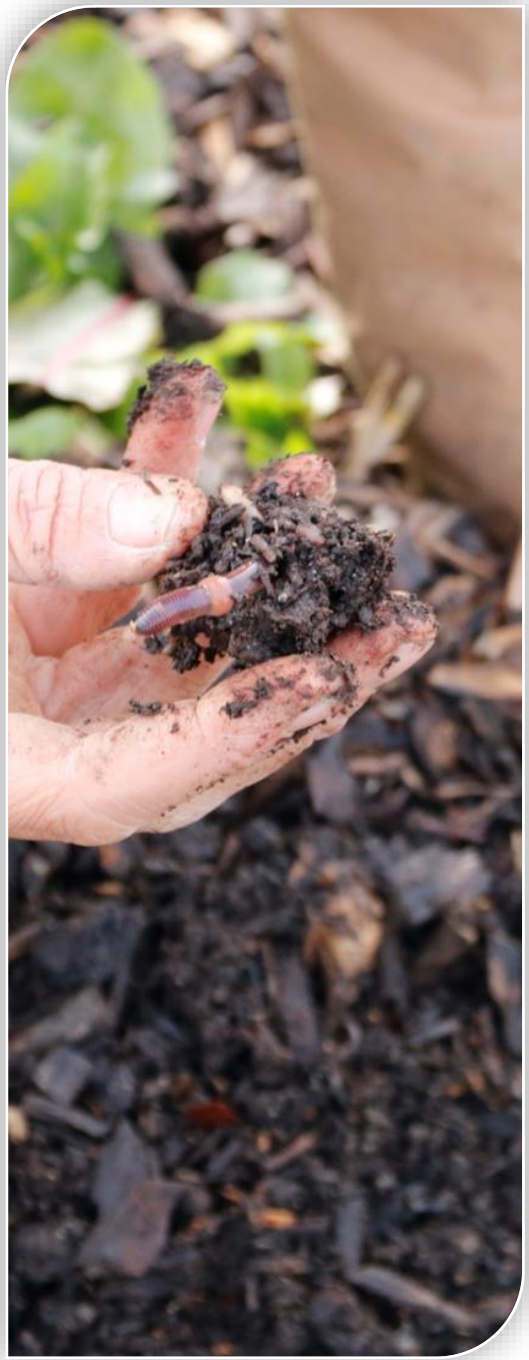
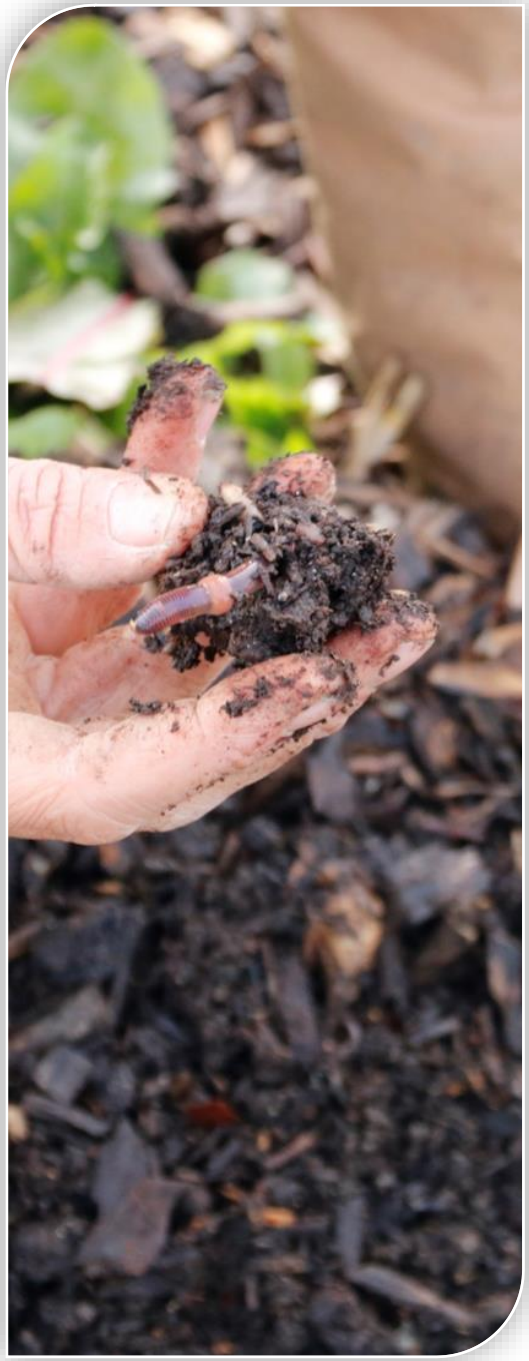


5 december 2022
Soil Health Conference

Mechanisms of soil health restoration in regenerative agriculture

Dr. Ir. Koen Willekens

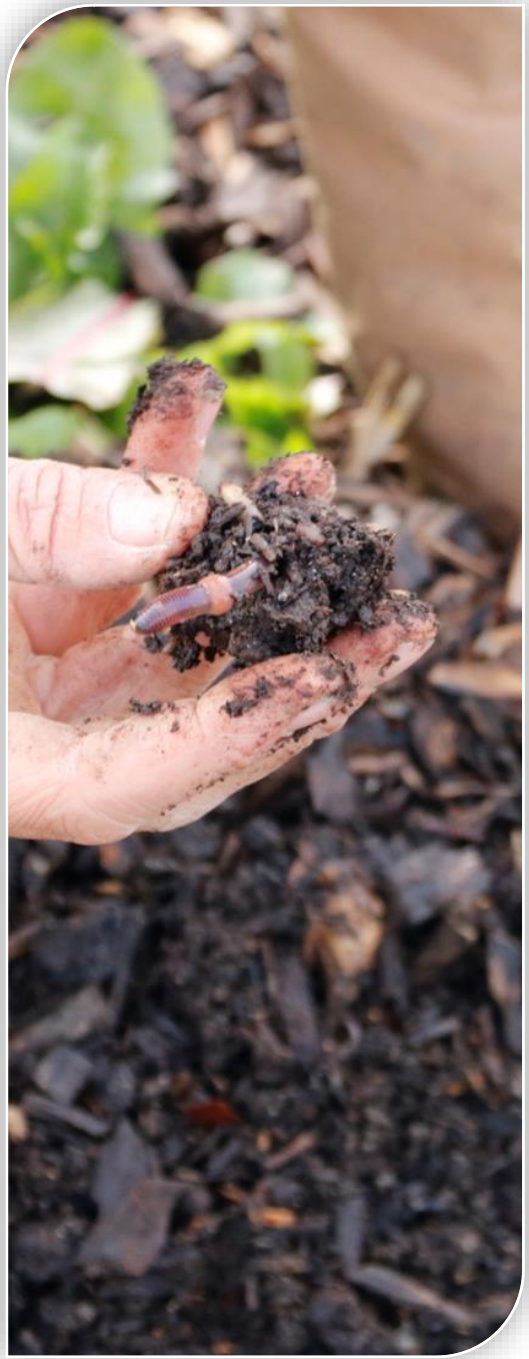
ILVO – Soil scientist



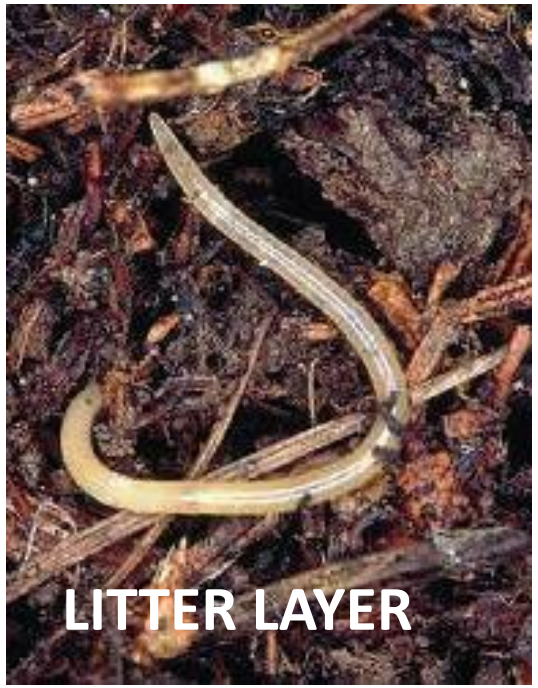
Regenerative soil management in agroecosystems relies on several natural processes:

- ✓ Soil organic matter (humus) build-up
- ✓ Nutrient cycling
- ✓ Plant nutrition
- ✓ Plant protection

Soil organisms (~soil Life) and their mebabolism are main players in ALL these processes



Soil life metabolic processes



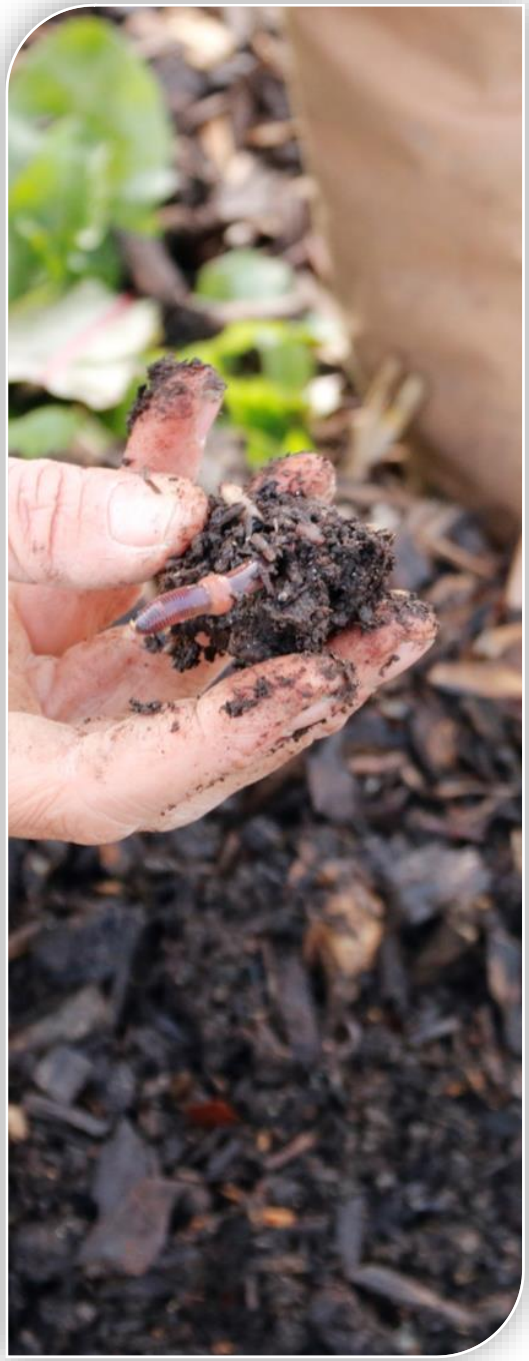
Decay of plant residues

Conversion into humus

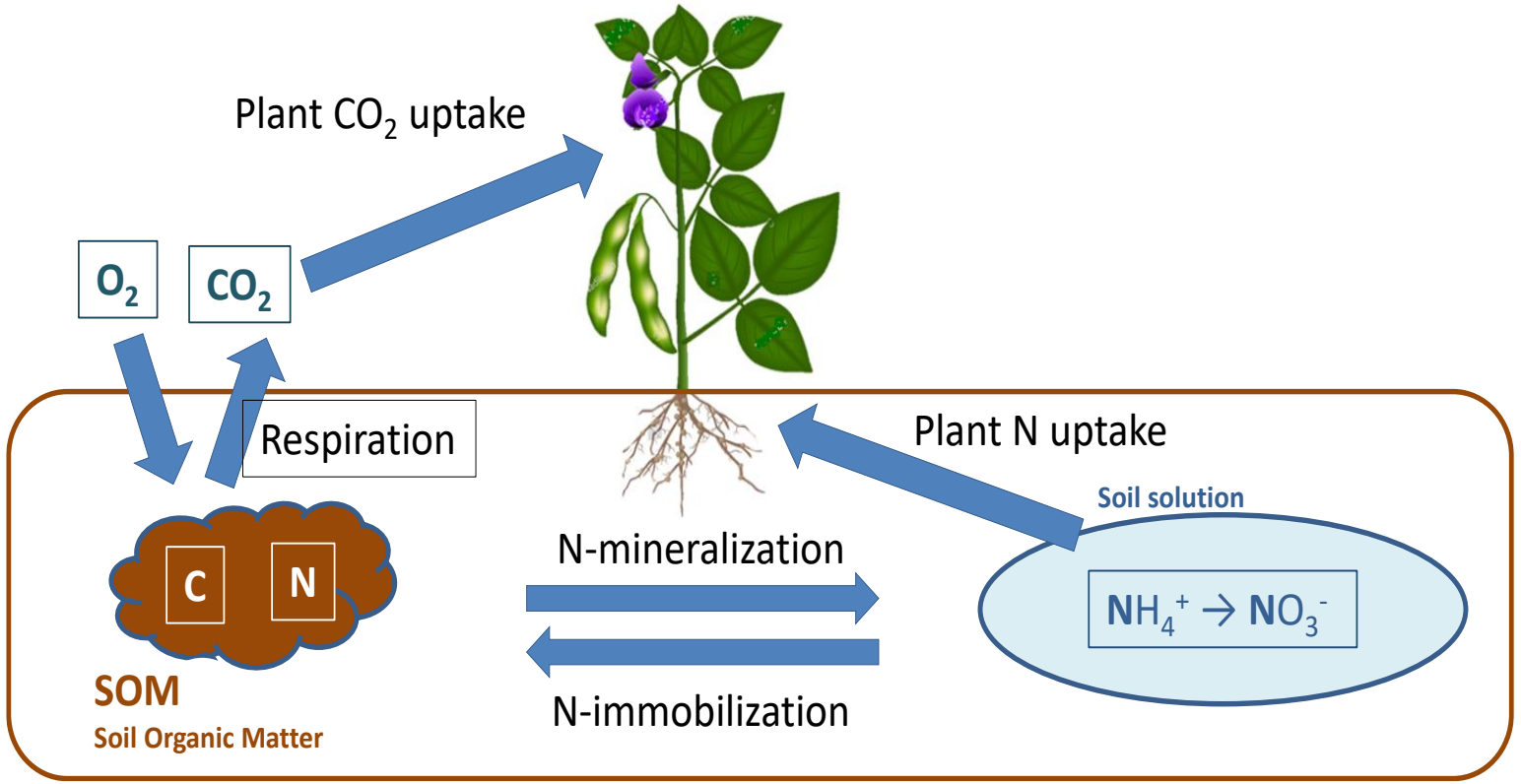
Root exudates

→ Stimulate microbial activity

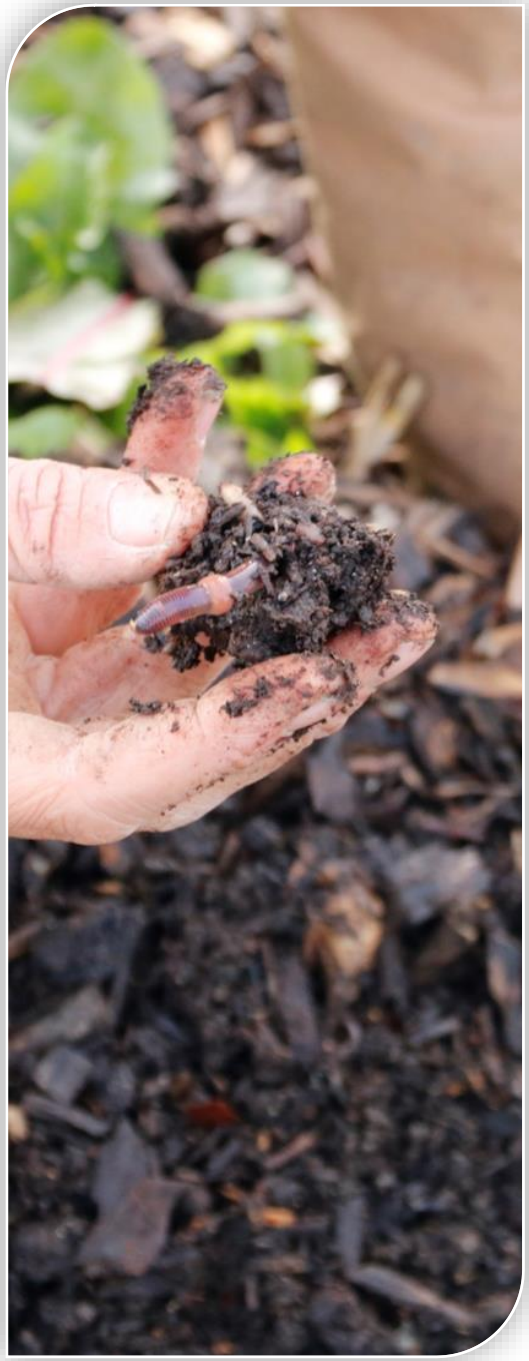
→ Important for symbiotic associations



Carbon and Nitrogen cycli are interconnected



Soil Organic Matter (SOM) is derived from fresh organic material
SOM = organic residues, soil organisms and protected organic compounds



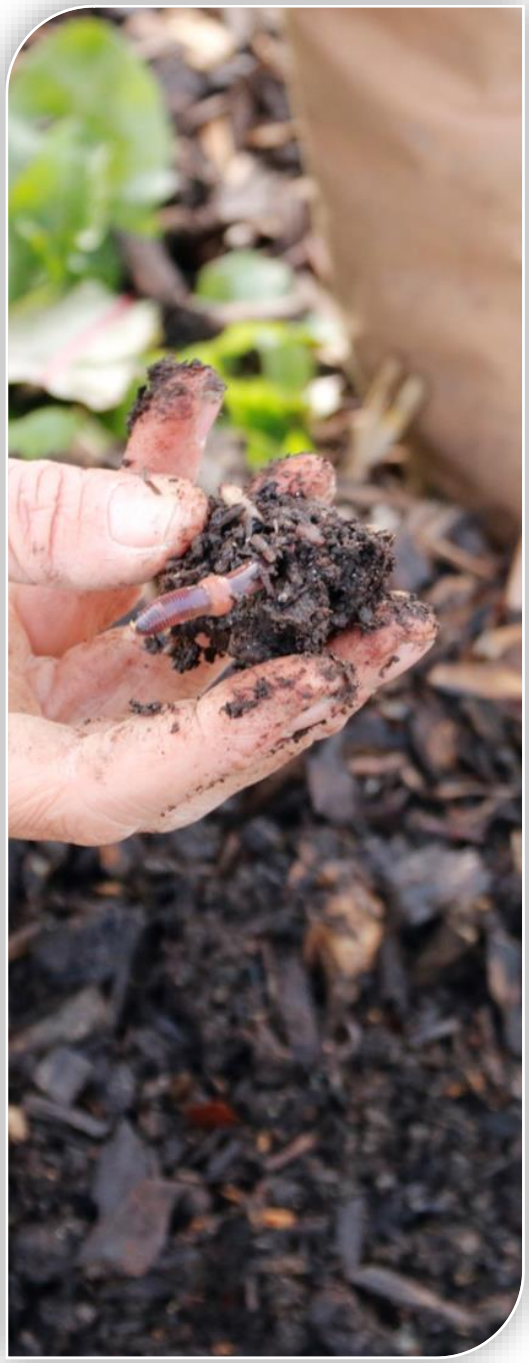
Types of SOM

Soil Continuum Model (SCM) focuses on the ability of decomposer organisms to access soil organic matter and on the protection of organic matter from decomposition provided by soil minerals.

- ✓ Plant and animal residues
- ✓ Microbial biomass
- ✓ Microbial necromass
- ✓ C-compounds (biopolymers and monomers), decomposition products of plants and all living soil organisms

Protected against decomposition by:

- Adsorption to mineral surfaces
- Incorporation into soil aggregates



SOM build-up requires input of organic C AND organic N

On-site produced organic material

- ✓ Aboveground plant parts
- ✓ Roots
- ✓ Root exudates

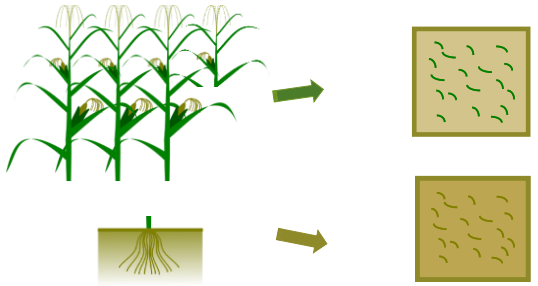
External input of organic material = organic fertilization

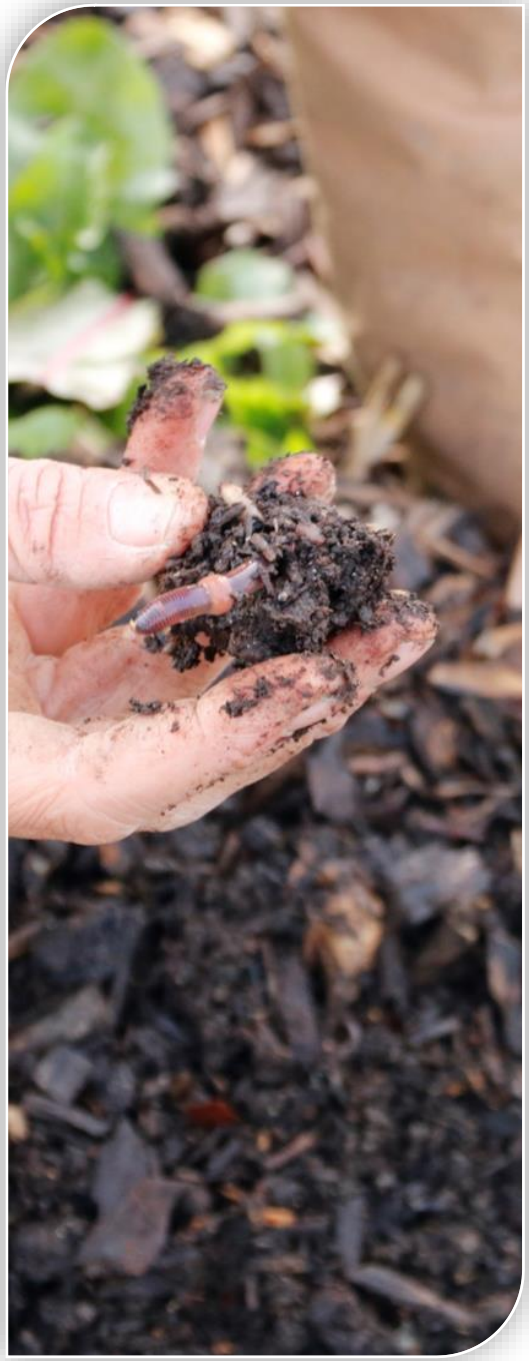
- ✓ Animal manure
- ✓ Compost
- ✓ Cut and carry fertilizers (e.g. grass mowings, wood chips, …)

Contribution to SOM build-up

- ✓ On-site produced organic material ↔ External input of organic material
- ✓ Aboveground ↔ Belowground plant biomass

Maize: The relative contribution of roots was on average 3.5 times more than shoots to the build-up of SOC

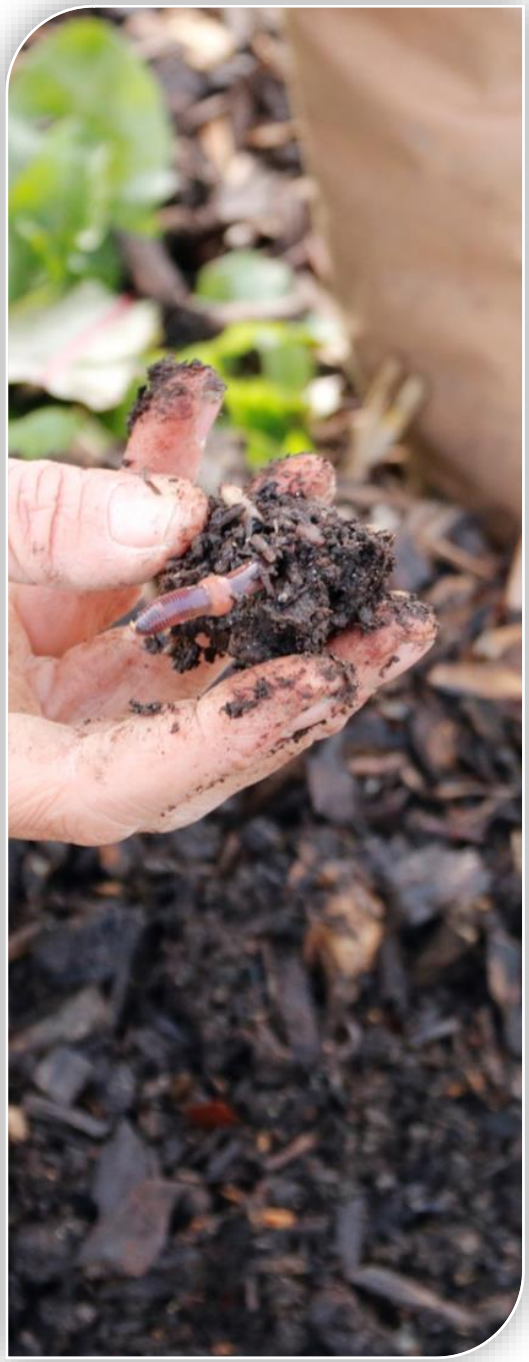




Factors affecting SOM persistence / C storage

- ✓ Soil structure and texture
- ✓ Soil temperature and moisture content
- ✓ Soil life
- ✓ Soil management
  - Tillage practices
  - Fertilization (quality and quantity)
  - Cropping system

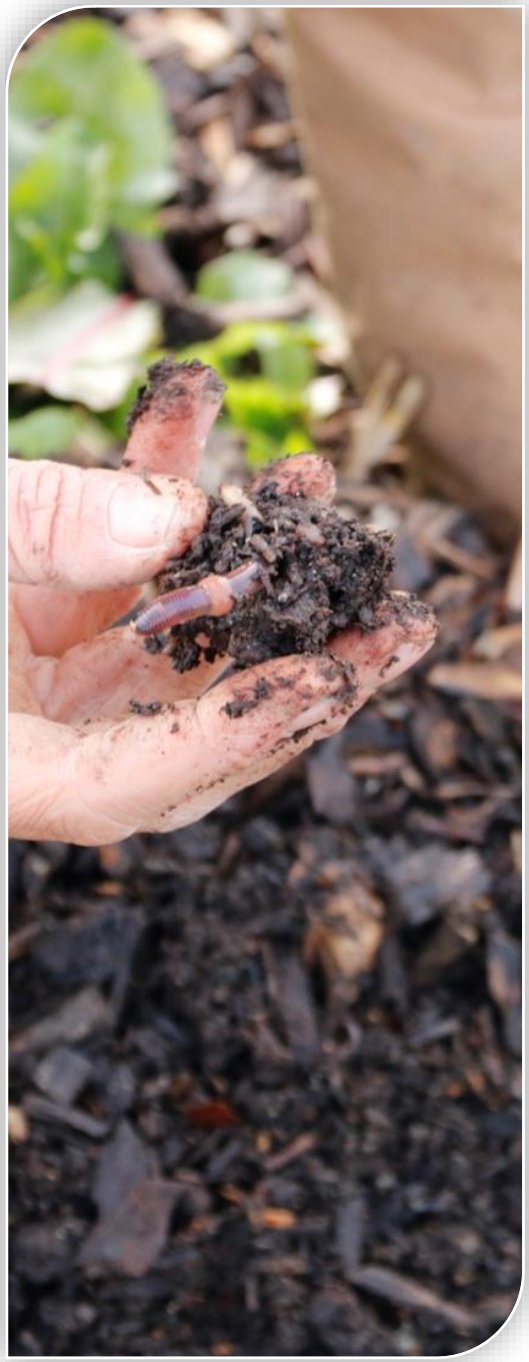
Interactions among all these factors are complex and in some cases poorly understood



To which extent do we need organic fertilization for SOM build-up (C-sequestration)?

NO, we do not need it, or we need it much less in cropping systems with:

- ✓ C sequestering crops (e.g. winter cereals, cover crop mixtures, …)
- ✓ Leguminous crops, N input due to symbiose with N-fixing bacteria (e.g. alfalfa)
- ✓ Activated free living N-fixing bacteria



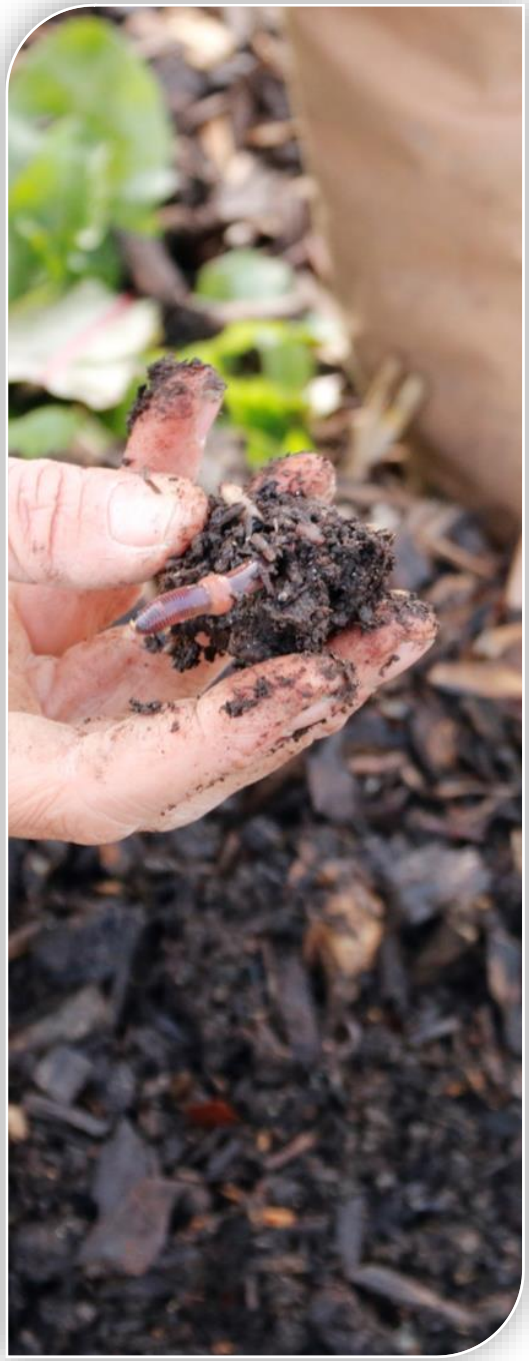
Why do we need a diverse crop rotation?

We need it:

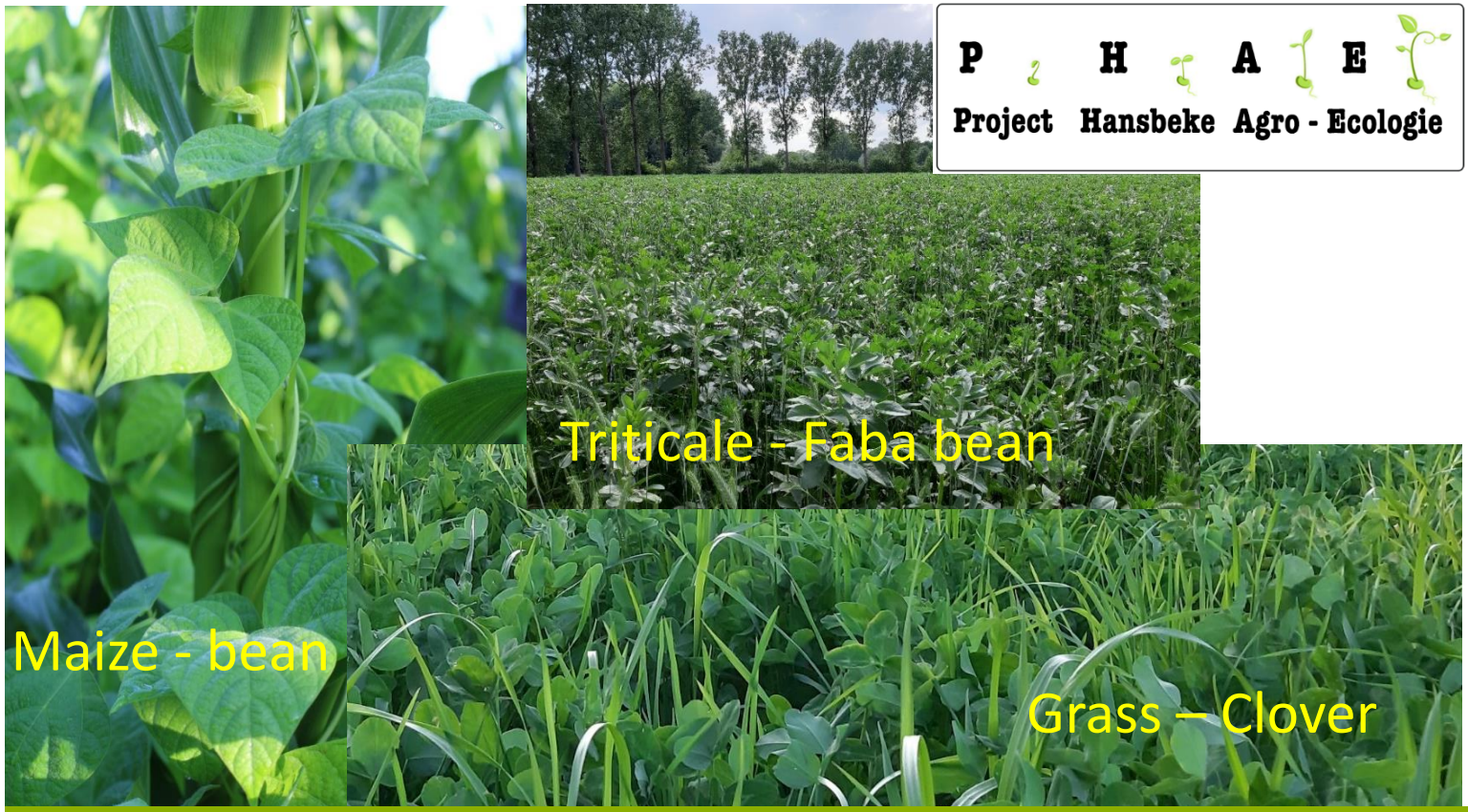
- ✓ To prevent and control pests, diseases and weeds
- ✓ Higher crop diversity → Higher soil life diversity
- ✓ SOM build-up by on site production of organic material for restoration of soil quality

    - More recalcitrant C-rich material (e.g. lignin) is favorable for SOM building, but should be combined with an appropriate N input.

    - SOM building needs both C and N input and C:N ratios have an effect on long-term accumulation of organic matter.



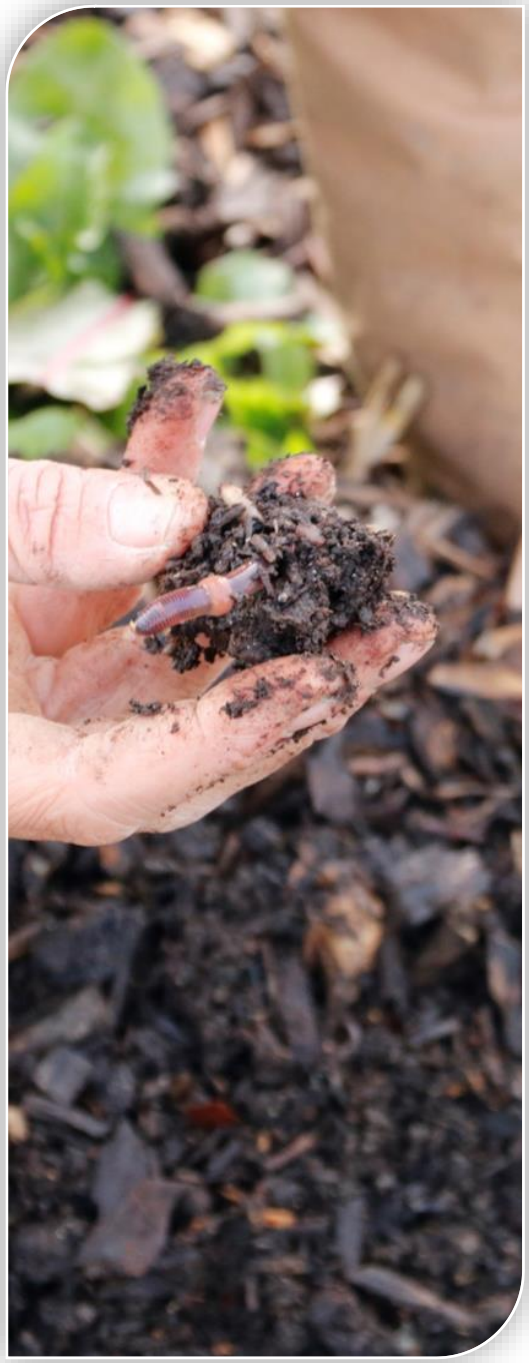
Mixed cultivation of grasses and leguminous crops



P H A E
Project Hansbeke Agro - Ecologie

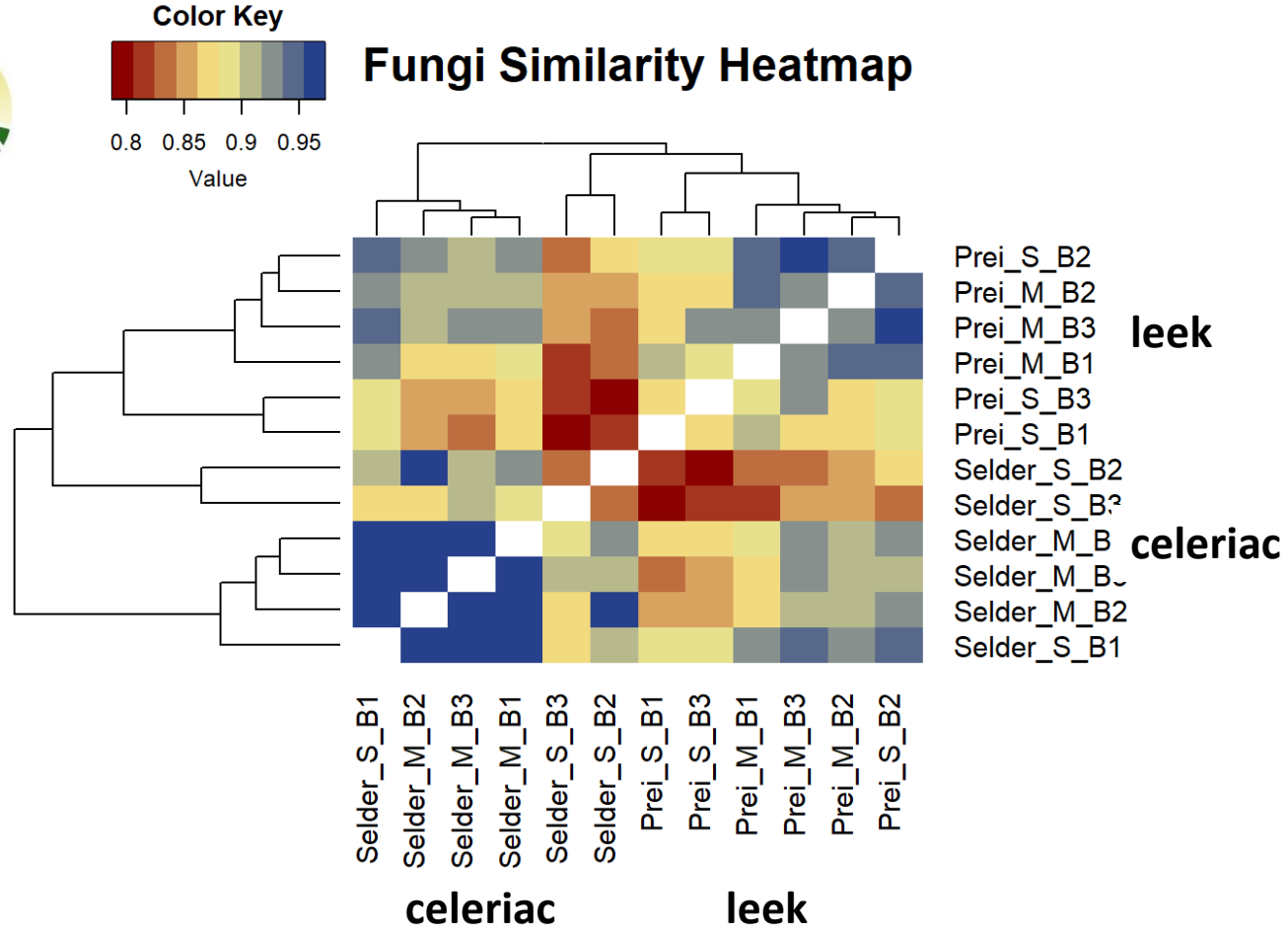
Legume cover crops rotated with grasses or cereals have a high potential of increasing SOM stocks because of relatively high C input into the system.

Maize/legume cropping systems as well provide a good balance between legume nitrogen rich material and more recalcitrant maize stover and increase both N and SOM levels.

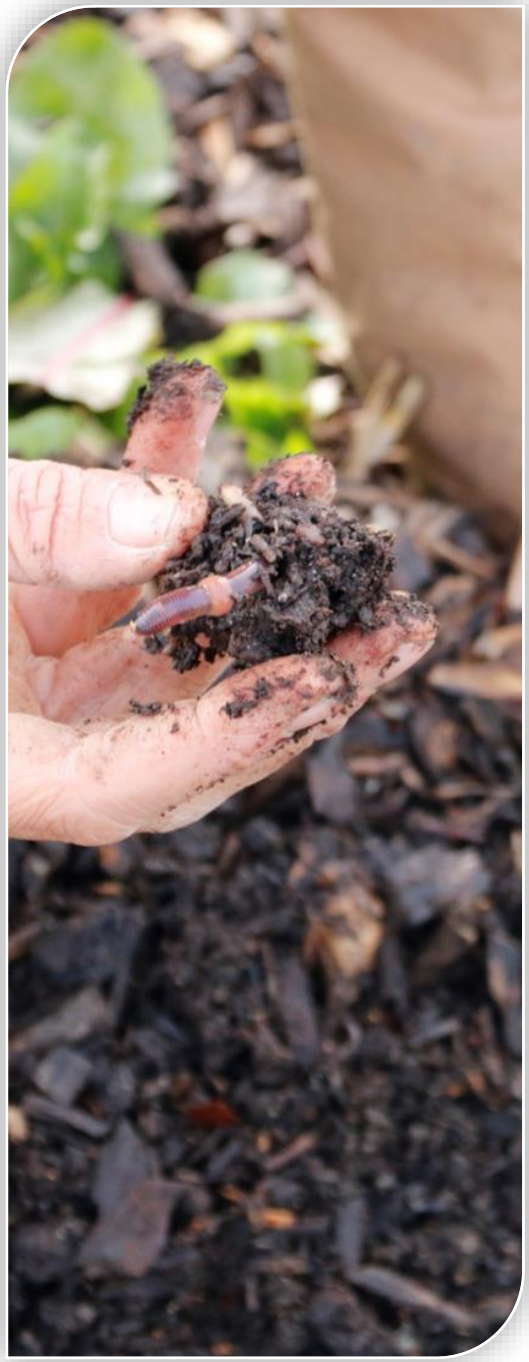


Relation crop – rhizosphere microbial community

Inagro-ILVO Strip-cropping experiment vs. monocropping of leek and celeriac
Metabarcoding for assessing rhizosphere bacterial and fungal communities



Each crop builds a specific rhizosphere microbial community due to complex plant – soil life interactions



Do we need organic fertilization for sufficient N availability?

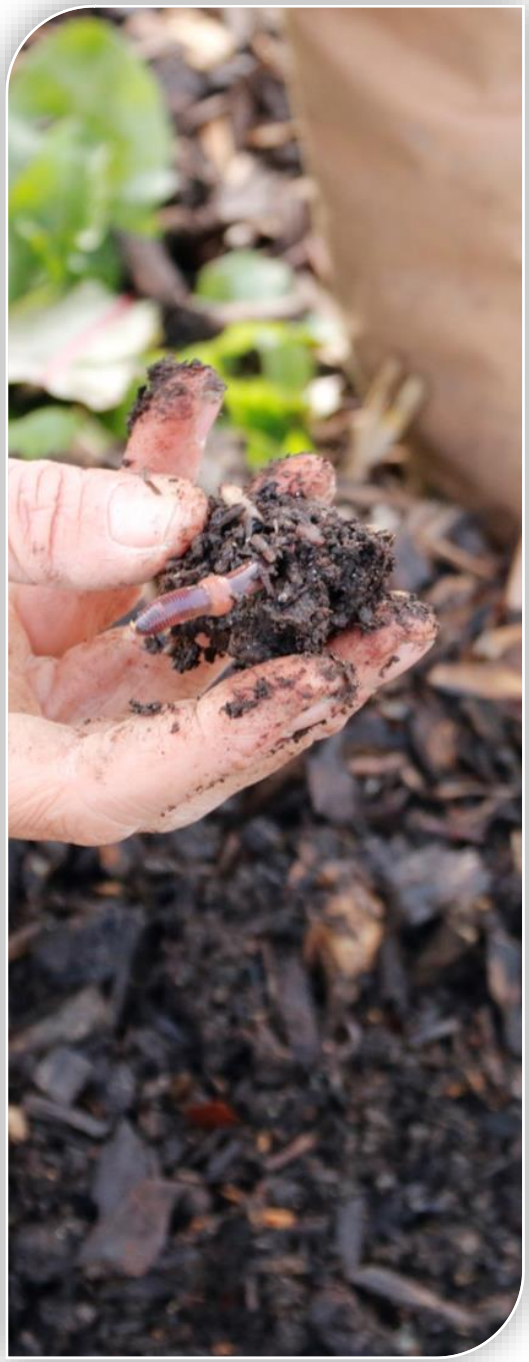
If lack of N availability from SOM at lower SOM contents in a transition phase, we have to start SOM built-up by diversification of crop rotation and the use of soil improving organic fertilizers.

However, if we excessively focus on fertilization to build SOM and guarantee N supply for crop, we will end up with N losses and nutrients surpluses, excesses and imbalances.

> Risk of a too high N mineralization potential due to frequent supply of farm yard manure.

We may compensate lack of N availability from SOM by using fast N releasing organic or artificial N fertilizers for crops with a relatively high N demand.

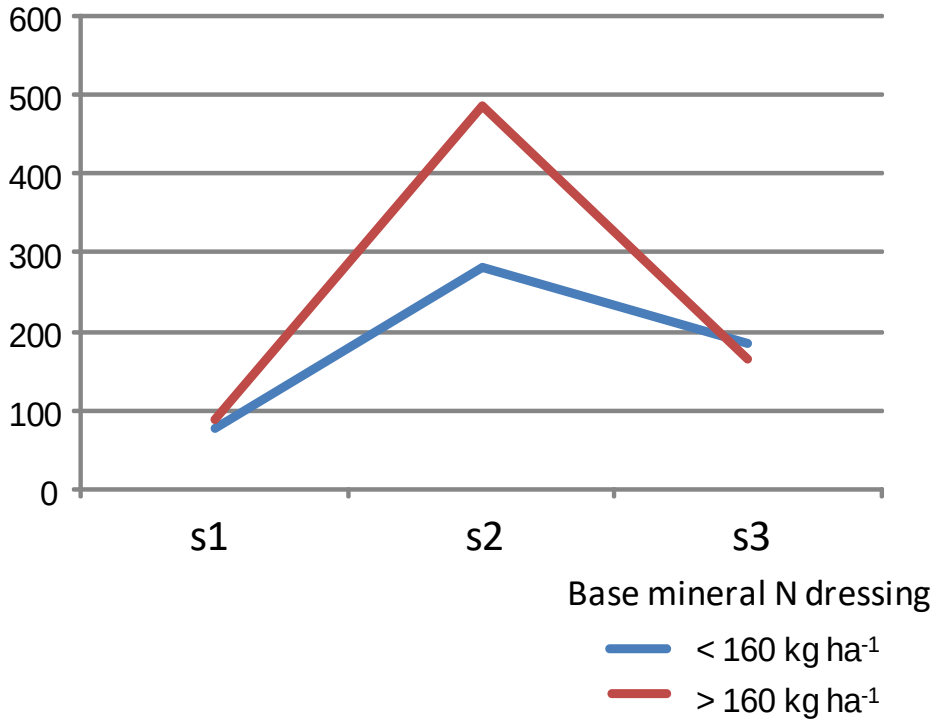
> Risk of priming effect due to excessive mineral N input from animal manure and artificial N fertilizers.



Priming effects by fast N releassing fertilizers

$Nmin_{0\text{-}90\ cm}$ kg ha^{-1}

FIELD SURVEY 2009: leek at 28 fields

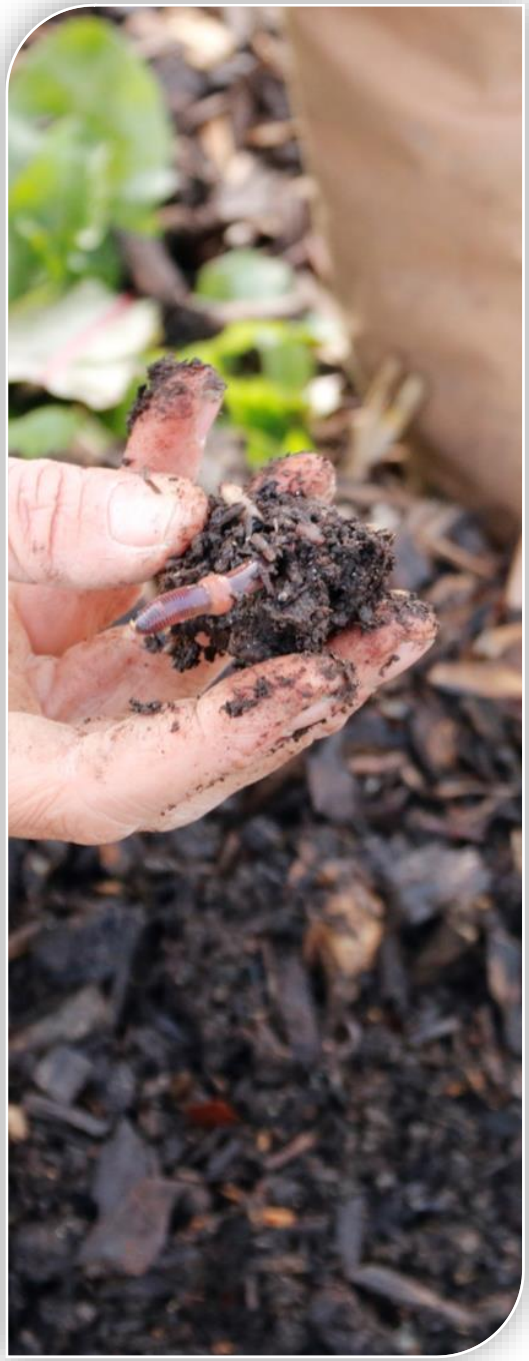


s1 - s2

- 1st half of the growing season
- Net N mineralization
- **Priming effect** by excessive base mineral N dressing

s2 - s3

- 2nd half of the growing season
- Net N immobilization **correlated with Cmic** (Microbial biomass assessed by measurement of microbial C)

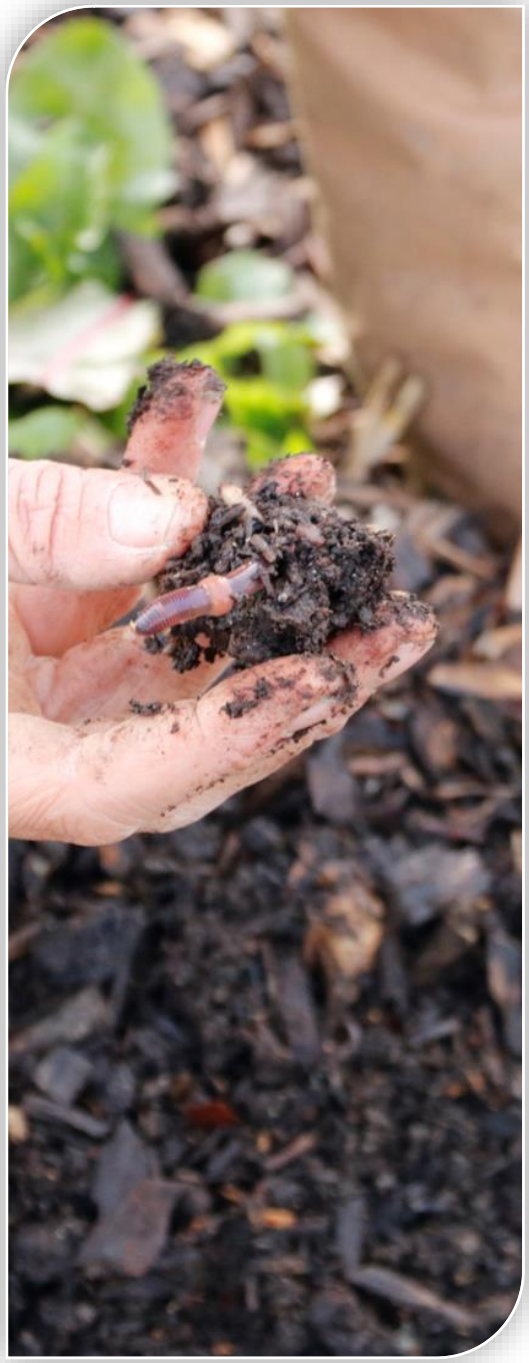


Besides by fertilization, residual soil mineral N is affected by agronomic practices and growing season.

FIELD SURVEY: 31 fields, 2010-2011

	class	residual $Nmin_{0\text{-}30\ cm}$	nitrate N residue
livestock	no	29.5	79.2 [a]
	yes	49.0	129.2 [b]
FYM, compost & cover crops	no	55.6 [b]	121.6
	yes	31.5 [a]	99.8
growing season	2010	27.7 [a]	99.2
	2011	54.0 [b]	117.3

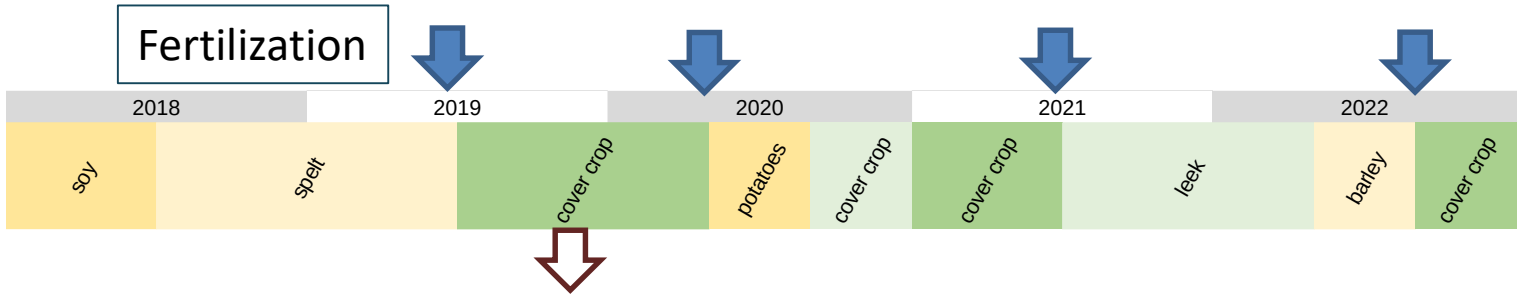
Regular soil quality improving practices as the use of FYM, compost and cover crops reduced the risk of surpassing the nitrate N residue threshold as it was associated with a significantly lower residual $Nmin_{0\text{-}30\ cm}$



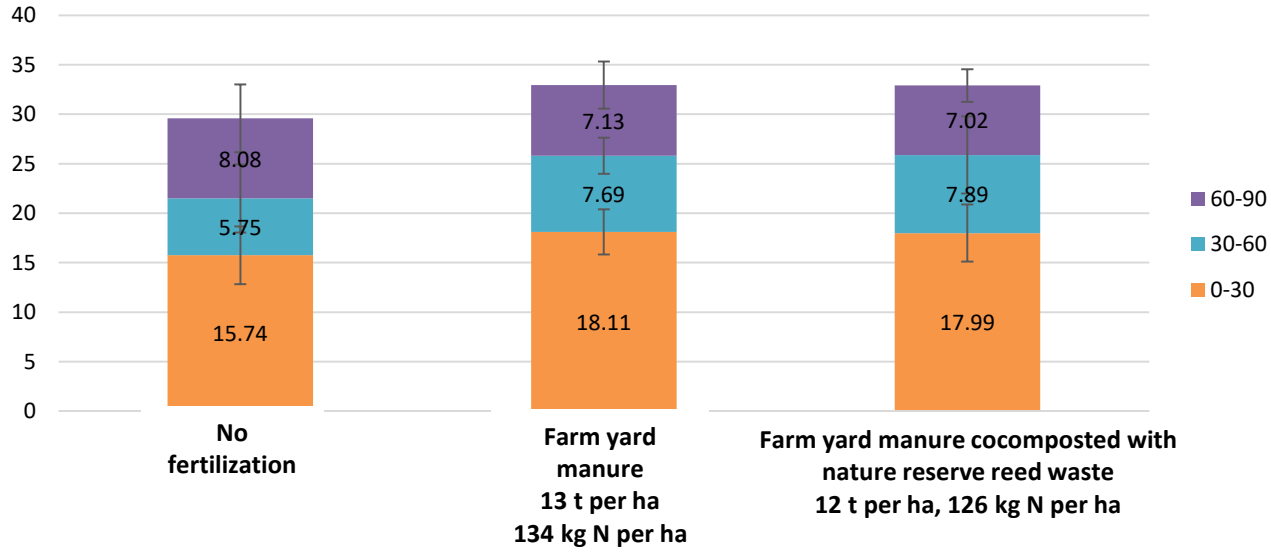
Why should we apply C-rich soil improving organic fertilization in spring and not in autumn?

VLAAMSE LAND MAATSCHAPPIJ Vlaanderen is open ruimte

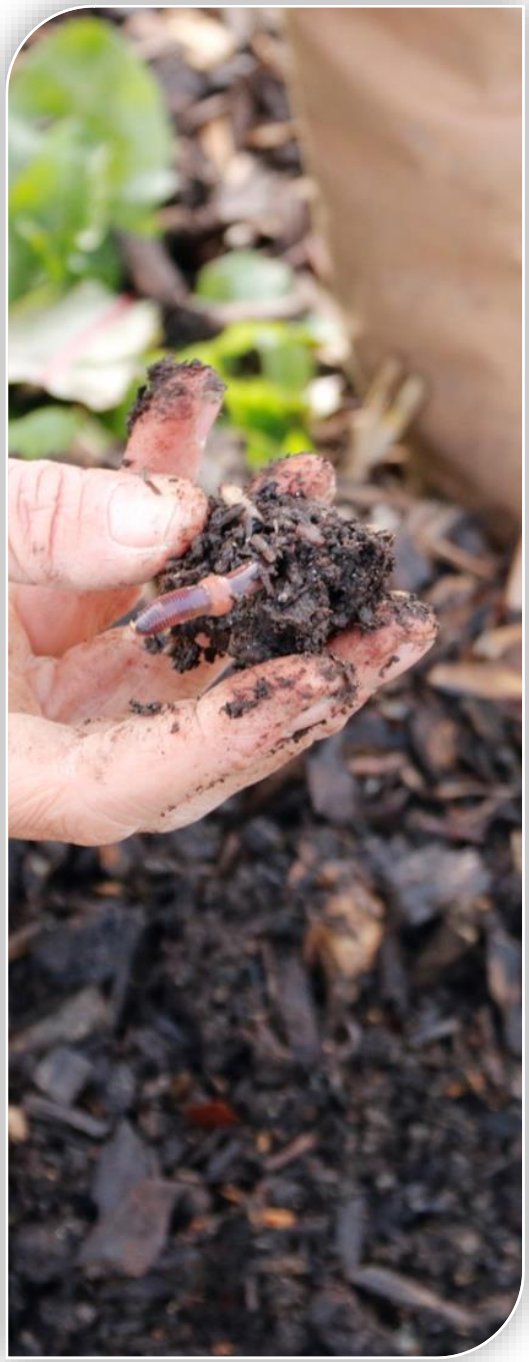
Project: Optimaliseren van bemestingsstrategieën vanuit de principes van de biologische landbouw



Nmin (kg/ha) 0-90 cm at 19/11/2019; no significant differences at p > 0.05



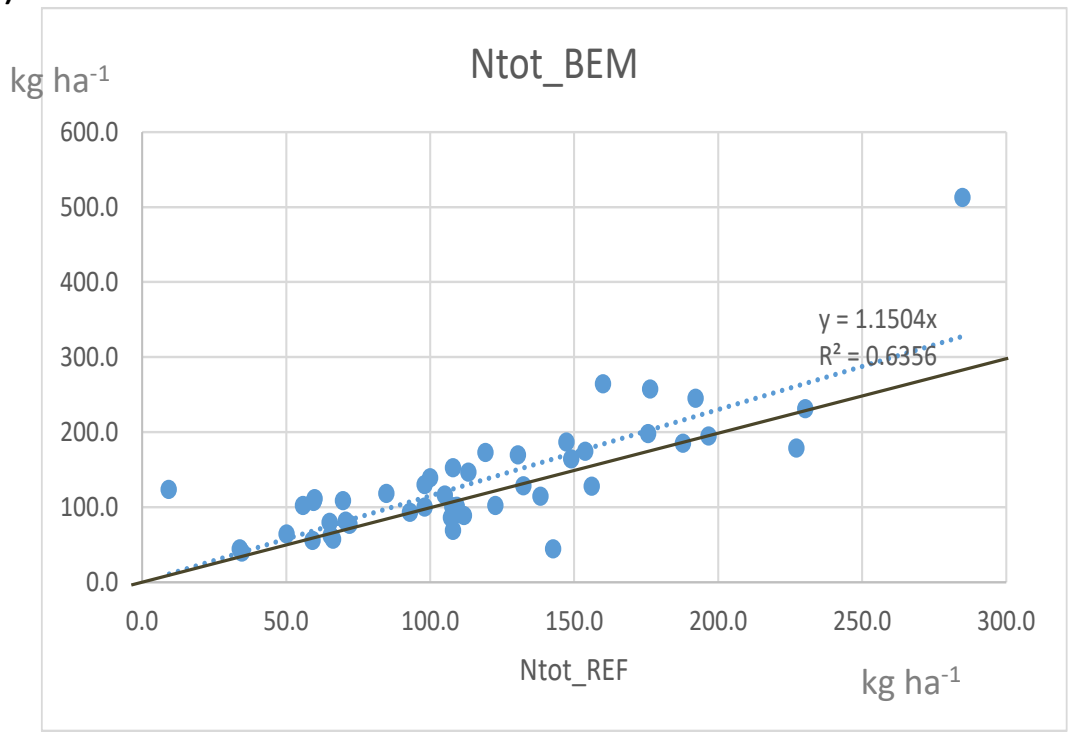
Input of organic material with high C/N ratio (e.g., farm yard manure) or stabilized C (compost) is key for improving soil fertility.Late summer or autumn application does not necessarily result in an increase of residual soil mineral N, and if it does, it is a minor increase.



Why should we apply C-rich soil improving organic fertilization in spring and not in autum?

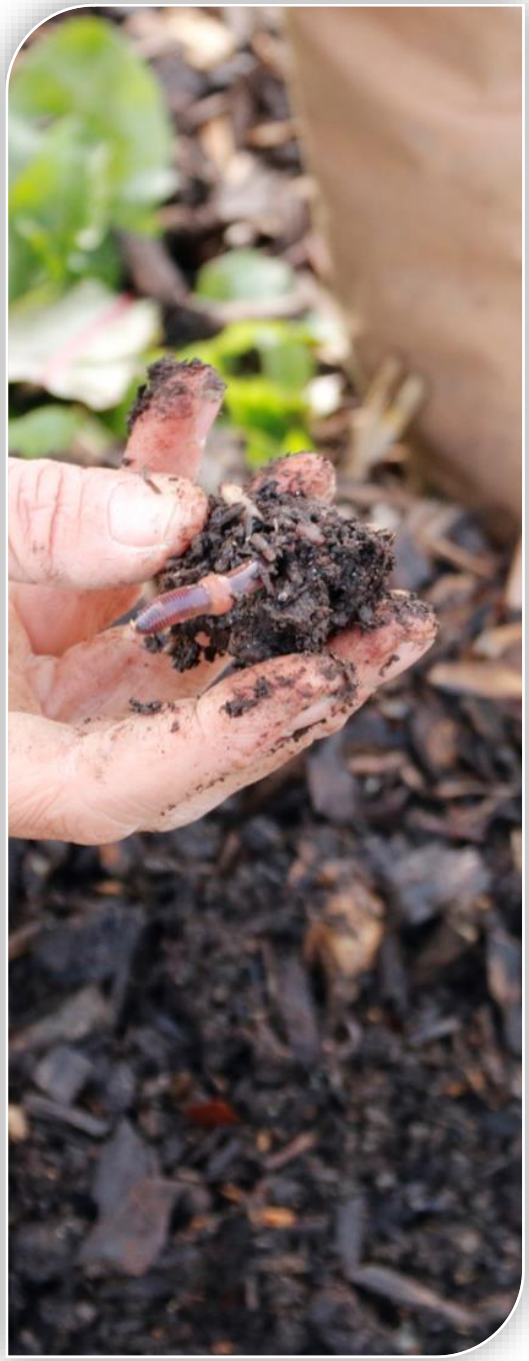
A soil improving fertilization applied in spring does not necessarily increase crop N uptake.

Crop N uptake of fertilized plots (Ntot_BEM) compared to non-fertilized plots (Ntot_REF)



Project Noptimabio

ILVO inagro ONDERZOEK & ADVIES IN LAND- & TUINBOUW UNIVERSITEIT GENT ORGANIC FOREST Vlaanderen is landbouw & visserij

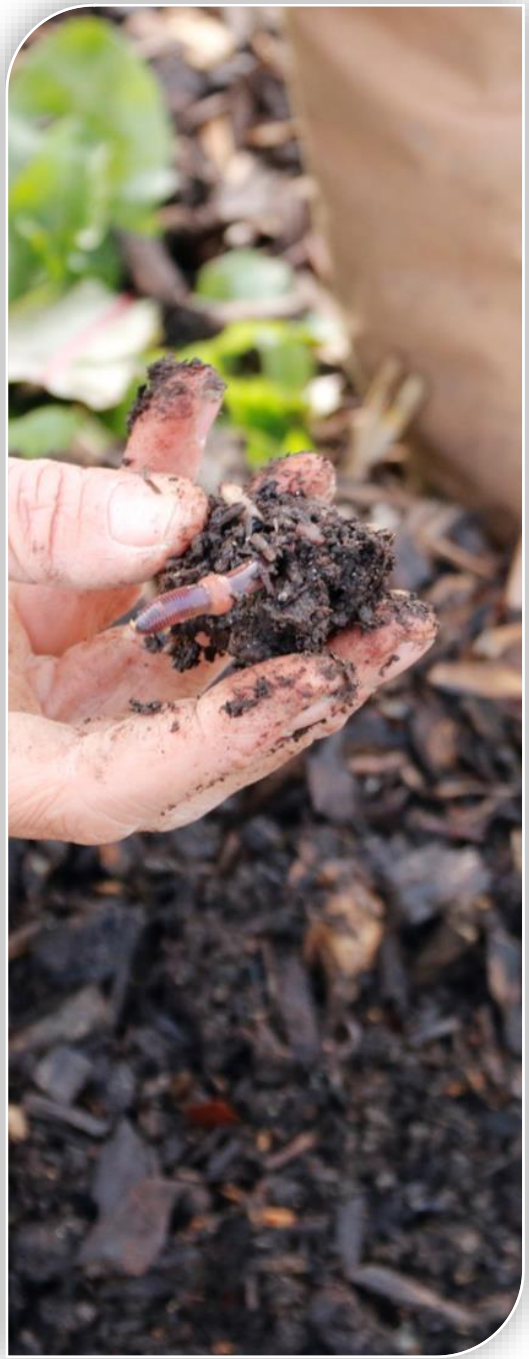


Why should we apply C-rich soil improving organic fertilization in spring and not in autumn?

Cover crops that are left for a long period in the field up to maturity leads to an increase in C:N ratios → positive contribution to long-term build up of SOM.

In natural ecosystems, litter material arrives in autumn on top of the soil.

Mulching can counteract maize-bean emergence and development in wet conditions (e.g. 2021)
Perhaps better to mulch in autumn than in spring.

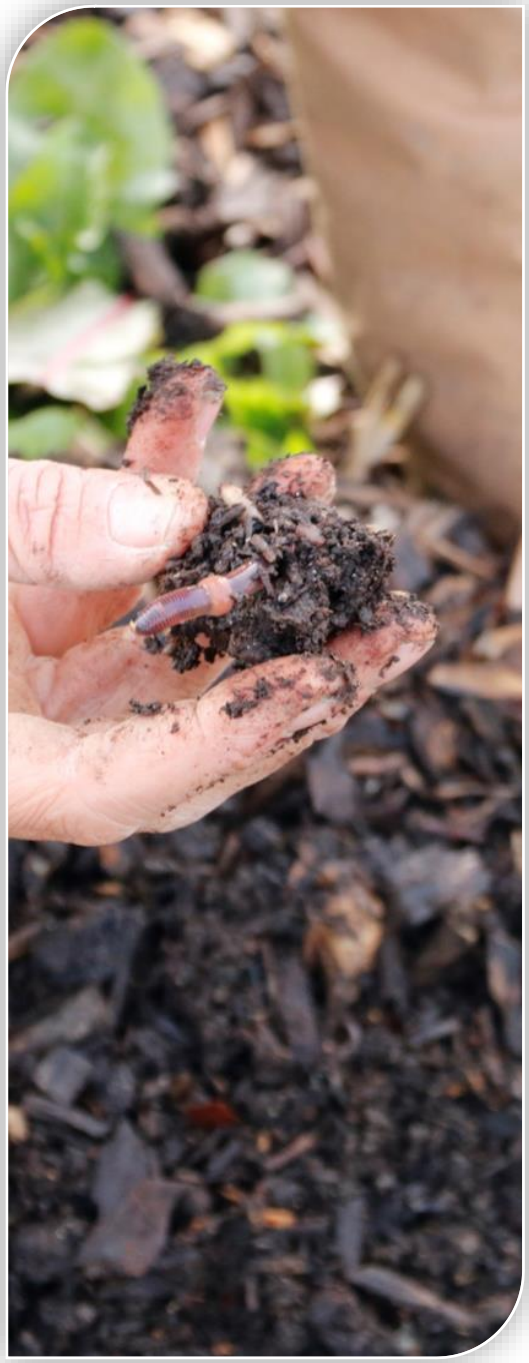


Why would we till the soil?

Why we think we need it?

- ✓ Seed or plant bed preparation
- ✓ To remediate soil compaction - for a more favorable soil condition for rooting and plant growth

If we can prevent compaction, we do not have to relieve it.



Soil management field experiment (Vegtilco; 3 year) stratification of SOM (conventional cropping system):

TOC

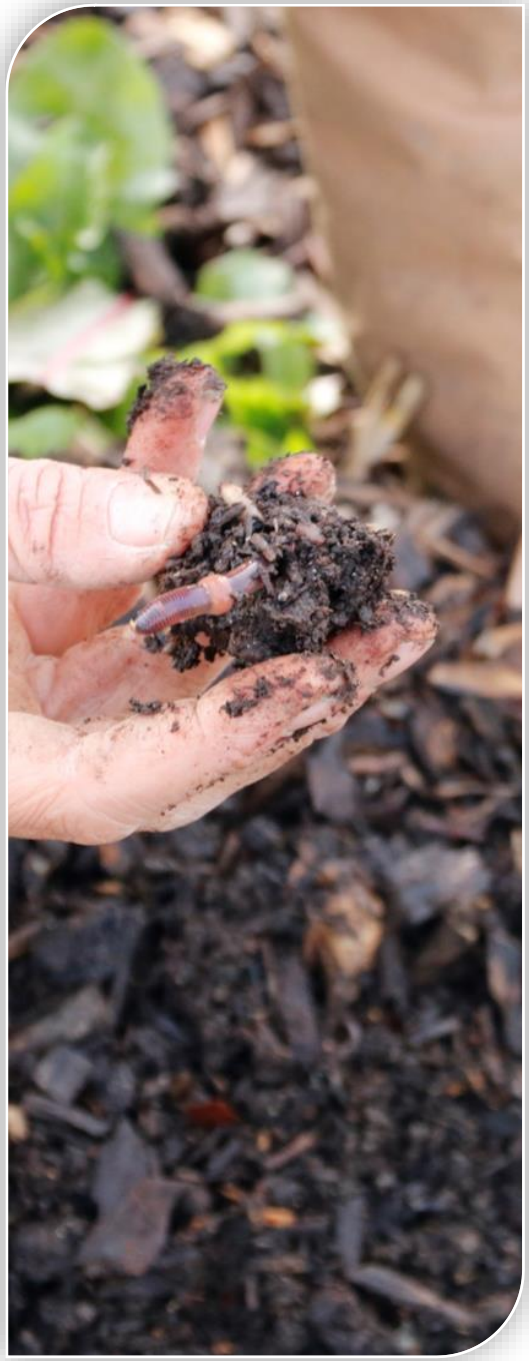
tillage

layer cm	CT	RT	Anova p-value
0-10	0.88 (0.06) b	1.05 (0.13) c	< 0.1
10-30	0.90 (0.08) b	0.93 (0.09) b	
30-60	0.61 (0.05) a	0.61 (0.12) a	
	p < 0.001	p < 0.001	

CT: conventional tillage
Mouldboard Plough

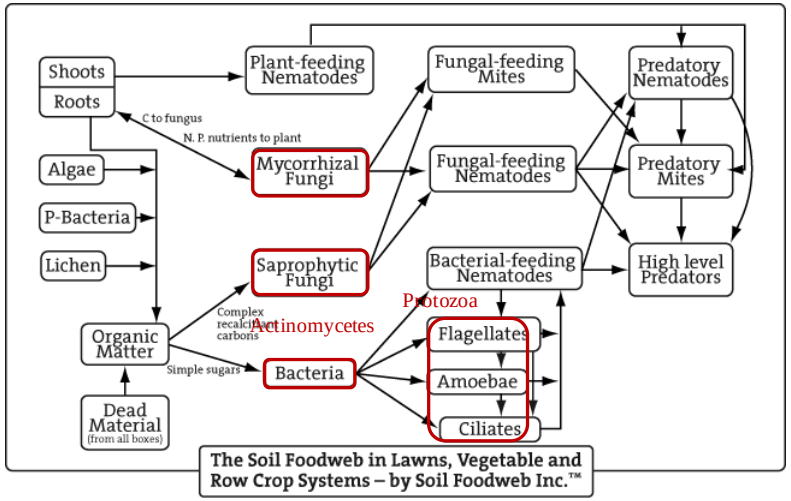
RT: Reduced tillage
Actisol ©

TILLAGE: stratification of SOM / reduction of nutrient leaching



Soil management field experiment (Vegtilco; 3 year) Soil microbial life 0-10 cm

Functional groups assessed by Phospholipid fatty acids (PLFA)

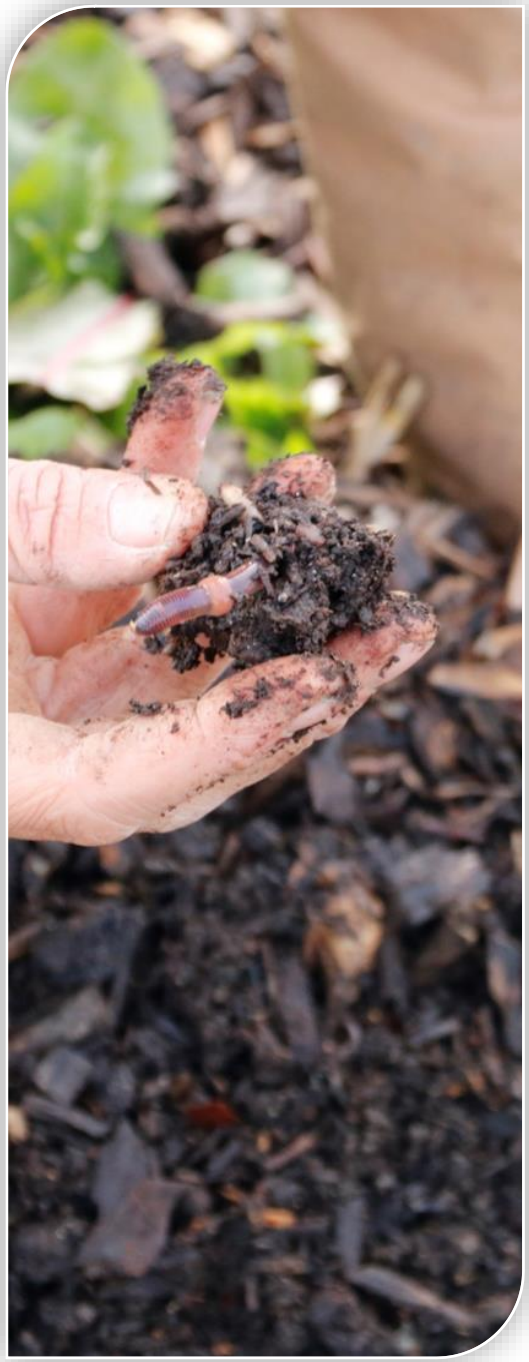


CT: conventional tillage
Mouldboard Plough

RT: Reduced tillage
Actisol ©

nmol g^{-1}	CT	RT
Total	14.11 a	20.29 b
G+ bacteria	2.60 a	3.51 b
G- bacteria	1.59	2.01
Actinomycetes	1.12 a	1.54 b
Fungi 18:2ω6	0.34 a	0.77 b
Fungi 18:1ω9	0.74 a	1.30 b
Fungi 18:3ω3	0.05 a	0.19 b
AMF	0.66 a	1.11 b
B:F 18:2ω6	13.13 b	7.60 a

Reduced, non-inversion tillage stimulates the growth of most groups of soil micro-organisms.

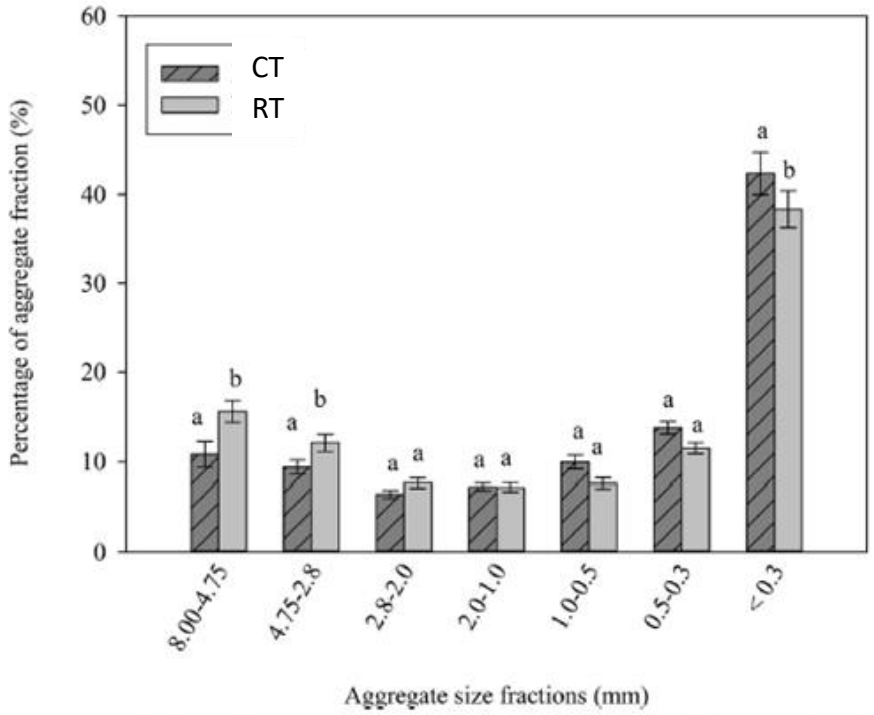


Soil management field experiment (conventional system): soil structure

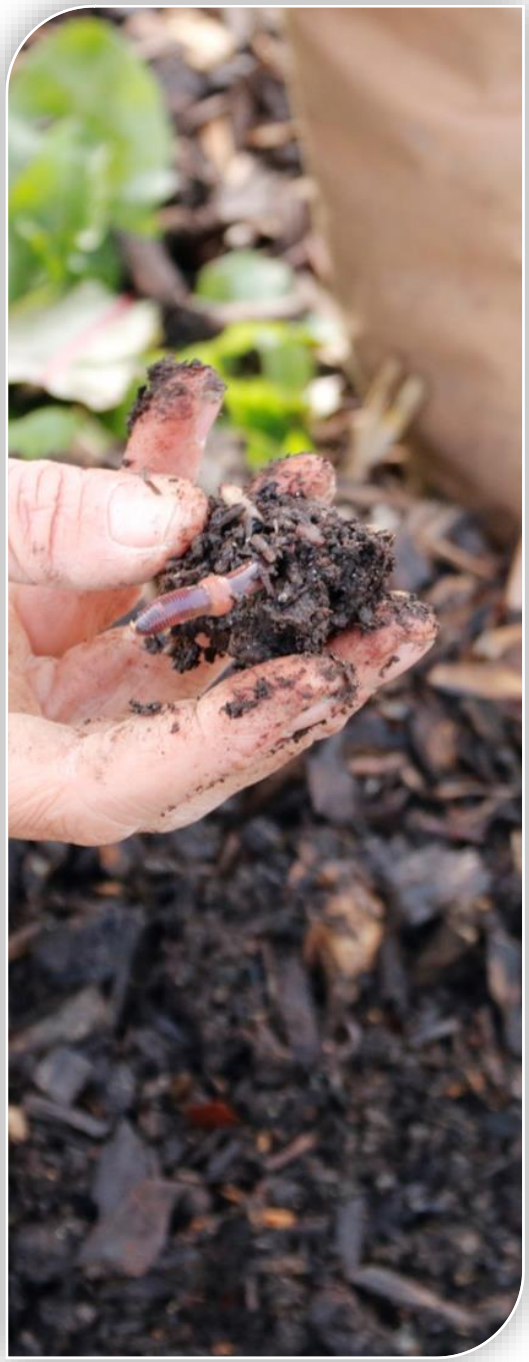
BOPACT trial at ILVO-Merelbeke, August 2012
Dry and wet sieving method
Aggregate size fractions in 0-10 cm soil layer after 3 years

CT: conventional tillage
Mouldboard Plough

RT: Reduced tillage
Actisol ©



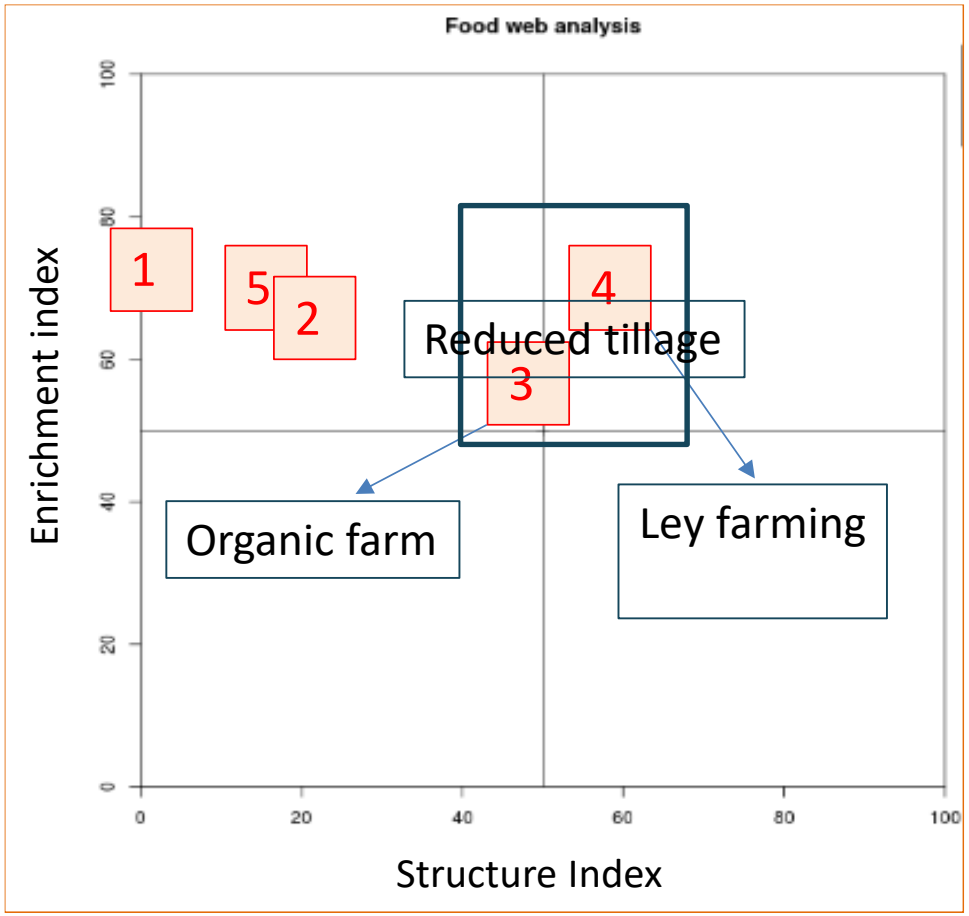
Ploughing causes more aggregates in the smallest size fraction (<0.3 mm)



Soil food web analysis based on nematode communities

Trophic levels and coloniser-persister categorization

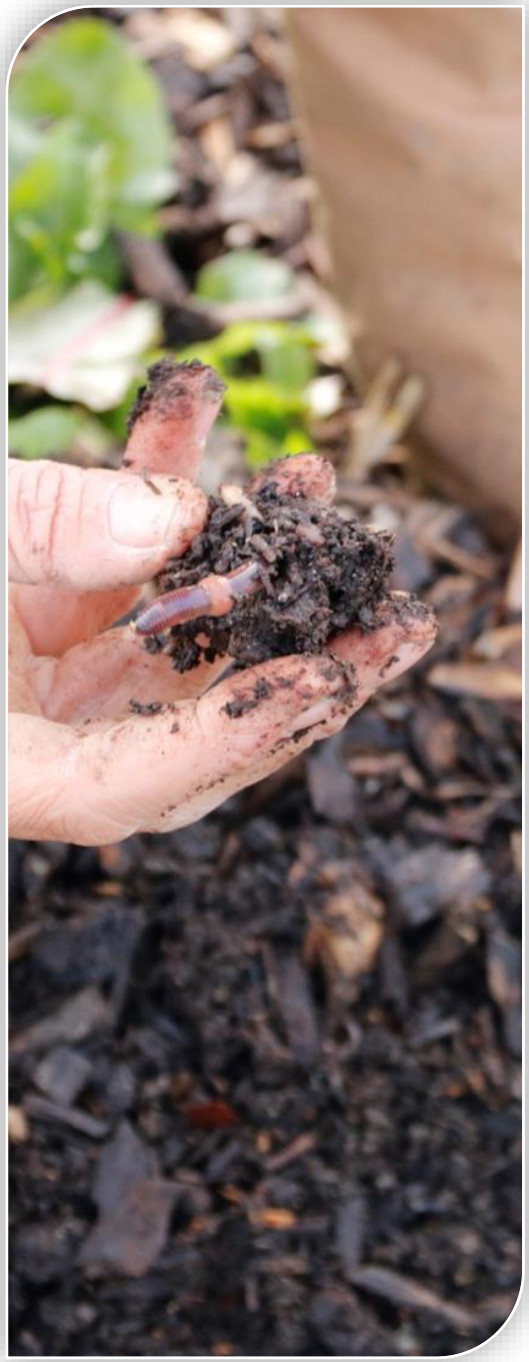
- ✓ Enrichment index = measure of nutrient richness
- ✓ Structure Index = degree of completeness of the soil food web



Vlaanderen
is bodembewust

Project: Bodem Doorgrond

RIVIERENLAND
LANGS NETE, DIJLE, ZENNE & RUPEL



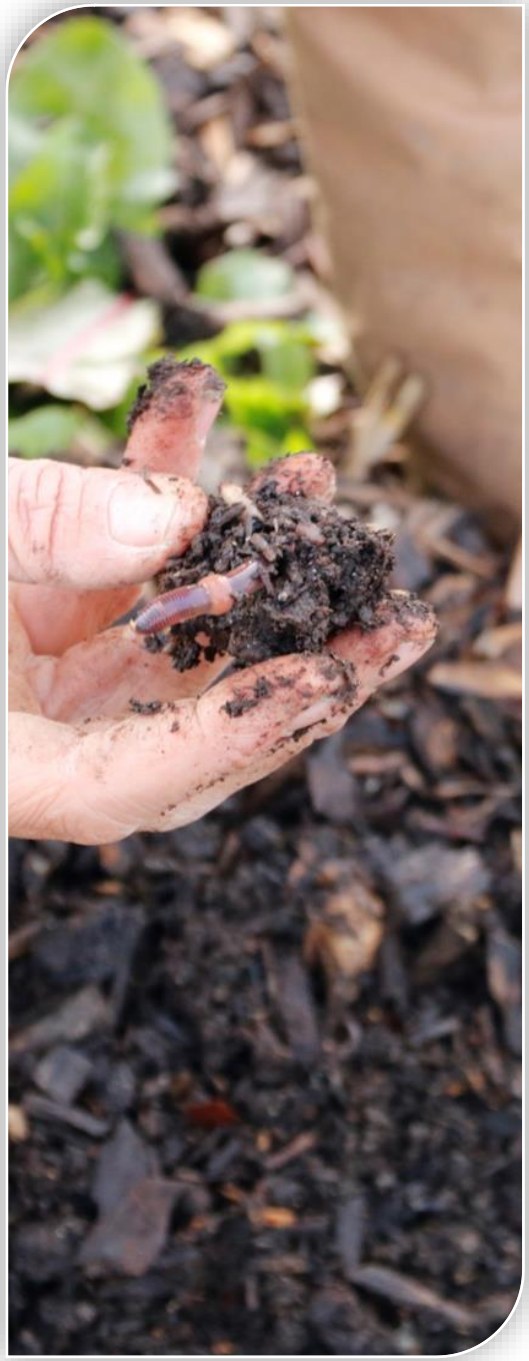
Why would we incorporate aboveground plant parts / soil improving organic fertilizers?

Have we any reasons to do so?

Can soil life HELP US TO INCORPORATE this organic material?
Detrivorous organisms, arthropodes and earth worms in the litter layer of natural ecosystems DO SO!

Incorporation effect on C sequestering?
Positive? Or, either neutral or negative due to soil tillage?

Need for innovation of sowing and planting machinery able to deal with plant residues or organic fertilizers on the top of the soil.



Experimental Platform for Agroecology in Hansbeke

P H A E
Project Hansbeke Agro - Ecologie

ILVO

RHEA
NATURAL RESOURCES HUMAN ENVIRONMENT AND AGRONOMY

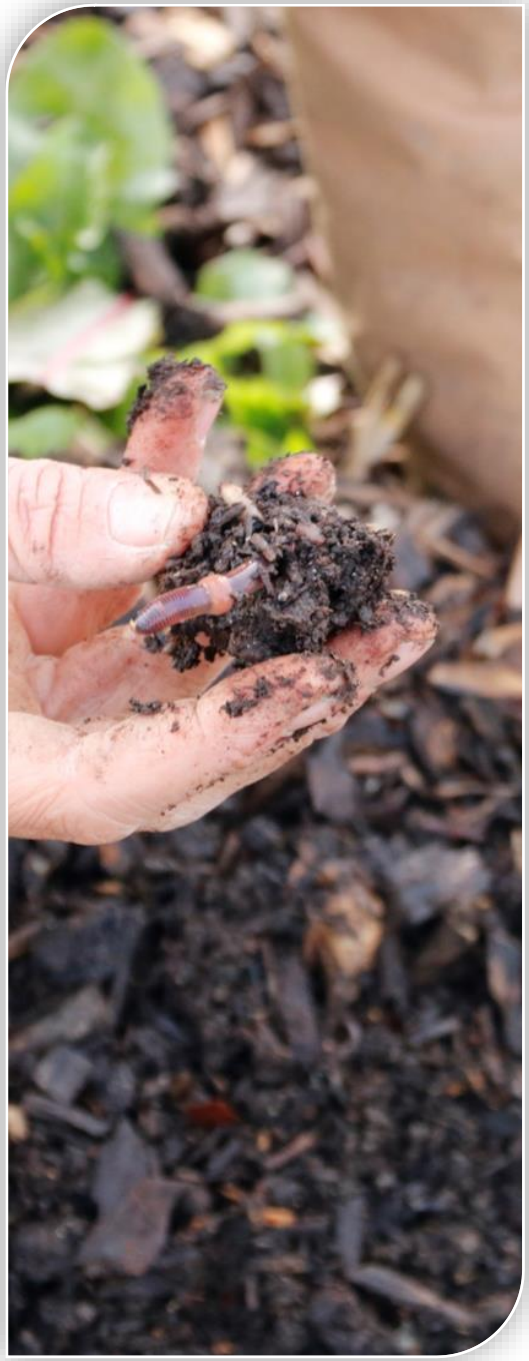
Sowing wheat in a Biomax cover crop, put down with a roller-crimper

Biomax:

- Flax
- Phacelia
- Egyptian clover
- Faba bean
- Pea
- Sunflower
- Vetch

Horsch Express 3TD sowing machine

www.ppaehansbeke.be/en/



Recommendations to farmers with respect to regenerative soil management

CROP ROTATION

Increase crop diversity by:

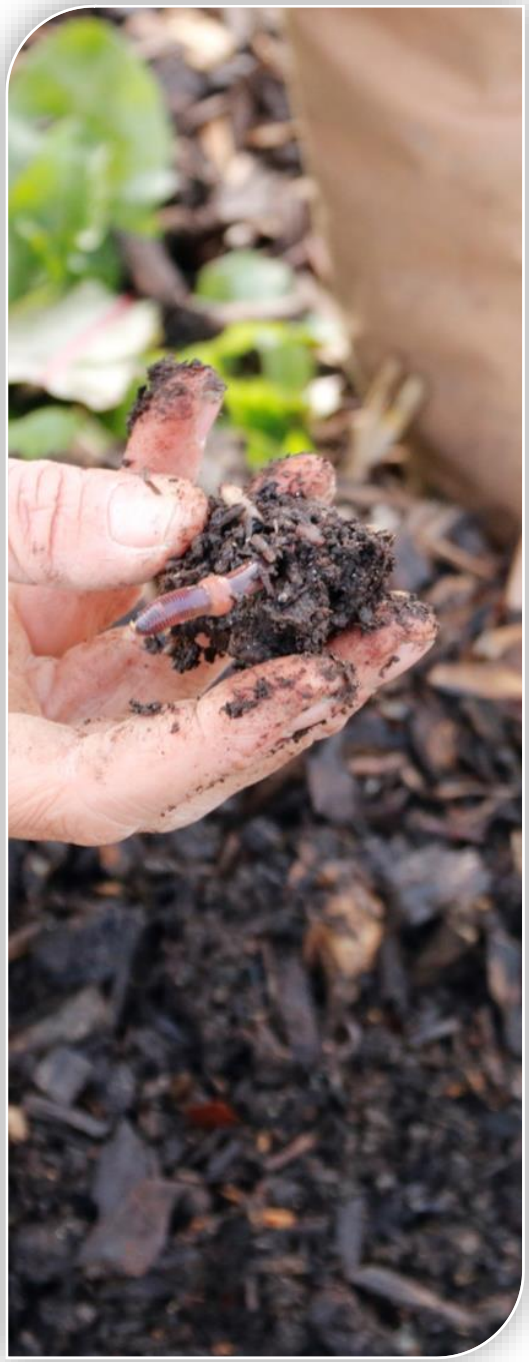
- ✓ Larger crop rotation
- ✓ Mixed cropping systems
- ✓ Intercropping
- ✓ Multispecies cover crop mixtures
- ✓ Inclusion of leguminous species

SOIL TILLAGE

- ✓ Reduce soil tillage
- ✓ Apply non-inversion tillage methods

FERTILIZATION

- ✓ Apply yearly C-rich soil improving organic fertilizers late summer / autumn, at low to medium dosage, followed by sowing a cover or winter crop.
- ✓ Do not surpass nutrients export by input from fertilization, unless a structural nutrient lack or imbalance.



Recommendations to policy makers

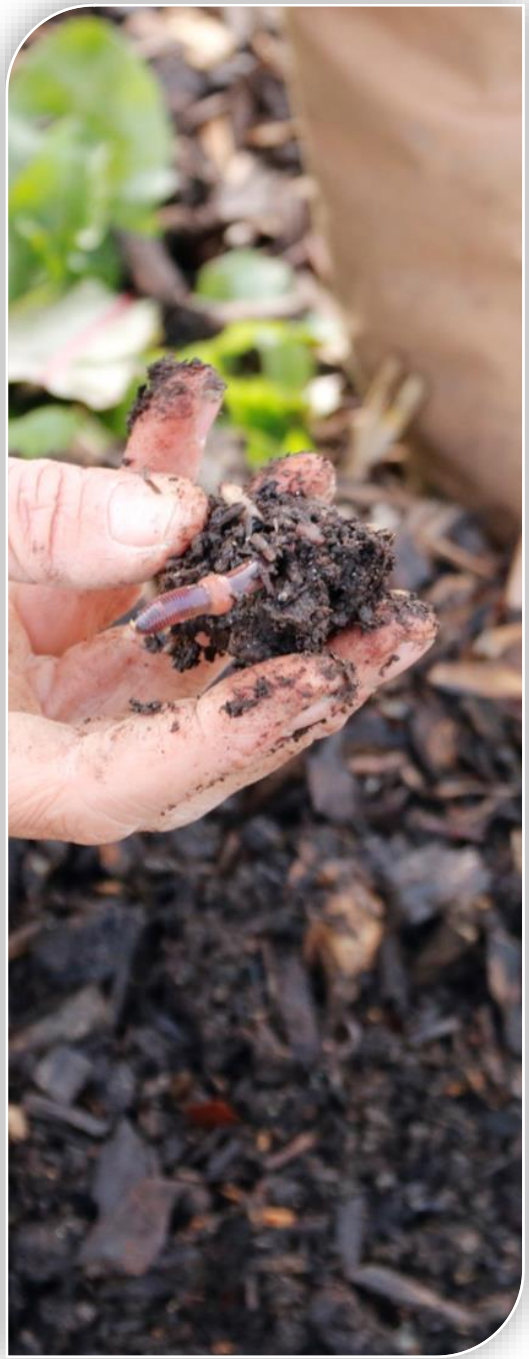
Regulations:
Soil care should be reflected in regulations concerning environmental issues.

Regulations should not compromise soil quality enhancement, but should facilitate cultivation measures that contribute to a good overall soil quality.

Support **farmers** by subsidizing extension and advisory services that can coach farmers aiming at a regenerative soil management practice. Support peer learning processes.

Support **research** that delivers insights in soil functioning in relation to soil management strategies.

Create **market** conditions that reward farmers for healthy food products derived from healthy soils.



From today on :

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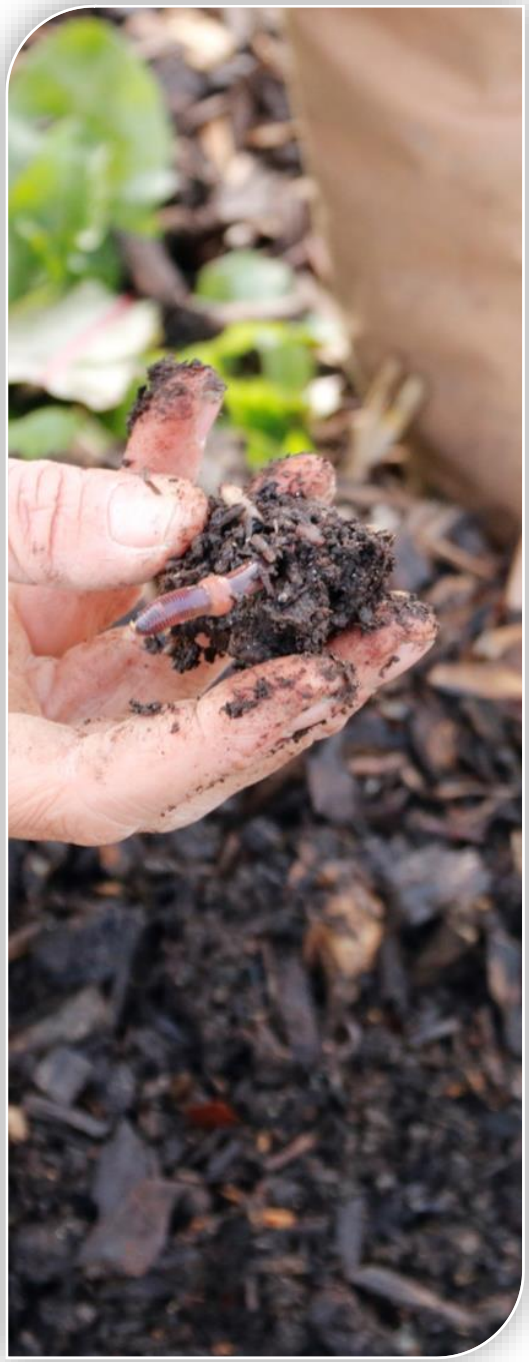

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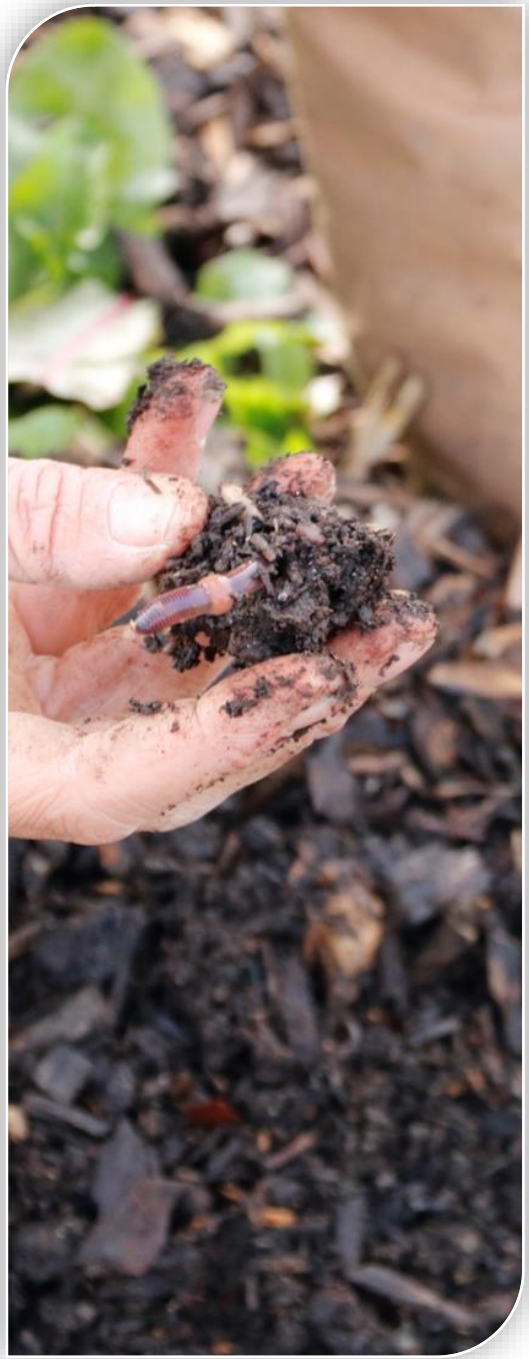

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Thank you

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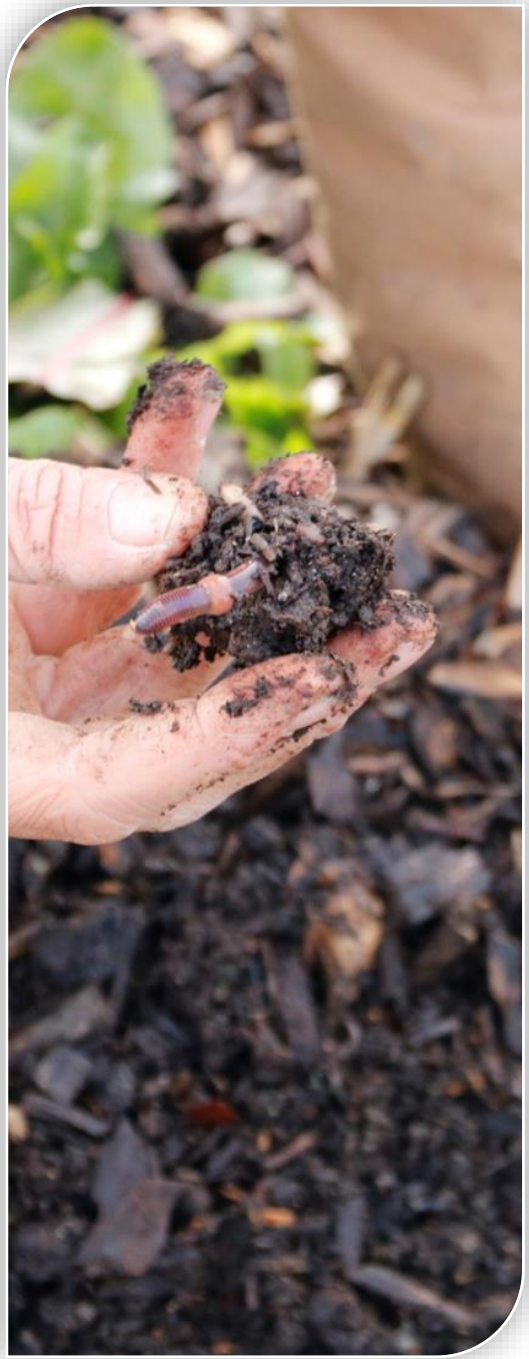

Questions?