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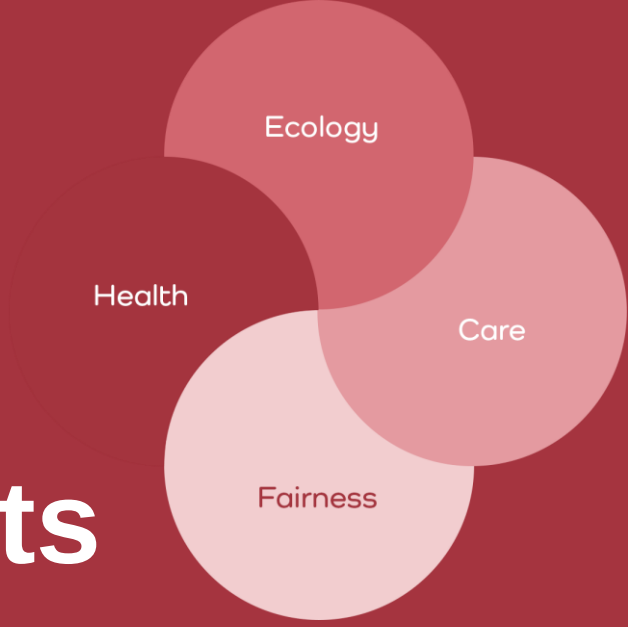



# Properties of compost and its impact on climate

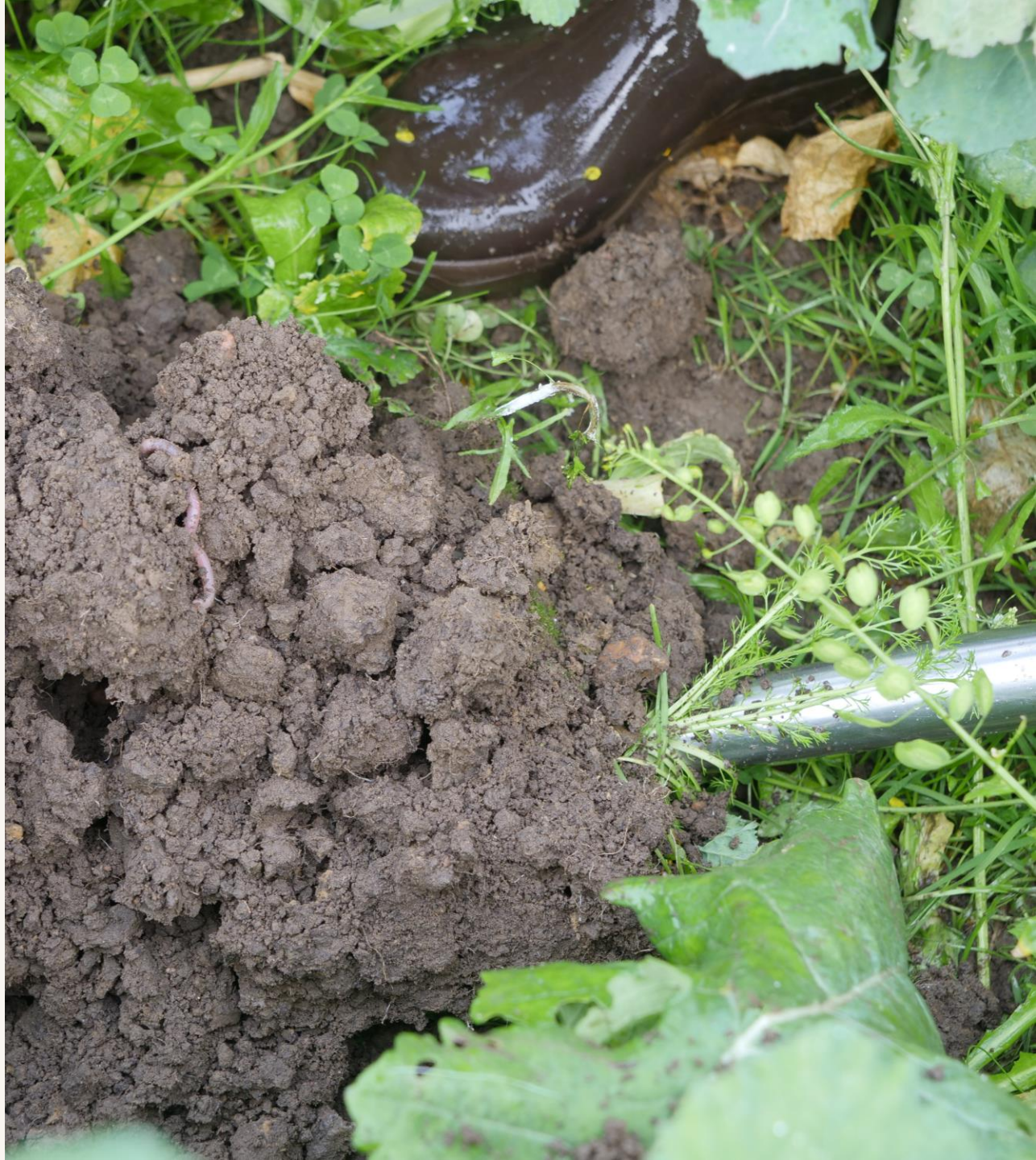
Morten W. Vestenaa

Plantekongres 2025

Promilleafgiftsfonden for landbrug

# The next 15 minutes

- Compost to regenerate soil carbon
- Climate footprint of pile composting
- Climate footprint of compost field application



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# Compost to regenerate soil carbon

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Foto: Jesper Truelsen

Tabel 1. Næringsstofindhold og tungmetaller for 'landbrugskompost' fra de 10 lokaliteter (8 markstakke og 2 genbrugsstationer), som er med i undersøgelsen. Også mængden af synligt plastik og sten figurerer i tabellen.

30 t compost / ha

178 kg N / ha

32 kg p / ha

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen (N*1) | kg/ton | 7,65 | 5,21 | 8,65 | 6,28 | 4,57 | 4,75 | 6,29 | 4,59 | 5,53 | 5,66 | 5,92 |
| Fosfor, total | kg/ton | 1,2 | 1 | 1,5 | 1,2 | 0,92 | 0,96 | 0,97 | 0,9 | 0,97 | 1 | 1,06 |

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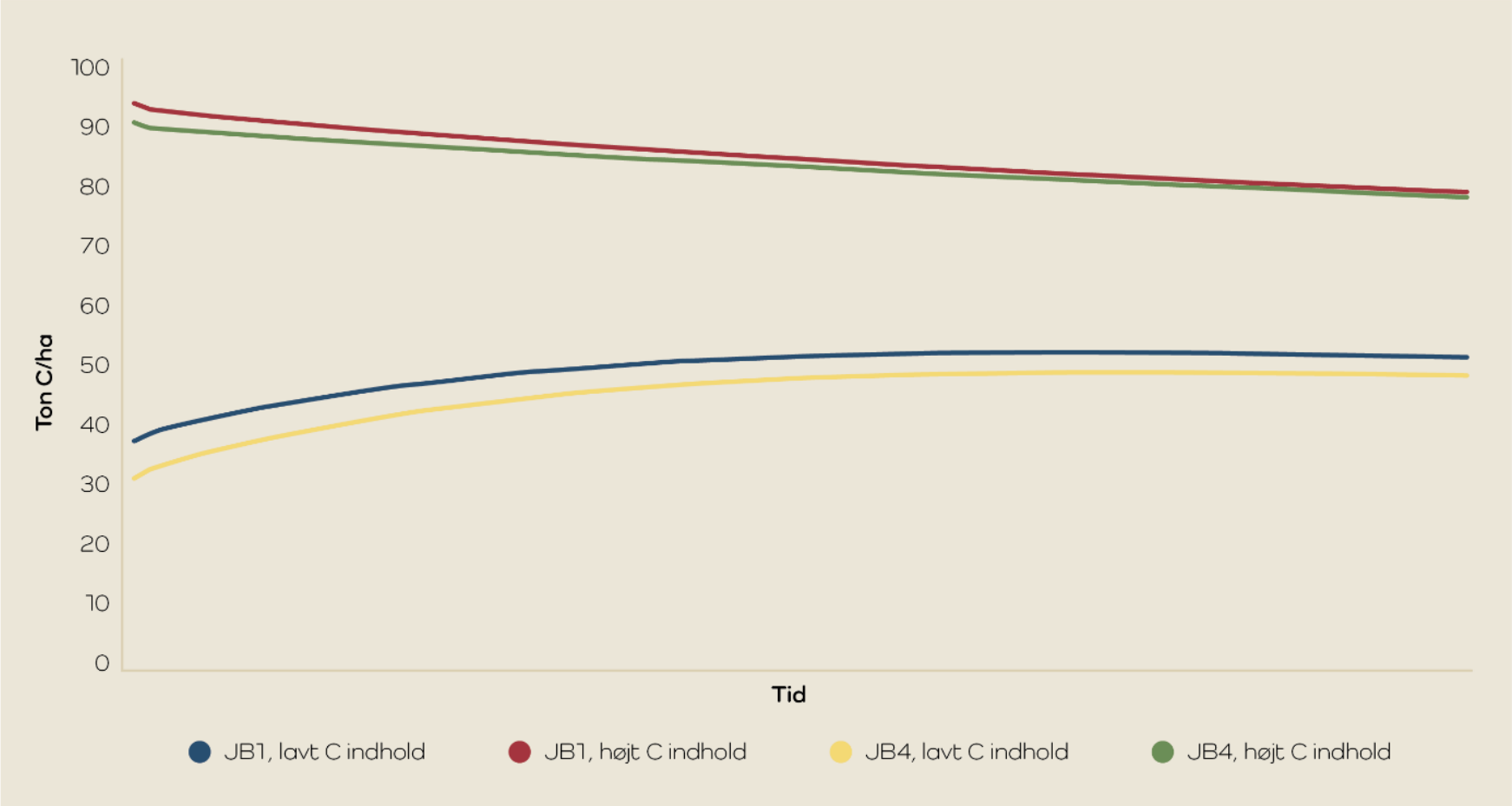
# Initial carbon stock and application rate determine if carbon stocks are regenerated or lost

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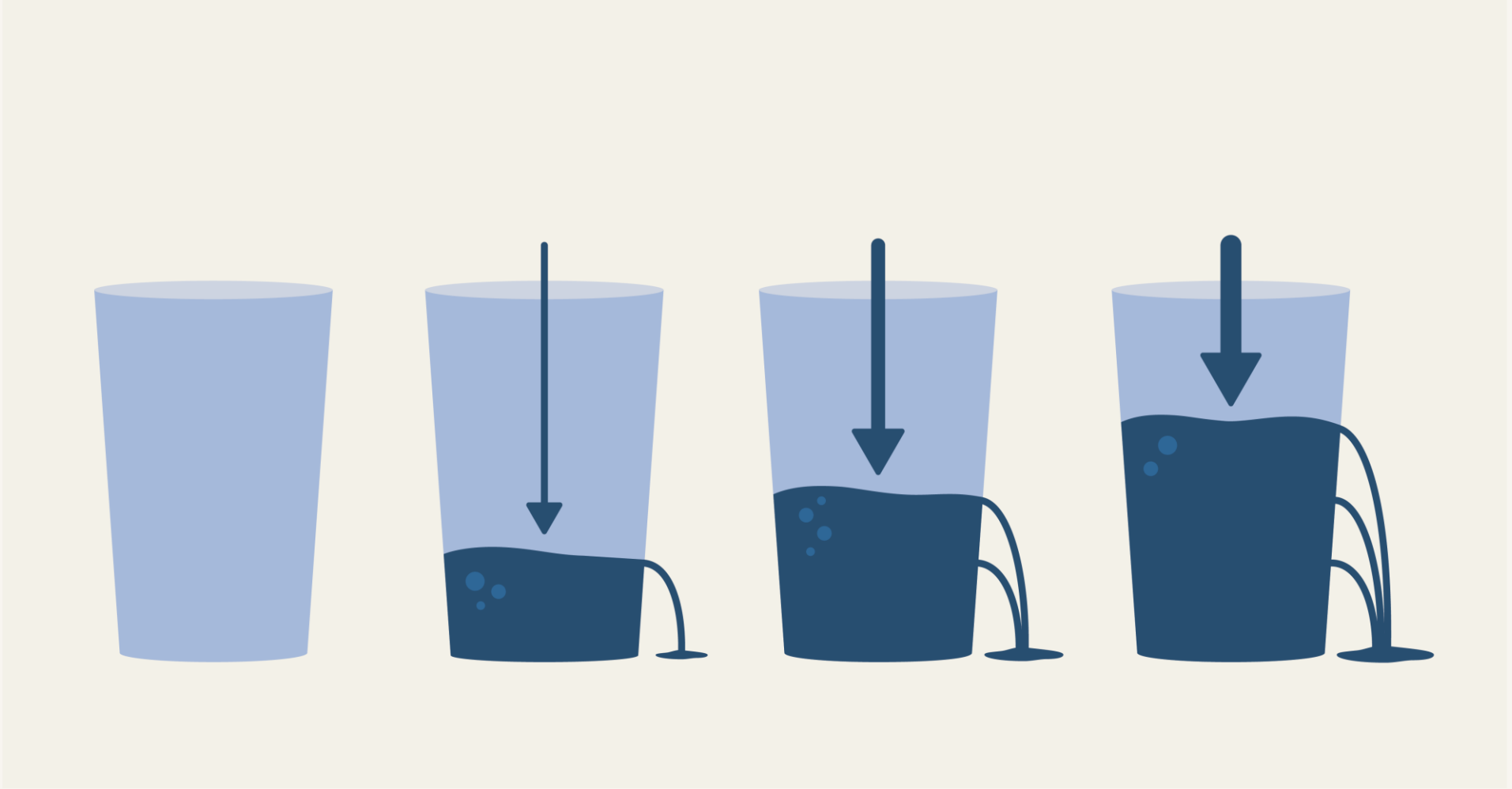
# Soil Carbon equilibrium



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# DOKK Trails

Swiss trails started 1978

- 0,7 or 1,4 aminal units /ha
- Conventional with and without manure

CONFYM – Conventional practice with manure and mineral fertilizer

BIOORG – Organic practice with ”rodden” manure

BIODYN – Biodynamic practice with composted manure

| Farming system | Mean annual SOC change | | |
|---|---|---|---|
| | [mg $kg^{-1}$ soil $yr^{-1}$] | | |
| NOFERT | −91.71 | 6.99 | e |
| BIODYN 0.7 | −27.47 | 7.11 | cd |
| BIOORG 0.7 | −37.56 | 7.04 | d |
| CONFYM 0.7 | −37.43 | 7.18 | d |
| BIODYN 1.4 | 35.84 | 7.17 | a |
| BIOORG 1.4 | 9.17 | 7.01 | ab |
| CONFYM 1.4 | 1.68 | 7.13 | bc |
| CONMIN | −27.75 | 7.08 | cd |

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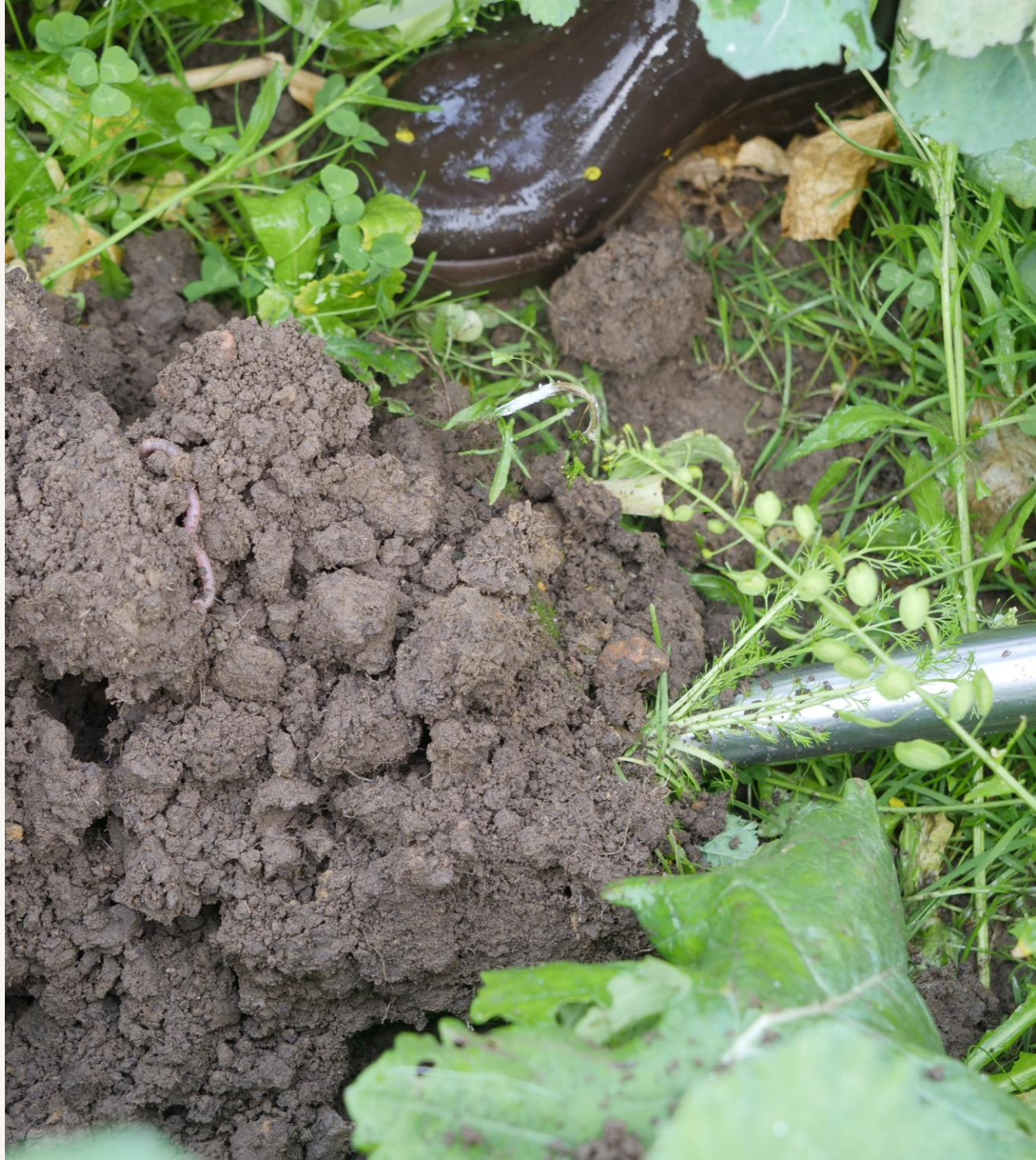
Kilde: Krause, H. M., Stehle, B., Mayer, J., Mayer, M., Steffens, M., Mäder, P., & Fliessbach, A. (2022). Biological soil quality and soil organic carbon change in biodynamic, organic, and conventional farming systems after 42 years. Agronomy for Sustainable Development, 42(6), 117.

## Key message

”Regenation of soil carbon with compost depends on application rate and initial soil carbon status.„

- Compost to regenerate soil carbon
- Climate footprint of pile composting
- Climate footprint of compost field application
- Questions



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# Greenhousegas emmisions during pile composting

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Foto: Anton Rasmussen

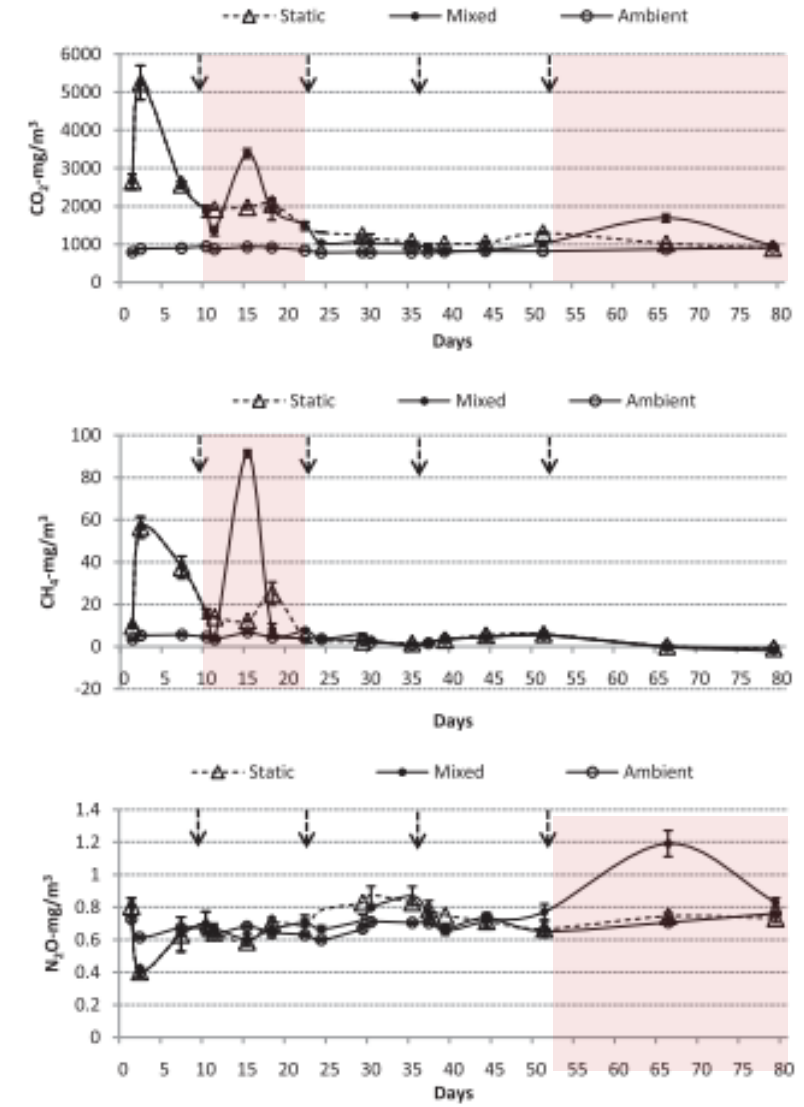
# Greenhousgas emissions from composting

- $CH_4$ – 28 times stronger than $CO_2$
- $N_2O$ – 265 times stronger than $CO_2$
- $CO_2$ – biogenic*

$CH_4$ and $N_2O$ form in oxygendepleted cavaties in compost piles where diffusion < respiration

# Greenhousgas emissions from composting

- Mixed and static compost piles emit $CH_4$ and $CO_2$ in the initial composting phase
- Mixing promotes emission of $N_2O$, $CH_4$ and $CO_2$ in later in the proces




Concentrations (mean ± SE of 3 piles) of $CO_2$, $CH_4$, and $N_2O$ in ambient air and in flux chamber emissions from static and mixed compost piles. The arrows indicate mixing dates.

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# Carbon loss during pile composting

Biogenic, but…

| | 18 tons kompost |
|---|---|
| % C loss during composting[1] | 32 % |
| t untreated biomass | 23,8 |
| Emissions $CH_4$, kg[2] | 60,4 |
| Emissions $N_2O$, kg[2] | 1,4 |
| Kg $CO_2e$, from $CH_4$ | 1.692 |
| Kg $CO_2e$, from $N_2O$ | 366 |
| Kg $CO_2e$, total | 2058 |

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Kilde: Graasbøll, S., Berggreen, S. K., Guldberg, A. N., Gudsøe, C. L., Schjødt-Hansen, J., Fredenslund, A. M., & Scheutz, C. (2023). Reduktion af klimagasser fra behandling af haveaffald-Del 2: Emissionsfaktorer for behandling af haveaffald i Danmark.

[1] Biomassetab ved kompostering målt i Andersen et al., 2010
[2] Beregnet med emissionsfaktorer fra Graasbøll et al., 2023

# Emissions during pile composting of garden/park waste (DK)

| | 18 tons kompost |
|---|---|
| % C loss during composting[1] | 32 % |
| t untreated biomass | 23,8 |
| Emissions $CH_4$, kg[2] | 60,4 |
| Emissions $N_2O$, kg[2] | 1,4 |
| Kg $CO_2e$, from $CH_4$ | 1.692 |
| Kg $CO_2e$, from $N_2O$ | 366 |
| Kg $CO_2e$, total | 2058 |

For comparison, the greenhouse gas emissions from stable and storage facility that produce 27 tons of animal manure ab animal is approx. 1400 kg $CO_2e$.

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Kilde: Graasbøll, S., Berggreen, S. K., Guldberg, A. N., Gudsøe, C. L., Schjødt-Hansen, J., Fredenslund, A. M., & Scheutz, C. (2023). Reduktion af klimagasser fra behandling af haveaffald-Del 2: Emissionsfaktorer for behandling af haveaffald i Danmark.

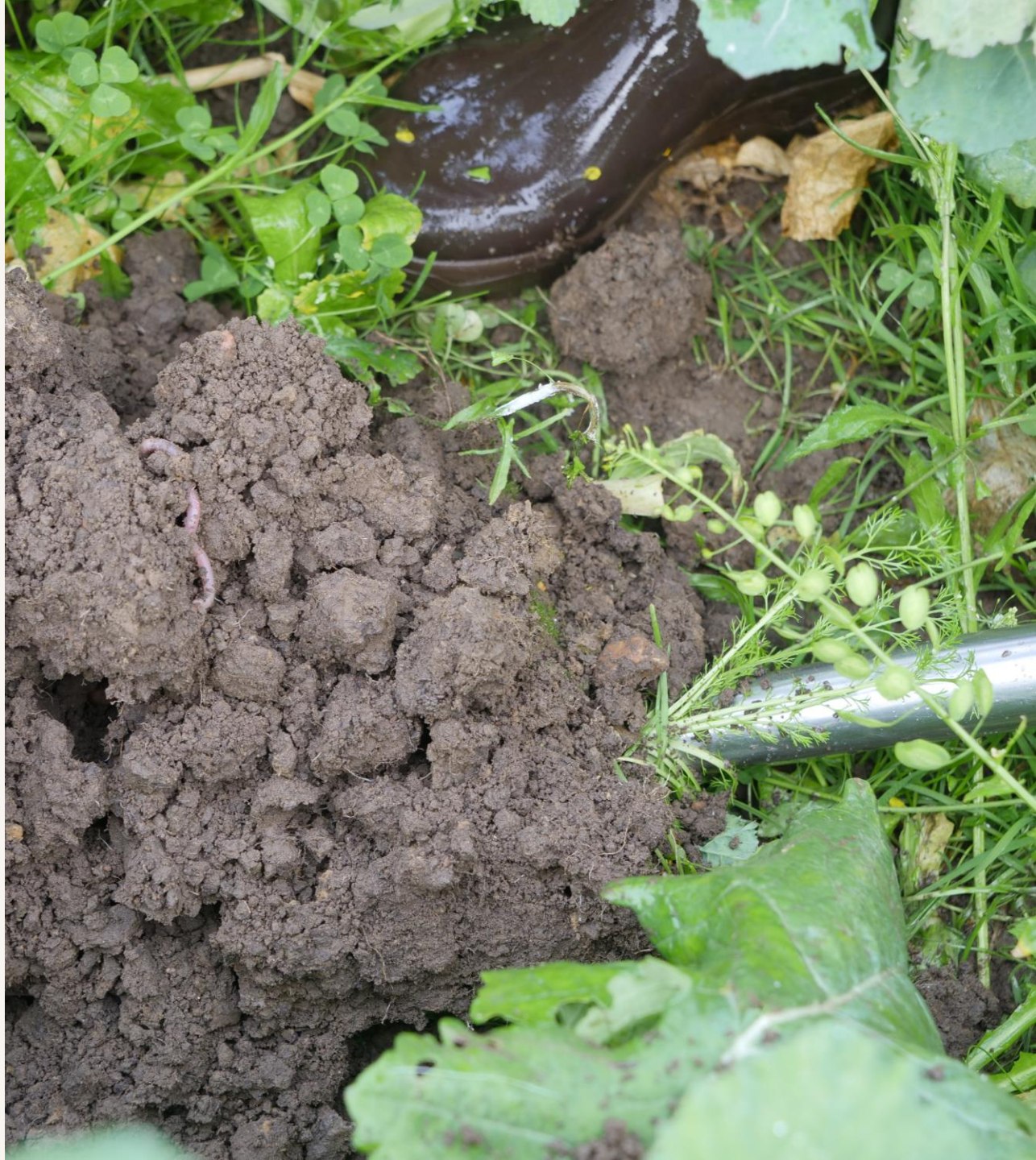
[1] Biomassetab ved kompostering målt i Andersen et al., 2010
[2] Beregnet med emissionsfaktorer fra Graasbøll et al., 2023

## Key messages

”Pile composting emit greenhouse gases due to carbon and nitrogen turnover and variation of oxygen pressuere in piles.”

”Climate footprint of composting biomass is larger than current manure handling practices.”

- Compost to regenerate soil carbon
- Climate footprint of pile composting
- Climate footprint of compost field application
- Questions



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# Climate footpring of compost field application

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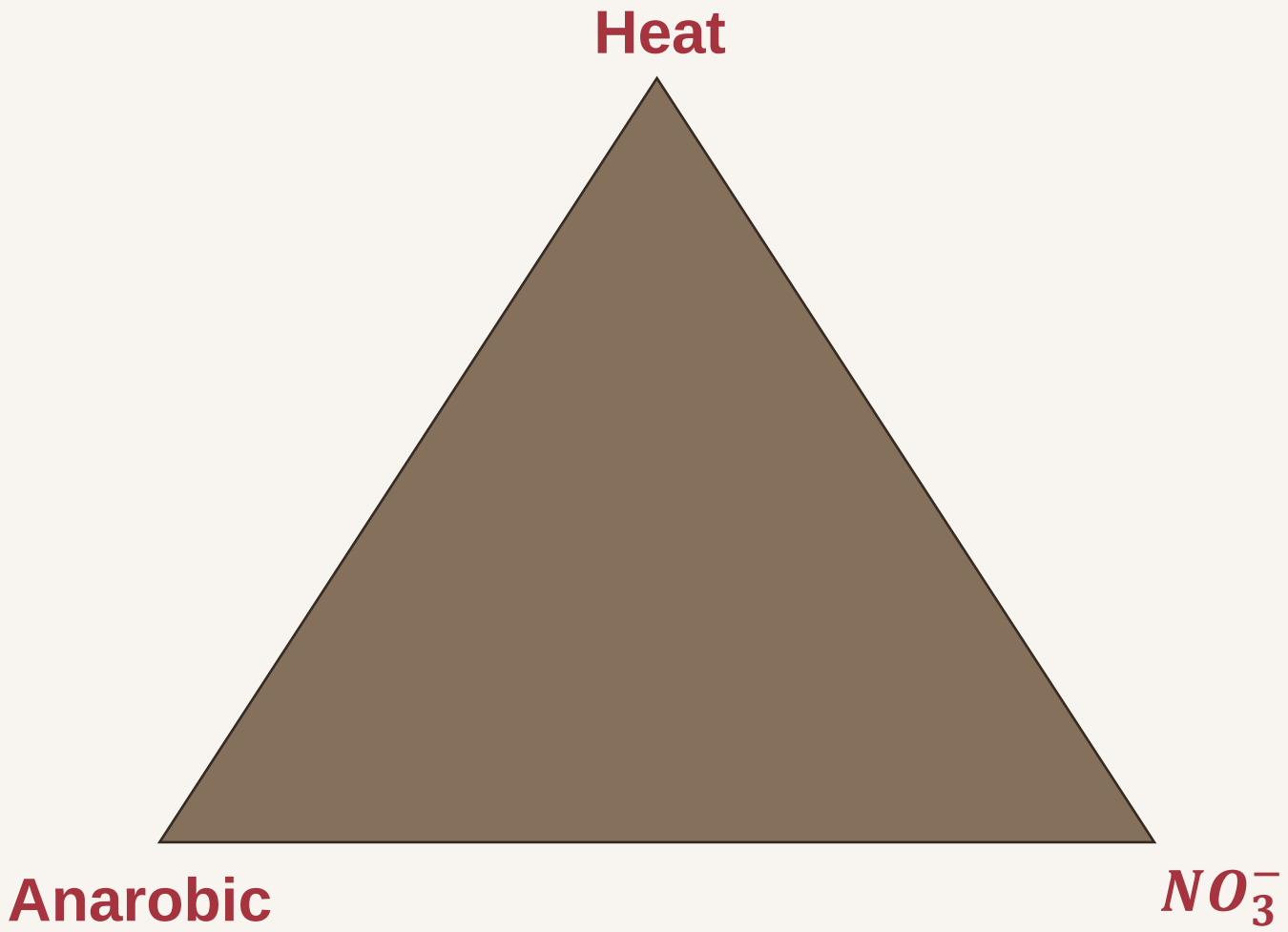
Foto: Linda Rosager Duve

# $N_2O$ emission triangle



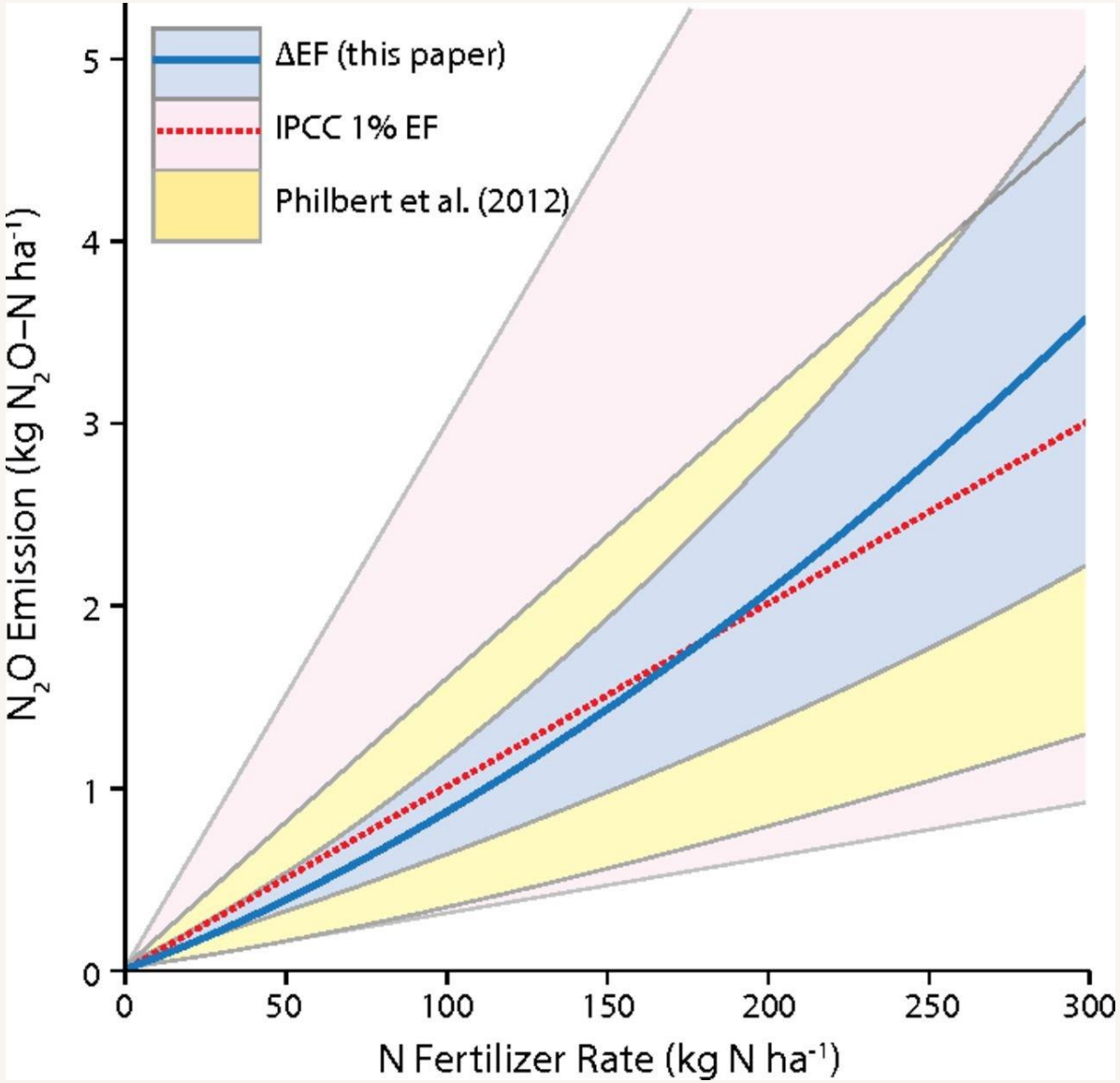
# Emmisionsfactor

**Present:**

Emissionfactor 1%

**Future:**

Technique, fertilizer and fertilizer rate specific emissionfactors

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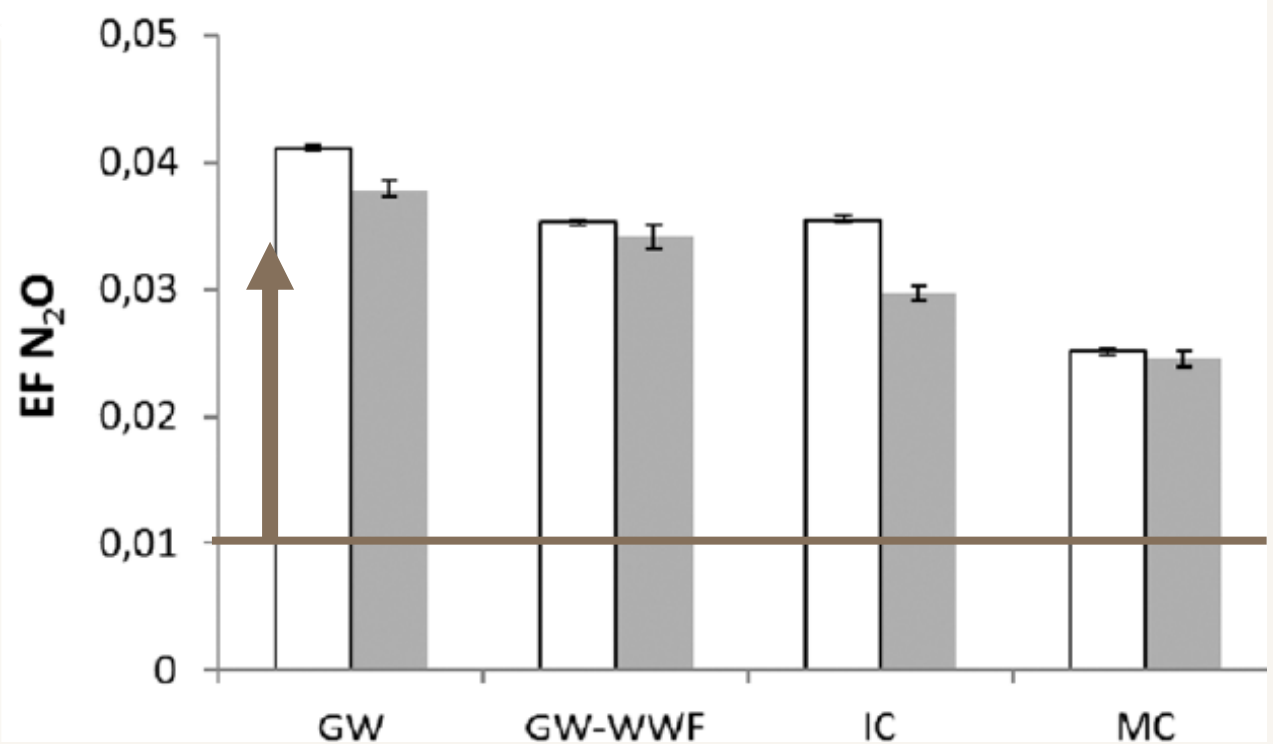
Shcherbak, Iurii et al. “Global metaanalysis of the nonlinear response of soil nitrous oxide (N2O) emissions to fertilizer nitrogen.” *Proceedings of the National Academy of Sciences* 111 (2014): 9199 - 9204.

# What is the $N_2O$ emissionfactor for compost?

- The emissionfactor can potentiely be higher than 1 % for compost

- But it can also be lower… One large meta-study found emissionsfaktor of 0,27 % upon field application.

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Kilder:
Nielsen, M. P., Yoshida, H., Raji, S. G., Scheutz, C., Jensen, L. S., Christensen, T. H., & Bruun, S. (2019). Deriving environmental life cycle inventory factors for land application of garden waste products under Northern European conditions. Environmental Modeling & Assessment, 24, 21-35.
Charles, A., Rochette, P., Whalen, J. K., Angers, D. A., Chantigny, M. H., & Bertrand, N. (2017). Global nitrous oxide emission factors from agricultural soils after addition of organic amendments: A meta-analysis. Agriculture, Ecosystems & Environment, 236, 88-98.

# ICOEL long term compost $N_2O$ emission trail

- 3 years
- Low input organic crop rotation
- Residual emission and fertilizer effects of compost

Field trip 27th of january. See ICOEL.dk


er Laursen

Innovationscenter for Økologisk Landbrug

**Compost to regenerate soil carbon**

”*Compost add carbon to soil, but do not nessesarily regenerate soil carbon stocks.*„

**Climate footprint of pilecomposting**

”*There are emissions of climate gasses during pile composting larger than that of current manure handling practices.*„

**Climate footprint of compost fertilisation**

”*Current emissionfactor yield compost as a climate heavy fertilizer it should be revised*„

# “Next-generation” compost strategies for enhancing soil health and crop resilience

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Internationalt Center for Forskning i Økologisk Jordbrug og Fødevaresystemer

Miljø- og Fødevareministeriet
gudp

ComCrop



CLOSECYCLE
Interreg North Sea
Co-funded by the European Union

About **95%** of our food nutrients come from soils

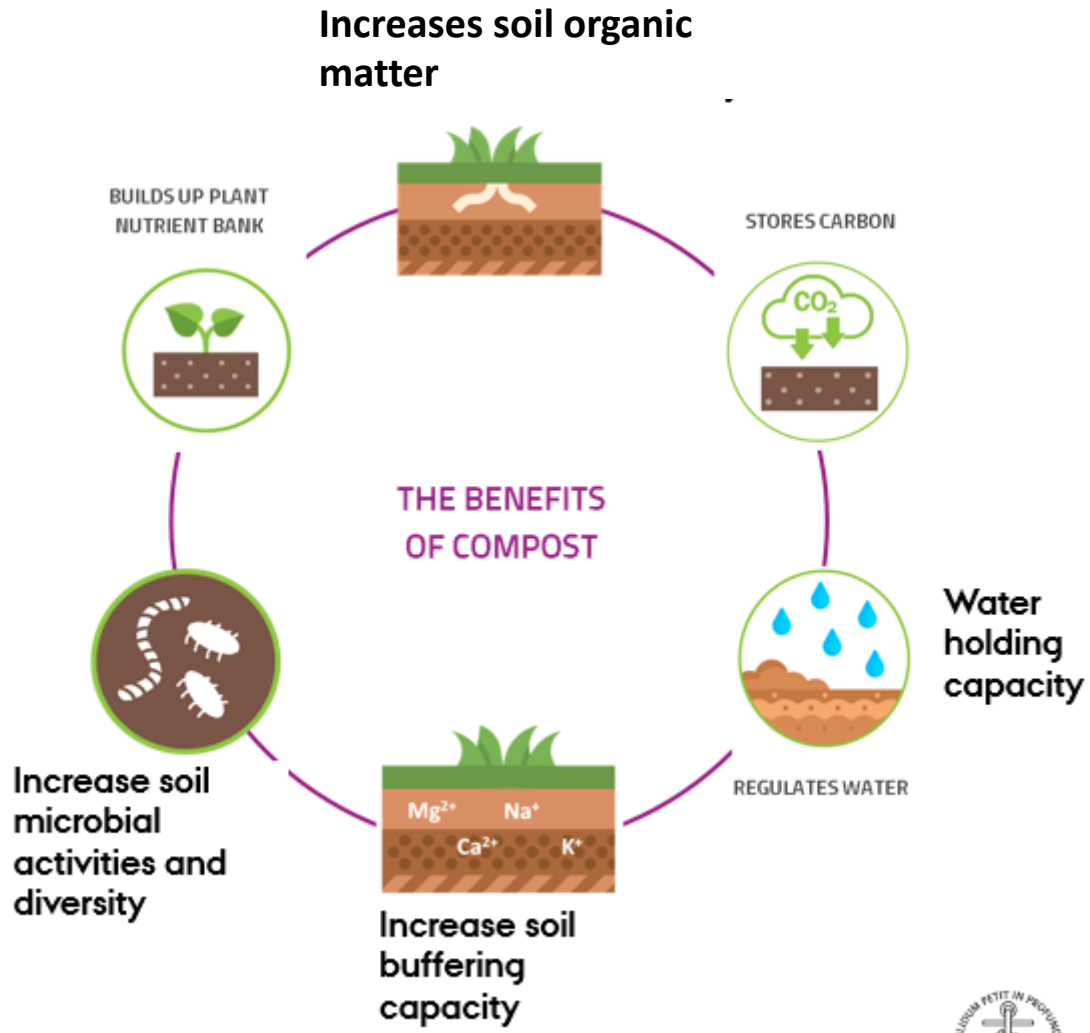
Food and Agriculture Organization of the United Nations

Over **60%** of European soils are **unhealthy**

Panagos et al., 2024

- How can we improve soil health?

## Compost plays a significant role in **restoring soil health** and improving **crop resilience**




Adapted from EU composting network

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# Projects at AU-Food on composting and its applications

Soilcom : Sustainable soils by **quality compost** (2020-23)

CloseCycle : Closing cycles by products from residue-based bioresources on **regional levels** (2024-27)

ComCrop : New **composting technology** for on-farm nutrient and carbon recycling (2021-24)




ICROFS

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Interreg North Sea Region SOILCOM European Regional Development Fund EUROPEAN UNION

CLOSECYCLE | Interreg North Sea Co-funded by the European

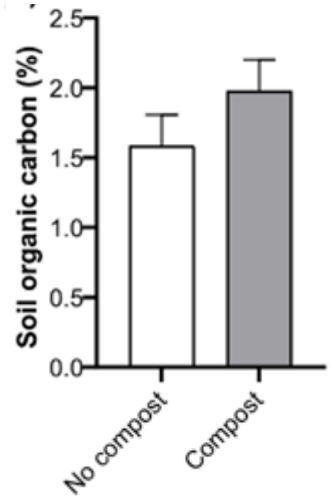
# Outline of this presentation

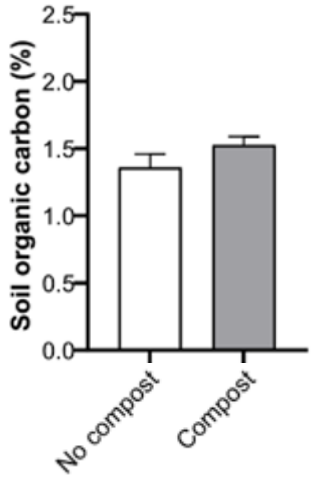
1. Selected results that **highlight the benefits and limitations** of compost application on soil health and crop production
   - ✓ Soil organic C
   - ✓ Soil microbial activity and diversity
   - ✓ Crop yield
2. **Strategies** to minimize the limitations and maximize the benefits of compost application

# Long term effect of compost application on SOC

- **SOILCOM** long-term field experiments

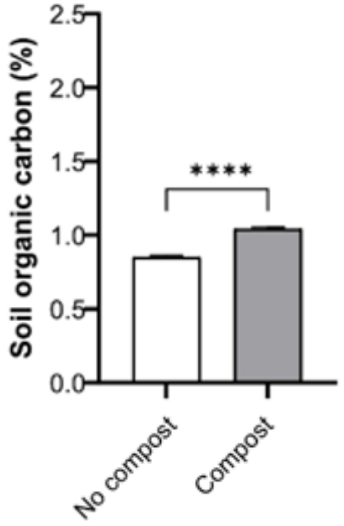
- 10-30 tons /ha
- Sandy loam soil
- Garden park waste compost
- **3 years**
- AU-DK

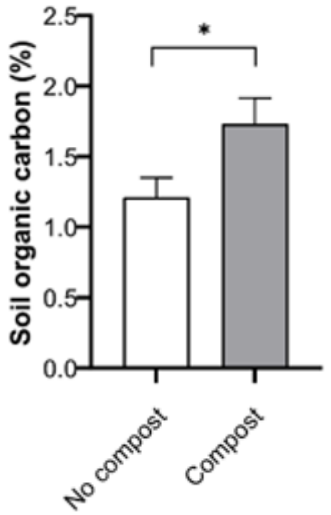



- 48 tons/ha
- Sandy soil
- Green waste compost
- Ornamentals
- **9 years**
- PCS-BE

- 2 tons C/ha
- Sandy loam soil
- Farm compost
- **11 years**
- ILVO-BE

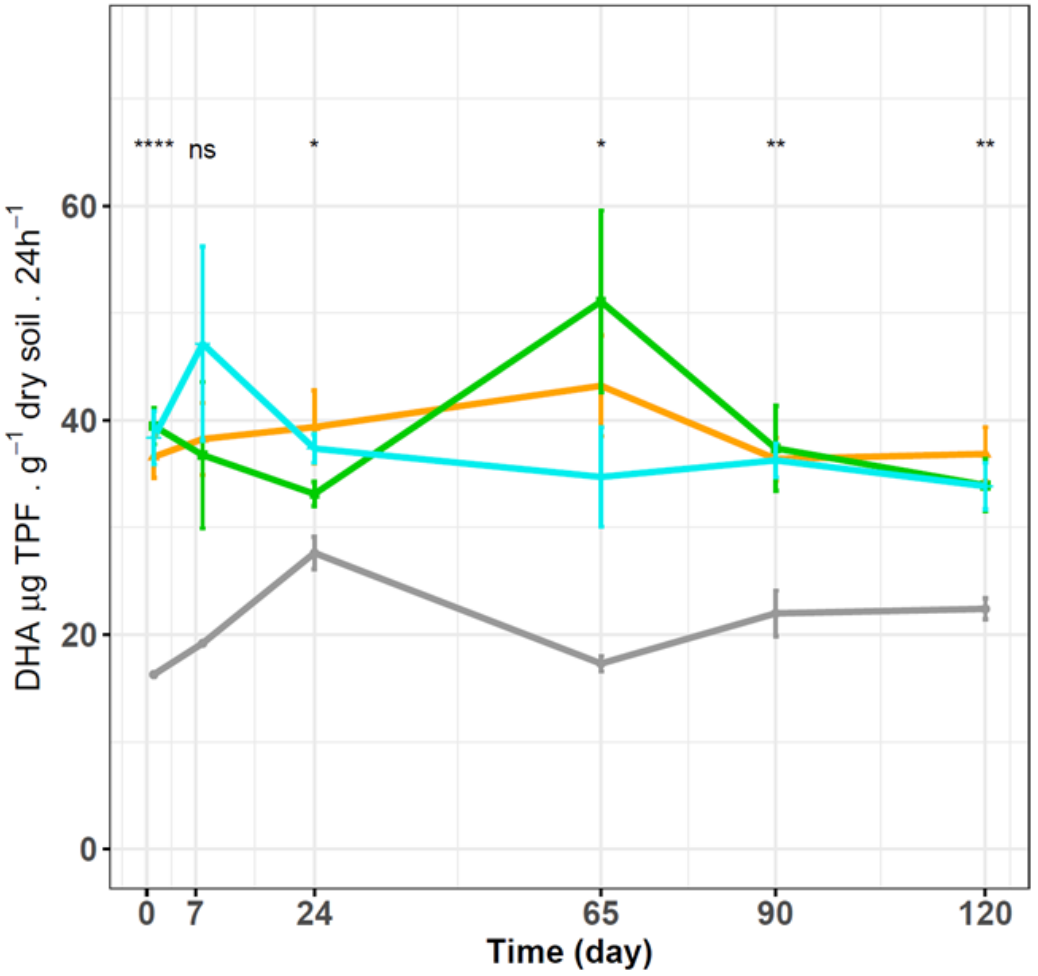



- 10 tons OM/ha
- Sandy soil
- Every 2-3 years
- Vegetables
- **15 years**
- PSKW-BE

# Short term effects on soil microbial activities

- **Dehydrogenase enzyme assay**




**Incubation experiment**

- **40 tons FW ha$^{-1}$**
- **17 º C**
- **50% WFPS**

**GPW compost mixed with grass** @ICOEL

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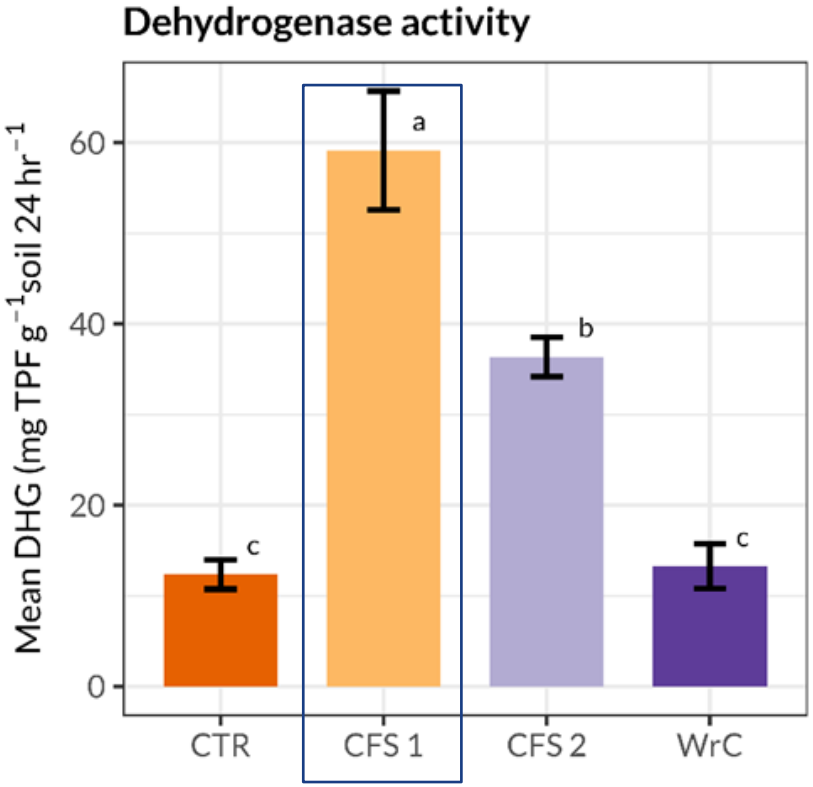
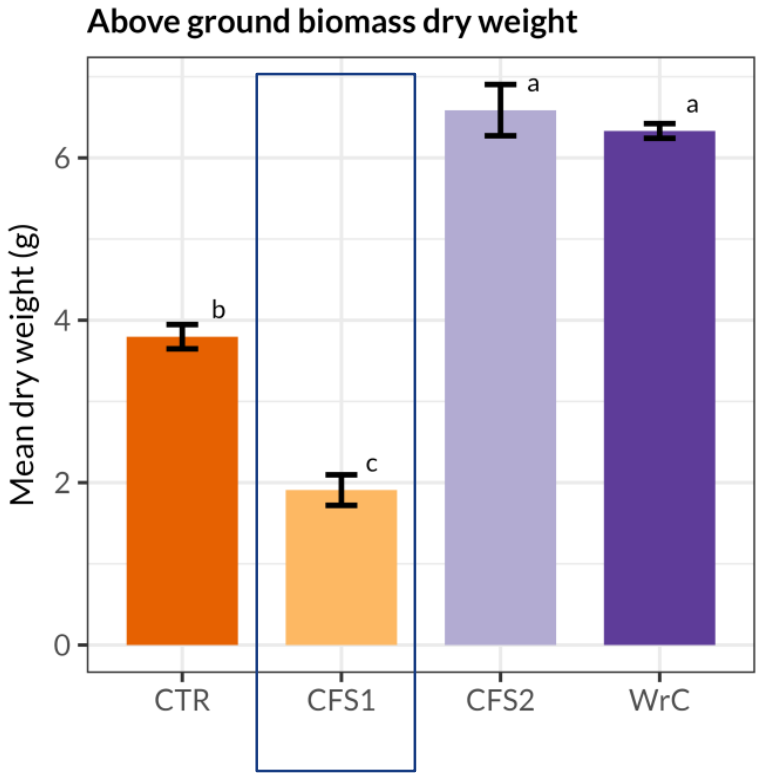
TECHNICAL SCIENCES

# Short term effects on soil microbial activities



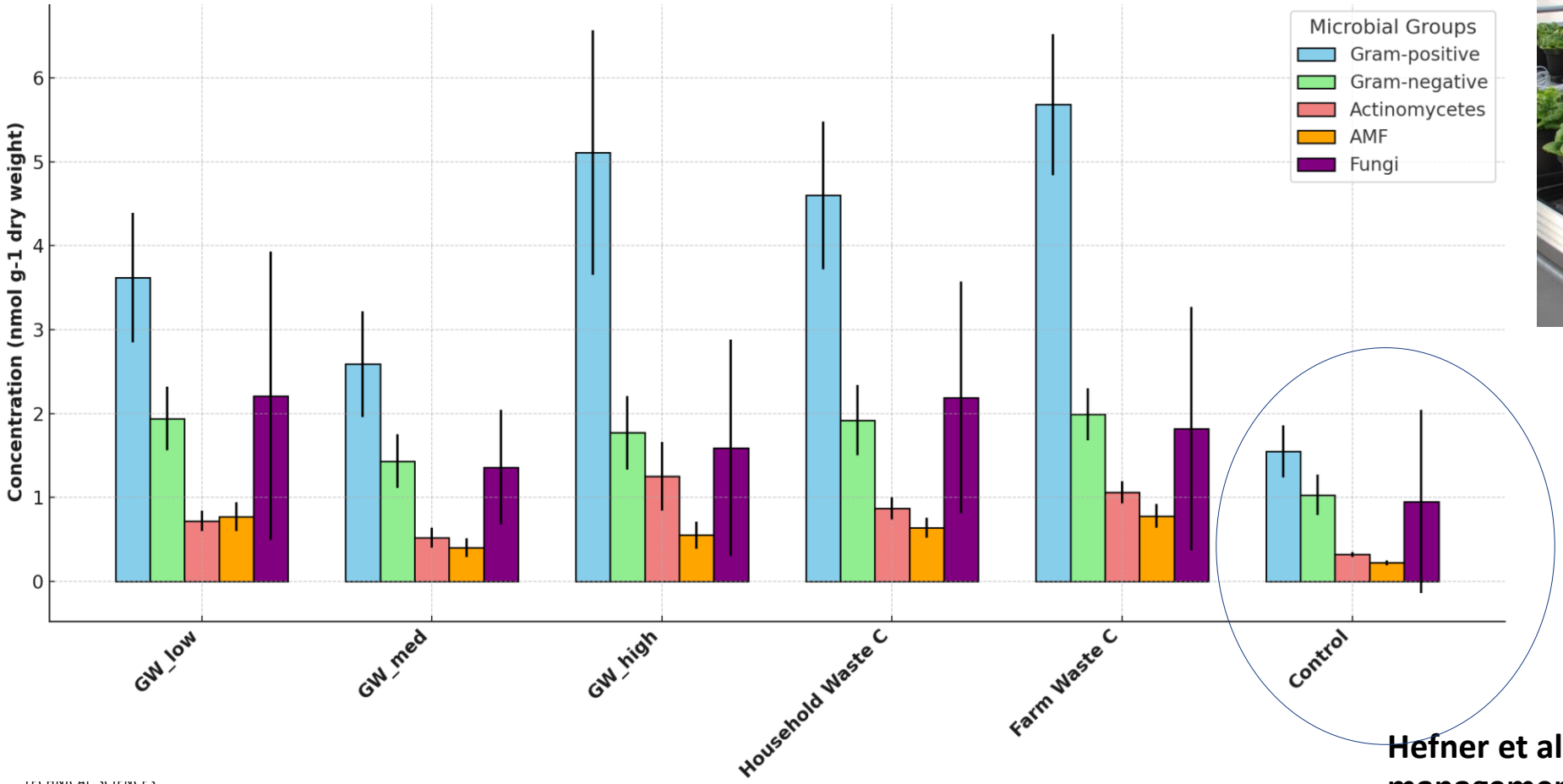

**Closed composting system**@comferm

**Windrow composting system**@Åstiderne

| Compost | C:N | Rate (t DM/ha) | TOC (t/ha) | TN (kg/ha) |
|---|---|---|---|---|
| **CFS#1** | 24 | 23 | 9,8 | 404 |
| **CFS#2** | 19 | 16 | 7 | 362 |
| **WrC** | 12 | 19 | 2,3 | 180 |

# Compost increases the abundance of microbial groups

- Soil microbial groups abundance as measured by phospholipid fatty acid biomarkers




**Lettuce trial at AFP**

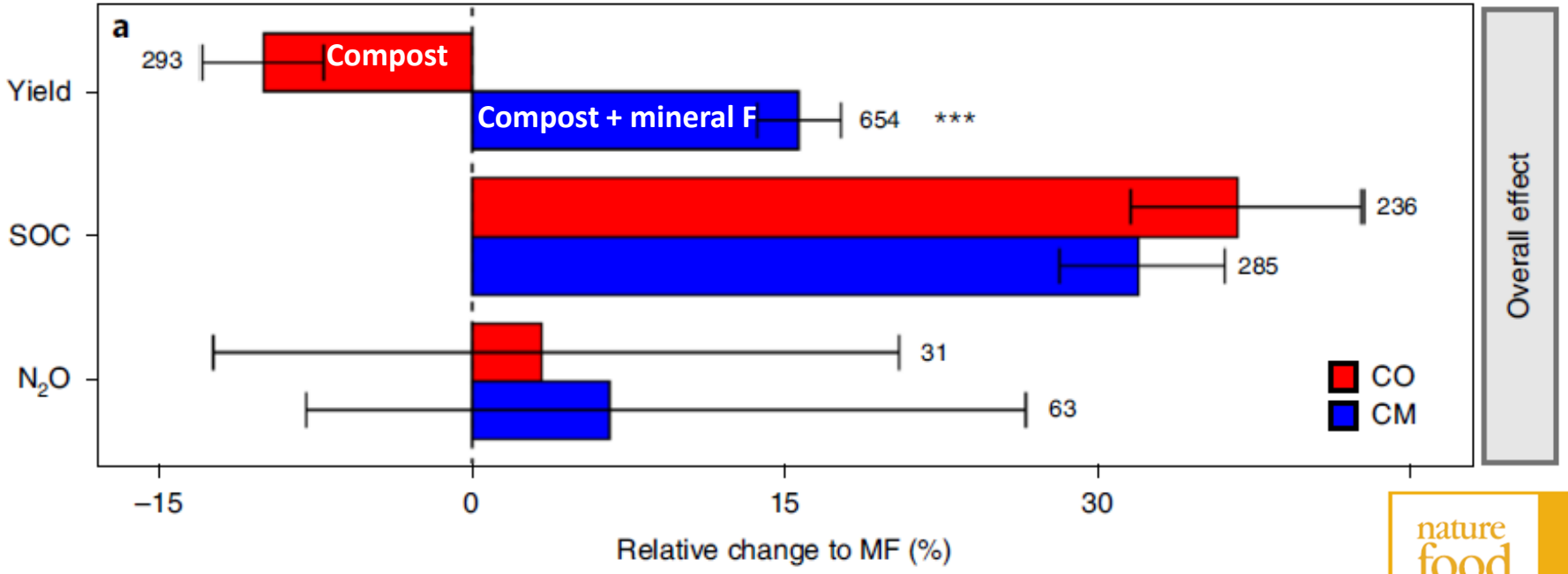
**Hefner et al., 2022 Soil management and use**

# Global effect of compost application on SOC and yield

Global meta-analysis (257 published studies, 2058 observations, **34 countries**)

The **overall effect** of compost application **compared to mineral fertilizer**:

- **+36%** on SOC
- **-10%** on yield




Zhao et al., 2022

# Outline of this presentation

1. Benefits and limitations of compost application on soil health and crop production
   - ✓ Soil organic C
   - ✓ Soil microbial activity and diversity
   - ✓ Crop yield
2. **Strategies to minimize the limitations and maximize the benefits of compost application**

# “Next-generation” compost and application strategies:

## #1. Tailor-made compost intended for specific use:

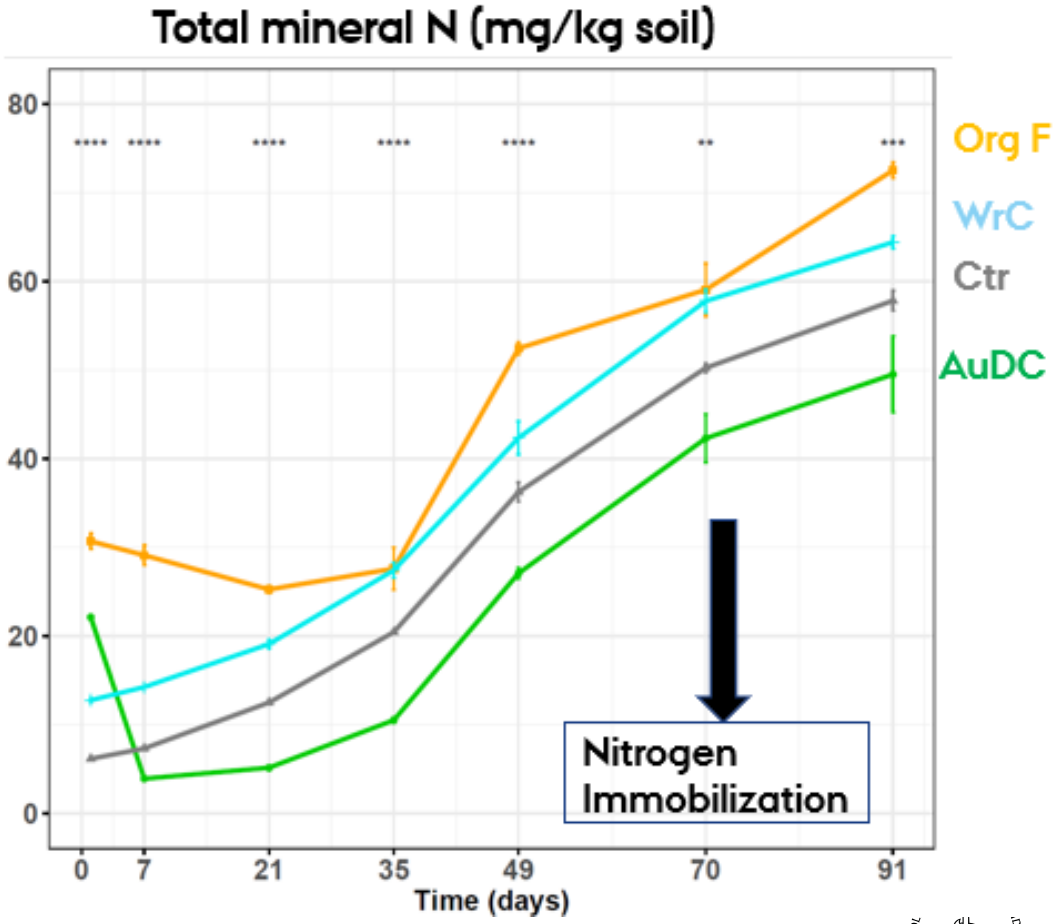
- **What is the intended use of the compost?**
  - Improve **soil organic C and soil structure**?
  - ✓ More structural materials high in C, such as woodchips, straw…
  - Improve **disease suppressiveness**?
  - ✓ Apply microorganisms during the composting process
- **Which crop to grow**?
  - ✓ Vegetables need nutrients at an early stage
- **Which soil properties** (SOC and texture)?
  - ✓ Low SOC/Sandy soil → low C:N

❖ Appropriate feedstock combination **(recipe)** for the targeted use

# “Next-generation” compost and application strategies:

## #2. Synchronize nutrient availability with crop need

- ✓ **Estimate** the nutrient availability dynamics
  - C: N
  - Mineral N
  - Potential N mineralization rate
- ✓ Adjust the time of application to **synchronize** nutrient availability with crop need
- ✓ Calibrate and validate **comprehensive mechanistic models** to simulate nutrient availability under various soil, climatic, and crop types




Gebremikael et al. JMC under review

# “Next-generation” compost and application strategies:

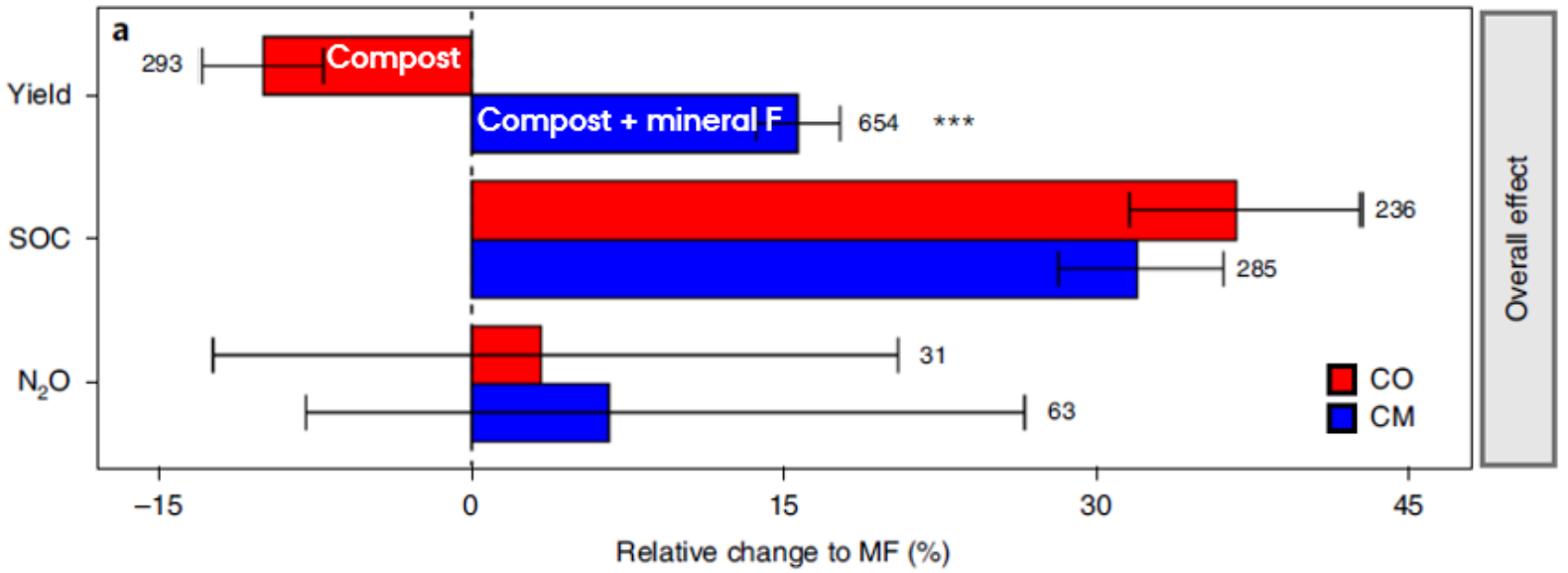
## #3. Combine compost with additional readily available nutrients

- Mineral fertilizer in **conventional agriculture**
- Fast N-releasing organic fertilizer

Compost

NPK

✓ Early availability: **(fertilizer N)** + later availability **(compost N)**= a better synchrony of N supply and crop demand



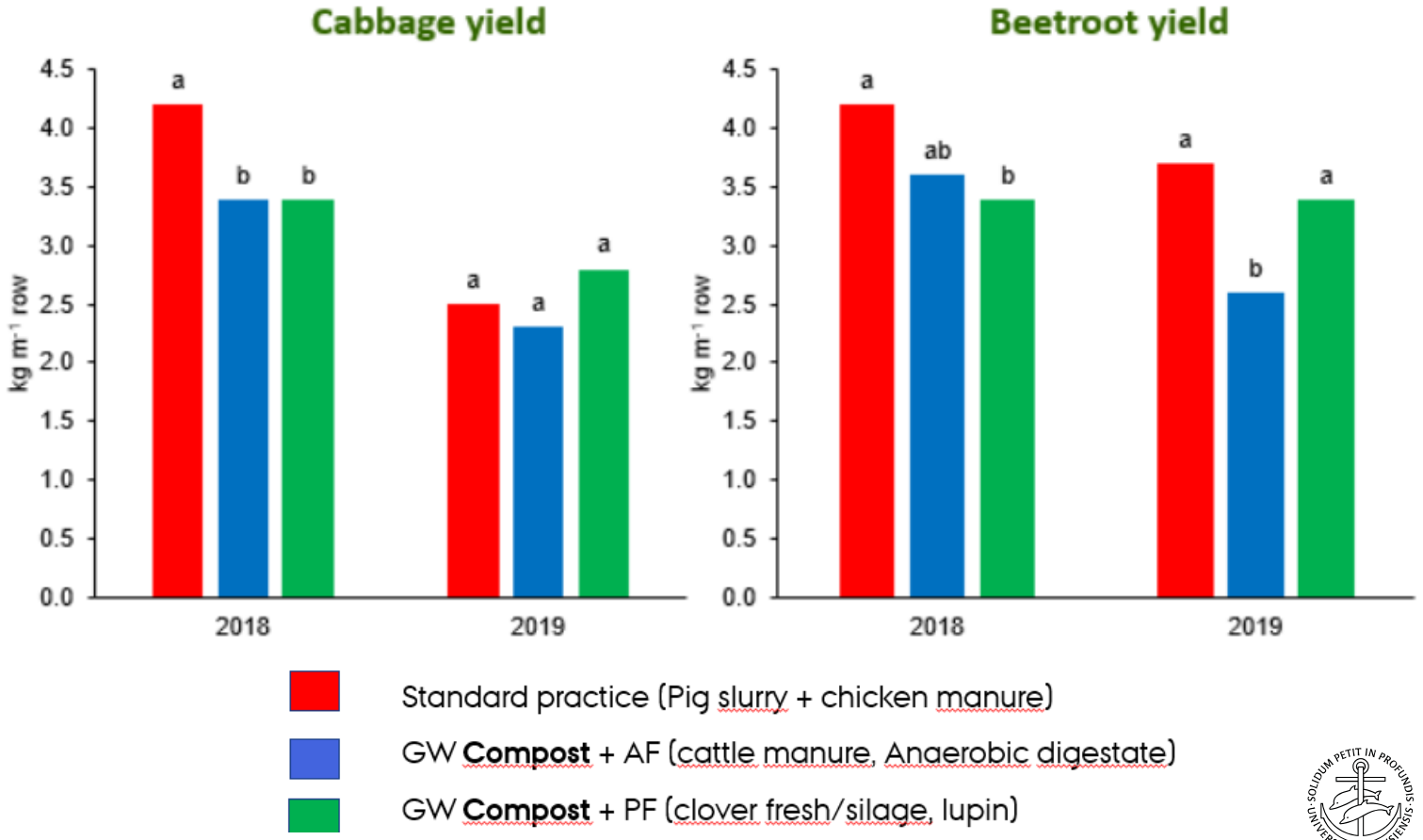
# “Next-generation” compost and application strategies:

## #3. Combine compost with additional readily available nutrients

- Fast N-releasing organic fertilizers

- **Yield has been maintained in addition to all other benefits**

**@AU-Årslev**



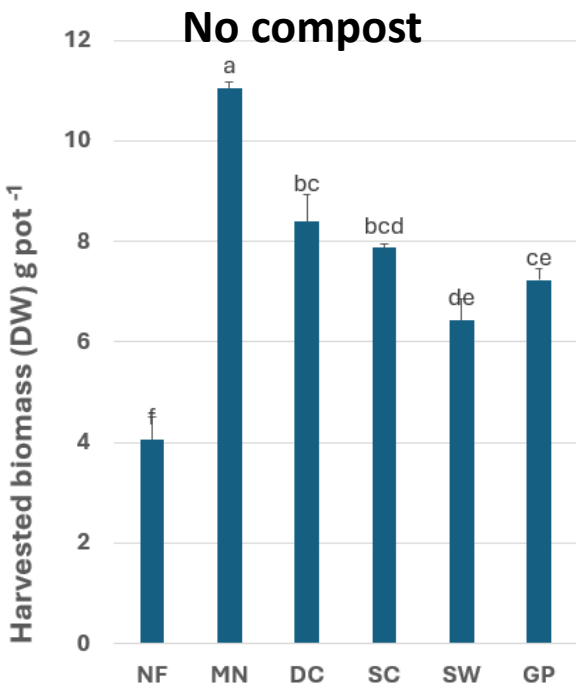

Shanmugam *et al.* (2022) EJA

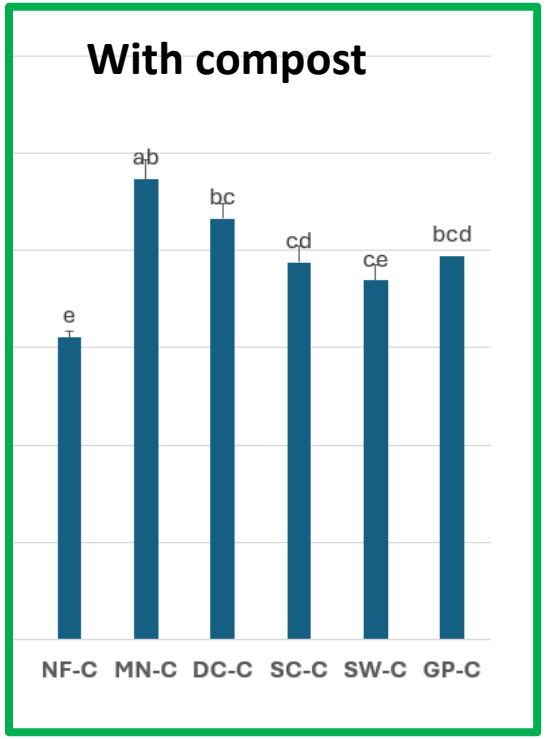
# Next-generation compost and application strategies:

## #3. Combine compost with additional readily available nutrients

- Fast N-releasing organic fertilizers


**NC: No compost**
**C: Compost**
**NF: No N fertiliser**
**MN: mineral N fertiliser**
**DC: Dried clover**
**SC: Silaged clover**
**SW: Seaweed**
**GP: Gas protein byproduct**




Shanmugam *et al. Under preparation*

# Summary

- Compost has potential to regenerate soil and improve soil health through:
  - ✓ Increasing SOC/SOM: **local** and **global** evidences
  - ✓ Increasing soil microbial activities and abundance
- Compost application could reduce yield particularly in the short term

- **Strategies** need to be developed and validated to minimize the impact of compost application on **yield reduction**
  - Tailor-made compost preparation
  - Estimating and synchronizing nutrient availability with crop demand
  - Combine compost with readily available nutrient sources

# Acknowledgments

ICROFS
gudp
Interreg North Sea Region SOILCOM European Regional Development Fund EUROPEAN UNION
ComCrop
ClimateVeg
SureVeg
ComFerm Solutions by nature
AARSTIDERNE
Innovationscenter for Økologisk Landbrug
HortiAdvice
CLOSECYCLE | Interreg North Sea Co-funded by the European Union

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