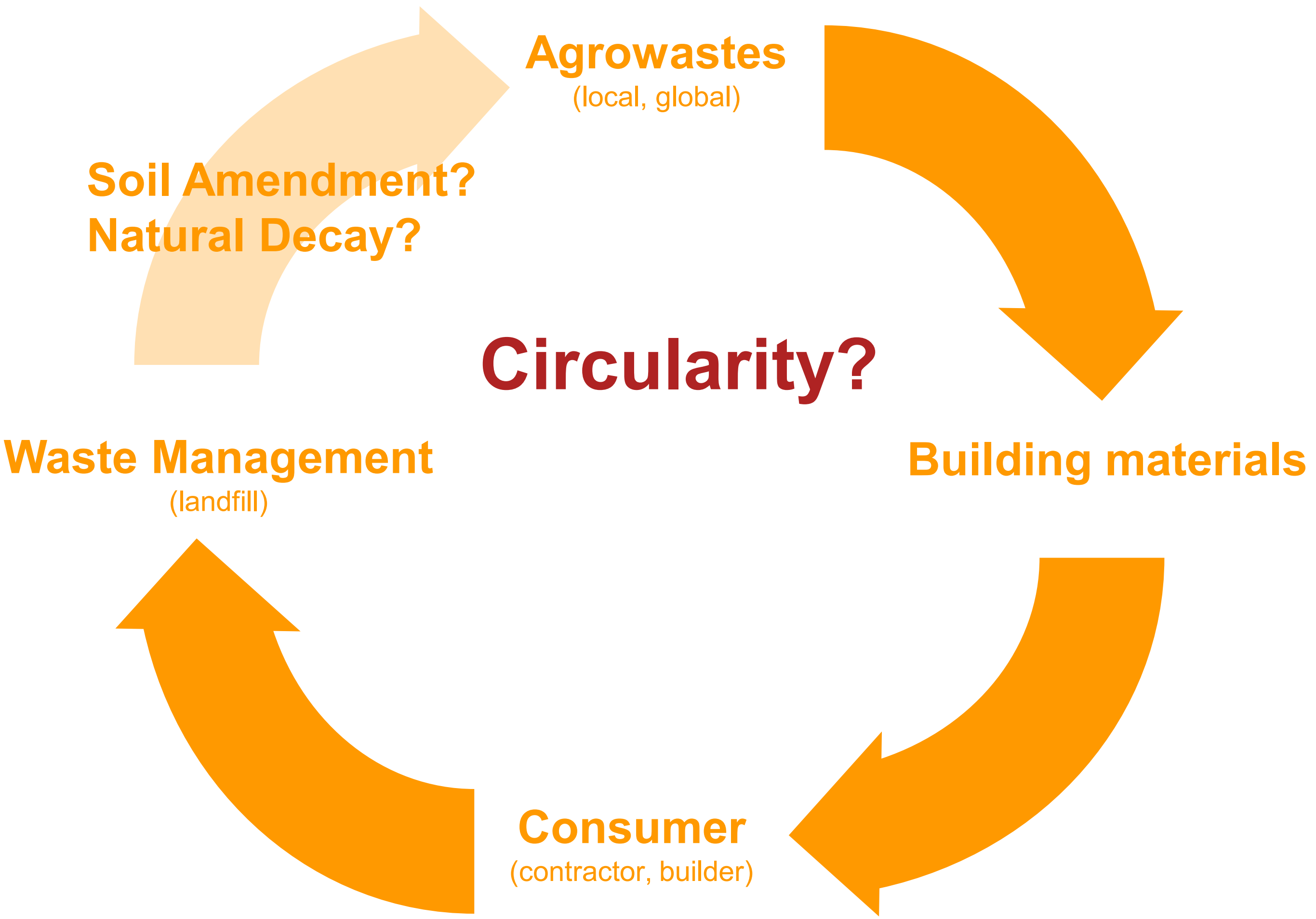
Circular Economy for Biochar-based Materials



Environmental application:

Stormwater
Water filtration
Retention basins
Harbor sediments
Green roofs
Vertical gardens

Circular Economy for Biochar-based Materials



No soil =
No circularity?

Not just technology….

Community of practice
Community of purpose

www.CBENetworks.org
2024 Kisumu, Kenya

Take-home principles

Biochar enabling spatial redistribution of carbon and nutrients from where it is a burden to where it is needed

Leveraging 'externalities' that may emerge as the key drivers (e.g., mass&odor reduction of wastes and…)

Community of practice&purpose as an outgrowth and sustainability principle to close the circle

Biochar as a way of thinking

Cross-Sectoral Approaches for Circularity

Consider "waste" biomass as a value

Consider its carbon, energy and nutrient value

Consider end-of-life even of biochar use in non-soil industries

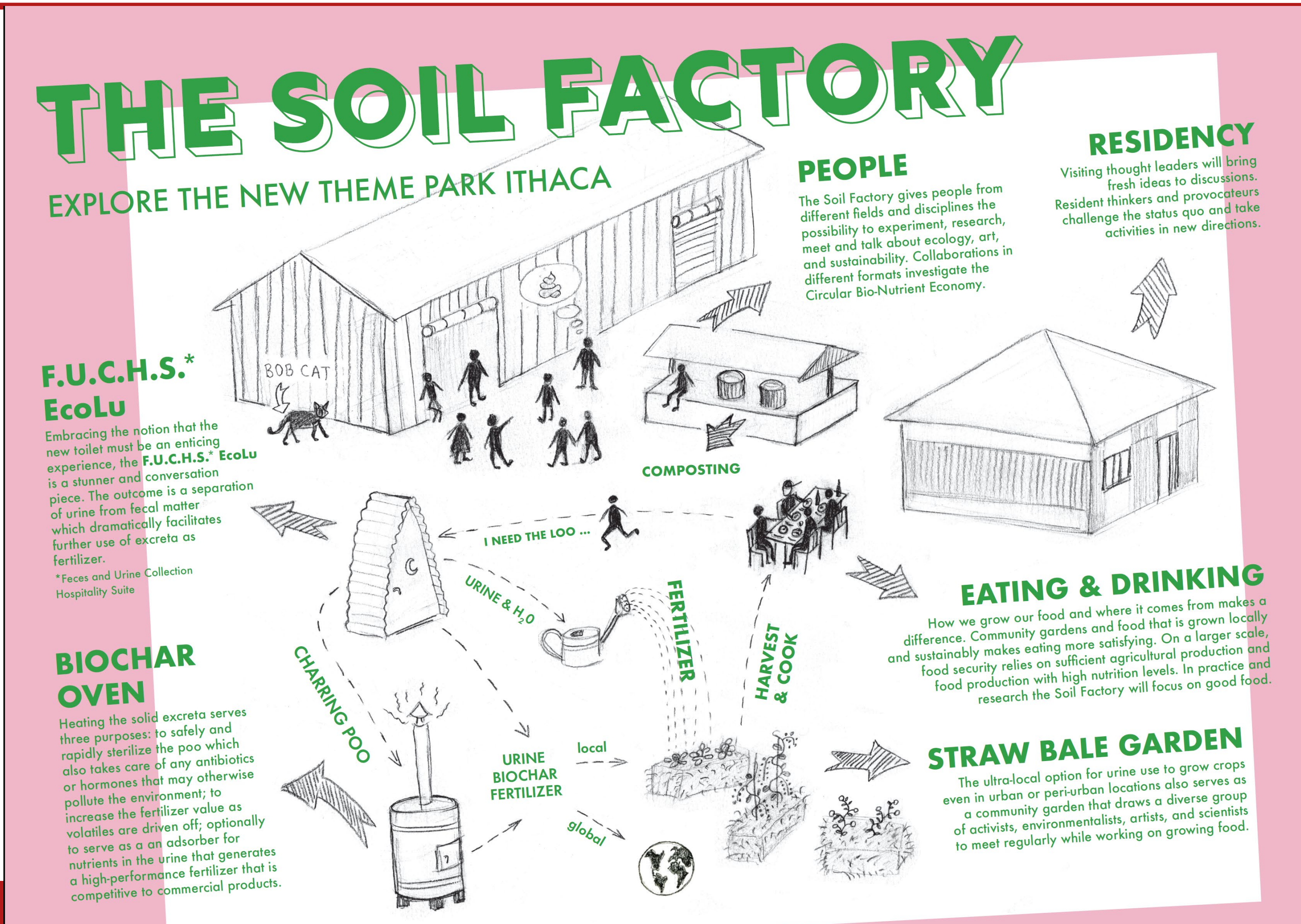
Requires a global database across sectors (energy-carbon-nutrients) at high spatial resolution where decisions are made (country-level data are not enough!)

Requires multi-criteria decision support tools and includes human decision making

AI-CLIMATE

Requires enabling a global biomass management industry: redistribution locally & regionally & globally

The Soil Factory: Innovating Circularity



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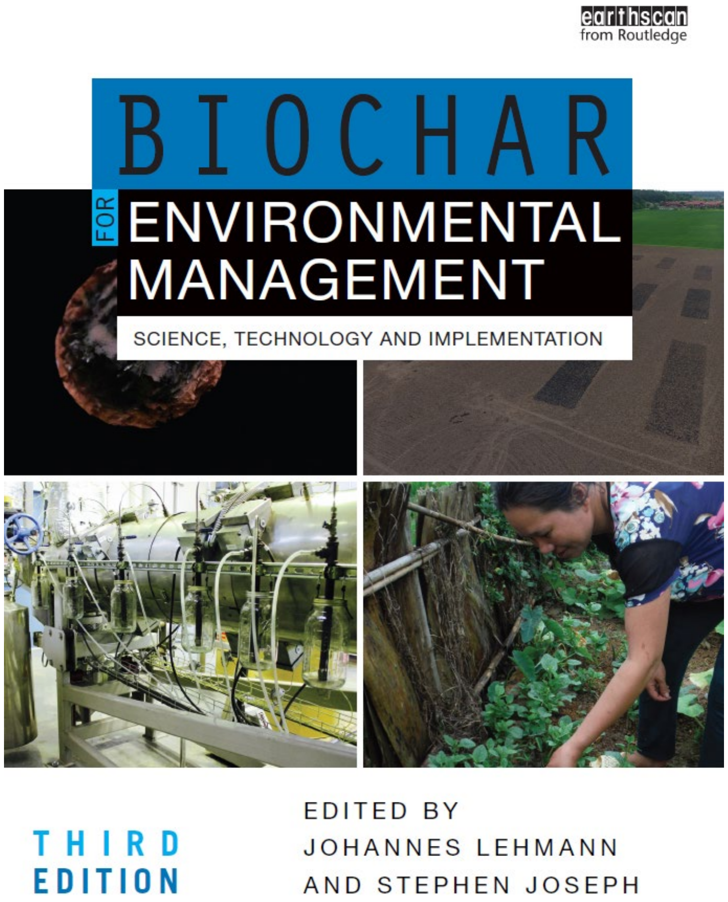
http://www.thesoilfactory.org/
https://blogs.cornell.edu/lehmannlab/research/art-and-sciences/the-soil-factory/

Thank you



Late 2024

Including:

- **Building materials**
- **Transport-storage-application**
- **Animal feed**
- **Policy**
- **And updates on previous chapters**

Discount for IBI members, advance purchase and bulk orders