



Rich Earth Institute

Overview and Recent Research

May 2026



Our Nutrient Landscape

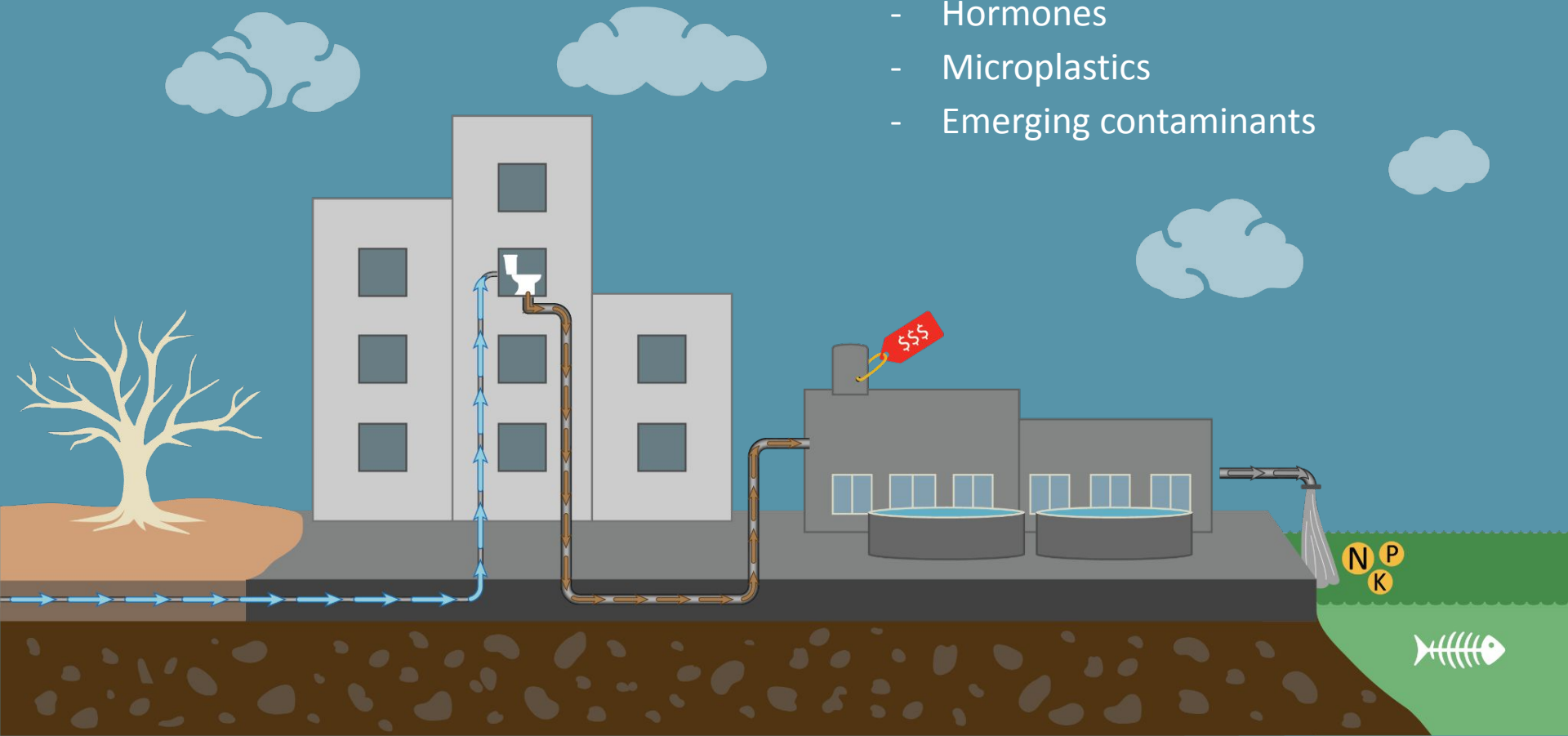
Flush and forget?

SEWER & SEPTIC SYSTEMS REMOVE:

- Organic matter
- Pathogens

BUT OFTEN STILL RELEASE:

- Nutrients
- Pharmaceuticals
- Hormones
- Microplastics
- Emerging contaminants



Nitrogen and
phosphorus
fertilize algae
blooms, killing fish
and making water
unfit for drinking.



Long Island 2015

What if we could
recover these
nutrients and
use them as
fertilizer in
agriculture?

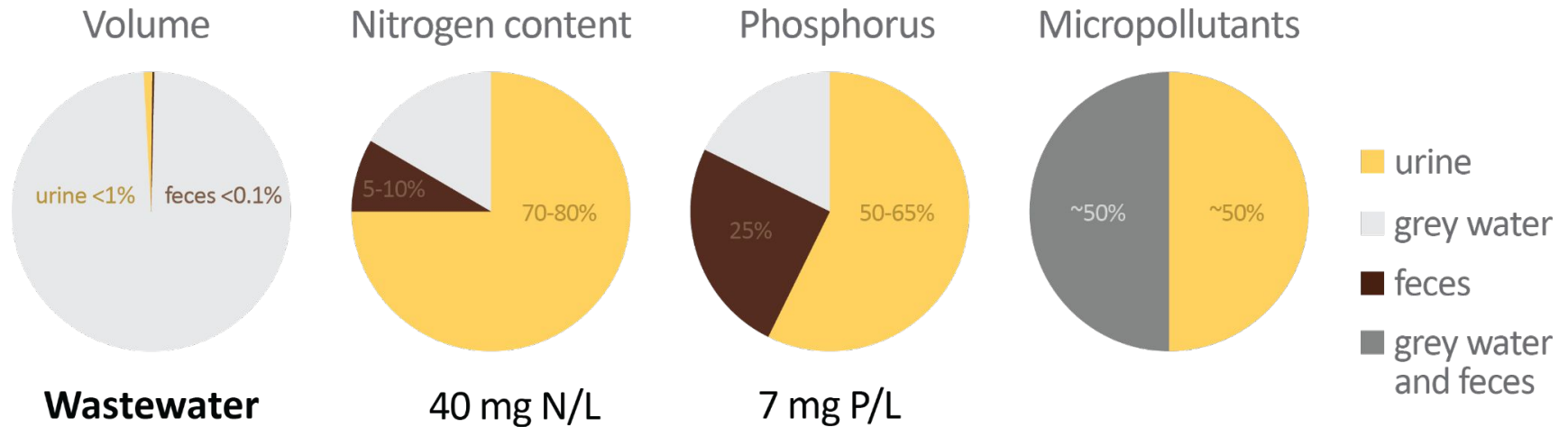


From linear...



...to circular!

Constituents of urine, feces, and greywater

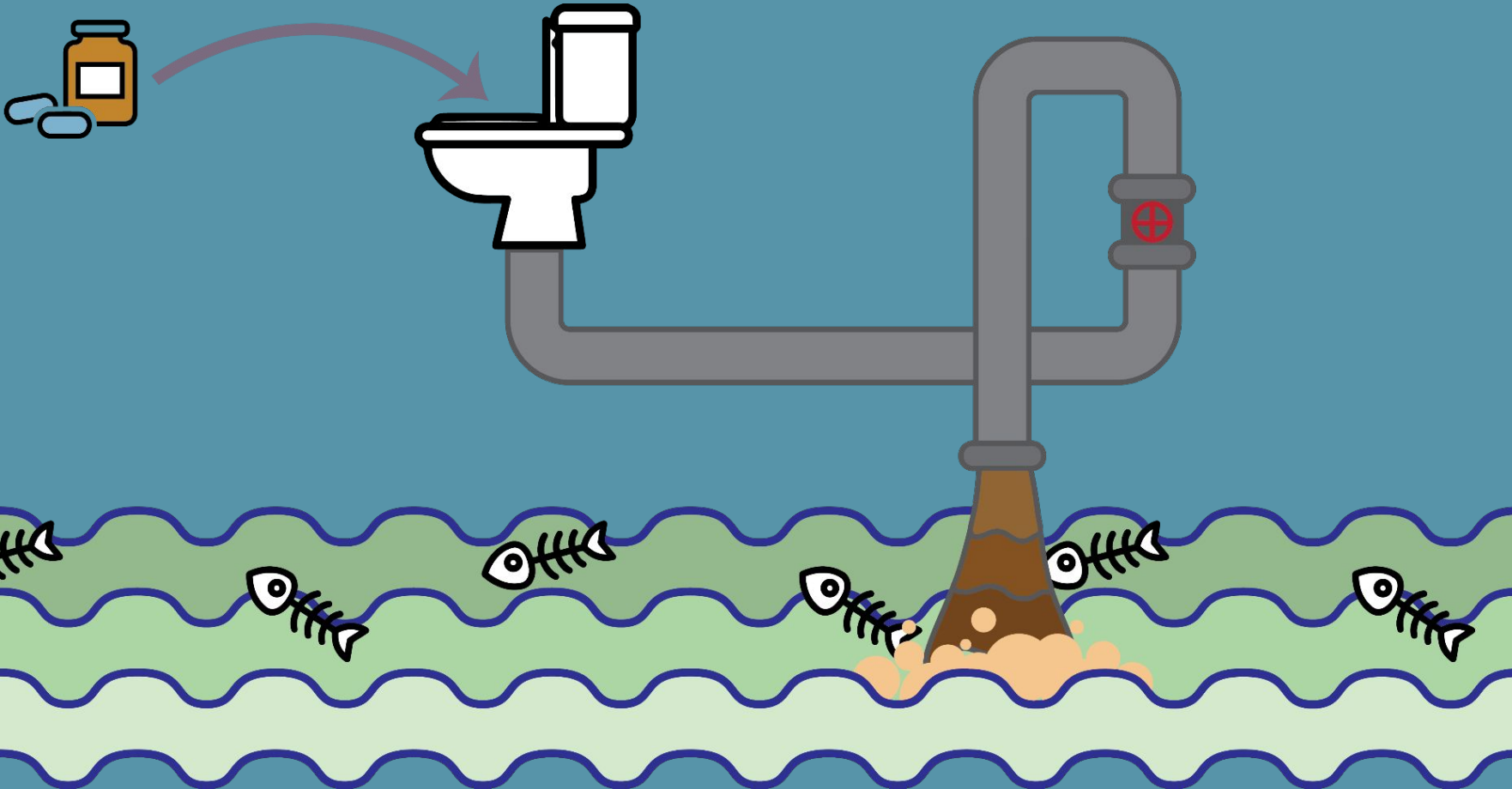


Urine contains most of the nutrients and half the pharmaceuticals in human waste

What happens to the pharmaceuticals in our urine?

When you take medicine or drink coffee and then flush your pee, what happens to it?

Most of the time our pharmaceuticals end up disrupting aquatic life...



When reclaimed as fertilizer...



By collecting urine and keeping it out of the wastewater stream, we can contain pharmaceuticals before they reach sensitive aquatic ecosystems and water supplies.

But that raises new questions:

Do these compounds end up in edible crops?
How do they affect long-term soil health?

What we found...

Rich Earth Institute
conducted a 6 year study
in collaboration with:



CROP

Eat one pound of urine-fertilized lettuce every day for 1,000 years to ingest the equivalent of one large cup of coffee.

The pharmaceuticals we detected were extremely small – in the nanogram per gram (or parts per billion range.)

SOIL

We found small levels of pharmaceuticals in the soil (parts per billion range).

GROUNDWATER

Pharmaceuticals were detected in the groundwater in even lower levels (parts per trillion range.)



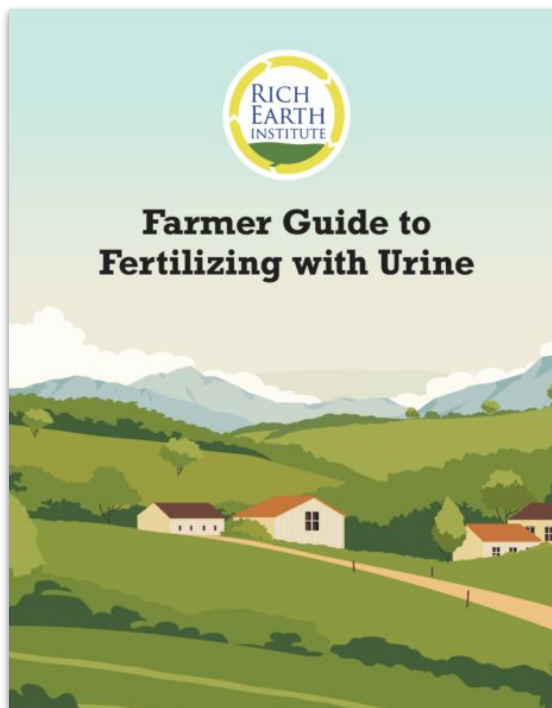
Fertilization

9 Farm Partners

*trialing urine
fertilization for a wide
range of crops*

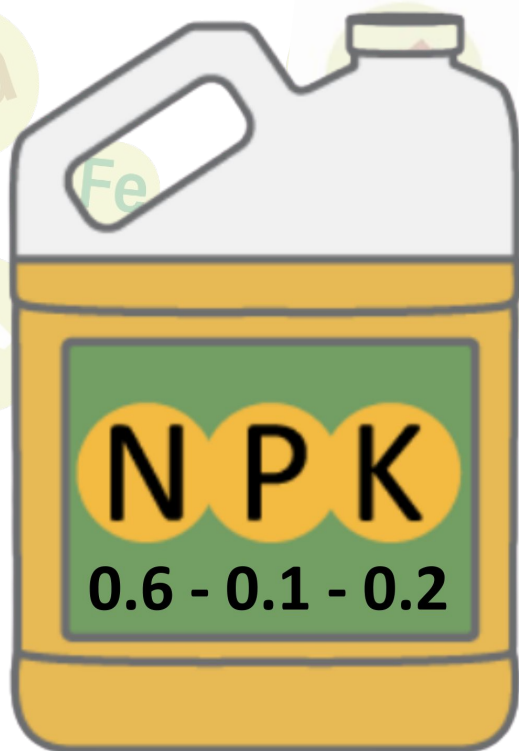


13 *years of
on-farm
research*



Properties of Urine Fertilizer

URINE FERTILIZER NUTRIENT CONTENT:



Nutrient	lbs/100 gallons of urine	%
Nitrogen	4.8	0.57
Phosphorus (as P ₂ O ₅)	0.69	0.082
Potassium (as K ₂ O)	1.6	0.19
Sulfur	0.37	0.044
Calcium	0.019	0.0023
Magnesium	0.0059	0.00071
Boron	0.0016	0.00019
Zinc	0.00025	0.00003
Iron	0.00017	0.00002
Copper	0.00017	0.00002
Sodium	1.2	0.15

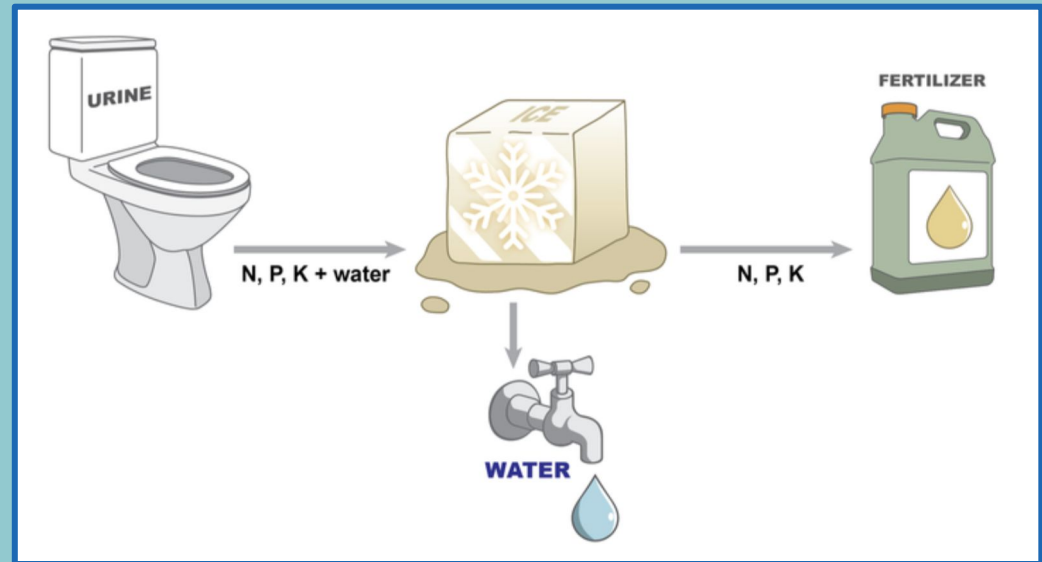
Current Project - Farm Partners

Pete's Stand - John Janiszyn

Application of concentrated urine on sweet corn

Concentrated Urine

- Reduces transport costs & fuel
- Reduces application time
- Increases ammonia volatility of product
- Produced with Brightwater Tools Freeze Concentrator

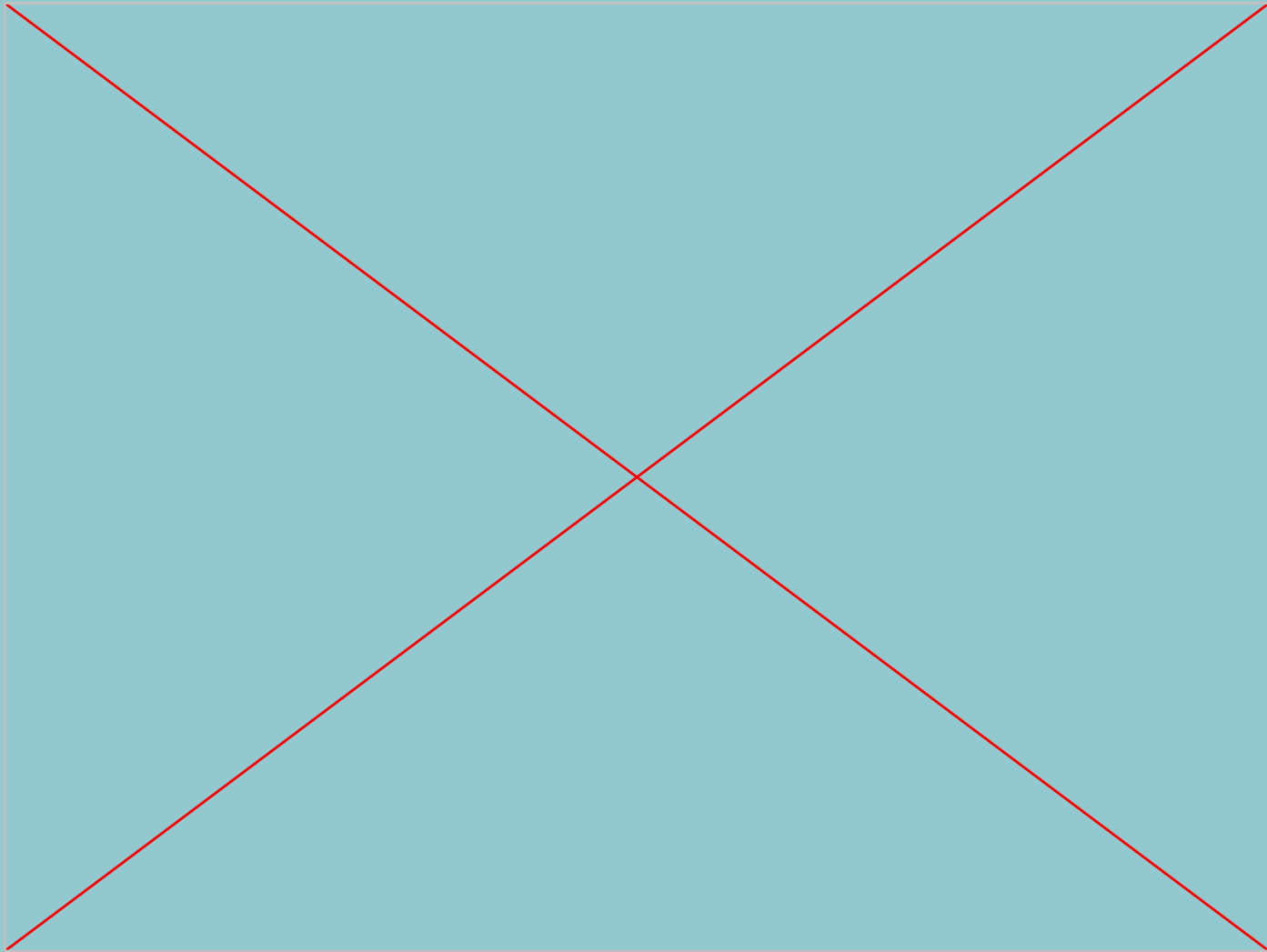


BRIGHTWATER TOOLS

Technologies for Regenerative Sanitation

Current Project - Farm Partners

Pete's Stand - John Janiszyn - Application of straight urine followed by application of concentrated urine on sweet corn



Current Project - Farm Partners

Roller Pump Applicator used at Pete's Stand with John Janiszyn



Biochar from Biosolids and Source Separated Human Urine:

Soil Health Impacts and Farmer Perspectives

5-year soil health study

In partnership with:



Cornell University
& Cooperative Extension
of Suffolk County

Funded by:



Introduction to Waste-Derived Amendments



Source Separated Urine:

- Urine collected at the source, prior to combination with other wastewater streams
- **Role in soil:**
 - Adds fast-acting nutrients
 - Soil microbes may be helping degrade pharmaceuticals - what is the effect of doing that 'work' on soil health?



Compost:

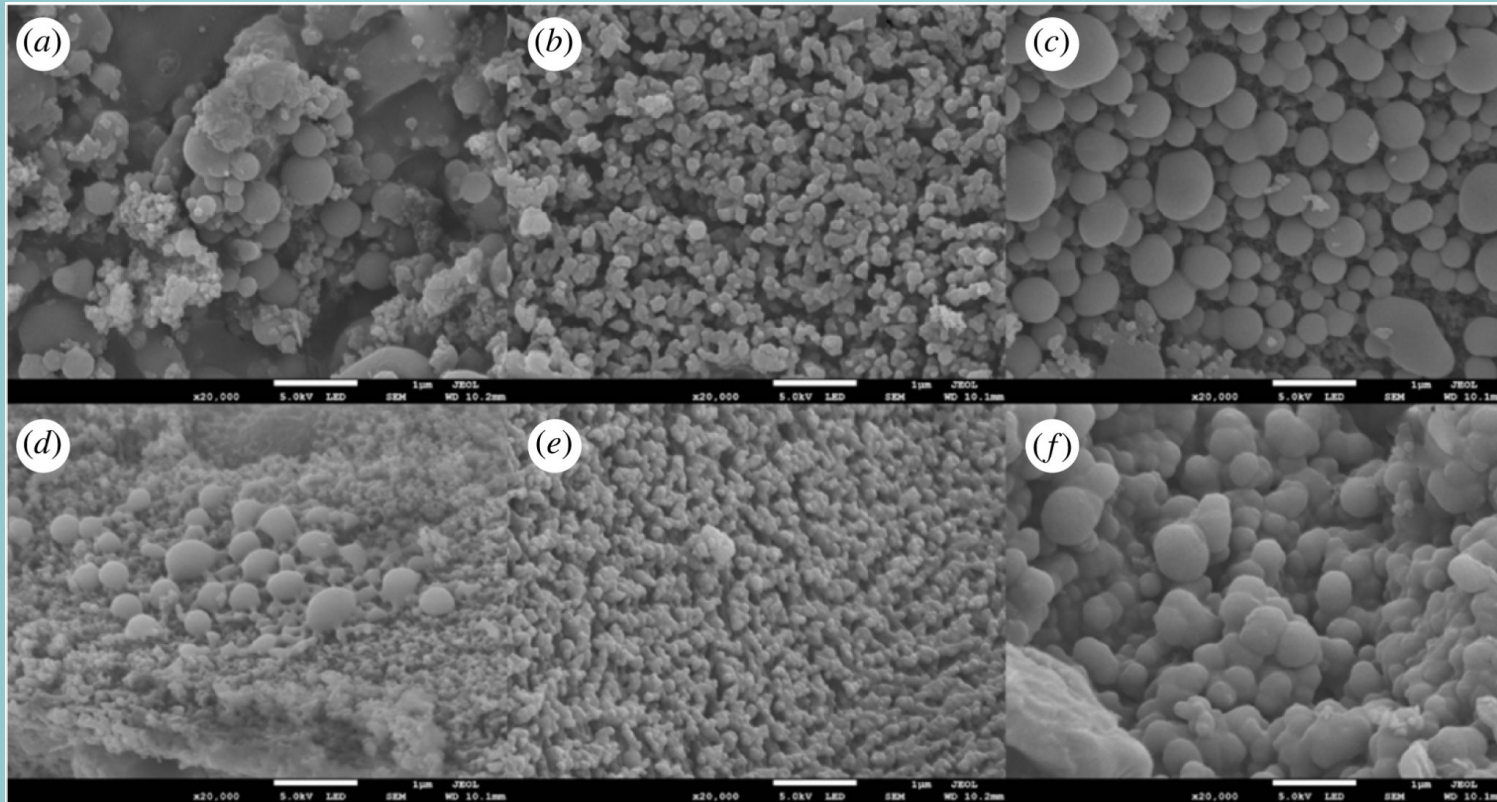
- Decomposed food scraps & other organic matter
- **Role in soil:**
 - Adds a quick-to-decompose form of organic carbon
 - *Combined with urine:* provides multiple forms of fast-acting nutrients



Biochar:

- Charcoal-like material created when organic matter is pyrolyzed—burned at high temperature with low oxygen
- **Role in soil:**
 - Adds a slow-to-decompose form of organic carbon—a way of storing carbon in the soil with positive climate impacts
 - Provides a structure for soil microbes to live in
 - *Combined with urine:* biochar can adsorb the nutrients from urine, keeping available in the soil for longer/enabling a slower-release

Charging biochar with nutrients



← Before
adsorption of
ammonium
nitrogen

← After
adsorption of
ammonium
nitrogen

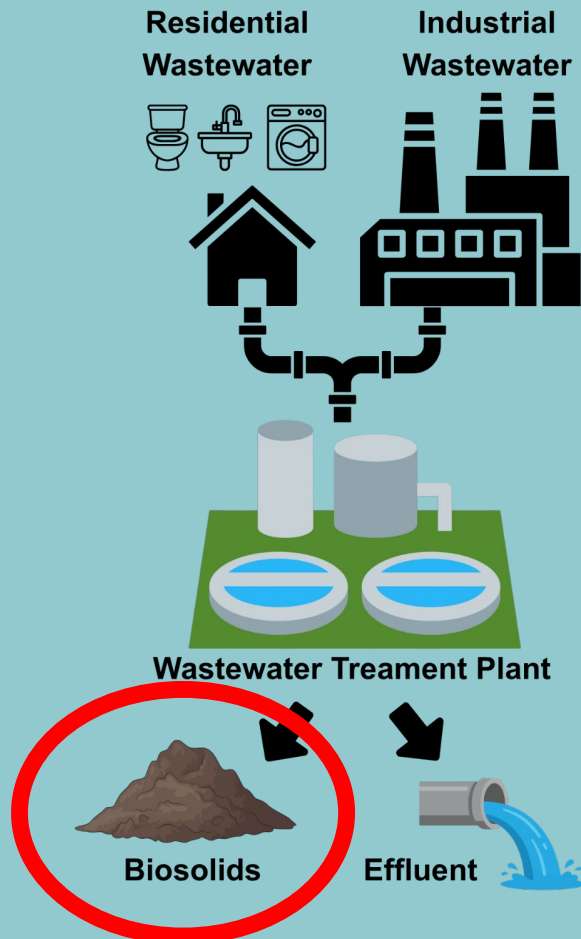
(Wang et al., 2023)

Types of Biochar

Biochar can be made from many sources of organic matter

Woody biochar: biochar made from pyrolyzing wood material

Biosolids biochar: biochar made from pyrolyzing biosolids



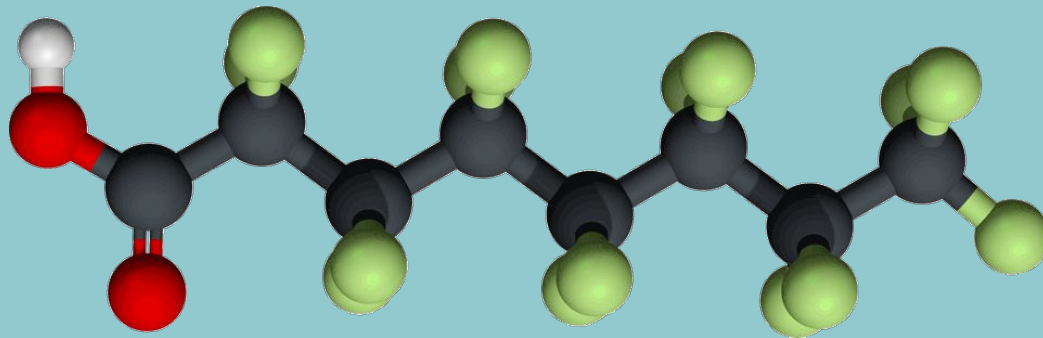
Biosolids: Sewage sludge that has been treated to meet EPA standards for land application as a fertilizer.

Contains:

- Carbon
- Nutrients (nitrogen, phosphorus)
- Heavy metals
- Organic contaminants
- PFAS

Per- and polyfluoroalkyl substances (PFAS) contamination

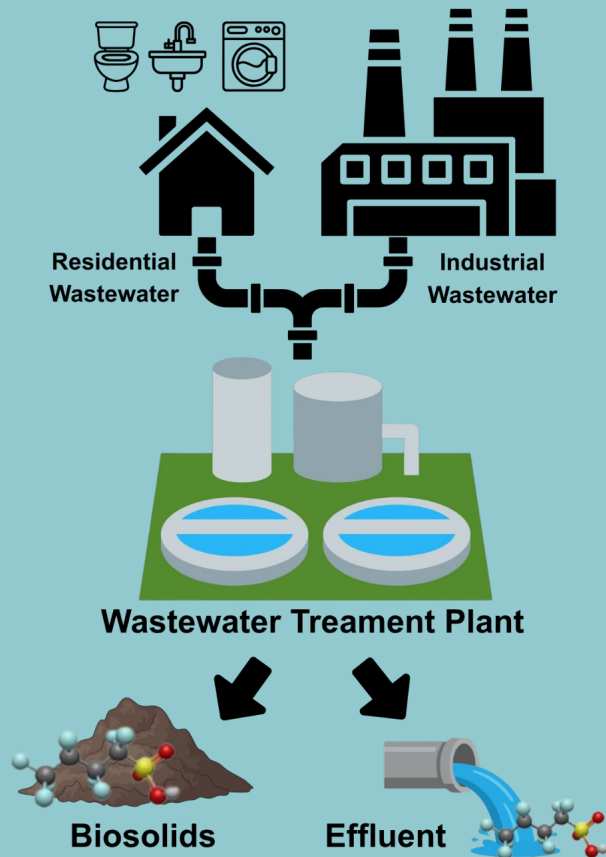
- Large group of synthetic chemicals, used in consumer products since the 1950's
- Environmental pollutants with links to negative effects on human health
- Strong carbon-fluorine bond “backbone” of PFAS molecules
- Microbiologically inert
- Environmentally persistent
- Commonly found in biosolids



PFAS in Biosolids vs. Source Separated Urine

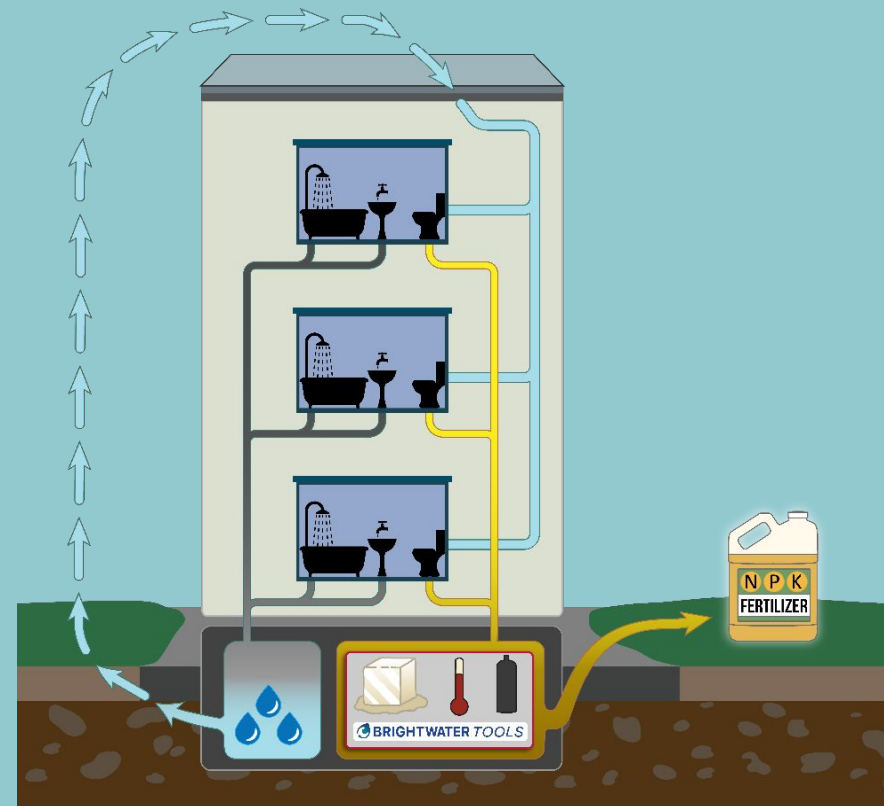
Centralized Treatment & Biosolids

- Human nutrients combined with other wastewater streams and processed at a centralized wastewater facility
- **PFAS:** High levels of PFAS, can vary widely from plant to plant depending on influent sources

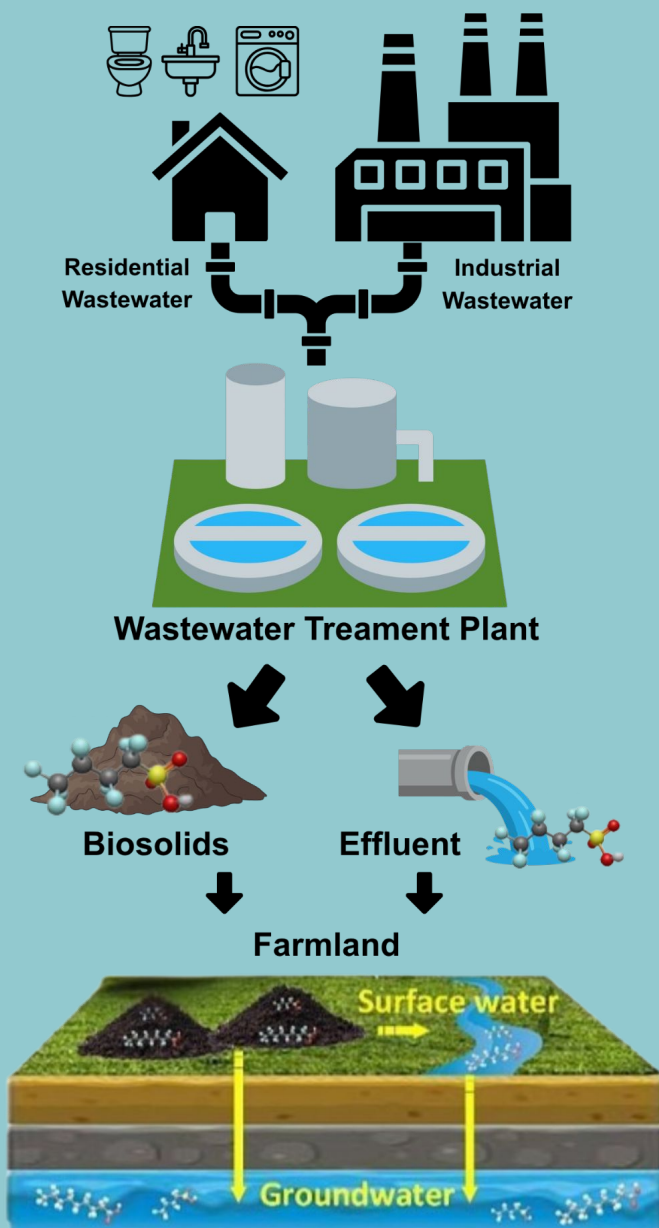


Source Separated Urine

- Human nutrients separated at the source and processed separately
- **PFAS:** very low levels present; annual addition of urine fertilizer adds less than:
 - background levels already present in the soil
 - annual rainfall



PFAS in Biosolids



Halting PFAS production (treating the cause) and cleanup of existing PFAS (treating the symptom) are both critical to a wholistic PFAS management

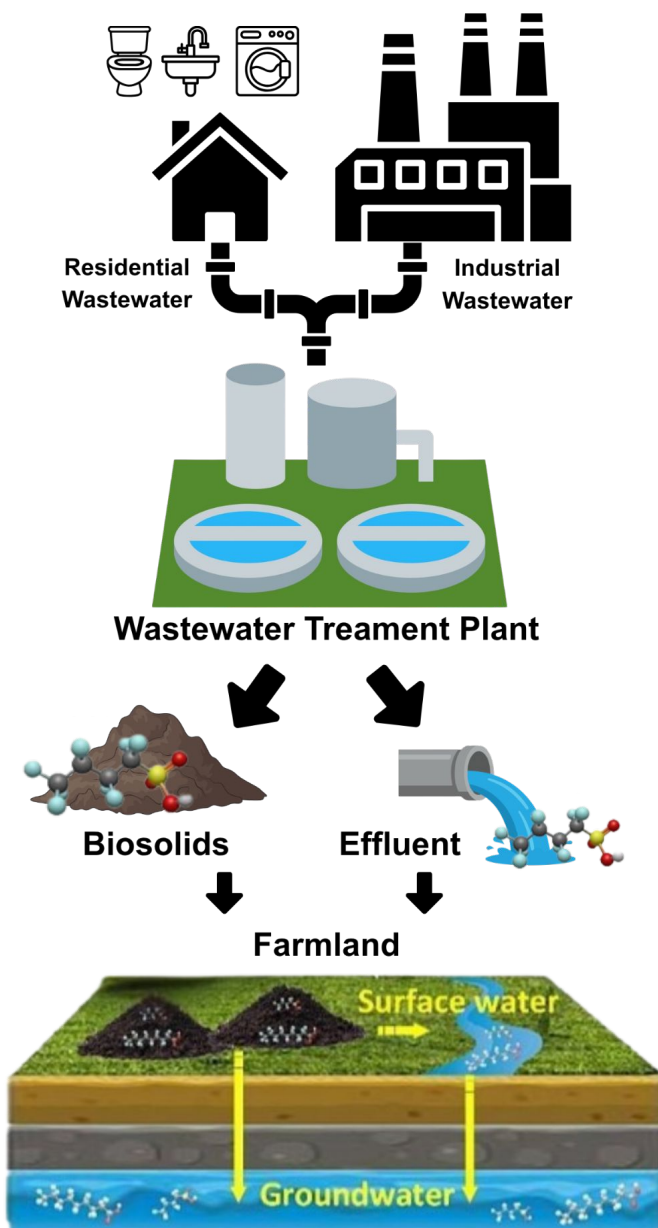
Running out of options for wastewater sludge | Column

At present, landfilling is Maine's single sludge-disposal option, and we are running out of space.



The Juniper Ridge Landfill rises above the trees in Old Town in July 2025. The state-owned landfill takes almost 90% of Maine's sludge and is expected to reach capacity in 2028 (Daryn Slover/Staff Photographer). [Purchase this image](#)

PFAS in Biosolids



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Pyrolysis (making biochar) reduces PFAS in biosolids

- High pyrolysis temperatures have been shown to reduce PFAS levels in the resulting biochar by **74 to 99.9%**, and to immobilize heavy metals
- There may be PFAS in gas and oil emissions from pyrolysis plants

Two full-scale production facilities in the US:

- BioForceTech:
Redwood City, CA, since 2017
- Anaergia Inc.:
Carlsbad, CA, since 2013



(<https://www.filtewater.com>)

Sources:

- Kundu et al., 2021; McNamara et al., 2023; Thoma et al., 2022; Paz-Ferreiro et al., 2018
- Askeland et al., 2020; Krahn et al., 2023; Sørmo et al., 2021
- Winchell et al. 2021, McNamara et al., 2023

Biosolids Biochar as a Soil Amendment



↑ CEC
↑ Water retention
↑ Porosity
↑ CO₂ capture

(Patel et al., 2020)

N	2-4%
P	5-15%
K	>1%
C	20-30%

(Faria et al., 2017)

Biochar (woody or biosolids) can also bind to PFAS in soils and reduce their uptake by plants

(Winchell et al. 2021, McNamara et al., 2023)

Research Questions

Field Trials:

- What soil health and yield impacts result from the use of human waste-derived soil amendments applied alone and in combination?
- Can human waste-derived soil amendments replace conventional amendments with no negative impacts on soil health or yield?

Social Research:

- Are farmers interested in using biosolids biochar an/or urine?
- What are their primary concerns and/or perceived benefits?



Silage Corn field trials in NY (left) and VT (right)



NY site soil



VT site soil



9 Treatments, replicated 5x per field site

Treatment Name	Amendments Applied
No Fertilizer	None
SN	Synthetic nitrogen (Urea)
U	Urine
C + SN	Compost + synthetic nitrogen (Urea)
C + U	Compost + urine
WB + U	Wood biochar + urine
BB + WB + U	Biosolids biochar + wood biochar + urine
WB + C + U	Wood biochar + compost + urine
BB + WB + C + U	Biosolids biochar + wood biochar + compost + urine



All fertilized treatments received equal nitrogen, potassium, and phosphorus

Waste-derived amendments

Biosolids Biochar (BioforceTech)

- Pyrolyzed at 650°C

Woody Biochar (Terra Char)

- Southern Yellow Pine pyrolyzed at 800°C

Urine-Derived Fertilizer

- Sourced from the Rich Earth Institute's Urine Nutrient Collection Program
- Source-separated and pasteurized
- Concentrated in 2025 trials to reduce volume, making handling and application easier
- Used for biochar charging & field application

Compost (Vermont Compost Company)



Biochar and compost application

Woody Biochar Blend: 0.5 tons/year

Biosolids/wood biochar blend: 0.74 tons/year





Time-of-planting fertilization



Sidedress fertilization



Data Collected

Yield Data (Sep, years 1 - 5)

- Yield (dry tons/acre)
- Ear fill
- Ear length
- Forage analysis



Soil Health Data

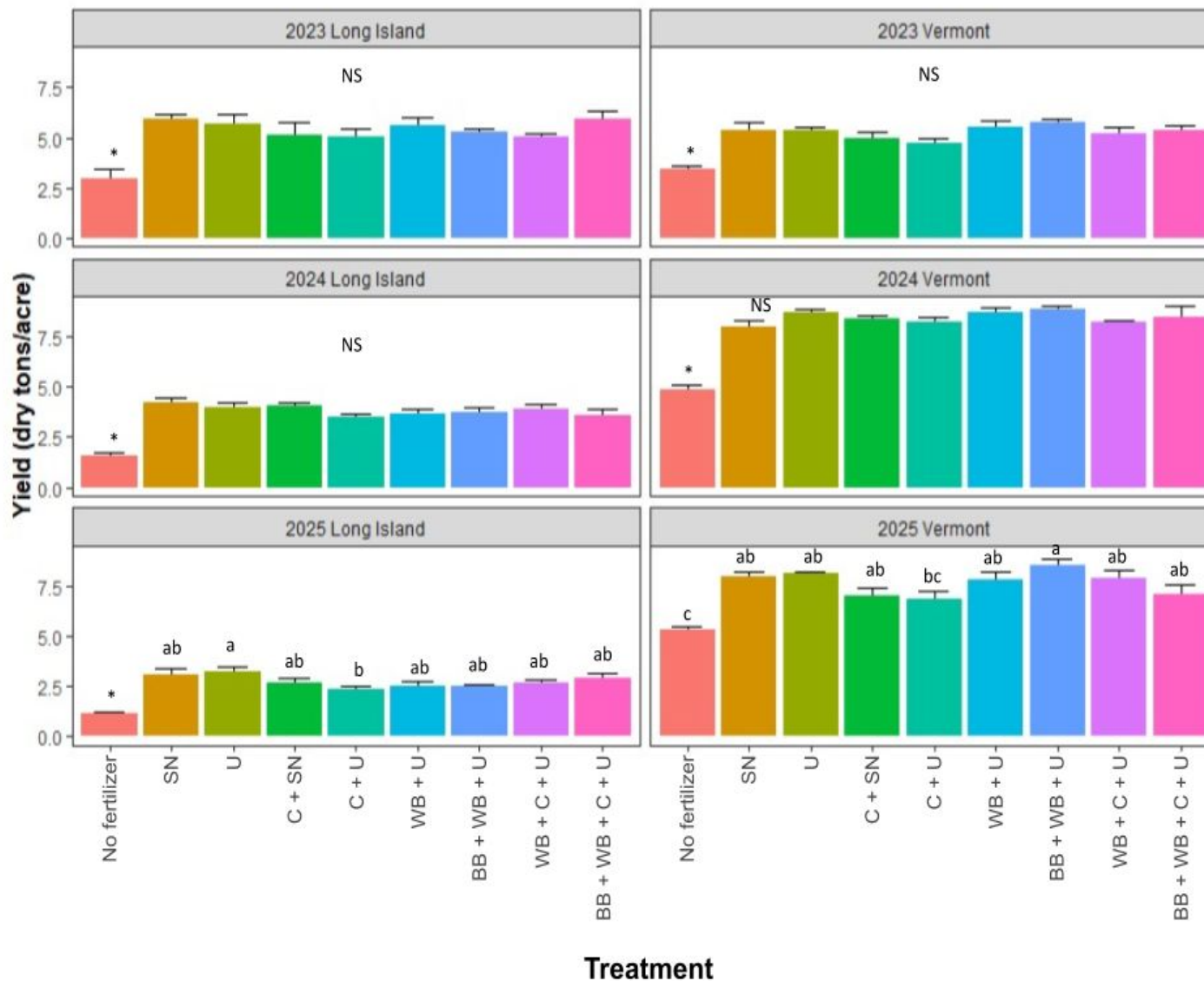
- Comprehensive Assessment of Soil Health (CASH) (Oct, years 1, 3 & 5)
- Amplicon sequencing (April, years 1 & 5)
- Phospholipid fatty acid (PLFA) analysis (April, years 1 & 5)



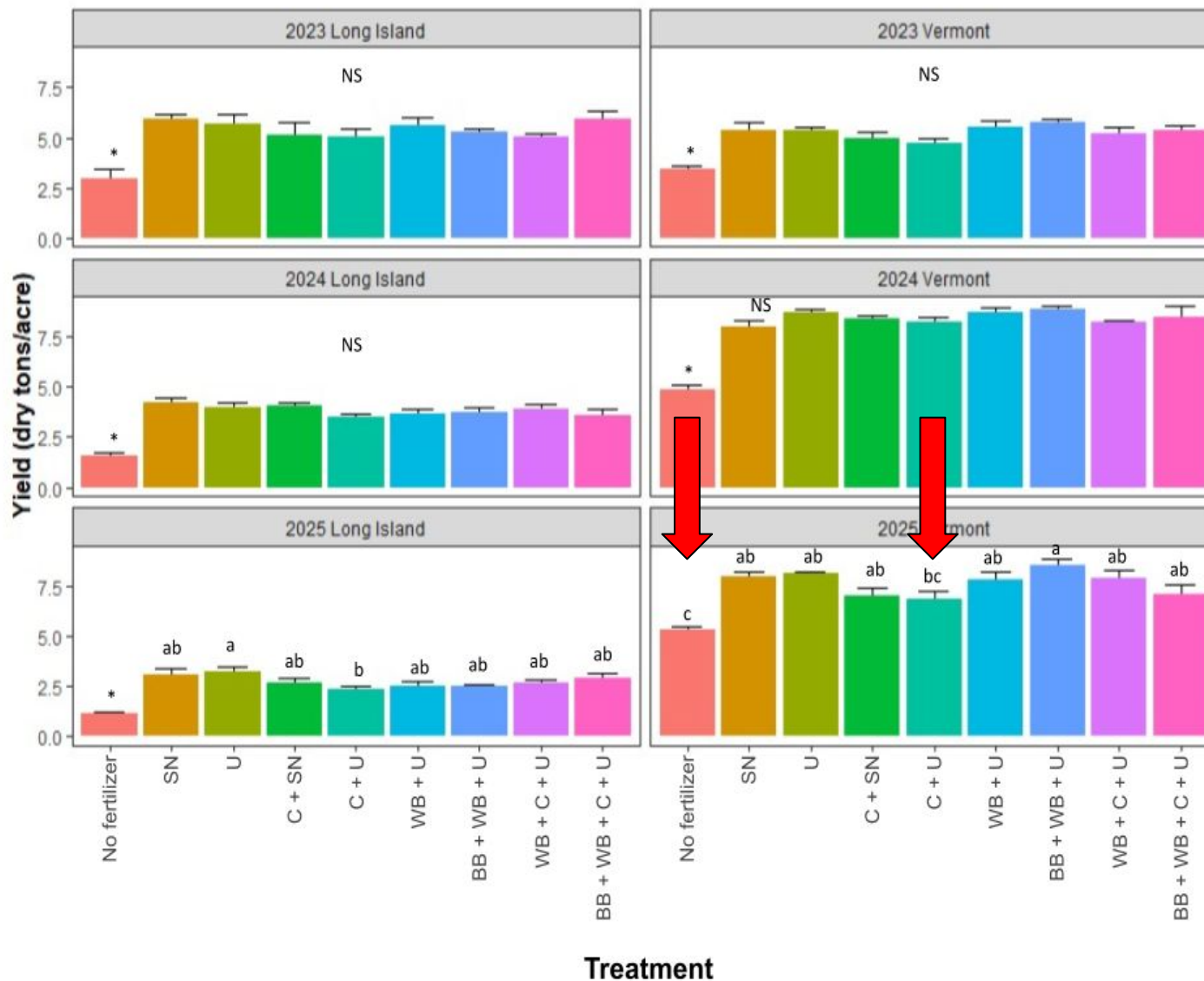
Field trial results - year 3 of 5



Long Island, 2025



Note: 2024 & 2025 were particularly dry years on Long Island!



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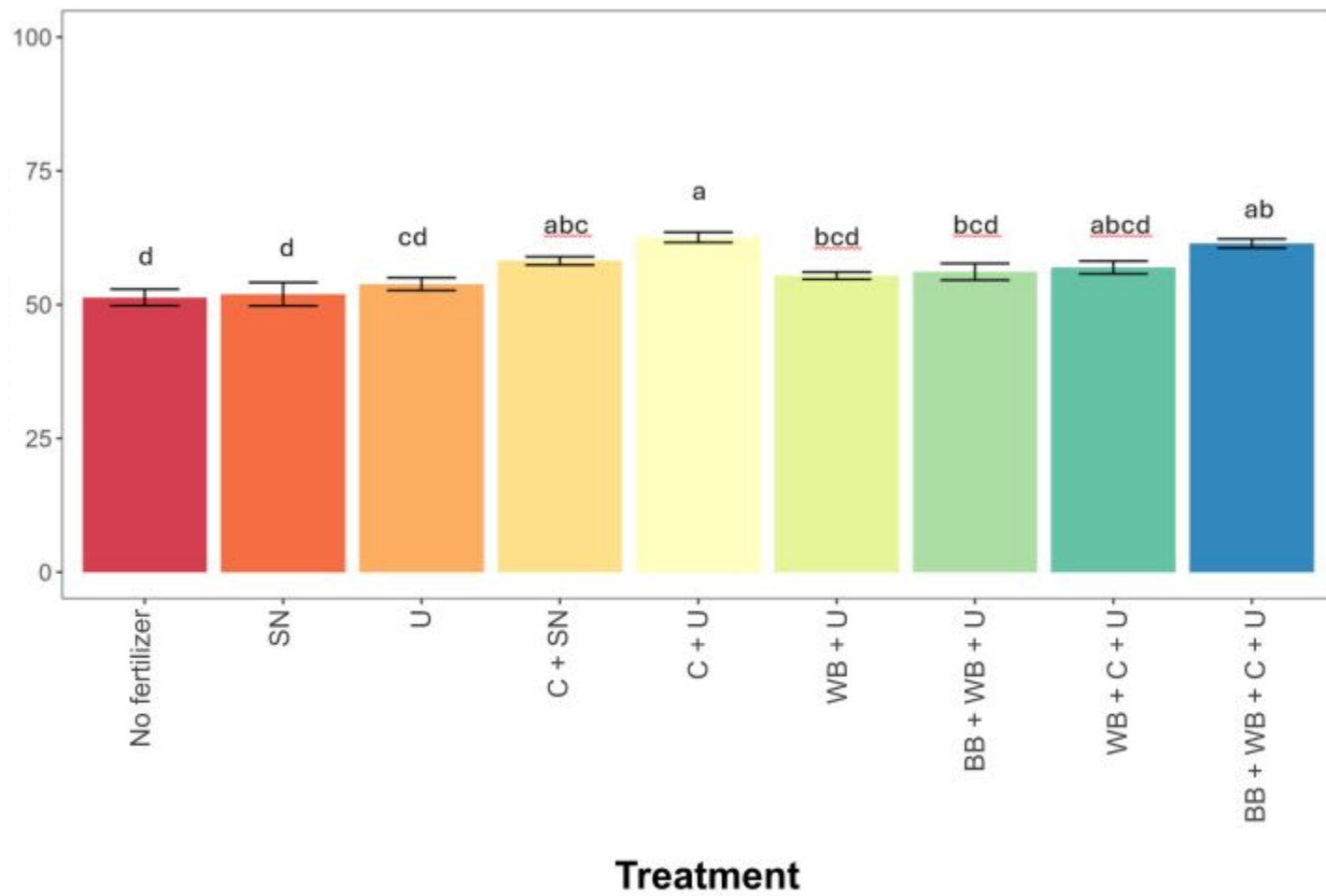
Takeaways:

Urine may be substituted for urea fertilizer with no negative yield effects.

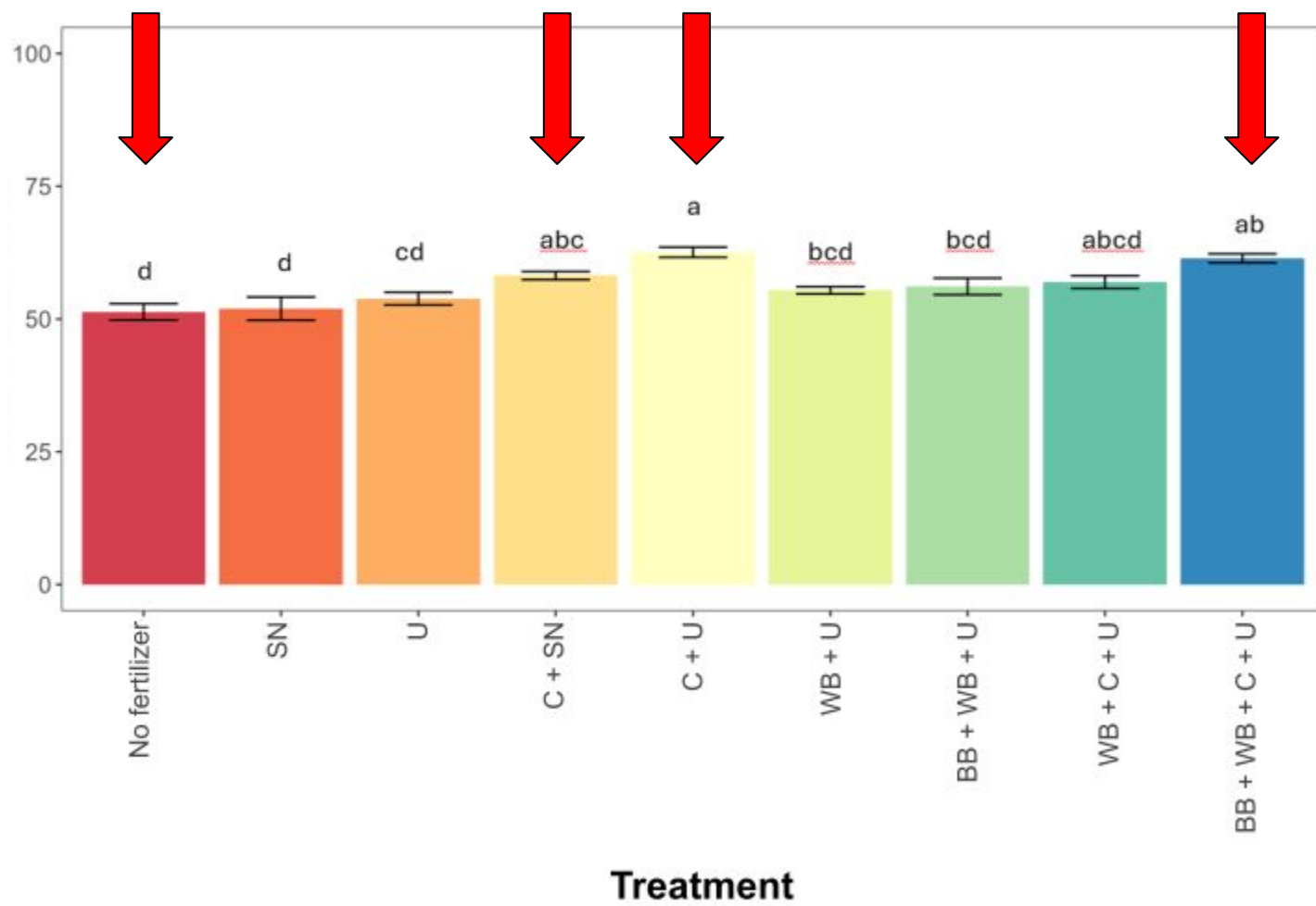
Biosolids biochar and woody biochar may be applied with no negative yield effects.

Lower yields in treatments containing compost, likely due to a higher fraction of organic-N that is not as plant-available

NY Site Soil Health Score



NY Site Soil Health Score



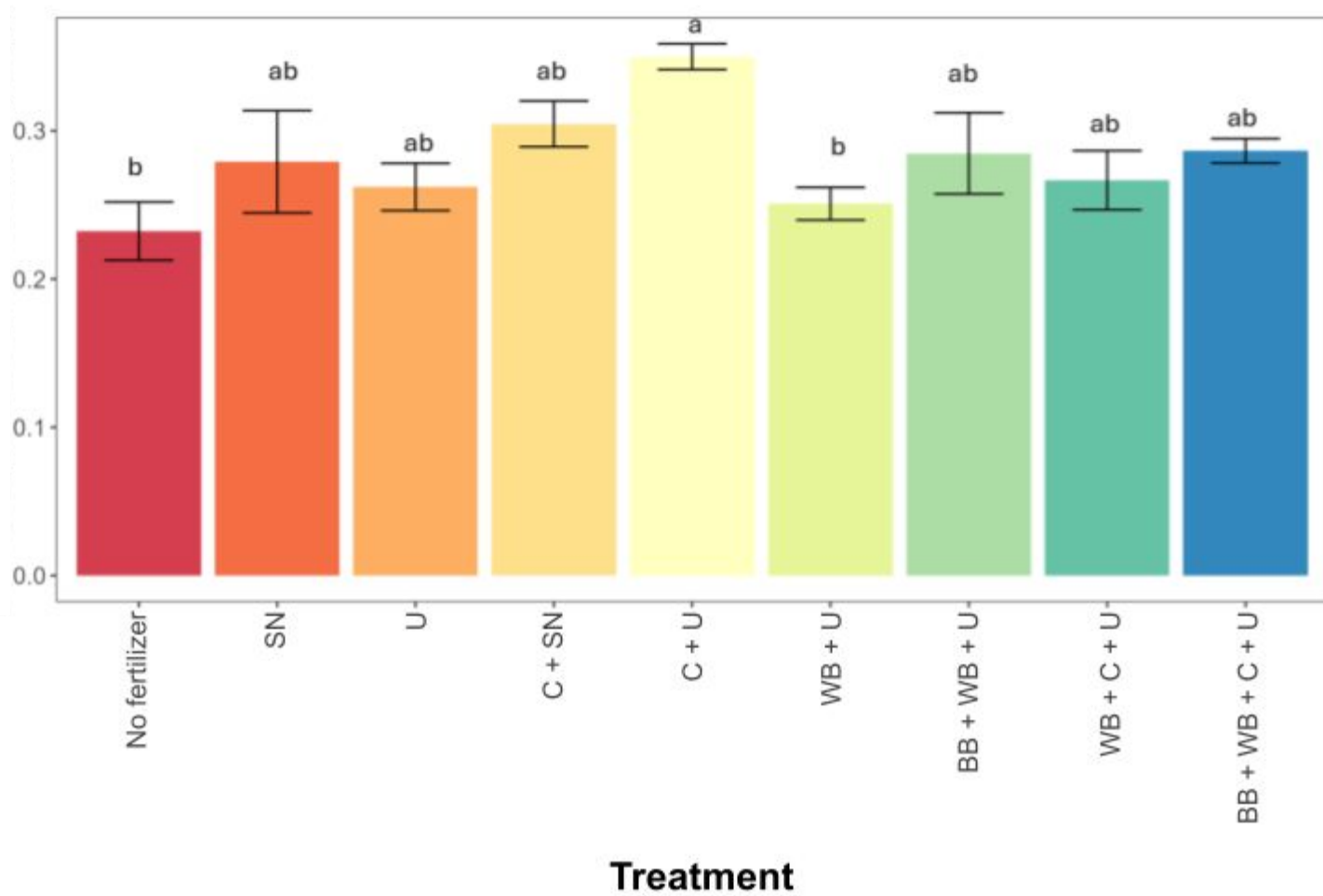
Takeaways:

Effects on soil health were location-dependant, and the benefits of compost were enhanced in sandy soils.

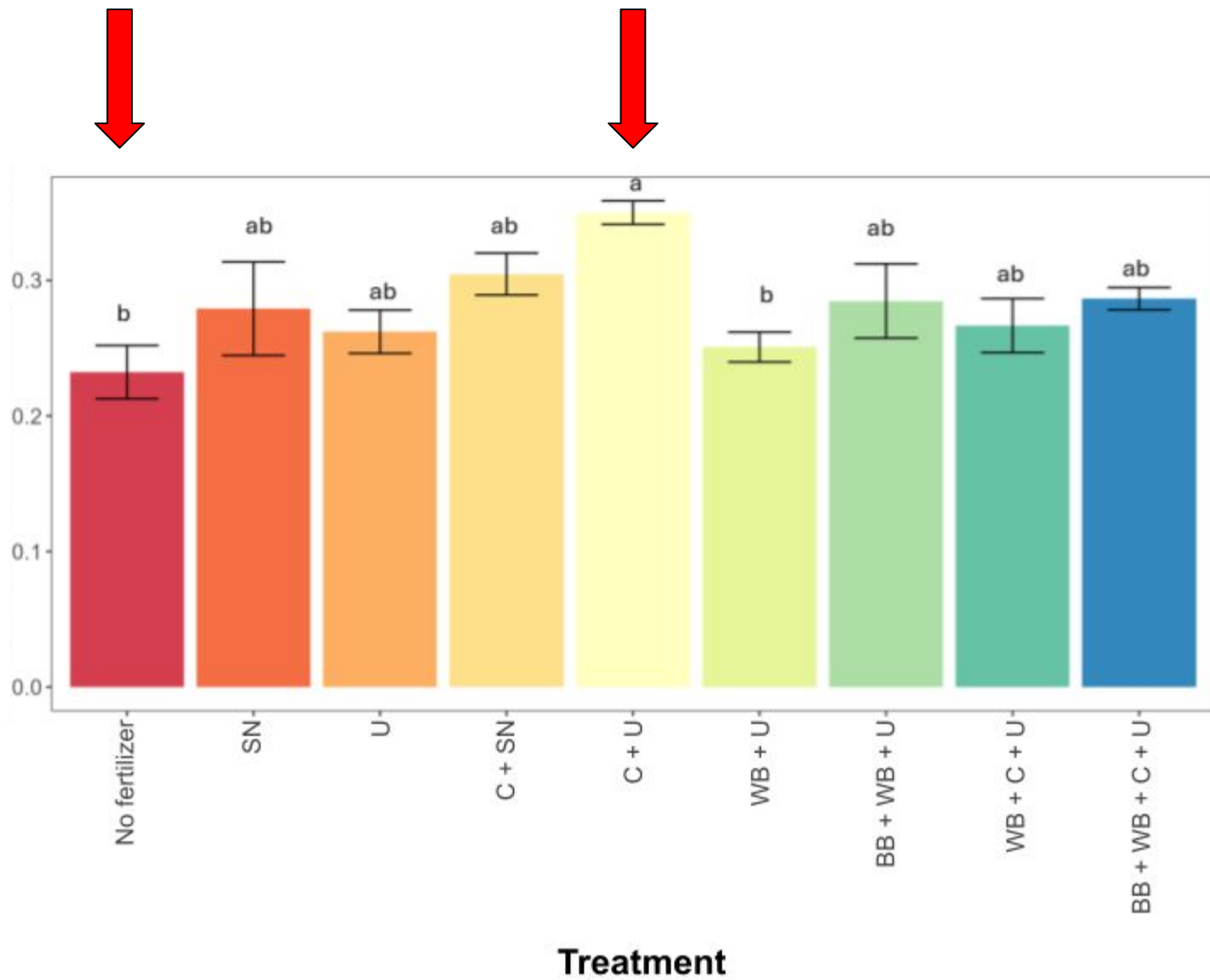
At the NY site, compost-containing treatments generally showed the greatest improvement in soil health, underscoring the importance of regular organic matter additions in building soil health.

Significant improvements to soil health from organic matter additions were observed in as little as three years.

NY Site Soil Respiration (mg CO₂/g dry wt)



**NY Site Soil Respiration
(mg CO₂/g dry wt)**



Takeaways:

There may be synergistic soil health effects of the co-application of **compost & urine**.



Biochar from Biosolids and Source Separated Human Urine: Soil Health Impacts and Farmer Perspectives

Social Research Component



Demographics of interviewees:

- 23 interviews conducted
 - 15 farmers, 1 hort industry, 1 community gardener, 1 planner, 3 landscape company managers, 1 arborist, 2 ag service providers
- Age of participants - 29 - 75
- Gender identities of participants
 - More female than male
- Race/Ethnicity - mostly white, some mixed
- Educational Level
 - Most highly educated
- Range/Size of operation <1 - 500 acres (most 10 - 100)
- Location - LI, Cape, W. Ma, VT, upstate NY
- Type of crop - varied
- Organic, not organic, etc.
 - Most "organic, not certified"
 - Most eco-oriented, "regenerative," "eco-friendly"
 - 2 "conventional" or "traditional"

Demographics - Field Day/Survey Participants

- Field days in Vermont and LI - Approximately 50 participants altogether
- Surveys - 31 total at both events
 - 23 did not attend dialogue group
 - 8 filled out survey AFTER participating in dialogue group
- Dialogue groups - 4 participants at each group
 - Gender: 3 male, 3 female, 1 non-binary,
 - Age: 25 - 73
 - 3 farmers (1 hydroponic, 1 organic), 1 landscape designer, 2 agricultural service providers, 1 community garden manager and 1 environmental engineer.

Key Themes and Ideas

- Influence of personal philosophy on farming practices
- Familiarity
- Soil Health Indicators
- Motivations
- Concerns
- Comfort Level
- Barriers to Adoption
- Info/Support Needs
- Best Crops for Application
- Education Recommendations
- Other (Interesting points and anecdotes)

Philosophy: Or overall farming objectives

- Frugality
 - Concern for utilizing human waste in a better way
 - Wanting to run farms in an energy efficient way
- **“Closing loops”**
 - Recycling
 - Circularity
- Relationship to natural world
 - *“We think of ourselves as part of nature, not separate from.”* - Educational Farm Manager

Familiarity with these amendments

- Urine
 - Most, not all, interviewees were familiar with urine recycling/fertilizer use
- Biochar
 - Most had heard of biochar from other sources
 - Most were not familiar with biosolids biochar
- Terminology Confusion
 - “Source Separation” -
 - “Biosolids” and “Biochar from Biosolids”
 - “Novel” Amendments

“Yeah, I'm sorry... I didn't realize it had to be after sewer ... treatment. I thought it would be done more small scale.”

-Participant in Dialogue Group 1

Soil Health Indicators

- **Plant Observations**
- Soil Tests
- Microbial Life
- Soil Life (seeing mycelia)
- Soil Observations
 - Compaction
 - Erosions
 - Water holding capacity
- Knowledges of Previous Land Use

" I look at soil as an investment into the future"

"Diversity equals resilience..., the higher microbial diversity, the better, the more resilient our system will be, especially as we're seeing a shifting climate."

Key Motivations

- "Closing Loops" - 64 mentions!
- Re-use materials otherwise thought of as "waste"
- "Local"- potential for reduced transportation
- Fitting in with their overall philosophy or farming goals
- Crop type - preference for non-edible crops
- Improving soil health (biochar)
- Potential to reduce contaminants

***"I just know
that it's good.
It's like, what
we eat, it's what
we drink, it's full
of everything
that goes into
our body."***

-Vegetable & Flower
Farmer

Key Concerns (Abstract, hypothetical, complex solutions)

- Unforeseen long term impacts
 - Soil health/Human health
 - Contaminant accumulation over time - **57 mentions**
- Public perception/education needs
- Availability and Infrastructure
 - Crop types - some may require larger volume than readily available, or at reasonable cost

“Urine as fertilizer isn't really a folk story that we're cozy with yet. And there's a lot of, a lot of people, my sense, ... that vacation [here]... and a lot of people that have financial power there are attracted to the pastoral quality of life.” -Community Planner

Key Barriers to Adoption

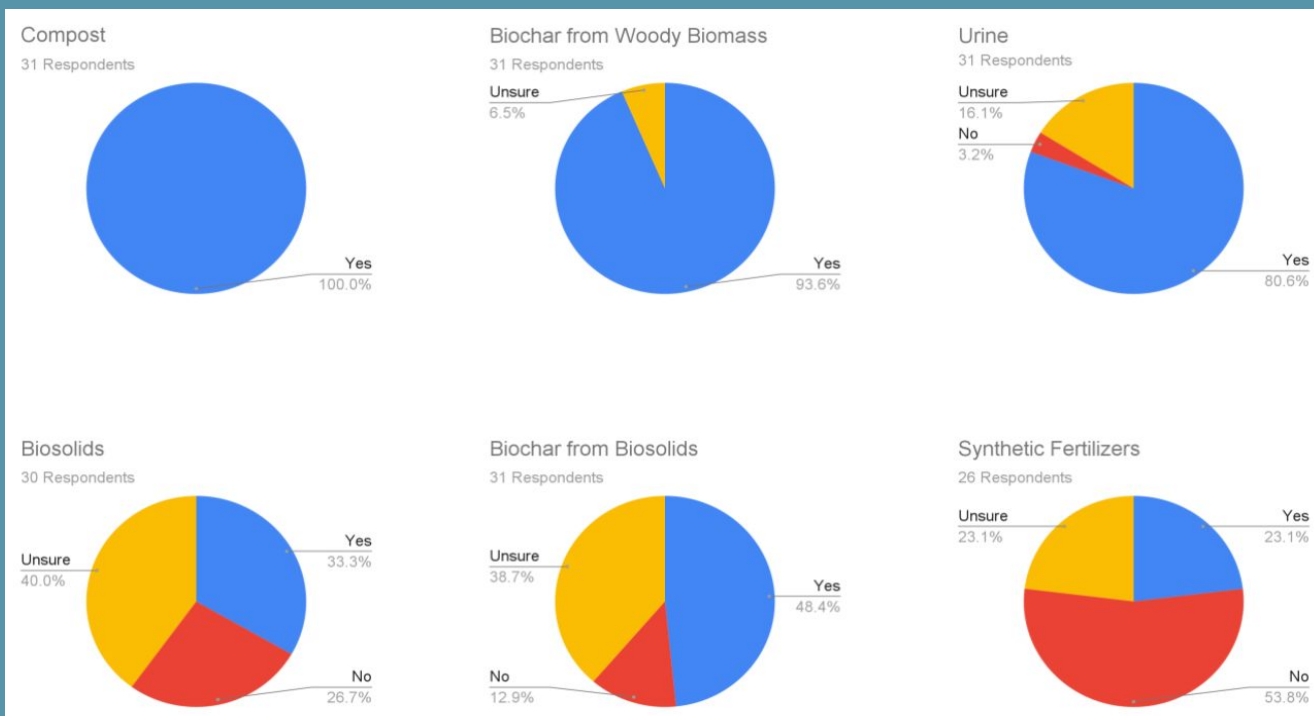
(concrete problems with tangible/pragmatic solutions)

- Availability and transportation needs
- Price
- Consistency of product
- Lack of information
- Funding

“If the ball is rolling and you're starting to produce the stuff... you've got to be able to keep going because... when you don't have it available or it's not available they're going to switch to something else and then you're going to lose their interest and concern... in purchasing it.”

-Greenhouse Manager

Survey Results



Ranking

	1	2	3	4	5	6	Average Ranking	Total Respondents
Compost	53.3%	33.3%	3.3%	10.0%	0.0%	0.0%	1.7	30
Biochar from woody biomass	16.7%	33.3%	30.0%	10.0%	10.0%	0.0%	2.6	30
Urine	16.7%	20.0%	30.0%	16.7%	10.0%	6.7%	3.0	30
Biochar from biosolids	10.0%	0.0%	26.7%	36.7%	20.0%	6.7%	3.8	30
Biosolids	0.0%	6.7%	6.7%	13.3%	36.7%	36.7%	4.9	30
Synthetic fertilizers	3.3%	6.7%	3.3%	13.3%	23.3%	50.0%	5.0	30

Key Information/Support Needs

- Experimental trials on specific crops
- Data on nutrient composition
- Guidance for application
 - MSDS
- Data on contaminants
- Application requirements

If we could have a 50-year study and the results were overwhelming that it helps your soil, that would be the biggest help a guy could have. But just what is the analysis when you put it on your soil and then what happens after five years? ... because...within five years you'd either have a buildup or you'd have a change in the soil if there is gonna be one.

Regulation

Thoughts about how and by whom these amendments should be regulated

Yeah, good question. I don't know. I mean, yeah, I guess when I originally interpreted your question, I was like, universities should be doing, you know, should be running the tests. But yeah, I don't, I don't really have an answer for that. I mean, I think some sort of independent or, I don't know, I don't know, I wish everybody like... [trails off]. I trust, I trust a lot. But I think that some people aren't trustworthy, I guess, I'm learning in my old age [laughs]. So yeah, unfortunately... maybe it is university... independent, like, you know, that go out there and get paid to, you know... I don't know, I don't know. I don't know!

Education Recommendations

- Straightforward language
- Align communication with goals of municipalities
- Highlight conservation benefits

Format:

- Popular communication (social media, local extension)
- Preference varied
 - Shorter format is best
 - Clear, eye catching graphics
- On-farm demonstrations

Overall Takeaways from the Social Research

I would say on the whole, I'm very supportive of the research that you guys are doing and the potential for diverting these waste streams and making something useful out of them and closing the loop is absolutely something that... I want to see happen soon. I don't necessarily know that our farm, because of ...our scale and also ...our marketing strategy and the types of things that we're producing, I don't necessarily know that we would be an early adopter of human derived fertilizer products, but I think... there's loads and loads of potential maybe in other types of farms that aren't necessarily a market garden style and are more... non-food crops or something like that would be really good.

-

Final Takeaways from Field Work and Social Research

- Farmers are motivated to improve soil health; many were intrigued by the potential of biosolids biochar to improve soil health characteristics in the long term.
- Urine can be substituted for synthetic fertilizer without causing changes in yield or soil health; a biosolids biochar/woody biochar blend can be substituted for woody biochar without significantly affecting yield or soil health.
- Farmers were open to the idea of using human waste derived amendments as a way to "close loops," and felt that finding alternatives to current methods of managing human waste is important.
- Co-application of compost and urine to the sandy soil of the NY field site significantly improved soil health compared to no fertilizer, synthetic nitrogen, urine, and urine + biochar.

Final Takeaways from Field Work and Social Research

- Urine was as effective a fertilizer as synthetic nitrogen; combining urine with other amendments does improve soil health depending on prior soil conditions.
- Further exploration of the potential of biosolids biochar as a soil amendment is warranted; more data is needed to fully understand the costs and benefits of pyrolysis of biosolids as an alternative method of managing human waste.
- Farmers would like to see transparent and accessible information about input sources and processing methods for biosolids biochar.

Extra slides

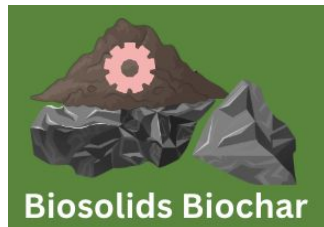
PFAS in agriculture

	PFOA Concentration	Annual addition to cropland (ng PFOA/ square meter cropland)
Rural rainwater , Wisconsin, USA (Pfothenauer et al., 2022)	0.16 ng/L	105
Urine from general population , Hubei, China (Zhou et al., 2014)	19 ng/L	39
Biosolids Biochar (Bioforcetech), California, USA, (Thoma et al., 2022)	80 ng/Kg	27
Biosolids , Michigan, USA, (Link et al., 2024)	4800 ng/Kg	1402
Background soil levels , Massachusetts, USA (McIntosh et al., 2025)	778 ng/Kg	157,545

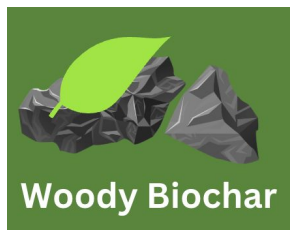
Amendment Summary



Biochar: A solid, charcoal-like material created when organic matter is pyrolyzed (burned in a low oxygen environment).



Biosolids: Sewage sludge that has been treated to meet EPA standards for land application as a fertilizer. They can contain nutrients, such as nitrogen and phosphorus, as well as contaminants, such as heavy metals and organic contaminants.



Biosolids biochar: Biochar made from a biosolids feedstock

Woody biochar: Biochar made from a woody feedstock



Source-separated human urine: Urine that has been collected separately from other waste streams, using urinals or a urine-diverting toilet. The nutrients from source-separated urine can be reclaimed as a fertilizer.

SARE Novel/FFAR Study intro/ background story arch:

New study looking at long-term effect of urine fertilizer on soil health, not only with urine but also in combination with other soil health-building amendments, including compost and biochar.

What is biochar and why does it pair nicely with urine?

We also wanted to learn about a new contaminant in urine, and other wastewater streams — PFAS

What is PFAS and why is it in biosolids? Why is that a problem?

What is the comparative risk of PFAS in biosolids vs. in urine fertilizer?

- source separation is one way to keep our relatively clean

What can be done about the PFAS biosolids problem? We know we need to stop producing PFAS, but in the meantime of that—and/or a total transformation to source separation systems...—wastewater treatment plants continue to accumulate the burden of PFAS-laden biosolids. Maine tried banning land application, but the solids still need to go somewhere...

One idea is turning biosolids into biochar. Pyrolysis has shown to remove PFAS, some companies are already creating biosolids pyrolysis plants, but there are still questions about where the PFAS are going.. is it just creating a new environmental justice issue, with air pollution? And what about the soil?

That's why biosolids biochar is part of our soil health study, and also why we're doing social research into people's perspectives about this. these are all the amendments we're exploring in this project...