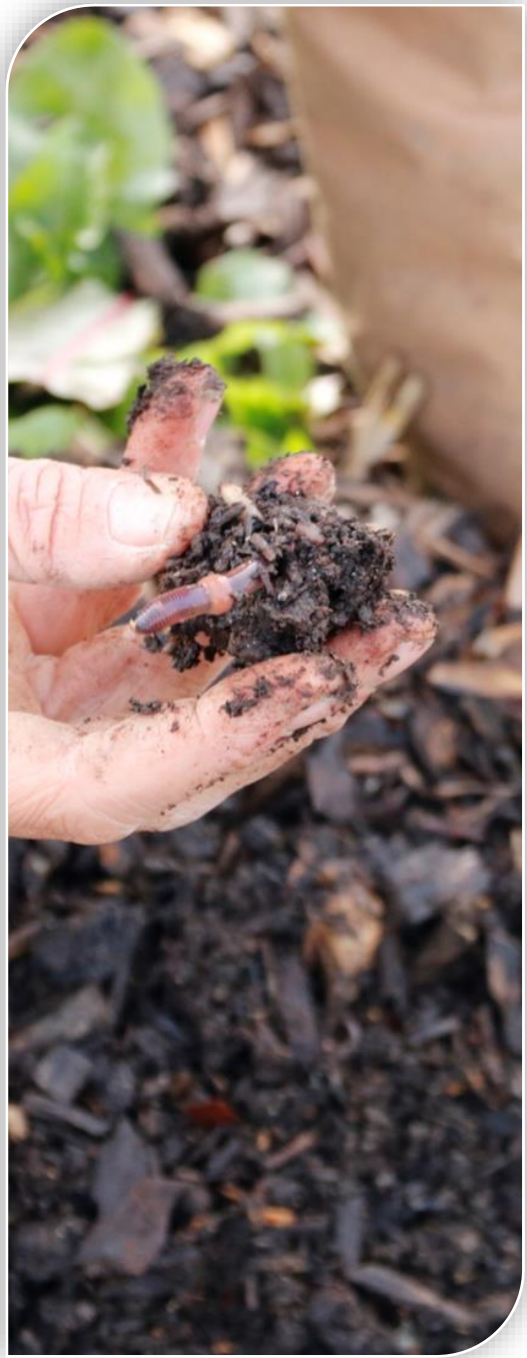
Soil Health Conference

Harnessing biodiversity for a better agronomy



Welcome!

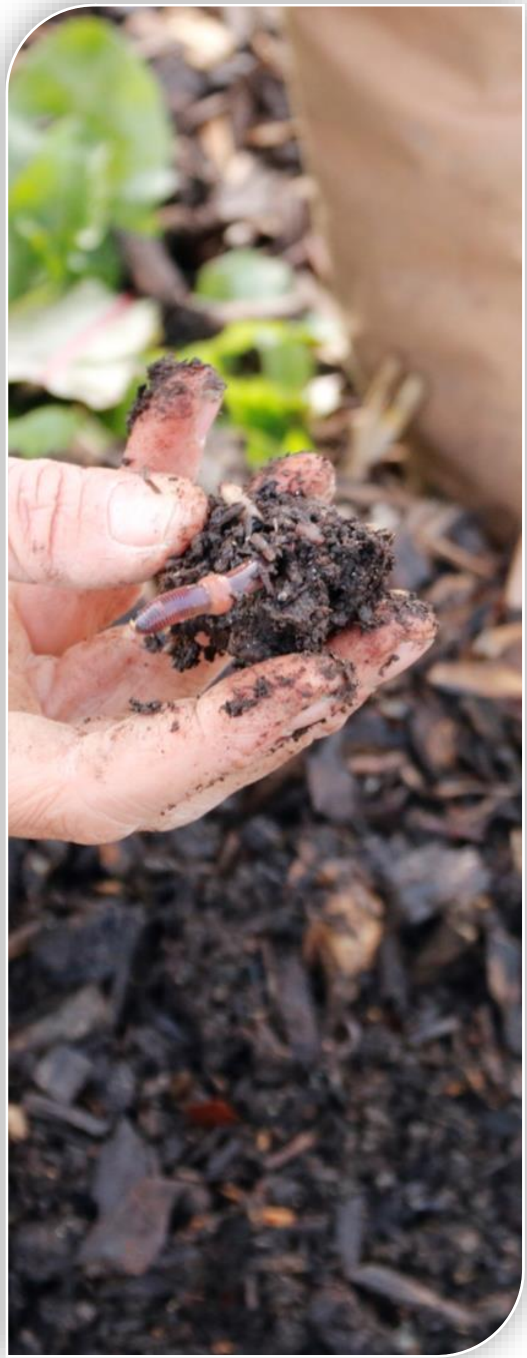
9h00 - Welcome
Jeroen Watté

9h05 - Why a World Soil Day
Raschad Al Khafaji

9h10 - Knowledge erosion about soils
Anton Nigten with Jozef Visser

9h45 - Mechanisms of soil health restoration in regenerative agriculture
Kris Nichols

10h35 - Coffee and tea break



10h50 - Mechanisms of soil health restoration

Richard Teague

Koen Willekens

12h30 - Lunch

13h30 - What can regenerative agriculture deliver for farmers

Peter Vanhoof

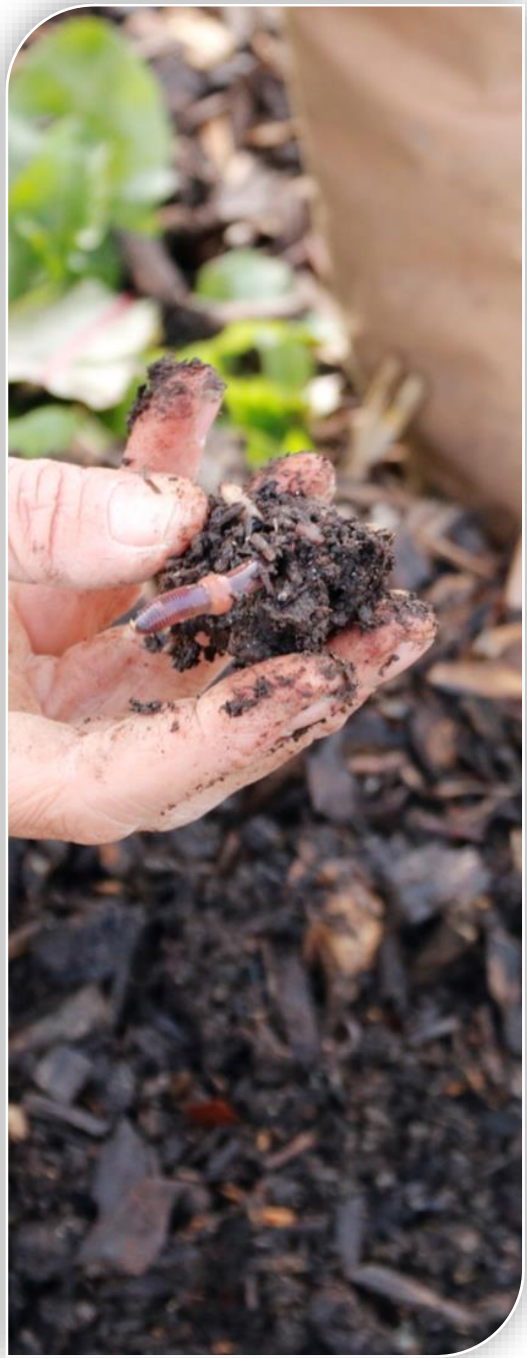
Emiel van de Vijver

Jos Van Reeth

15h30 - Panel discussion: Let’s start restoring our soils!

Anton Nigten, Richard Teague, Koen Willekns, Jos Van Reeth, Peter Vanhoof, Anette Schneegans (European Commission, DG AGRI), Martine Swerts (Flemish government, Soil & Environment) and Annemie Elsen (Soil Service of Belgium)

17h30 - Reception



Wi-Fi & social media

Wifi-network: VO Events
Password: vl#%nderen

Twitter
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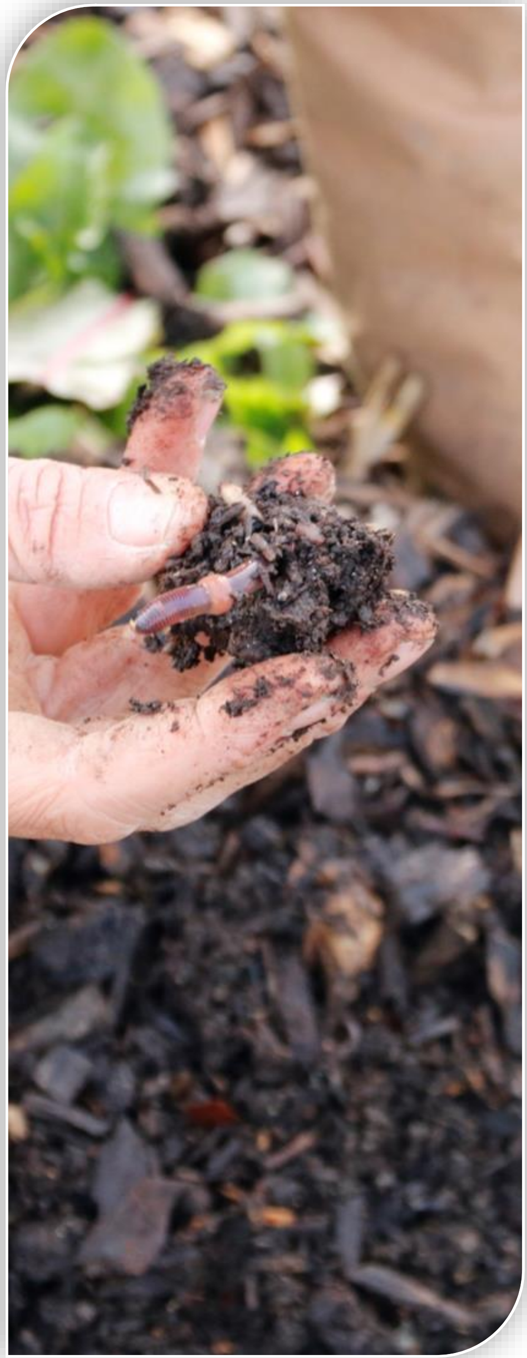
@ilvovlaanderen
#worldsoilday
#betteragronomy

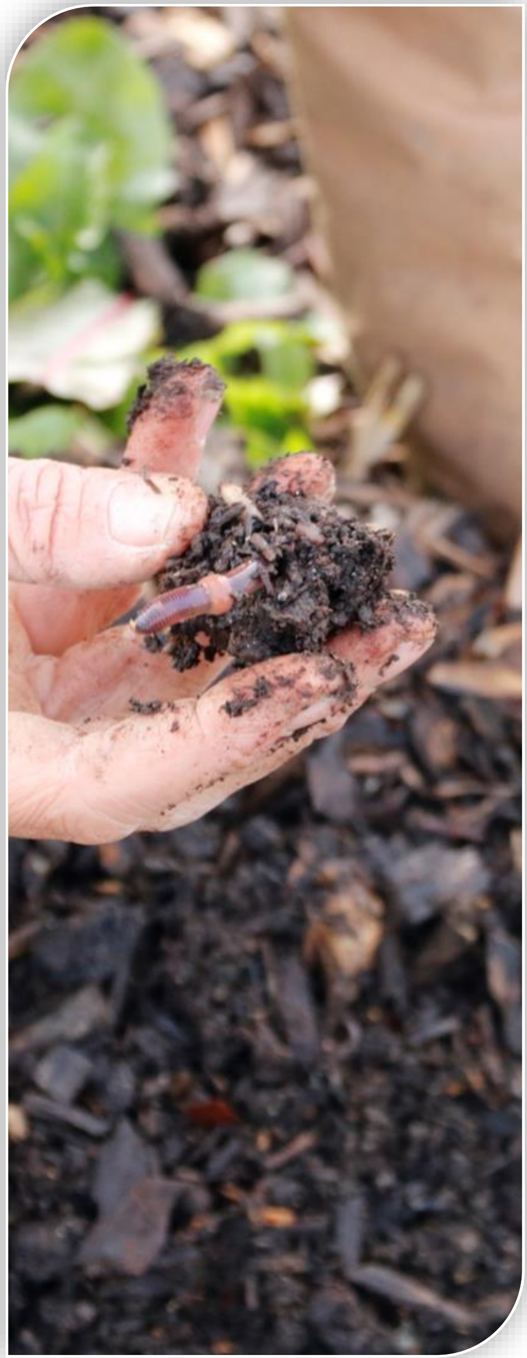

regenerative farmers
are 25 years ahead


knowledge
erosion

calibrate
before use



World Soil Day



Knowledge erosion about soils

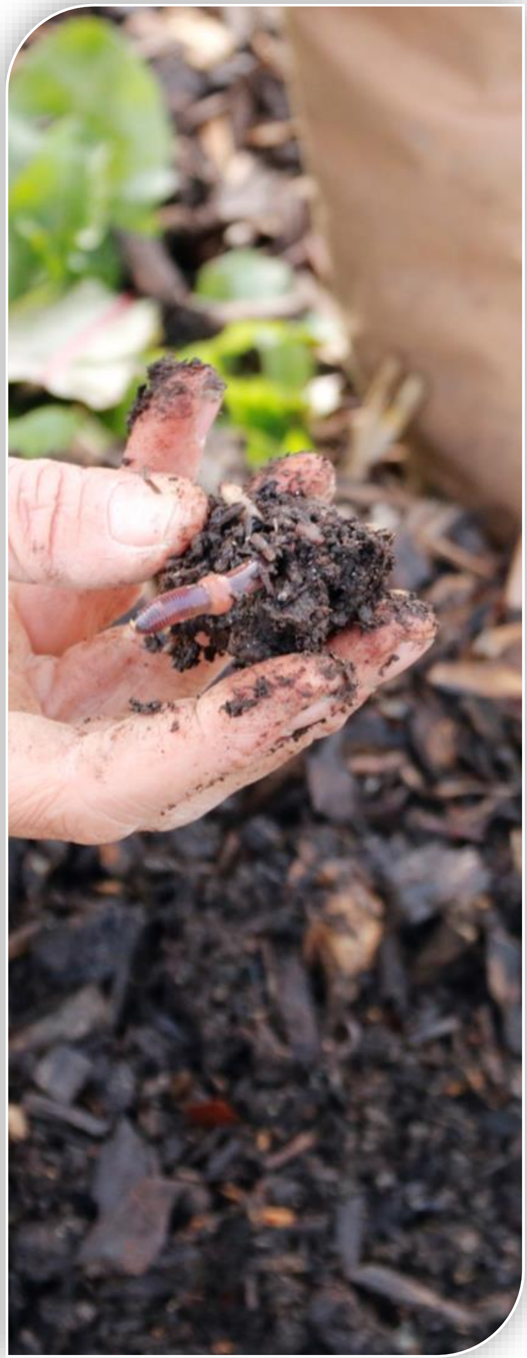
Anton Nigten

A vital soil is required for vital plants. Presentation for the Soil Health Conference:

December 5, 2022 in Brussels

Why are modern agricultural crops sick, and how can a different view on plant nutrition help us to revitalize our crops?

Anton Nigten, The Salt of the Earth. With the cooperation of Joost Visser.

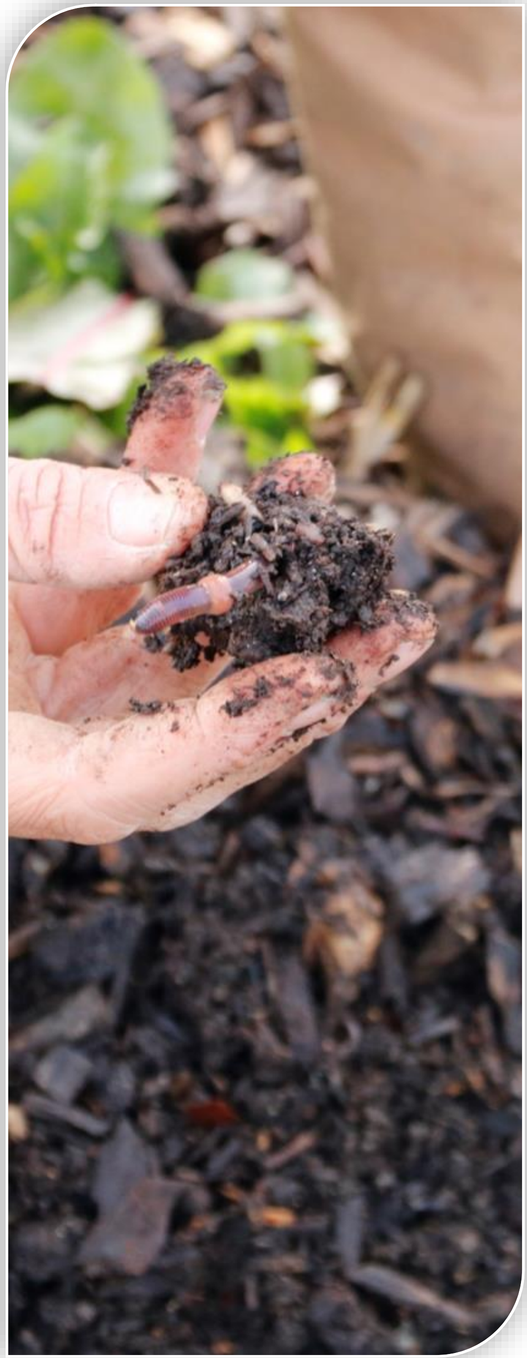


There are about sixteen to eighteen different fertilization systems worldwide. All these systems can be reduced to **two fundamentally different paradigms**.

> The salt paradigm.

> And the humus paradigm.

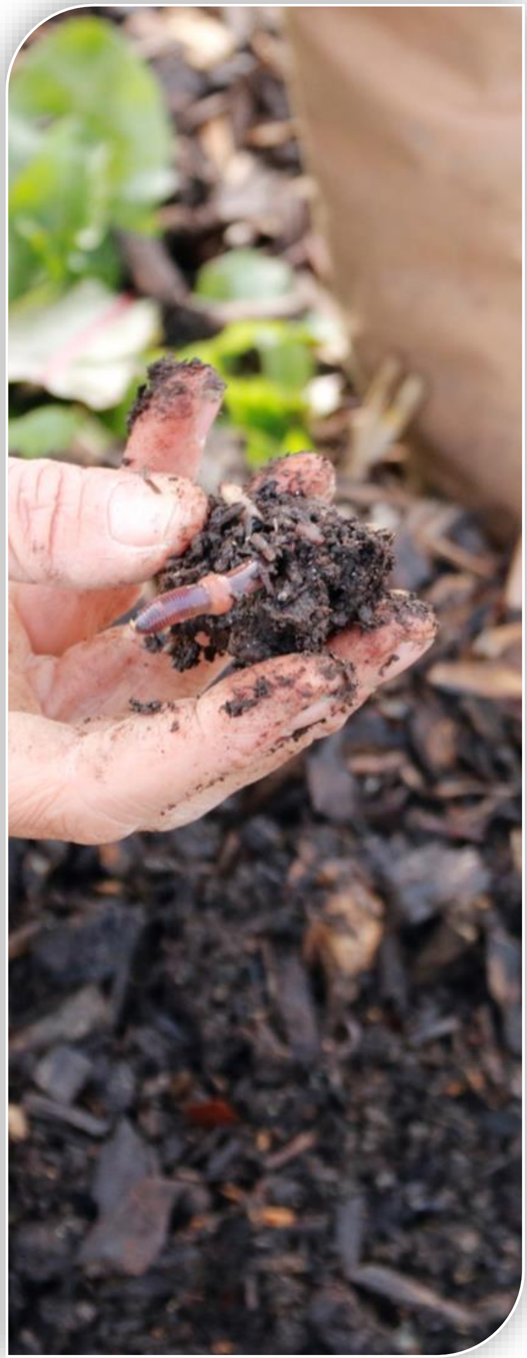
The battle over how to feed plants has been going on for over two centuries now.



According to the salt paradigm, the plants only need to have all the necessary salts to grow. You only have to know:

- Which salts does a specific crop need, and how much?
- How much is removed with the harvest?
- What stock is in the soil, and what should you add?
- This requires an ash analysis of the crop and a soil analysis;
- And you need to know how much, and how quickly the salts are released from the soil material through mineralization.

In this view the plants do well with sixteen elements.



But numerous complications arose.

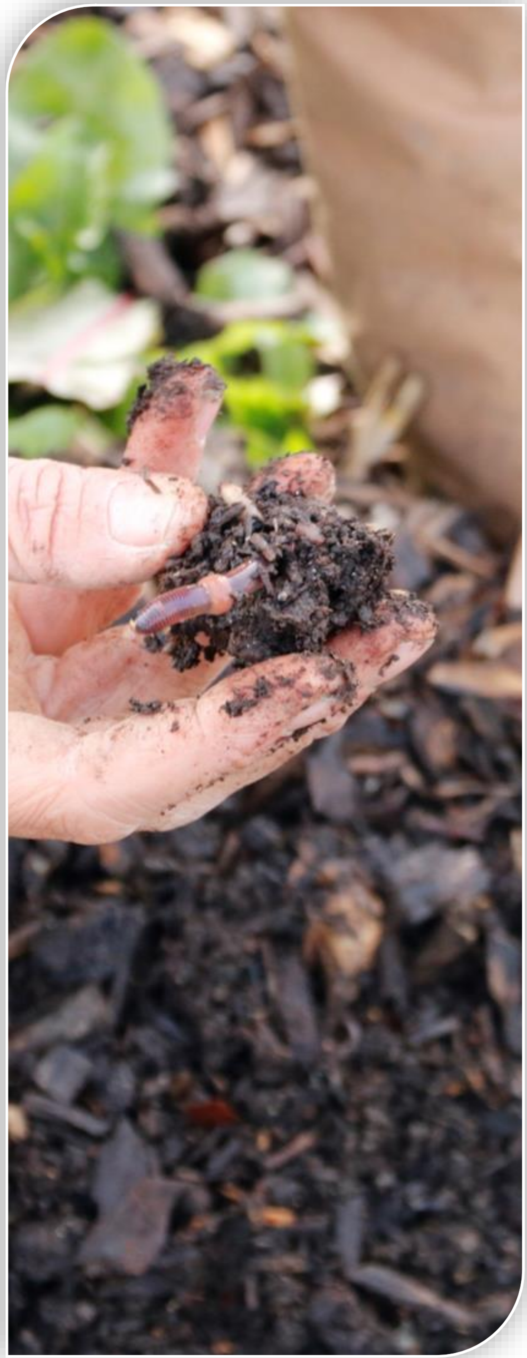
- Even if you give all 16 elements, the crops will still get sick;

- Each element inhibits or stimulates the absorption of other elements;

- Some salts are absorbed generously, other salts, on the other hand, only with difficulty;

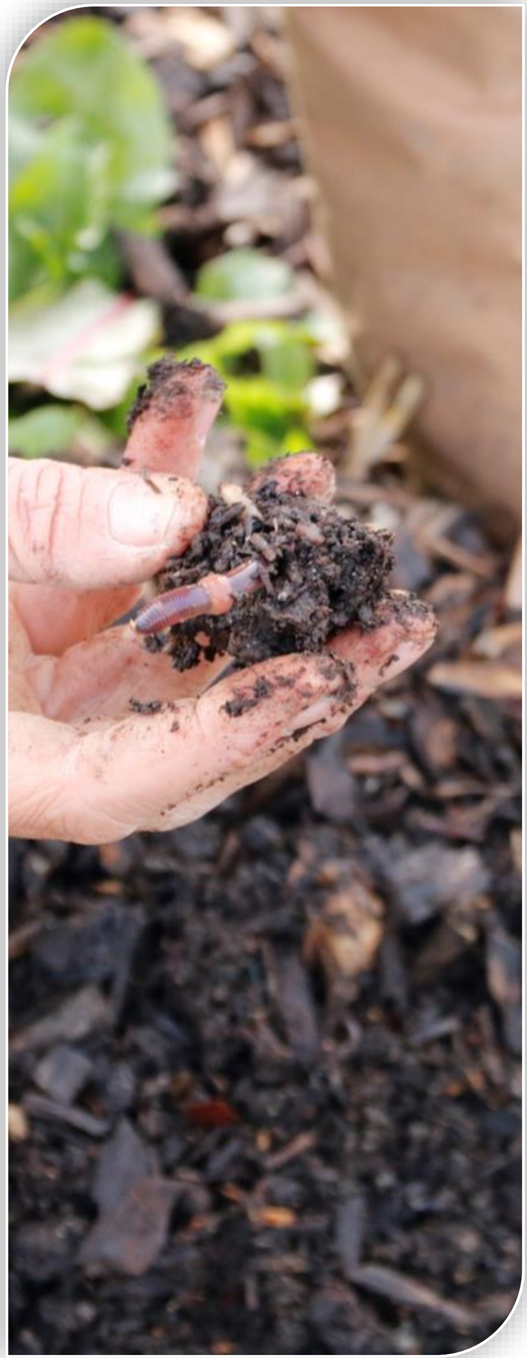
- Deviations and problems occur on every type of soil and there are major differences between farms;

- It turns out that it is not possible to actually use the elements for the full 100%.



- The use of salts leads to serious biodiversity losses;
- Some salts are harmful to soil life and symbioses;
- Some salts are harmful or toxic to certain plants;
- Many salts lead to soil compaction and soil degradation;
- There are places in the world where the same plants grow but with a very different mineral profile;
- On many soils, fertilizer agriculture leads to salinization or soda formation;

The complications are no reason for this school to revise the basic principles.



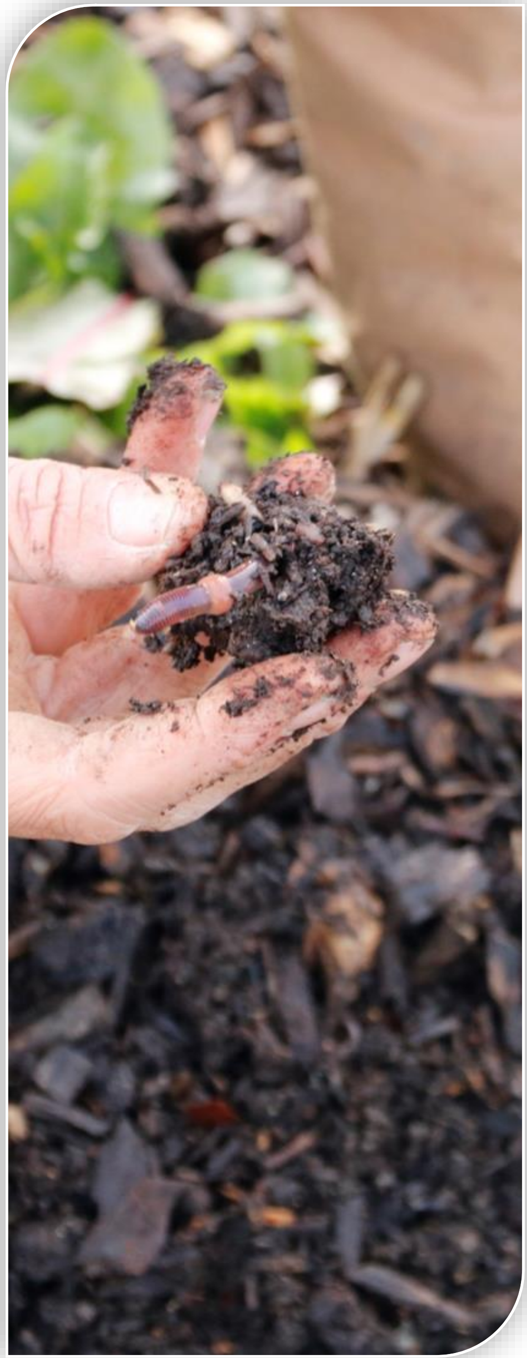
The main starting point of the humus paradigm is that plants (also) or perhaps exclusively feed on organic compounds.

Based on historical research, Mr. Visser has shown that there was already serious doubt about the salt paradigm of Liebig et al. around 1840.

The authors mentioned by Visser entered into a discussion with Liebig about his starting points, but Liebig hardly addressed their arguments.

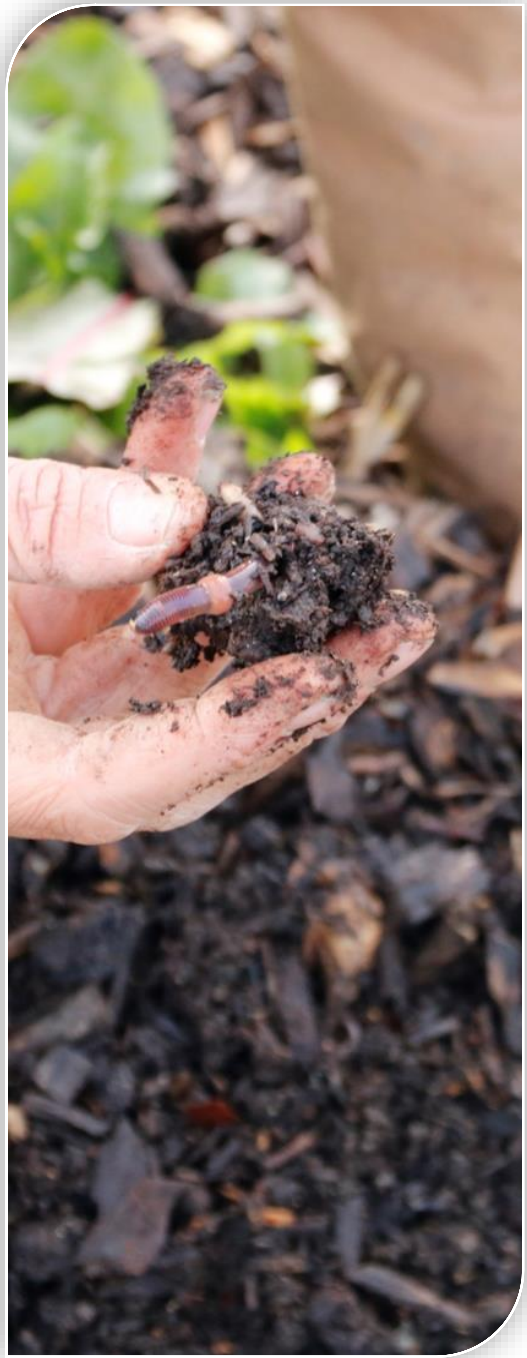
Something similar happened in thinking about food quality (Harvey Wiley, 1906) and about the role of bacteria in diseases between 1870 and 1912 (Béchamp versus Pasteur).

That is why we speak of knowledge erosion...



The conflict over the salts revolved around three areas:

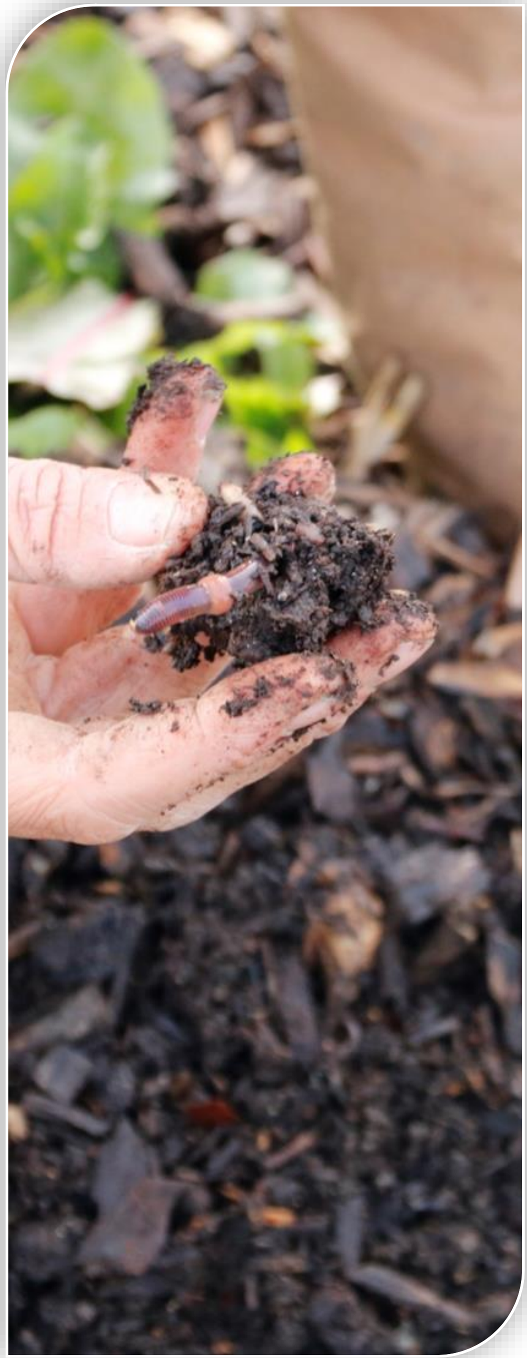
- **Where does the plant get its nitrogen from and in what form does it absorb it?**
  Are ammonium and nitrate harmful to plants?
- **How harmful is superphosphate?**
- **Why do plants absorb so much potassium? How harmful is potassium chloride?**



The battle for nitrogen went roughly as follows:

- Do the plants extract nitrogen or ammonia from the air? That was the view of Liebig and some others;
- But Boussingault distanced himself from his previous views on atmospheric nitrogen uptake;
- Around 1850, common sense was that plants only extract nitrogen from the soil;
- Legumes support the growth of non-legumes;
- But it was only after 1883 that agricultural science began serious research on legumes, based on the research of Schultz Lupitz, a farmer;

The research by Hellriegel and Willfahrt then led to the discovery that the rhizobium bacteria in the root nodules of the legumes were responsible for fixing nitrogen from the air. But that was not taken for granted.



Meanwhile, research into nitrogen fixation by non-legumes continued steadily.

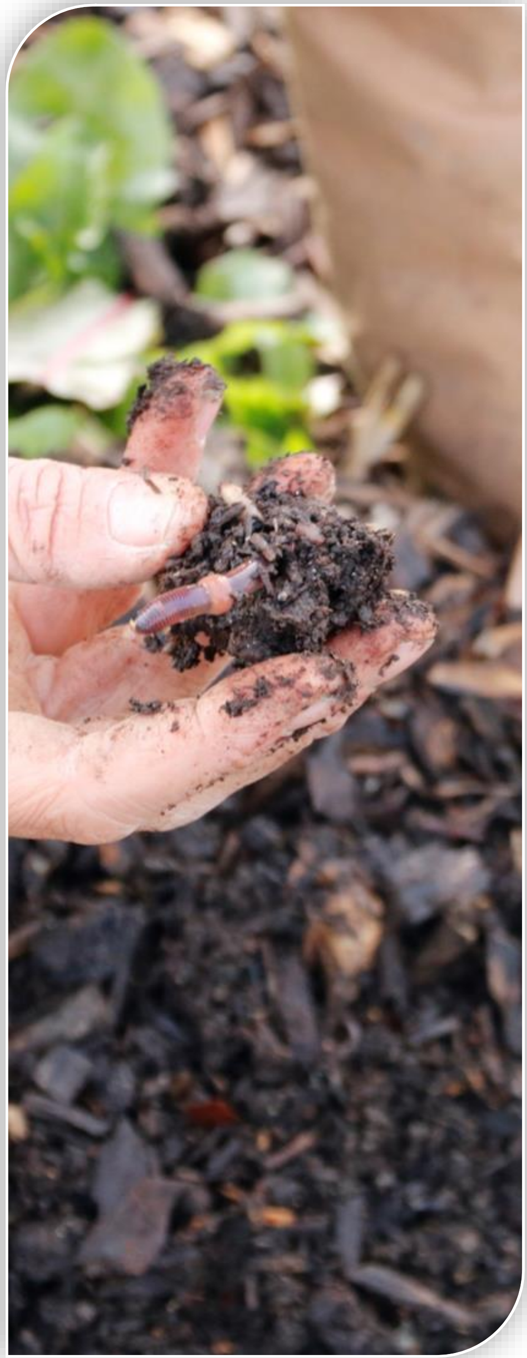
I would like to elaborate on three authors here: Ville, Stoklasa, and resp. Jamieson.

Ville built a test setup in 1853 to measure whether plants could assimilate nitrogen from the air. He showed that this was the case. That led to a renewed struggle.

Stoklasa questioned the function of root nodules on the roots of leguminous plants:

Lupins, his experiments showed, assimilate atmospheric nitrogen independently of the presence or absence of root nodules. The lupins without nodules showed no nitrogen deficiency in any way;

The N yields were higher in lupins without nodules or with imperfect nodules than in lupins with numerous, well-developed root nodules;

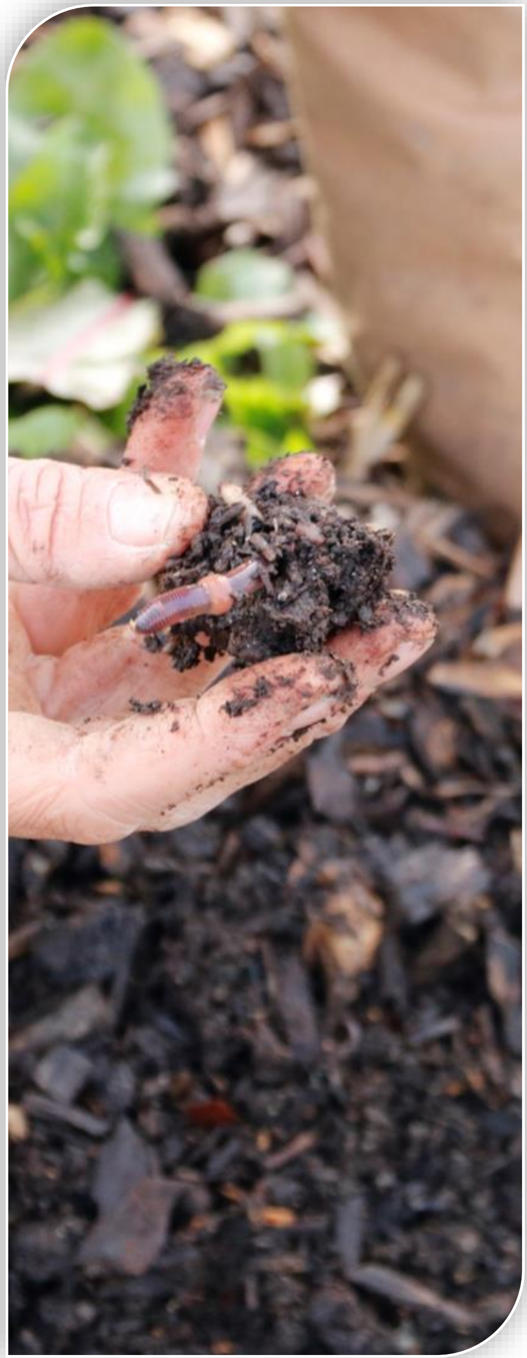


Jamieson conducted research in Scotland into the question which organ plants use to extract nitrogen from the air.

He discovered that this happened in special hairs on the leaves (1910). I assume that the cells in the hairs where nitrogen assimilation takes place are almost identical to the heterocysts of cyanobacteria.

Jamieson's results were completely ignored.

One year before Jamieson published his results, Haber and Bosch had discovered a method for converting atmospheric nitrogen into ammonia using a chemical process, more efficiently than their Norwegian predecessors. Their proces needs a lot of energy.



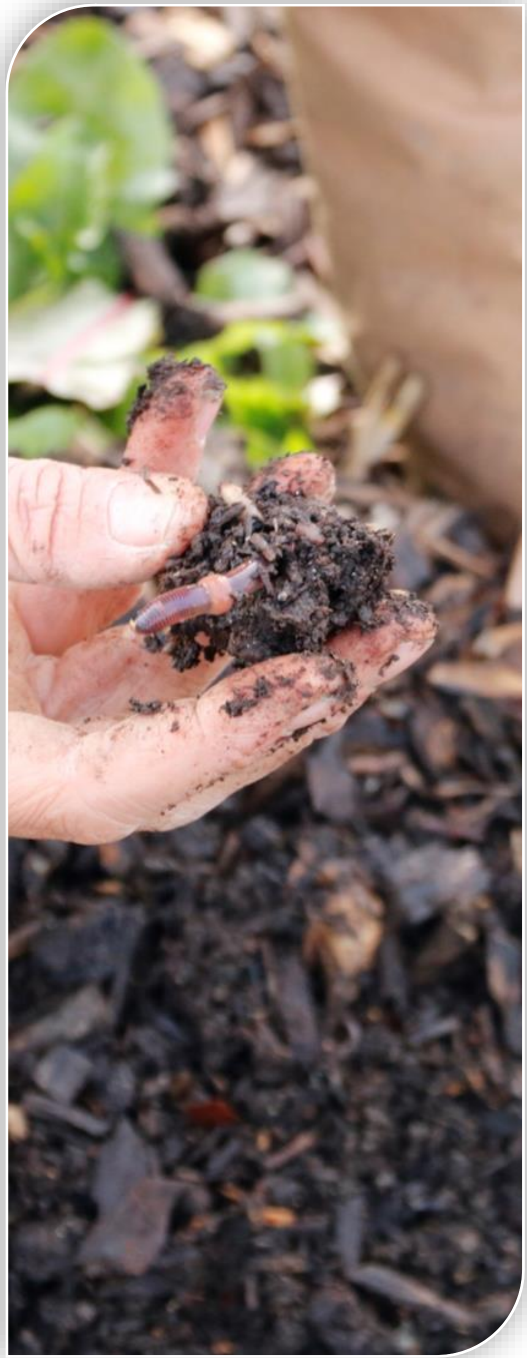
After 1950 there is a pause in research into nitrogen assimilation **by non leguminous plants**.

But that has changed rapidly since the eighties.

In grasses in particular, several resident bacteria are discovered that assimilate nitrogen from the air:

In addition to the absorption of nitrogen salts, five more ways in which plants collect their nitrogen have been discovered so far. And it always revolves around organically bound nitrogen.

White and his team at Rutger University discovered that plant roots eat 'their' bacteria and then strip them of their nutrients. And sent them back into the soil.

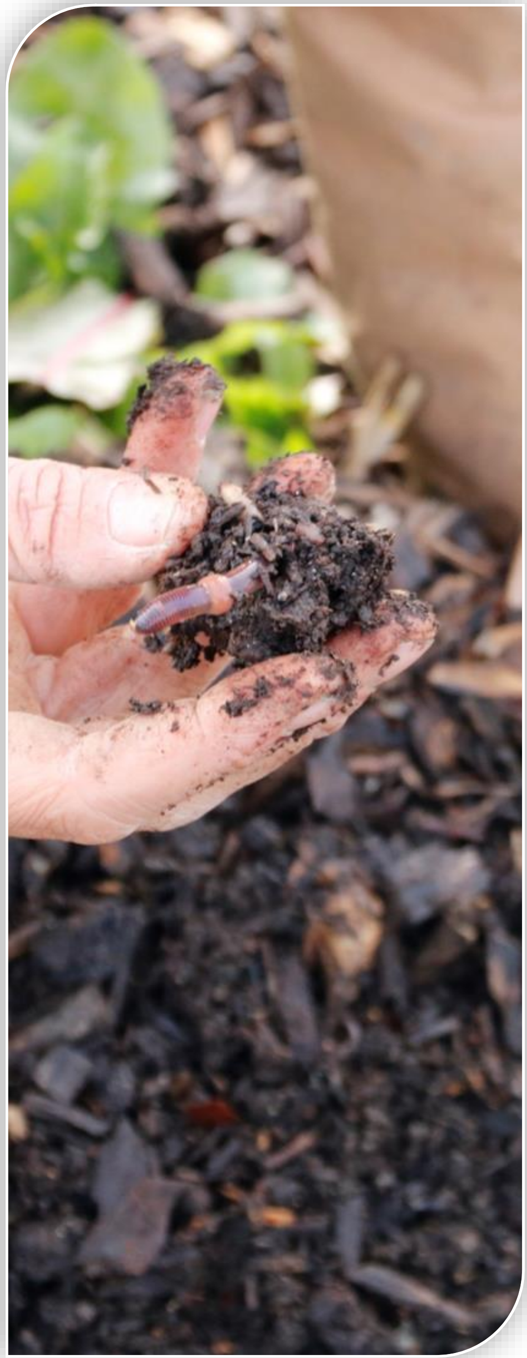


Christine Jones summarises as follows:

All green plants form associations with nitrogen-fixing bacteria. This phenomenon is not restricted to legumes. (..) In well-functioning soils, 85-90% of plant nutrient uptake is microbially mediated and N is no exception.

The first-formed product of biological nitrogen fixation, NH_3, is rapidly converted (within milliseconds) to non-toxic NH_4^+, which in turn is rapidly transformed to amino acids. (Christine Jones, 2017).

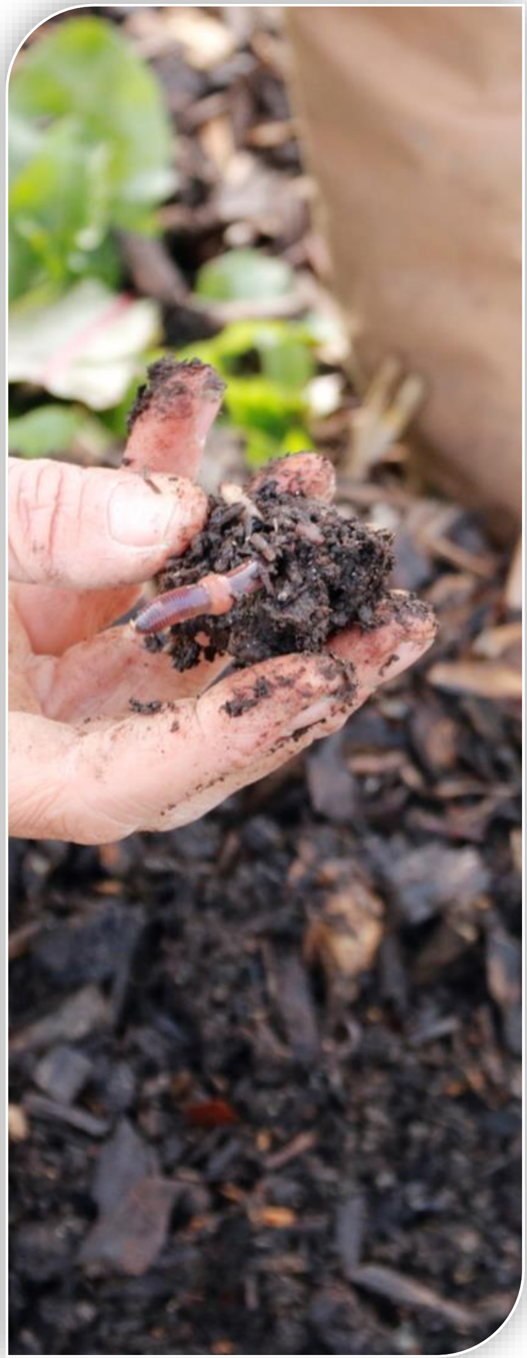
Now we will look at the consequences of fertilizing with salts for
the health of crops, animals and people.



The quality of feed for dairy cows is measured much more intensively in the Netherlands and elsewhere than the quality of humane food.

Today I want to answer two questions:

1. Is the quality of the cow feed properly measured?
2. And can we learn something from it for measuring the quality of humane food?



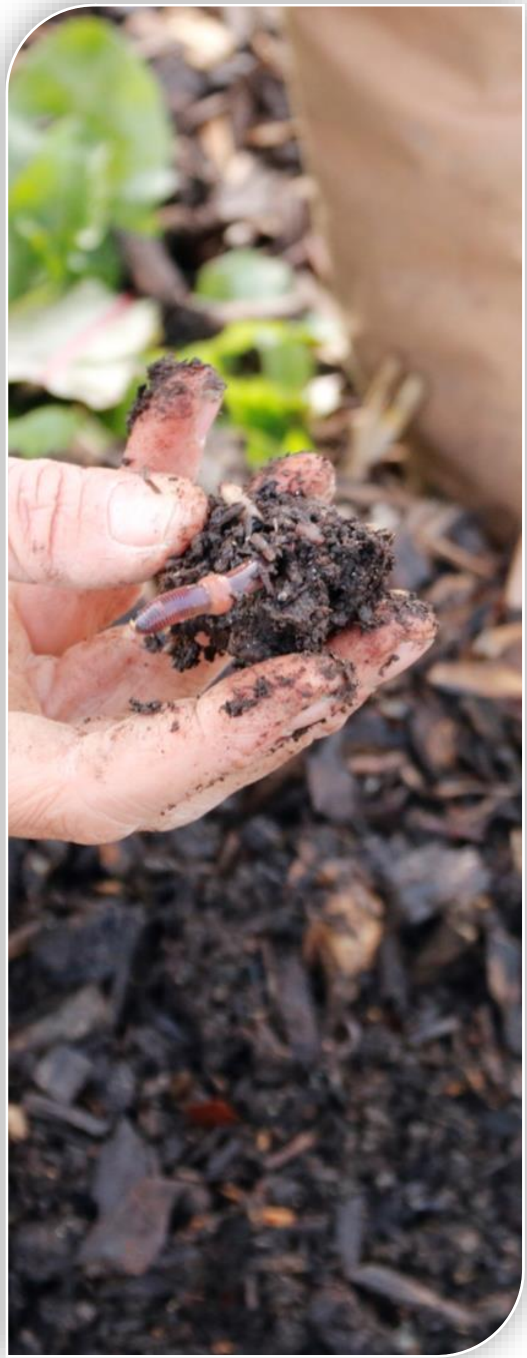
Which elements and which compounds should we measure?

Eurofins, the largest laboratory in the Netherlands, measures the following elements and compounds in cow feed:

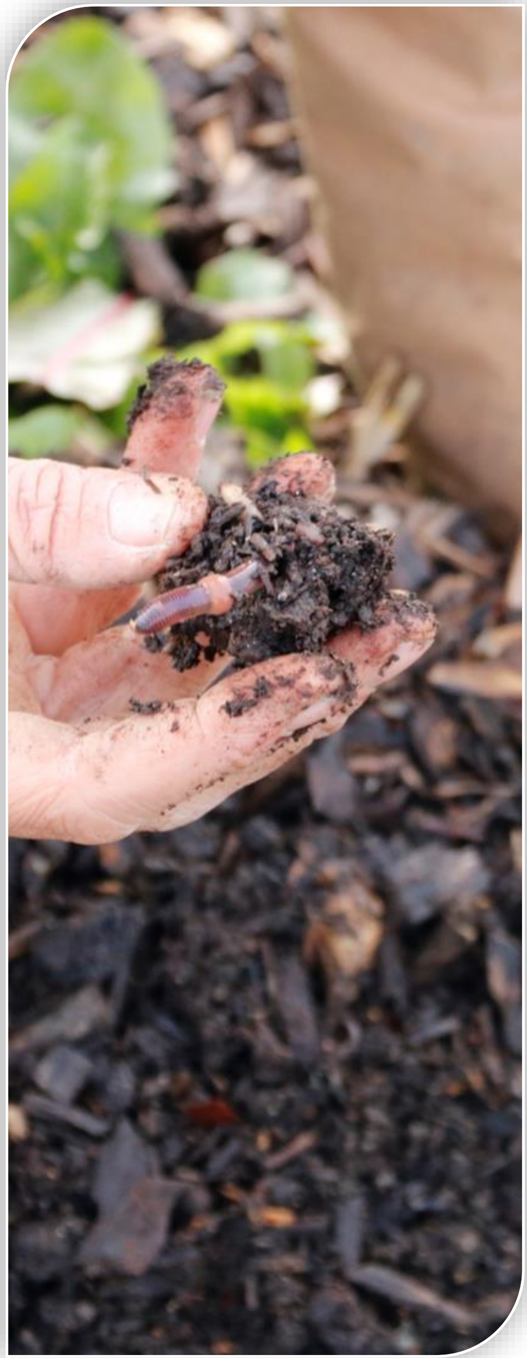
- **The macro elements:** potassium; sodium; calcium; magnesium; phosphorus; sulfur and chlorine;
- **The trace elements:** selenium; zinc; iron; buyer; iodine; boron; cobalt; molybdenum and manganese;
- With **nitrogen** they measure nitrate; ammonium and N total. From N total they calculate crude protein;

Not everything is measured: not silicon; amino acids and total non protein nitrogen. Also a number of harmful compounds, such as hydrogen sulfide; sulfate; phosphate; nitrite; nitric oxide; urea; and cyanide in the feed are not measured.

But, compared to human food, a lot is measured. In our food, only the red colored macro-elements are measured. And the red trace elements, and total N. Establishing the ratios between the macro elements is critical. But that doesn't happen. And important standards, including their own standards, for animal feed are ignored, trivialized or deliberately adjusted.

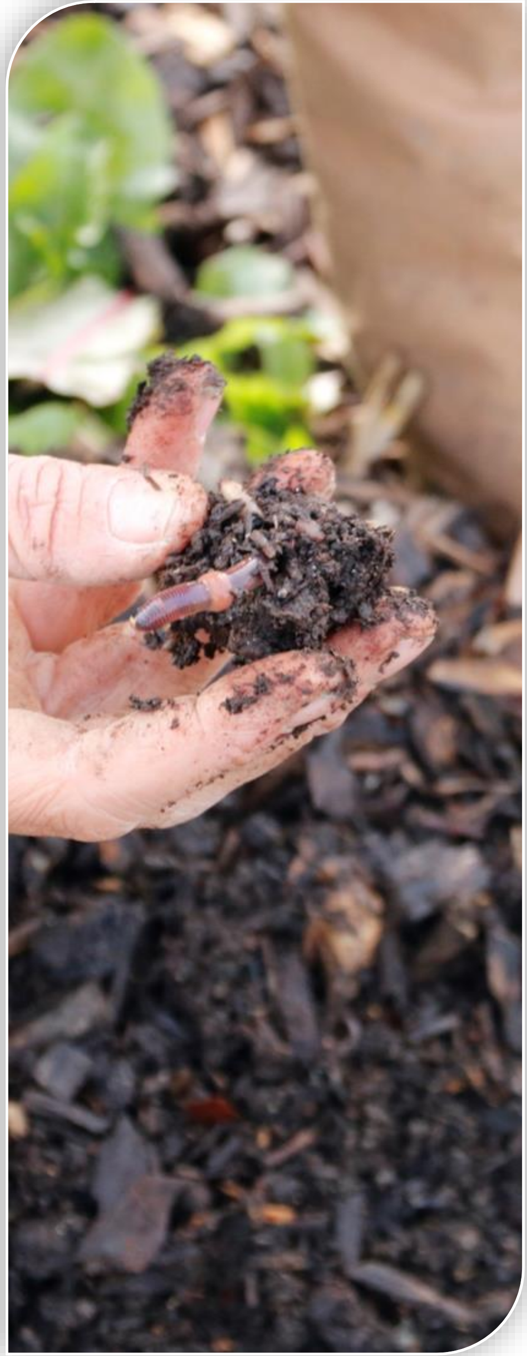


Ratio's	Optima	Grassdata from 1853 dairy farms in 2014 (DMS)	All 71 vegetables from the RIVM table. NEVO online, 2020.
Potassium/natrium	2–5 (max 7)/1	14,7	16,8
Potassium/magnesium	2–5 (max 7)/1	14,7	16,6
Calcium/Magnesium	1–2/1	2,3	3,2
Calcium/Phosphor	1–2 /1	1,3	1,3
Mg/(K+Na+Ca+P)	0.15–0.25; min. 0.10	0,05	0,043
K/(Ca+Mg) in mEq	< 2–2.2/1	1,9	1,73
nitrate	< 2.1–3.5 gram NO_3/kg ds	2,4	?
sulfur	< 2 á 3 gr/kg ds	3,5	?
NPN /N totaal	max 33%	46 %	?
Ammonium N plus nitrate N	Max 140 gram/day	216 gram/day	?
Potassium	max 20 (USA)	35,2	41



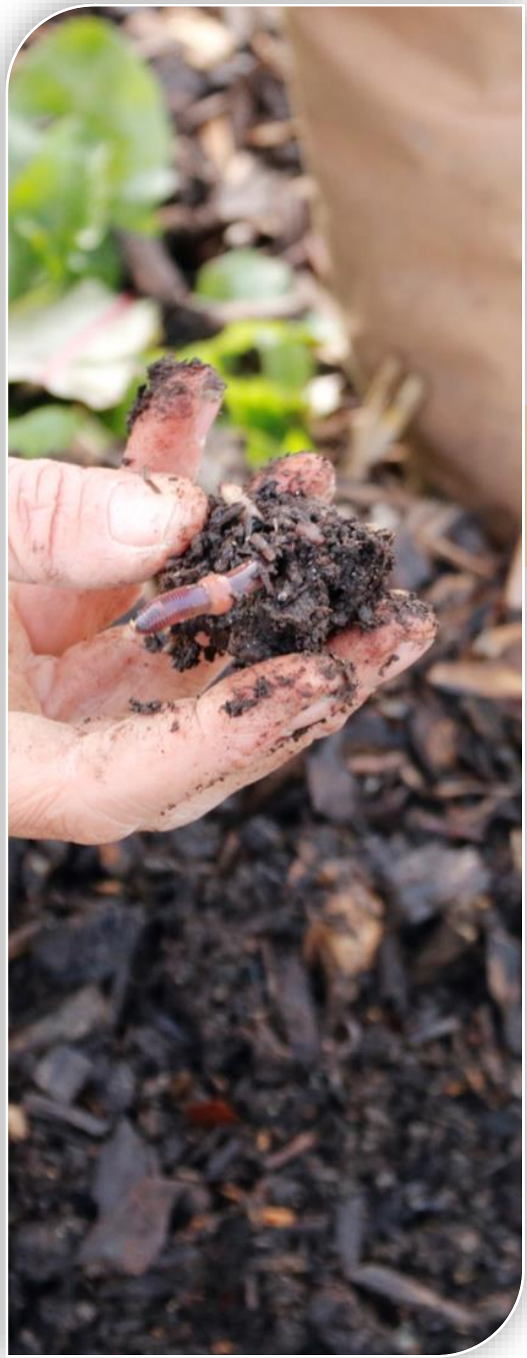
The effect of seaminerals and resp. volcanic stonemeal. Column 4 and 5.

Ratios	Optimal ratios for food for humans and animals per day (Nigten, 2017) NPN and NPS are missing.	Potato trial of the Louis Bolk institute. The average of 13 fertilizations (v/d Burgt, 2012). The Netherlands	Three potato varieties: Parmentier, Patraques and Vitelottes in Normandy (1864). The potatoes were fertilized with guano manure; seaweed; fish remains and manure (Wolff, 1871).				Potatoes in Pomerania, fertilized with rock meal (1890). Julius Hensel.
			Par	Pat	Vit	average	
K/Na	Optimum 2 – 5 /1	230	6	1.44	1.35	1,.95	12,2
K/Mg	Optimum 2 – 5 /1	25.5	9.61	10.5	11.6	10.36	1,8
Ca/Mg	Optimum 1 – 2 /1	0.77	0.72	0.91	2.6	1.29	2,3
Ca/P	Optimum 1 – 2 /1 (Max 3)	0.23	1.6	0.55	1.15	0.98	6,6
Mg/(Na+K+Ca+P)	0.15 – 0.25 (min 0,10)	0.033	0.08	0.049	0.04	0.054	0,21



Ideal ratios	71 Dutch vegetables 2020 (RIVM)	Ten vegetables from South West Nigeria (Adebisi, 2009).	Three vegetables from south West Nigeria. Sobowale ea. 2011. Mg/100 gram
K/Na: 2 - 5	16,8	1,15	3,35
K/Mg: 2 - 5	16,7	1,72	2,85
Ca/Mg: 2 - 1	3,3	0,94	1,1
Ca/P: 2 - 1	1,3	0,8	1,18
Mg/(K+Na+Ca+P): 0,15 – 0,25. Min. 0,10	0,048	0,19	0,17

Presumably in Nigeria it is a volcanic soil of basalt. However, I have not been able to verify it. Most farmers over there do not use fertilizers.



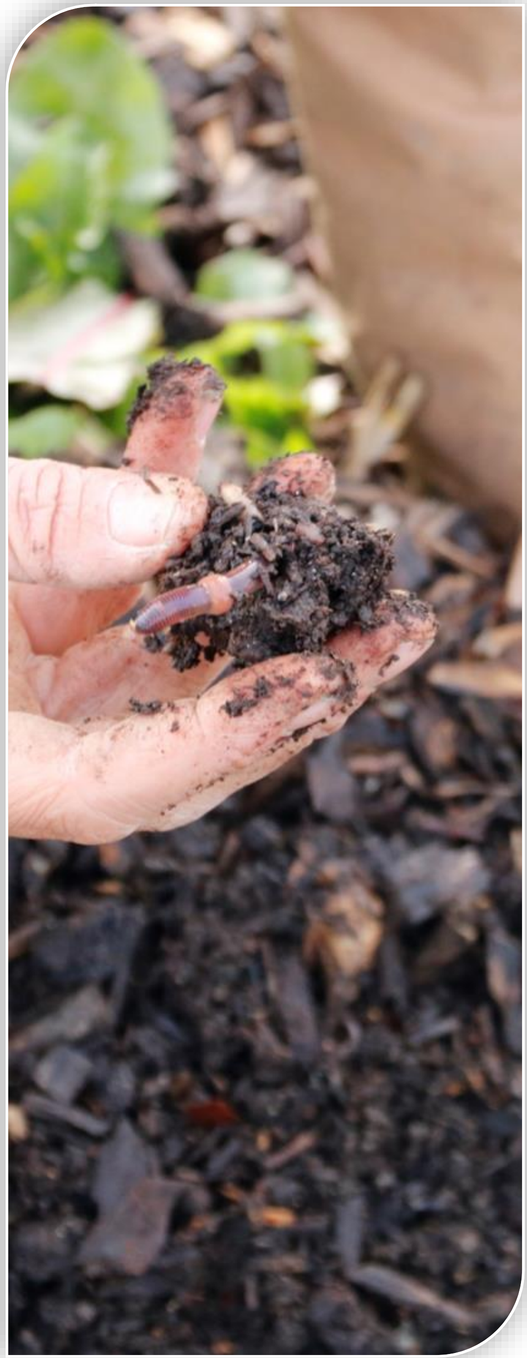
In the past, attention has been given to the risks of nitrate in food.

That attention has faded and the food authorities have declared nitrate harmless (2014).

And only in the last decade there has been done serious research into the risks of too much
phosphorus in our food.

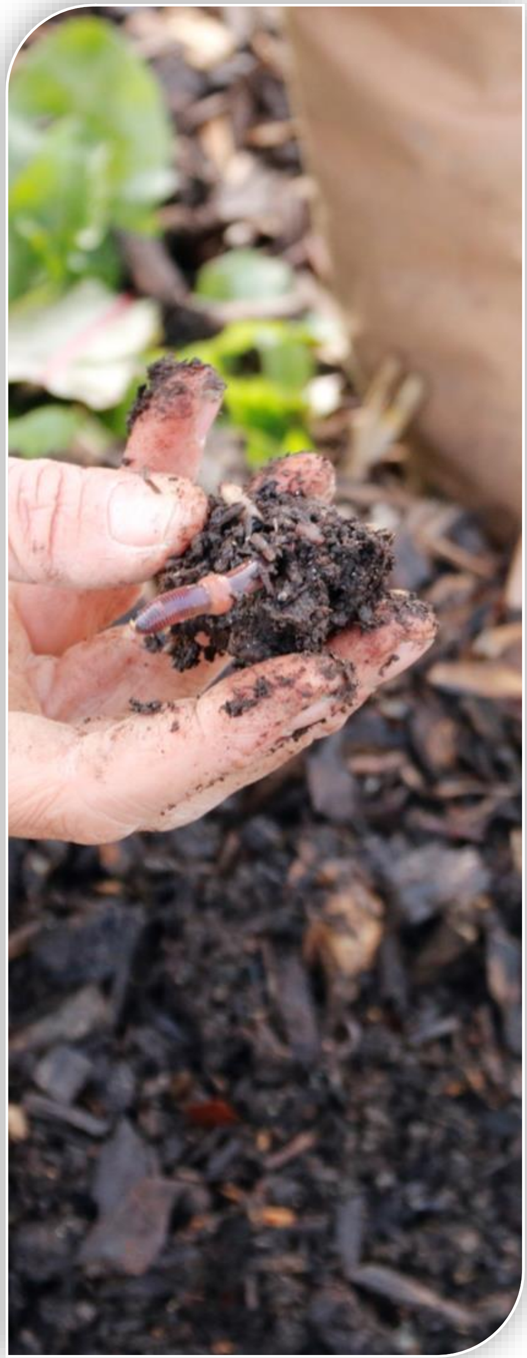
Calcification almost always involves calcium phosphate. And the mechanism is also clear:
because our food contains too many phosphates, calcium is extracted from the bones to
neutralize these phosphates. Just like nitrate is neutralized by sodium.

Because there is too little magnesium in our food, the calcium phosphates accumulate in
the most unlikely places in the body. It would therefore be better to talk about phosphatisation
rather than calcification.



The proven health damage of too much phosphorus is as follows:

- It leads to soft tissue calcification and at the same time weakening of bones and teeth;
- Too much phosphate encourages skin cancer; lung cancer, breast cancer; kidney cancer and prostate cancer .
- Calcification (= phosphatisation) of the heart muscle can result in heart failure;
- Calcification of the kidneys leads to kidney stones and kidney failure;
- Too much phosphate causes obesity; gingivitis; tissue damage; cell death; and mitochondrial oxidative stress;



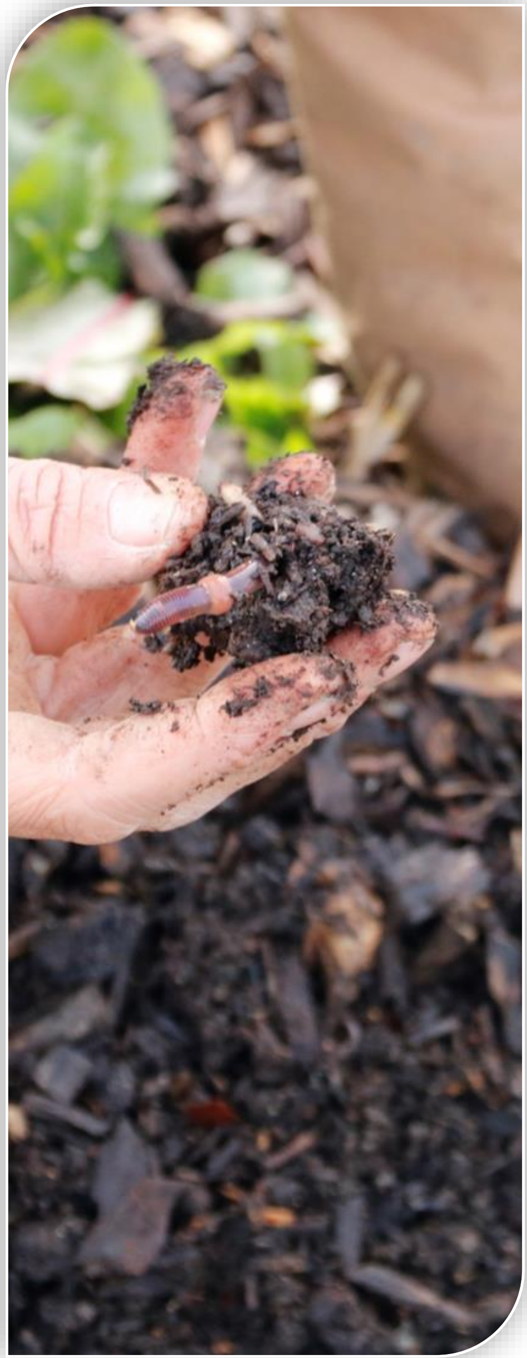
Between 1880 and 1910, the phosphate war raged in Great Britain – the battle of the phosphates.

Jamieson and his team had shown that superphosphate, in contrast to rock phosphate, led to clubroot formation in turnips. This was disputed by Lawes.

Potassium.

In the thirties of the 20th century, more and more cows suffered from head disease (grass tetany), partly due to too much potassium.

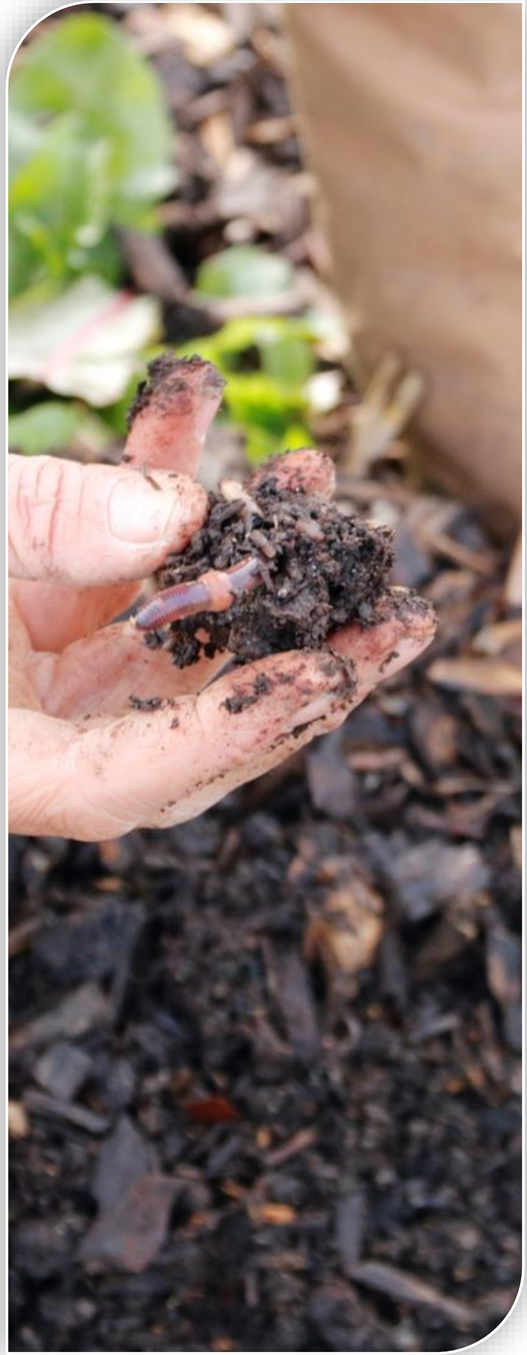
In 1933 Theel found in Germany that potassium, sulfur and chlorine in the hay had almost doubled compared to 1870. The levels of potassium in our fruit and vegetables and potatoes are still extremely high and sodium and magnesium far too low.



Conclusions:

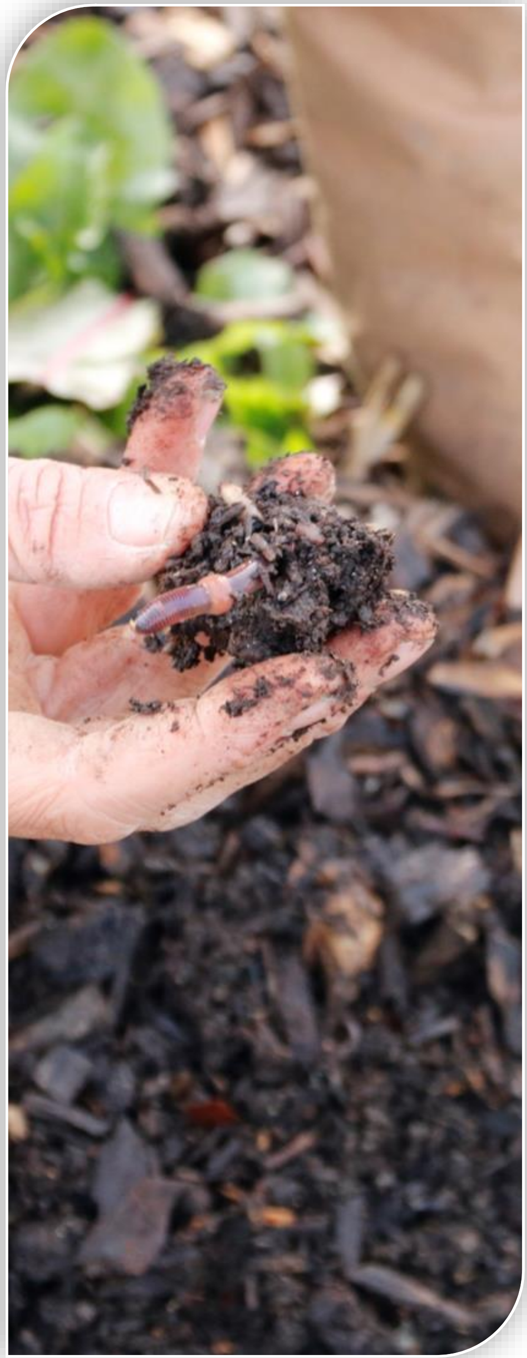
1. Our cow feed is measured much more thoroughly than human food;
2. But the standards for cow feed are often being disregarded;
3. The Dutch potatoes – conventional and organic – and the Dutch vegetables are not in balance;
4. The vegetables in South West Nigeria are often much better balanced;
5. Sea minerals, worm compost and rock meal can help restore balance. And soil in the manure helps too;
6. Phosphates are not only a problem for nature (algae growth), but also for people;
7. As with nitrogen, phosphate and sulfur must also be measured in what form we ingest it and how much;

NPK – the magic formula of modern agriculture – not only causes great damage to agriculture and nature, but also to people and animals that eat NPK-food. We get all three elements in too much and partly in the wrong form. We don't get enough other macro elements and trace elements.

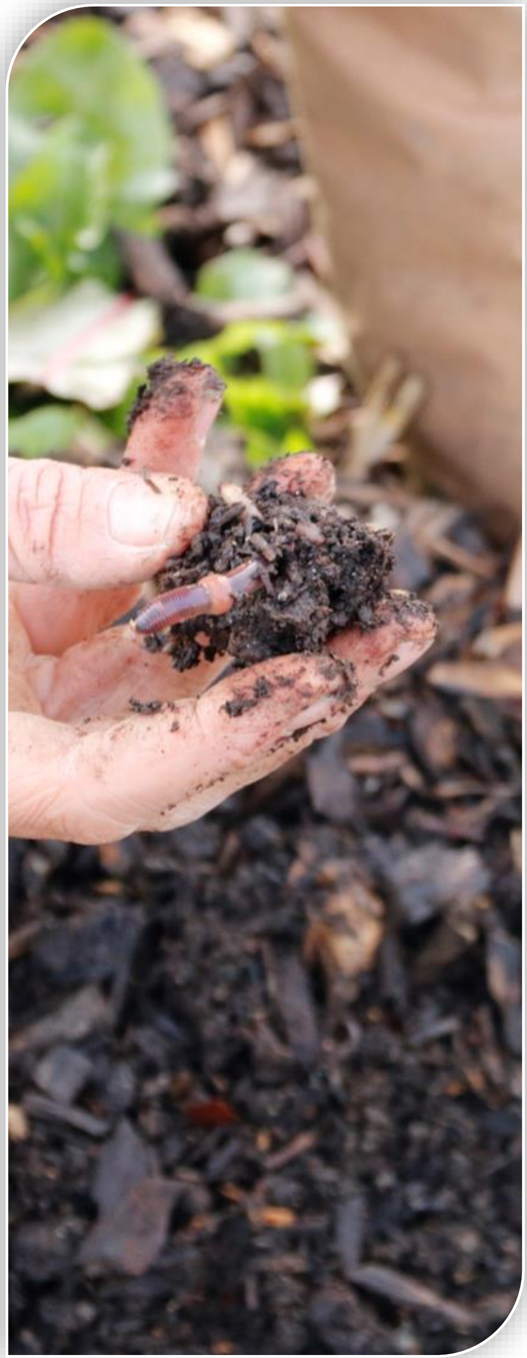


Annex:	Ten vegetables from South West Nigeria: Adebishi 2009.			
Average Mineral content mg/100 gram air dried products	All vegetables Average protein 4,65 gr/100 gram	Low protein vegetables < 3 gr/100 gram: 3 x (adebishi 2009) average: 2,5	Low protein vegetables < 4,5 gr/100 gram: 4 x (adebishi 2009) average: 2,97	High protein vegetables > 4,5 gr/100 gr : 6 x (adebishi 2009) Average: 5,7
Na	3,82	3,31	3,28	4,18
K	4,41	3,15	3,89	4,75
Ca	2,41	2	2,9	2,08
Mg	2,55	1,67	1,99	4,38
P	3,02	2,34	2,28	3,51
sum	16,21	12,47	14,34	18,9
Ash content	1,87	1,43	1,47	2,13

You see a shift in mineral composition: more sodium, potassium, magnesium and phosphorus in crops with a high protein content (right column). Calcium varies. Magnesium in high protein crops is sky high. Ash content and sum increase.

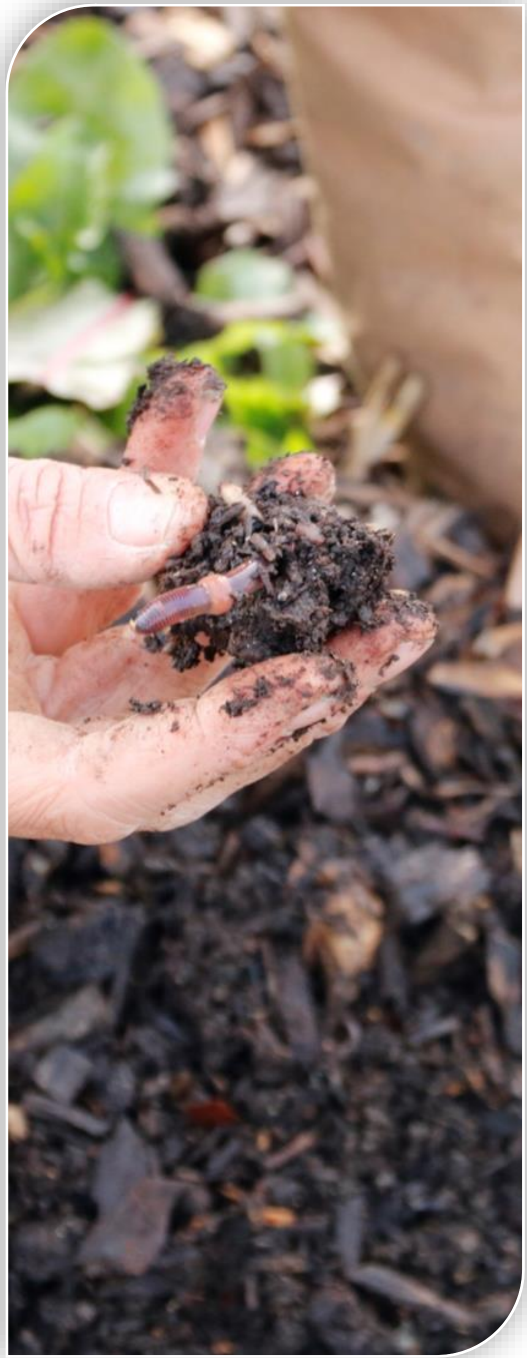


Questions?



Mechanisms of soil health restoration in regenerative agriculture

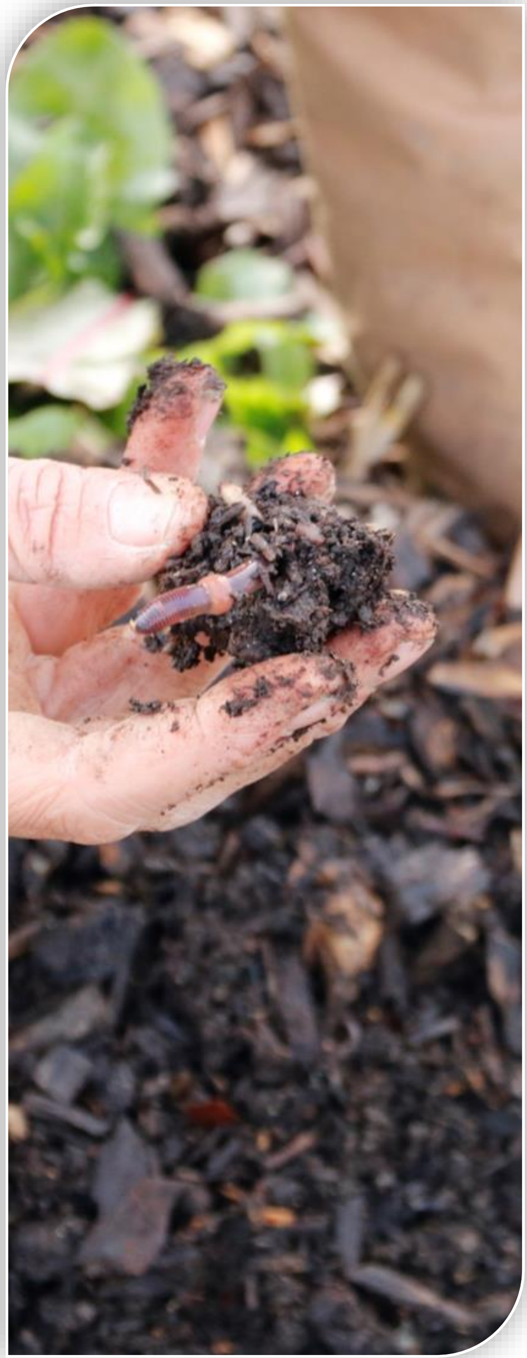
Kris Nichols



The Carbon Key

Physical Biogeochemistry Soil Regeneration

Dr. Kris Nichols
Food Water Wellness Foundation
MyLand Company LLC

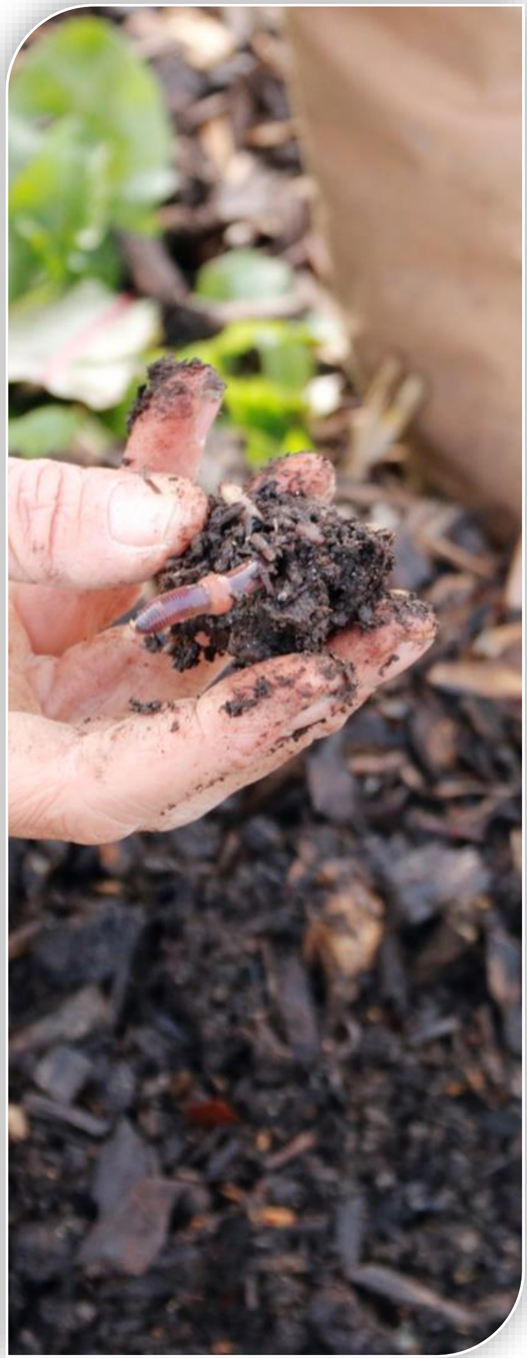


REGENERATIVE AGRICULTURE:

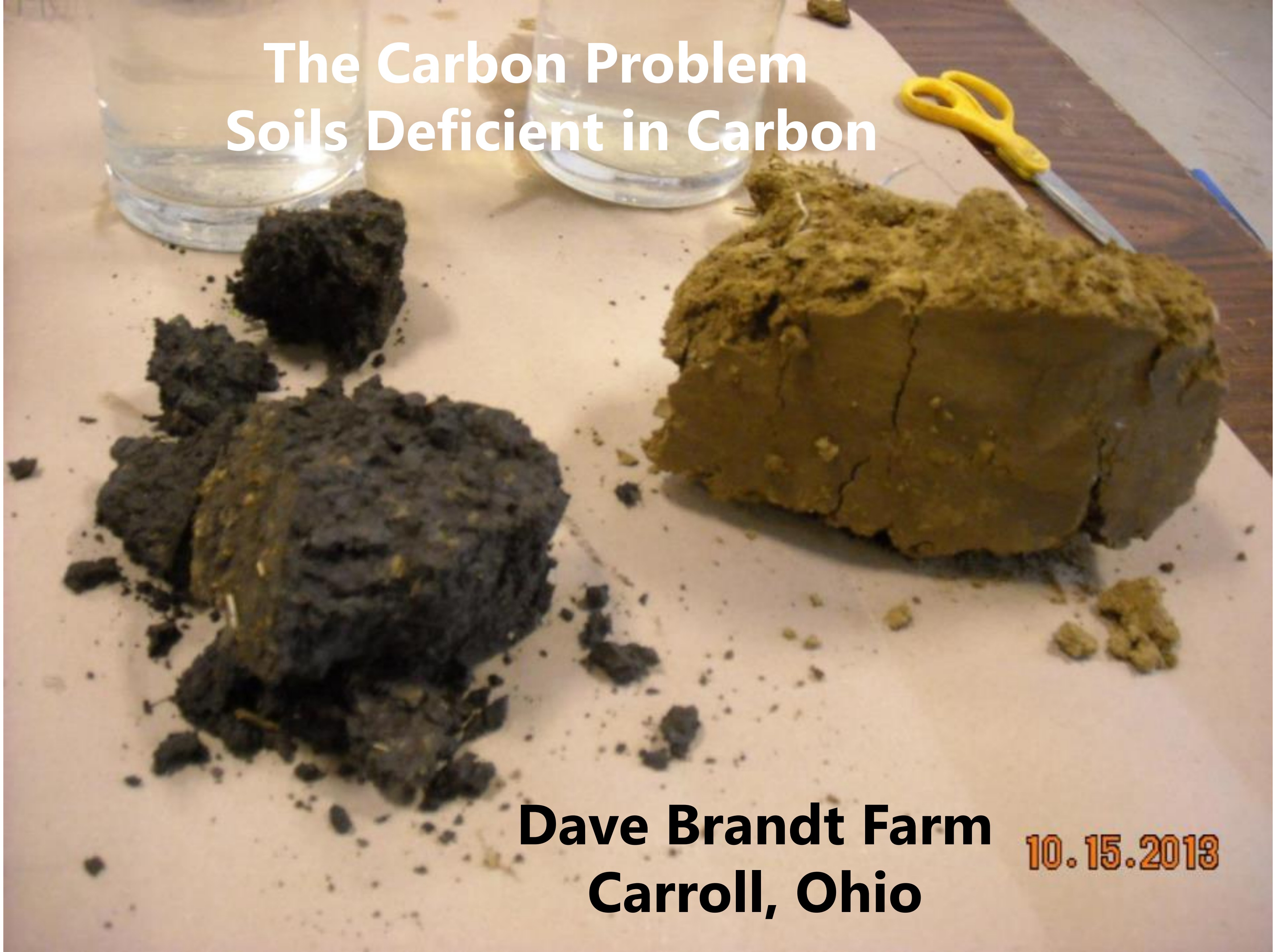
- **Systems Approach**
- **Dynamic, Innovative, Integrated, Intensive**
- **Photosynthesis – Carbon Flow/Costs**

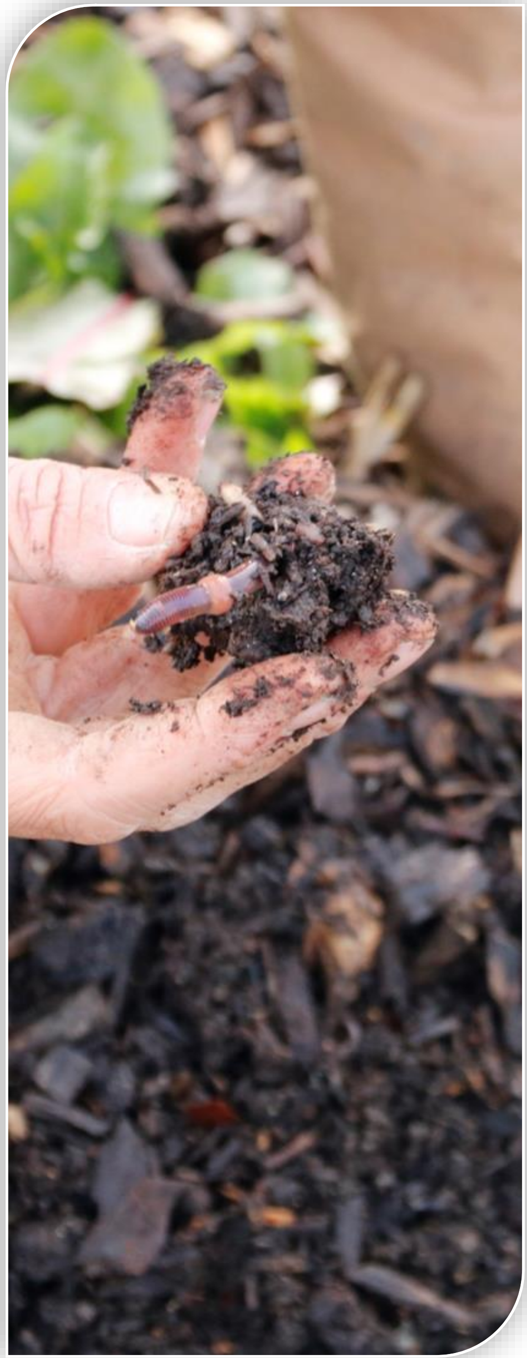
Photosynthesis – most efficient form of solar energy conversion to chemical energy in the bonds between carbon atoms or carbon atoms and other atoms.

Regenerating soils



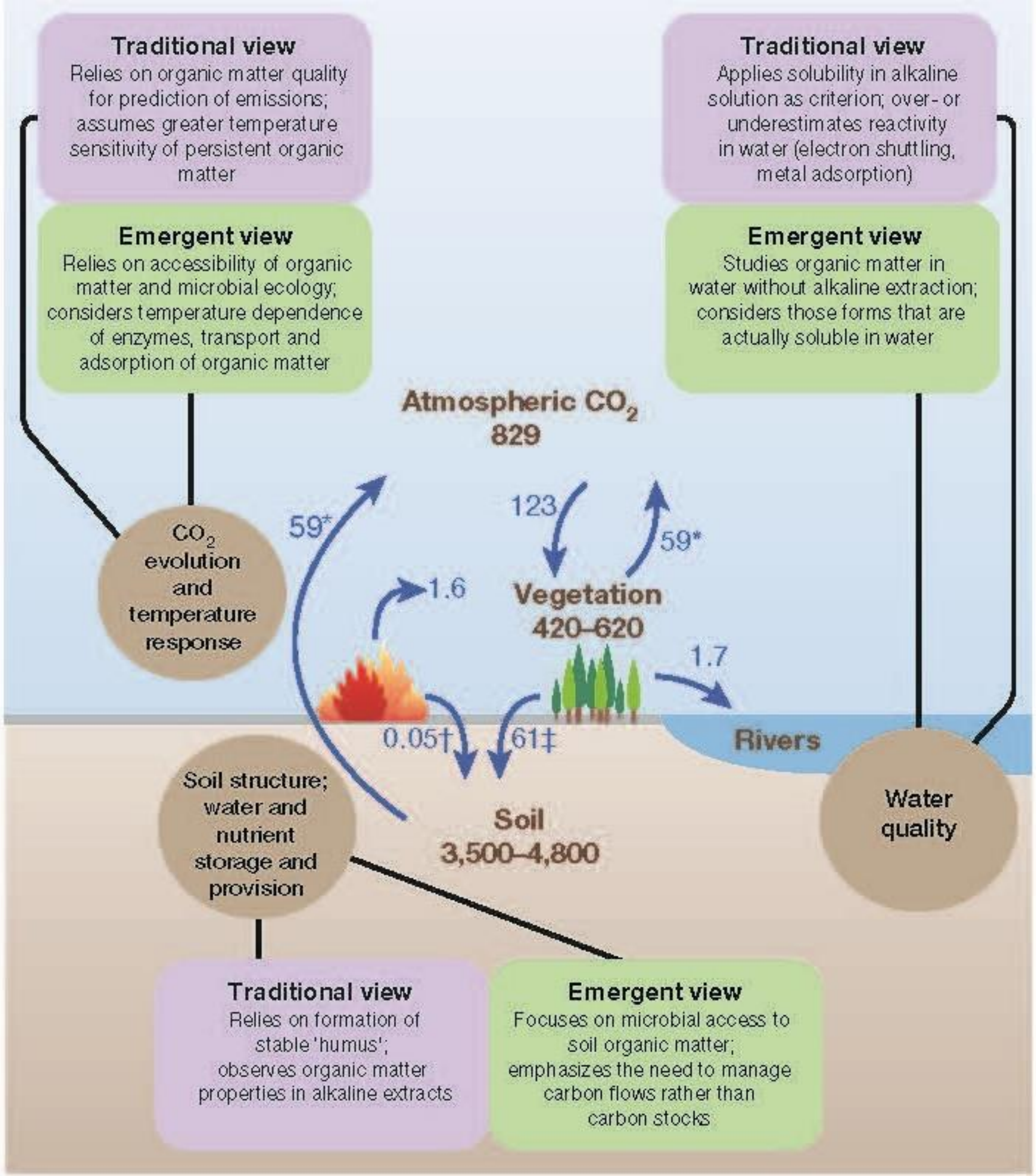
- Soil – Carbon, Hydrogen and Oxygen (Organic Matter) + Sand, Silt and Clay


The Carbon Problem
Soils Deficient in Carbon
Dave Brandt Farm
Carroll, Ohio
10.15.2013

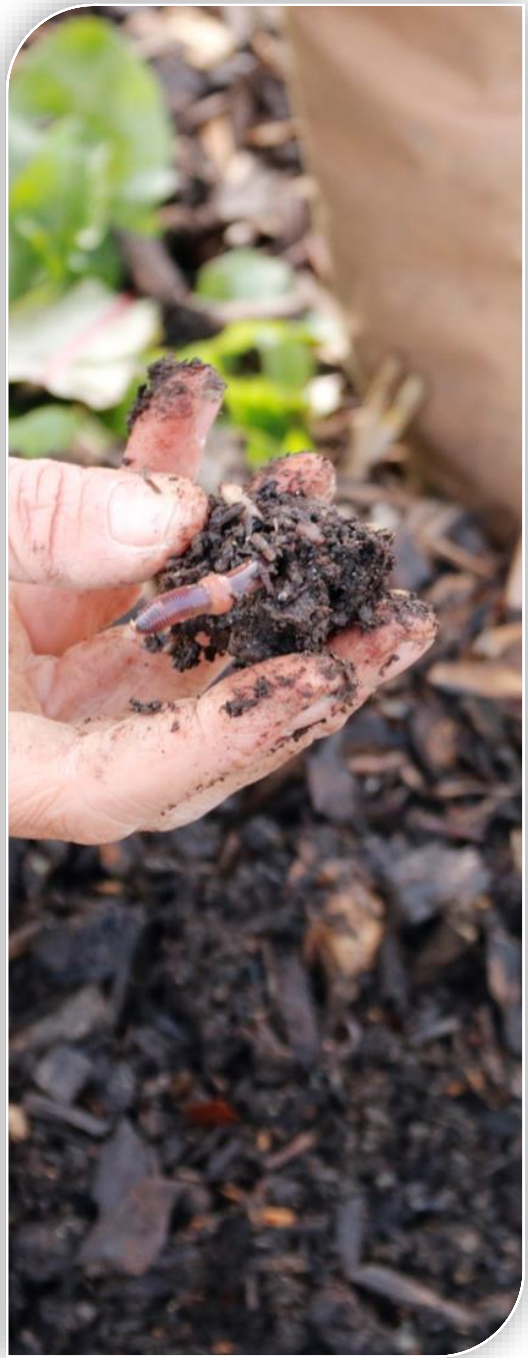


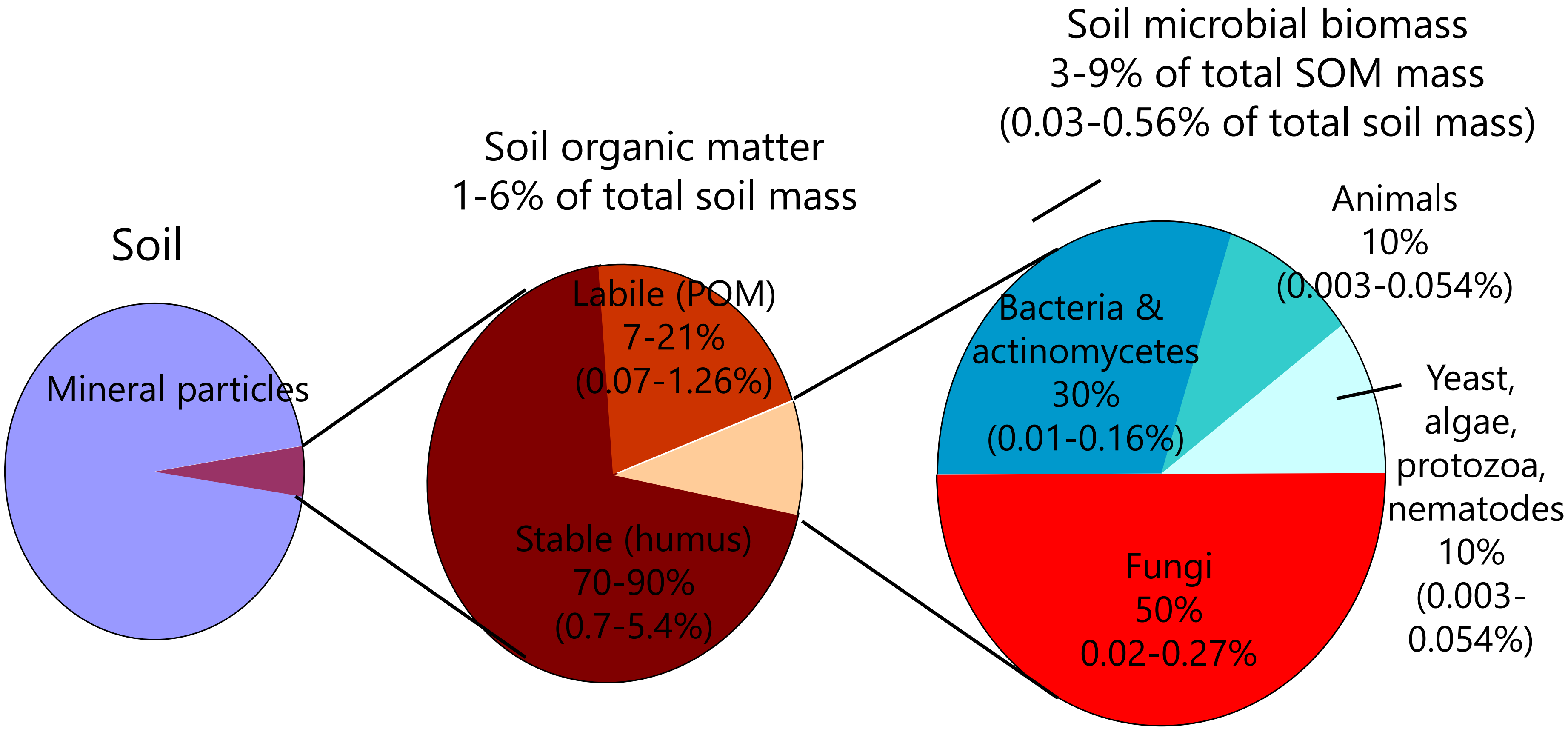
Emerging view of SOM supports Regenerative Ag – We can build SOM in our lifetime!

Lehmann and Kebbler, 2015

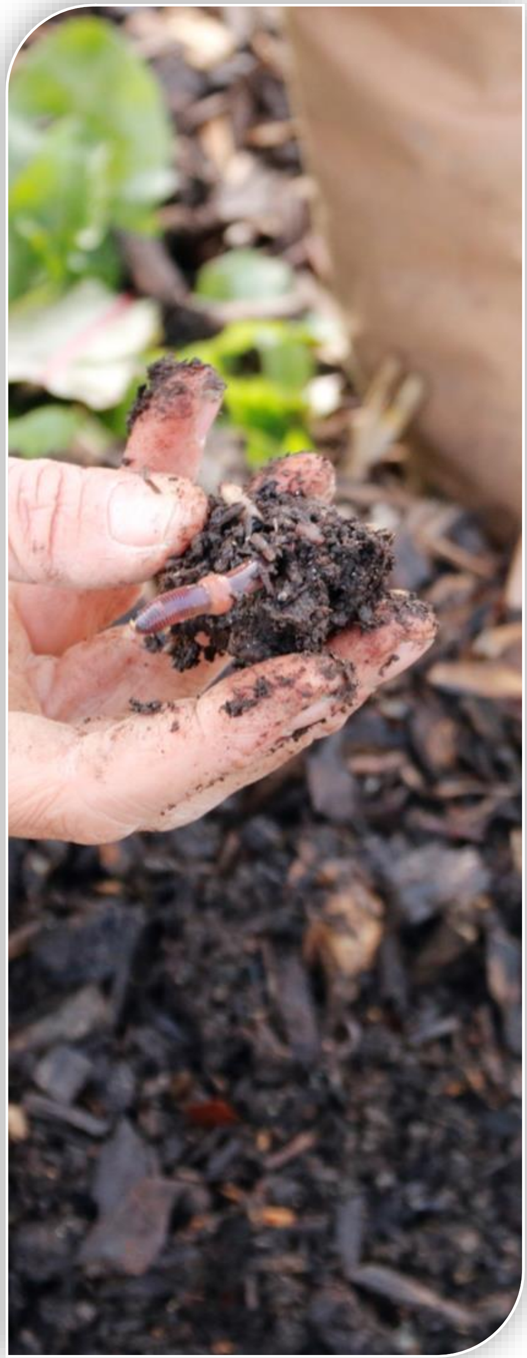


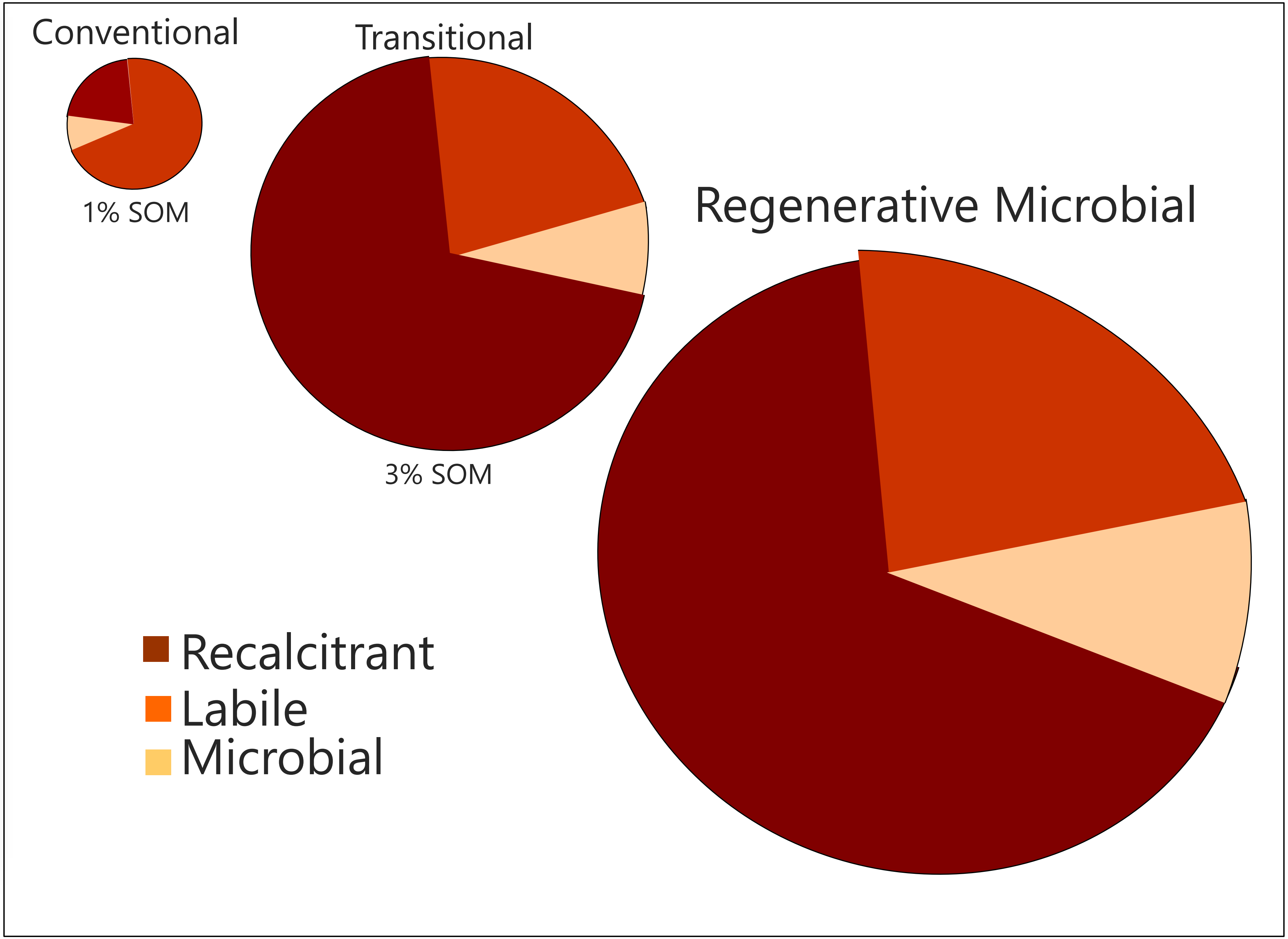
Soil Organic Matter Composition

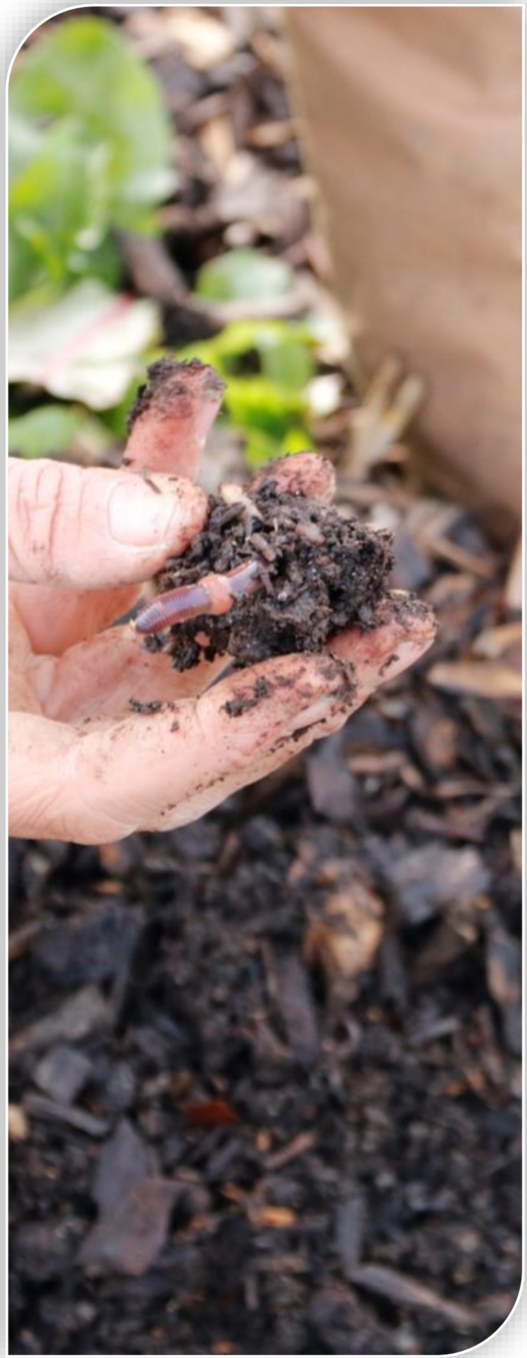


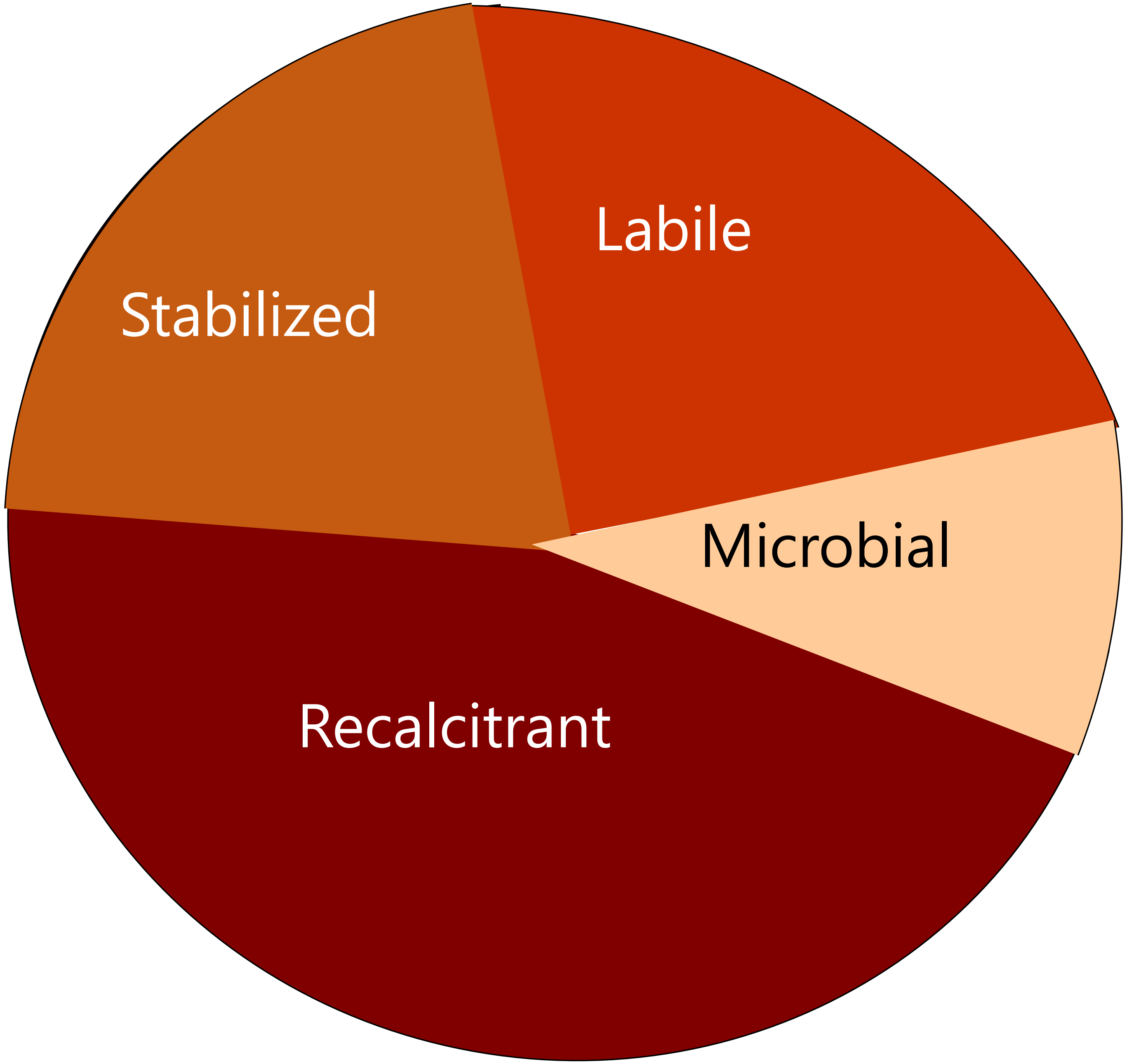


- Modified from Building Soils for Better Crops, Magdoff and van Es, 2000

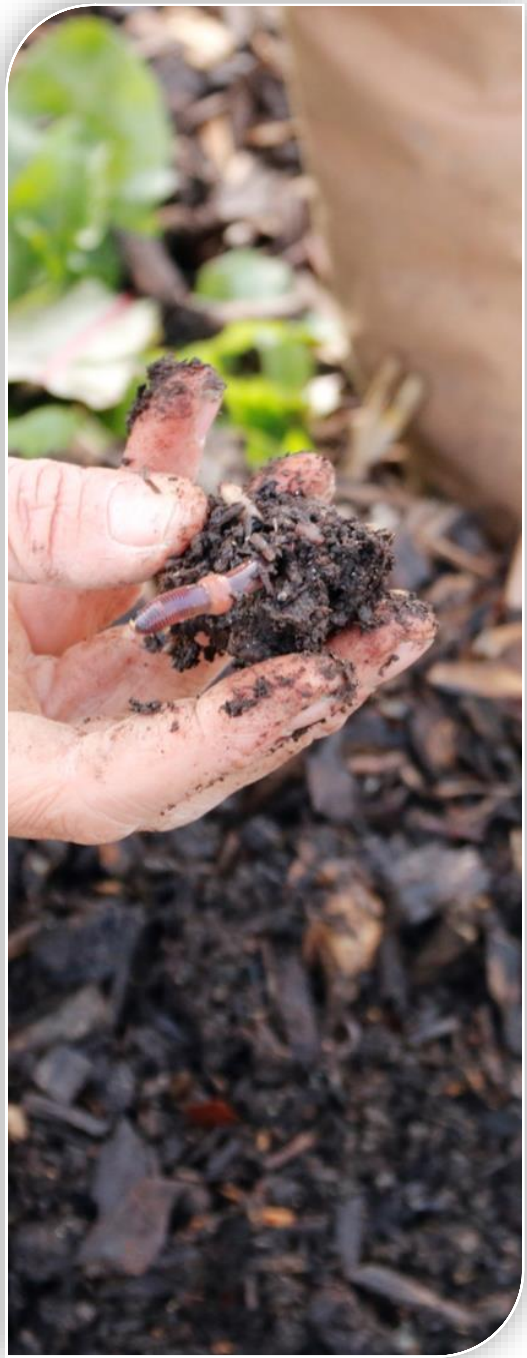



Conventional
1% SOM
Transitional
3% SOM
Regenerative Microbial
Recalcitrant
Labile
Microbial



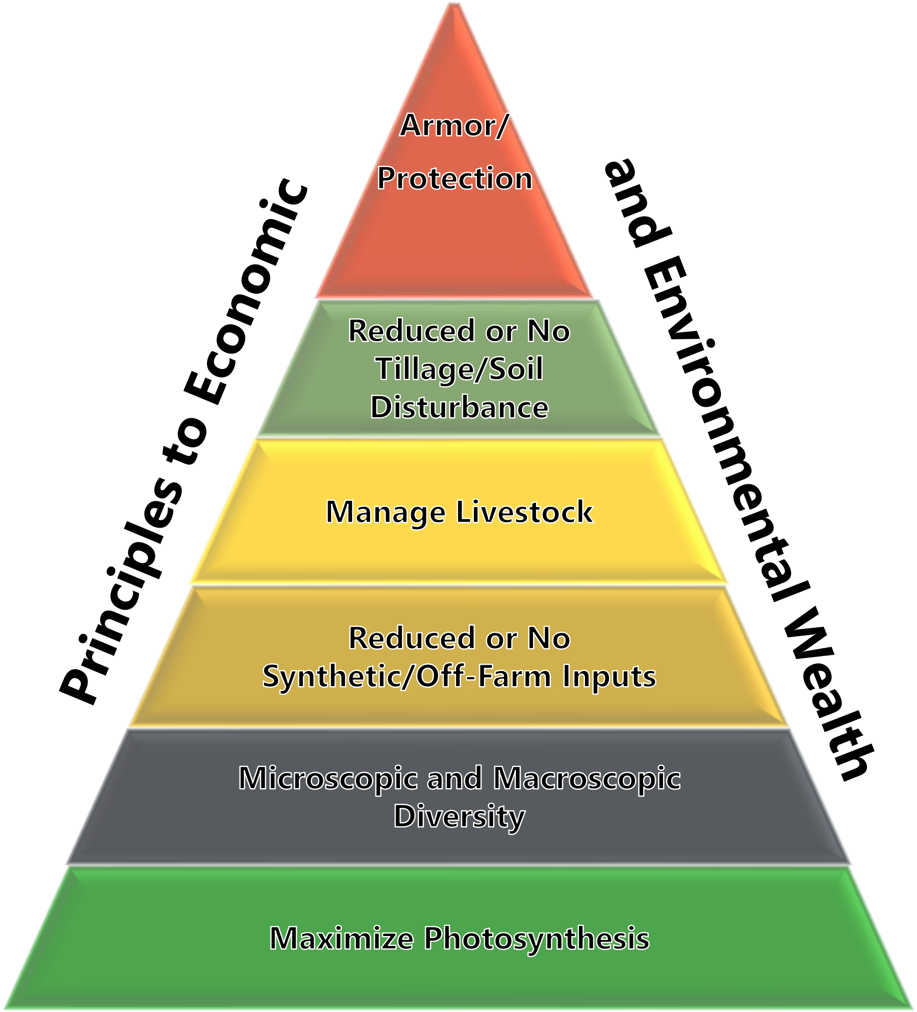

Labile
Stabilized
Microbial
Recalcitrant

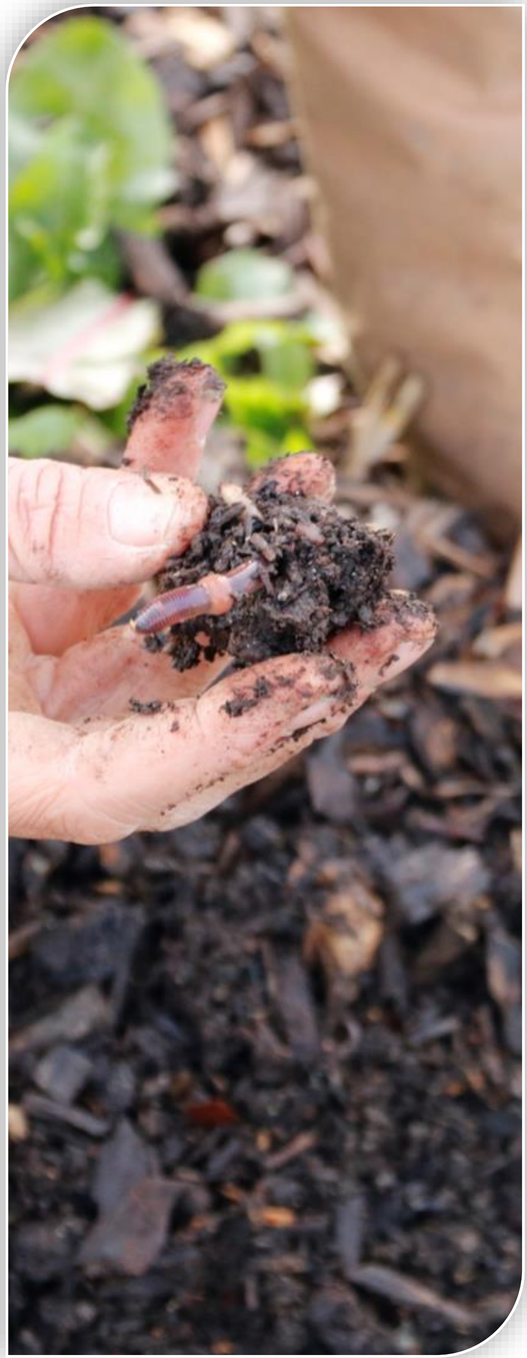
BROWN REVOLUTION

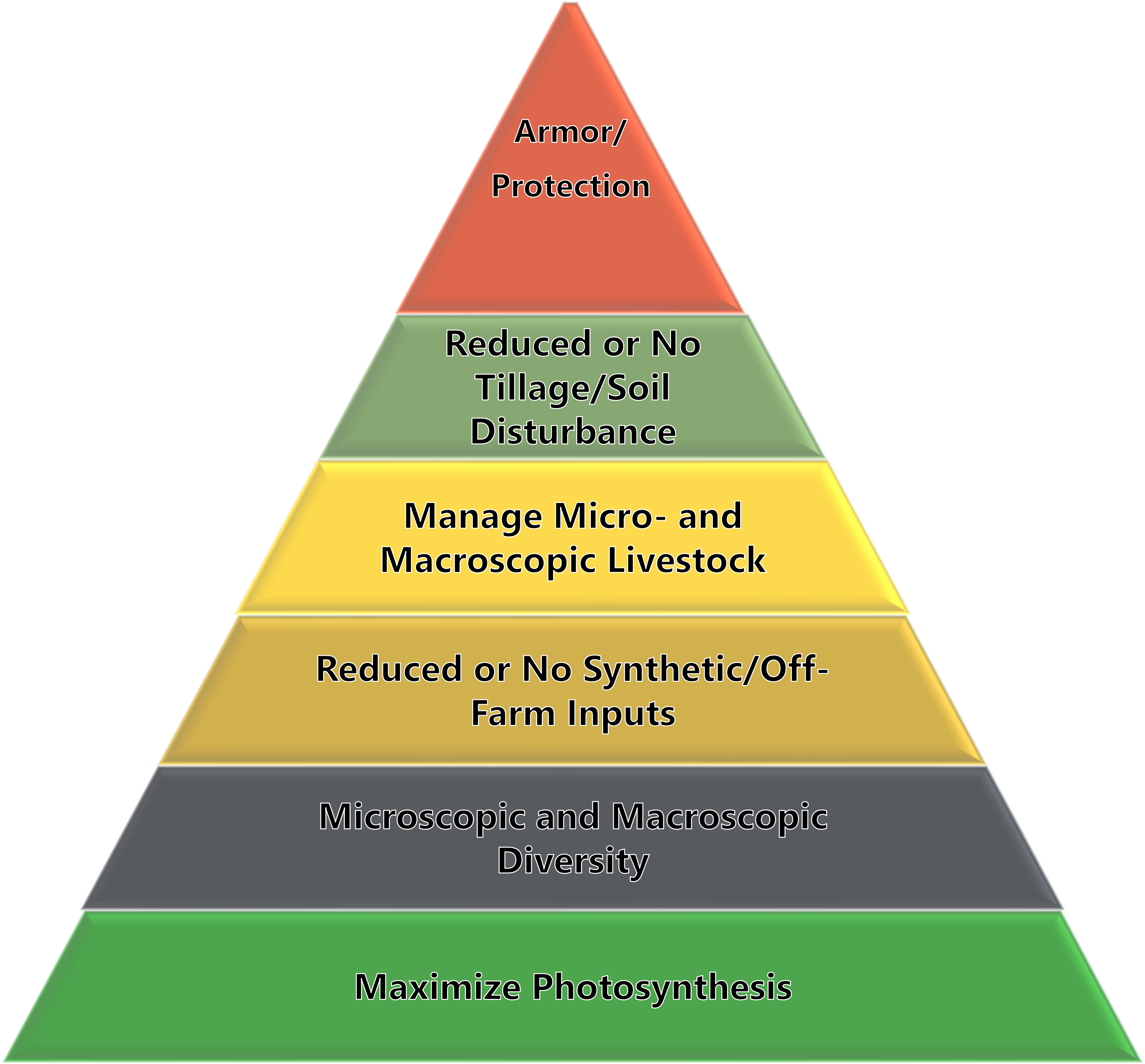


Eco-Functional Intensification

- Optimize landscape use
- Maximize efficiencies
- Not more but less
- Multiple enterprises
- Everything costs
- Redistribute risk
- Nutrient density

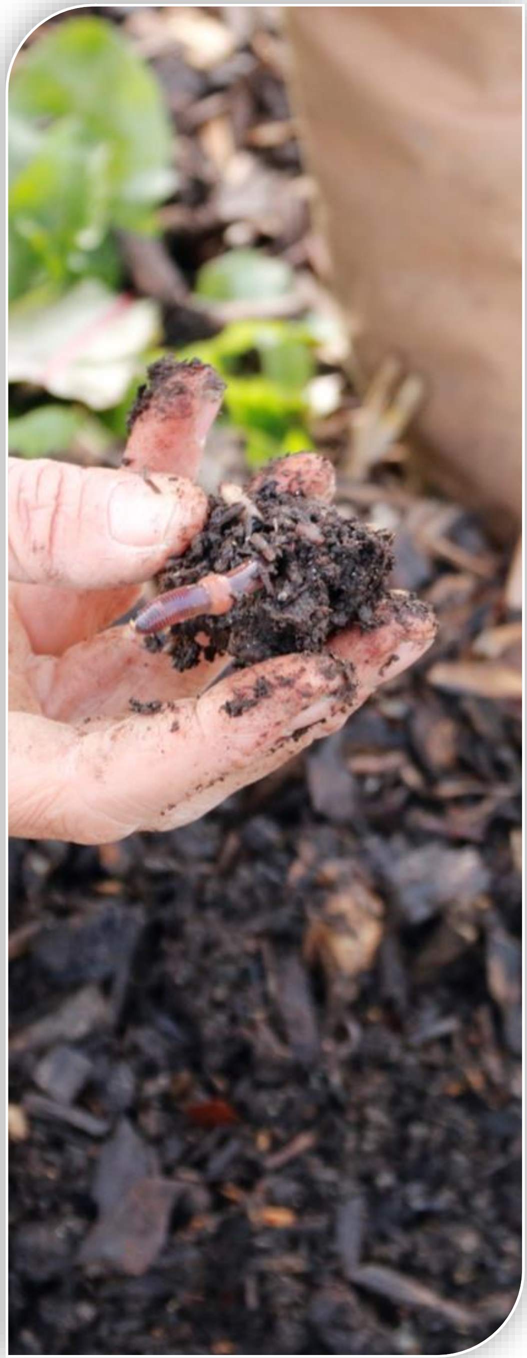





Armor/
Protection
Reduced or No Tillage/Soil Disturbance
Manage Micro- and Macroscopic Livestock
Reduced or No Synthetic/Off-Farm Inputs
Microscopic and Macroscopic Diversity
Maximize Photosynthesis

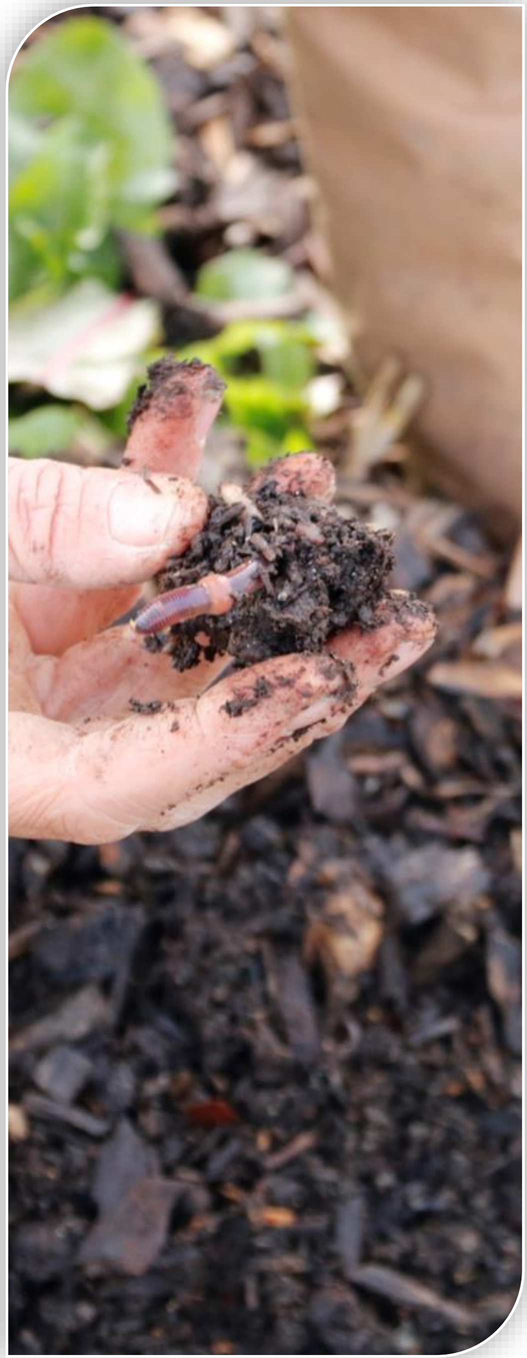
F I S T

System Not Tools and Practices



F – Frequency
I – Intensity
S – Scale
T – Timing

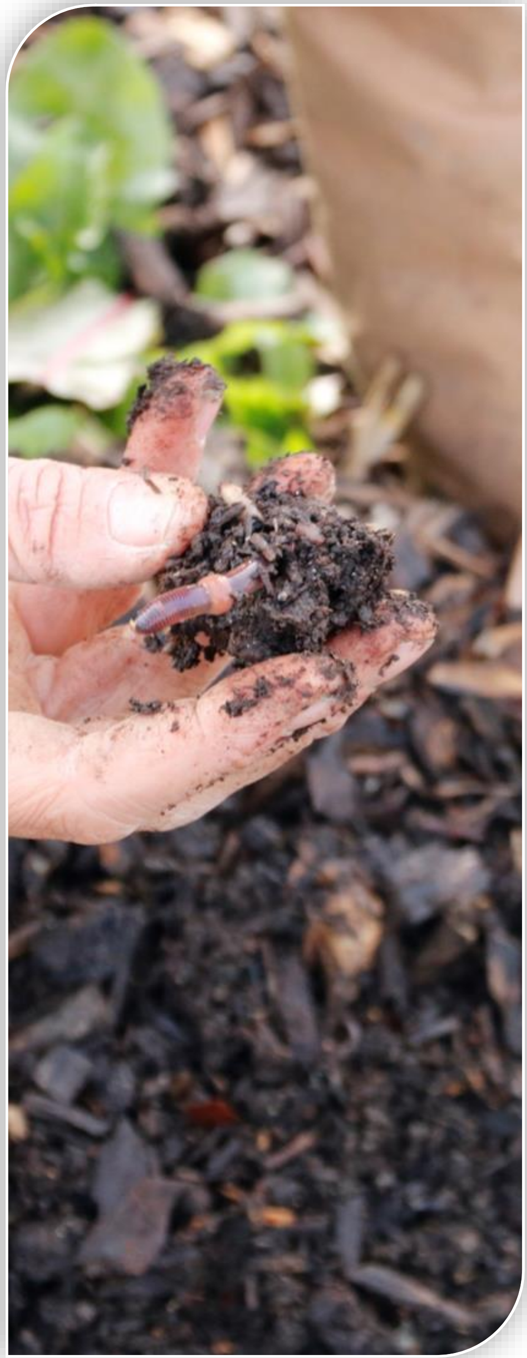
Nutrients
Tillage
Grazing
Nitrogen
Diversity
Phosphorus
Pesticides
Crops



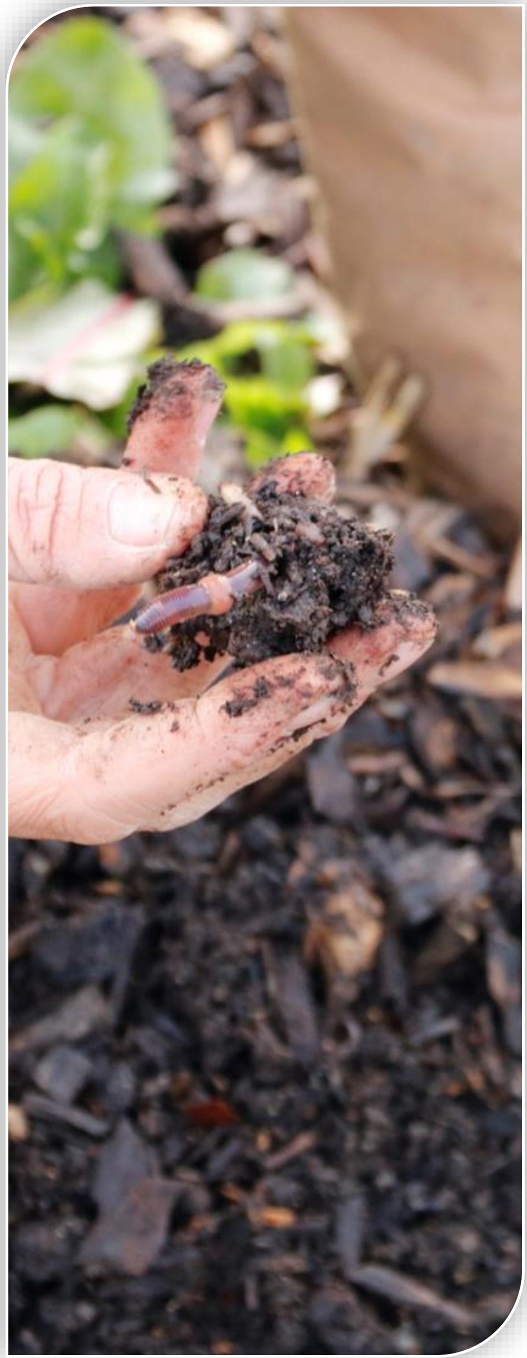
F I S T Matrix

Five Whys

Issue	**Perennial Weeds**			
Tool Choice	**Deep Tillage**			
Trade-Offs/ Carbonomics	Frequency (number of times tool is used in a season)	Intensity (amount of force to be effective)	Scale (total volume of soil impacted)	Timing (when is most effective)
Positives				
Negatives				



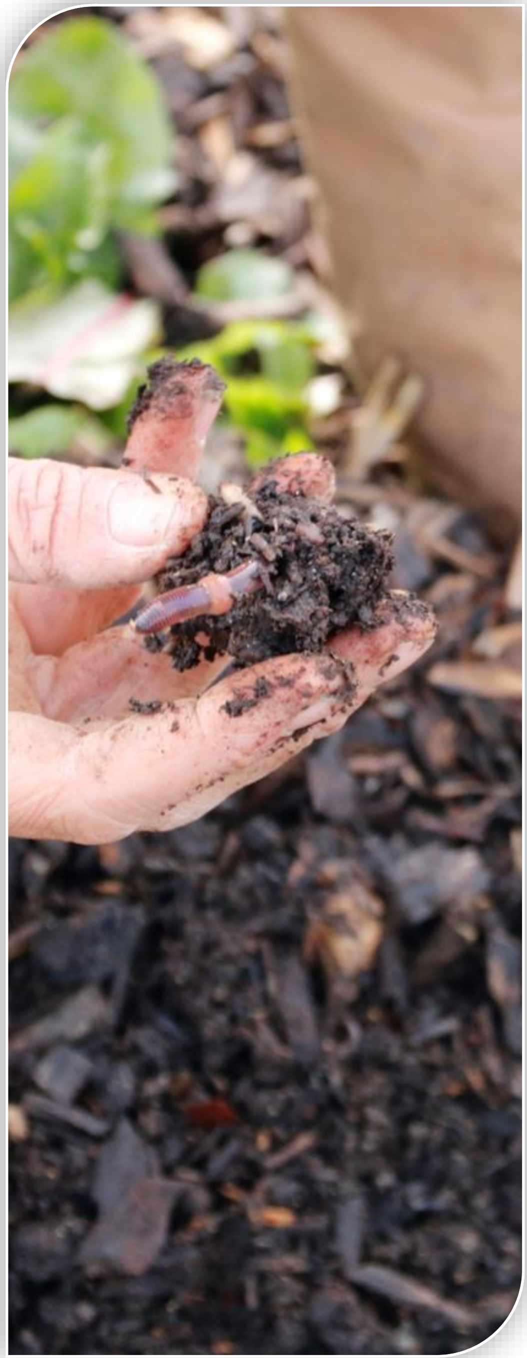
Issue	**Perennial Weeds**			
Tool Choice	**Deep Tillage**			
Trade-Offs/ Carbonomics	**Frequency**	**Intensity**	**Scale**	**Timing**
Positives	Prevents several in-season tillage passes; Prevents herbicide use; Fiscal costs are limited to equipment, fuel, and labor	Choosing an implement and tractor speed to be effective and not very destructive	Effective weed termination with deep tillage	Perennial weeds most impacted at weakest growth times; Labor needs at a low stress time
Negatives	Tillage may destroy aggregates and rip apart fungal hyphae; Multiple passes needed to be effective	Implement or speed needed for weed termination may be destructive to soil physical structure and biology	Deep tillage may more destructive; Although the implement being used goes deep into the soil is the volume of soil impacted more or less than a surface shredding such as rototilling	Impacts microbes if done at high growth periods



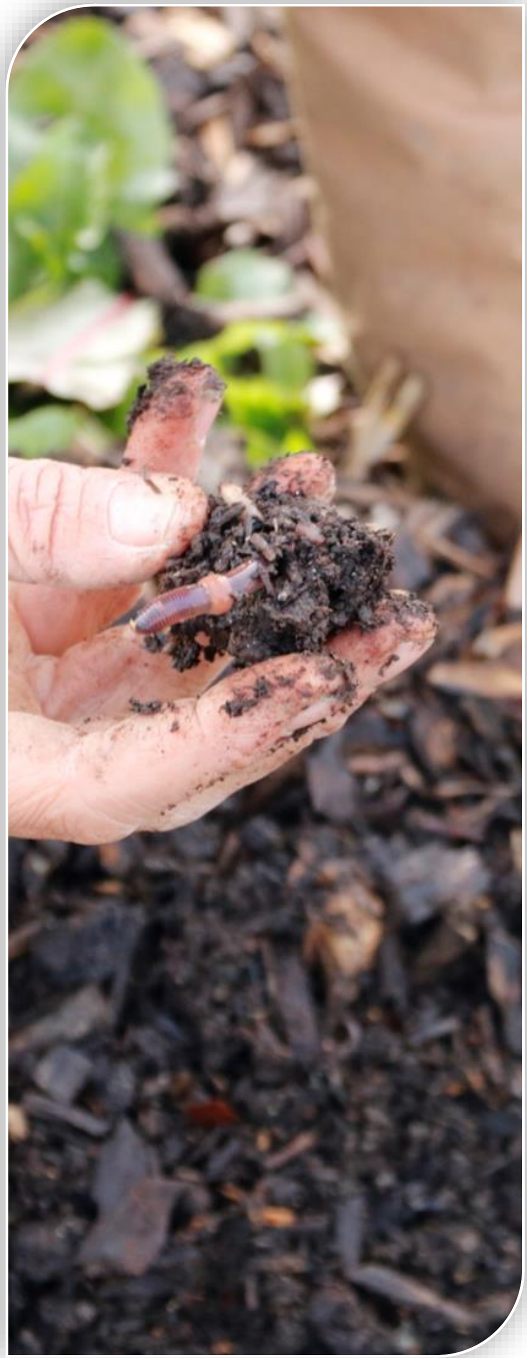
Issue — **Perennial Weeds**

Tool Choice — **Herbicide(s)**

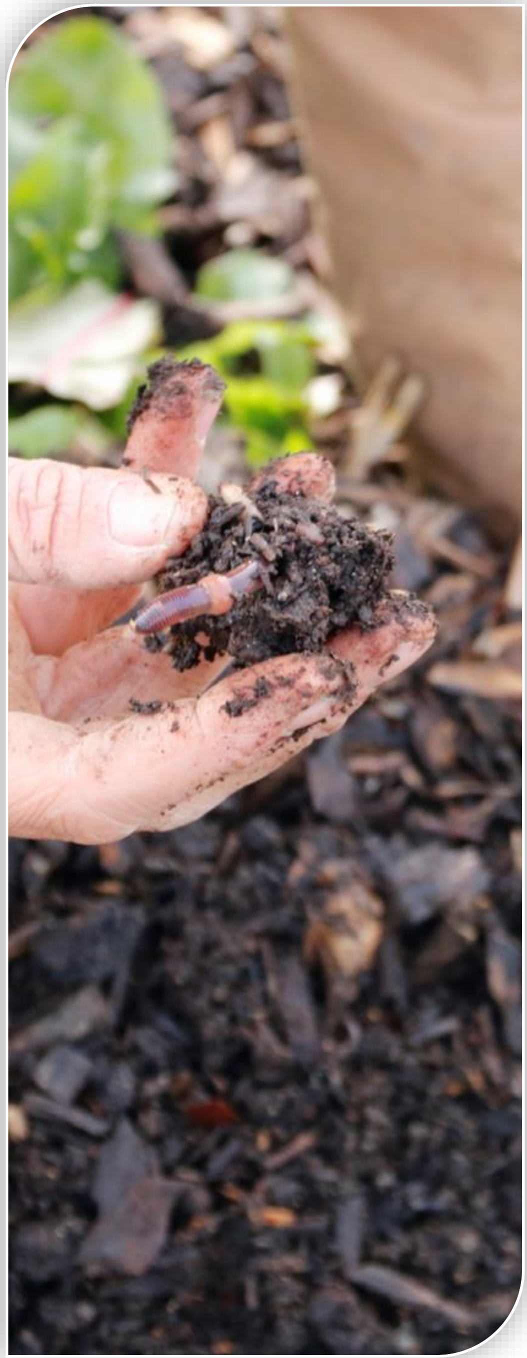
Trade-Offs/ Carbonomics	Frequency	Intensity	Scale	Timing
Positives	Prevents the use of tillage and/or herbicides		New application tools, chemistry, and genetics may reduce the amount needed	When most effective
Negatives	Fiscal costs compared to other tools; Efficacy may be limited and require increased frequency of use or additional tools	May negatively impact soil biology and physical structure	New chemicals or chemical combinations may be needed	Impacts on cash crops, labor, expenses, and soil biology and physical structure



Issue	**Perennial Weeds**			
Tool Choice	**Poly-, Inter-, Companion, or Cover Cropping**			
Trade-Offs/ Carbonomics	**Frequency**	**Intensity**	**Scale**	**Timing**
Positives	Prevents the use of tillage and/or herbicides	Crop choice may provide benefits - enhance nutrient cycling and soil physical, chemical, and biological activity for cash crop	Rooting depth and architecture may be positive; Leaf size and architecture needs to be a part of plant selection	When most effective
Negatives	Fiscal costs include seeds and field operations – planting; Efficacy may be limited and require increased frequency of use	Crop choice may have negative impacts on nutrient cycling soil and/or cash crop – too much nitrogen in the system, compaction, water use, etc.	Rooting depth and architecture may negatively impact water use and chemistry; Leaf shading is a concern	Impacts on cash crops, labor, and expenses



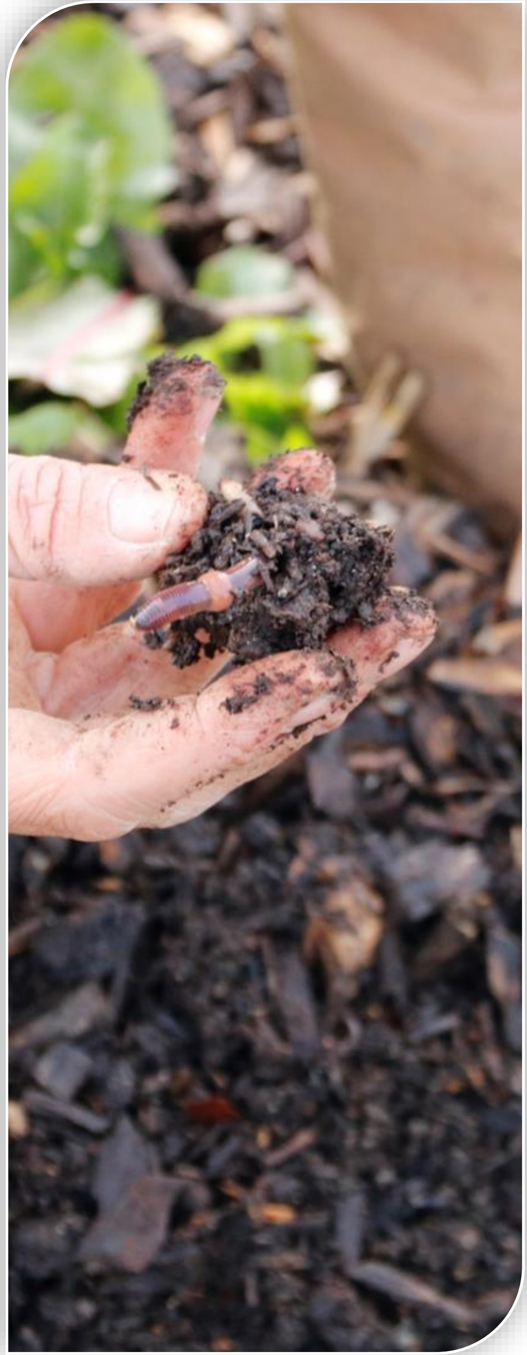
Issue	**Perennial Weeds**			
Tool Choice	**Grazing/ Haying/ Mowing – Plant Biomass Removal**			
Trade-Offs/ Carbonomics	**Frequency**	**Intensity**	**Scale**	**Timing**
Positives	Prevents the use of tillage and/or herbicides; Provides another potential income source; May add nutrients	Potential nutrient source; Add carbon; May alter soil temperatures	Potential nutrient source; May increase rooting depth; Add carbon; May improve soil compaction	Flexible timing may help with nutrients and water use
Negatives	May export some carbon and nutrients; Efficacy may be limited	Animal choice, animal units, and/or grazing days may be destructive; Mowing implements impact carbon flows	May cause surface compaction	Impacts on labor, expenses – animals, fencing, water, and labor; and soil biology and physical structure



F I S T

Recovery Plan/ Recarbonization

Issue	**Perennial Weeds**			
Tool Choice	**Herbicide(s)**			
Trade-Offs/ Carbonomics	**Tillage**	**Herbicides**	**Cropping**	**Grazing**
Recovery Plan/ Recarbonization/ Chaos	Offset soil carbon and soil structure losses and negative impacts on microbial community via cropping and/or grazing	Offset soil carbon and soil structure losses and negative impacts on microbial community via cropping and/or grazing	Assess plant species impacts on nutrient cycling and water use, including crop stressors and new weed pressures and respond with grazing or enhancing plant diversity	Overgrazing as a termination tool needs to offset soil carbon losses via cropping and/or additional grazing; If grazing is used continuously then you need to insert chaos into grazing plan; Choose plants to address any compaction issues caused by grazing



Compounding Principle of Consortia

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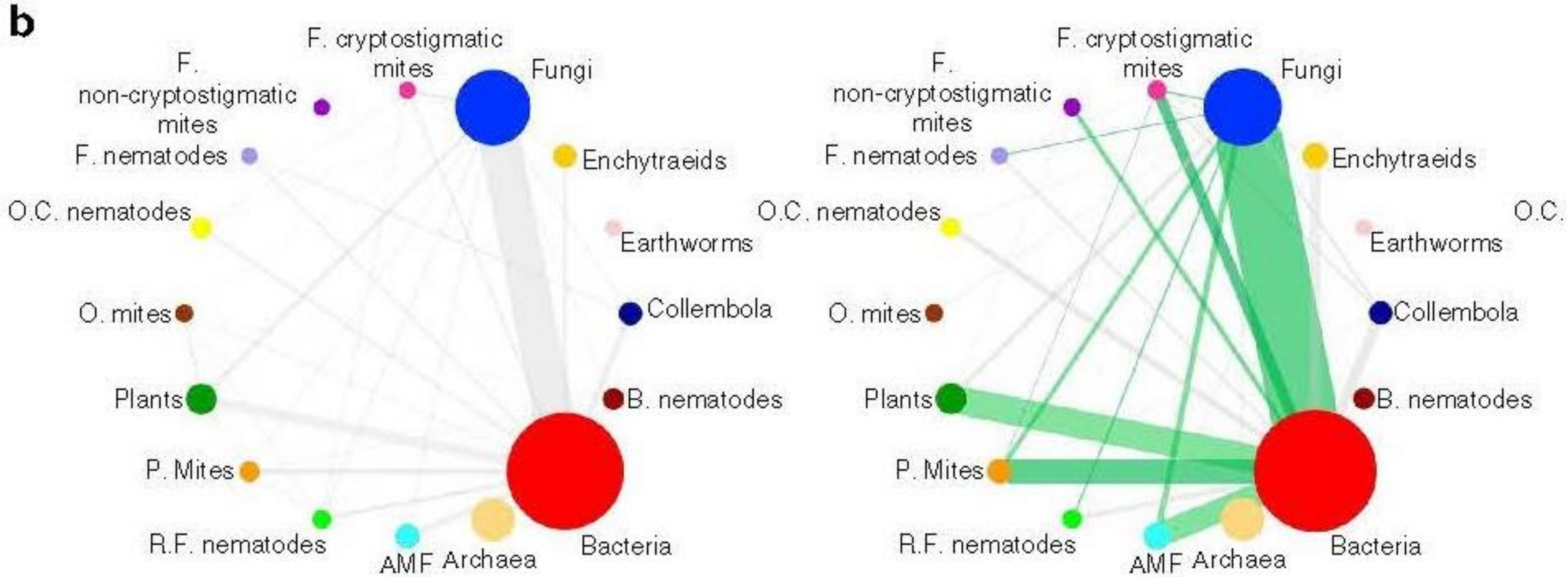
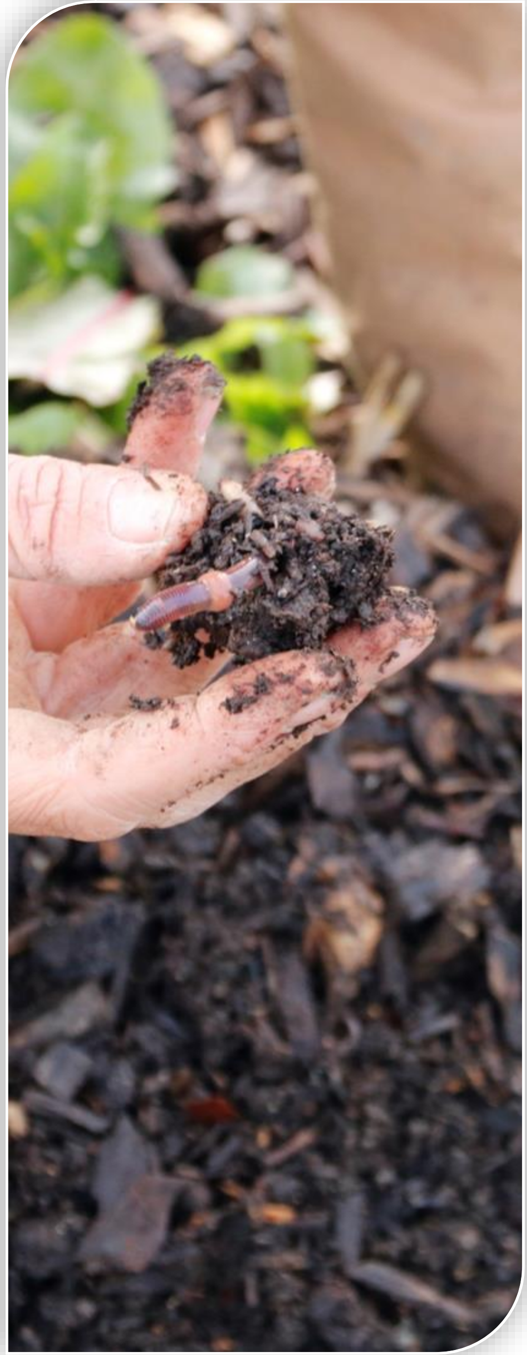
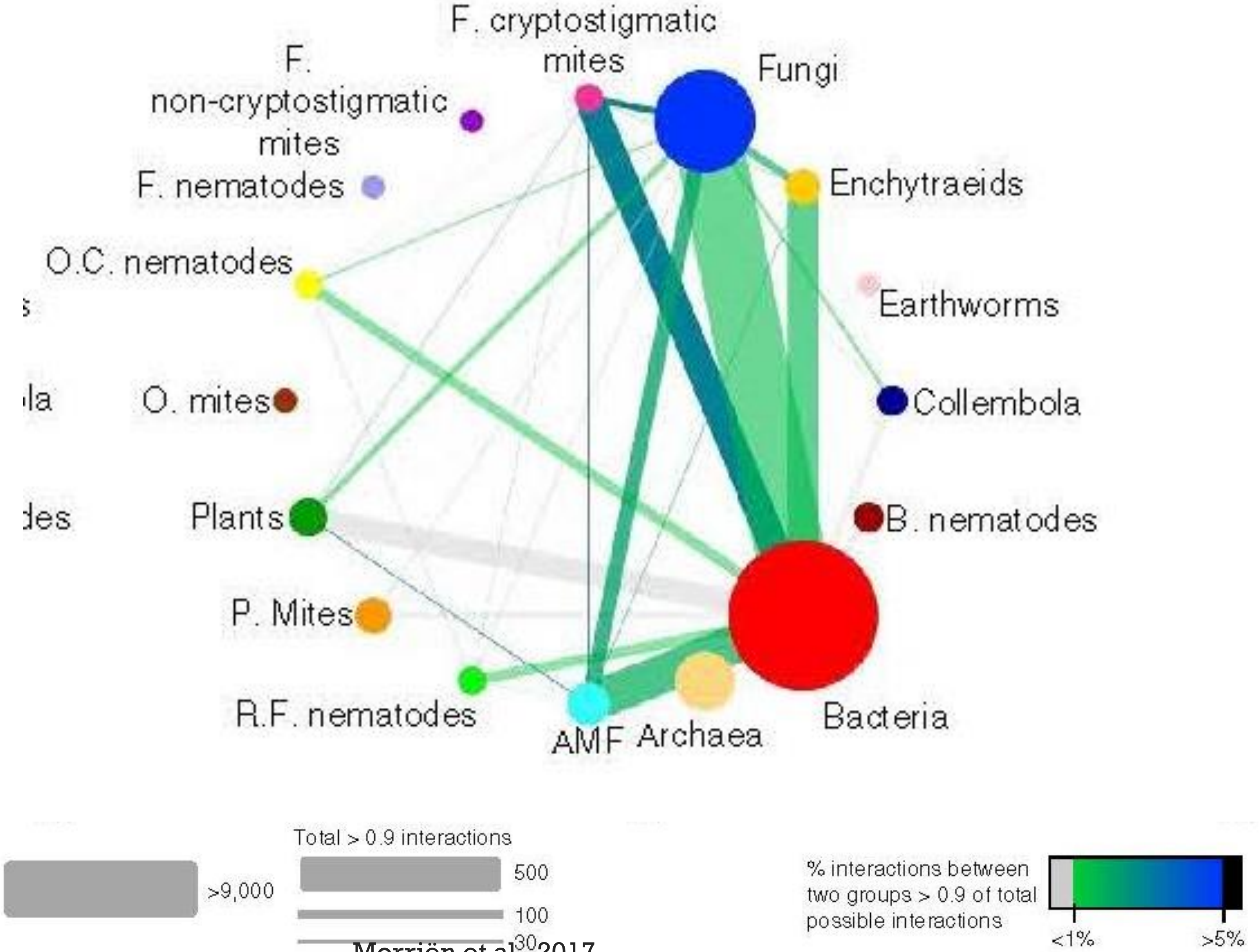


Morriën et al., 2017





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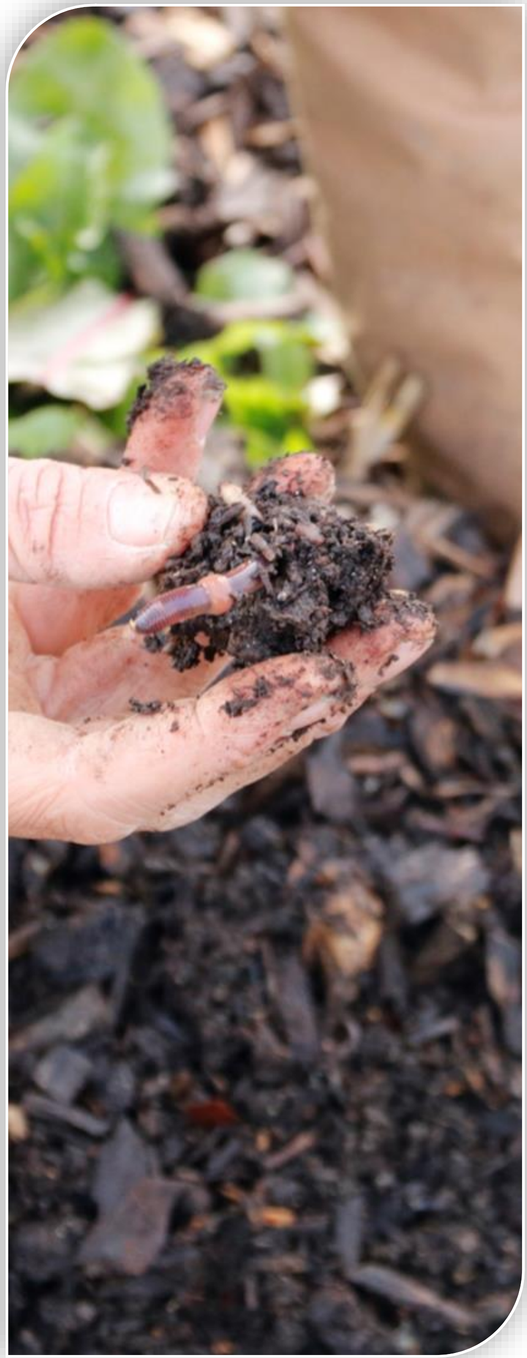
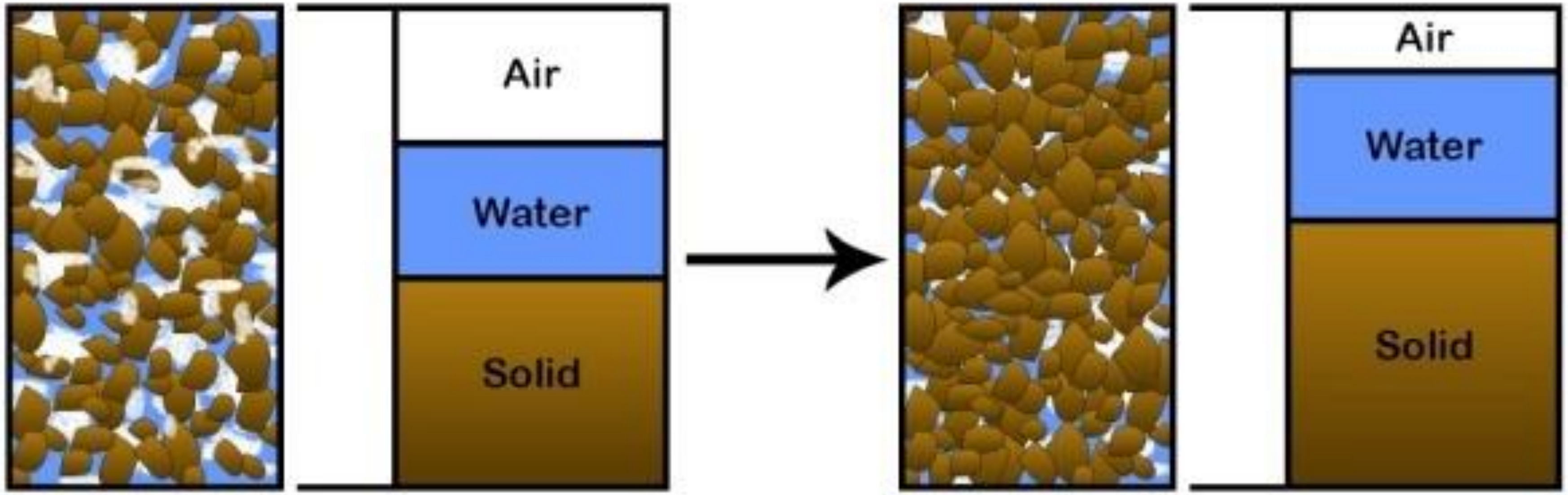


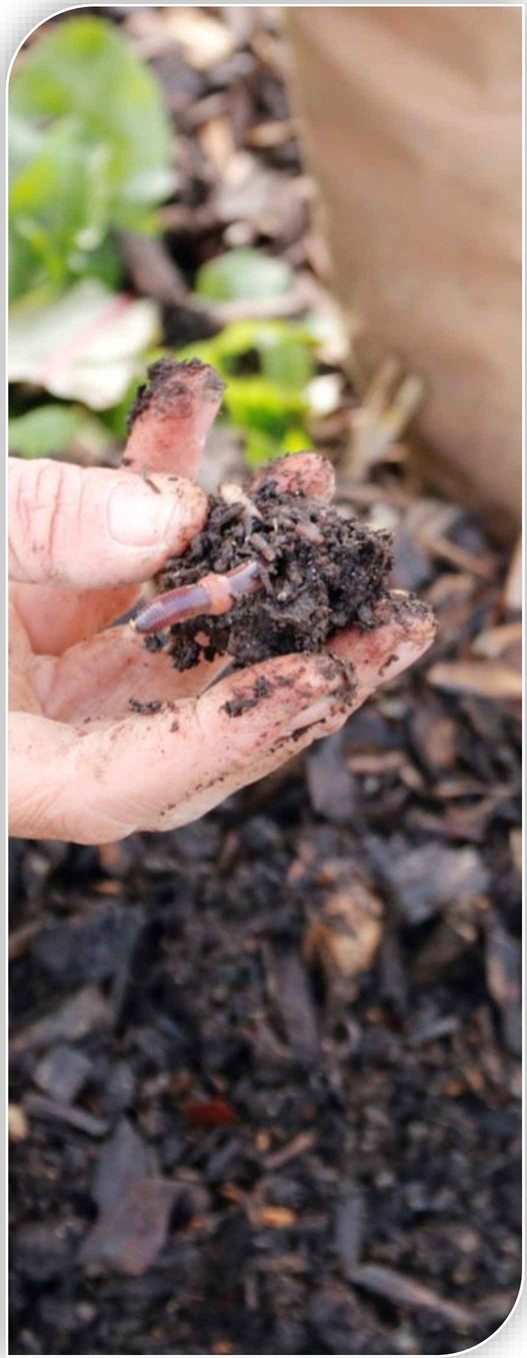
Soil Porosity



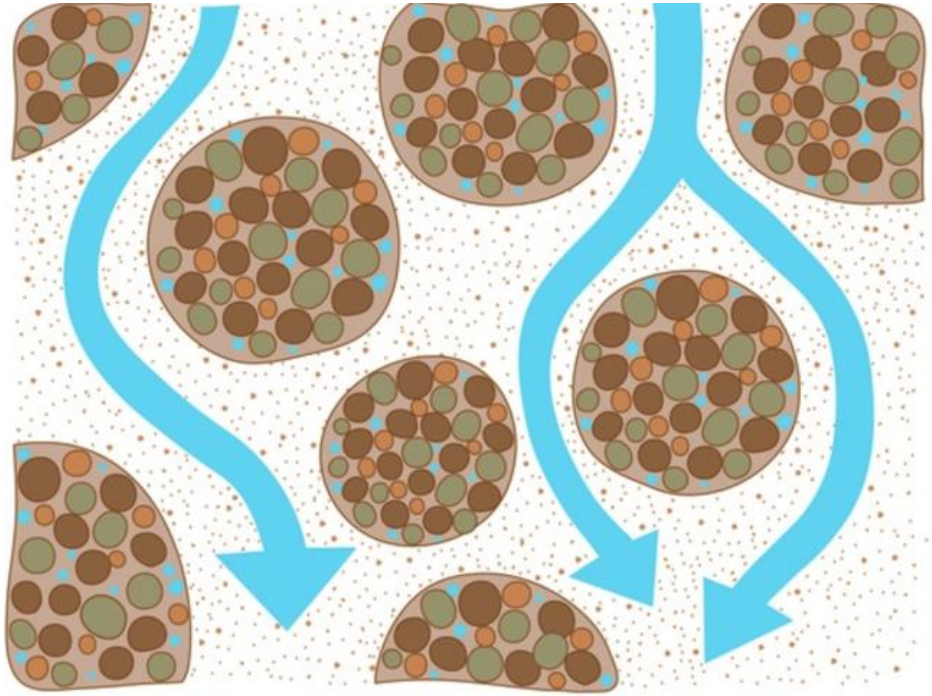
Healthy Soil **Unhealthy Soil**

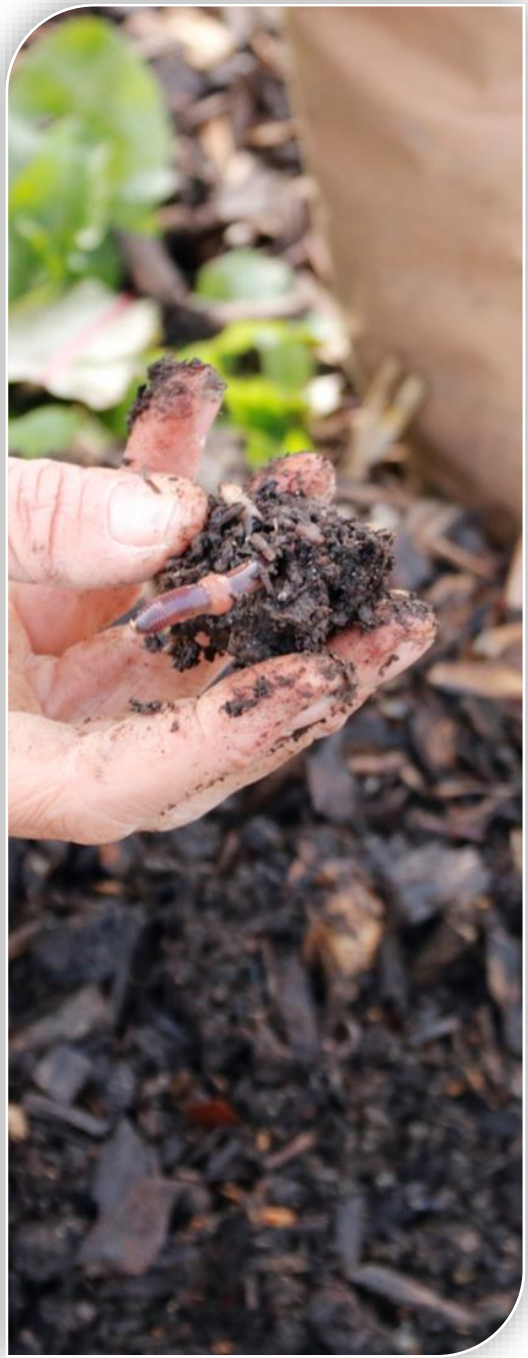
- 45% greater porosity increases infiltration by 167% for the first inch and 650% for the second inch - Karlen et al., 1998

Soil Aggregation and Porosity



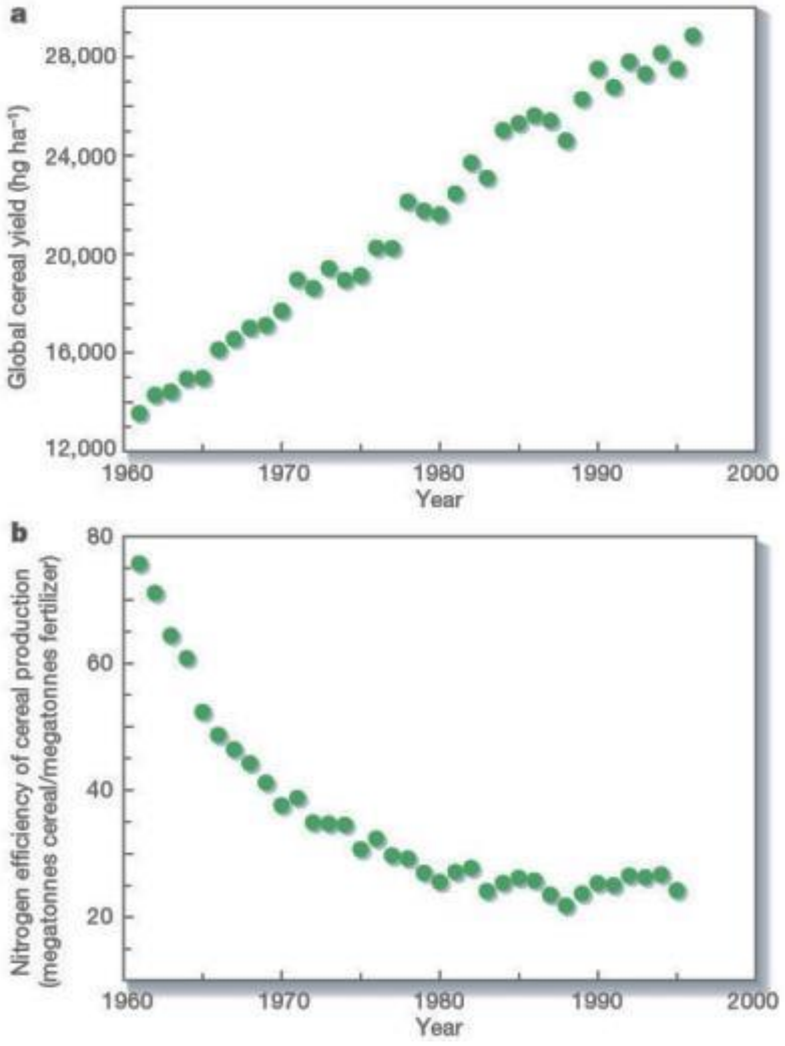
1-2 mm
Aggregates

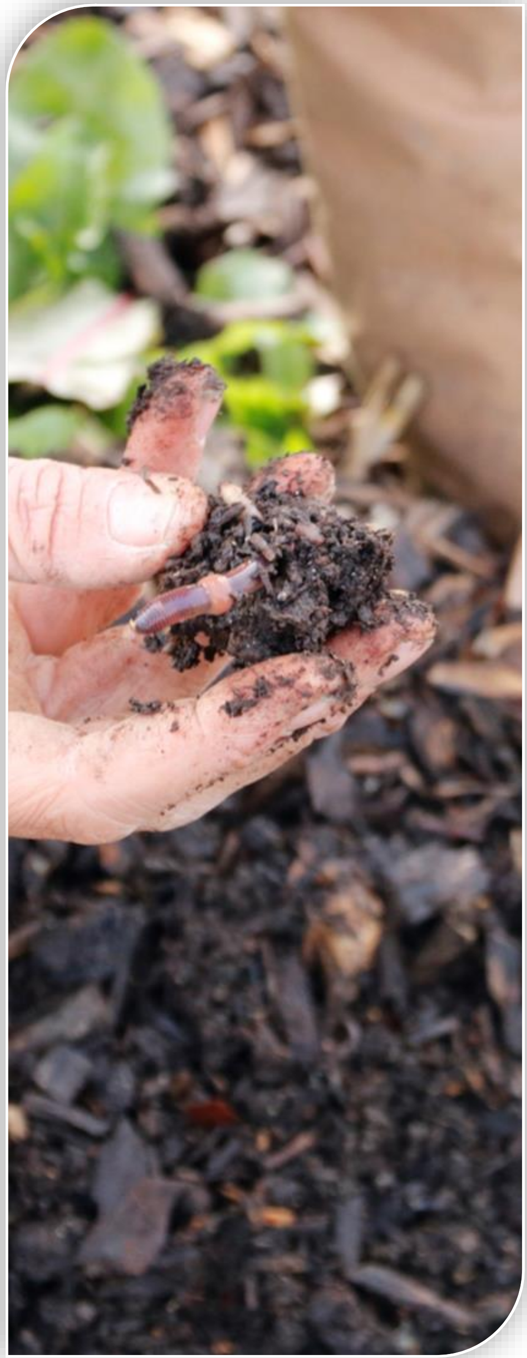




Nutrient Use Efficiency

- Plant available – synthetic vs. biologic
- 30-50% of nitrogen fertilizer is used by the plant (Hirel et al 2011)
- 30% of phosphorus is used by the plant
- Availability, timing, water, and pH





Fertility Management

- Too little fertility
  - Plant available – synthetic vs. soil biology
  - Fertility and water
- Too much fertility
  - Availability, timing, water, and pH

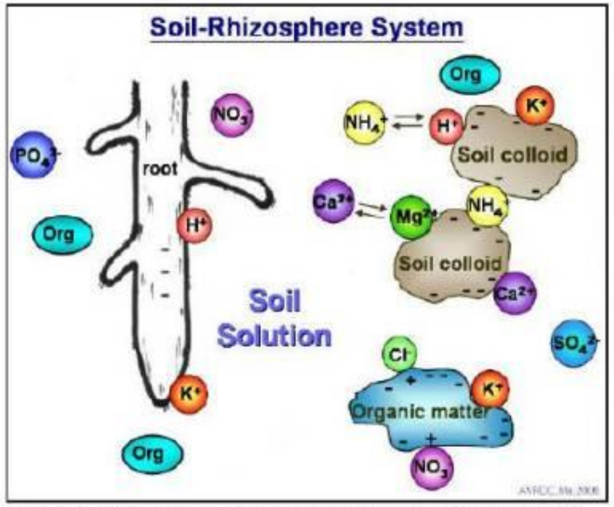
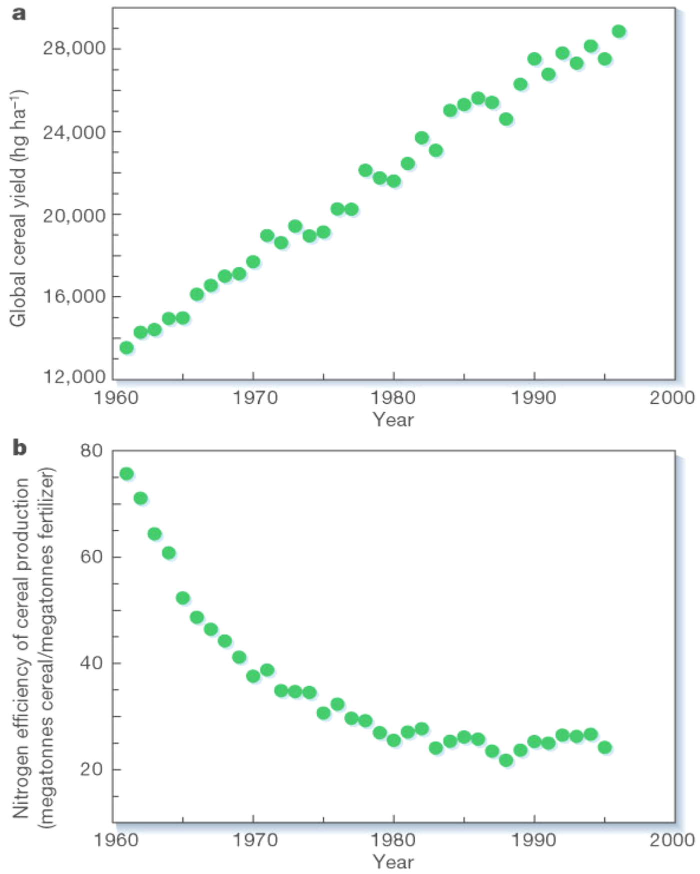
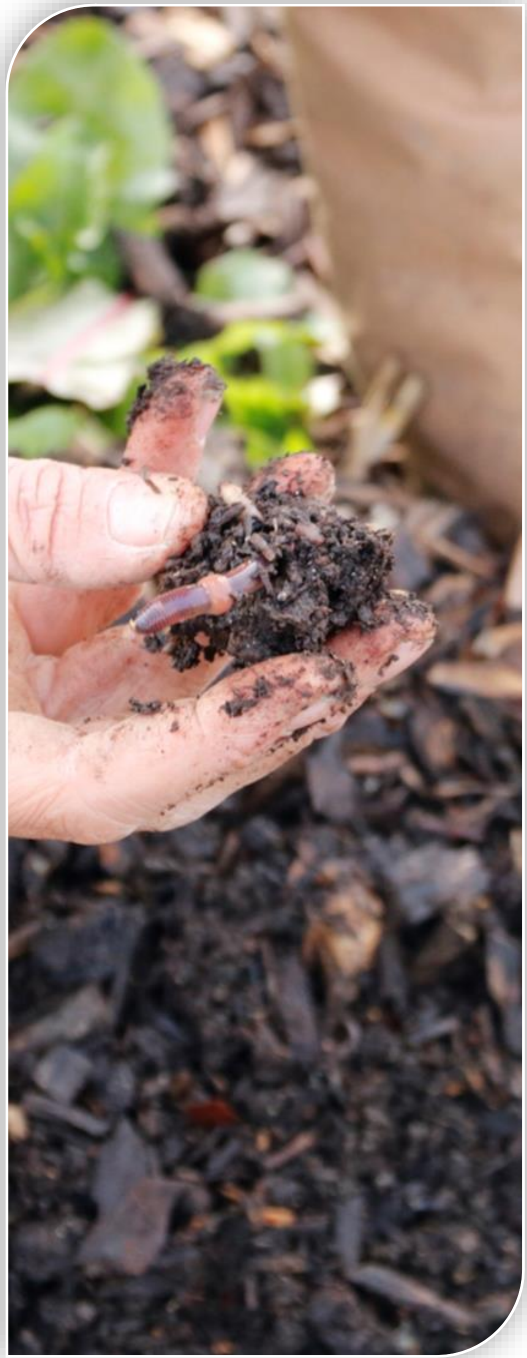


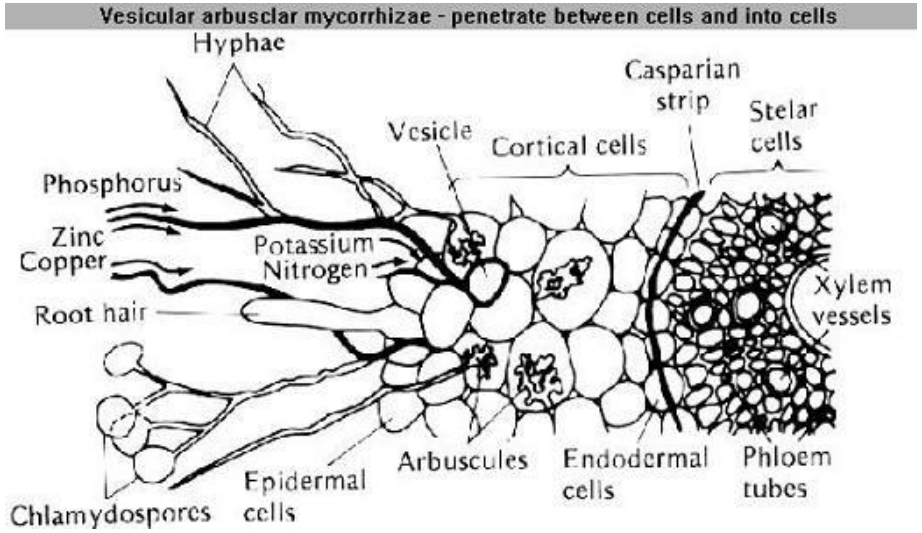
Figure 2. Components that relate to nutrient availability in the soil-rhizosphere system

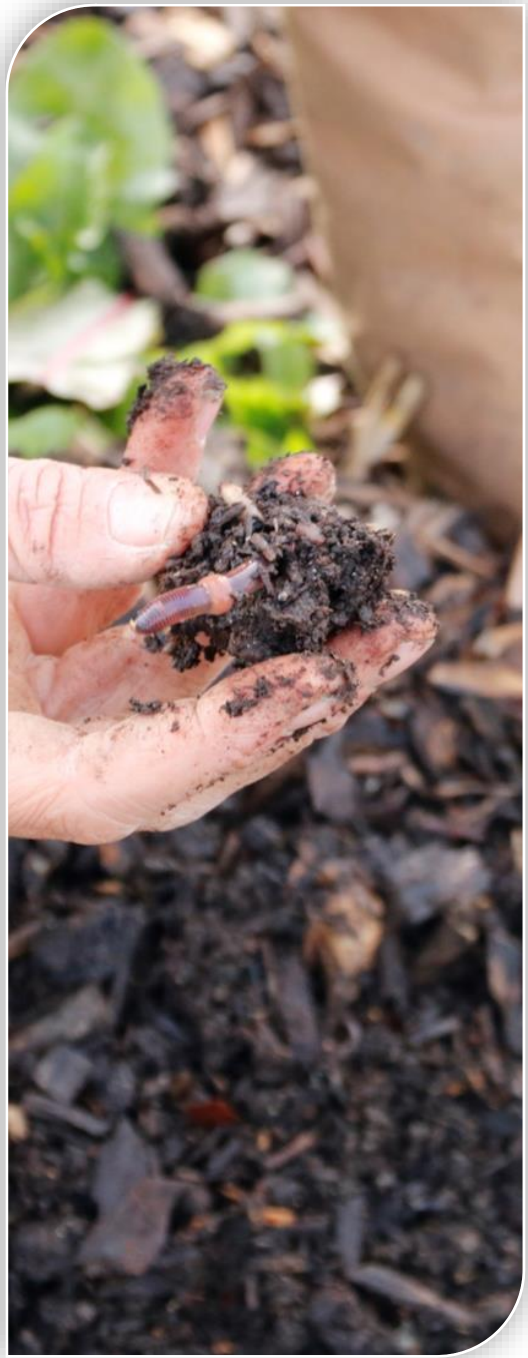


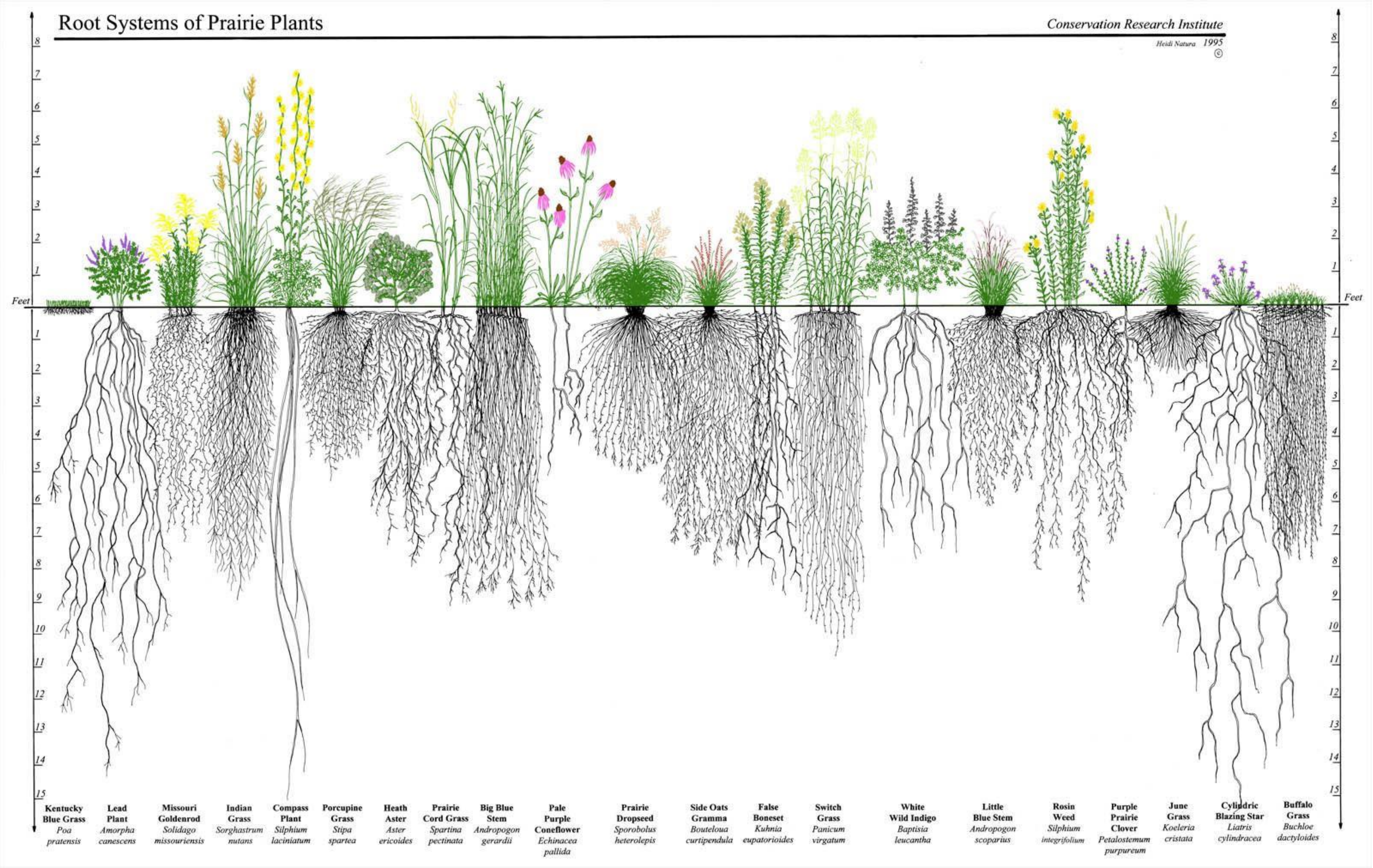


Arbuscular Mycorrhizal Fungi

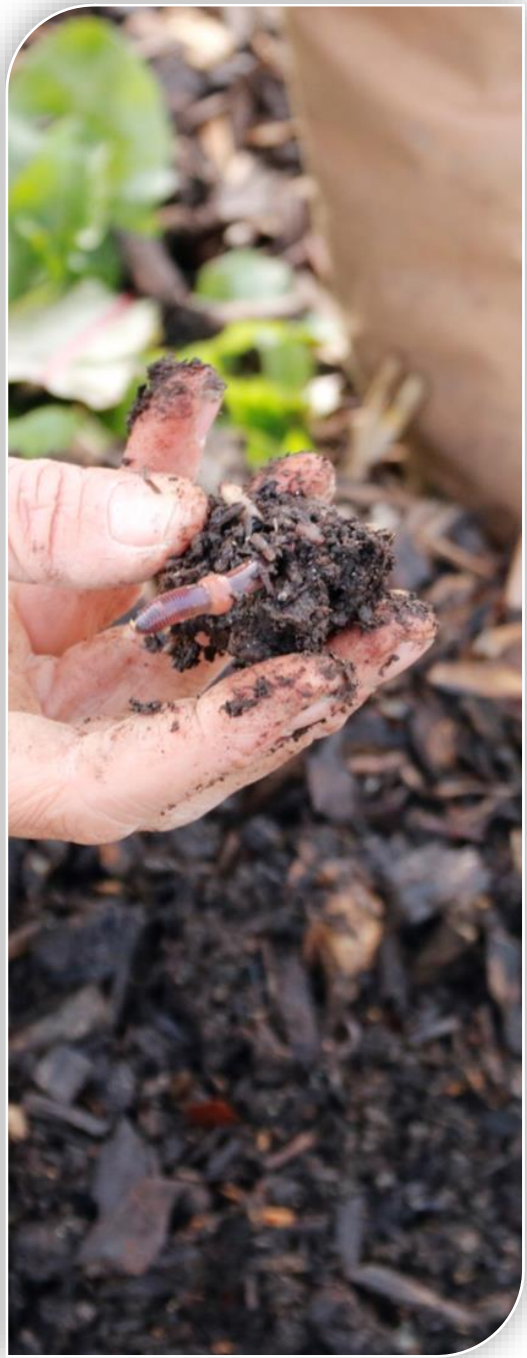
- Obtain nutrients (up to 90% of N and P) – Smith and Read, 2008
    - Phosphate-solubilizing bacteria – Toro and Barea, 1996
    - Mixed cultures more efficient, but this was also AMF species dependent – Walder et al 2012
    - Non-legume trades P for N via AMF and rhizobia activity – Chalk et al, 2014
- Transfer water
- Induce antioxidants (Garcia-Sanchez et al., 2014)

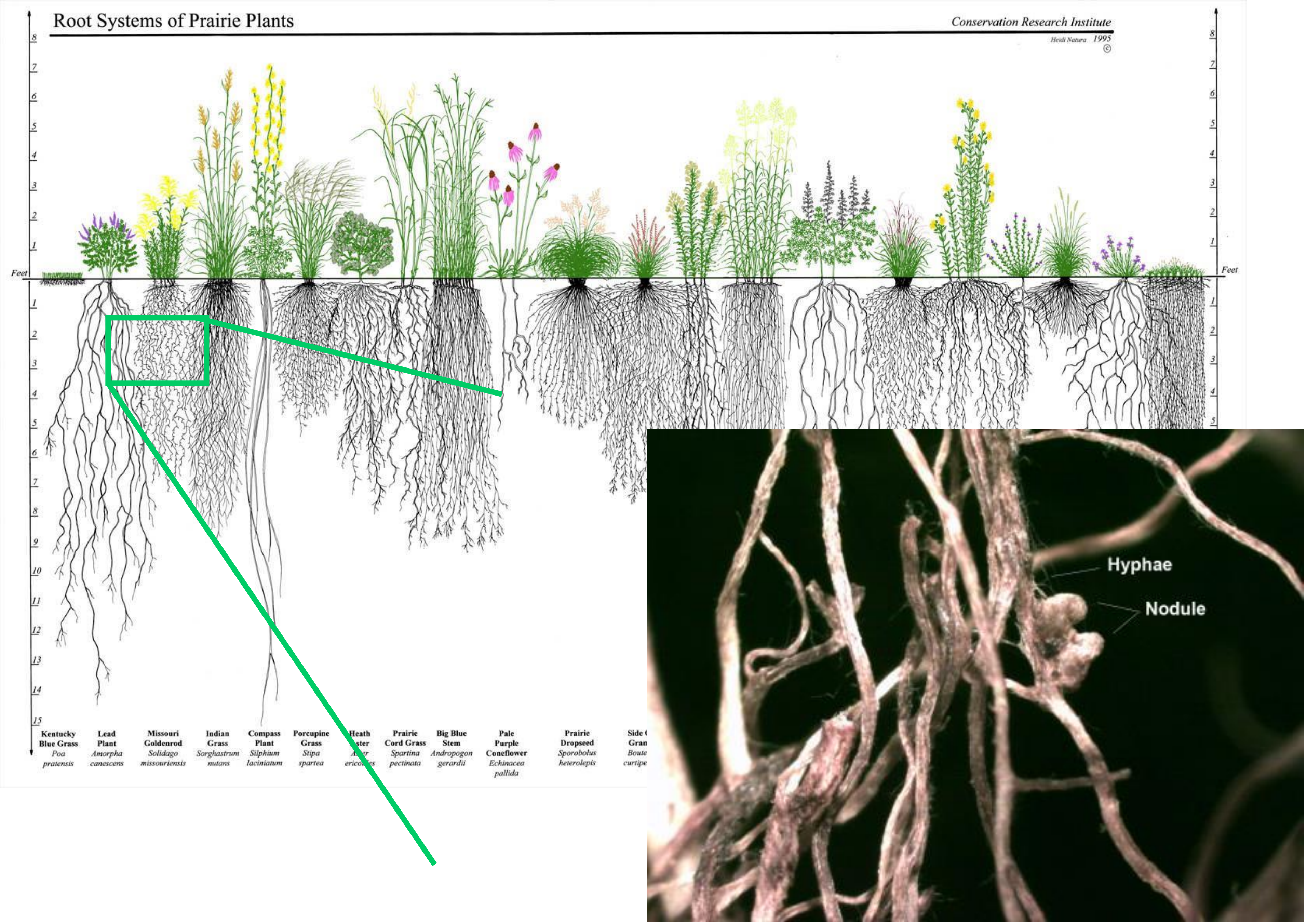






Root Systems of Prairie Plants
Conservation Research Institute
Heidi Natura 1995 ©
Feet
Kentucky Blue Grass *Poa pratensis*
Lead Plant *Amorpha canescens*
Missouri Goldenrod *Solidago missouriensis*
Indian Grass *Sorghastrum nutans*
Compass Plant *Silphium laciniatum*
Porcupine Grass *Stipa spartea*
Heath Aster *Aster ericoides*
Prairie Cord Grass *Spartina pectinata*
Big Blue Stem *Andropogon gerardii*
Pale Purple Coneflower *Echinacea pallida*
Prairie Dropseed *Sporobolus heterolepis*
Side Oats Gramma *Bouteloua curtipendula*
False Boneset *Kuhnia eupatorioides*
Switch Grass *Panicum virgatum*
White Wild Indigo *Baptisia leucantha*
Little Blue Stem *Andropogon scoparius*
Rosin Weed *Silphium integrifolium*
Purple Prairie Clover *Petalostemum purpureum*
June Grass *Koeleria cristata*
Cylindric Blazing Star *Liatris cylindracea*
Buffalo Grass *Buchloe dactyloides*





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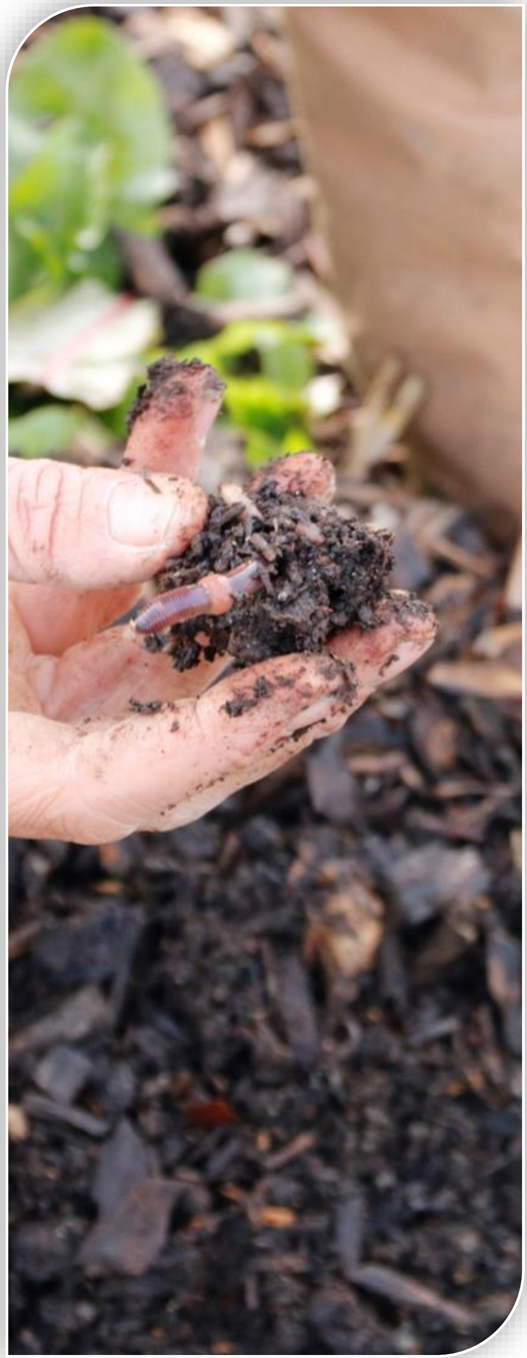
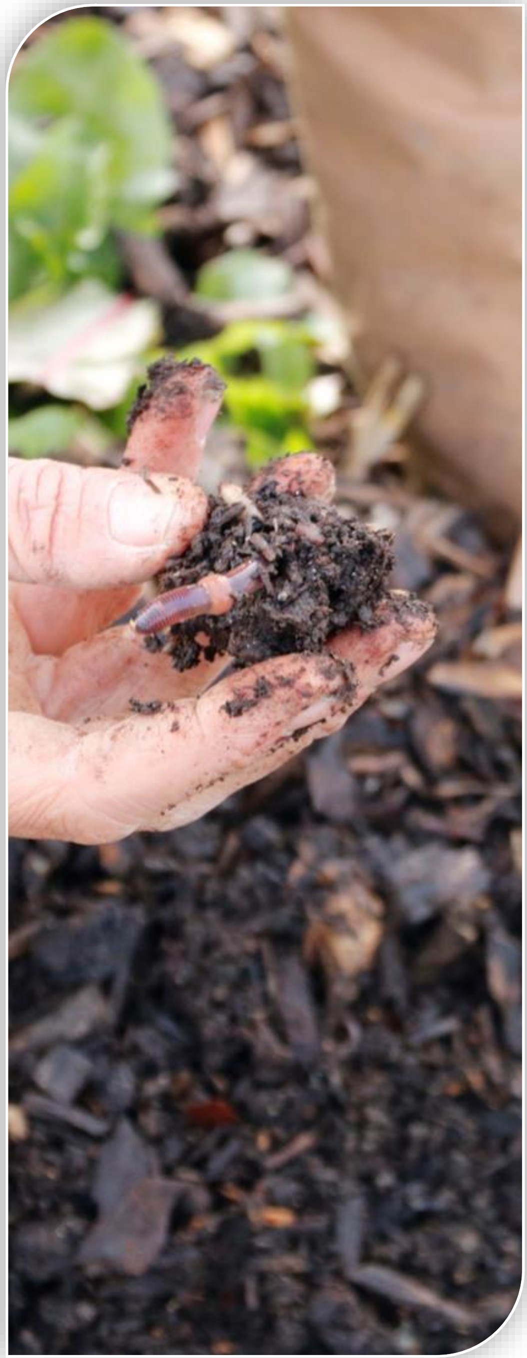
Prairie Dropseed
Sporobolus heterolepis
Hyphae
Nodule



Water Use Efficiency

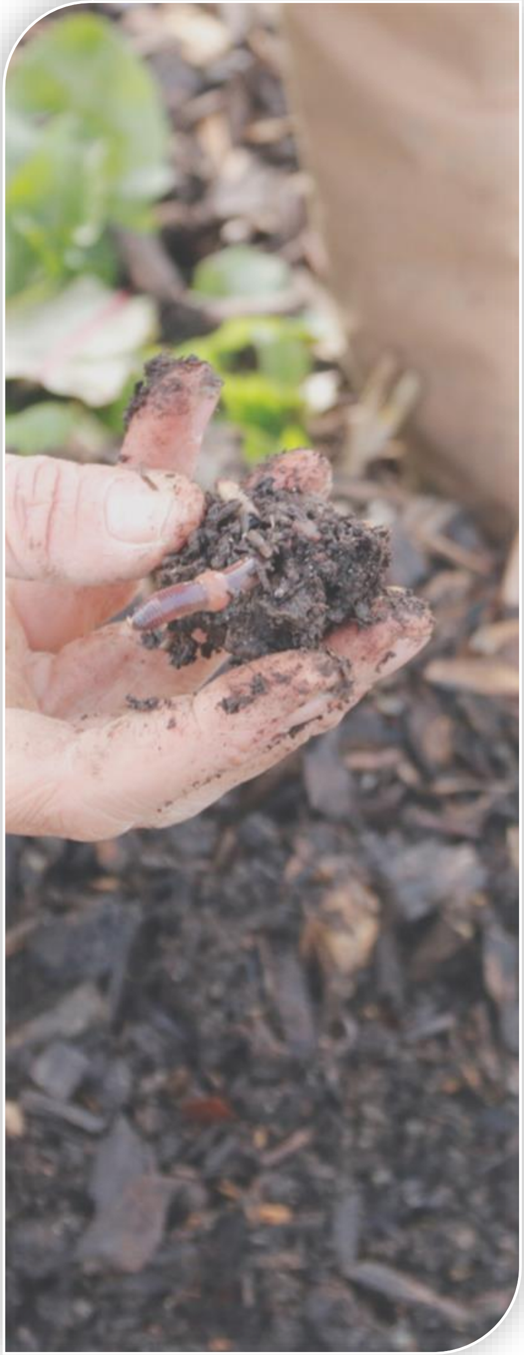
- The Drought Myth - a case of plant hunger rather than thirst - unfertilized corn required 26,000 gallons of water per bushel yielded 4X less than a fertilized field receiving only 5,600 gallons of water per bushel. – W.A. Albrecht, 2000
- Seven-way cover crop mix yield almost 3 times higher than of single crop on 7 in of soil moisture. Field with manure and no commercial fertilizer yielded the same as a fertilized field and plant tissues tested sufficient or high for N, P, K, and S – North Dakota, 2006
- 45% greater porosity increases infiltration rate by 167% for the first inch and 650% for the second inch - Karlen et al., 1998
- Loose soil has a slower rate of drying compared to packed soil, because the water films are discontinuous and moisture is not readily conducted to the surface.

Treat Soil Like you're supposed to treat yourself



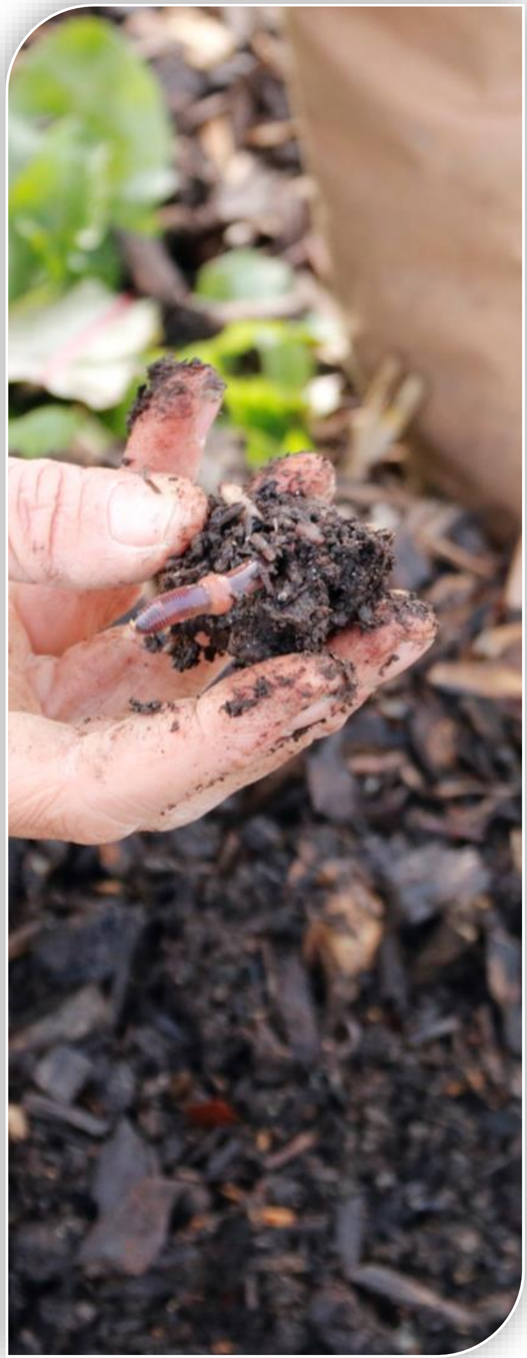
- Eat small meals throughout the day (be a grazer).
- Eat a diverse diet.
- Exercise but don't over exercise – FIST (Frequency, Intensity, Scale, Timing).
- Protect your body from injury, radiation, temperature extremes, etc. (armor).

KRIS Systems
Education & Consultation
Knowledge for Regeneration & Innovation in Soil

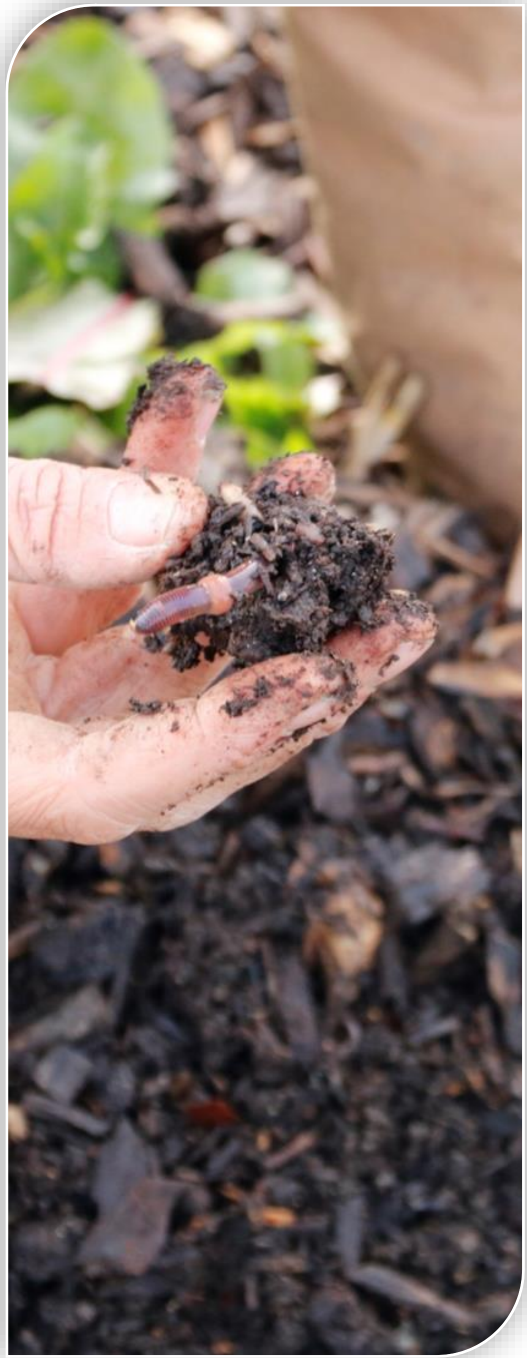


It really boils down to this: that all life is interrelated. We are all caught in an inescapable network of mutuality, tied into a single garment of destiny. Whatever affects one destiny, affects all indirectly. _ ***Martin Luther King Jr., Christmas Eve Serman, 1967***

Dr. Kris Nichols
Food Water Wellness Foundation
MyLand Company LLC, www.MyLand.ag
Kris@KRIS-Systems.com
glomalin1972@gmail.com

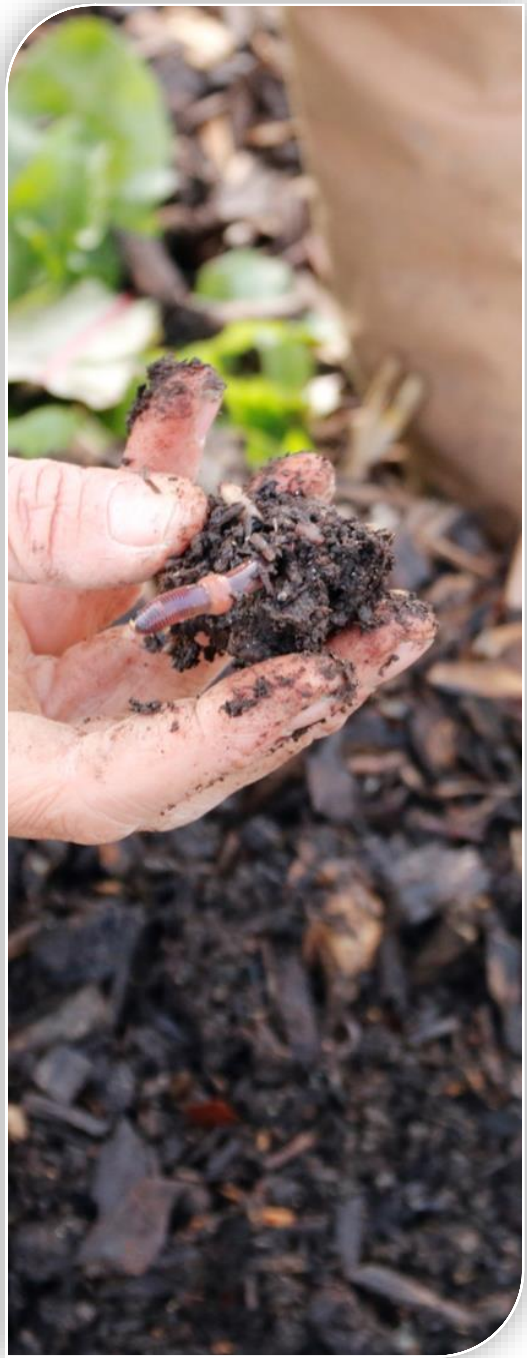


Questions?



Coffee Break

Till 10h50



Mechanisms of soil health restoration in regenerative agriculture

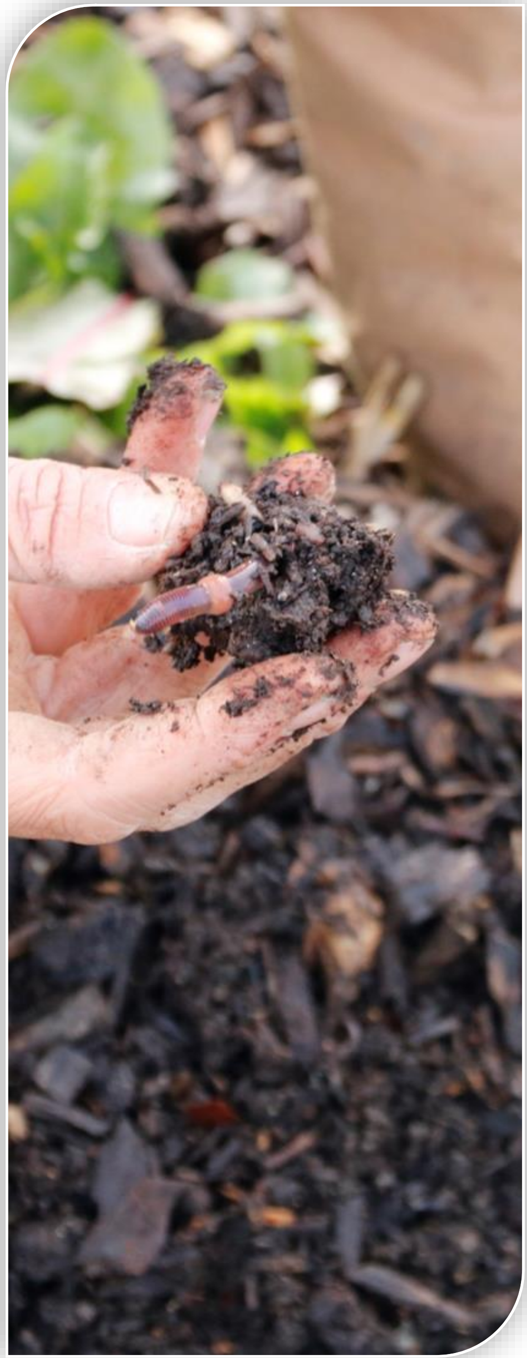
Richard Teague

Soil Health Restoration with Regenerative Grazing

Soil Health Conference, World Soil Day

December 5th 2022

Richard Teague,
Teague Regenerative Ranching LLC
Texas A&M AgriLife Research



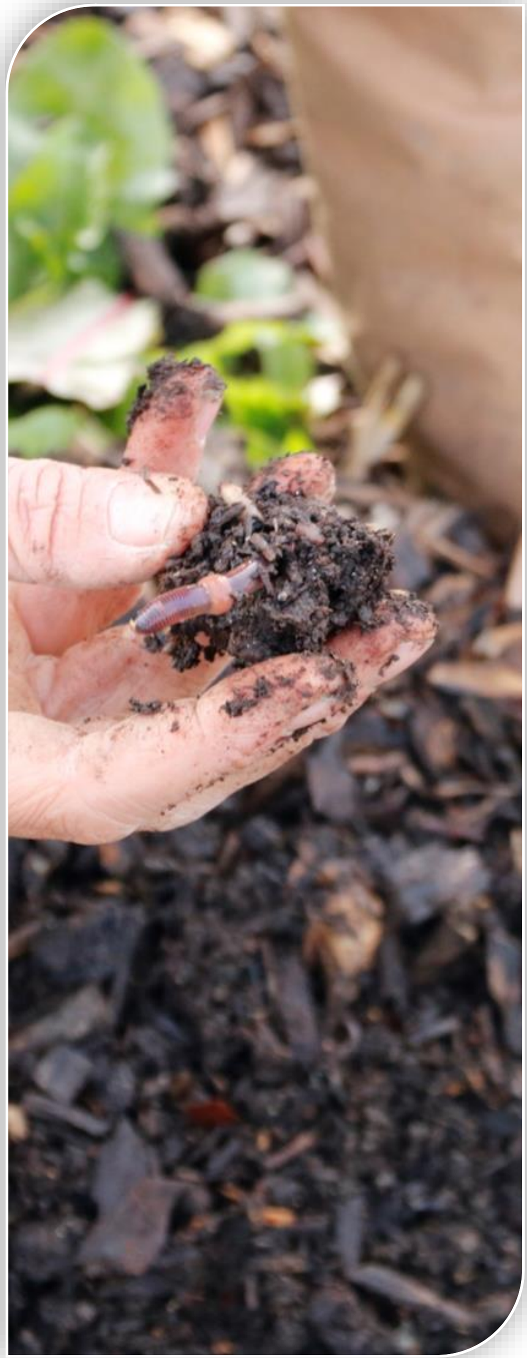
Our Framework

The properties of the parts can be understood only from the organization and constant development of the whole

Our Goal is to find the best grazing management for regenerating:

- Soil health and ecological function
- Delivery of ecosystem goods and services
- Farmer livelihoods and social resilience.

Teague et al. 2013; Savory and Butterfield 2016; Massy 2018



Observations:

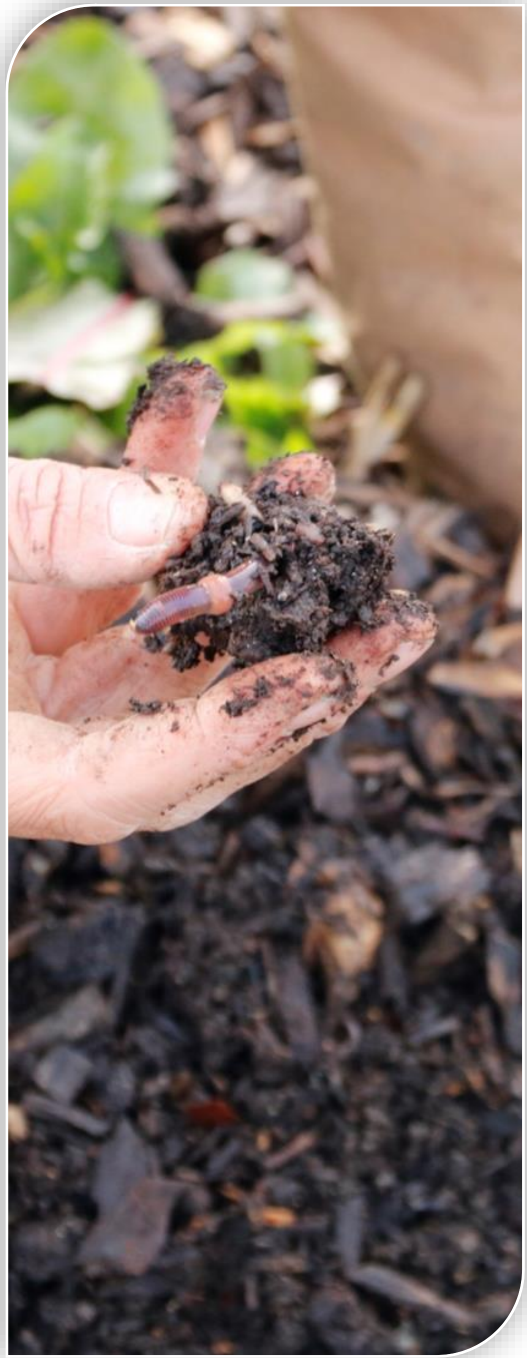
The USDA-NRCS soil mapping database identified the ranches with the highest SOC

Without exception, the highest SOC was with regenerative Adaptive Multi-paddock (AMP) grazing

Outstanding managers achieve much better resource and economic outcomes than research scientists

Partnering with these managers can help others improve management outcomes

Teague et al. 2013; Savory and Butterfield 2016; Massy 2018



Most current science

Rarely considers, let alone studies, unintended consequences to using different actions and practices

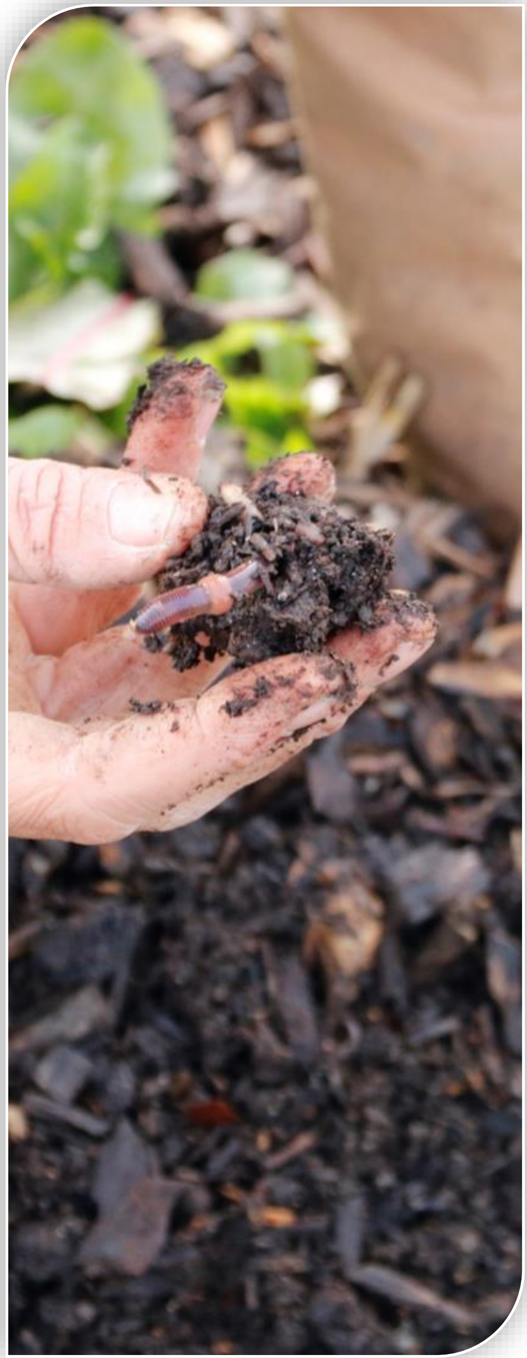
Aims at:

- How to achieve maximum yields
- Use biocides to kill problem pests
- Maximizing short-term profits selling "solutions"

What is needed is improving understanding of biological and ecological function at meaningful scales

These include wider species interactions, self-organizing properties and epigenetic developments that are constantly changing in nature

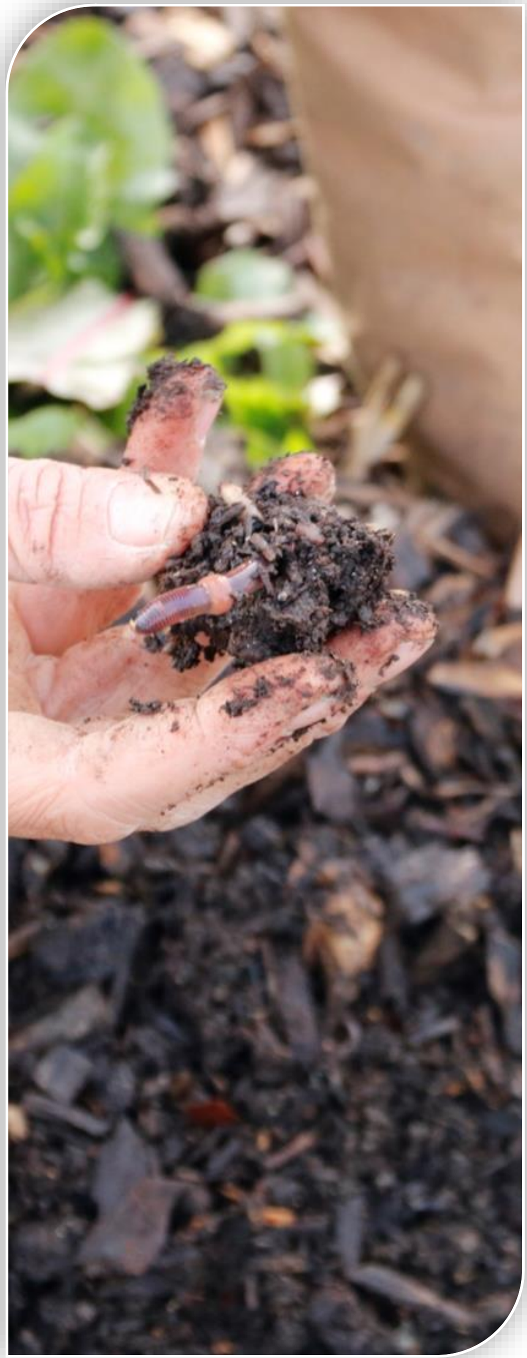
Van der Ploeg et al 2006; Savory and Butterfield 2016; Massy 2018



Working with leading farmers

- Addresses questions at more meaningful scales
- Integrates component science into whole-system interactions and responses
- Identifies emergent and self-organizing ecological properties
- Includes the human element essential for achieving economic and environmental goals
- Incorporates adaptive management to achieve goals
- Facilitates identifying unintended consequences

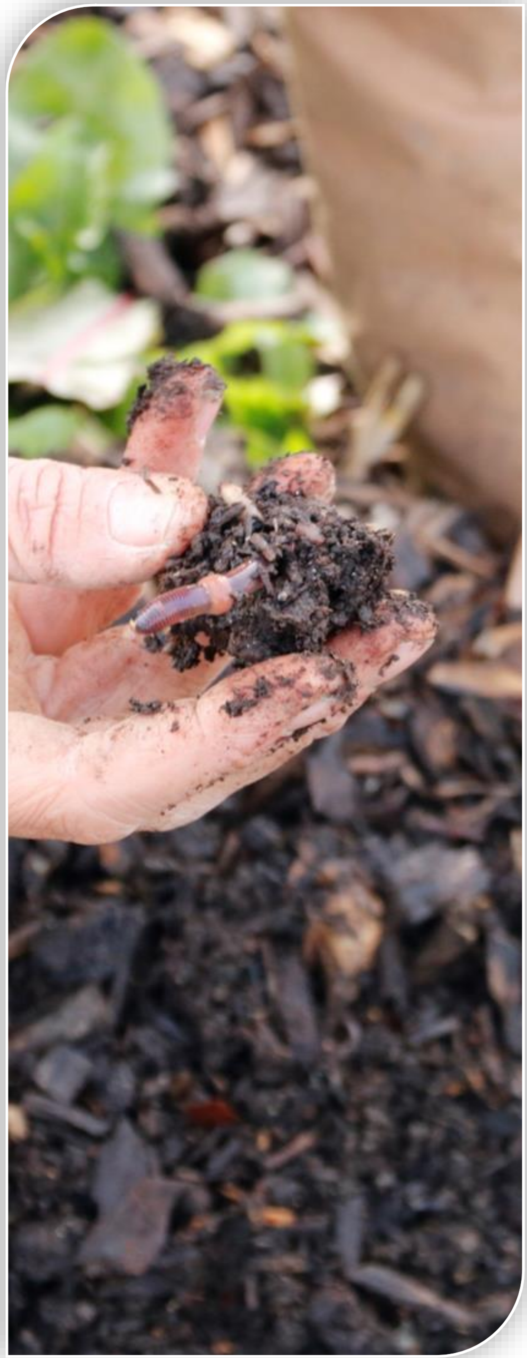
Van der Ploeg et al 2006; Teague et al. 2016; Massy 2018



Outline

- Why we have achieved different research results
- Soil biology in fully functional grazing ecosystems
- Research results
- Managing to improve soil health for full ecological and economic benefits
- Facilitating transitioning to regenerative grazing

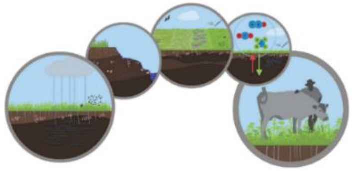
Norton et al. 2013; Jakoby et al. 2014; Teague et al. 2013; 2015

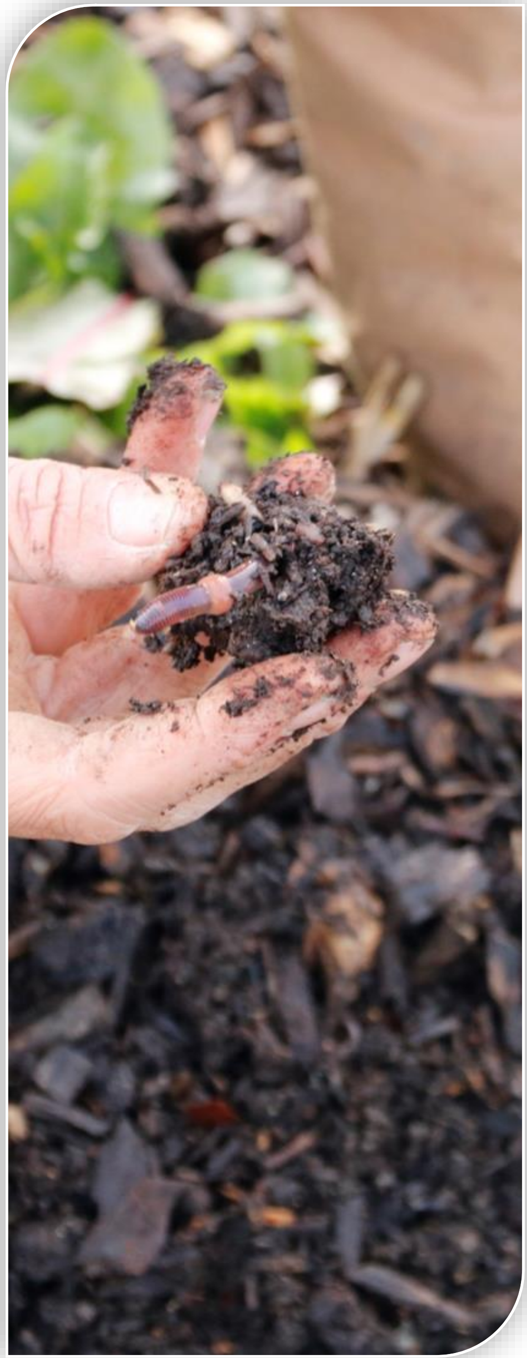


Our Research Hypothesis:

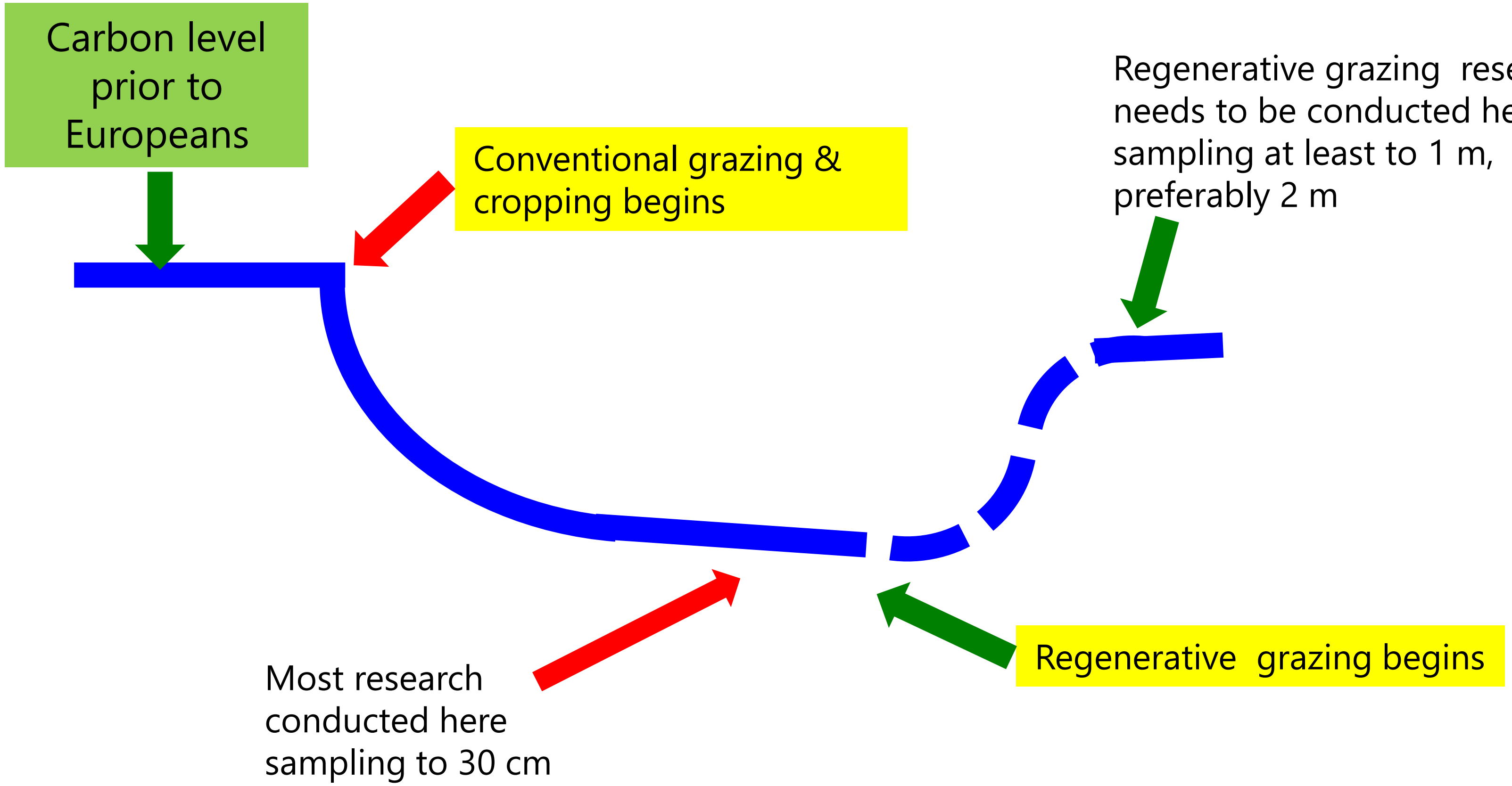
Ecosystem health is increased as soil Carbon increases, *resulting in*:

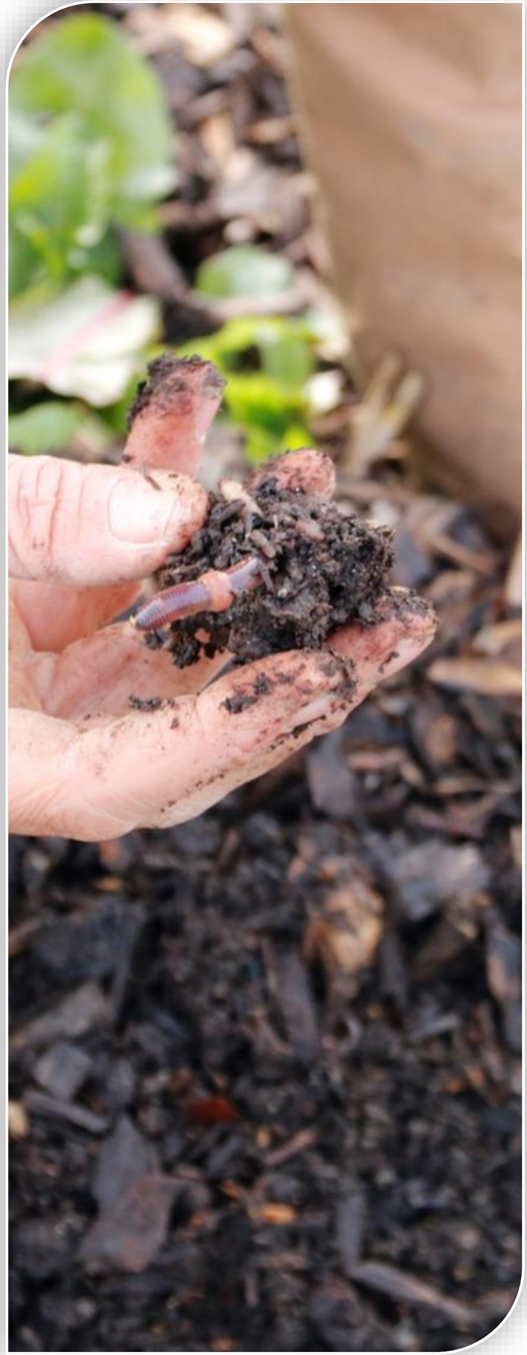
- Improves water infiltration and retention;
- Improves soil nutrient status, access and retention;
- Increases diversity of fungi, microbes, plants, insects;
- Improves wildlife diversity, nutrition and habitat;
- Reduces soil erosion and **net** GHG emissions;
- Improves livestock well-being and output; and
- Improves farmer **net** profits, resilience and well-being.

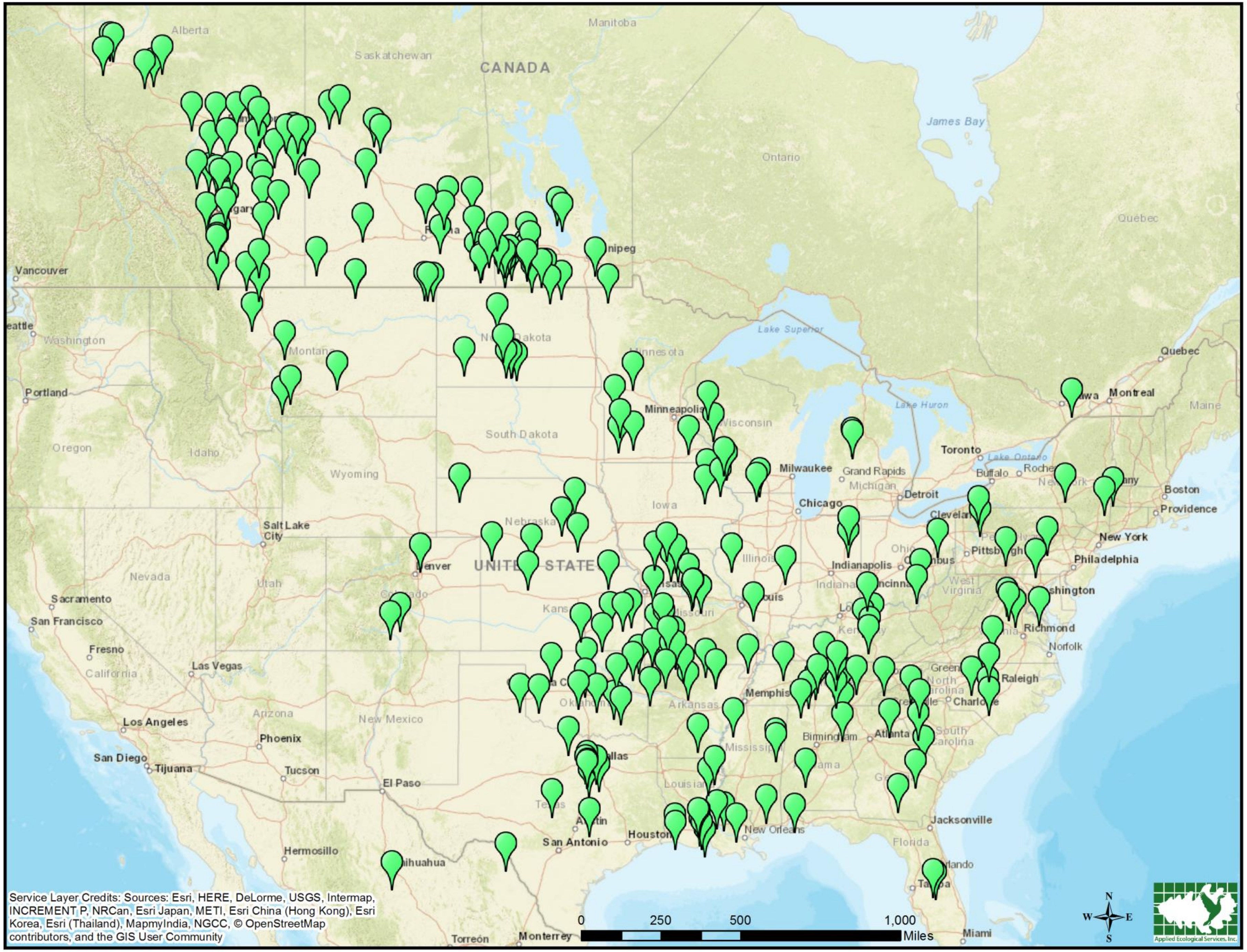




Soil Carbon changes with human management



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Wisconsin
Milwaukee
Lake Superior
Lake Huron
Lake Ontario
Toronto
Grand Rapids
Michigan
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Buffalo
Montreal
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Boston
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UNITED STATES
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Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community
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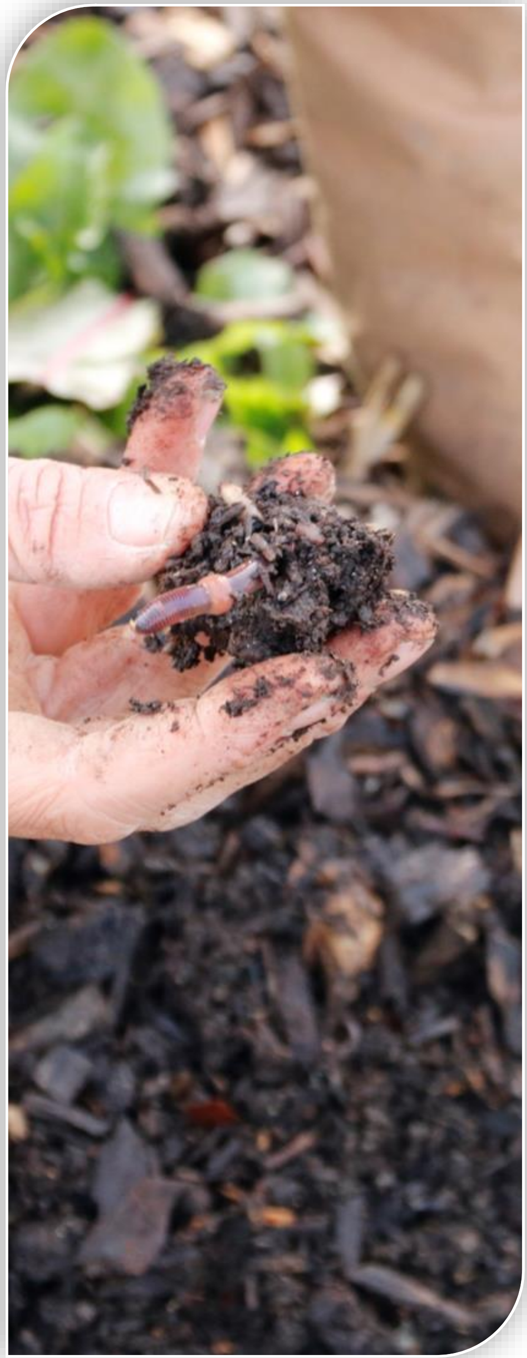
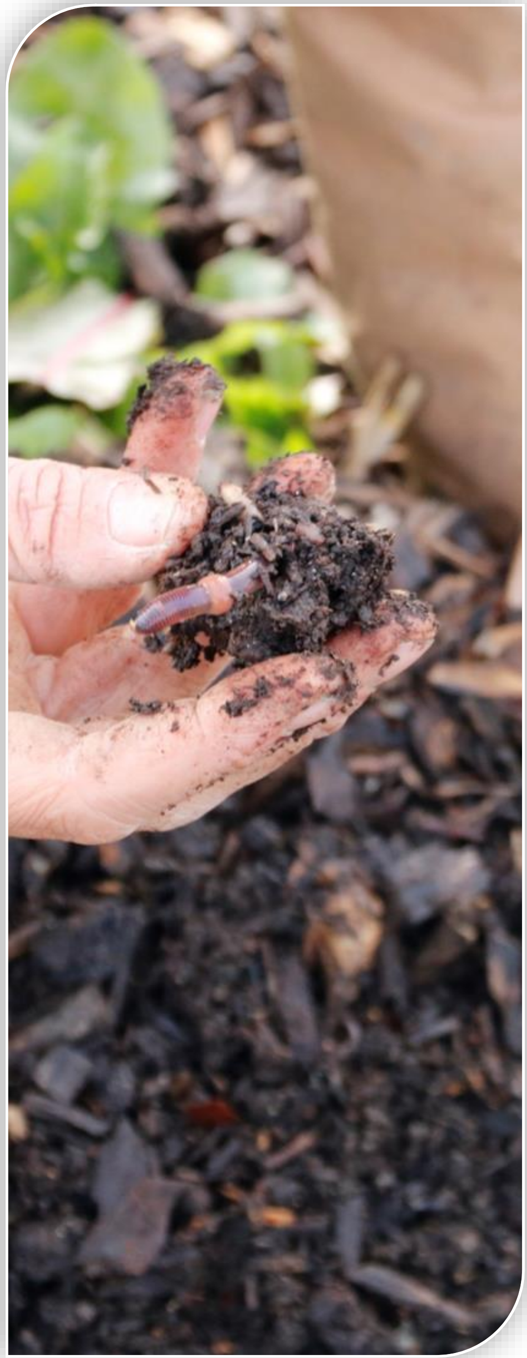
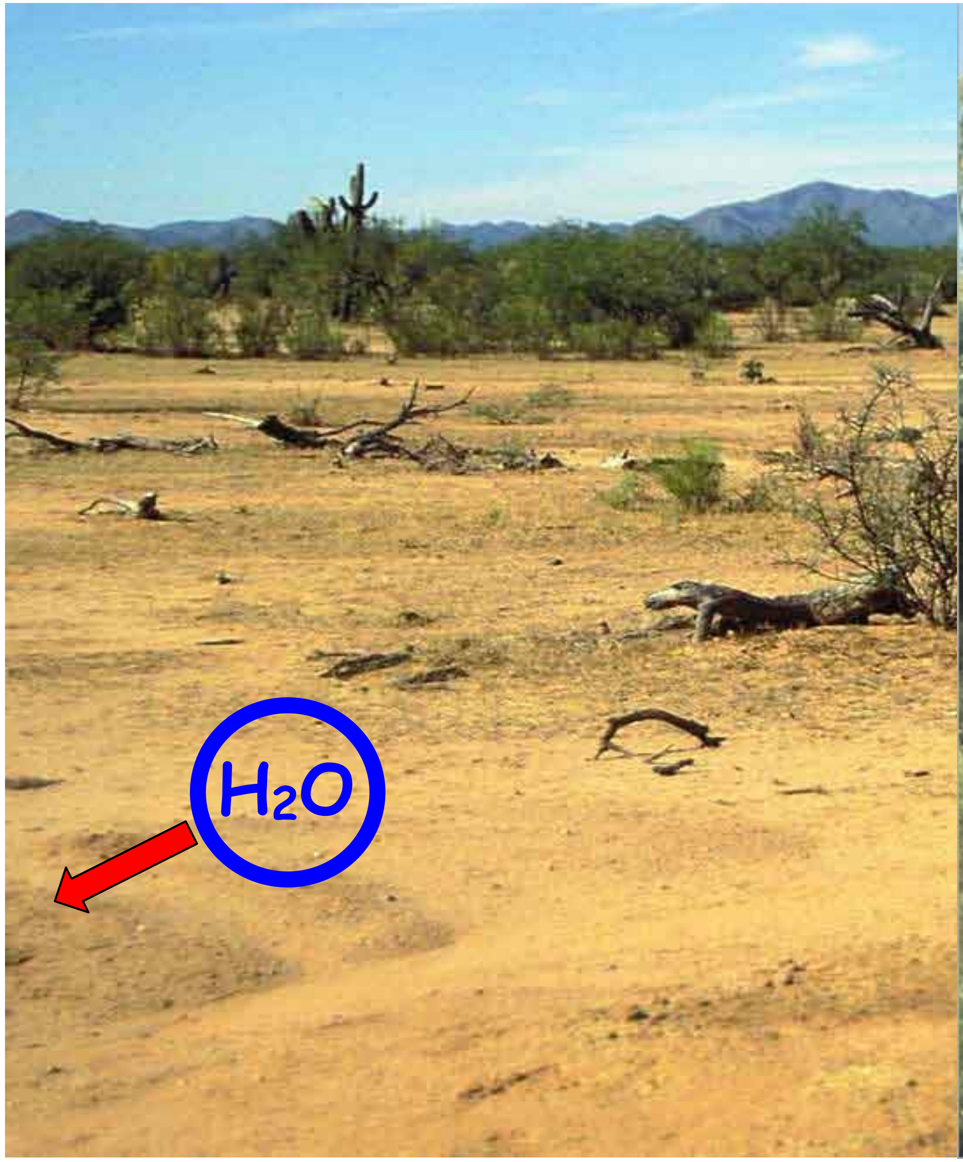


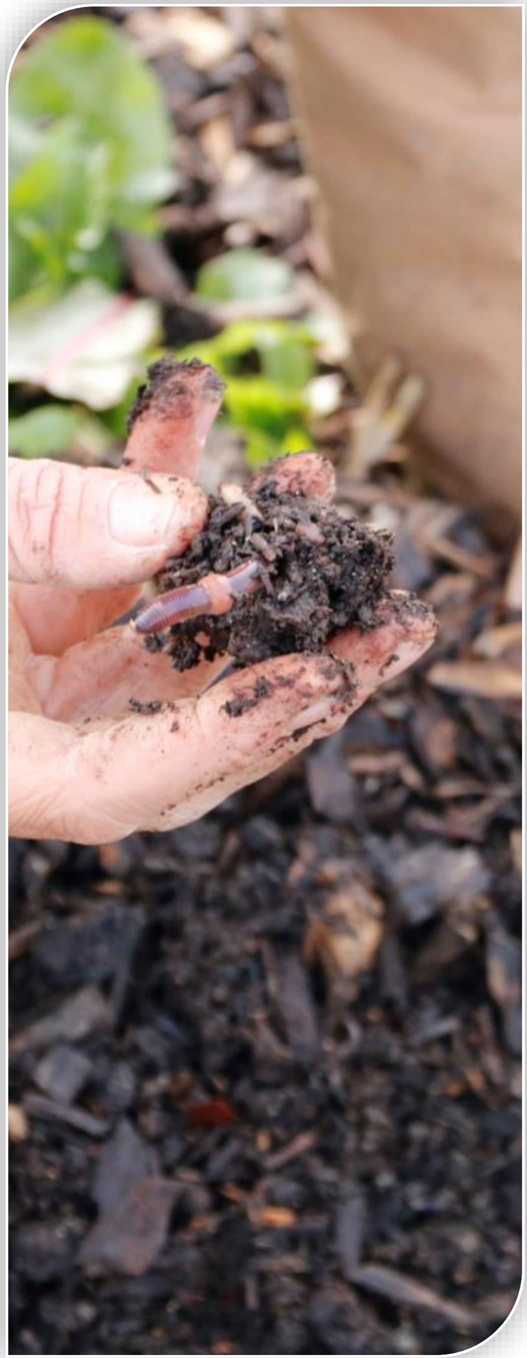
Soil biology in fully functional grazing ecosystems

Biggest limiting factor in grazing land

Water in the Soil



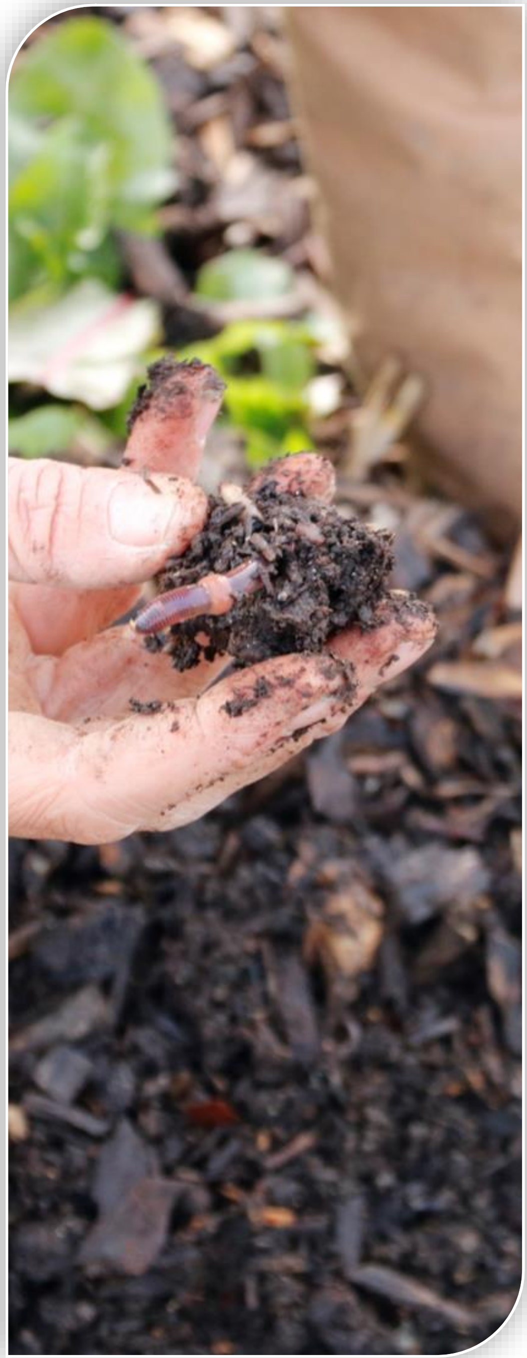




The Four Ecosystem Processes

1. Energy flow
2. Hydrological function
3. Mineral cycle
4. Community dynamics
5. Human component

Terrestrial Ecology 101; Savory and Butterfield 2016; Massy 2018

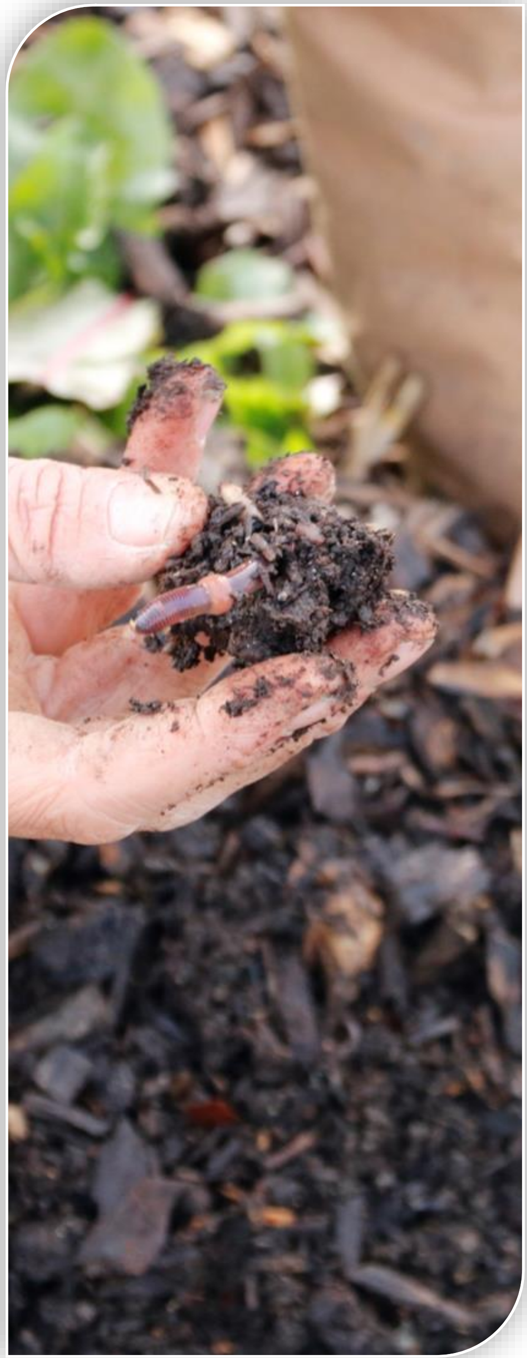


90% of Soil function is mediated by microbes

Microbes depend on plants

So how we manage plants is critical

Ingham 2000; Jones 2016; Lehman et al. 2016

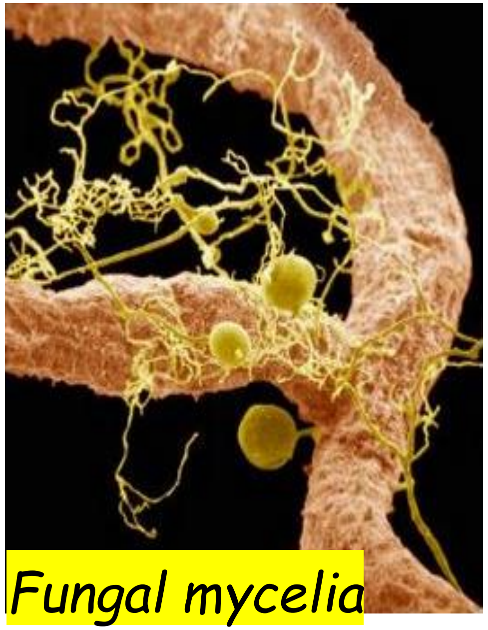


Importance of Microbes and Fungi

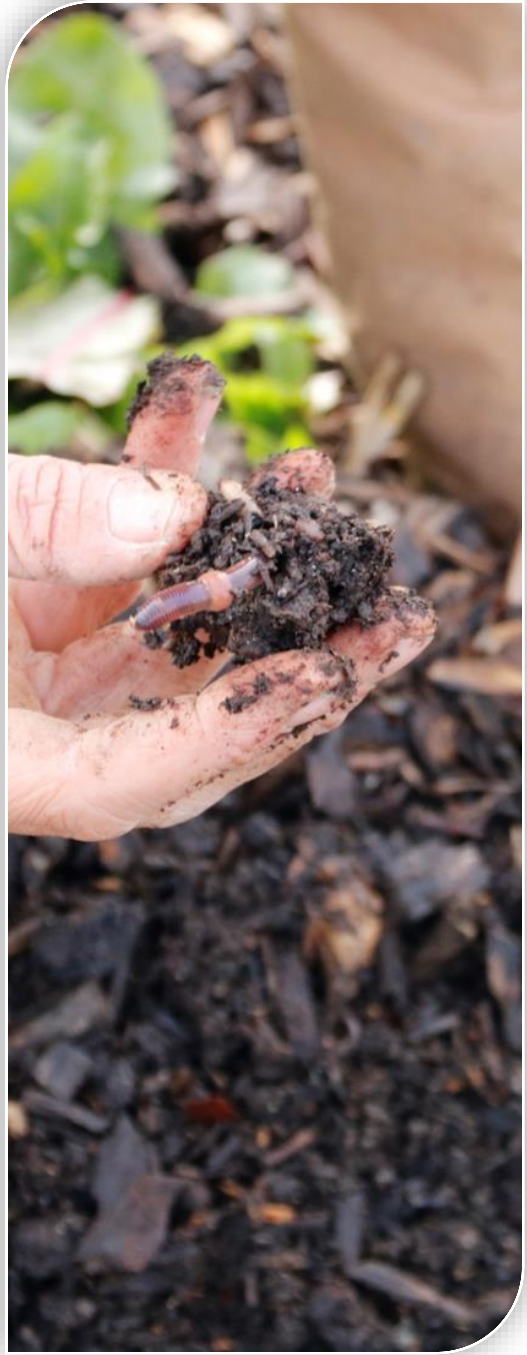
- Improve soil aggregation/structure
- Improve nutrient access for plants
- Extend root volume and depth
- Produce exudates to enhance soil C
- Enhance nutrient cycling
- Increase water and nutrient retention
- Plant growth highest with high fungi
- Fend off pests and pathogens

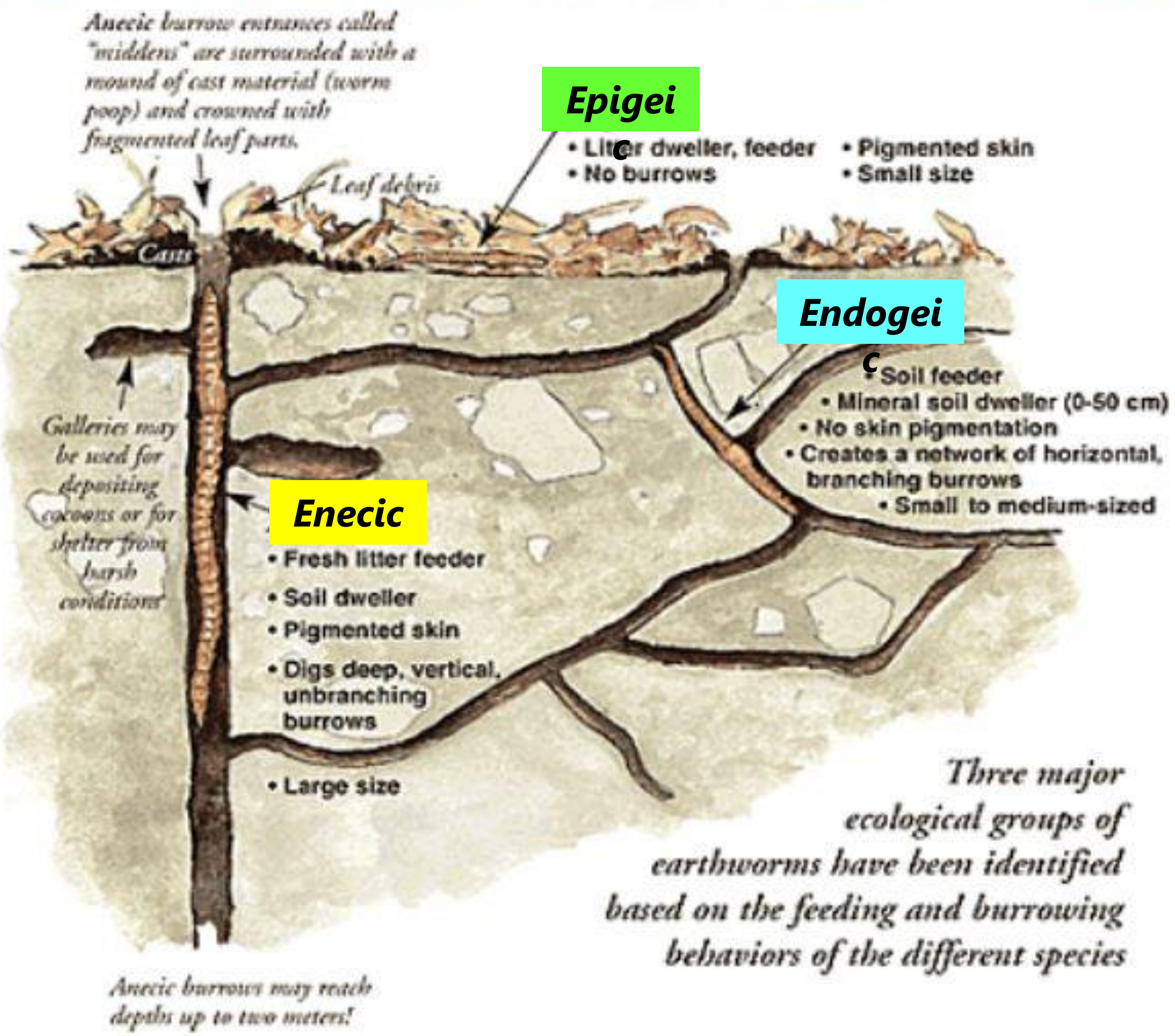
We must manage to enhance them

Ingham et al. 1985; Jones 2016; Lehman et al. 2016; Montgomery 2017



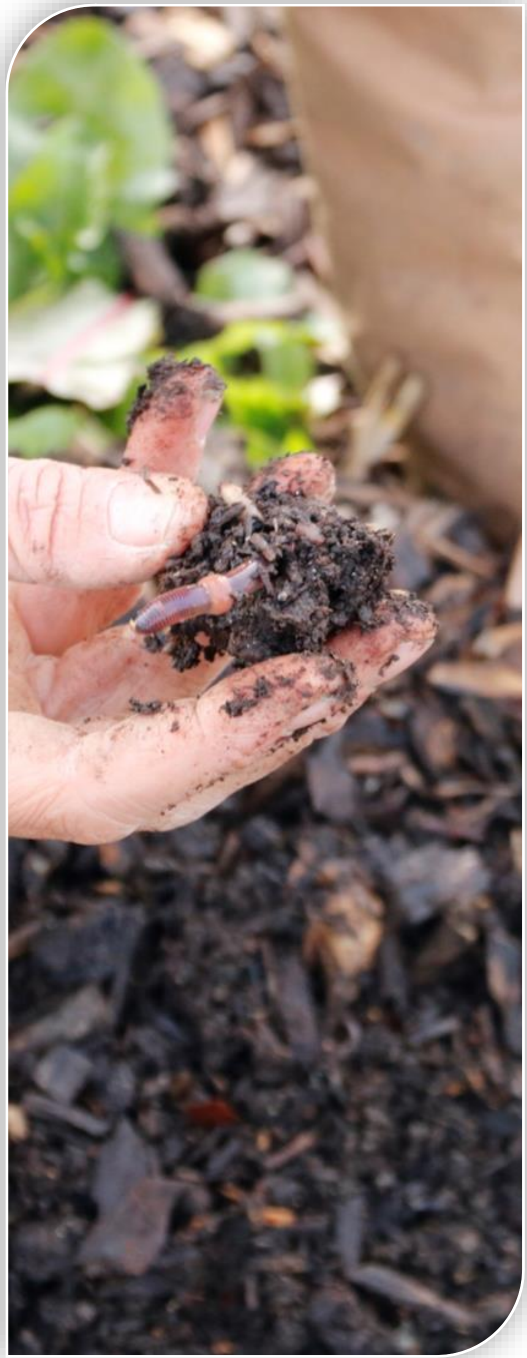
Earthworms in the ecosystem

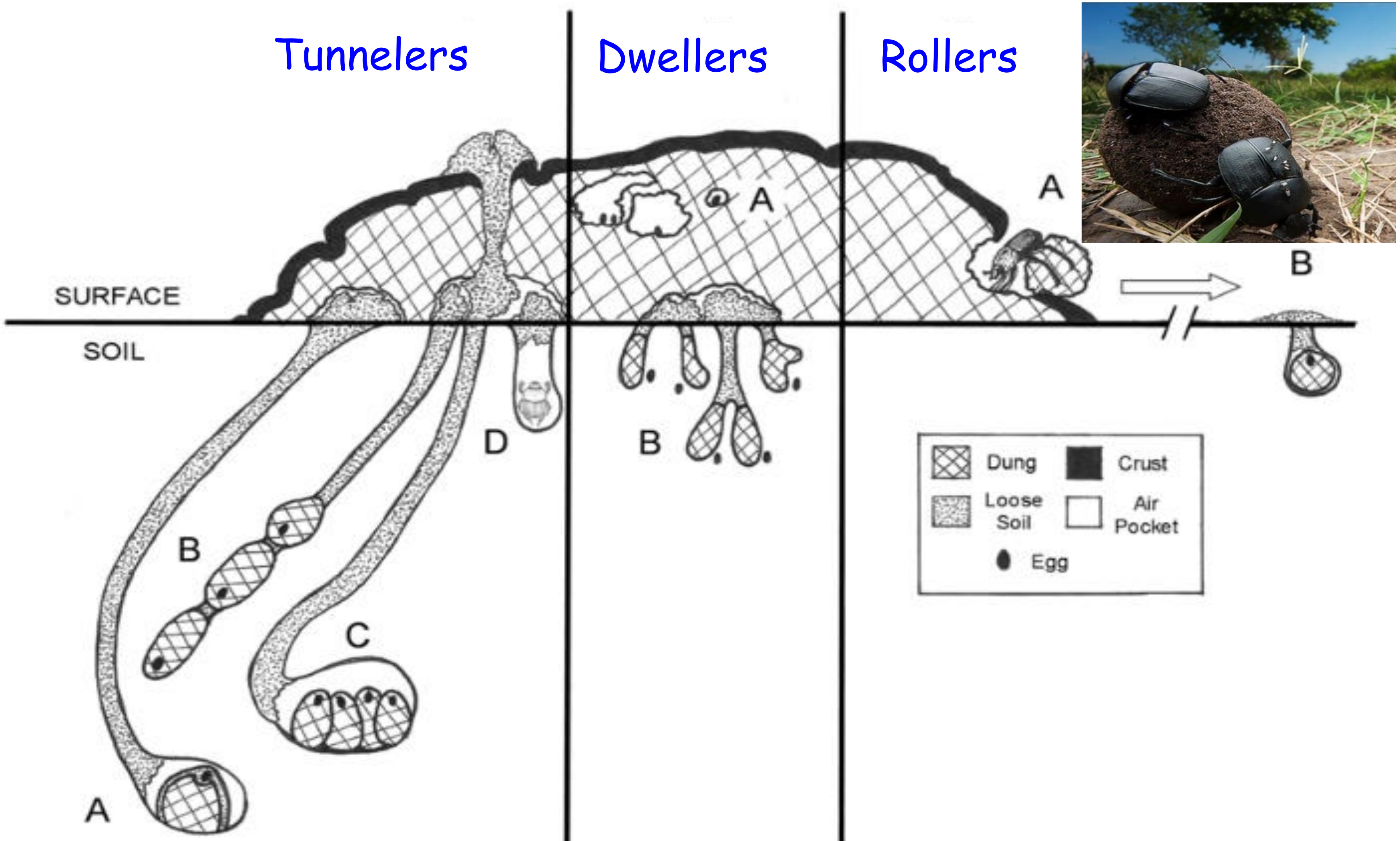




Wardle & Bardgett 2004; Blouin *et al.* 2013

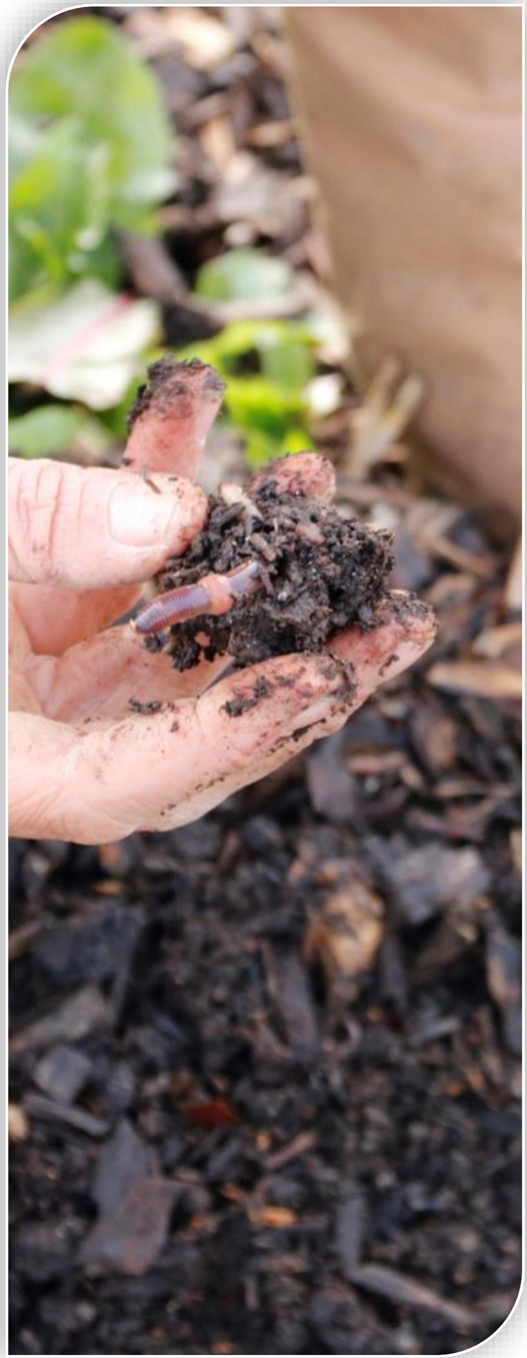
Dung beetles in the Ecosystem



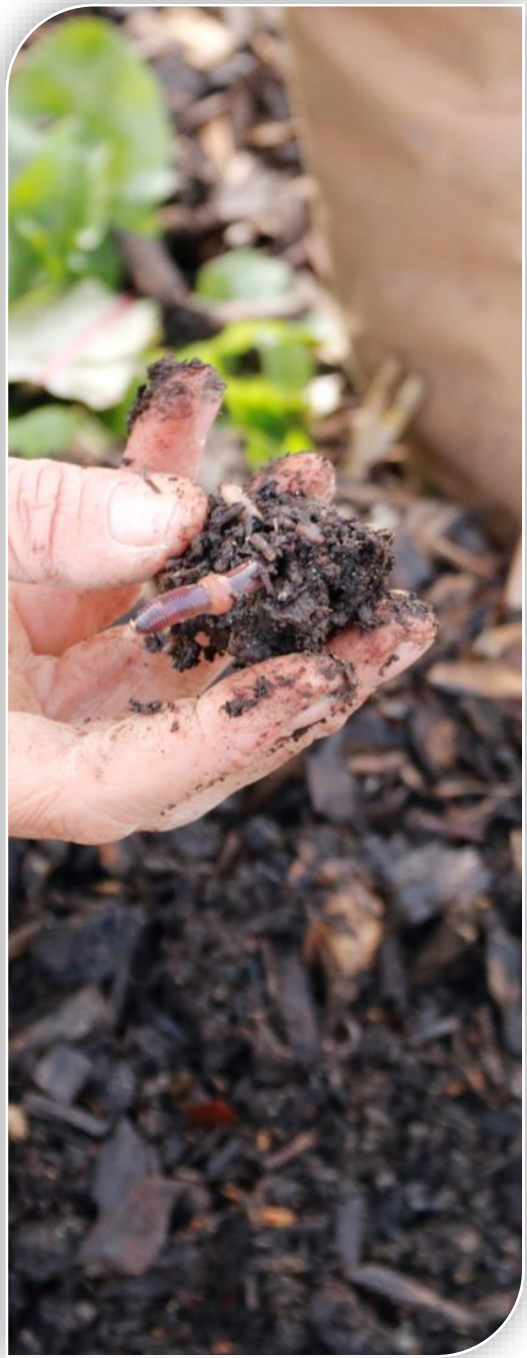


- 200 cows drop 25 tons of dung a week
- Increase infiltration ~ 130%

Herrick and Lal 1995;
Richardson *et al.* 2000

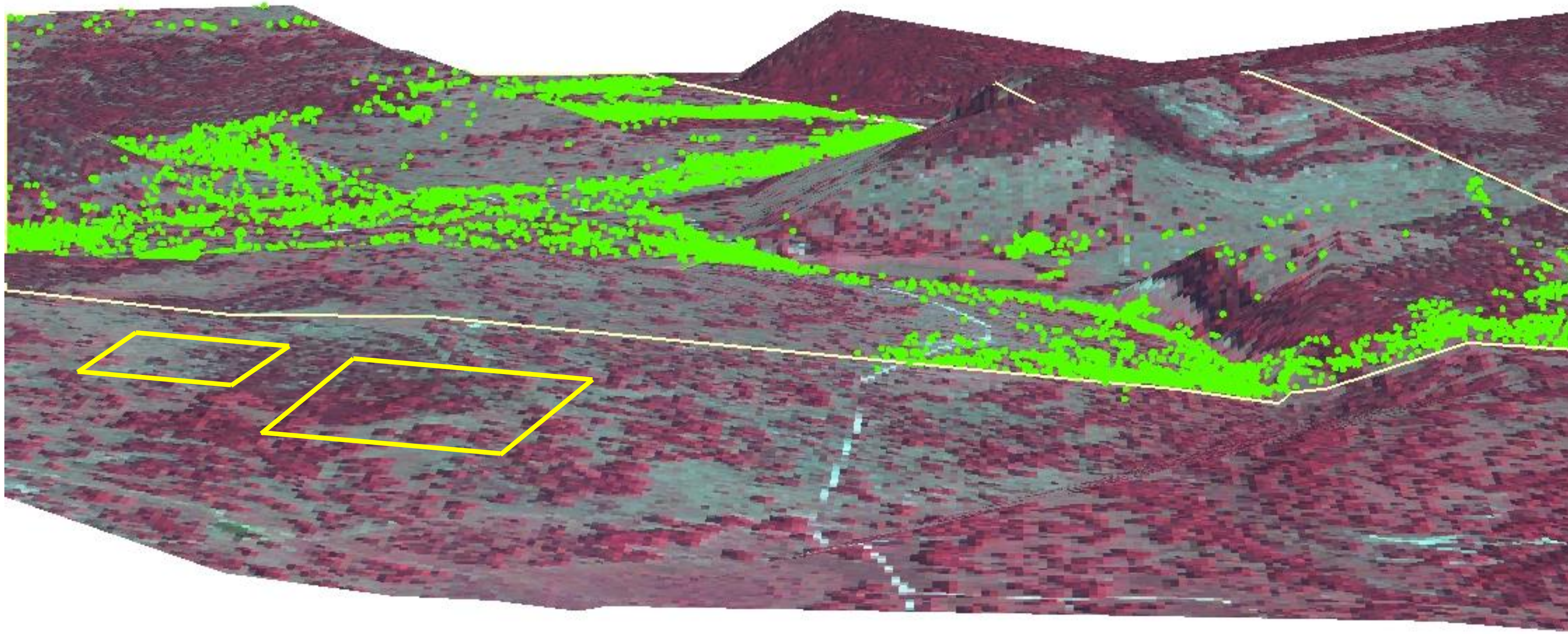


Research Results

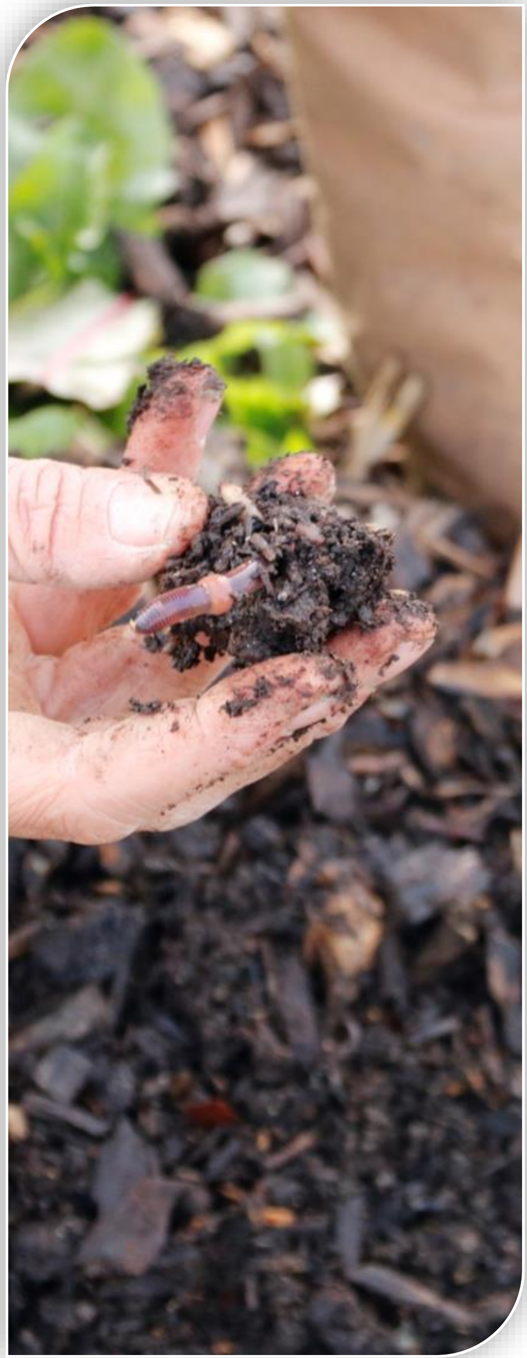


Landscape impact of continuous grazing

1. **39% area used**
2. **41% GPS points on 9% area**
3. **SR: 21 ac/cow**
4. **Effective SR: 9 ac/cow**

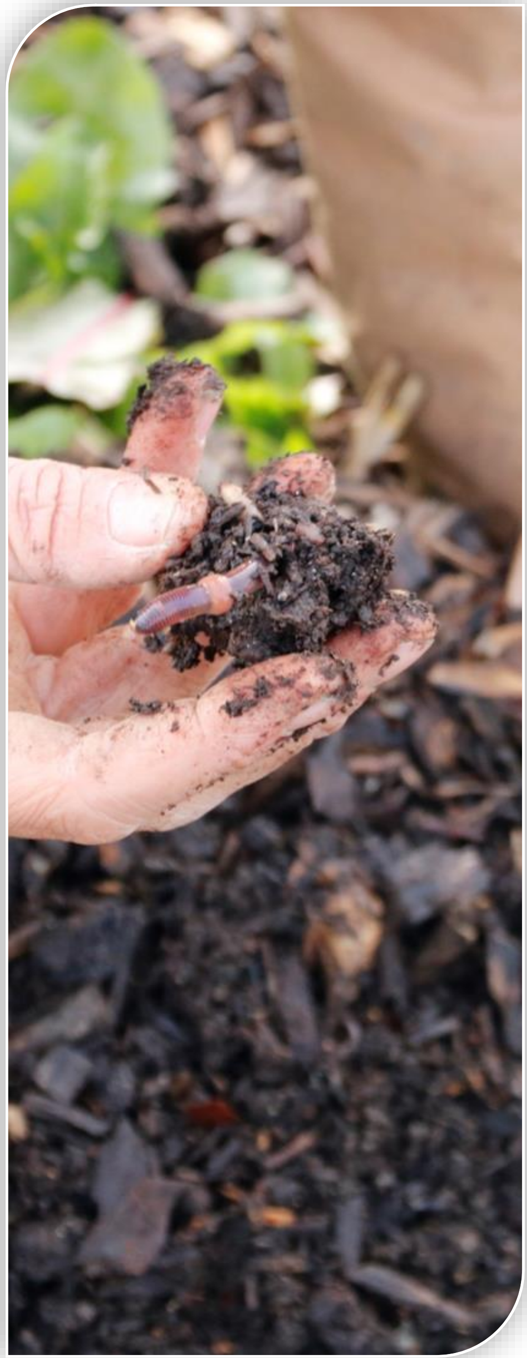


Norton 1998; Norton et al. 2013; Jakoby et al. 2014



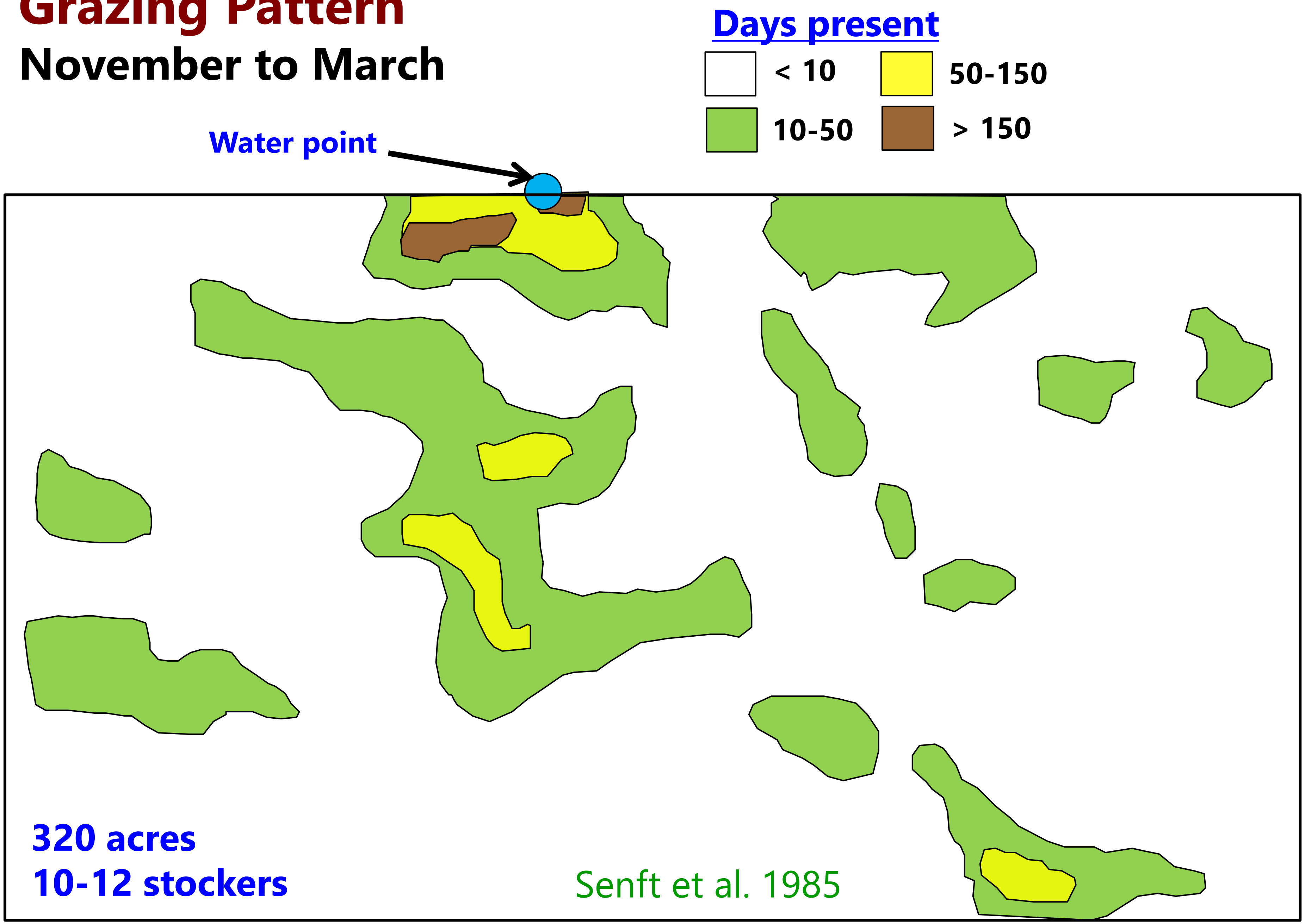

Light continuous grazing
•patch selection
•no recovery

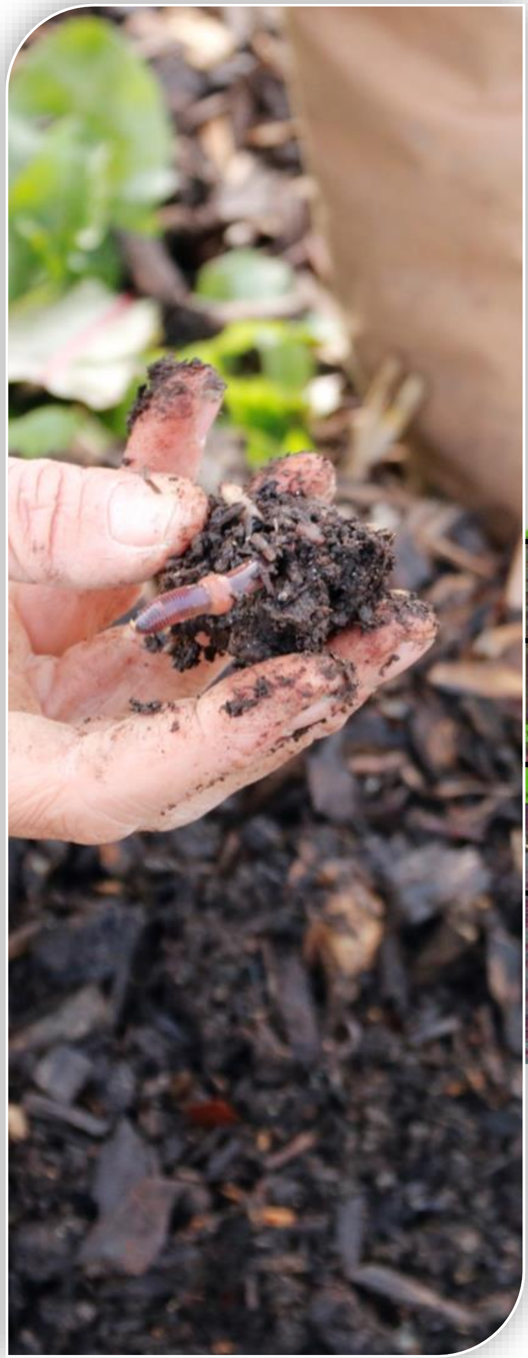

Heavy continuous grazing



Grazing Pattern

November to March

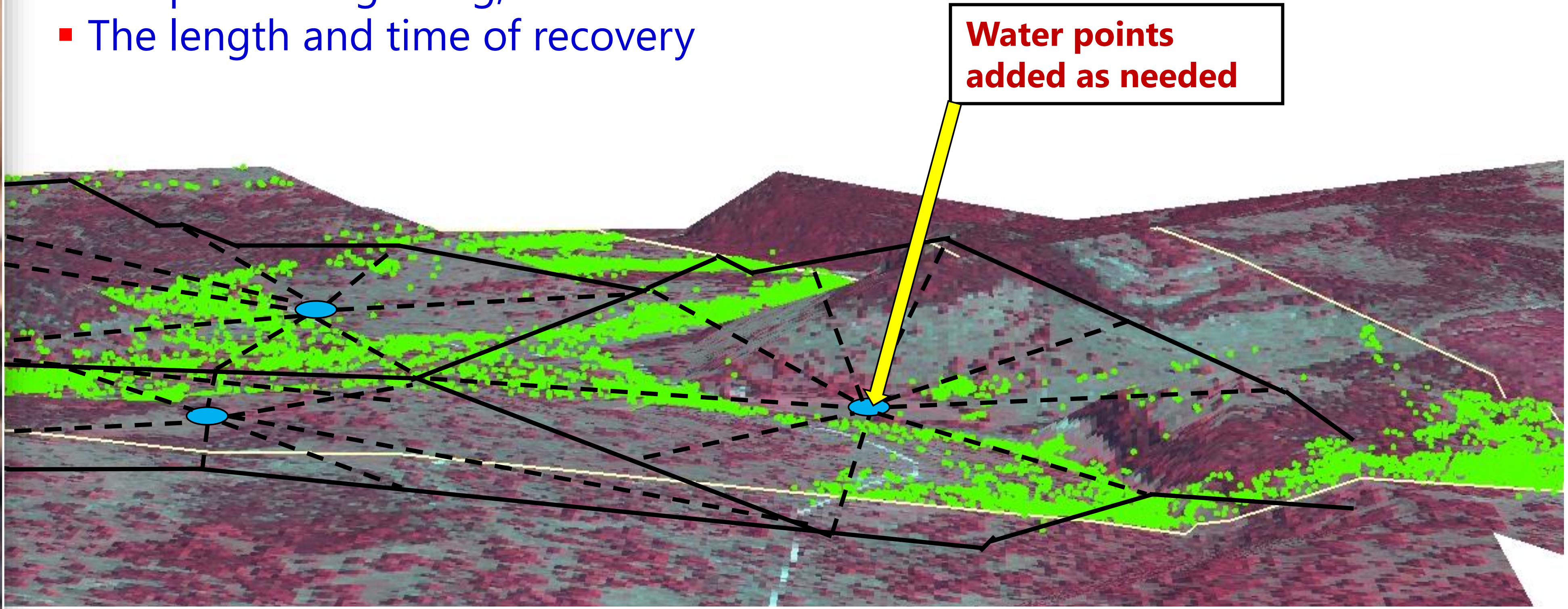




Adaptive Multi-Paddock (AMP) grazing

Manager can control:

- How much is grazed
- The period of grazing, and
- The length and time of recovery

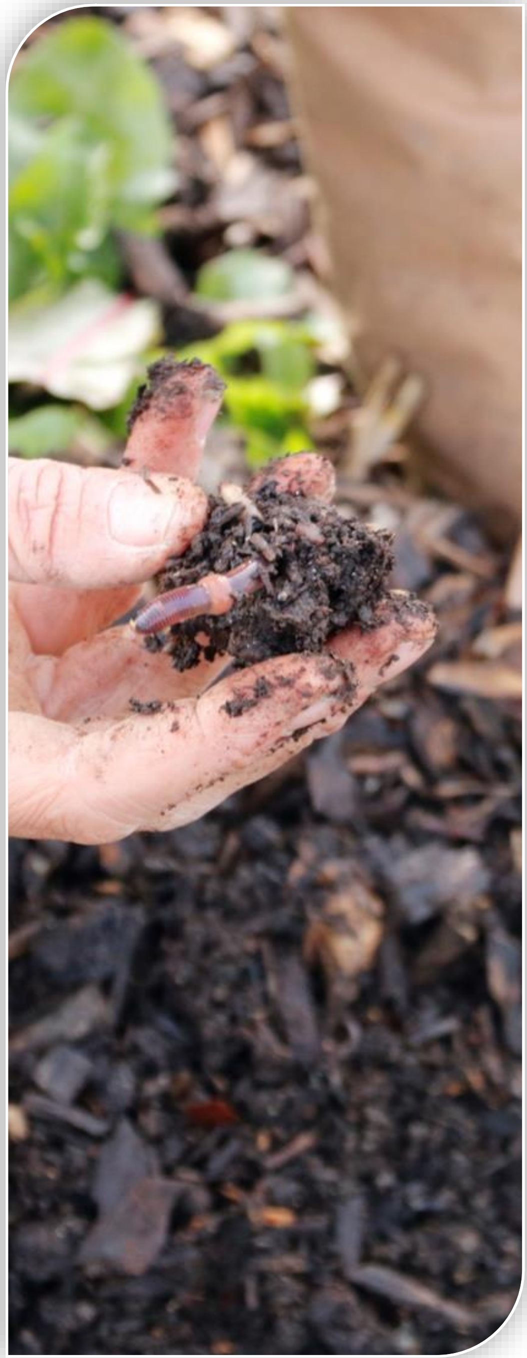


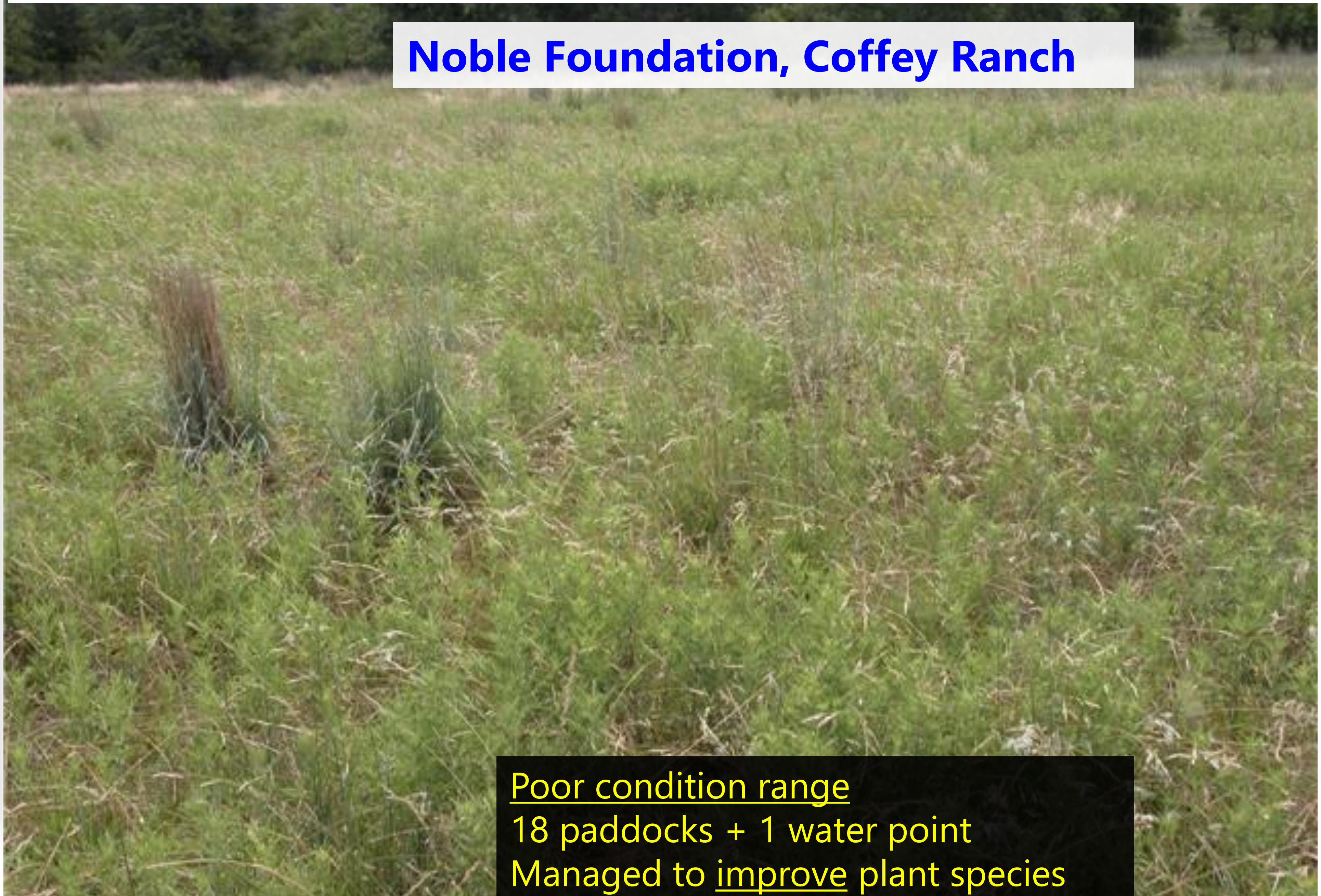
Animals:

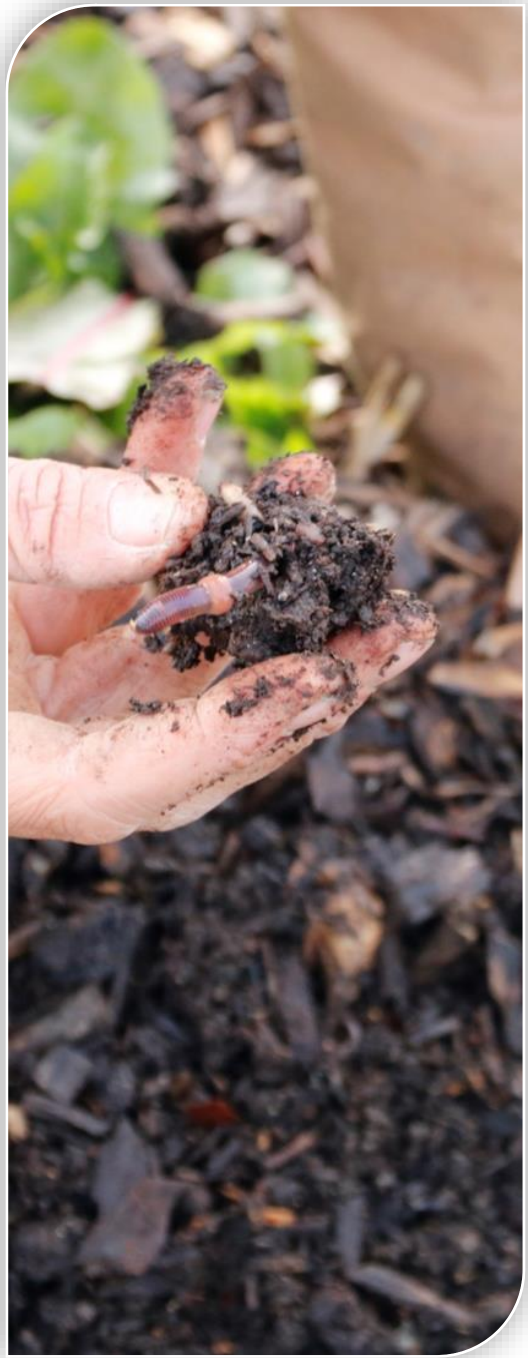
- Graze more of the whole landscape, one paddock at a time
- Select a wider variety of plant species

Norton et al. 2013; Jakoby et al. 2014; Teague et al. 2015

Regenerative Grazing



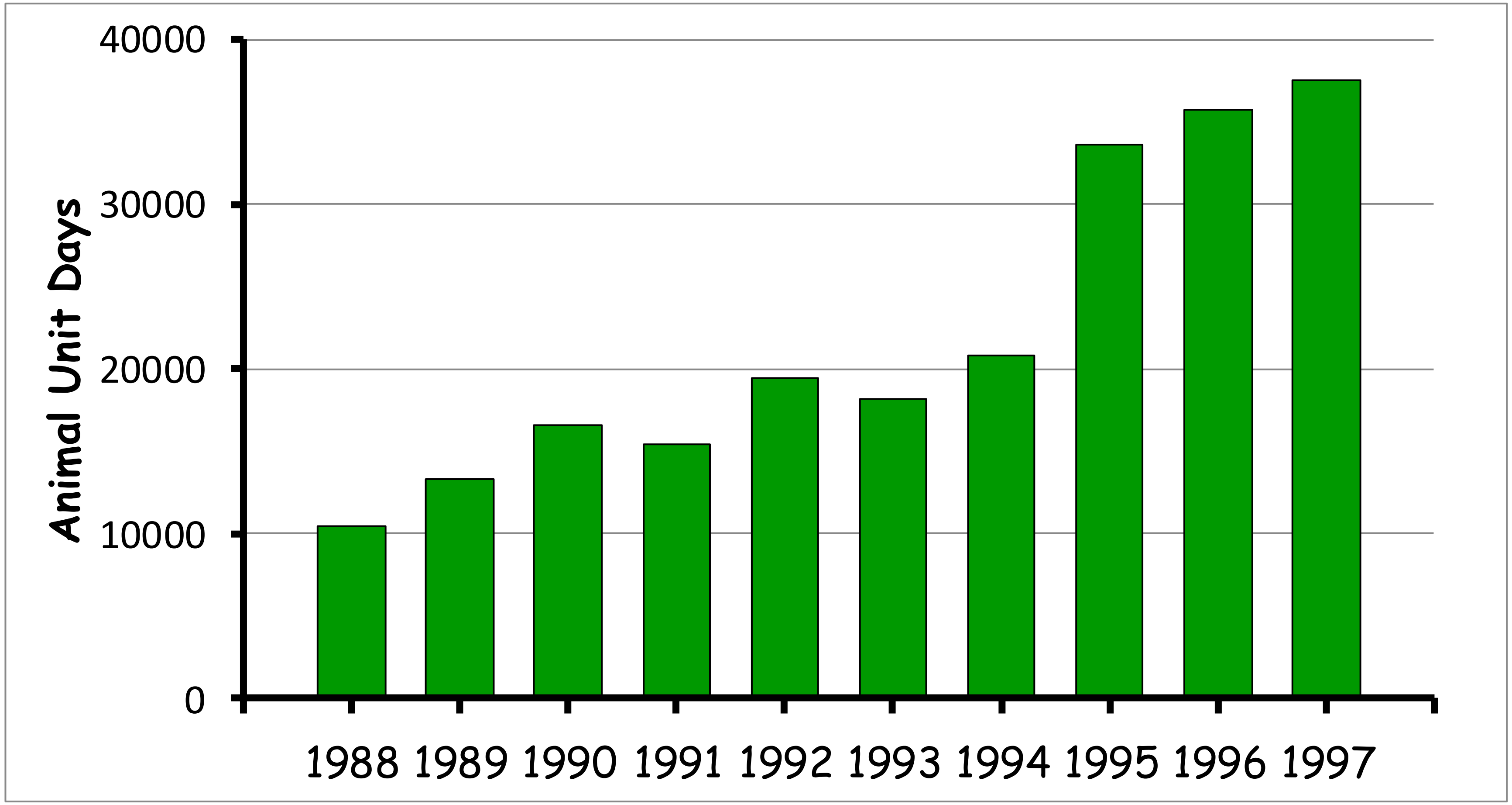


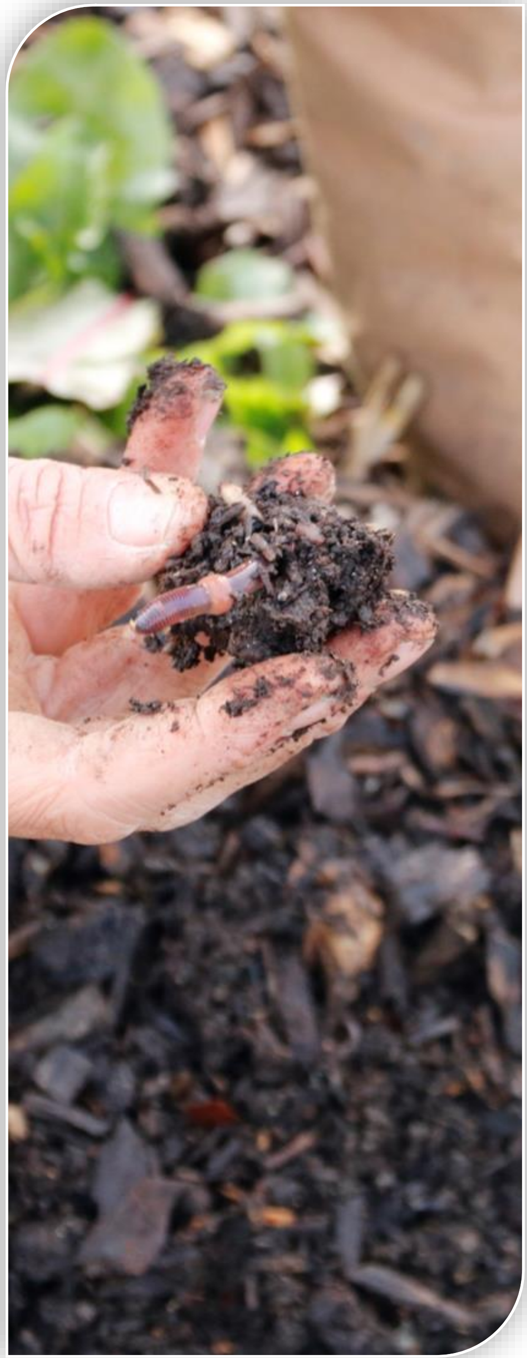


Regenerative Grazing

Noble Foundation, Coffey Ranch

Charles Griffith, Hugh Aljoe, Russell Stevens

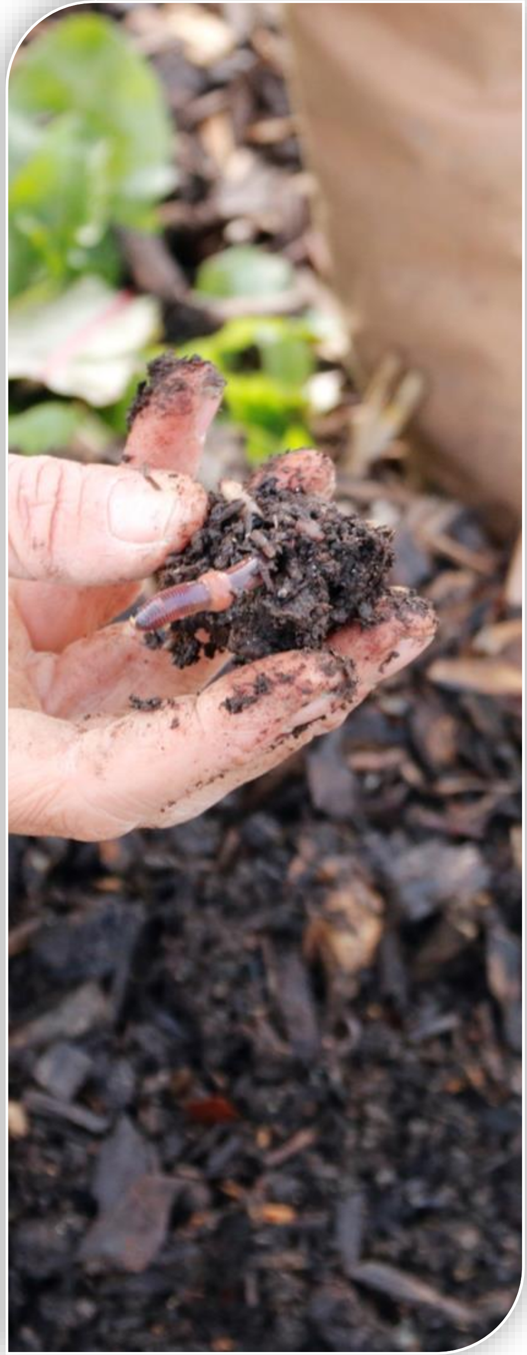




Managing AMP Grazing for Best Results

- Aim to improve ecological function to increase profits
- Flexible stocking to match forage availability and animal numbers
- Spread grazing over whole ranch, by grazing one paddock at a time
- Defoliate moderately in growing season
- Use short grazing periods
- Adequate recovery before regrazing
- Adjust as forage growth rates change

Norton et al. 2013; Jakoby et al. 2014; Teague et al. 2013; 2015



Hypothesized Causal Mechanisms:

AMP Grazing

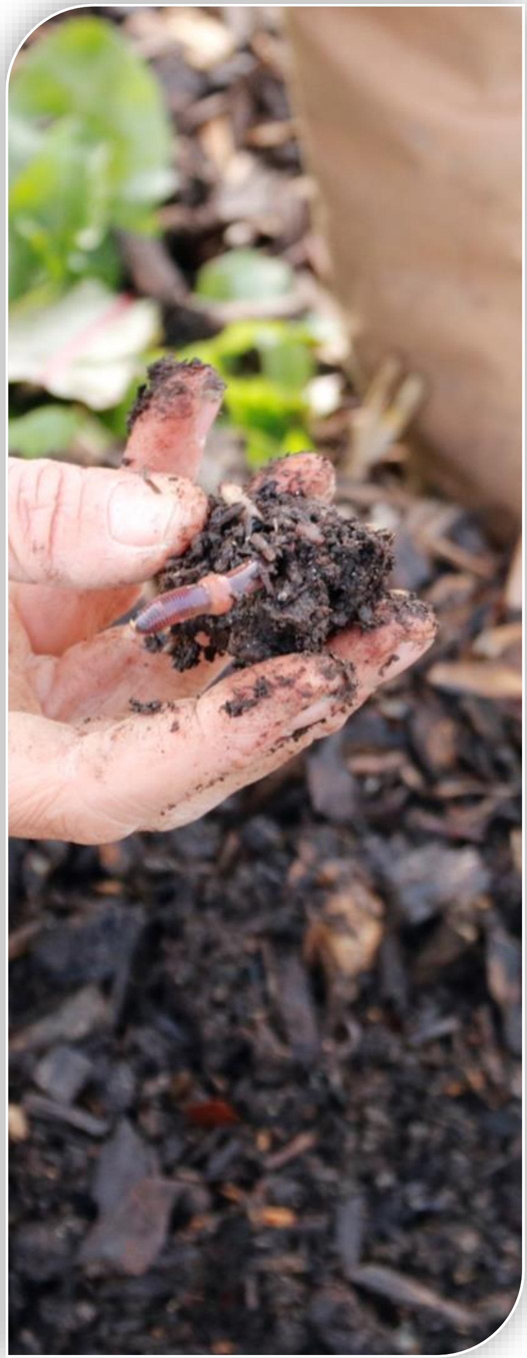
Light continuous grazing

No-grazing

Continuous grazing

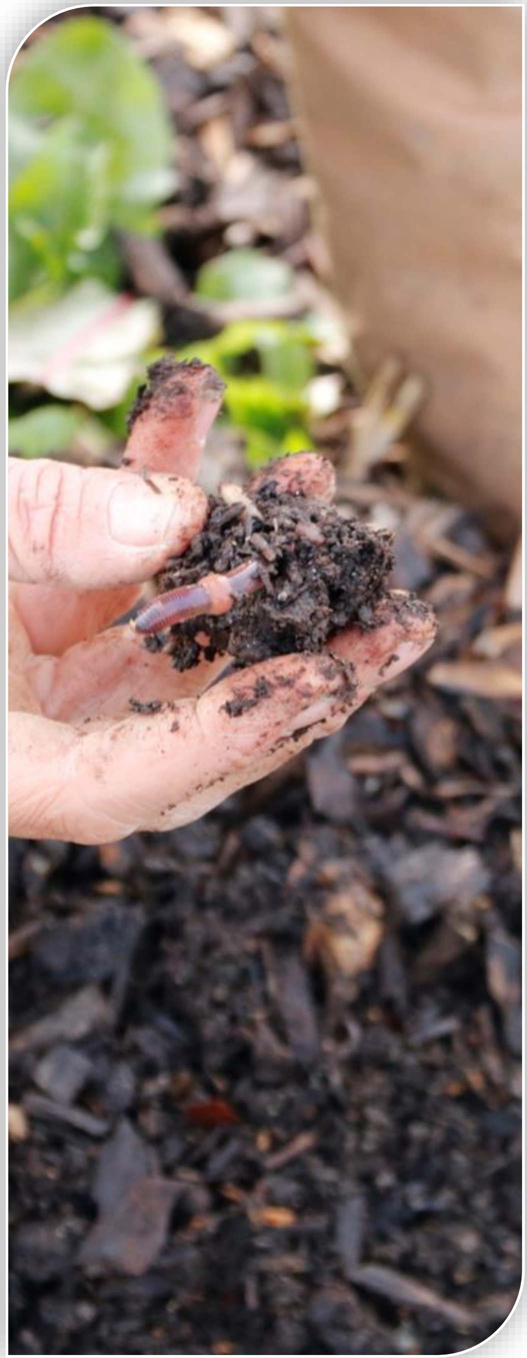
Energy Flow
Water Cycle
Mineral Cycle
Soil/Plant Diversity

Savory and Butterfield 2016; Massy 2018



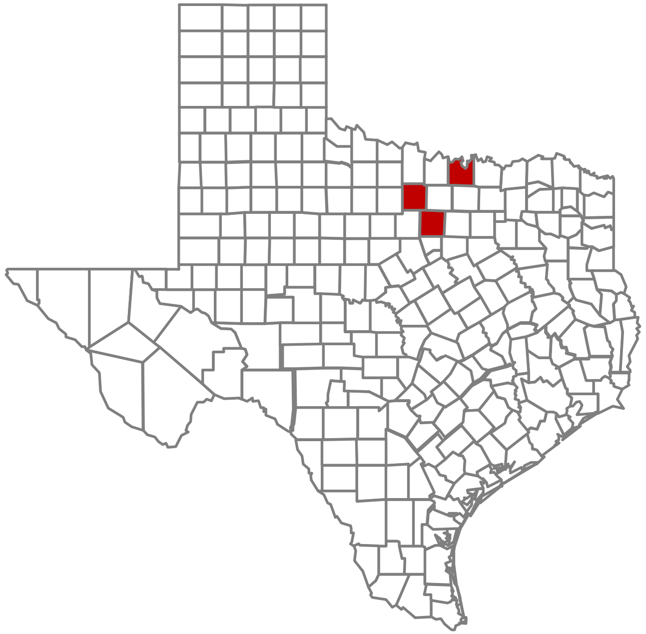
How grazing strategy impacts ecological processes

Ecological processes	Grazing management strategies			
	AMP	Moderate continuous	Heavy continuous	No grazing
Energy flow	Very high	Low	Low	Very low
Hydrology	High	Good	Poor	High
Mineral cycling	Very high	Low	Low	Very low
Community dynamics	Very high	Moderate	Poor	Very poor

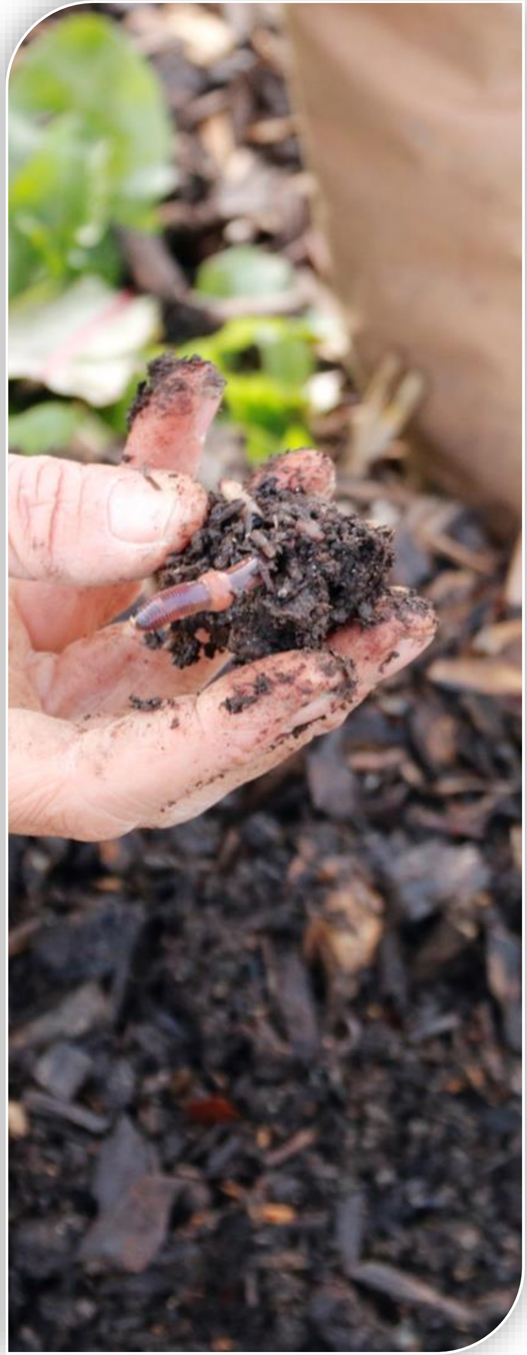


Initial Texas Grazing Research

- AMP grazing gave 3 tC/ha/year ***more*** than usual heavy Continuous grazing
- Improved plant species composition
- Improved soil fungi to bacteria ratio
- Improved soil water holding capacity
- Enhanced plant productivity
- Decreased bare ground
- Improved soil fertility
- Increased livestock production

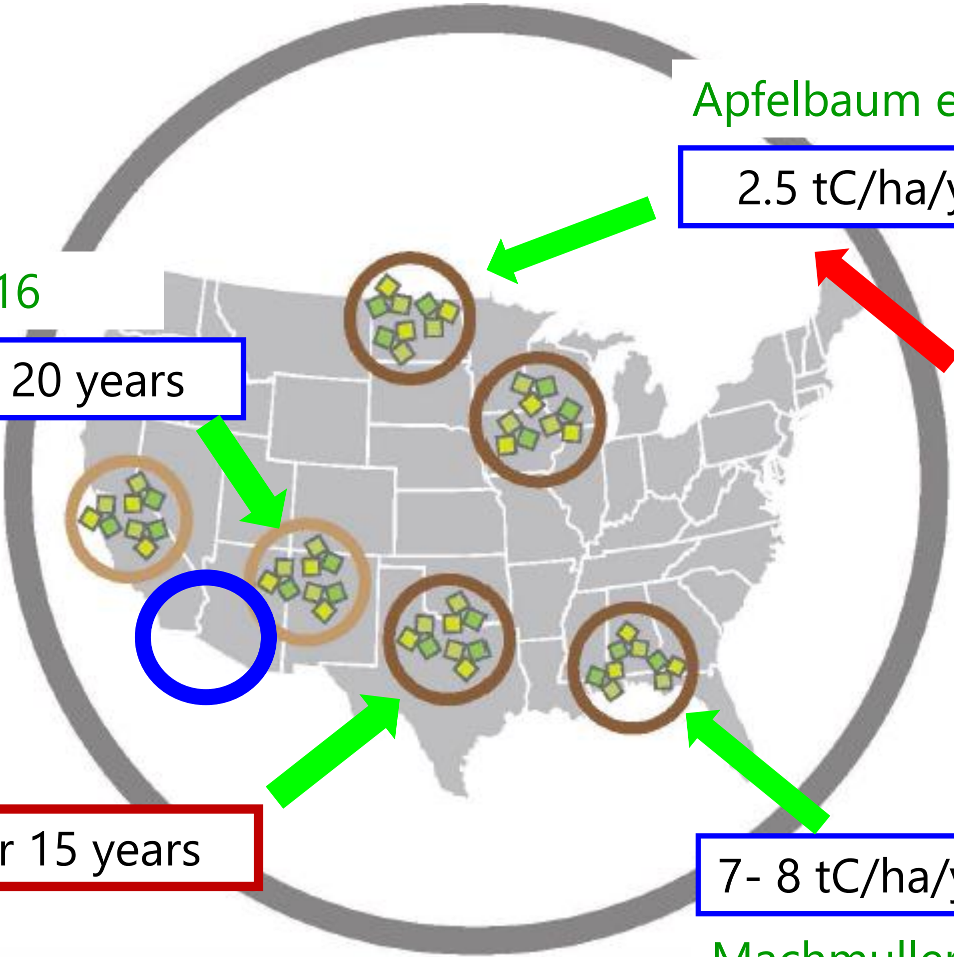


Teague et al. 2011



Published & Reconnaissance Sampling

AMP had higher C gain/year than continuous grazing neighbors



Apfelbaum et al. 2016

2.5 tC/ha/yr over 20 years

Apfelbaum et al. 2016

< 0.5 tC/ha/yr over 20 years

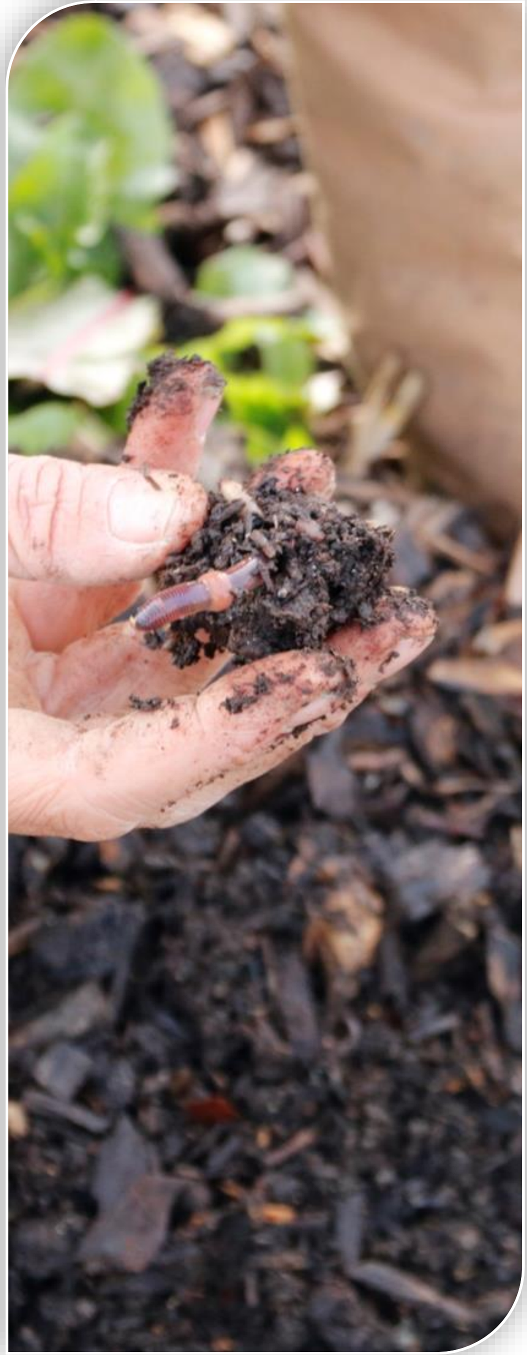
CO_2 Isotope Sampling
3.0 tC/Ha/yr

3 tC/ha/yr over 15 years

Wang et al. 2015

7- 8 tC/ha/yr over 5 years

Machmuller et al. 2015;
Williams et al. 2017



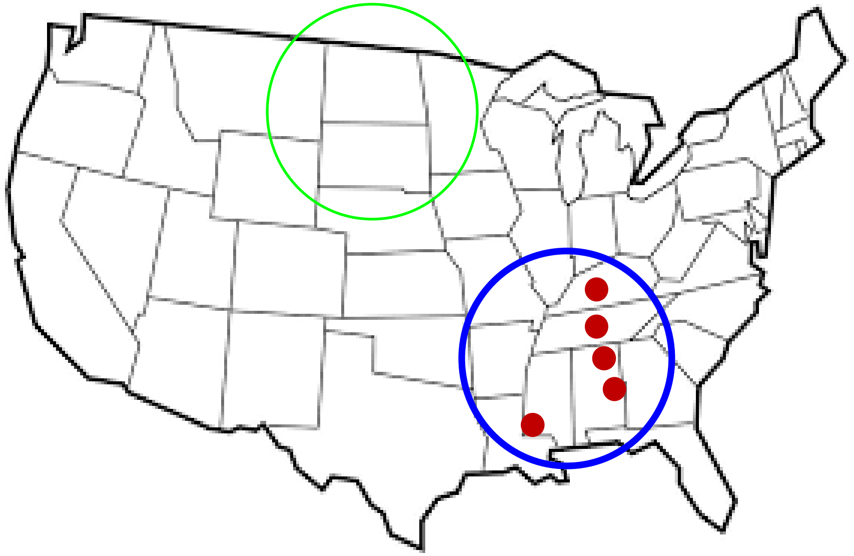
Soil Carbon

Infiltration

Vegetation sampling

GHG Sampling

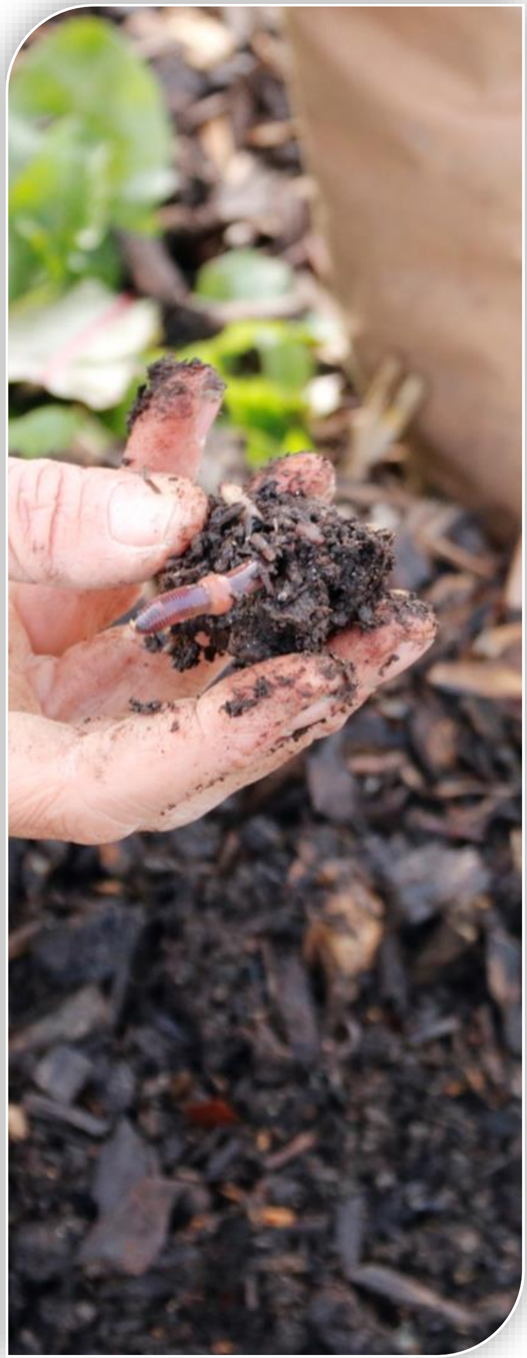
CO_2 fluxes

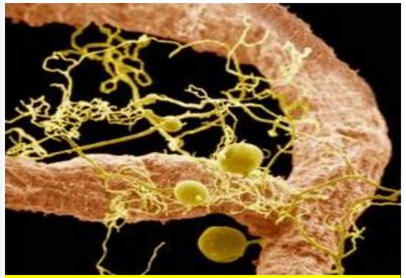


Microbiota DNA

CO_2 Isotope Fluxes

Soil and ecosystem biodiversity





Fungi

Bacteria

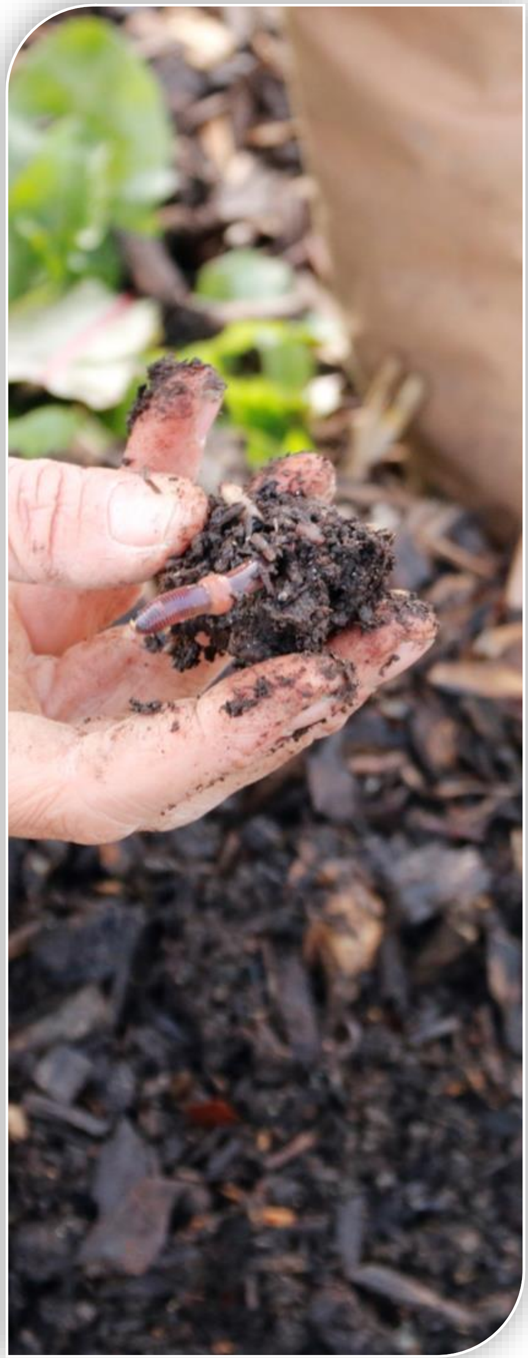
Earthworms

Does AMP grazing improve:

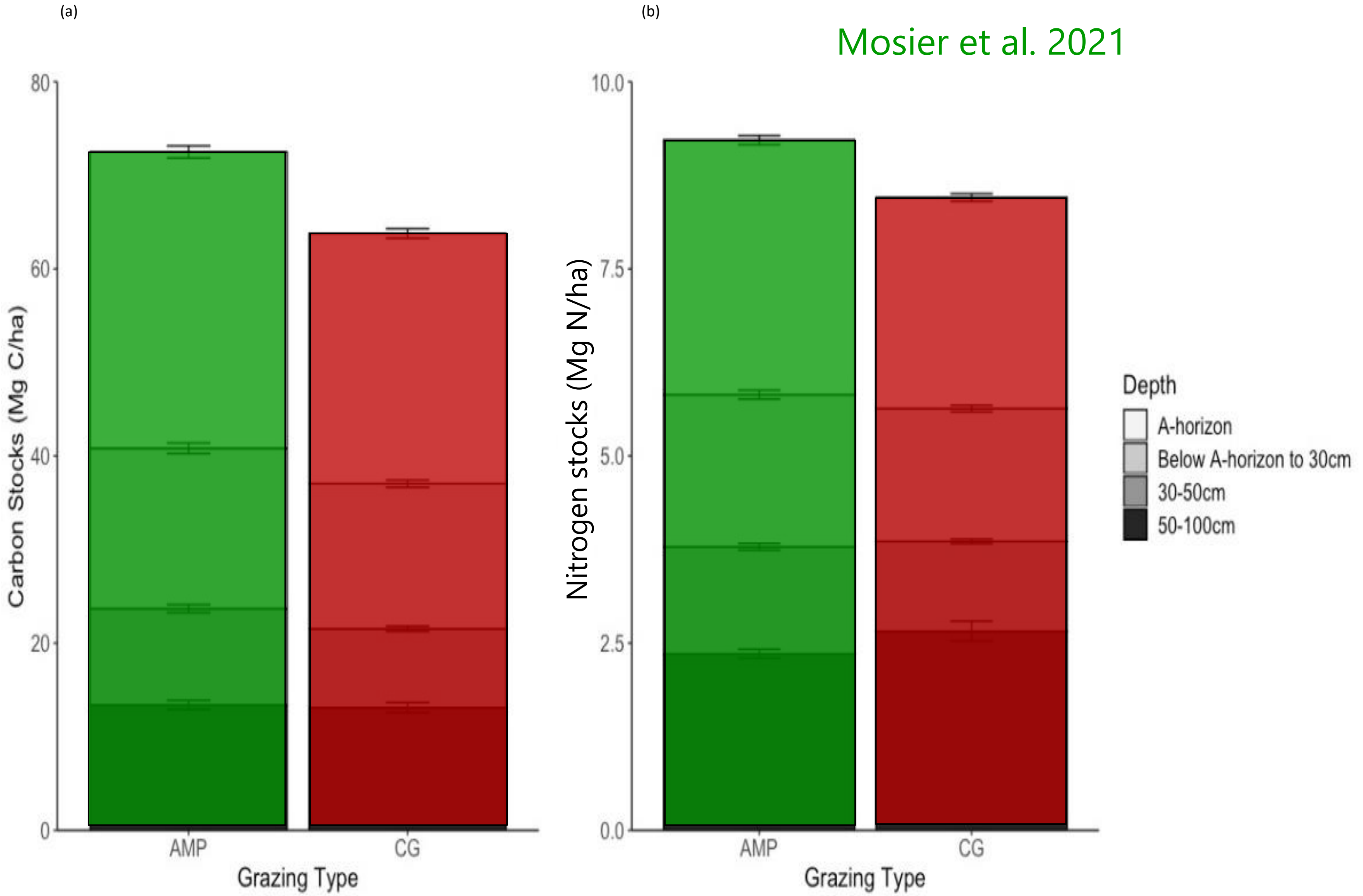
- function of soil biota;
- ecosystem biodiversity; and
- farmer livelihoods and well-being?

Dung beetles

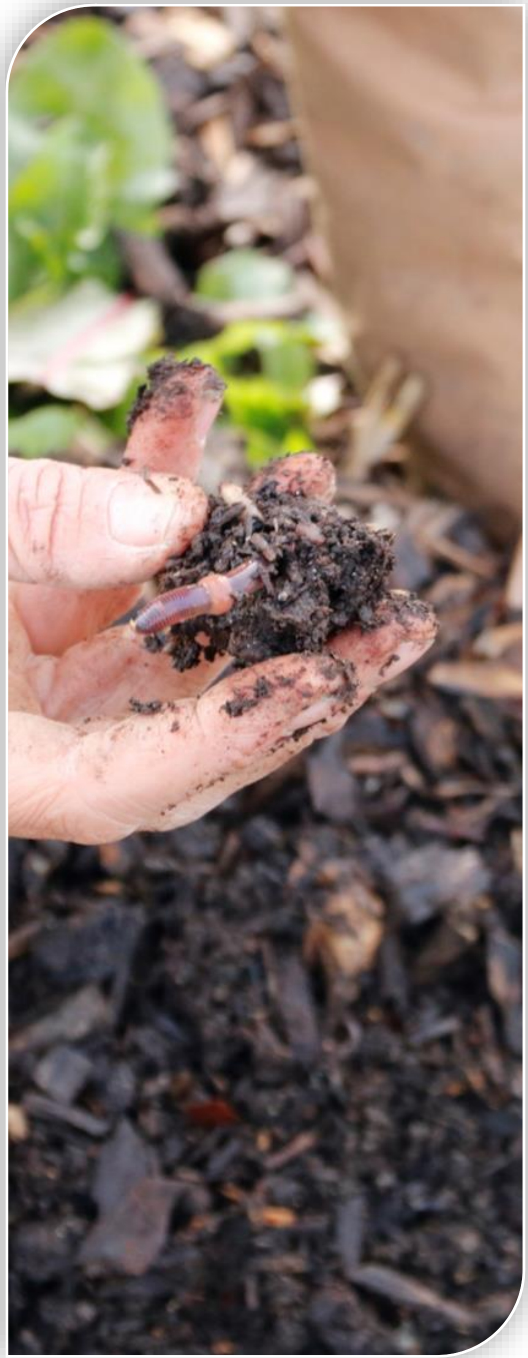
Ingham et al. 1985; Lehman et al. 2016; Lundgren, 2018



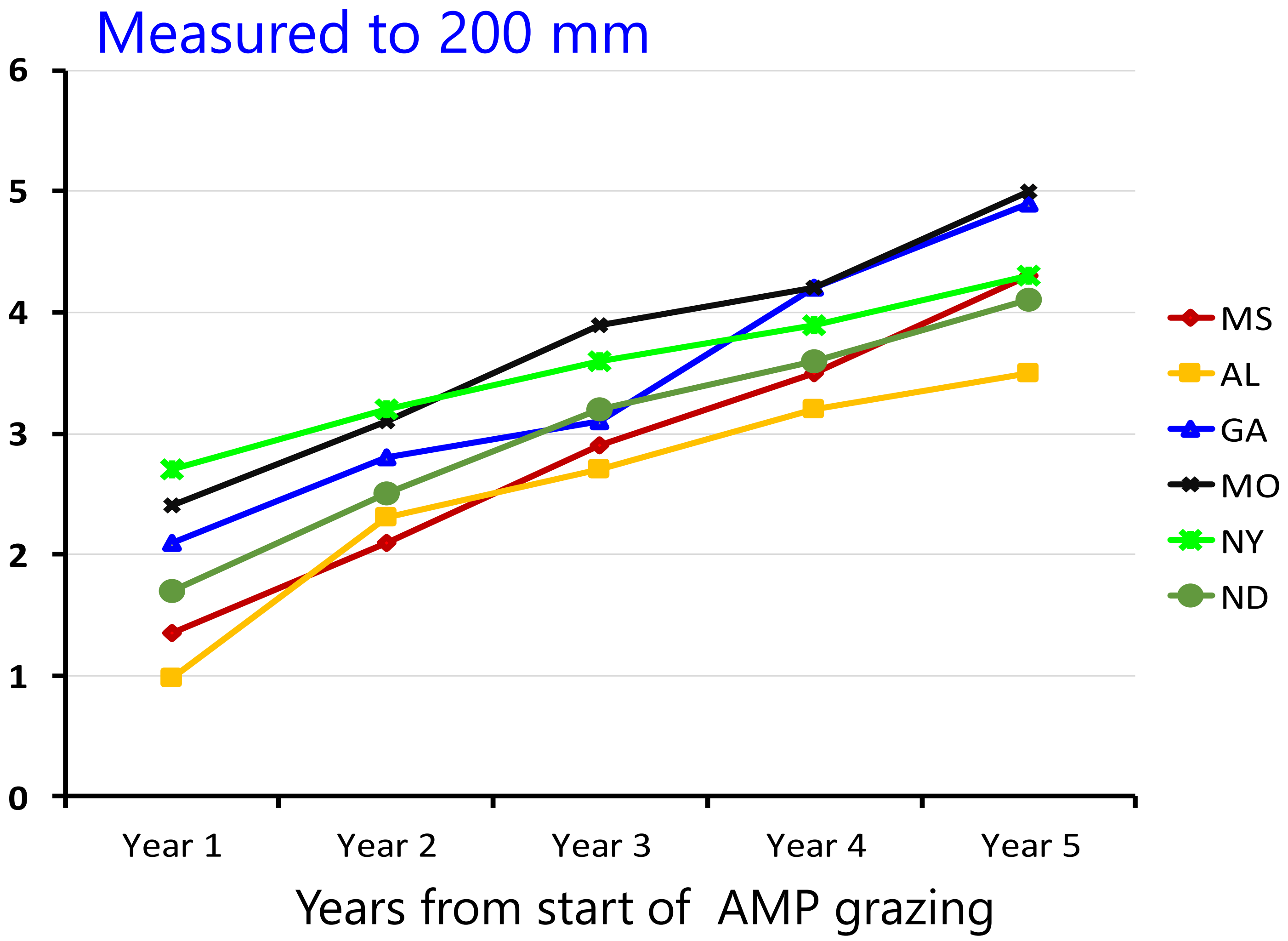
Total SOC and Soil N stocks to 1 meter



AMP increased the more persistent MAOM fraction at all depths

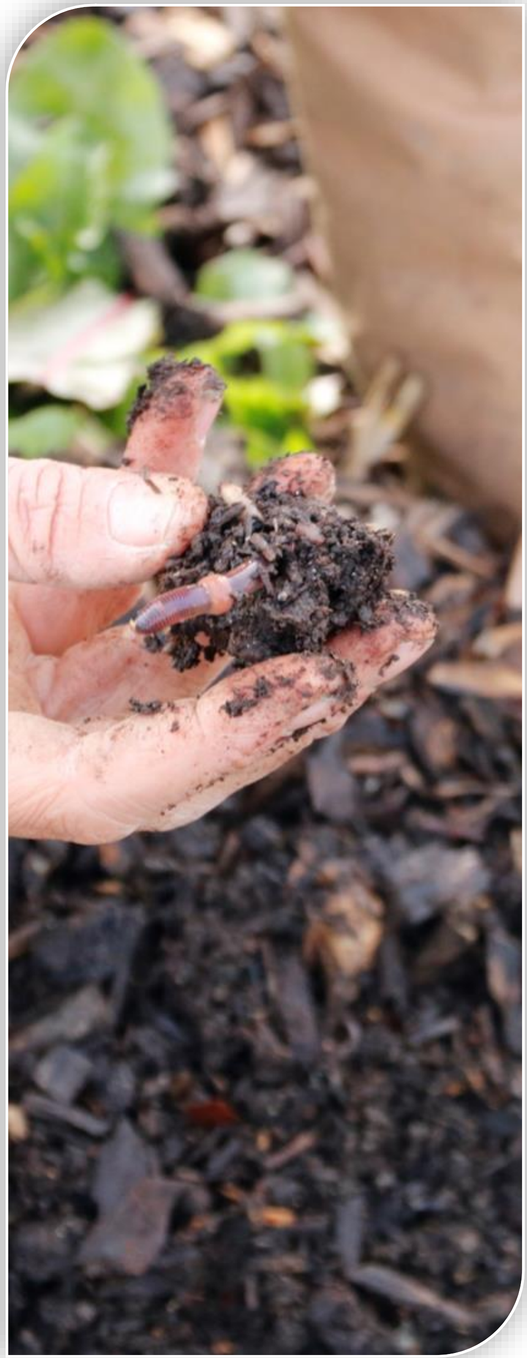


Building Soil Carbon Using AMP Grazing

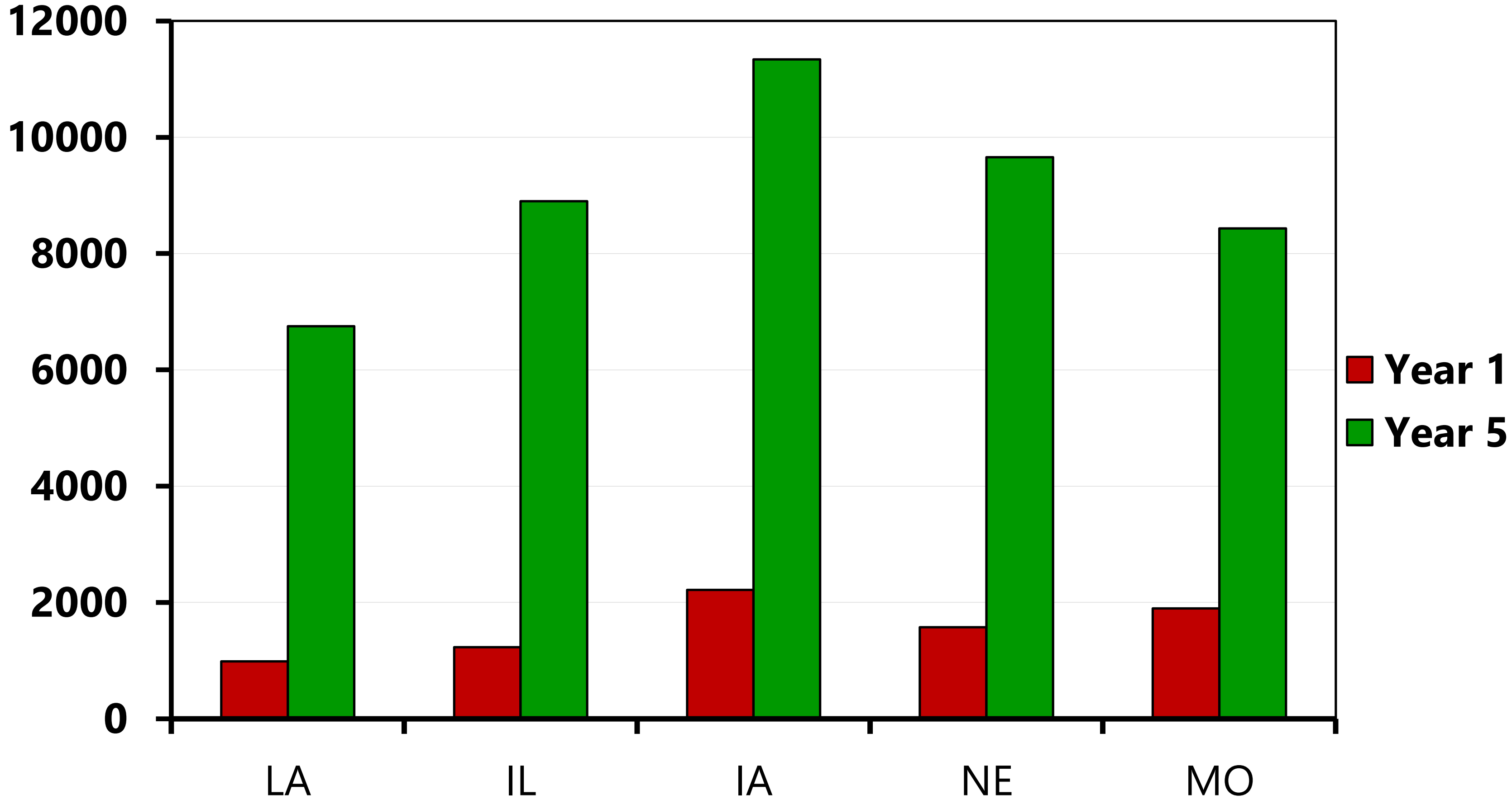


For 200 mm = mean ***increase*** of 8.6 tC ha^{-1} $year^{-1}$

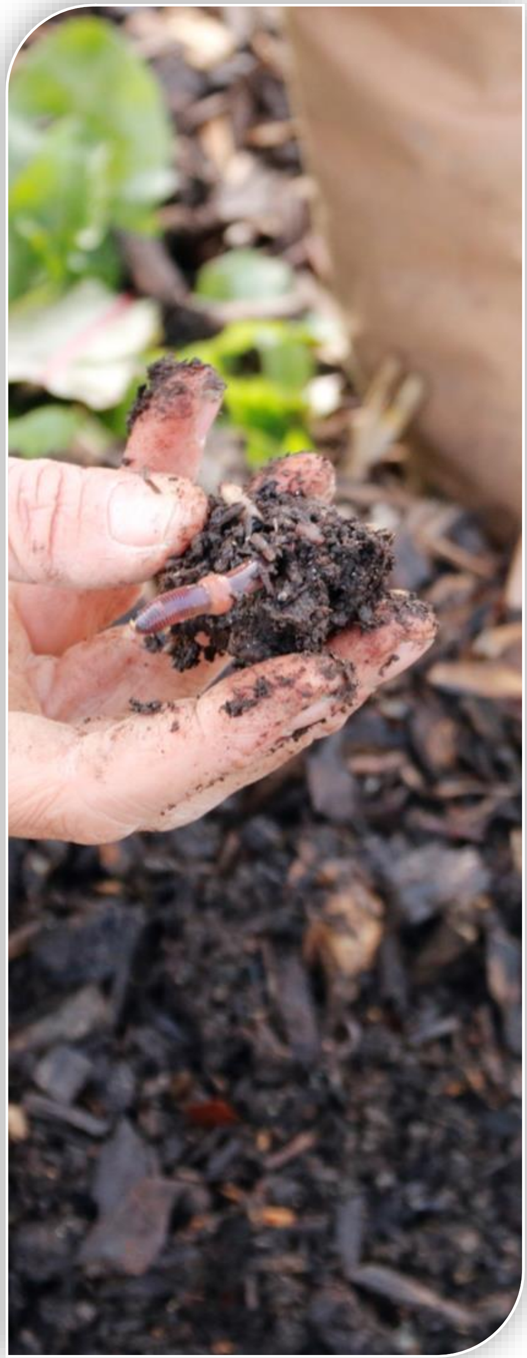
Williams et al. 2017



Building Microbial Biomass (ng/g of Soil)

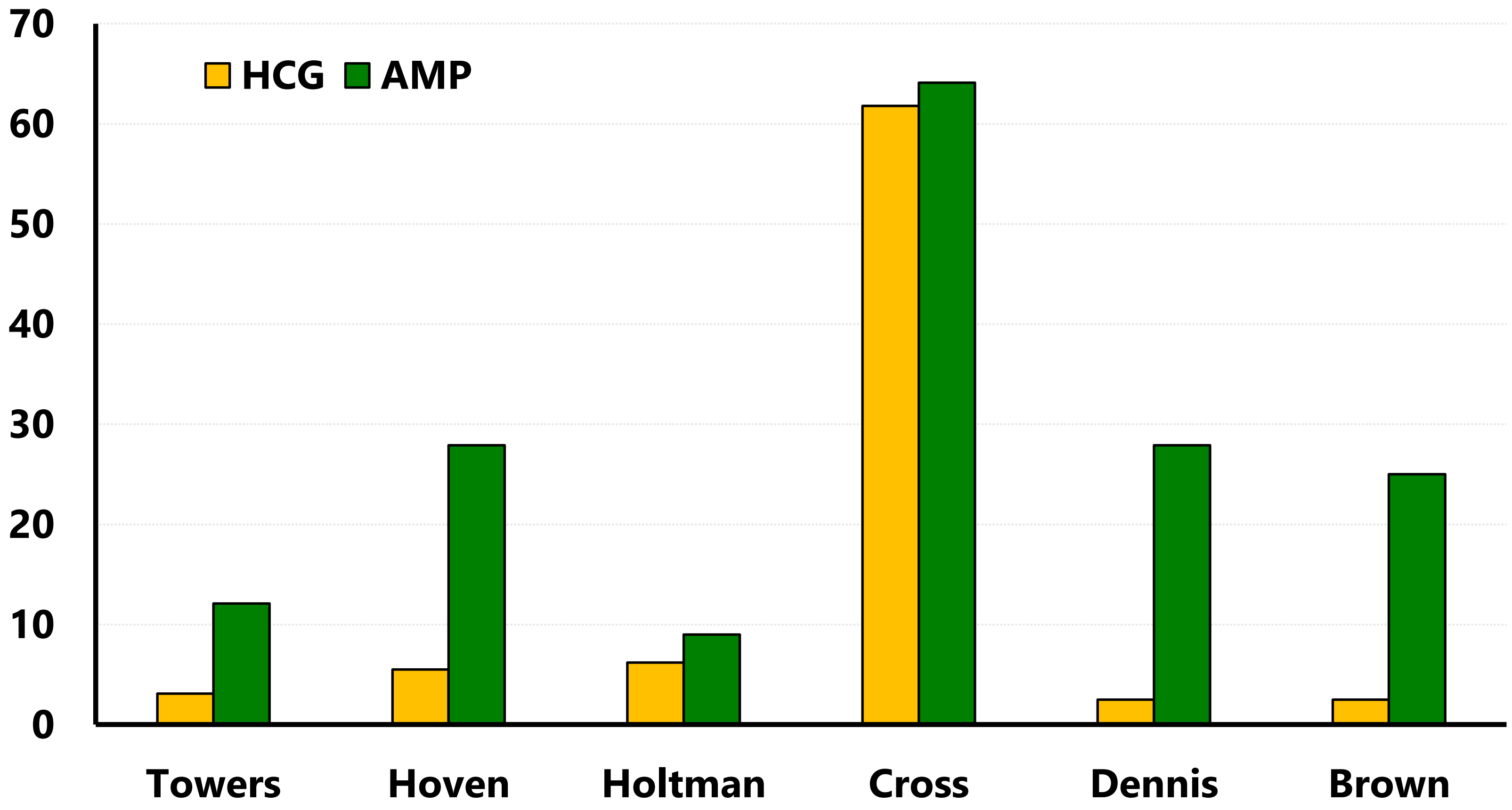


Williams et al. 2017

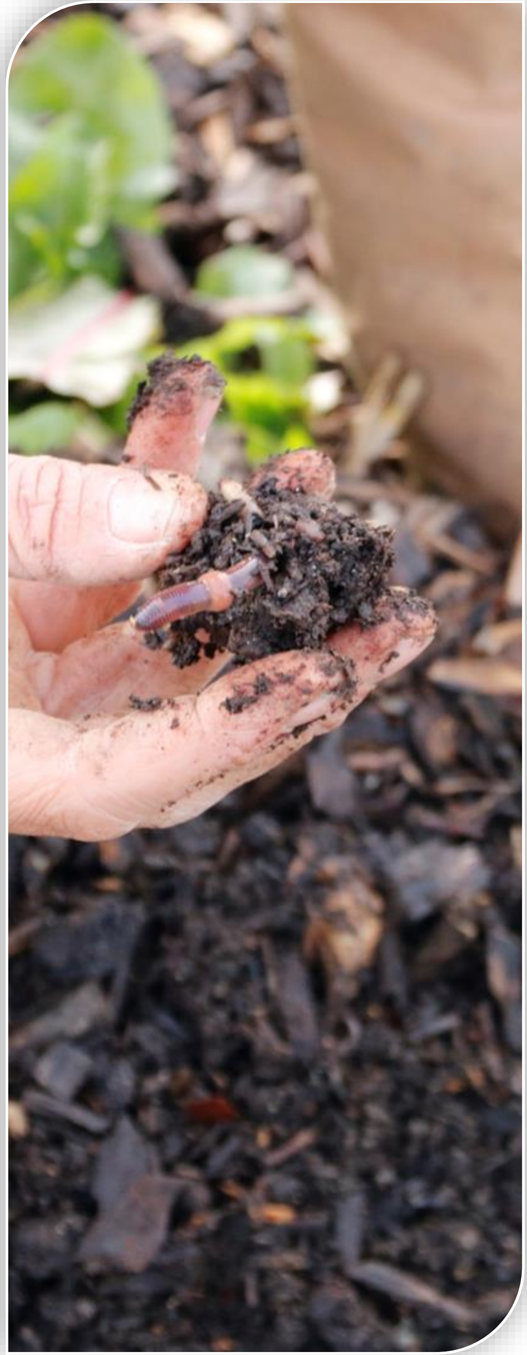


Infiltration on HCG vs. AMP grazing

Northern Great Plains



Apfelbaum et al 2016

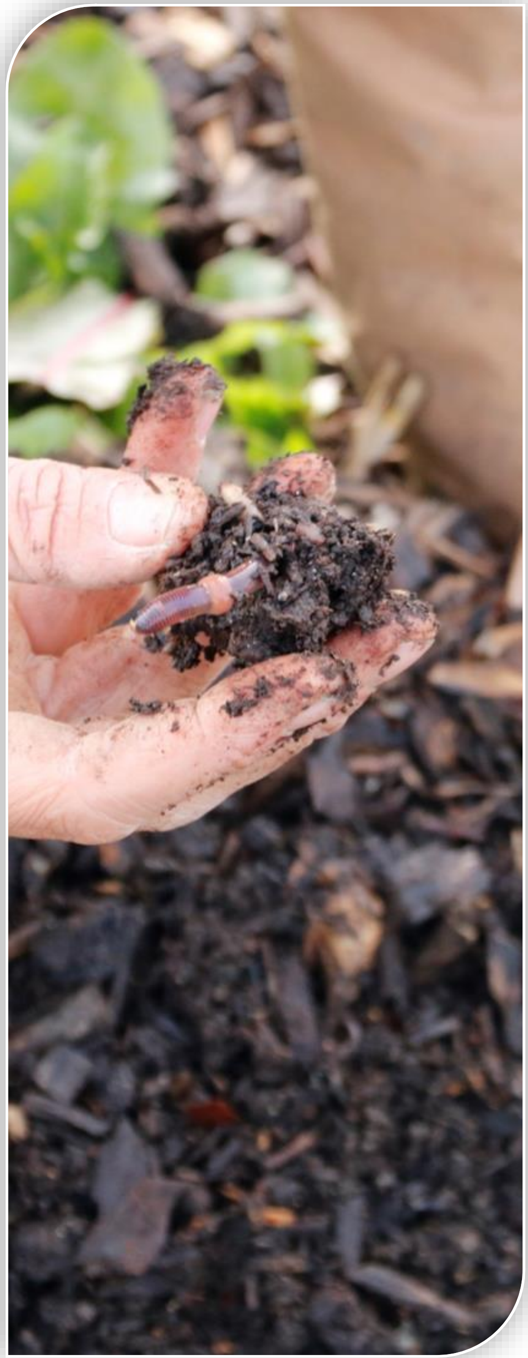


AMP Grazing on Converted Crop Fields

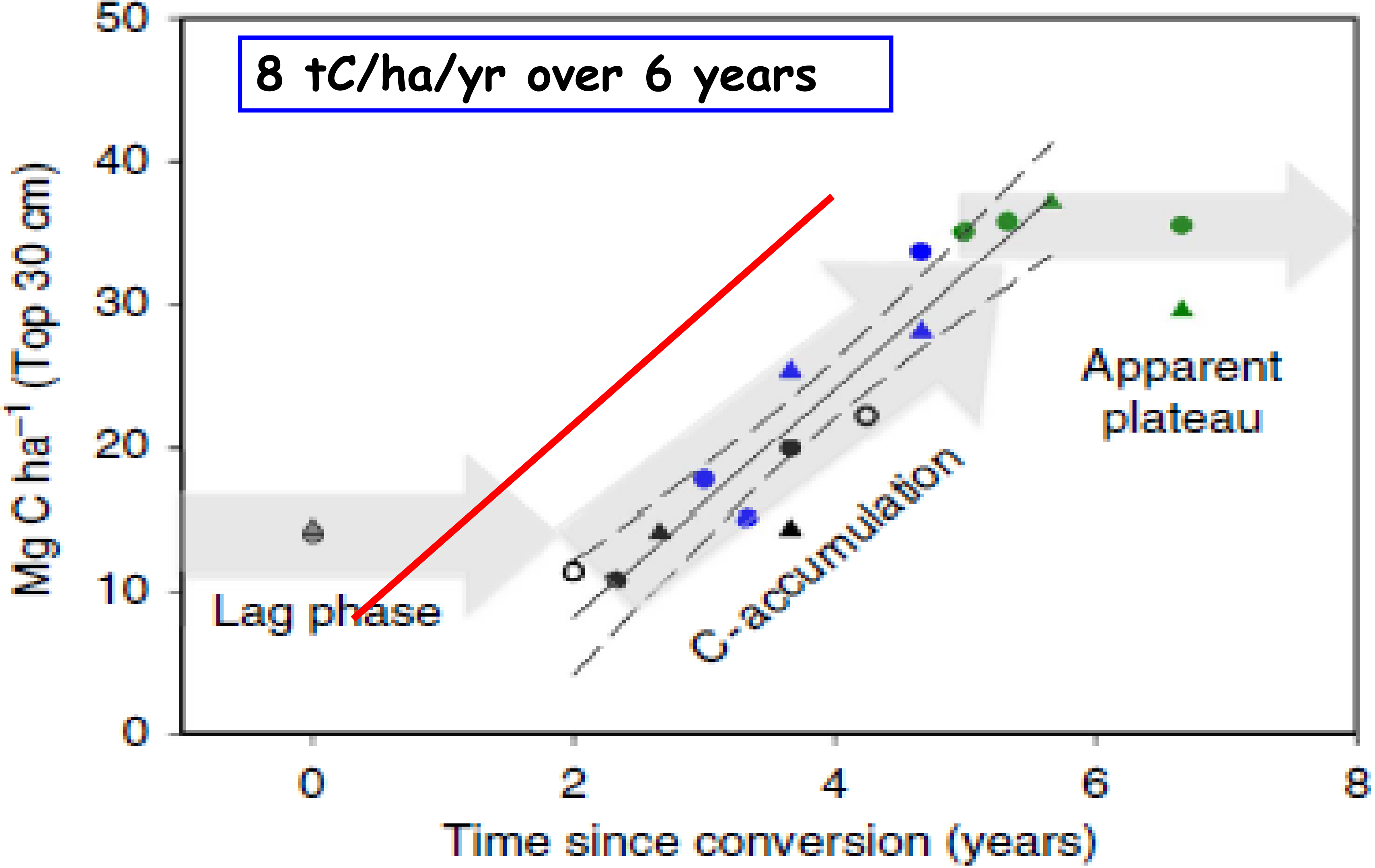
Georgia – 1,000 mm rainfall

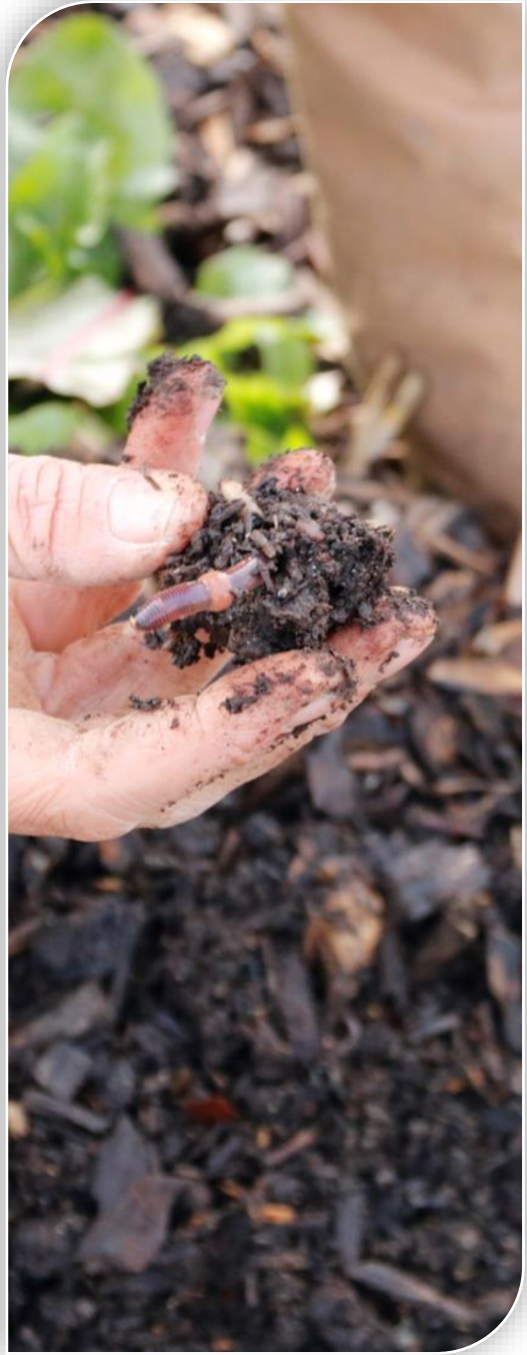
Machmuller et al. 2015

SOC Switching from Cropping to AMP



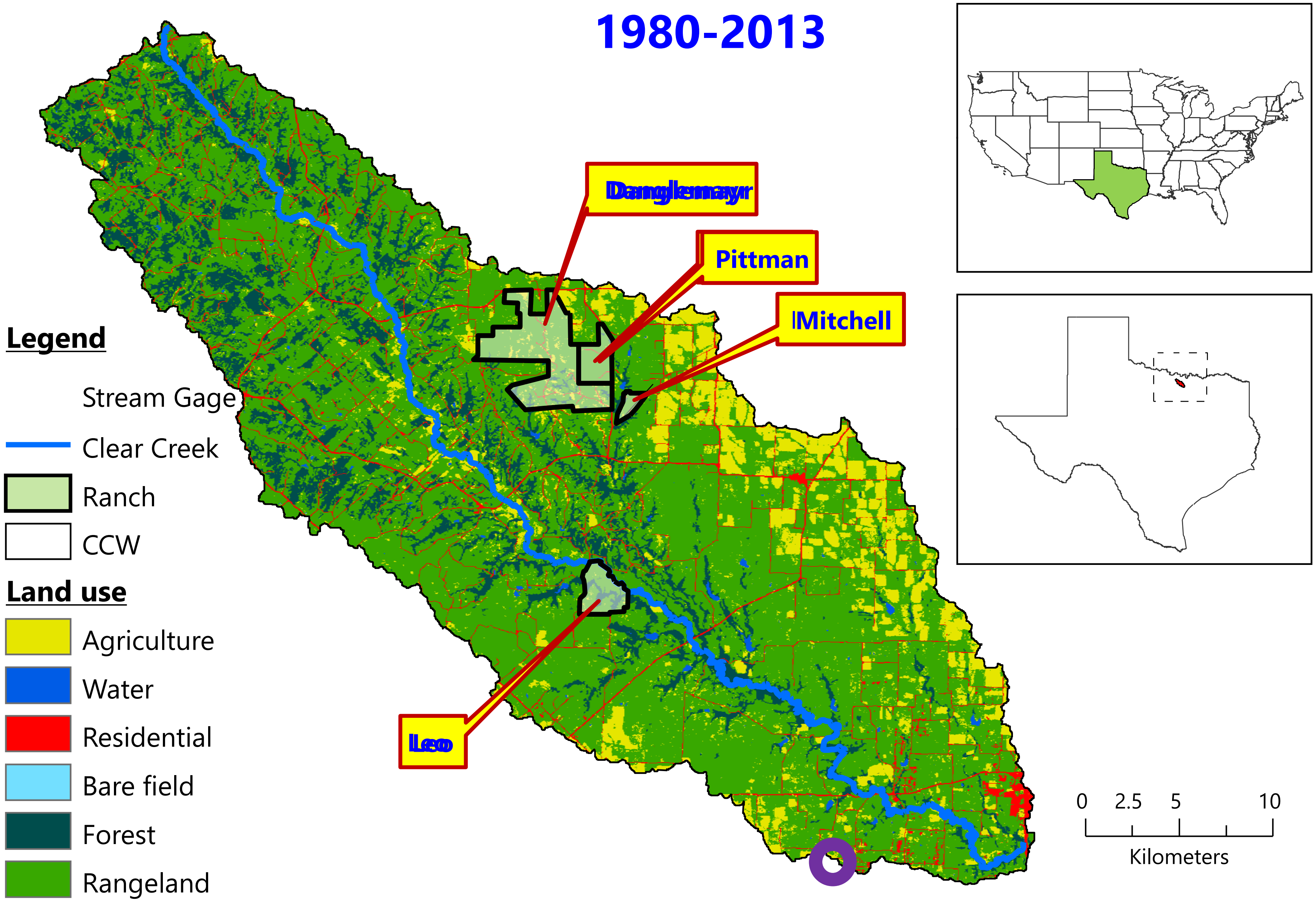
Measured to 30 cm





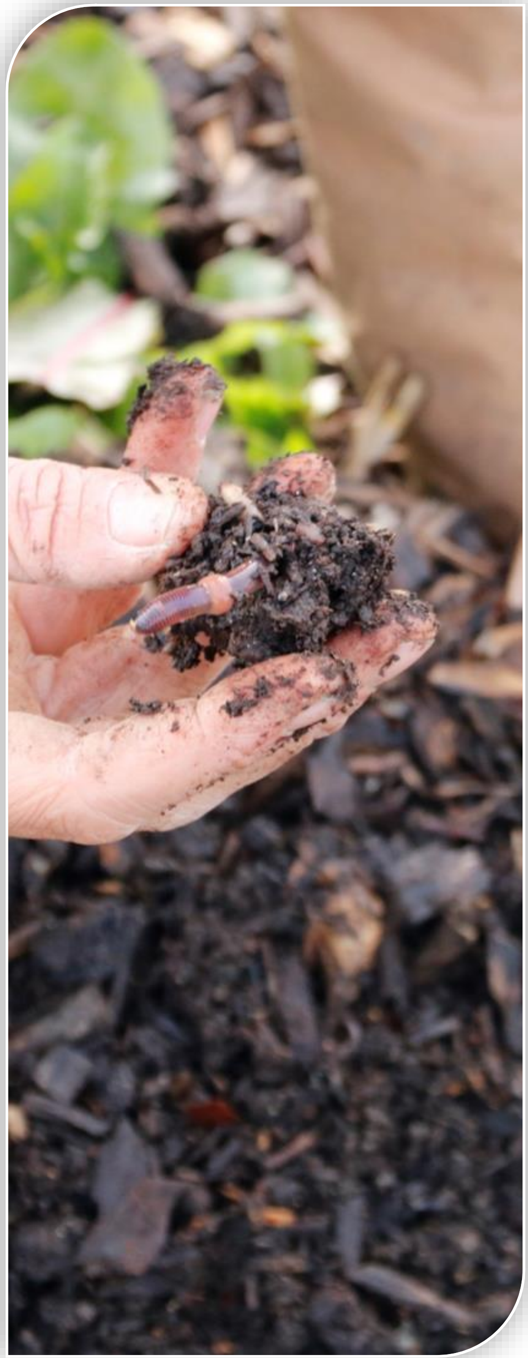
Clear Creek watershed, North Texas

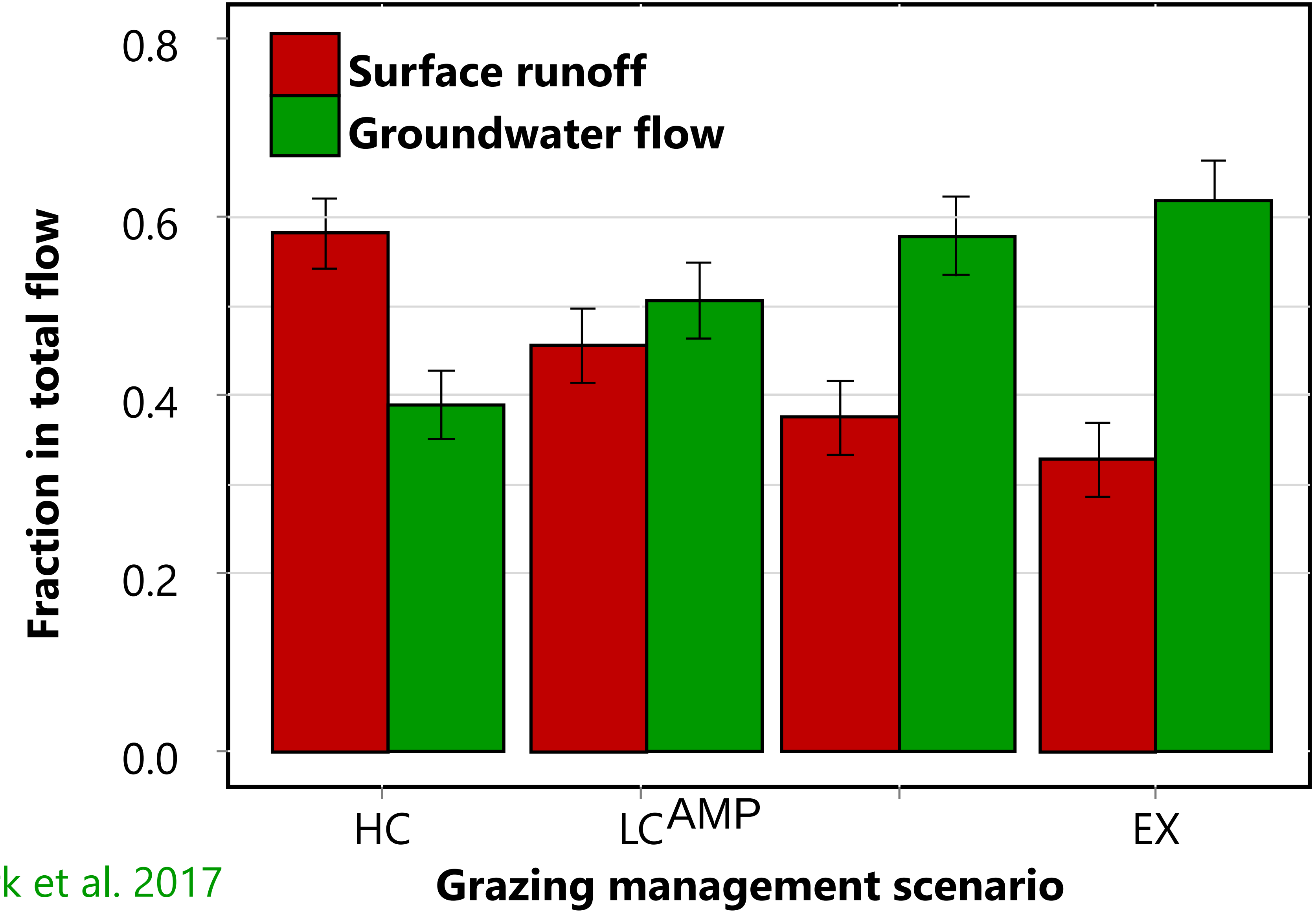
1980-2013



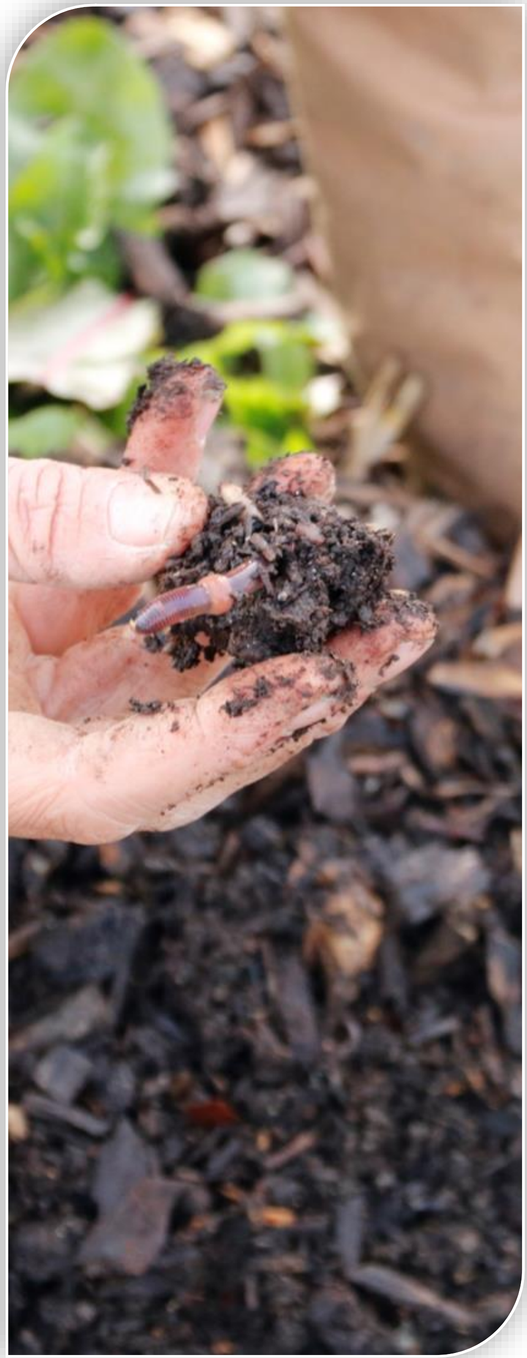
Park et al. 2017

Clear Creek watershed, North Texas

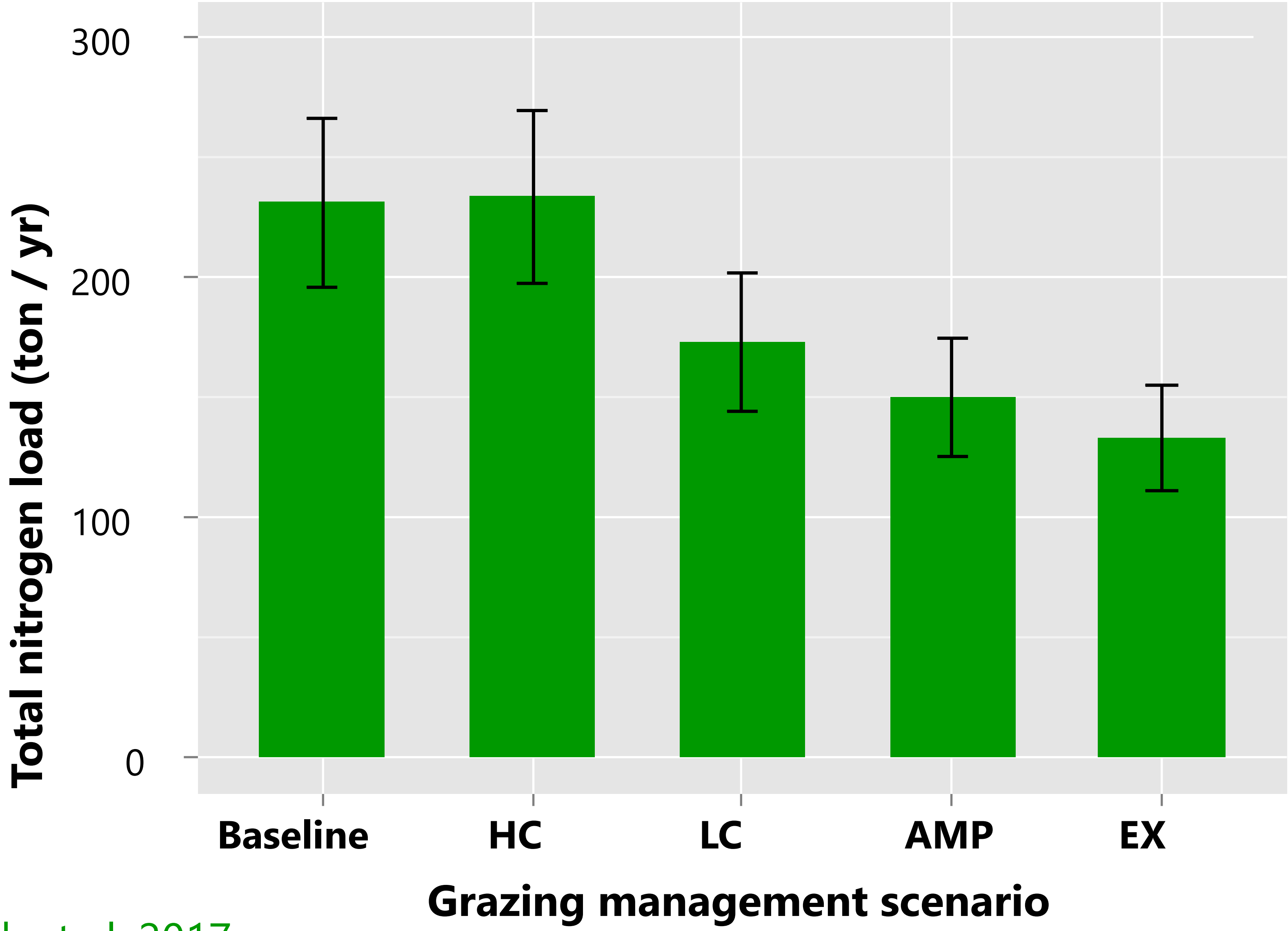




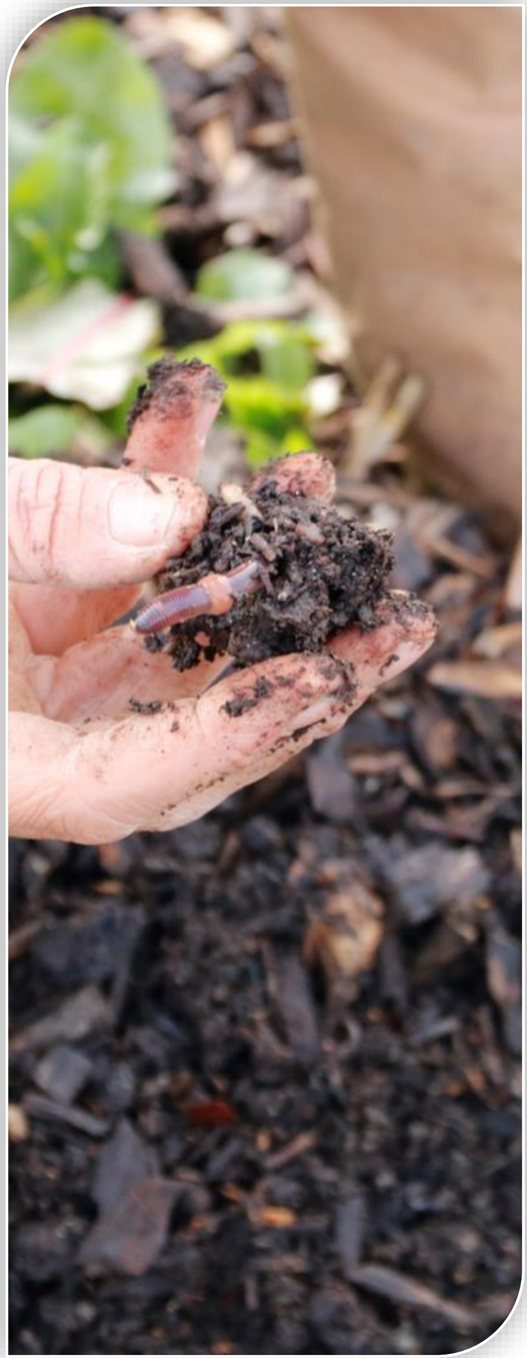
Park et al. 2017



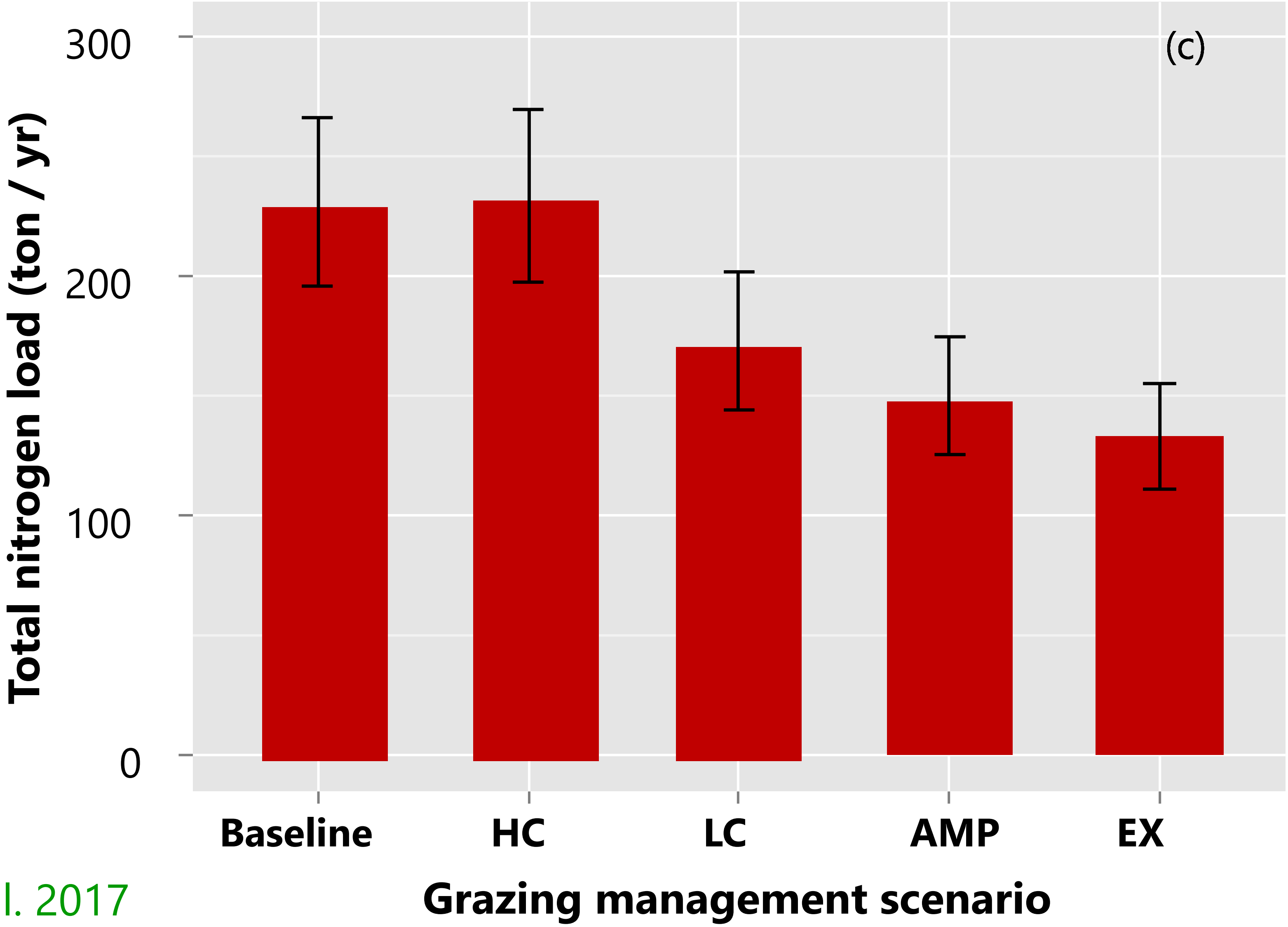
Clear Creek – Nitrogen load



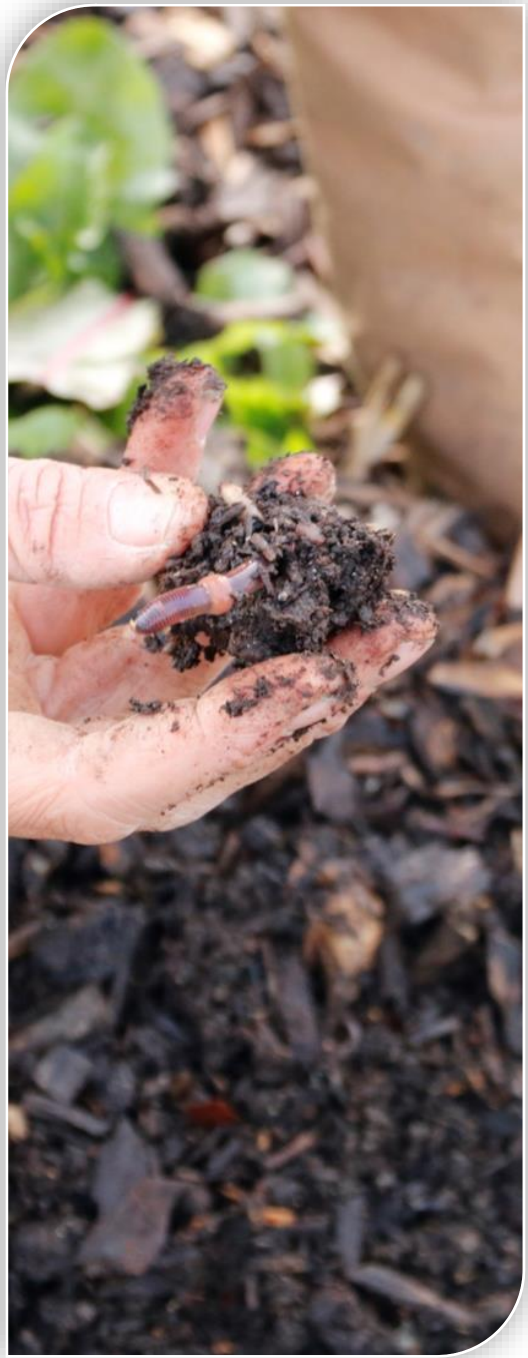
Park et al. 2017



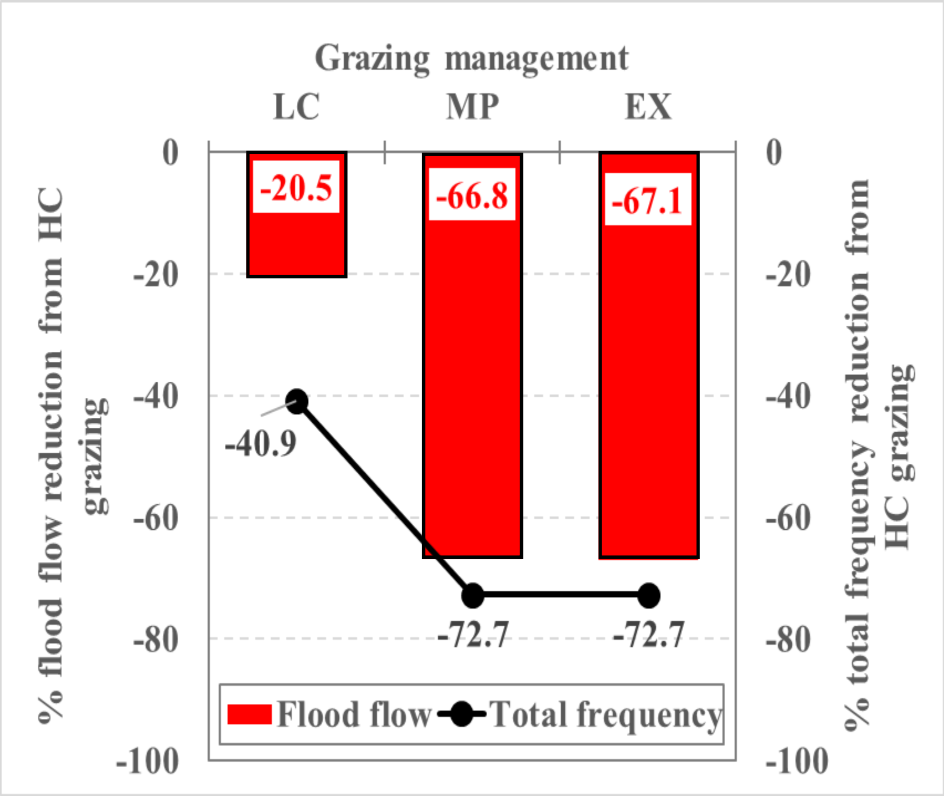
Clear Creek - Phosphorus load



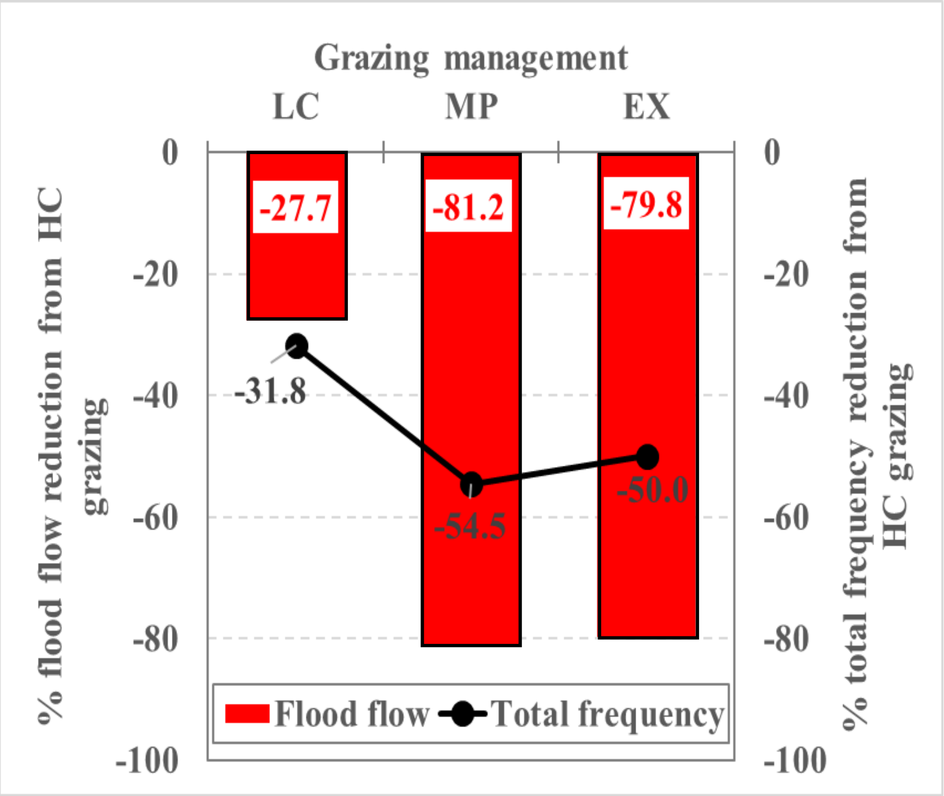
Park et al. 2017



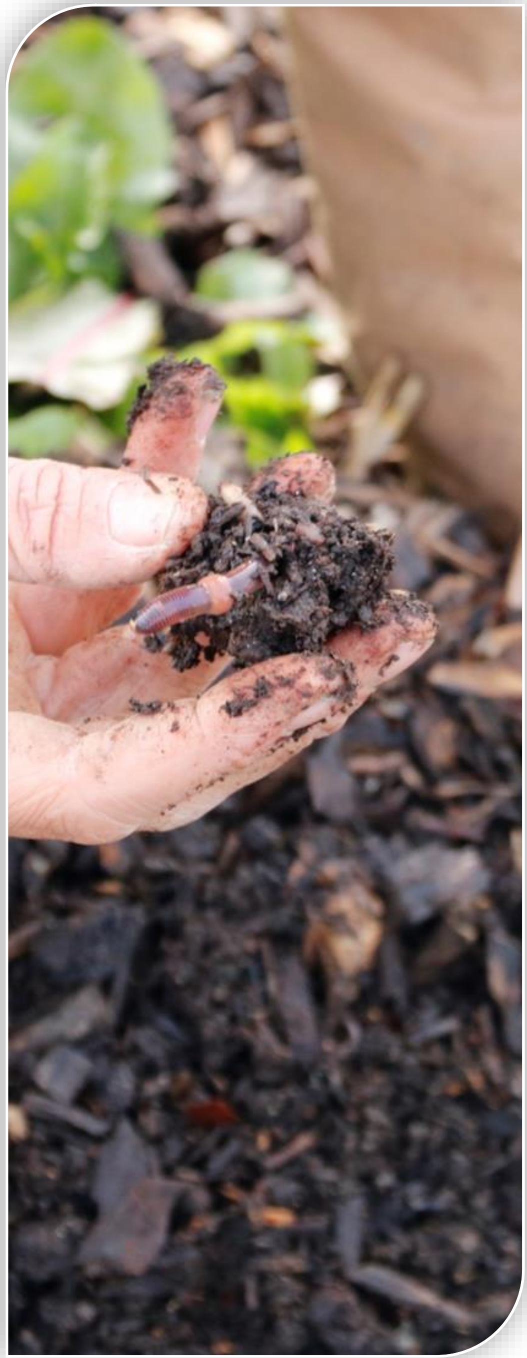
Effect of Grazing Management on Flood Flow and Flood Frequency



Red River Watershed, Texas

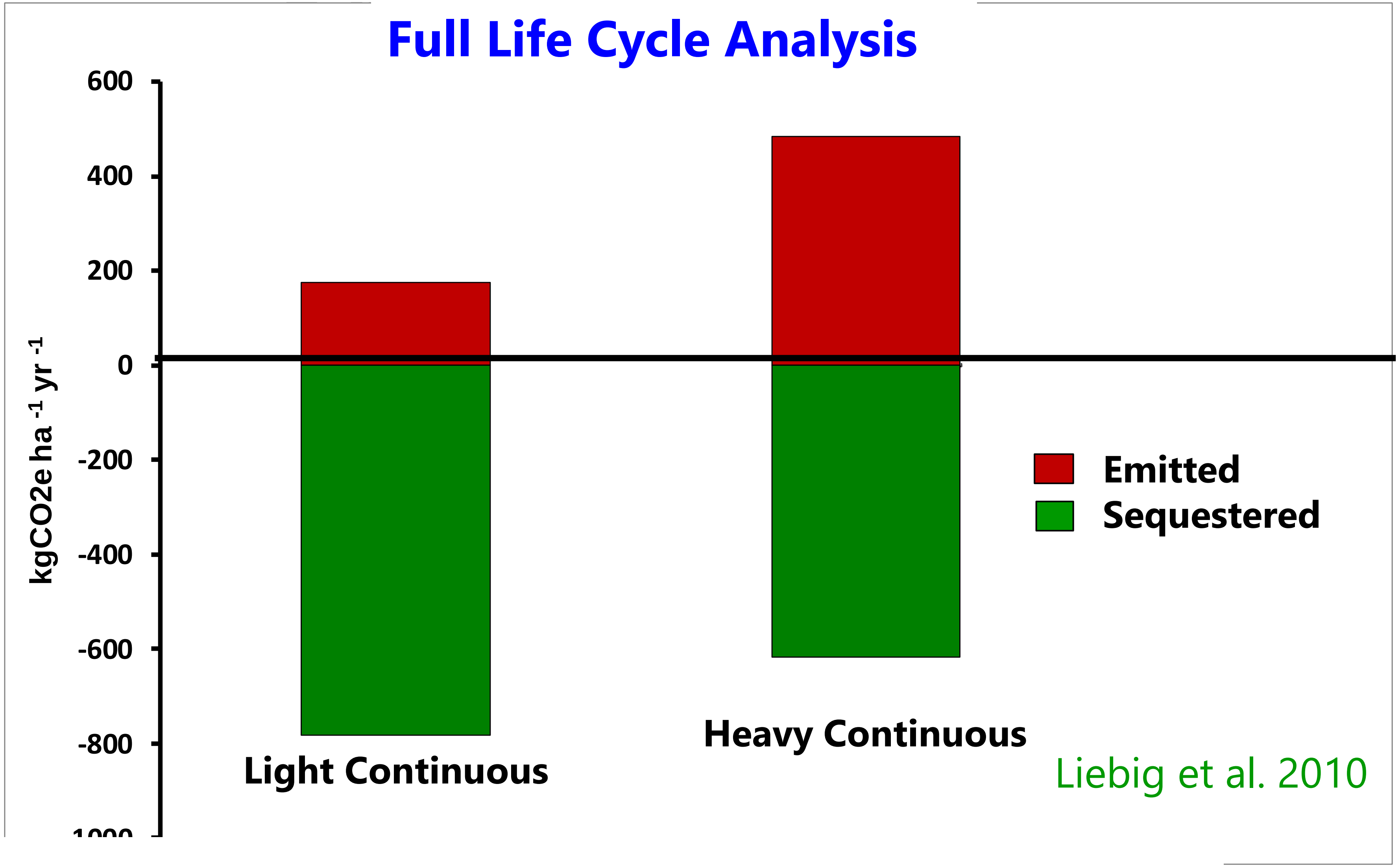


Apple Watershed, North

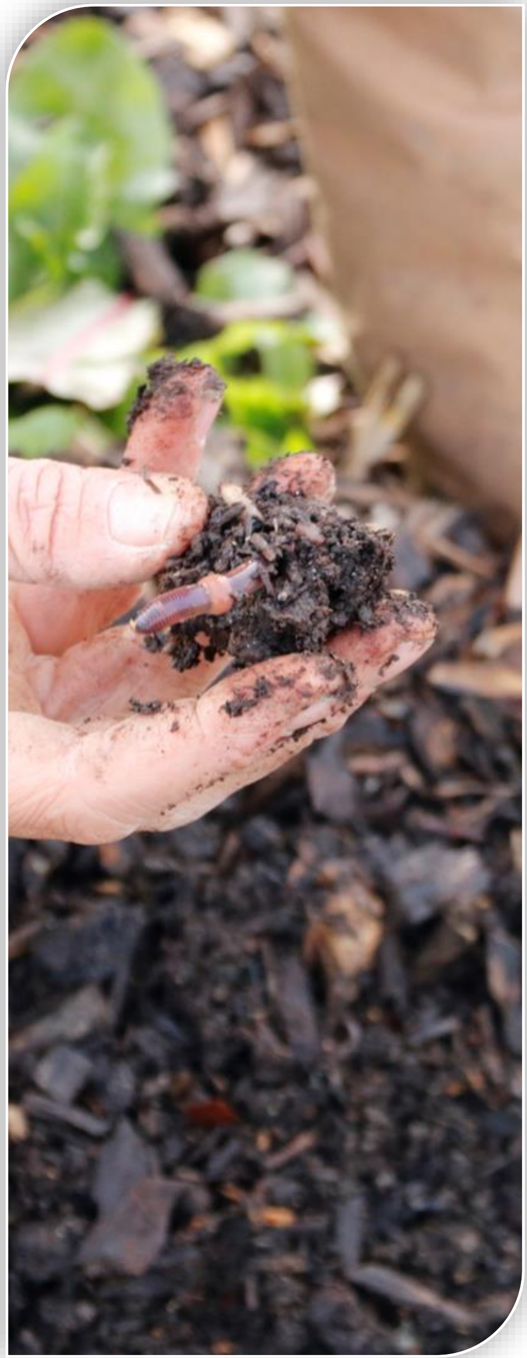


Carbon Sinks and Emissions:

Northern Plains rangeland grazing only Cattle Operations

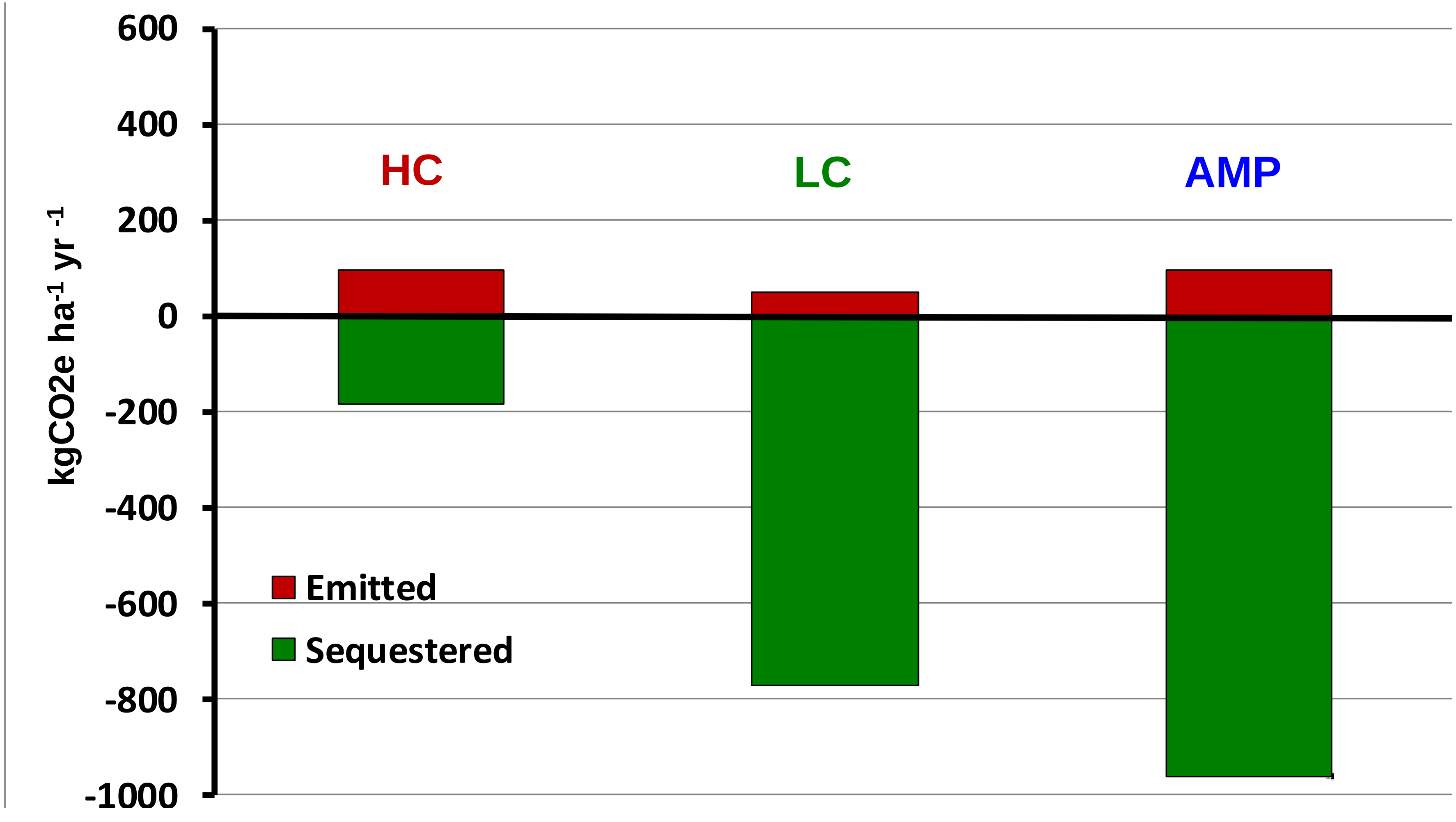


Liebig et al. 2010

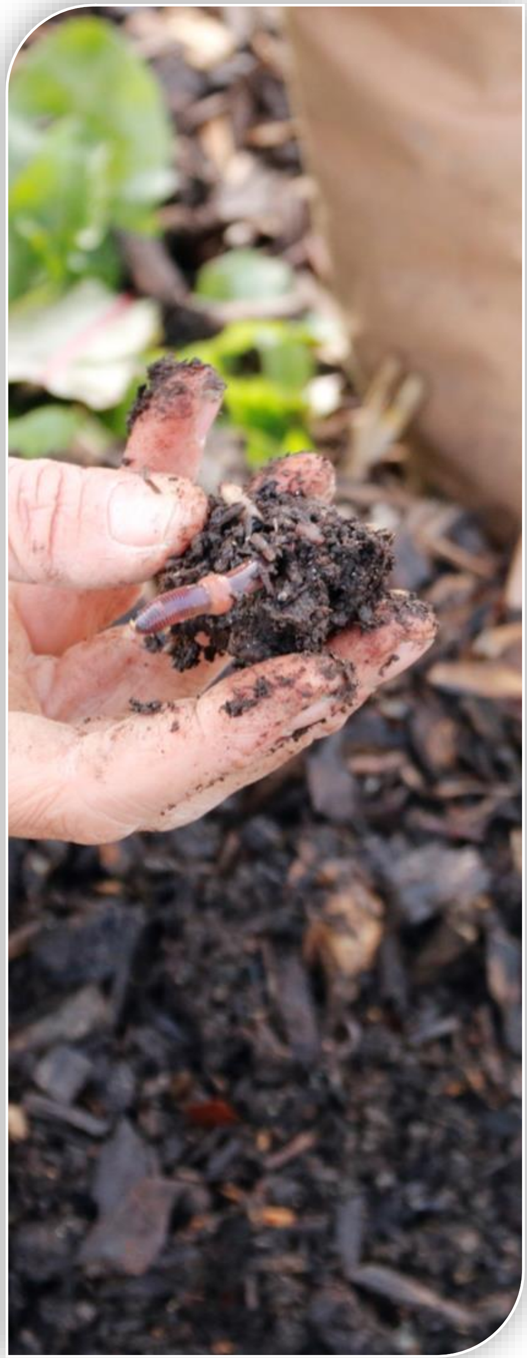


Life Cycle Analysis of Change in Management

Net C Emissions on rangeland grazing-only Cow-calf Operations

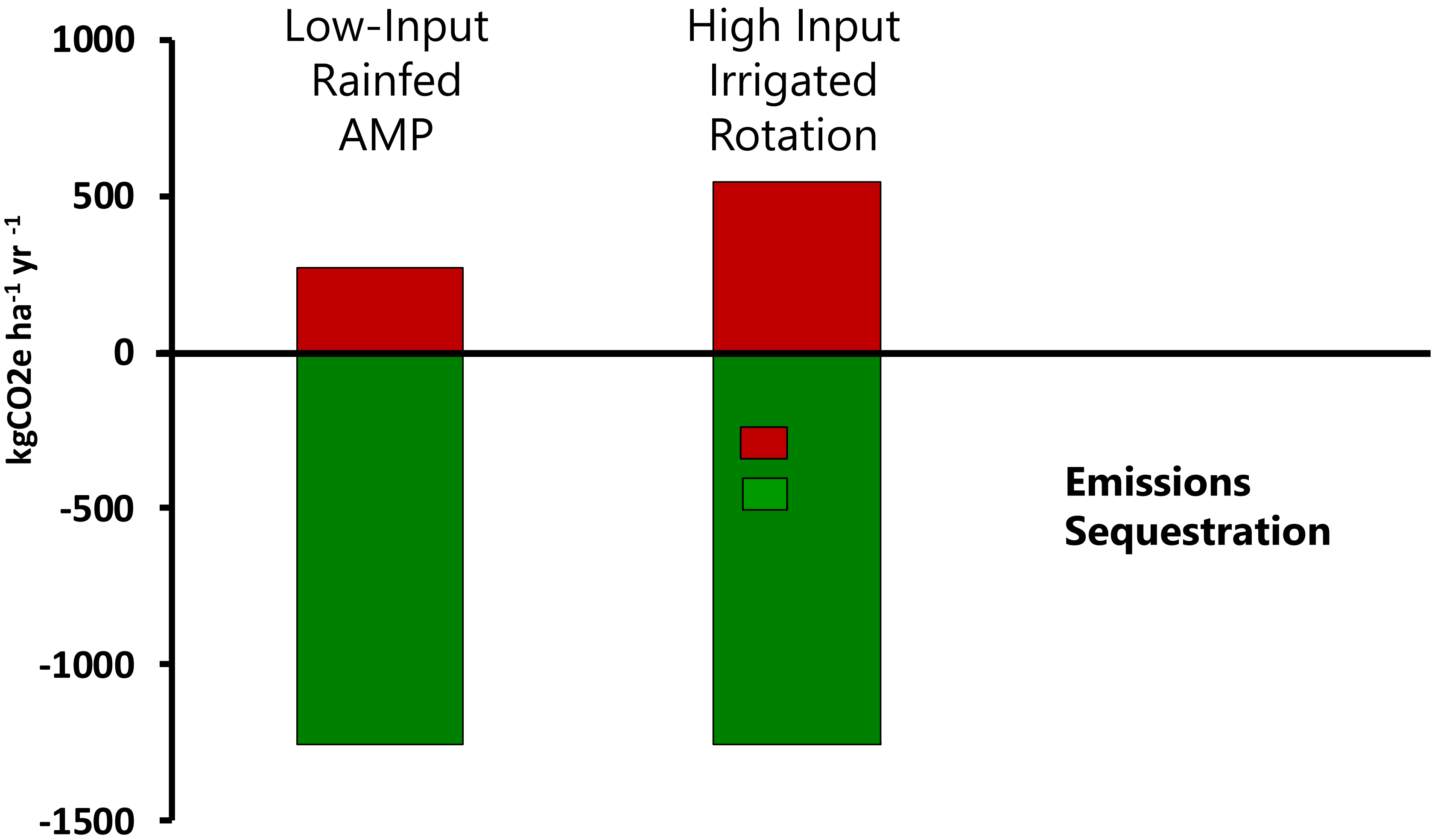


Wang et al. 2015



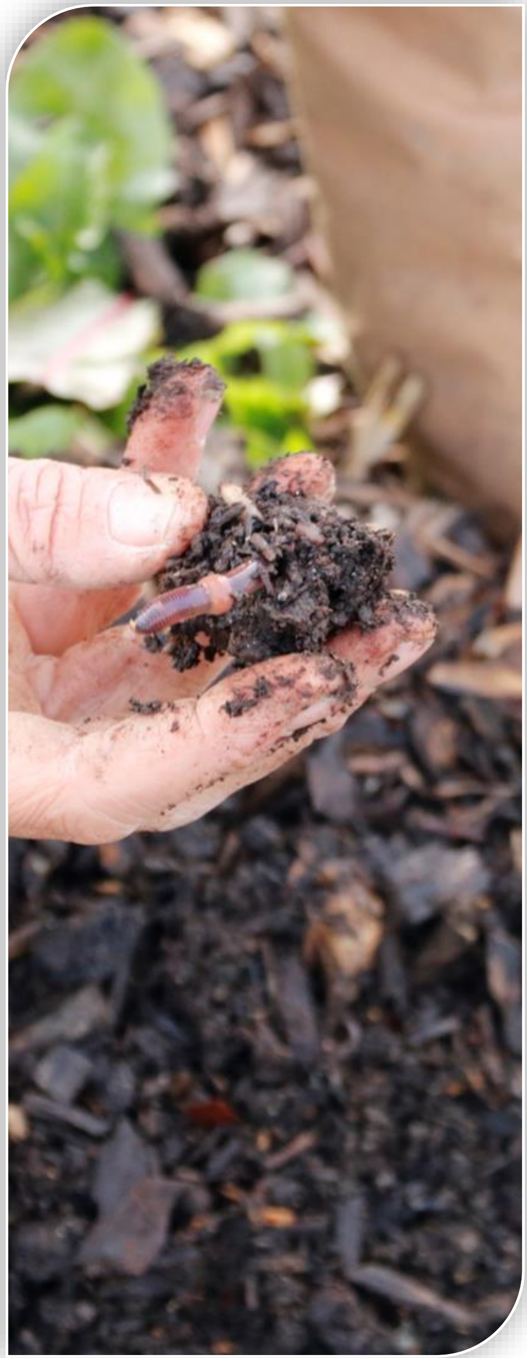
Emissions and Carbon Sinks:

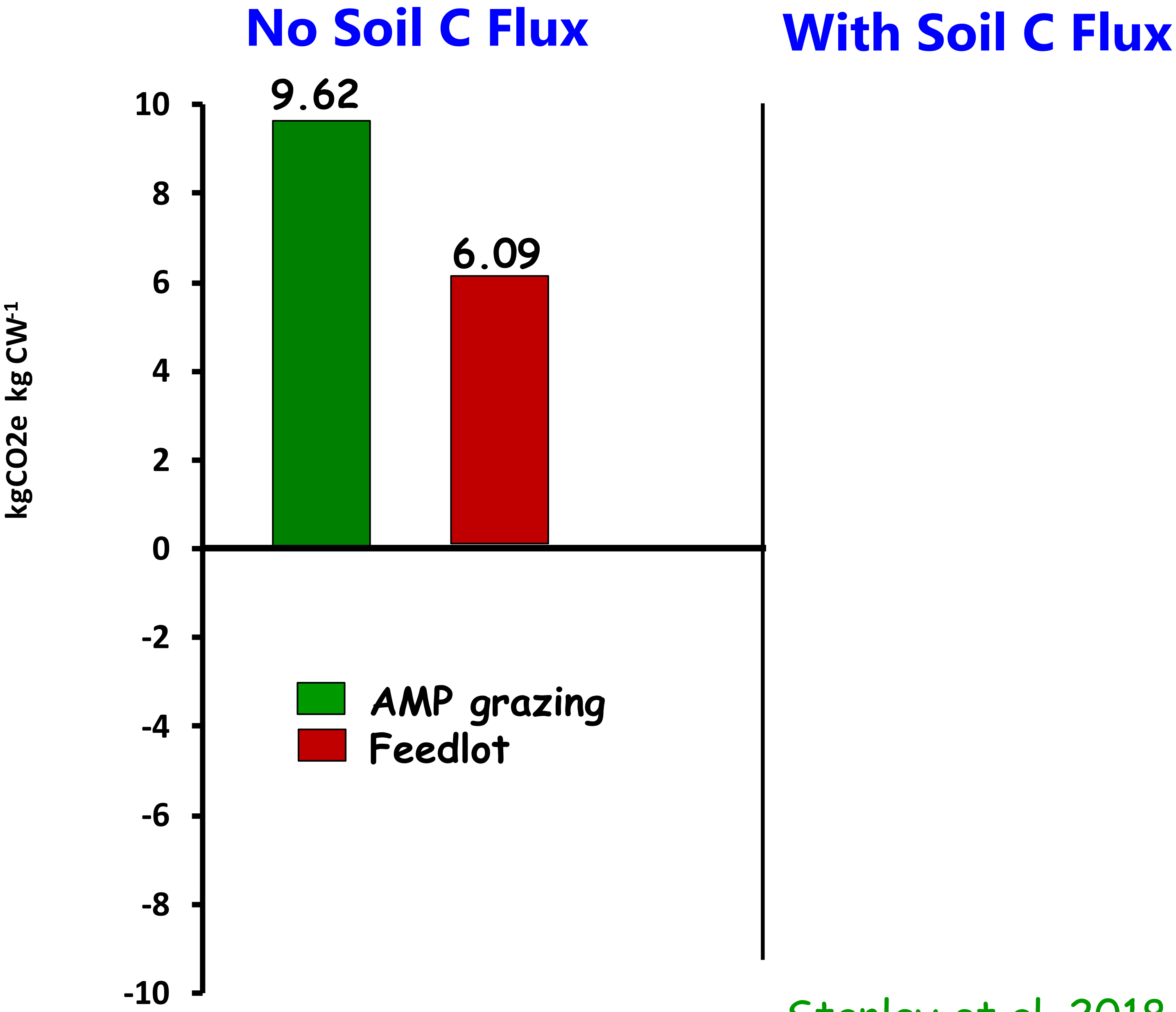
Michigan Grassfed Pasture – grazing only Cow-calf Operations



Rowntree et al. 2015

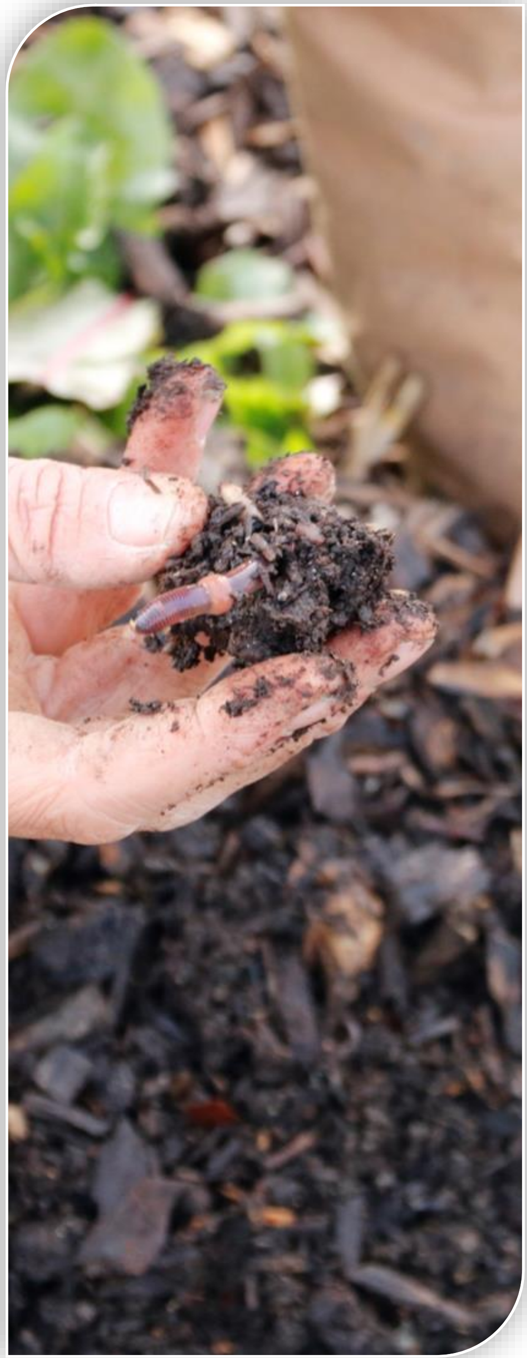
Net emissions: Feedlot vs. AMP finishing:

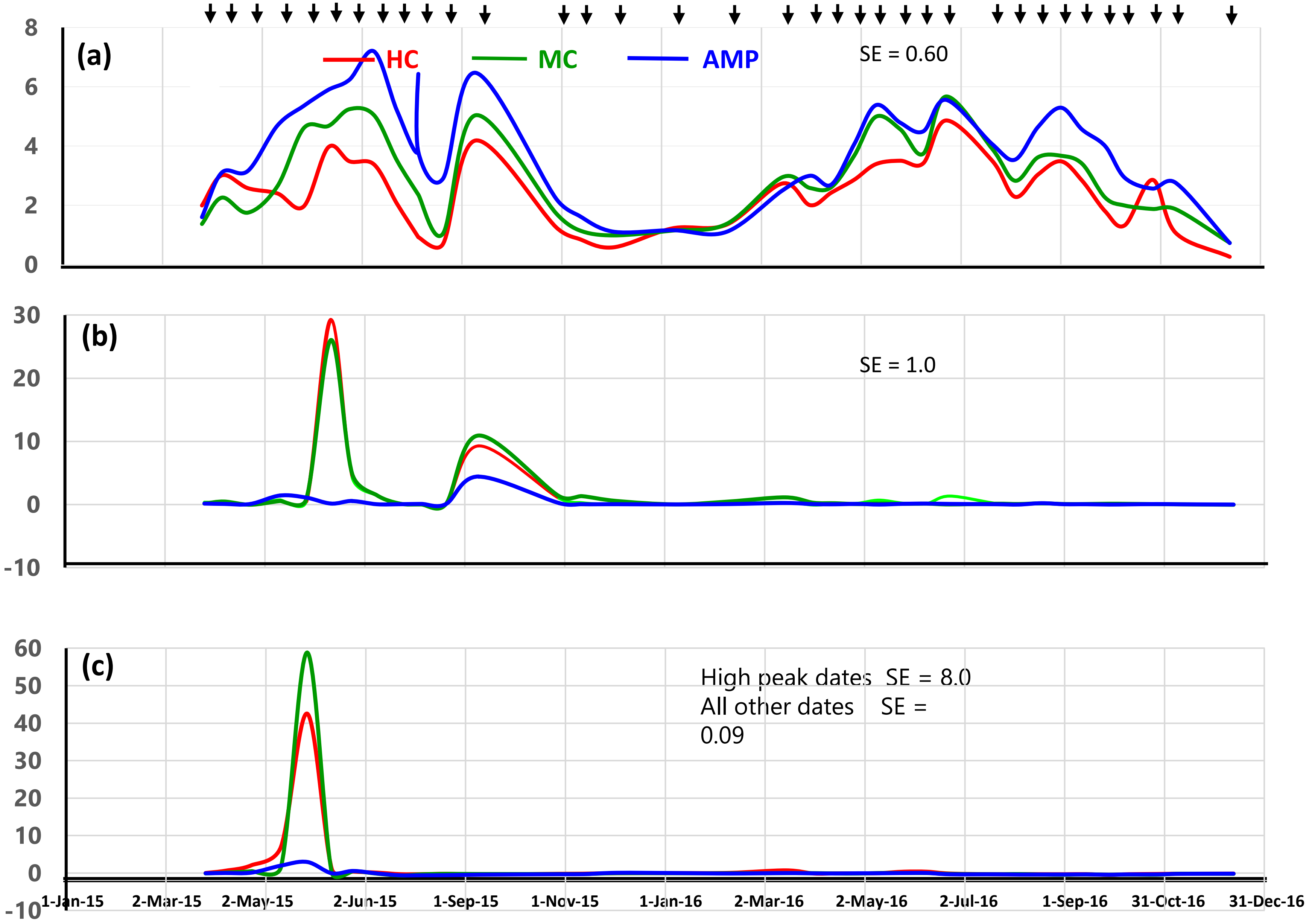


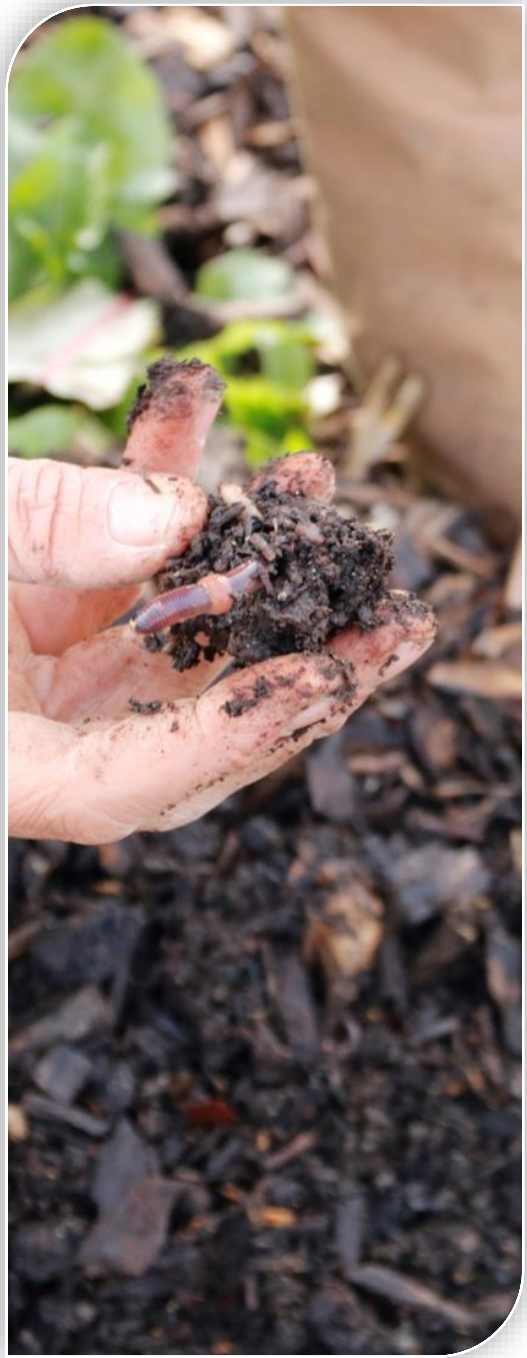


Stanley et al. 2018

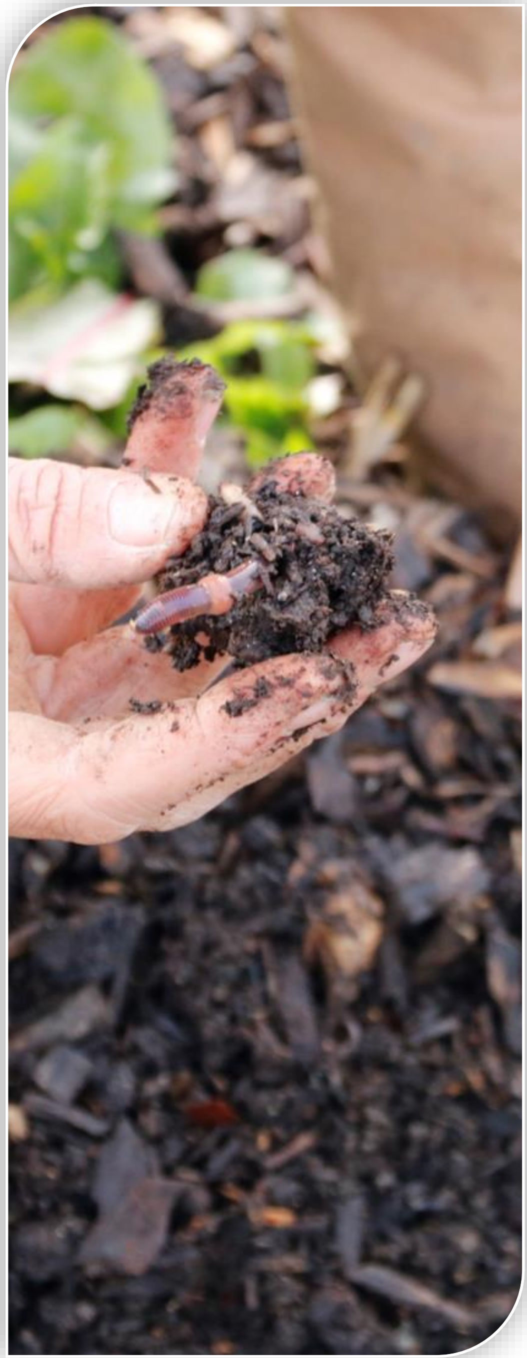
GHG Soil Surface Emissions







Managing to improve soil health and ecosystem services

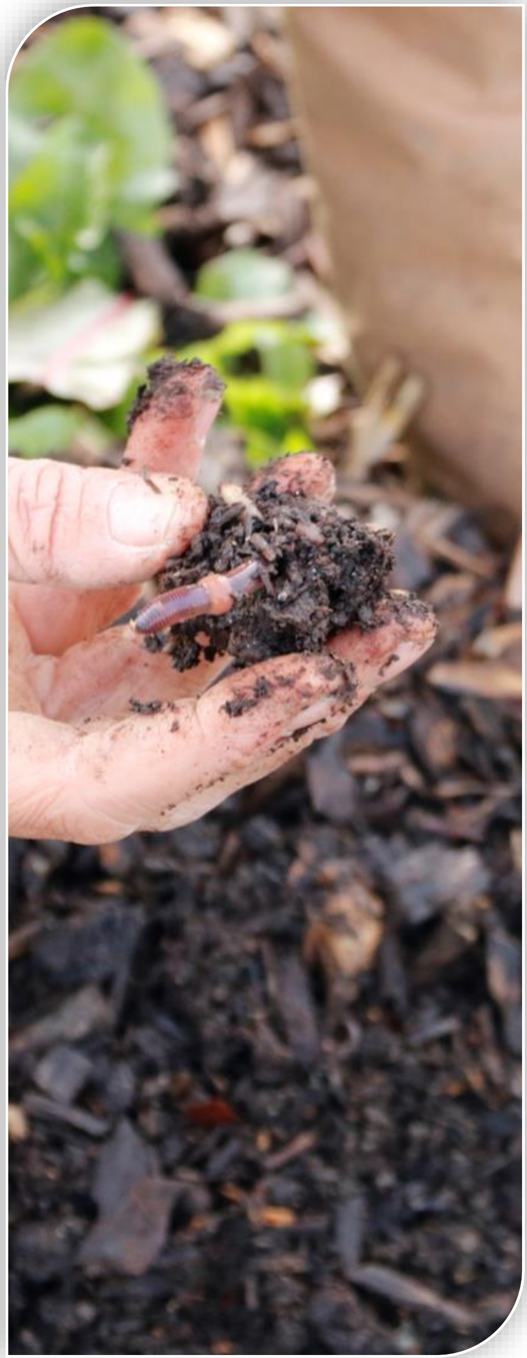


To improve Soil Health

Improve soil microbe function by:

- Keep the **4** ecosystem processes functioning
- Improving plant cover
- Use multi-species forage crops
- Perennial plants rather than annuals
- Manage for most productive plants
- Leave adequate plant residue
- Minimizing bare ground
- Manage for green leaves as many days as possible
- **Avoid tillage, inorganic fertilizers & biocides**

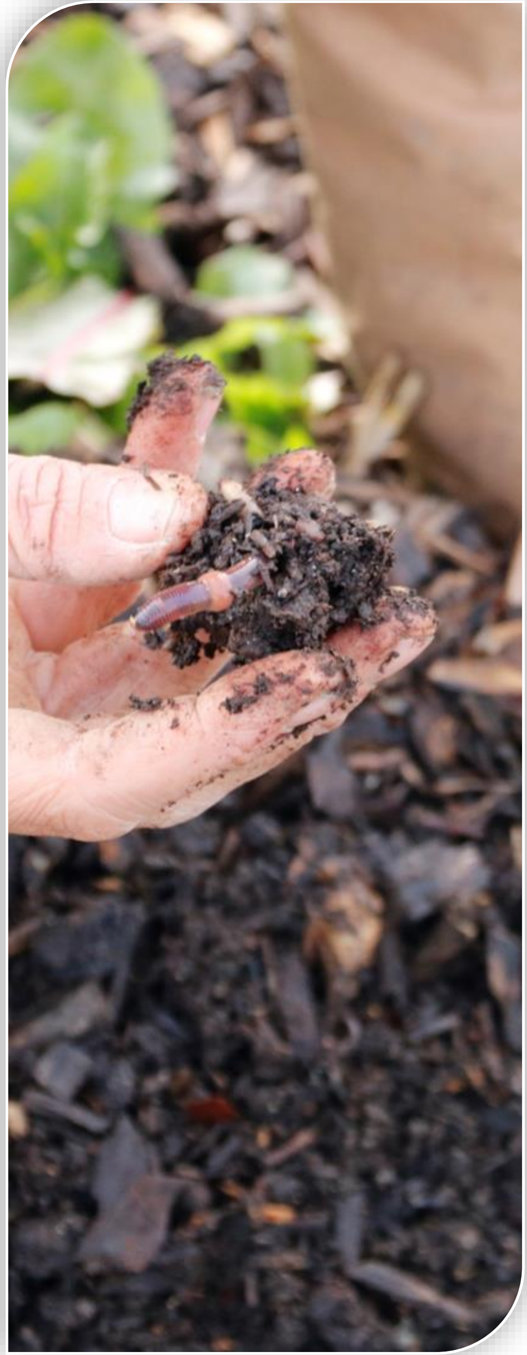
USDA-NRCS; Soil Health Institute



What we have learnt from ranchers……1

- It takes a minimum of 10 paddocks just to stop overgrazing
- Ranchers with 8 or fewer paddocks are not rotationally grazing, but ***rotationally overgrazing***
- To support decent animal performance takes 14-16 paddocks
- The most rapid range improvement takes 30 or more paddocks
- The biggest decrease in workload and greatest improvement has been with > 50 paddocks
- Long recovery periods are critical

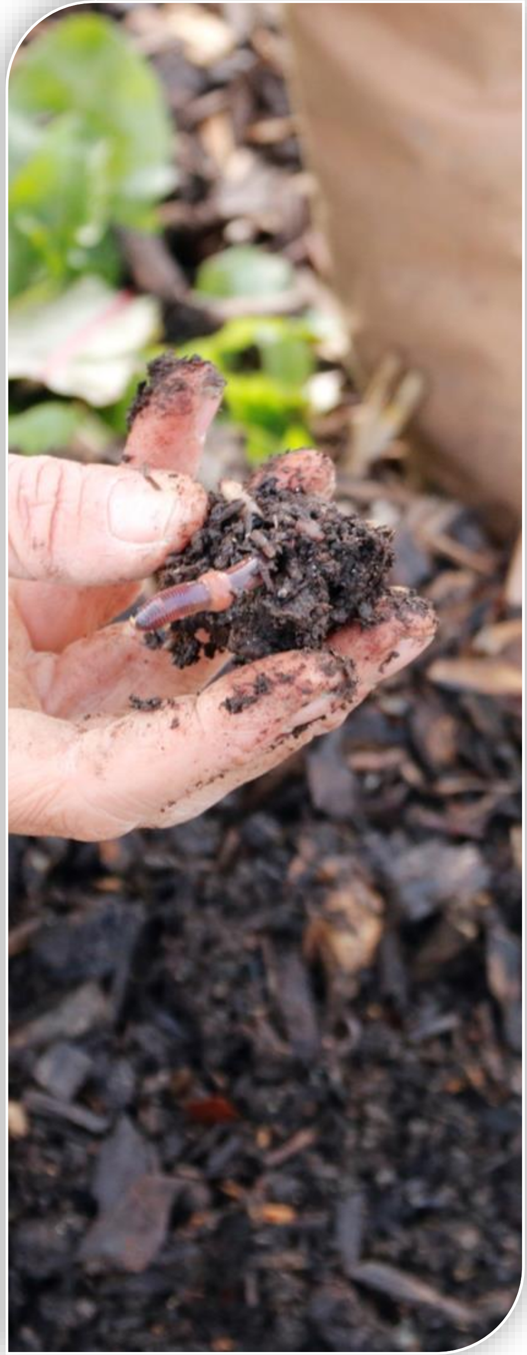
Walt Davis, Dave Pratt, Ranch Management Consultants



What we have learnt from ranchers……2

- The fastest, cheapest way to create more paddocks is combining herds
- 1 herd reduces workload a lot; checking 4 herds of 200 animals takes much longer than 1 herd of 800
- Productivity per acre is improved without decreasing individual animal performance
- Carrying capacity and total productivity are greatly increased at low cost
- Do not move to the adjacent paddock but to the paddock that has recovered the most
- Can't afford to NOT to use short graze with long rests

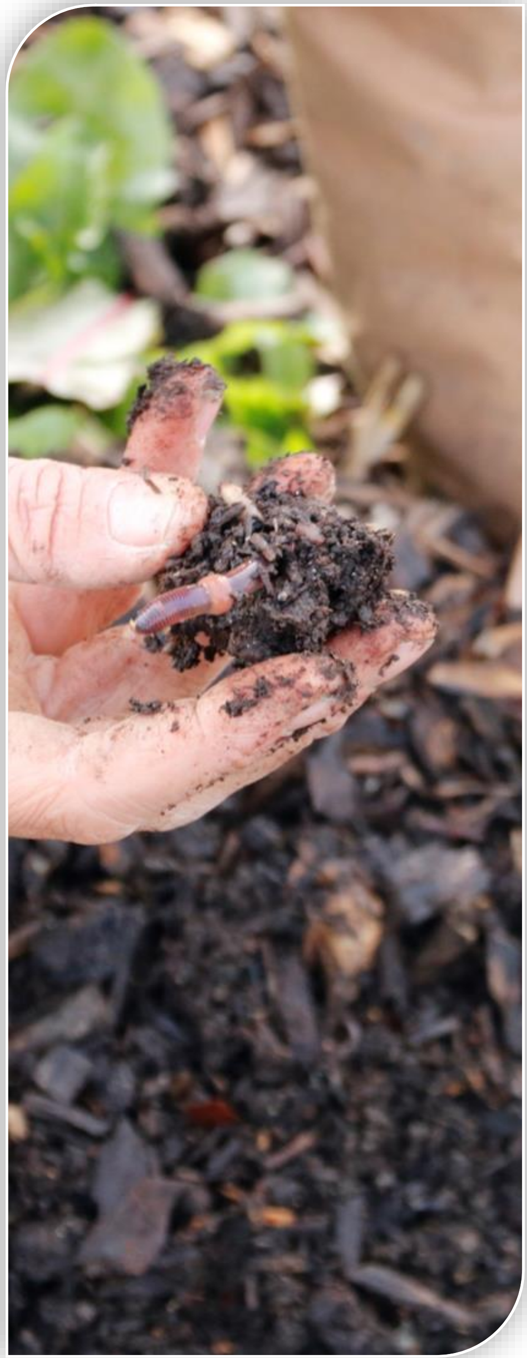
Walt Davis, Dave Pratt, Ranch Management Consultants



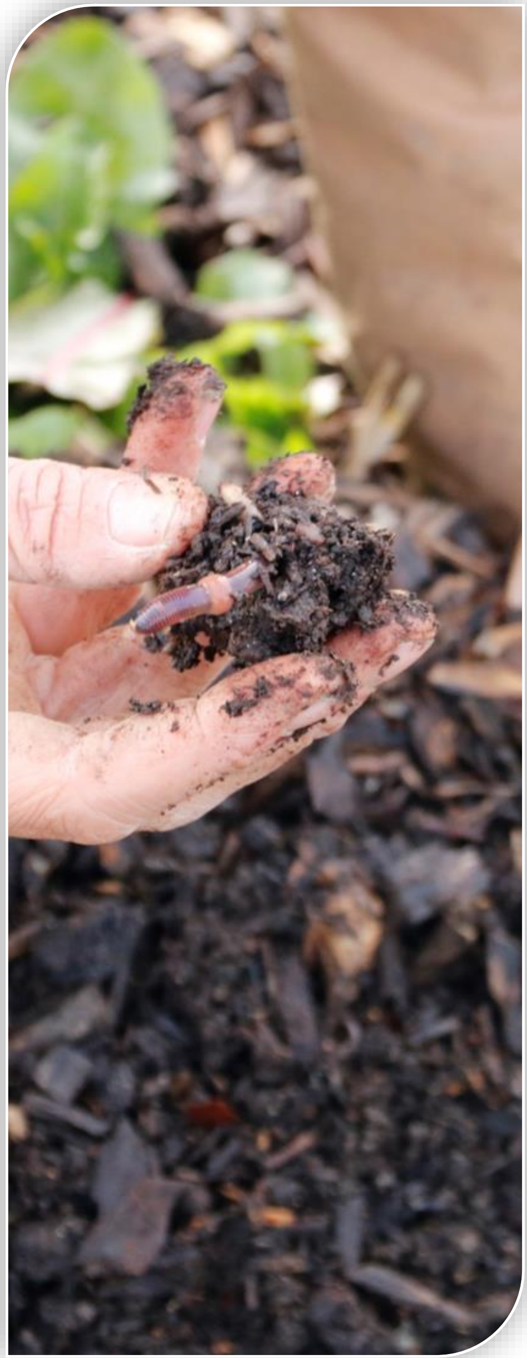
Research for Adequate Understanding

- Must account for the increasing heterogeneity of livestock impact with increasing scale.
- Changes in biology and soil carbon take place more slowly as growing conditions decrease.
- Adequate time must be allowed for treatments being tested. (Ranges from 5 - 30 years)
- Management must be conducted to adaptively achieve best possible results.
- Only studies at the commercial ranch scale and on appropriately managed ranches can include and facilitate:
  - inclusion of the impacts of scale,
  - time taken for changes to be measurable,
  - inclusion of top quality, adaptive management, and
  - inclusion of management options to achieve desired outcomes.

Teague et al. 2013; Teague et al. 2017

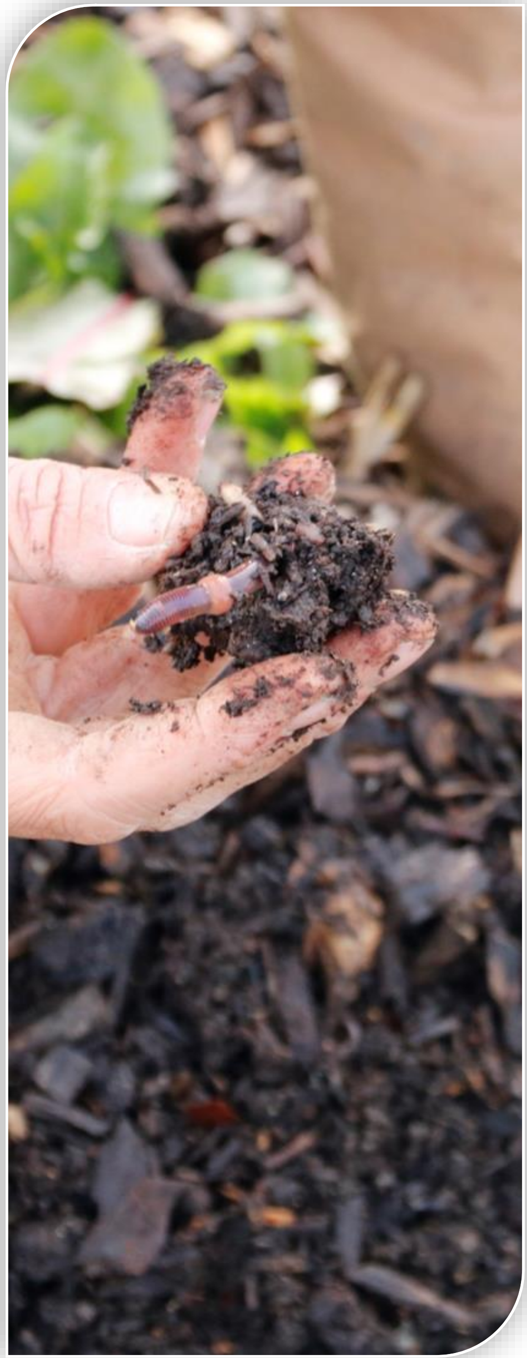


Facilitating transition to regenerative grazing

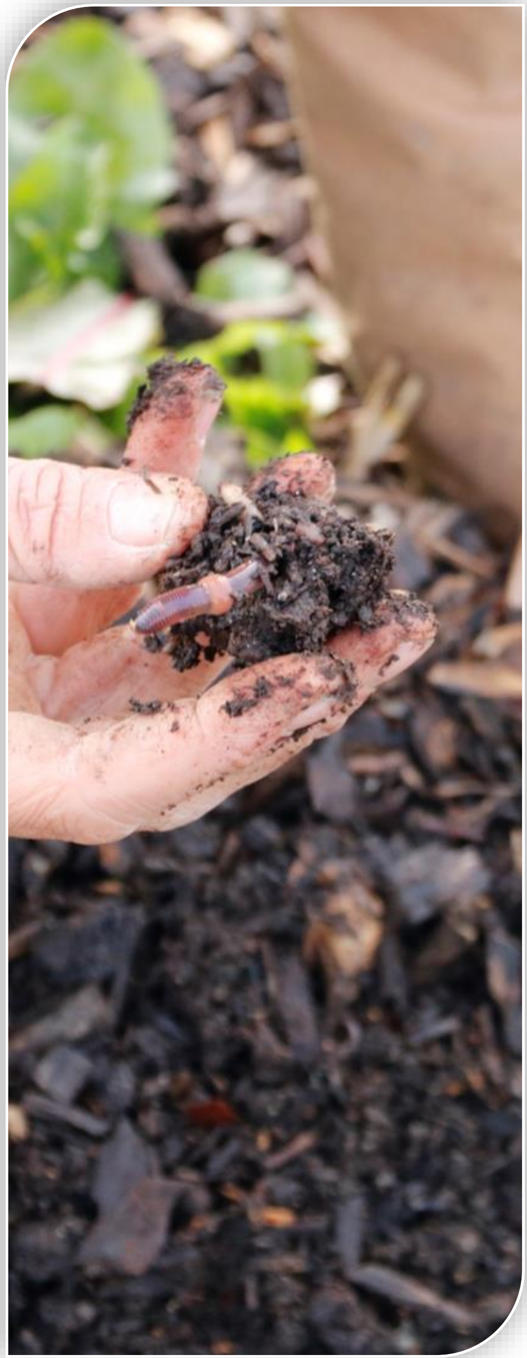


Aids to transitioning

- Attend classes from qualified educators
- Visit and learn from successful regenerative ranchers in similar and drier country than yours
- Be part of an active regenerative ranching network
- Start small – to get experience, confidence and good basic skills
- Get skilled and confident in anticipating and making adjustments towards your goals
- Persevere
- Keep learning and enjoy yourself



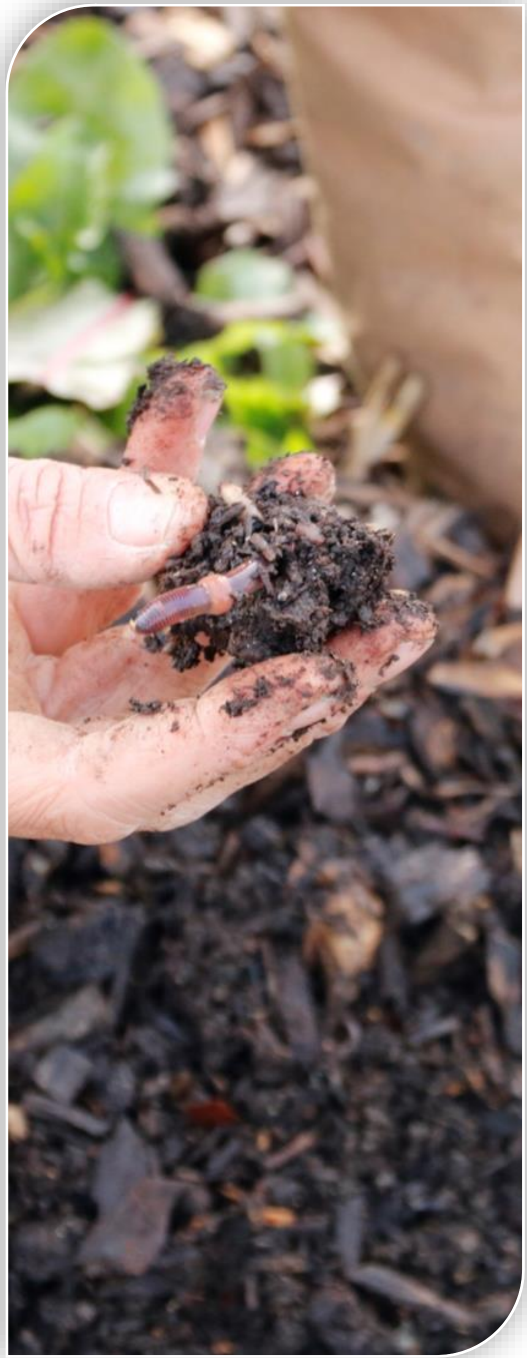
Conclusions



Regenerative grazing management shows:

- Build soil Carbon levels and soil microbial function
- Enhance water infiltration and retention
- Build soil fertility
- Control erosion more effectively
- Enhance watershed hydrological function
- Improve livestock production and economic returns while improving the resource base
- Enhance wildlife and biodiversity
- Enhance food nutrient density and human health
- Increase soils as NET greenhouse gas sink

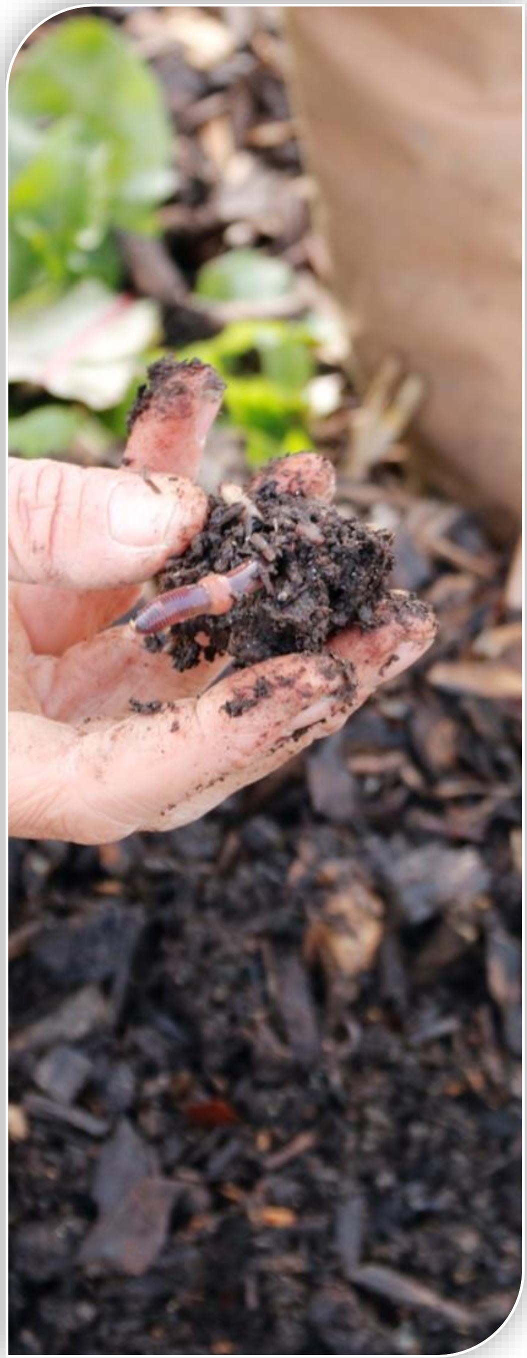
Park et al. 2017; Jakoby et al. 2014; Teague et al. 2015; Ritchie 2020; Fenster et al. 2021; Montgomery & Biklé 2022; Montgomery et al. 2021



Regenerative Grazing Research Shows:

- Ecological function and profitability increase with increasing number of paddocks
- Short periods of grazing with adequate recovery gave the greatest profit and ecological function
- Adjusting grazing management with changing conditions increases ecological function and profitability
- Stocking rates can be increased without damaging ecological function as number of paddocks is increased
- Fixed management protocols reduced benefits.

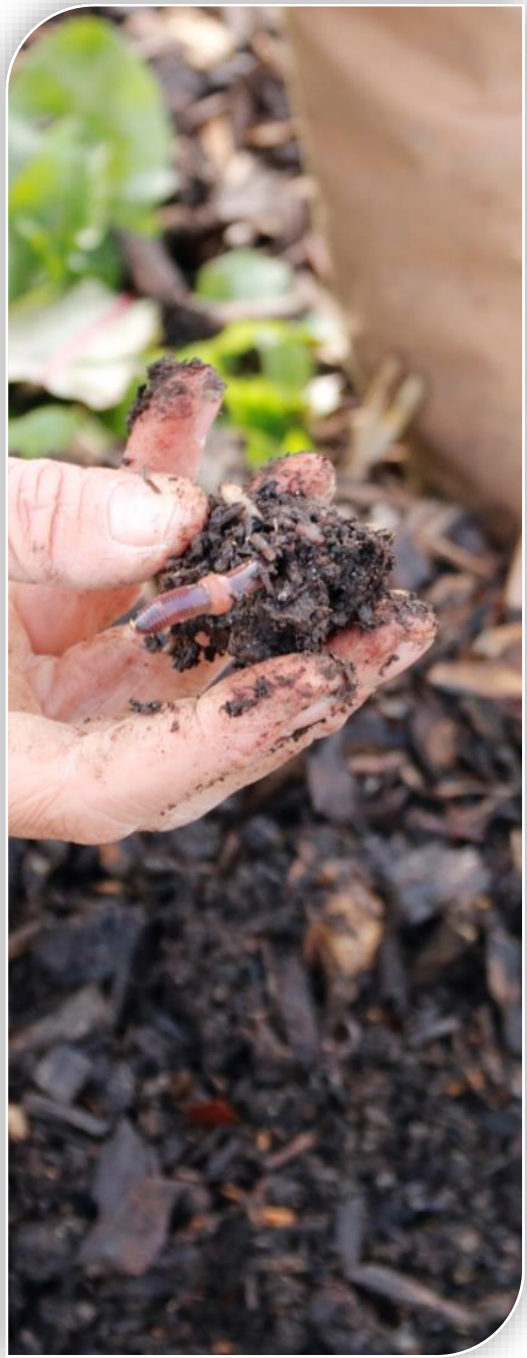
Martin et al. 2014; Jakoby et al. 2014; 2015; Teague et al. 2015.



AMP Field & Modelling Research Shows:

- Adaptive stocking is less sensitive to overstocking than constant stocking
- The advantages of AMP over continuous grazing are:
  - less at low levels of stocking, but
  - are increasingly important as stock numbers increase, improving net economic returns
- Short periods of grazing with long periods of recovery using a greater number of paddocks per herd allows higher stocking rates, giving:
  - higher net returns, lower income variability,
  - regeneration of ecological function, and
  - resource restoration over a range of management scenarios

Martin et al. 2014; Jakoby et al. 2014; 2015; Teague et al. 2015; Wang et al., 2018; Teague and Barnes 2018



Texas A&M AgriLife Research

NM State University

University of Hawai'i

Applied Ecological Services, Inc.

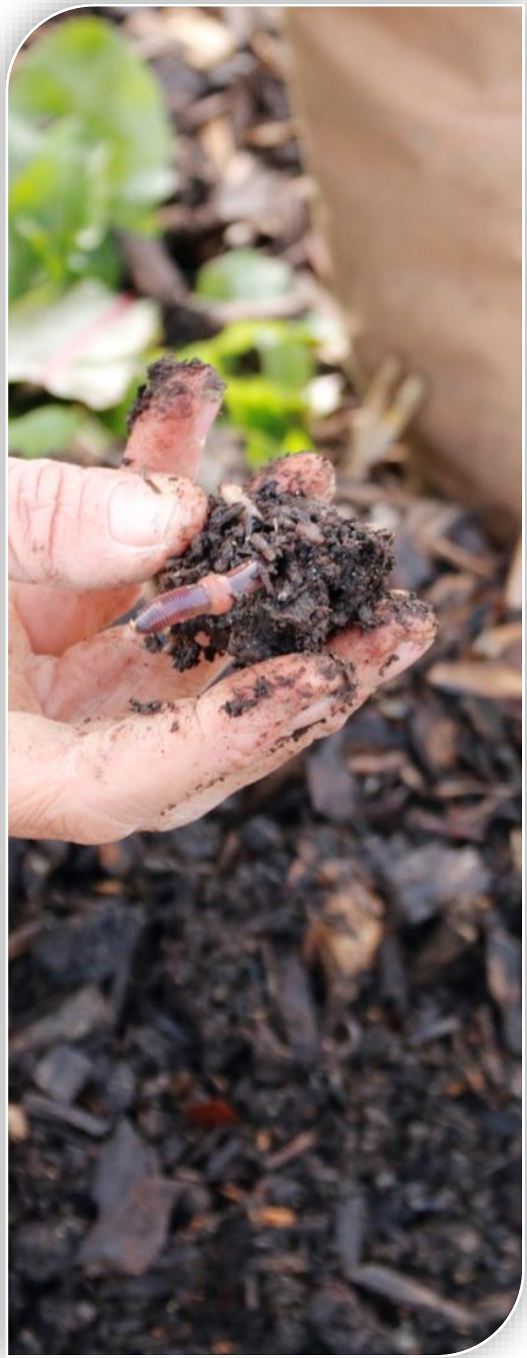
carbon nation

ASU

Michigan State University | AgBioResearch

The Dixon Water Foundation

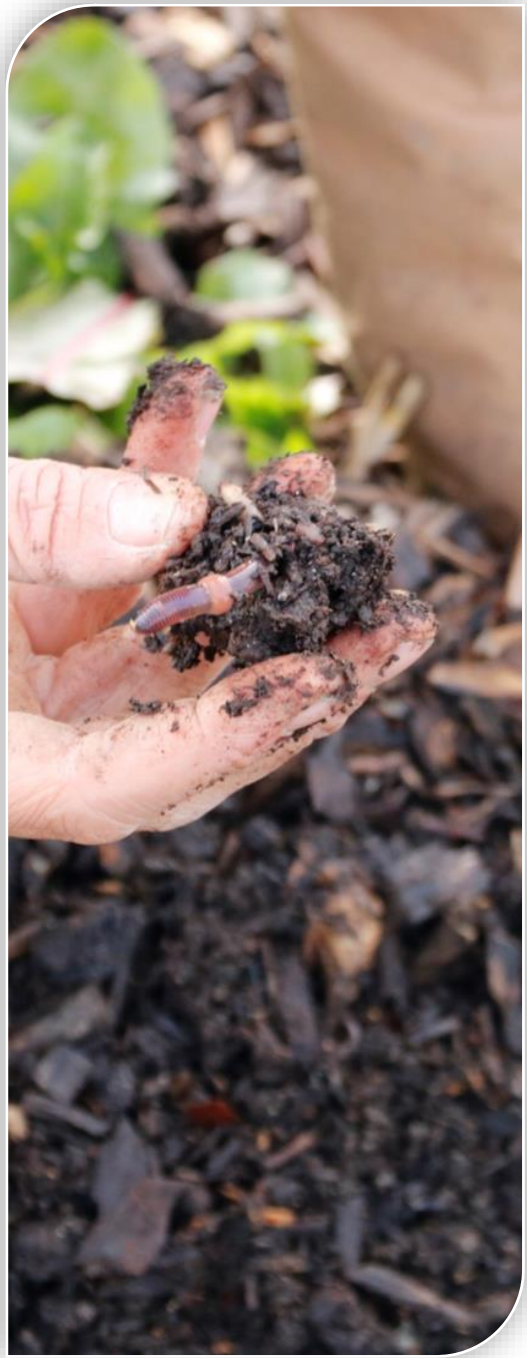
Thank you



Working with leading farmers

- Addresses questions at more meaningful scales
- Integrates component science into whole-system interactions and responses
- Identifies emergent and self-organizing ecological properties
- Includes the human element essential for achieving economic and environmental goals
- Incorporates adaptive management to achieve goals
- Facilitates identifying unintended consequences

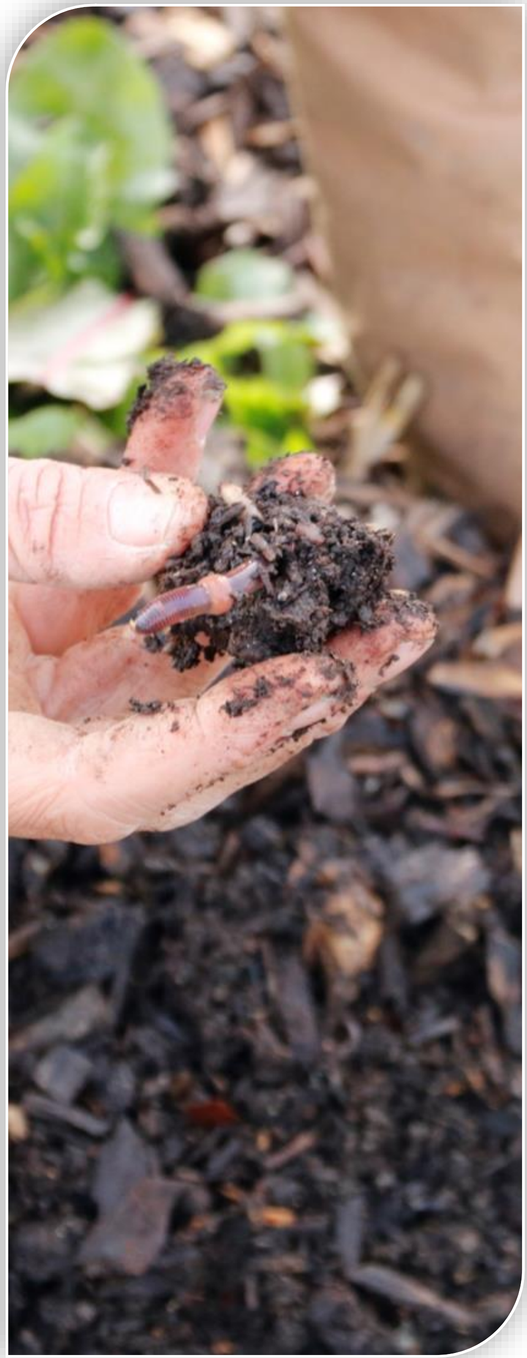
Van der Ploeg et al 2006; Teague et al. 2016; Massy 2018



To optimize microbe benefits:

1. Maintain year-round living cover of the soil, via perennial pastures on grazed land and/or multi-species cover crops
2. Provide support for the microbial bridge to enhance carbon flow from plants to soil
3. Reduce use of pesticides and high analysis fertilizers that inhibit the complex biochemical signalling between plant roots and microbes
4. Promote plant and microbial diversity to promote checks and balances for pests and diseases
5. Use short periods of grazing with adequate recovery on perennial pastures is best way to improve soils
   - Stimulates growth and provides extra nitrogen
   - Quickly adds carbon and improves infiltration

Jones 2016

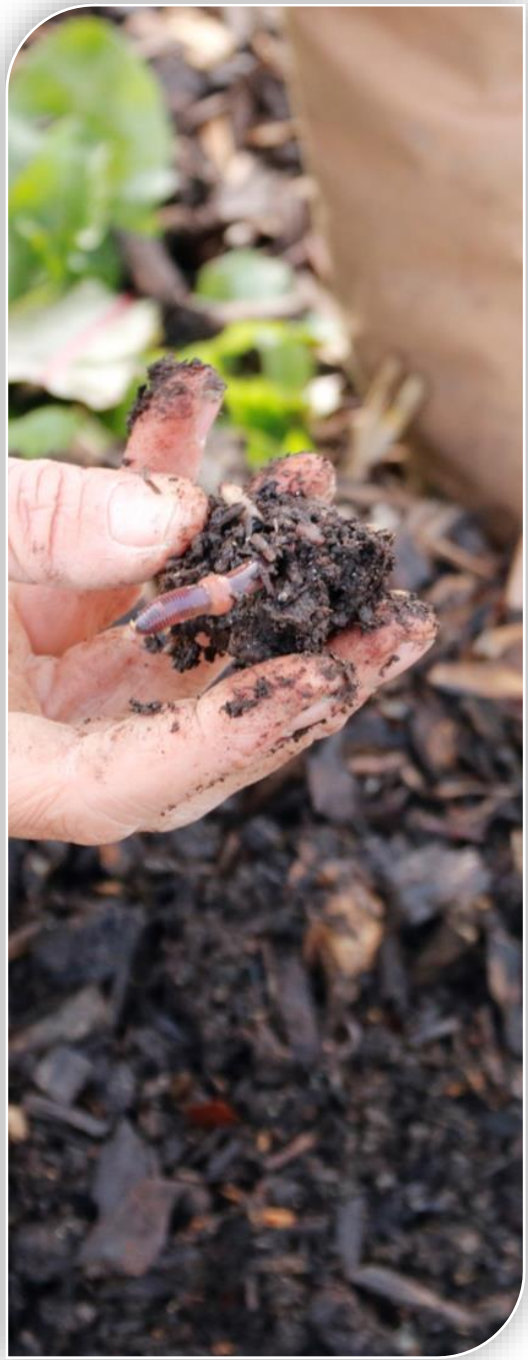


Summary

AMP vs. Continuous Grazing Research Shows:

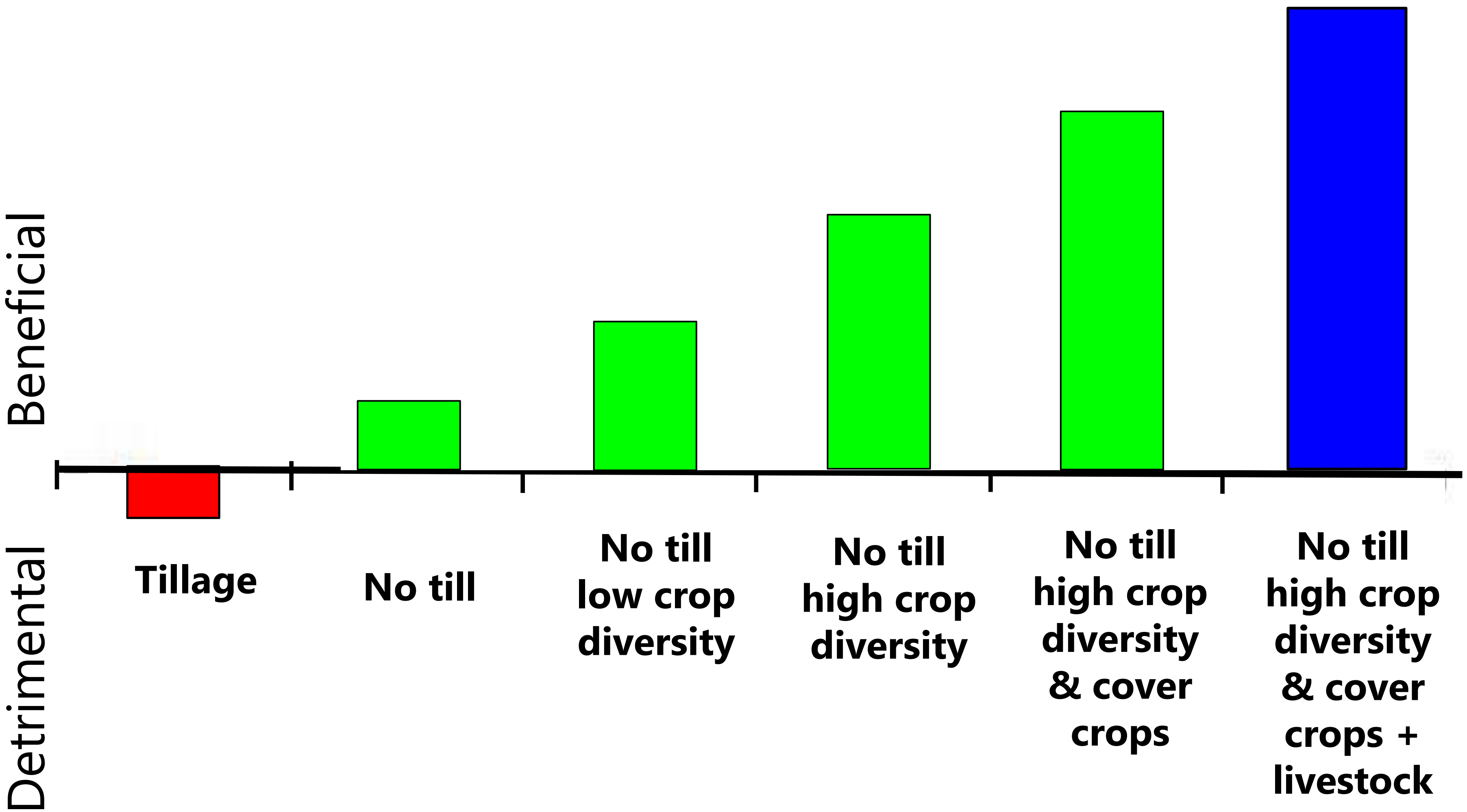
- Adaptive stocking is less sensitive to heavy stocking than fixed stocking
- As number of paddocks is increased, stocking rates can be increased while improving ecological function
- AMP advantages of over continuous grazing are more important as *paddock* and *stock* numbers increase
- Short grazing periods + long recovery with > 30 paddocks allows higher stocking rates, giving :
  - Maximum regeneration of ecological function
  - Higher net returns with lower income variability
- Profits are proportional to soil carbon and soil health

Martin et al. 2014; Jakoby et al. 2014; 2015; Teague et al. 2015; Wang et al., 2018; Teague and Kreuter 2020; Pecenka and Lundgren 2019; Ritchie 2020

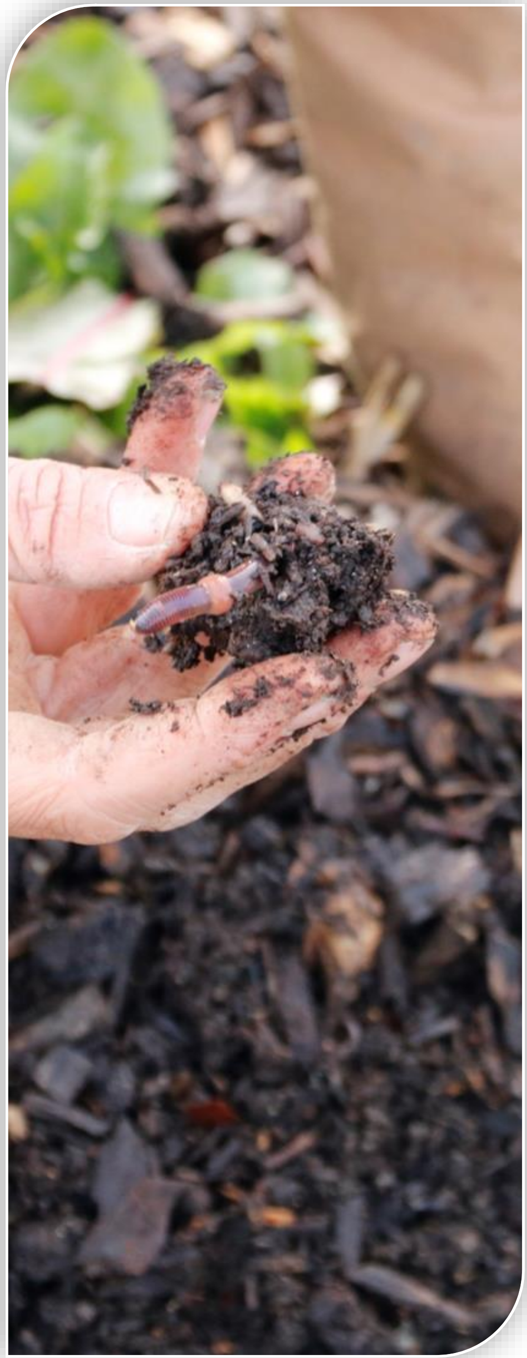


Cropland Soil Health

How different management practices influence soil health

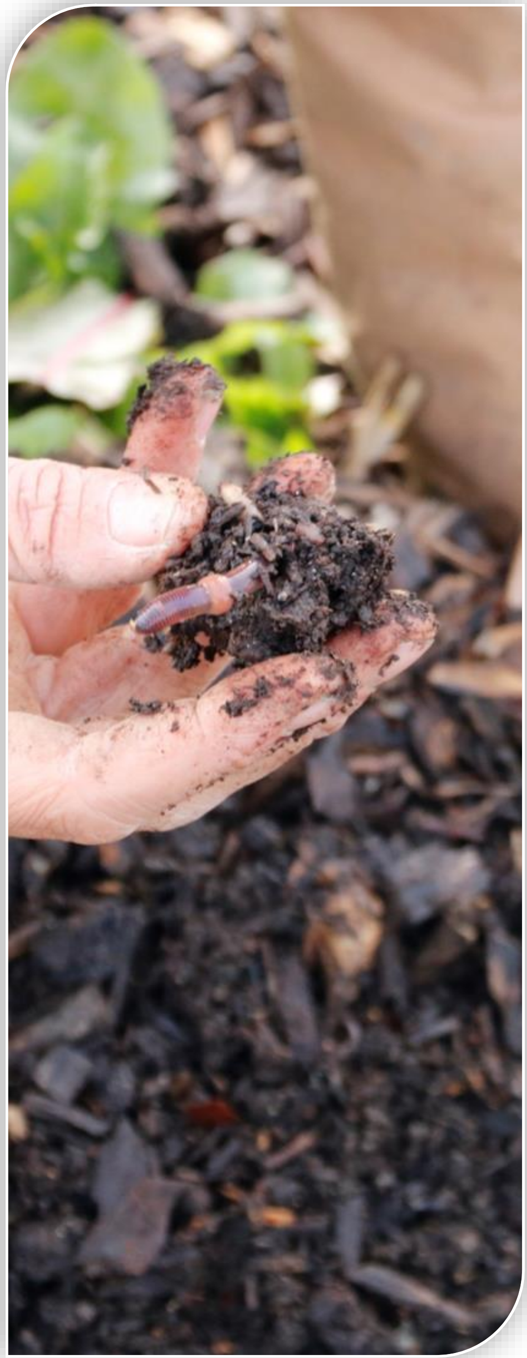


Jay Fuhrer, NRCS, North Dakota

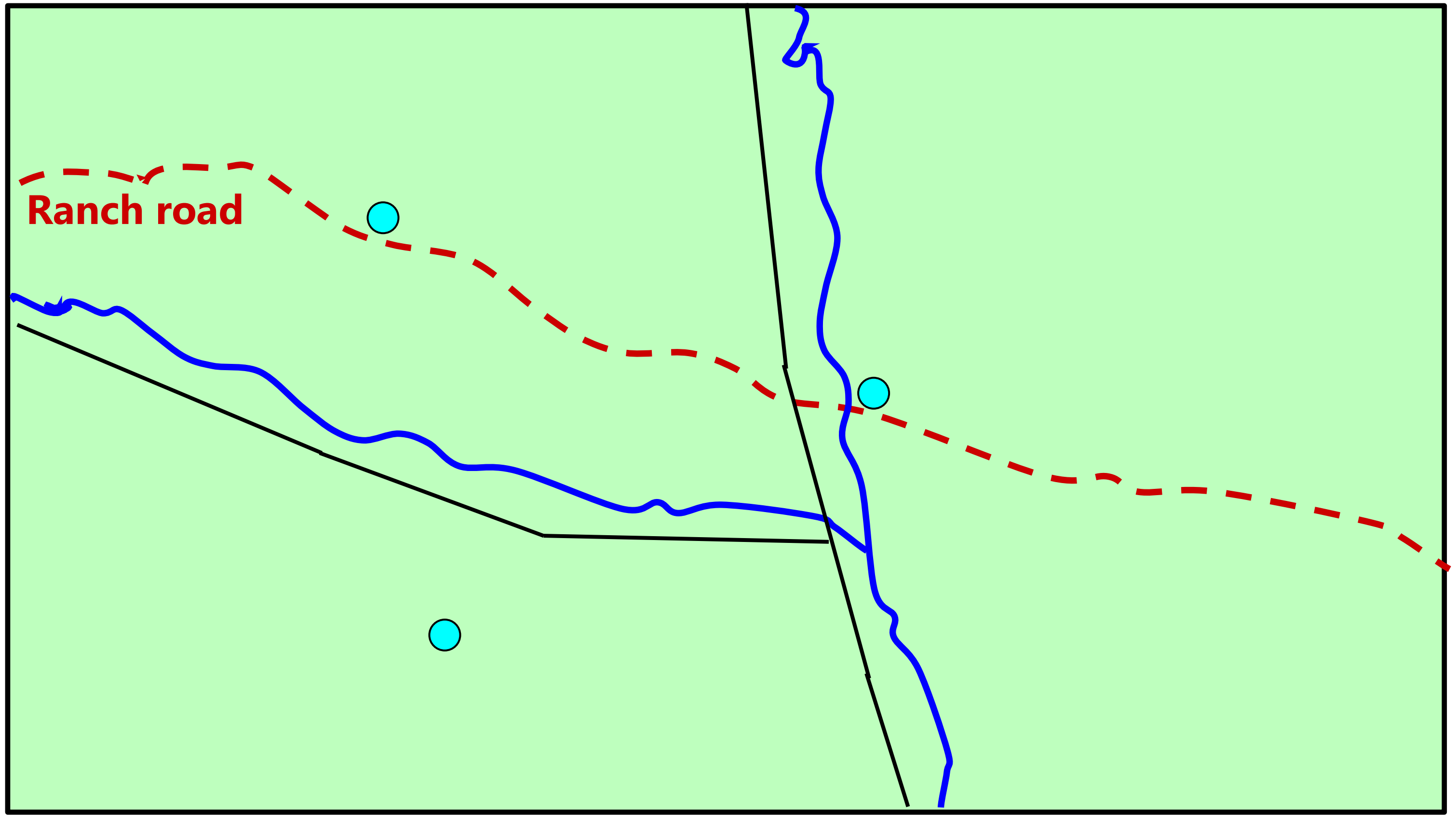


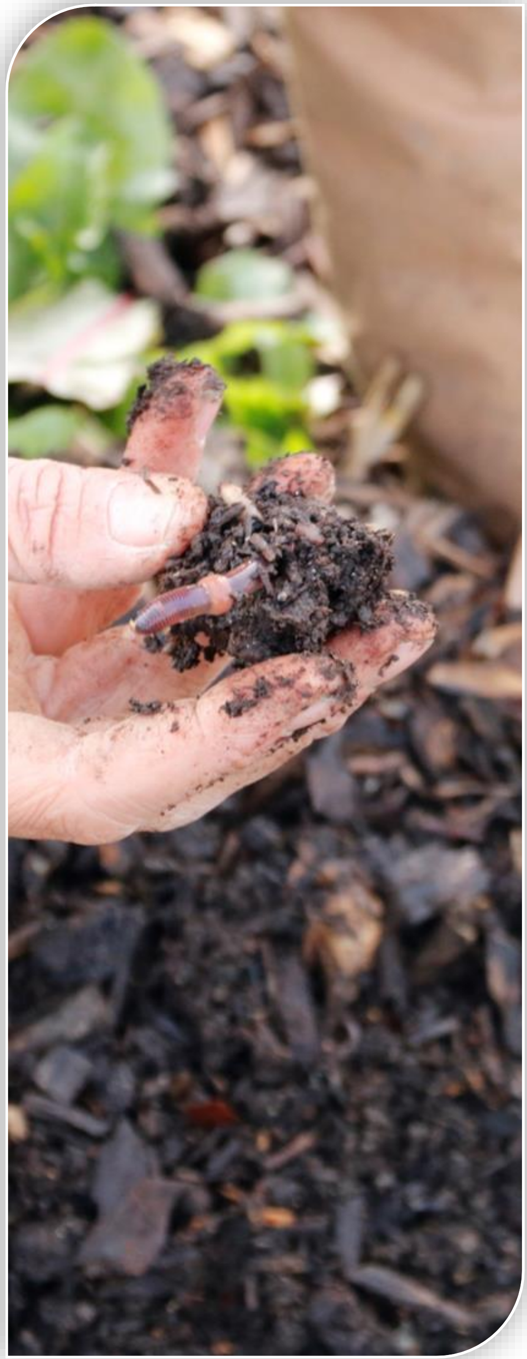
Positives with grass-based ruminants

- Rangelands are the greatest proportion of land globally
- Rangelands can only be used to produce human food via grazing animals
- Grazing converts plants inedible by humans into high quality food
- Food products from grazing animals has higher quality protein than from plants
- Food from grazing ruminants uses less concentrates than other livestock based human food
- Animal protein is superior to plant food for humans
- Food from appropriately managed grazing has strongly negative Carbon footprint
- Protein-food from grass has best omega 3 to 6 ratio

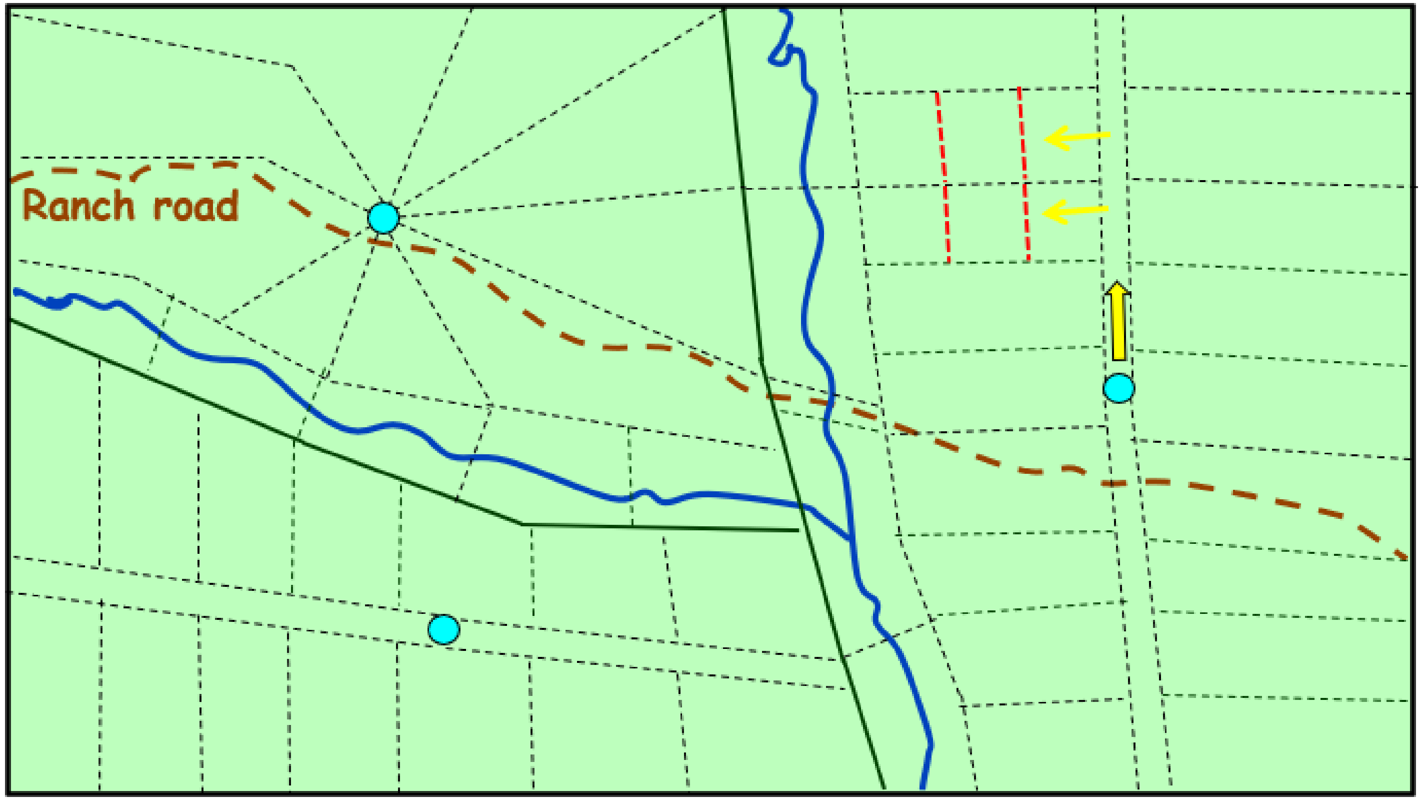


Continuous Grazing



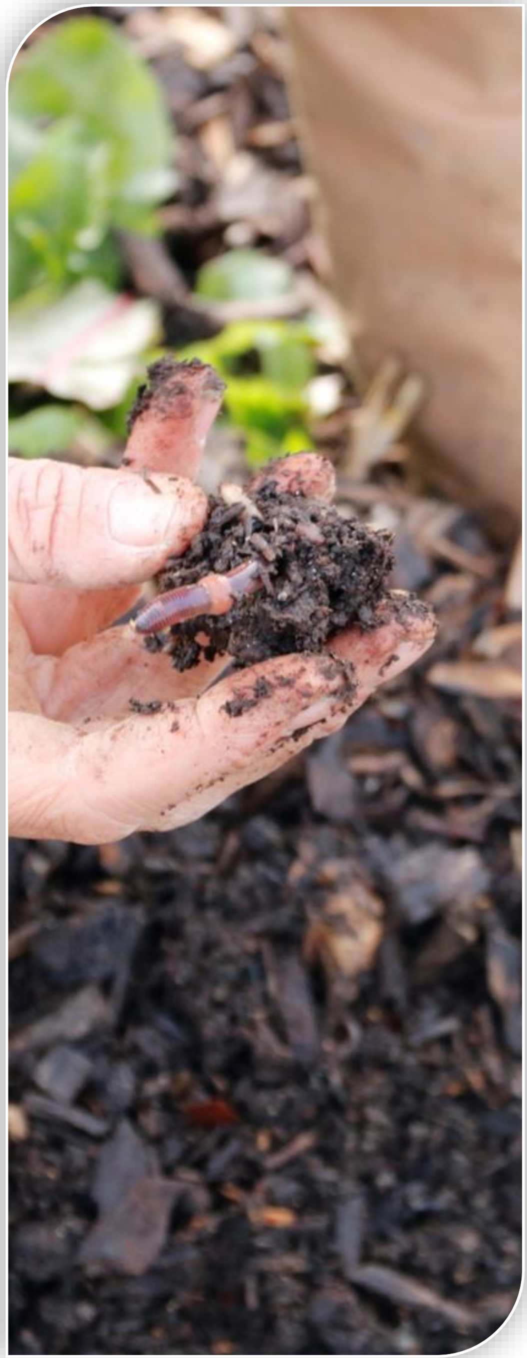


Application of AMP Grazing

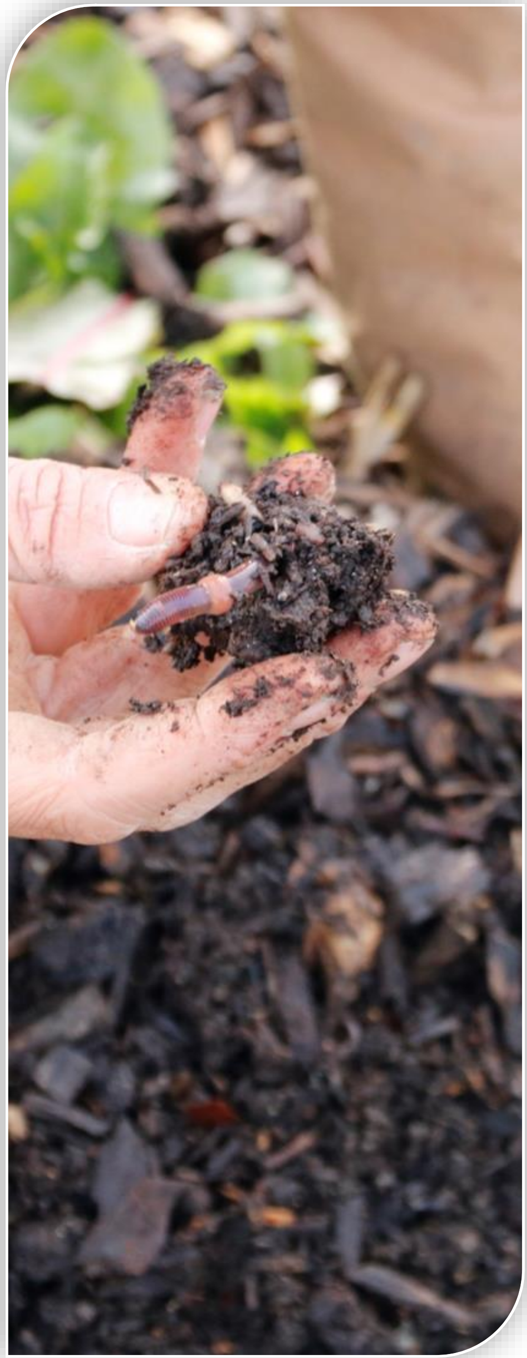


Existing fence
Electric fence
Water point

Norton et al. 2013; Jakoby et al. 2014; Teague et al. 2015

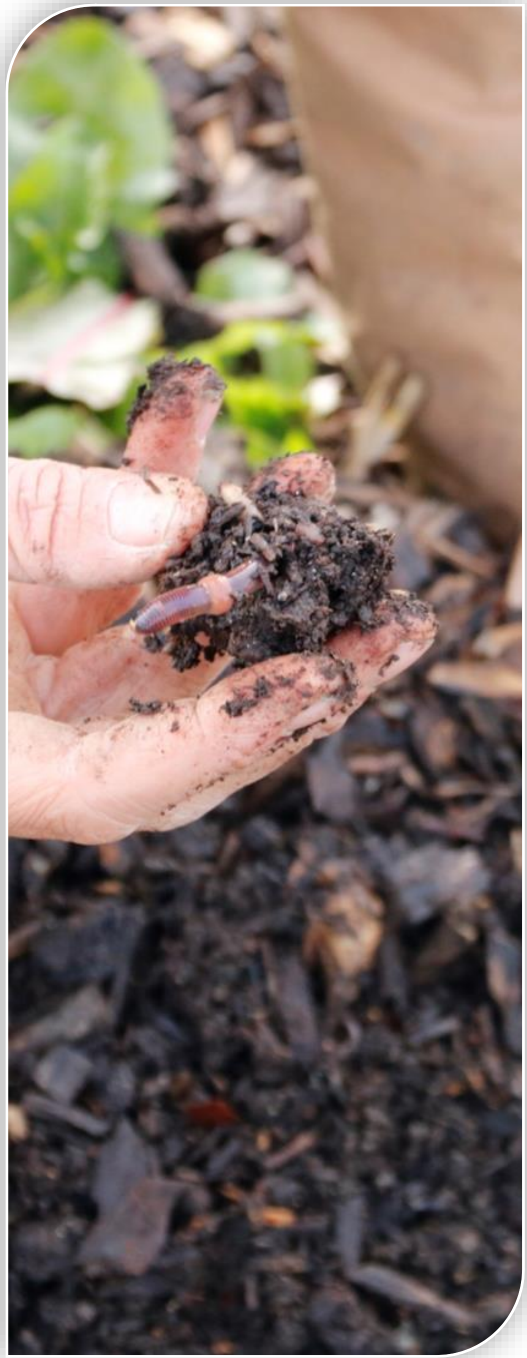


Questions?



Mechanisms of soil health restoration in regenerative agriculture

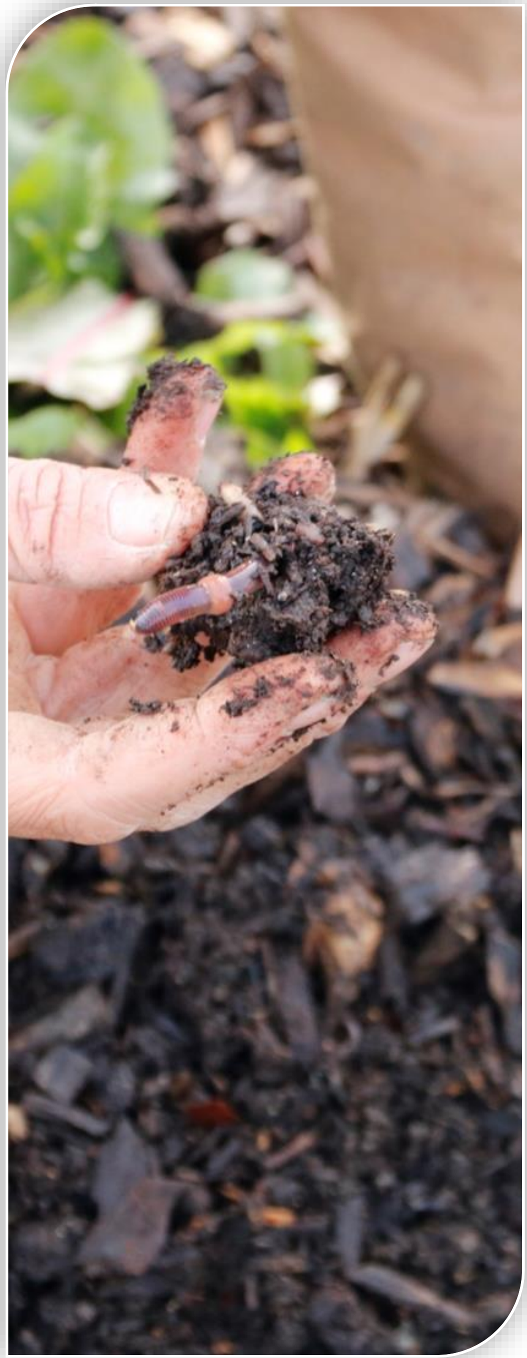
Koen Willekens



Smart soil management in arable cropping systems, improving soil quality and optimizing nutrients dynamics

Dr. Ir. Koen Willekens

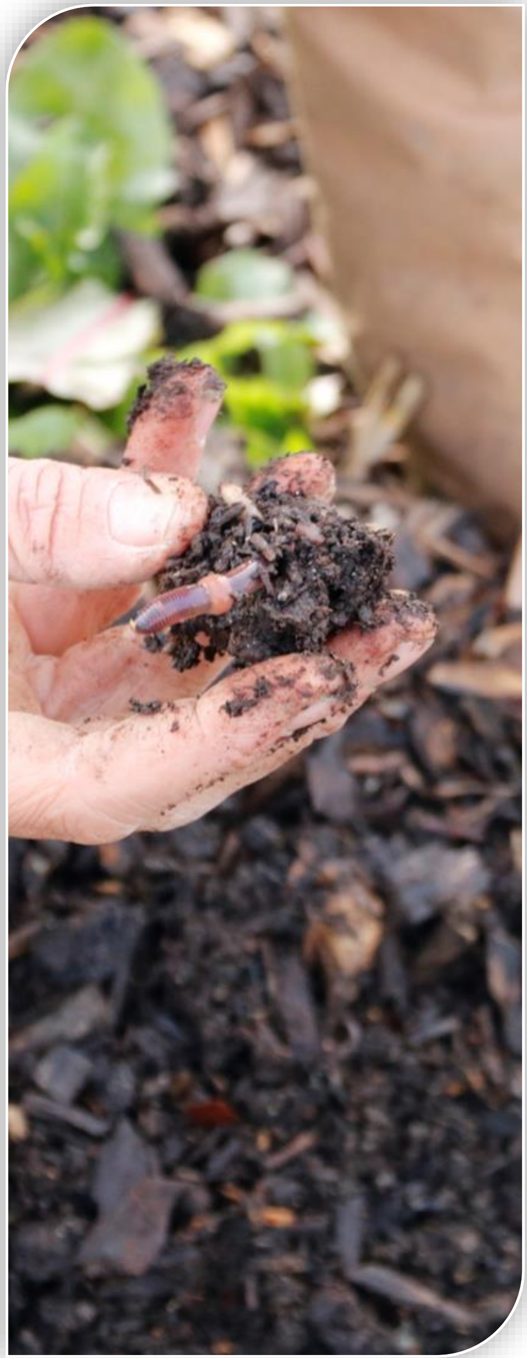
Soil Health Conference
Brussels, 5 December 2022



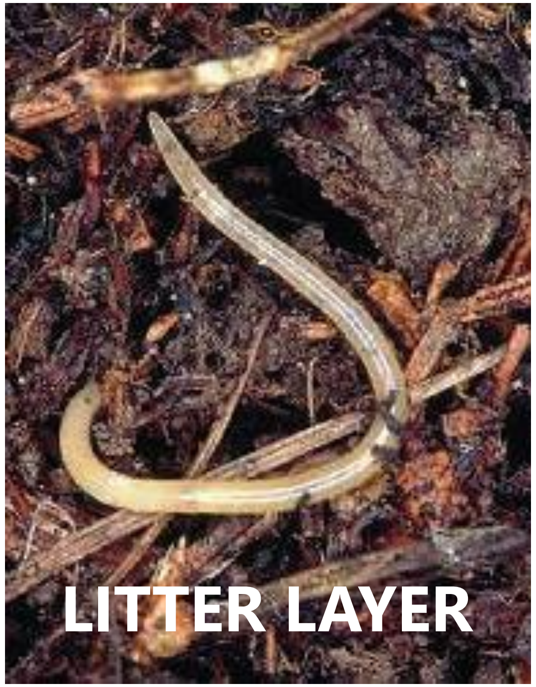
Regenerative soil management in agroecosystems relies on several natural processes:

- ✓ 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



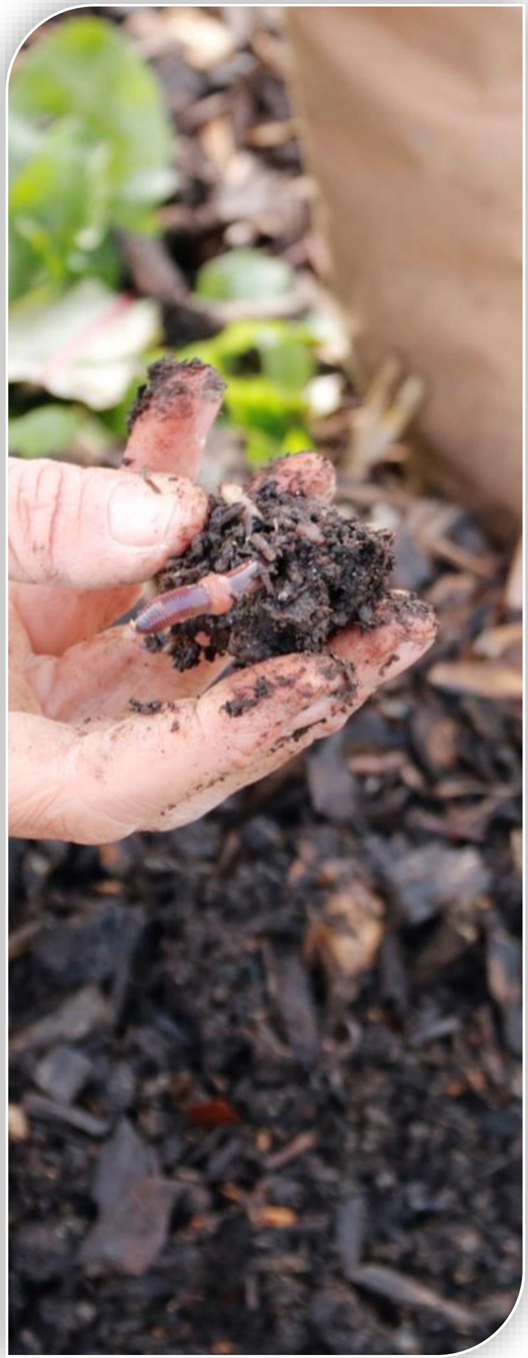
Decay of plant residues

Conversion into humus

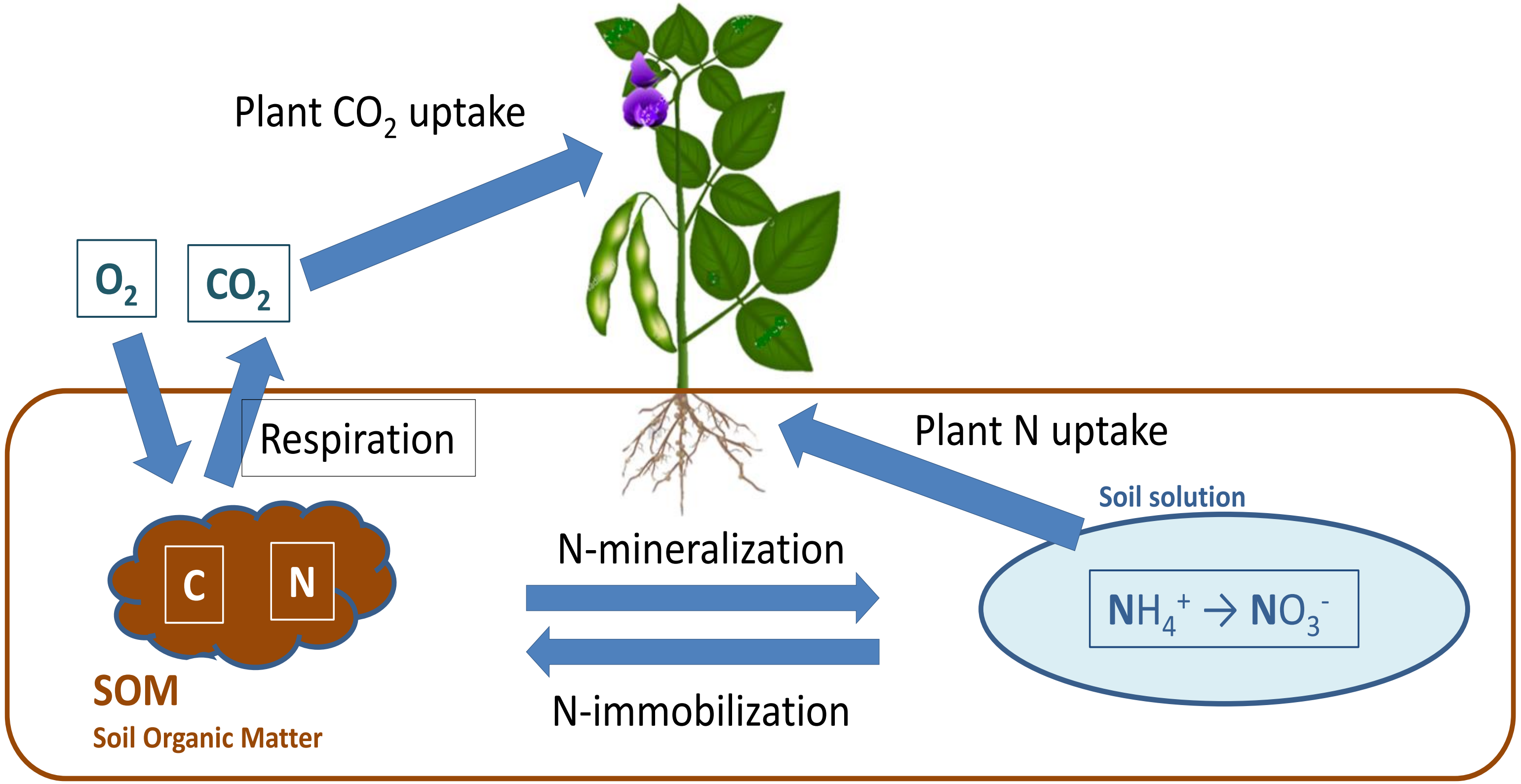
Root exudates

→ Stimulate microbial activity

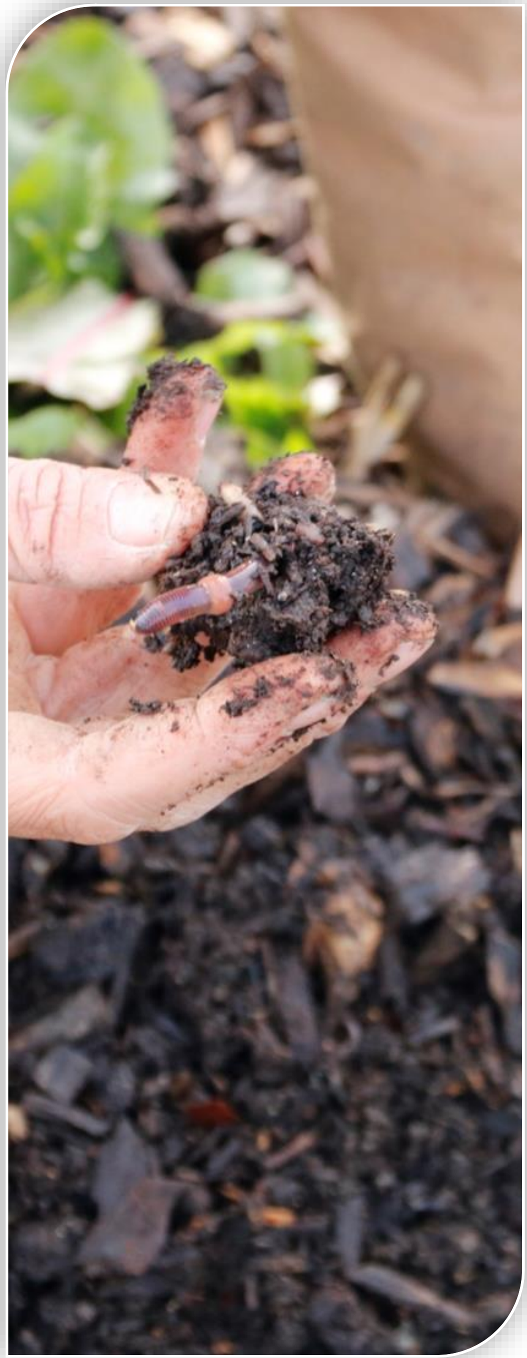
→ Important for symbiotic associations



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



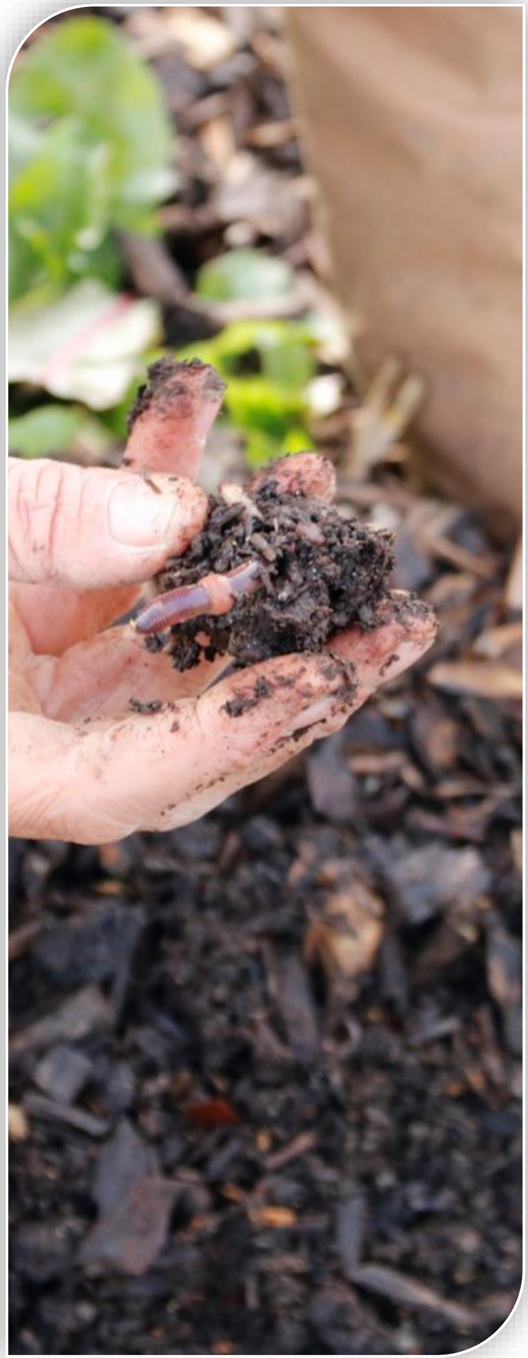
Types of SOM

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:

- o Adsorption to mineral surfaces
- o 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

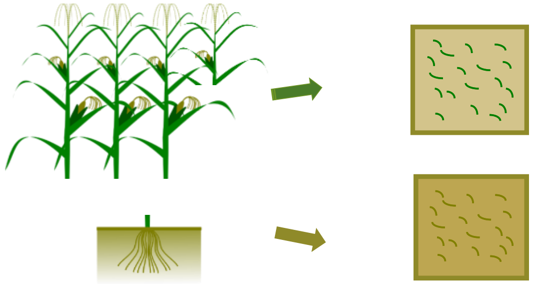
External input of organic material = organic fertilization

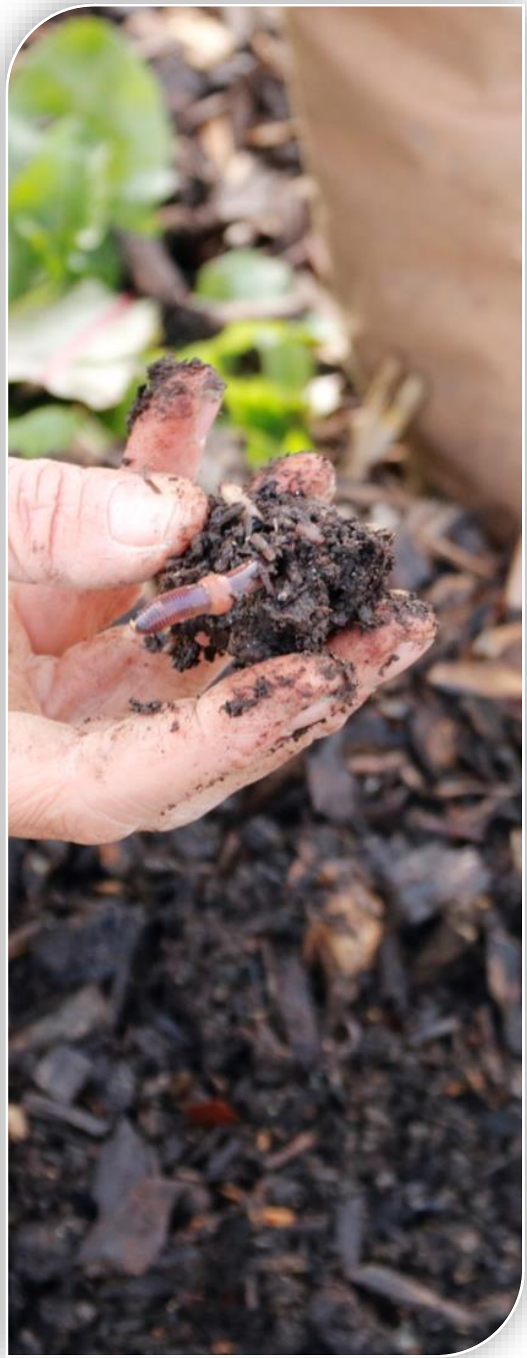
- ✓ Animal manure
- ✓ Compost
- ✓ Cut and carry fertilizers (e.g. grass mowings, wood chips, …)

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

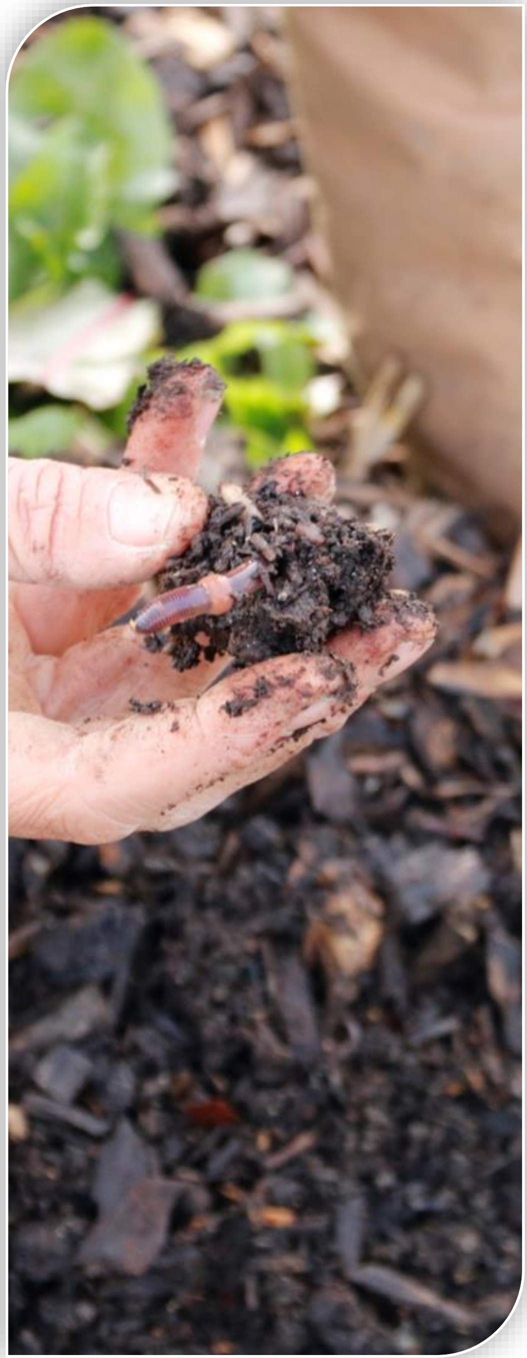




Factors affecting SOM persistence / C storage

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

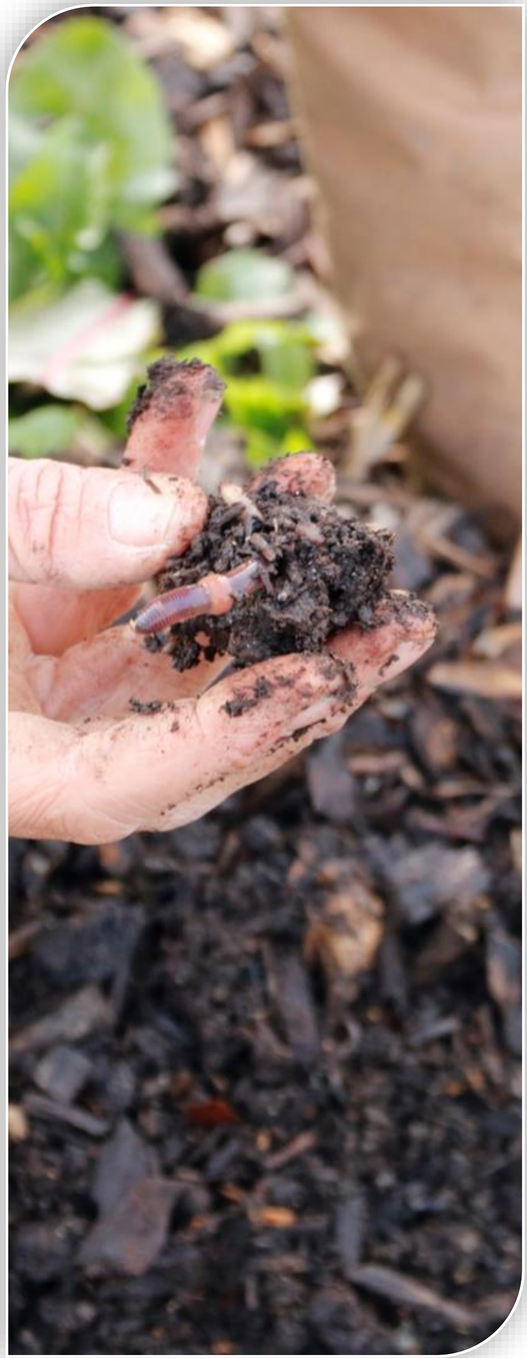
Interactions among all these factors are complex and in some cases poorly understood



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

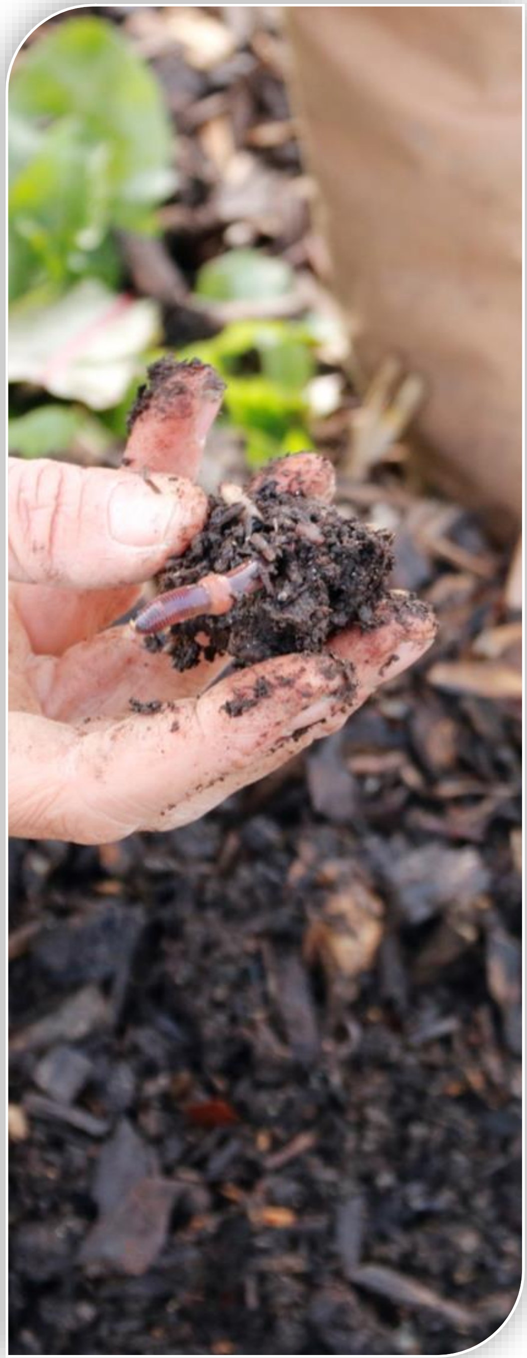


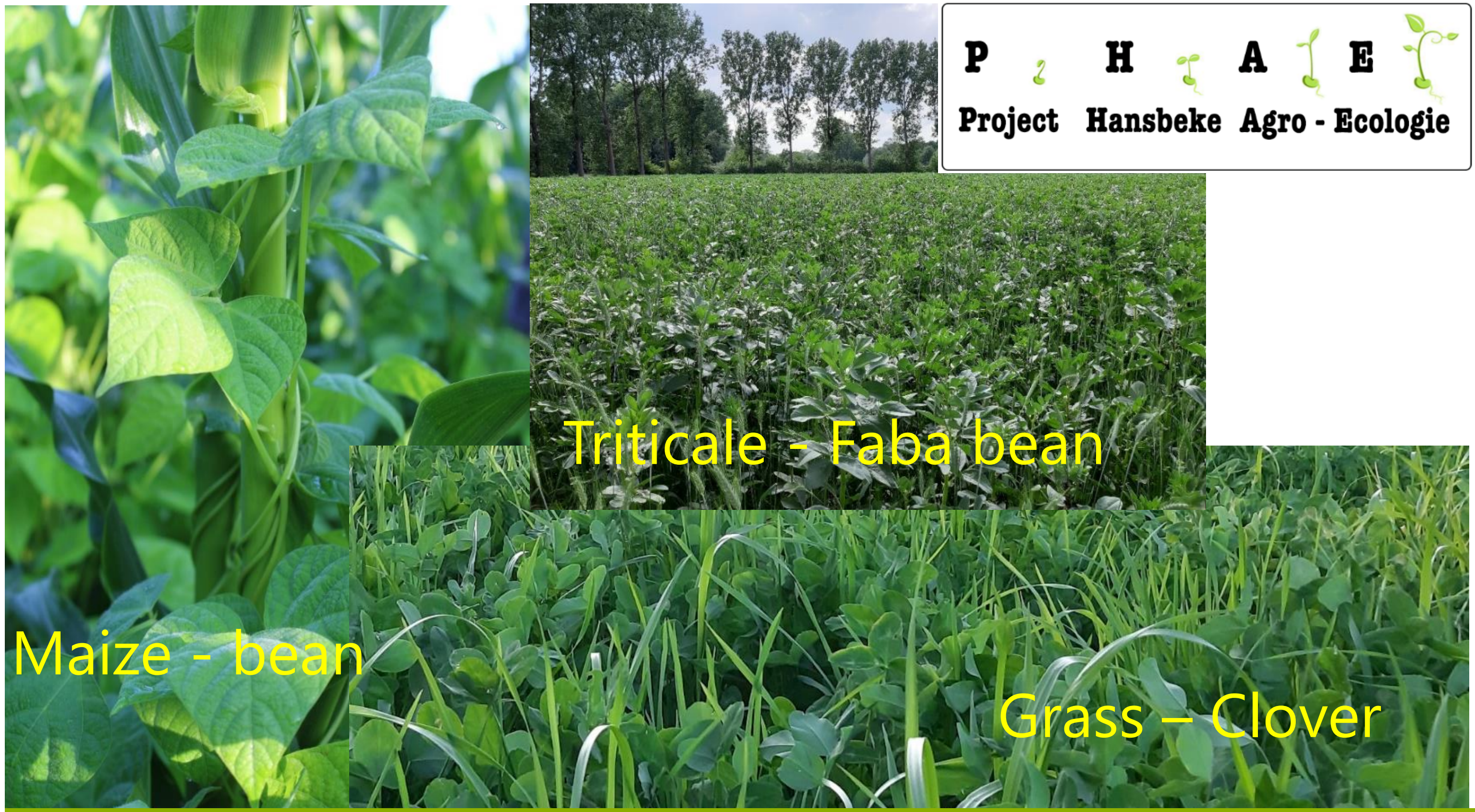
Why do we need a diverse crop rotation?

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.

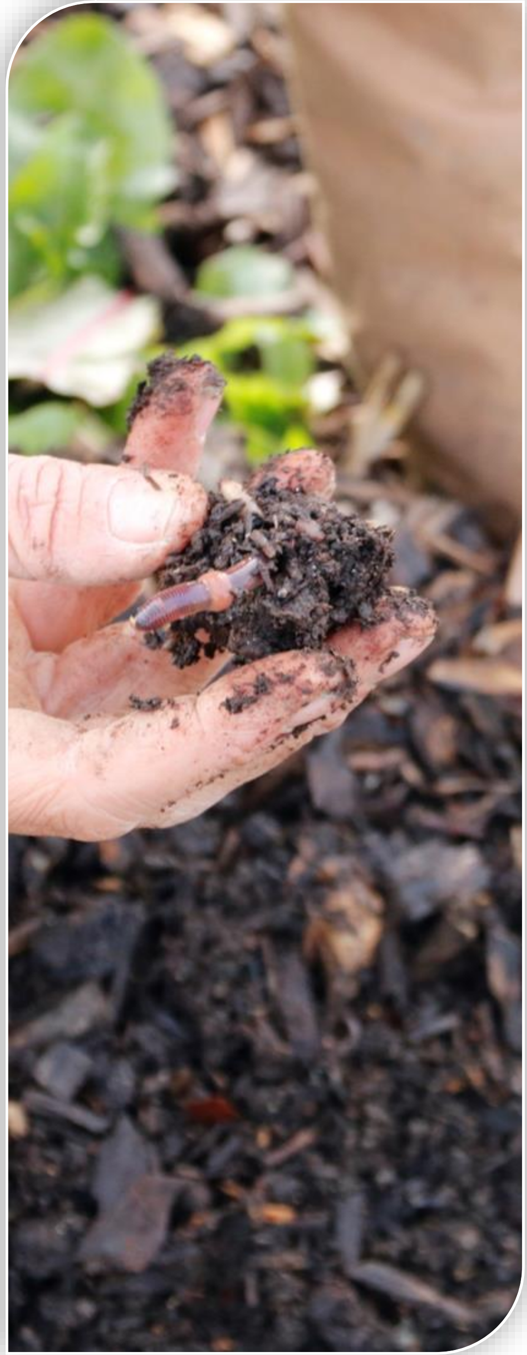
Mixed cultivation of grasses and leguminous crops





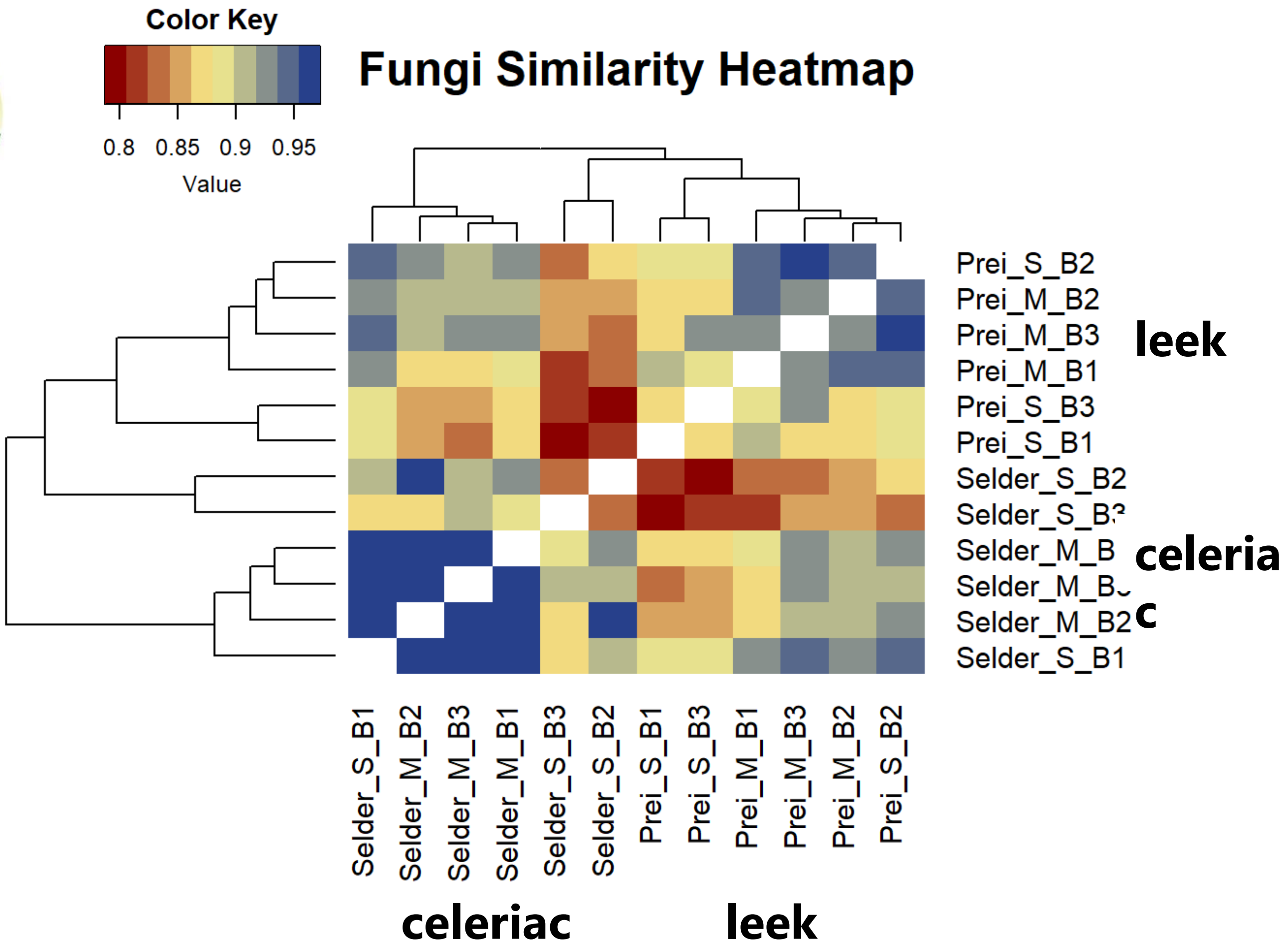
Legume cover crops rotated with grasses or cereals have a high potential of increasing SOM stocks because of relatively high C input into the system.

Maize/legume cropping systems as well provide a good balance between legume nitrogen rich material and more recalcitrant maize stover and

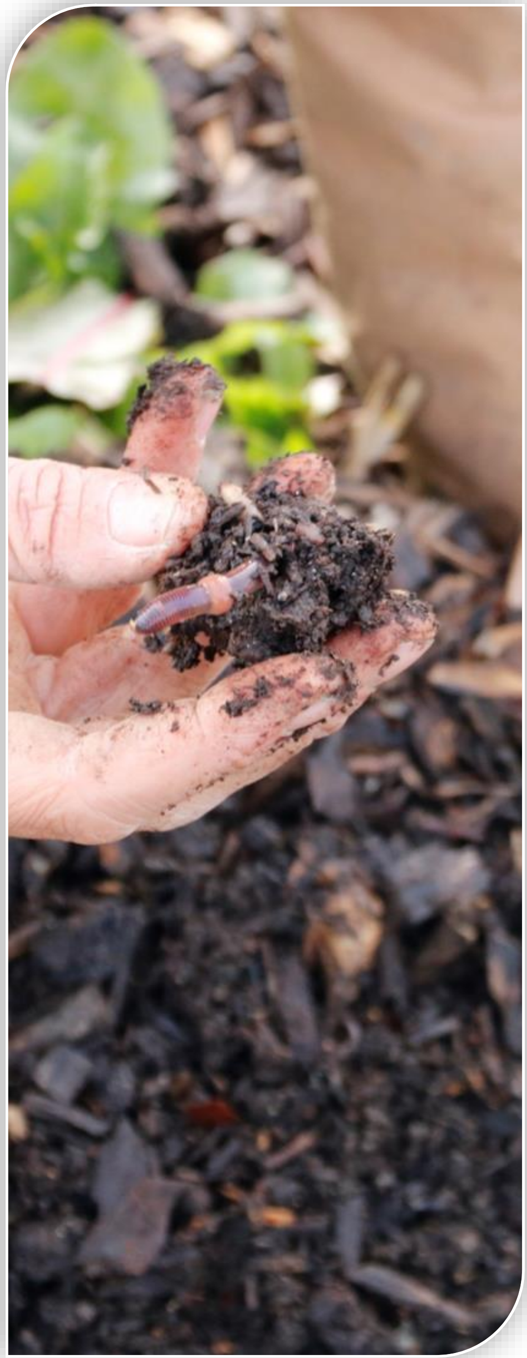


Relation crop – rhizosphere microbial community

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?

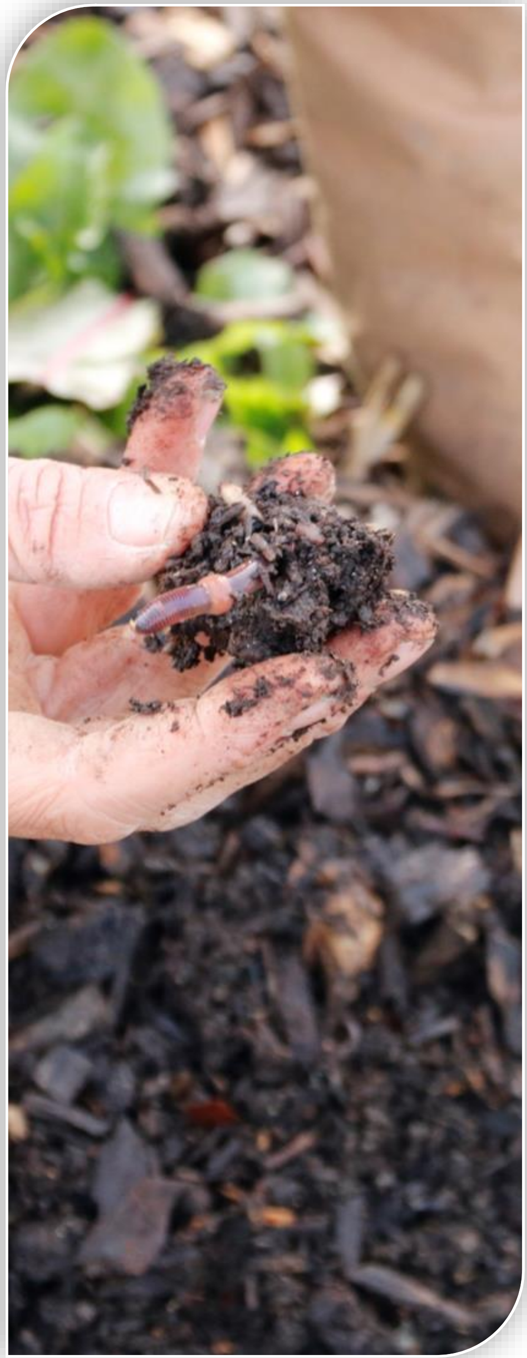
If lack of N availability from SOM at lower SOM contents in a transition phase, we have to start SOM built-up by diversification of crop rotation and the use of soil improving organic fertilizers.

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.

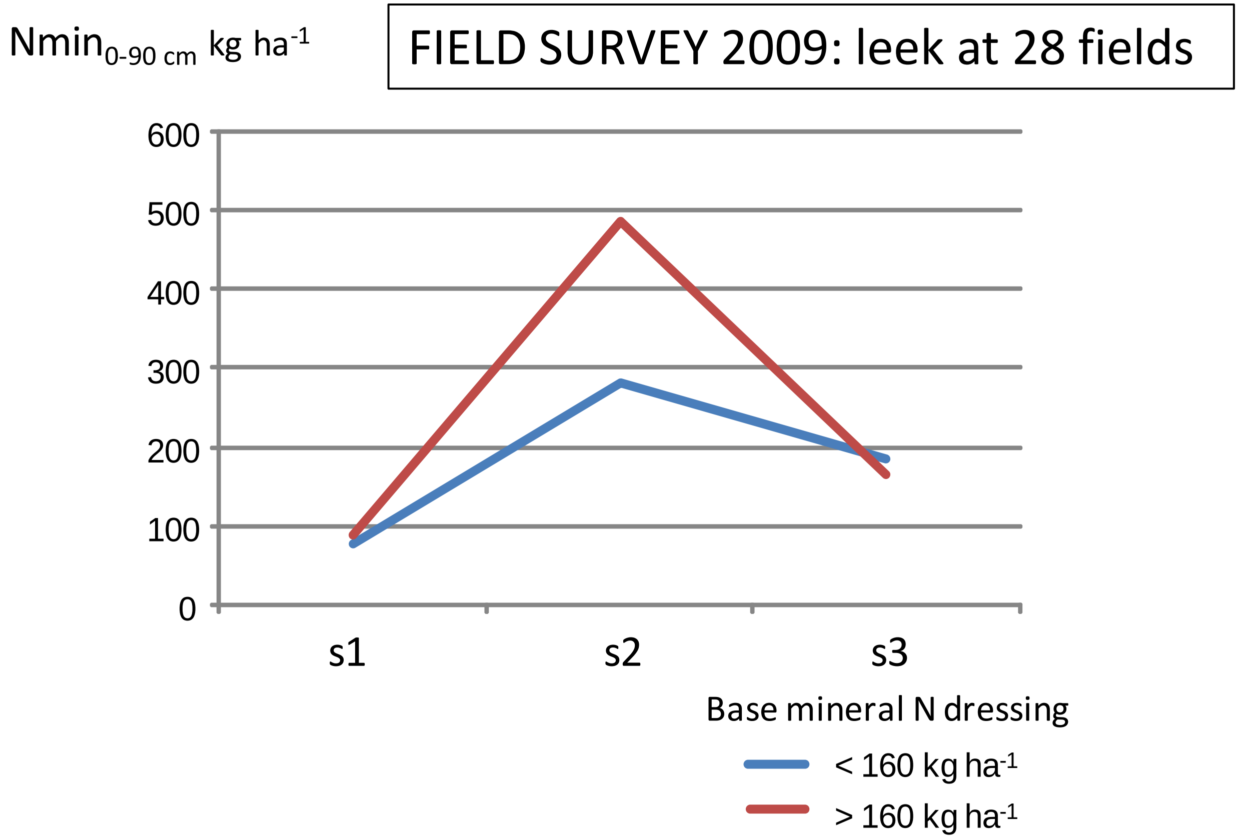
Risk of a too high N mineralization potential due to frequent supply of farm yard manure.

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

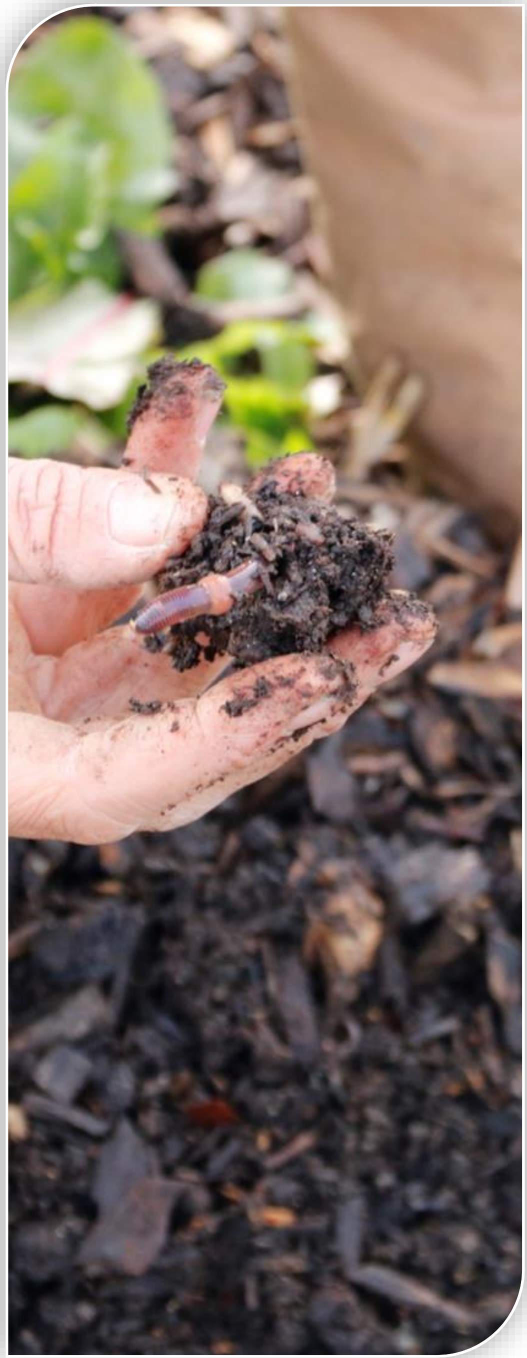


s1 - s2

- 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)

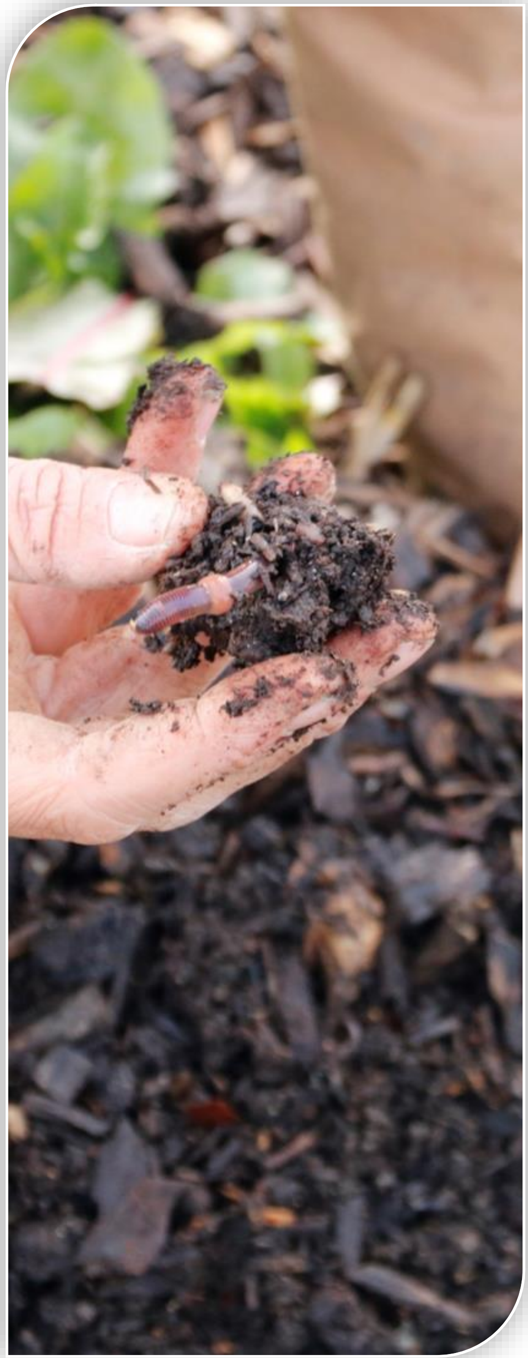


Besides by fertilization, residual soil mineral N is affected by agronomic practices and growing season.

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

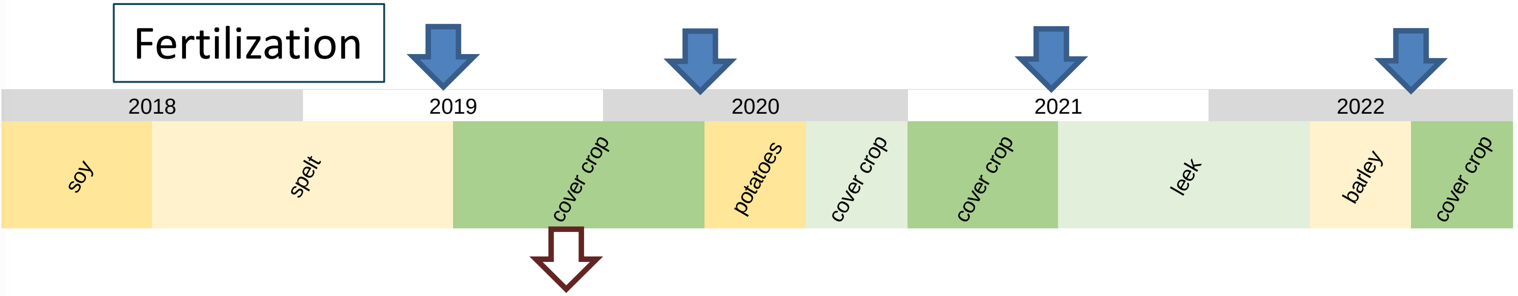
Regular soil quality improving practices as the use of FYM, compost and cover crops reduced the risk of surpassing the nitrate N residue threshold as it was associated with a significantly lower residual



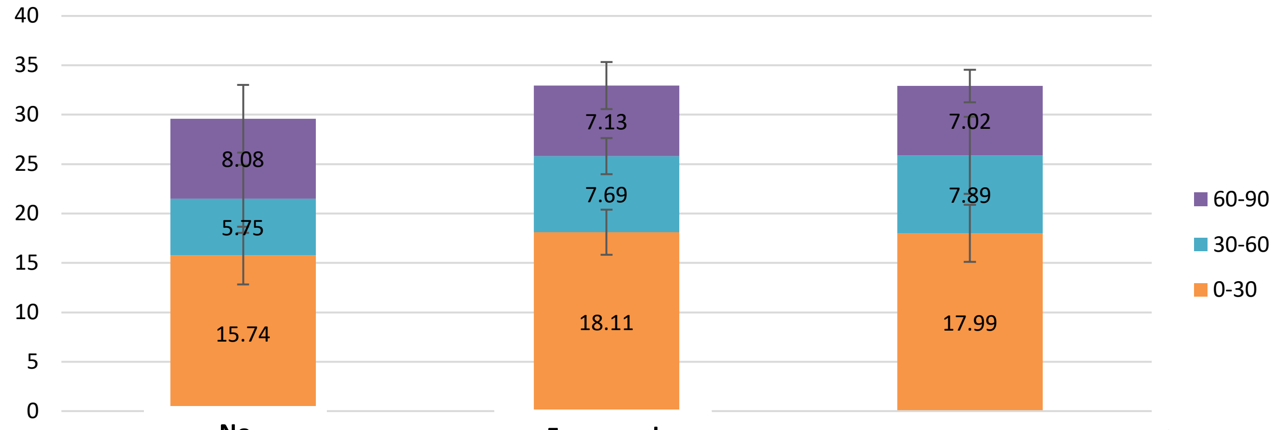
Why should we apply C-rich soil improving organic fertilization in spring and not in autumn?

VLAAMSE LAND MAATSCHAPPIJ
Vlaanderen is open ruimte

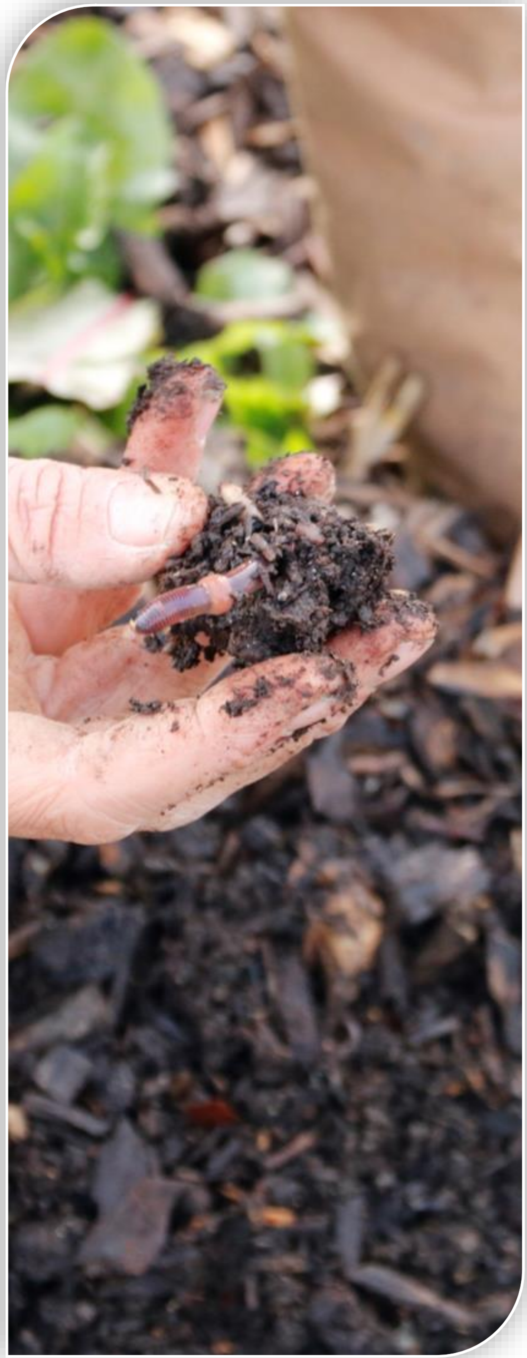
Project: Optimaliseren van bemestingsstrategieën vanuit de principes van de biologische landbouw



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

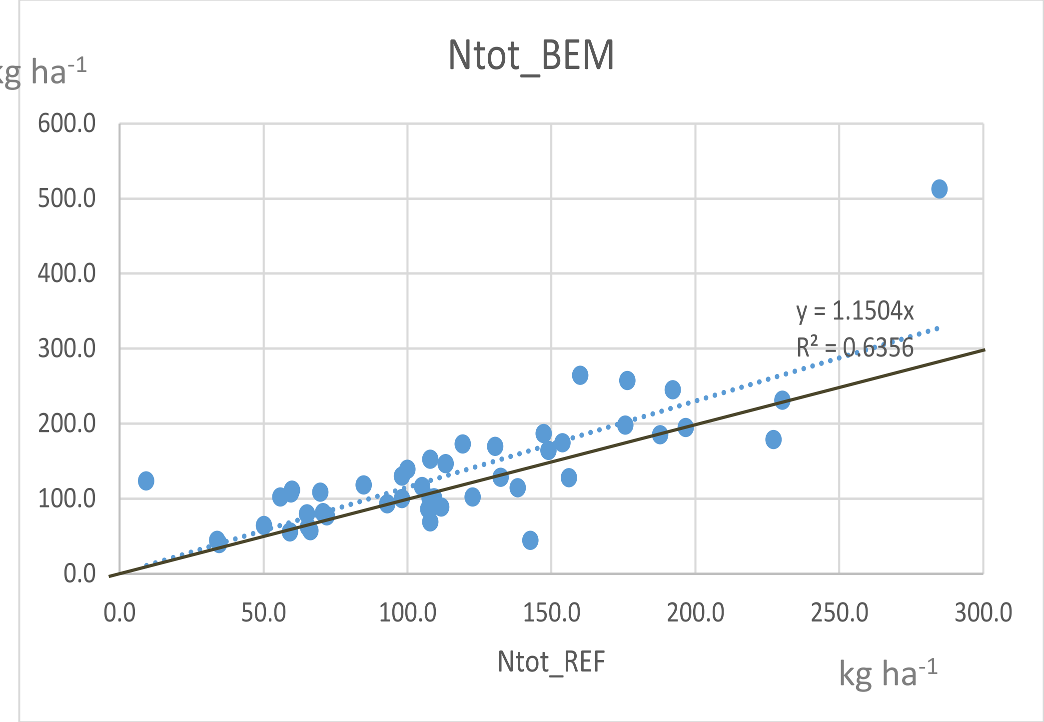


Input of organic material with high C/N ratio (e.g., farm yard manure) or stabilized C (compost) is key for improving soil fertility.
Late summer or autumn application does not necessarily result in an increase of residual soil mineral N, and if it does, it is a minor increase.



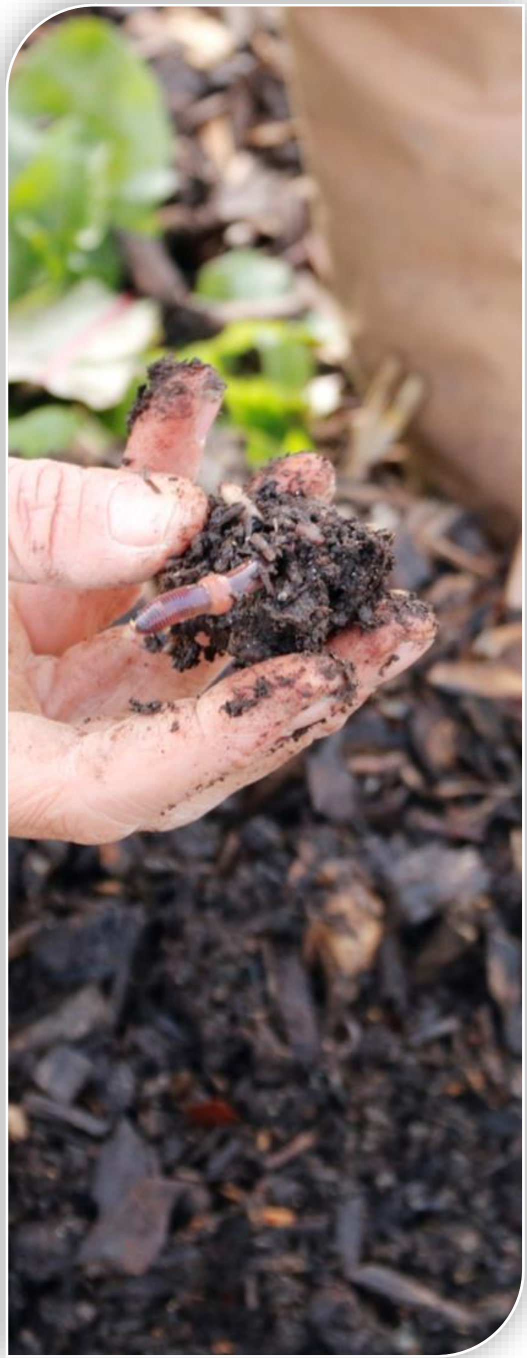
Why should we apply C-rich soil improving organic fertilization in spring and not in autum?

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 UNIVERSITEIT GENT Organic Forest Vlaanderen is landbouw & visserij

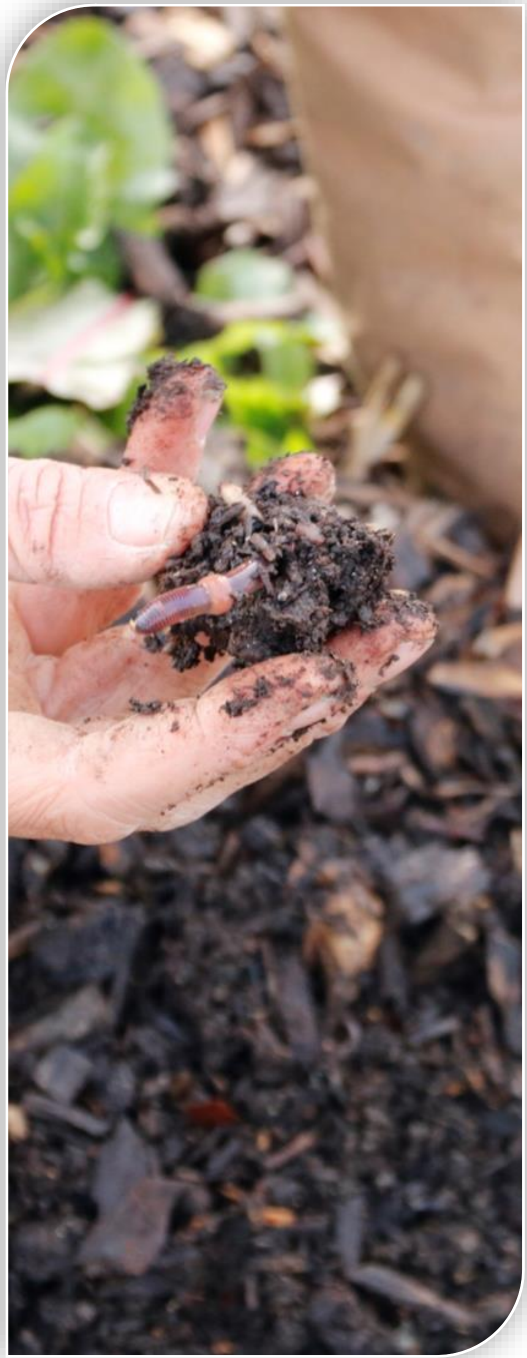


Why should we apply C-rich soil improving organic fertilization in spring and not in autumn?

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.

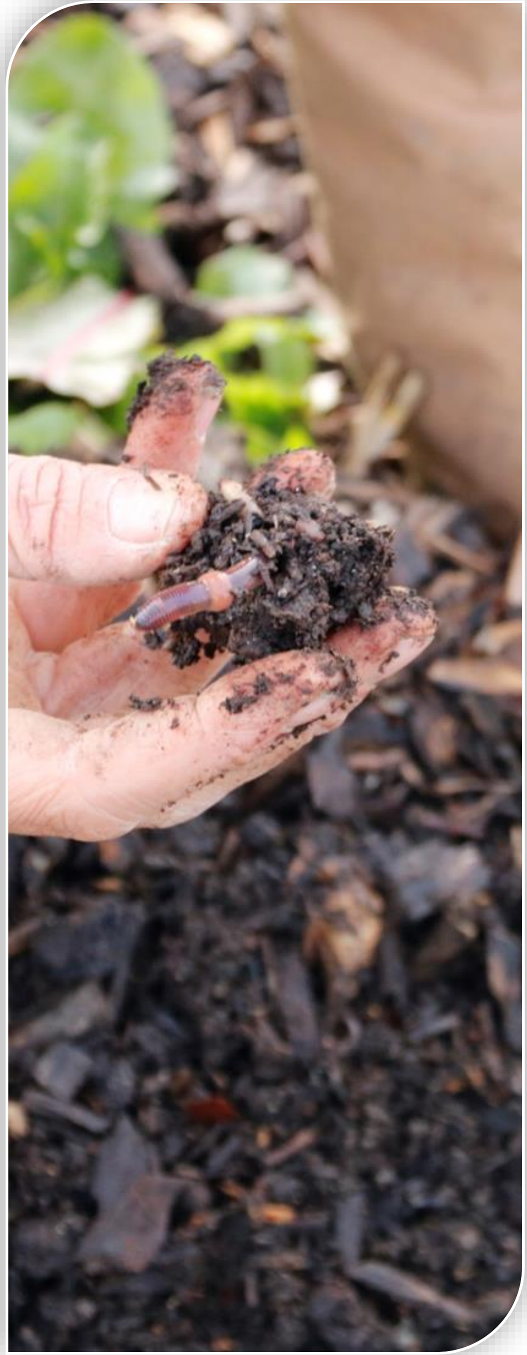


Why would we till the soil?

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

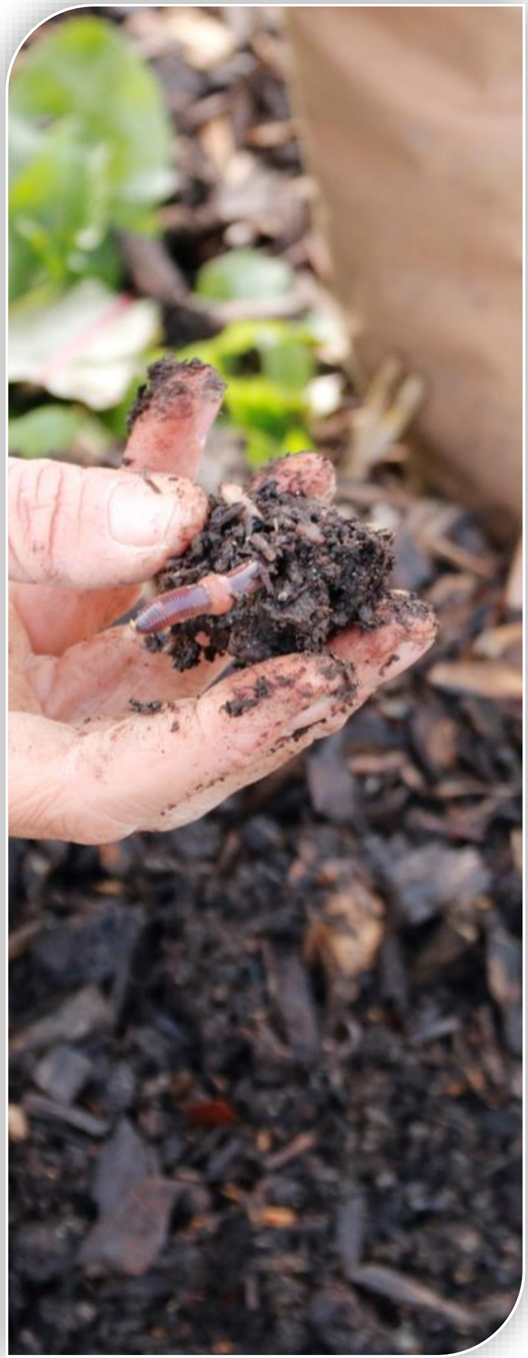
layer cm	CT	RT	Anova p-value
0-10	0.88 [b] (0.06)	1.05 [c] (0.13)	< 0.1
10-30	0.90 [b] (0.08)	0.93 [b] (0.09)	
30-60	0.61 [a] (0.05)	0.61 [a] (0.12)	
	$p < 0.001$	$p < 0.001$	

CT: conventional tillage
Mouldboard Plough

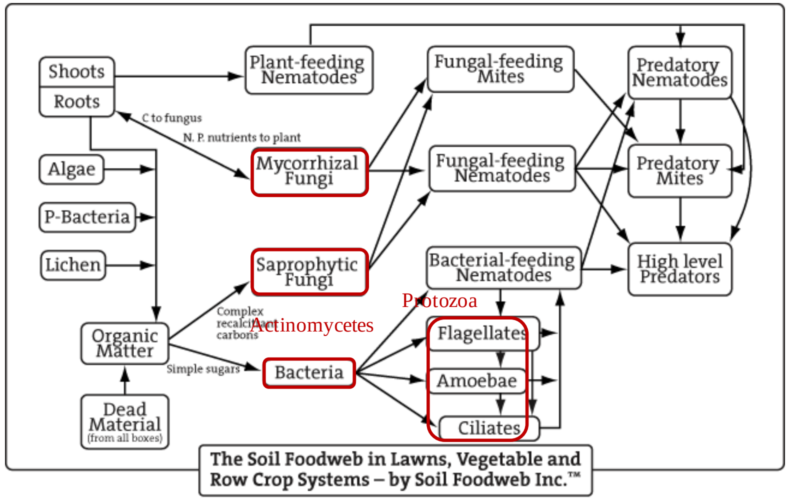
RT: Reduced tillage
Actisol ©

TILLAGE: stratification of SOM / reduction of nutrient le

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



Functional groups assessed by Phospholipid fatty acids (PLFA)



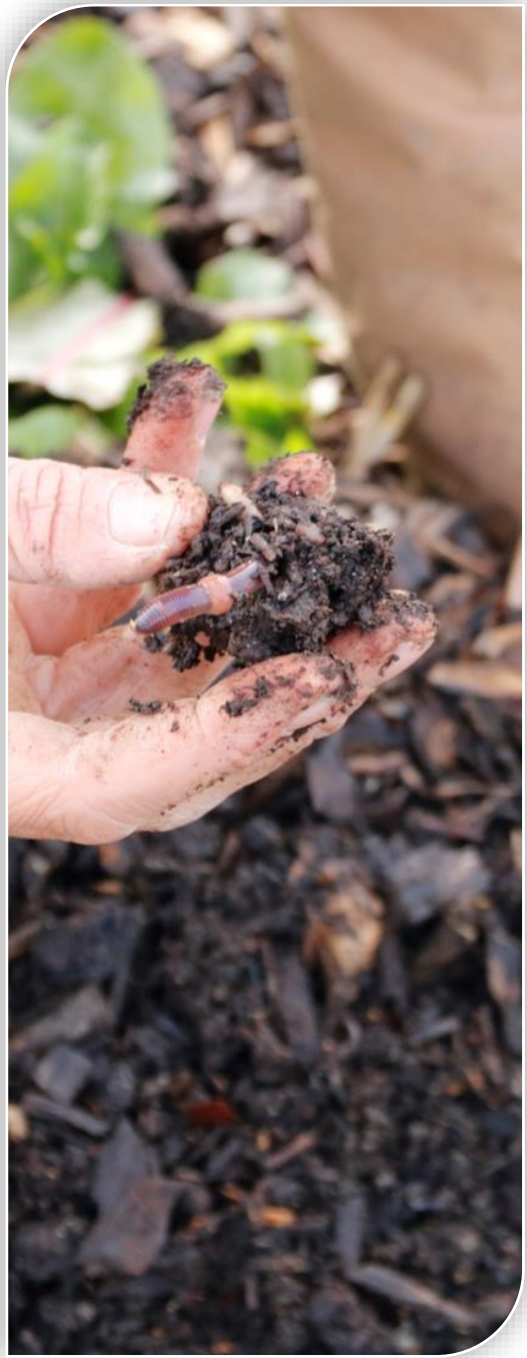
The Soil Foodweb in Lawns, Vegetable and Row Crop Systems – by Soil Foodweb Inc.™

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.

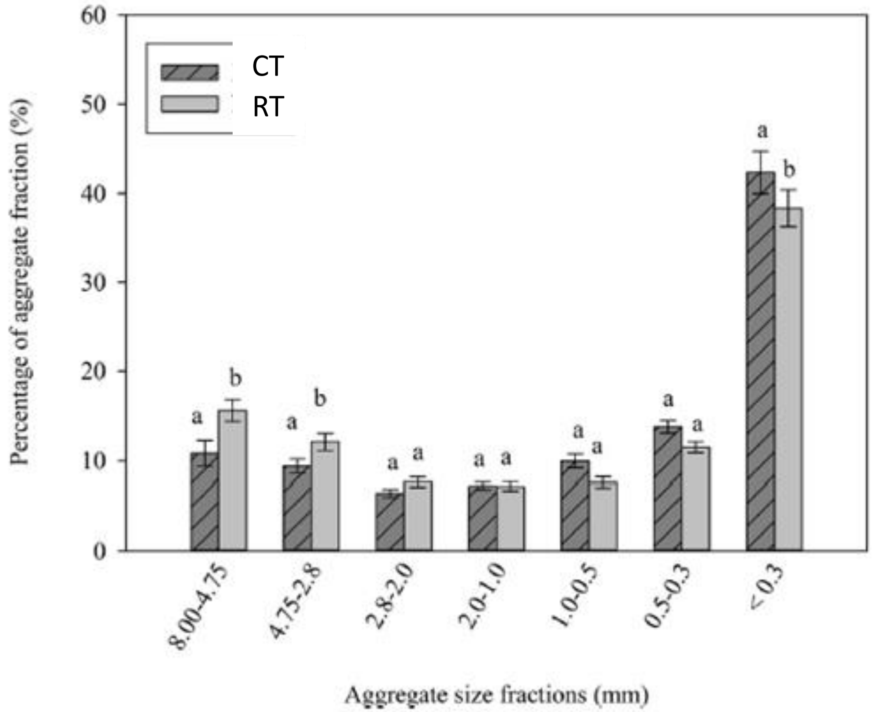


Soil management field experiment (conventional system): soil structure

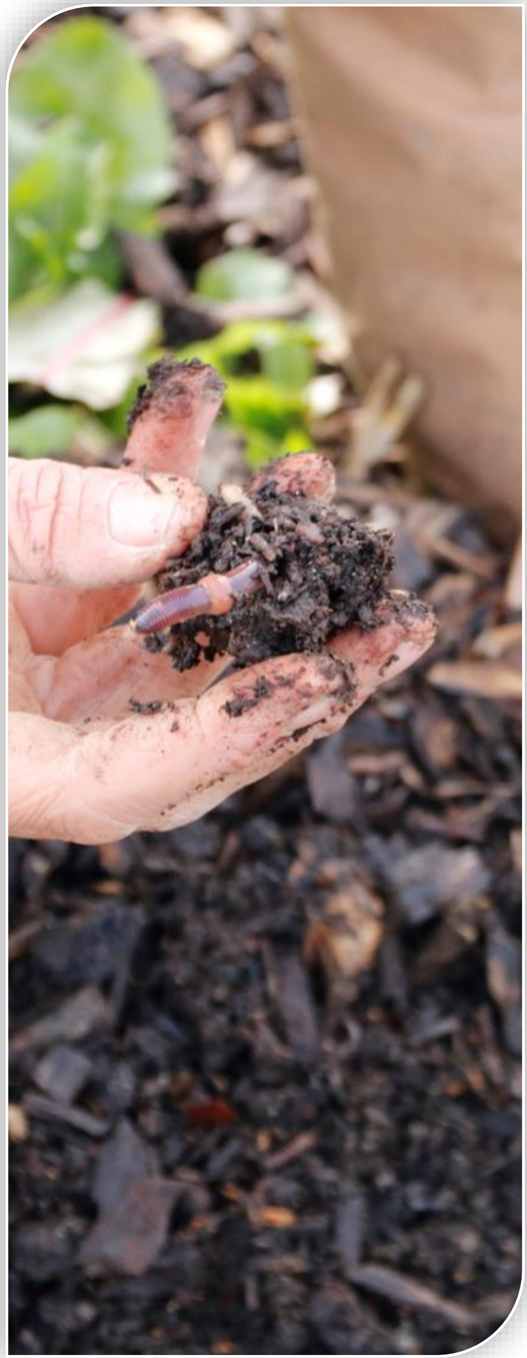
BOPACT trial at ILVO-Merelbeke, August 2012
Dry and wet sieving method
Aggregate size fractions in 0-10 cm soil layer after 3 years

CT: conventional tillage
Mouldboard Plough

RT: Reduced tillage
Actisol ©



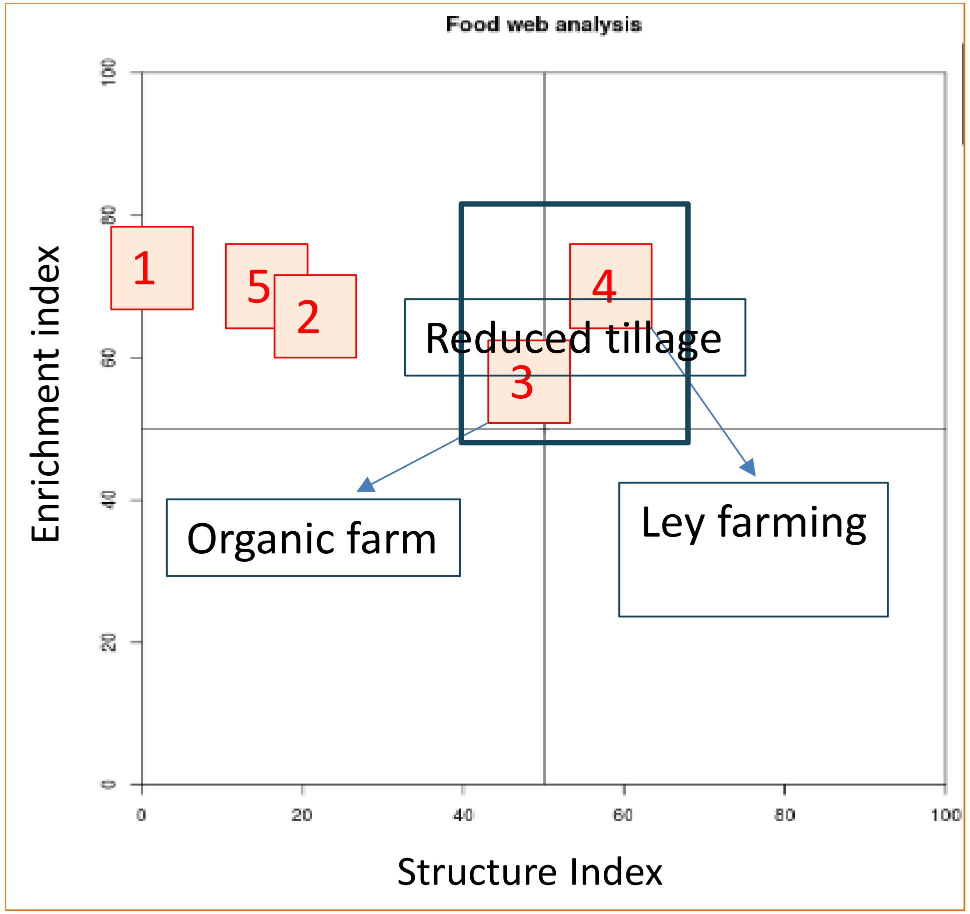
Ploughing causes more aggregates in the smallest size fraction (<0.3 mm)



Soil food web analysis based on nematode communities

Trophic levels and coloniser-persister categorization

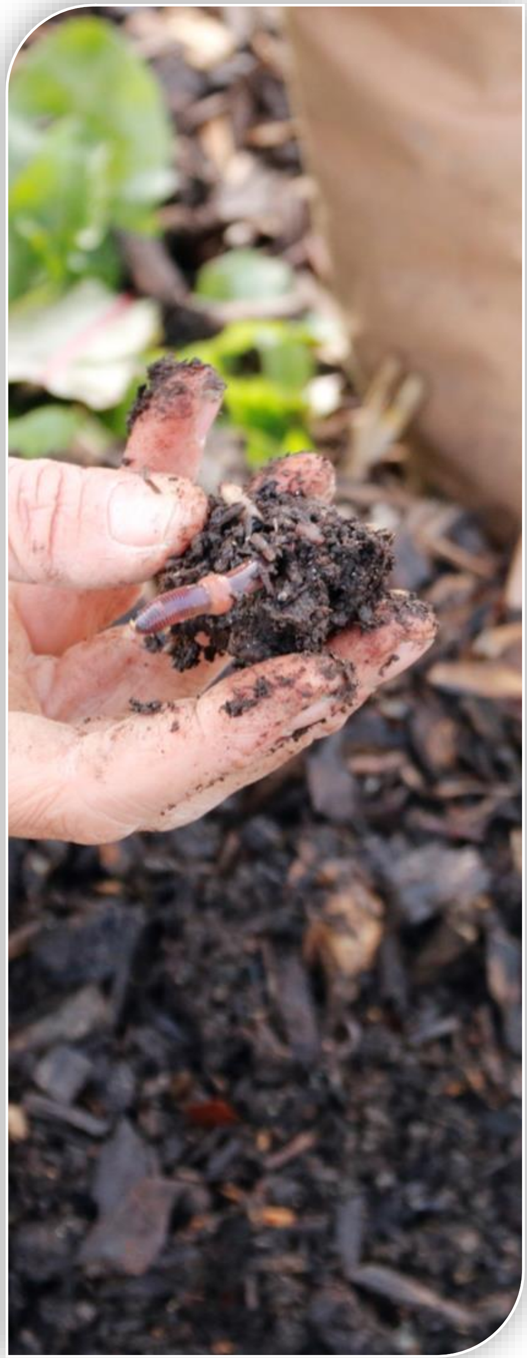
- ✓ Enrichment index = measure of nutrient richness
- ✓ Structure Index = degree of completeness of the soil food web



Vlaanderen is bodembewust

Project: Bodem Doorgrond

RIVIERENLAND
Langs Nete, Dijle, Zenne & Rupel



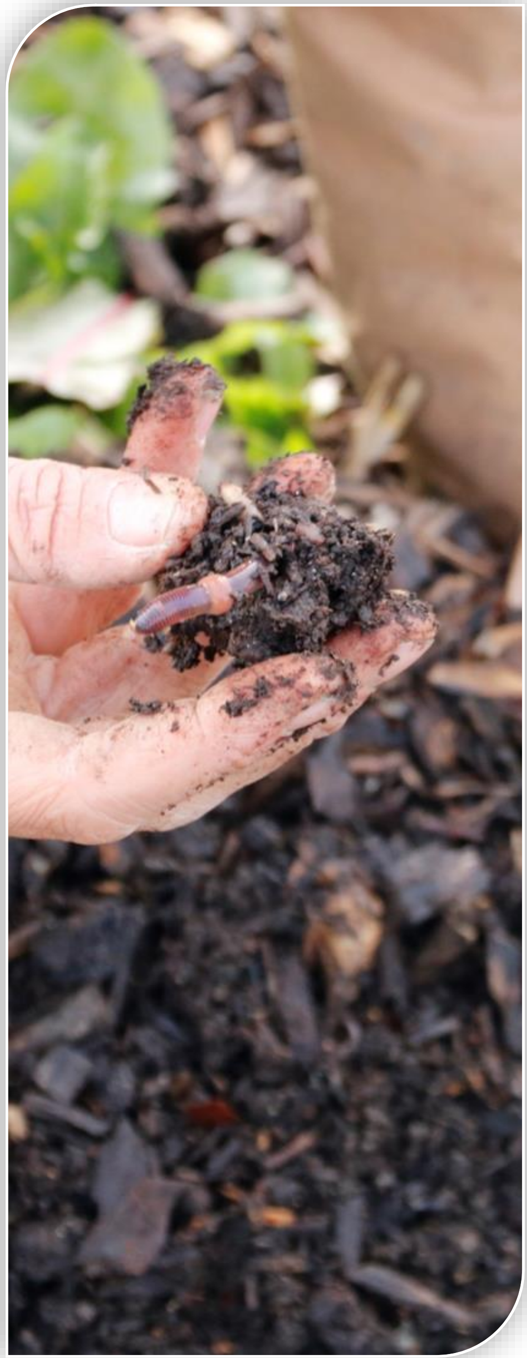
Why would we incorporate aboveground plant parts / soil improving organic fertilizers?

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 Hansb

Project Hansbeke Agro - Ecologie

ILVO

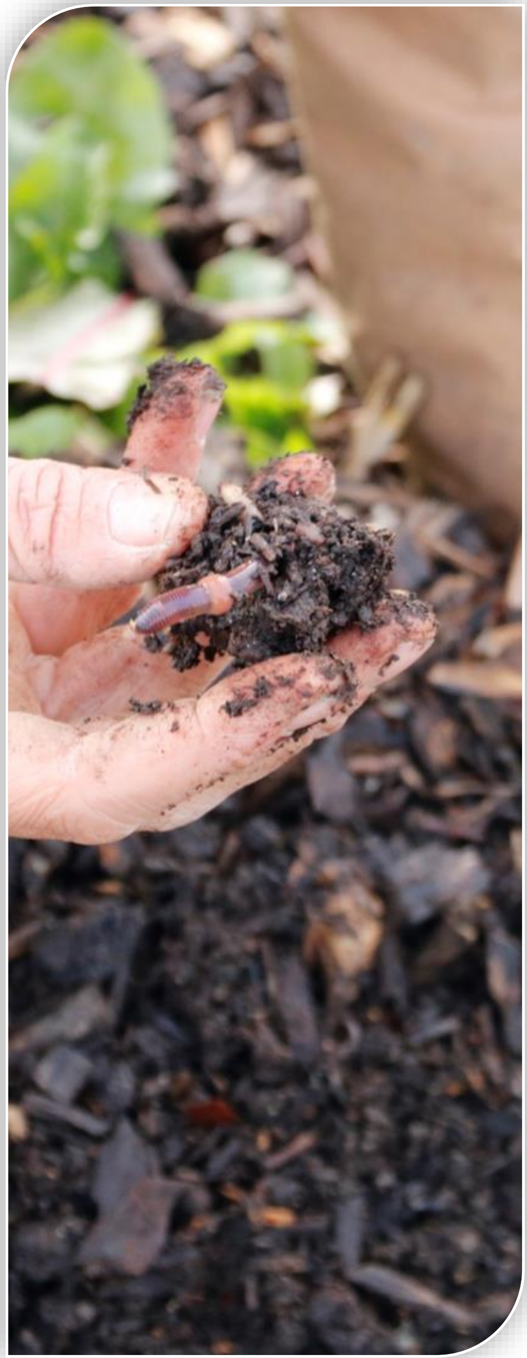
RHEA
Natural Resources Human Environment and Agronomy

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:

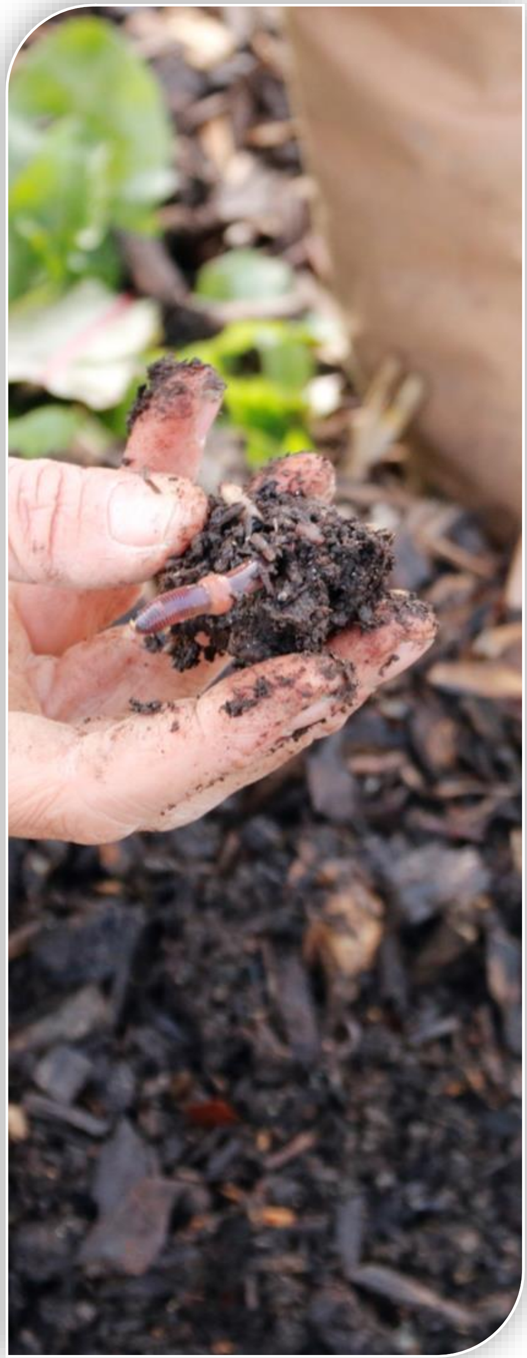
- ✓ Larger crop rotation
- ✓ Mixed cropping systems
- ✓ Intercropping
- ✓ Multispecies cover crop mixtures
- ✓ Inclusion of leguminous species

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

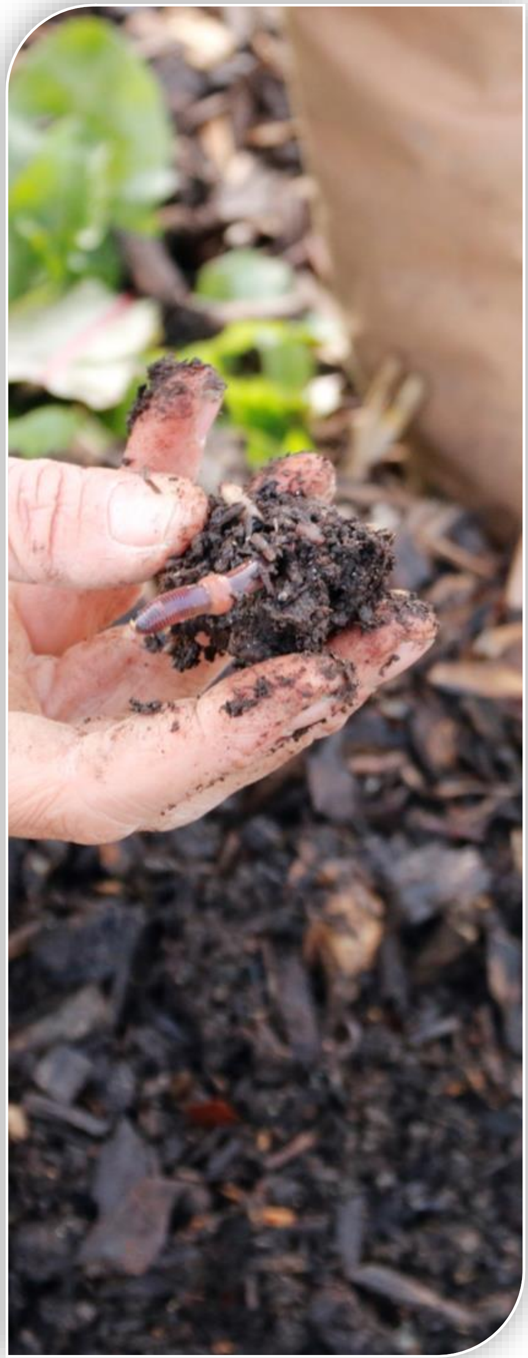
Regulations:
Soil care should be reflected in regulations concerning environmental issues.

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 :

Plant & Soil Living Lab

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.be

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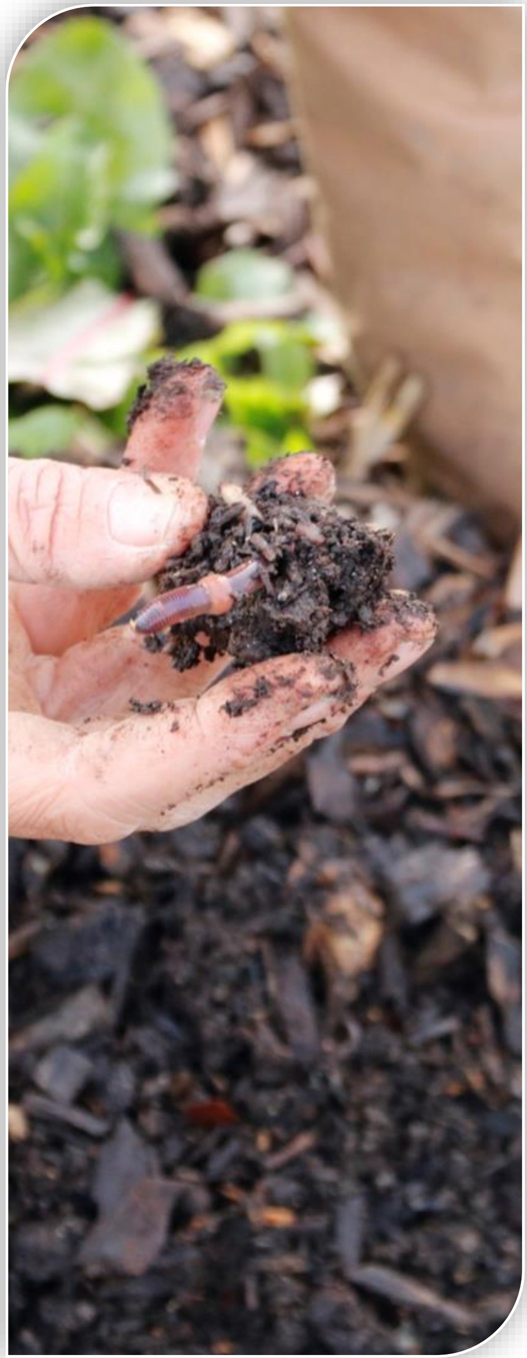
in ILVO Plant & Soil Living Lab



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Willekens, K., 2016. Nitrogen dynamics in relation to soil management and soil quality in field vegetable cropping systems. PhD thesis, Ghent University, Ghent, Belgium, p. 178, ISBN 978-90-5989-872-1.

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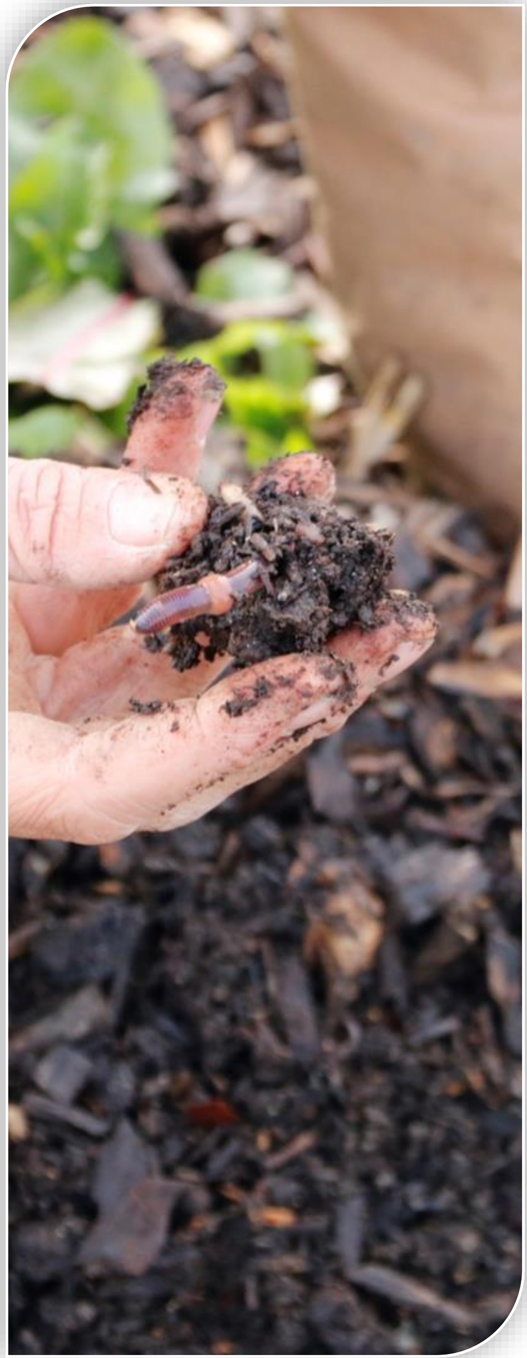
Xu H., Vandecasteele B., Boeckx P., De Neve S., Sleutel S. 2021. Do maize roots and shoots have different degradability under field conditions? — A field study of 13C resolved CO2 emissions. Agriculture, Ecosystems and Environment 319, 107504.



ACKNOWLEDGEMENTS

Soil team@ILVO

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- ✓ PHAE
- ✓ RHEA
- ✓ Organic Forest

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- ✓ Departement Landbouw en Visserij
- ✓ Vlaamse Landmaatschappij
- ✓ Departement Omgeving

Farmers community

Vlaanderen
is landbouw & visserij

Thank you

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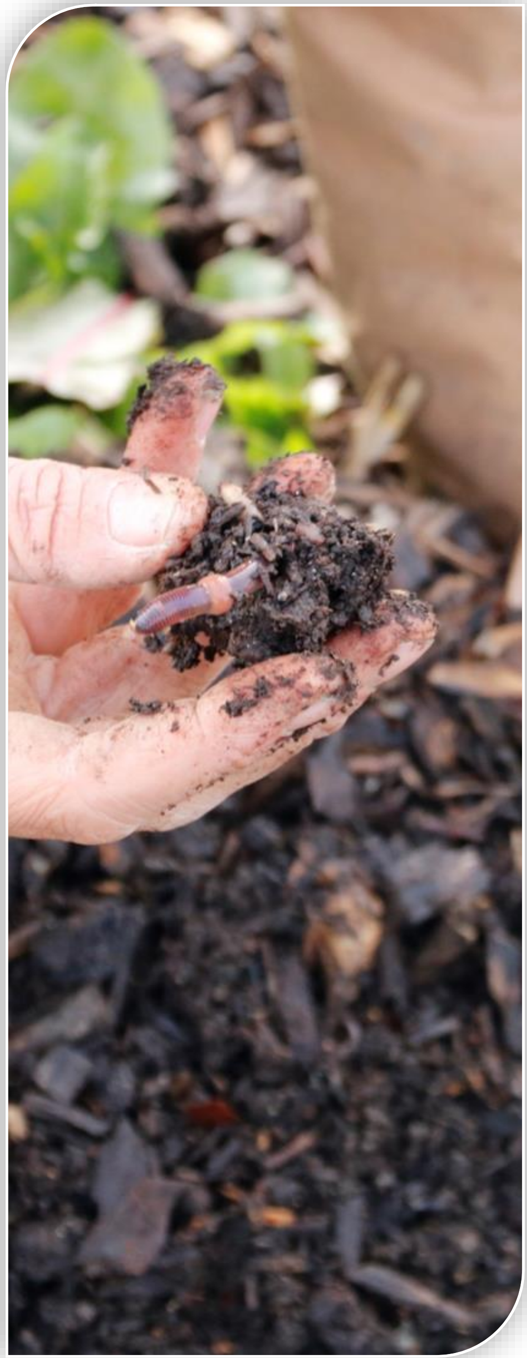
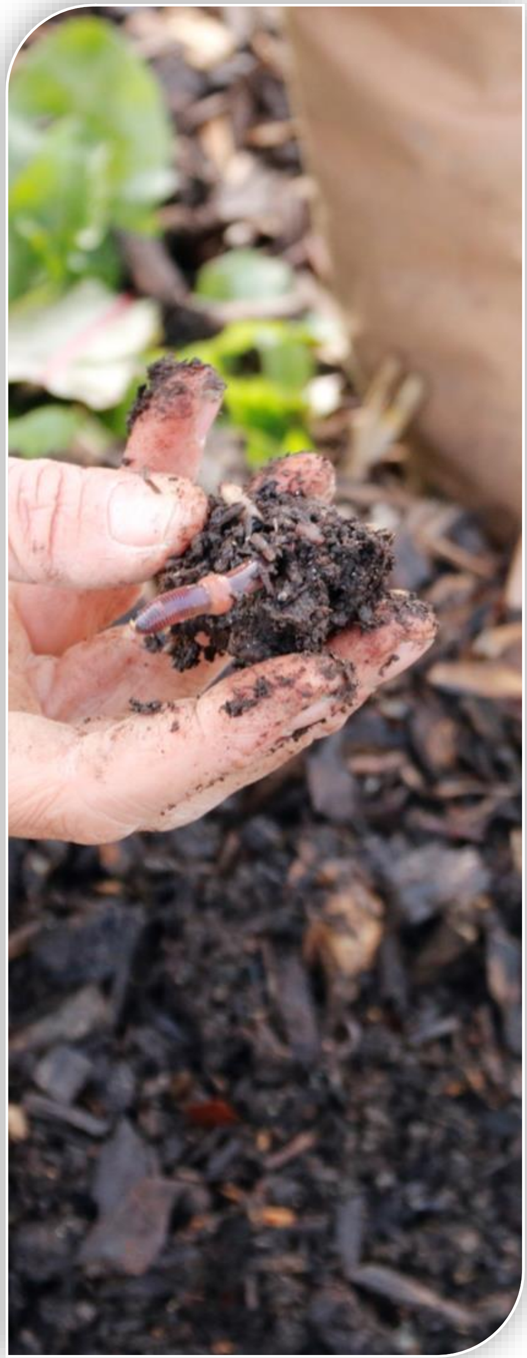
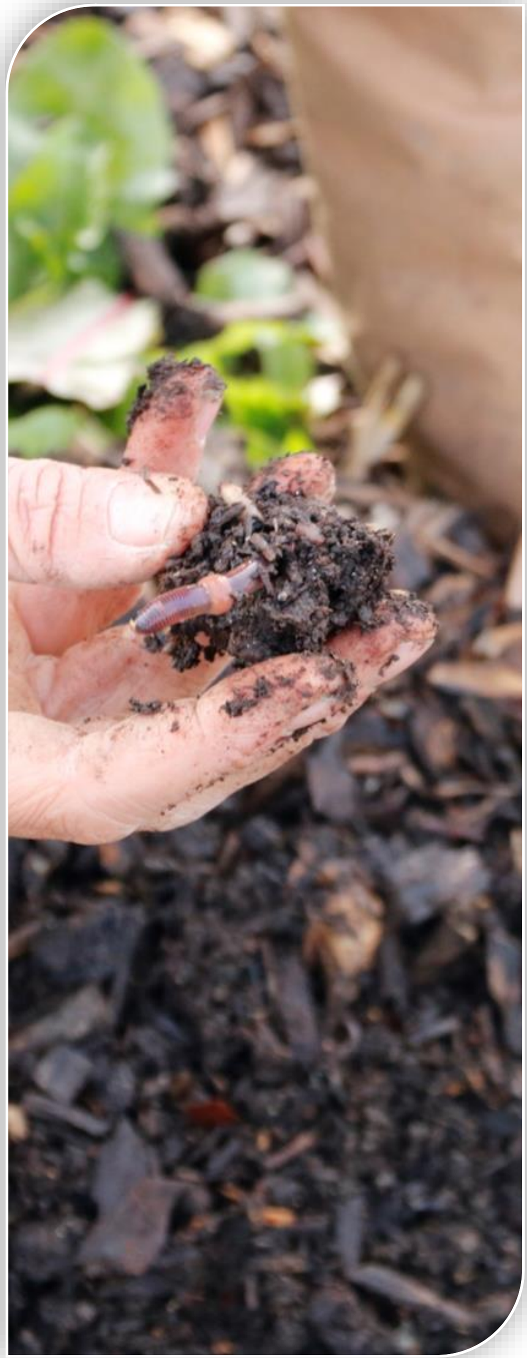


Questions?

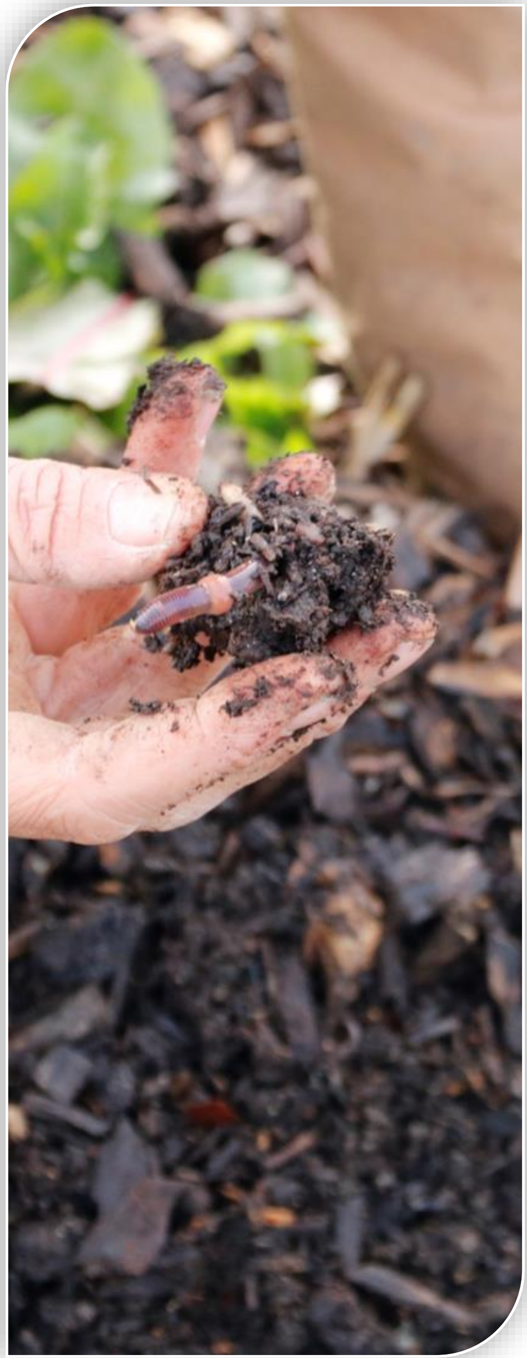


Discussion



Lunch

Till 13h30

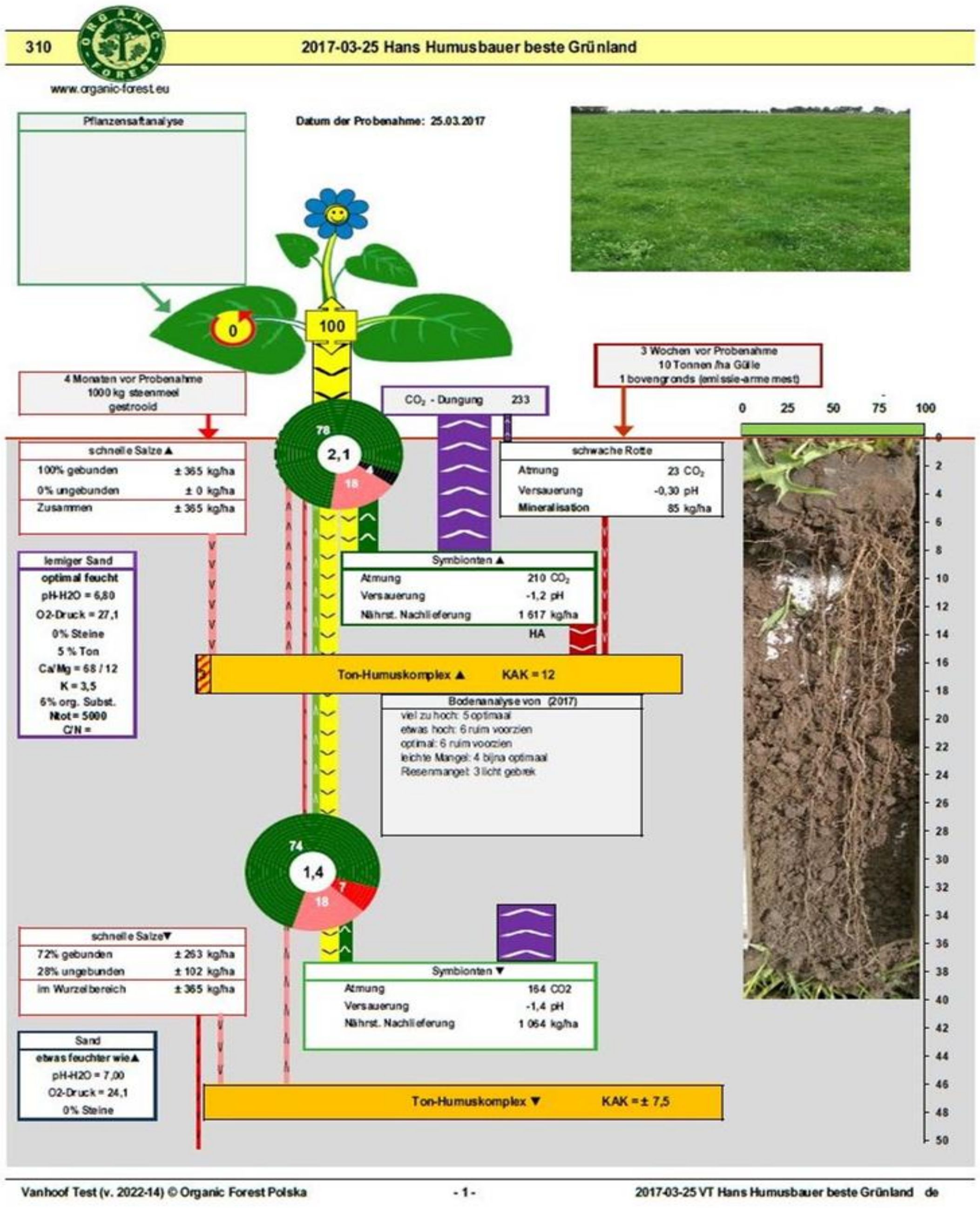


What can regenerative agriculture deliver for farmers?

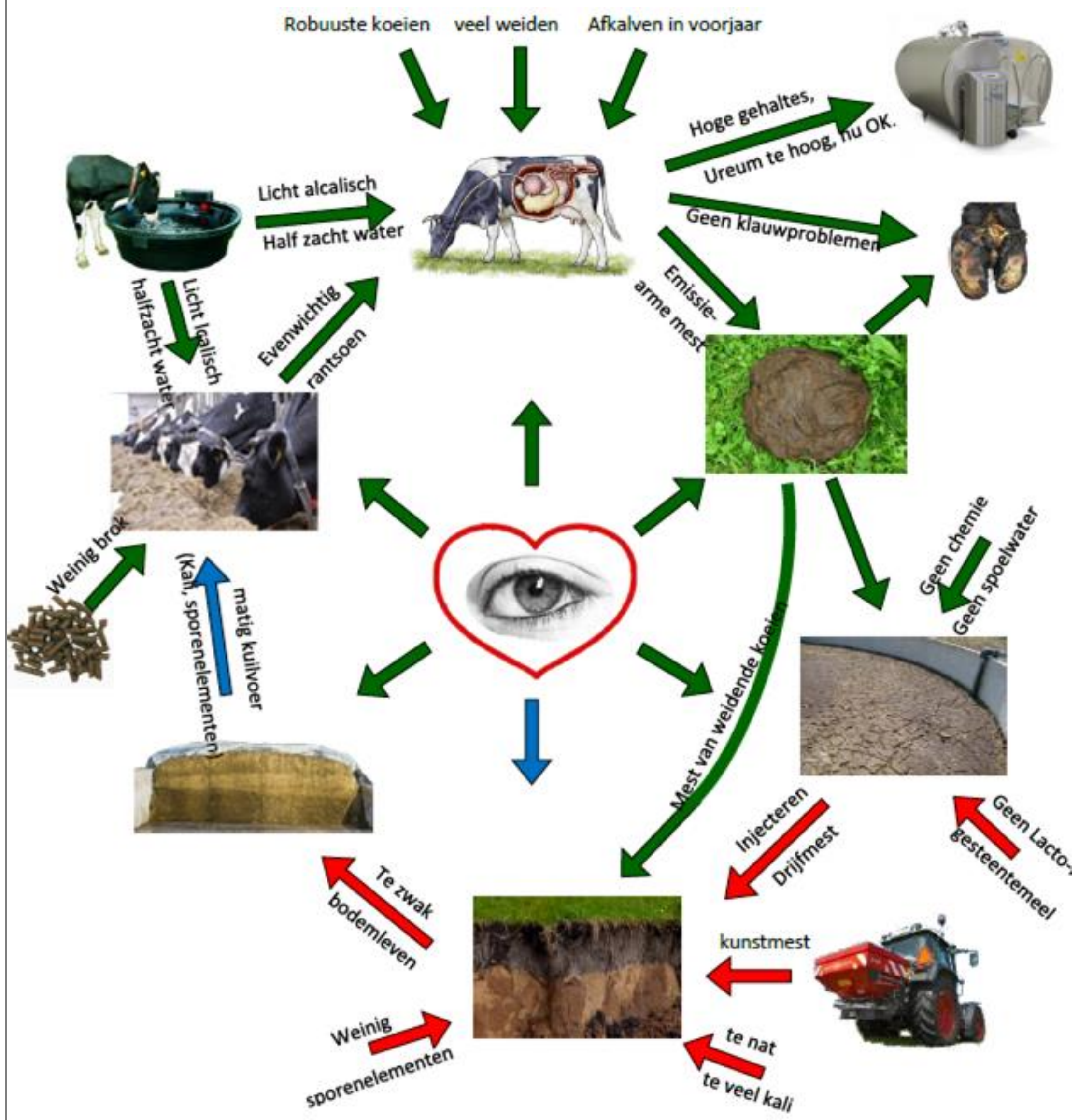
Peter Vanhoof

REDUCING COSTS THROUGH A POWERFUL BIOLOGY?

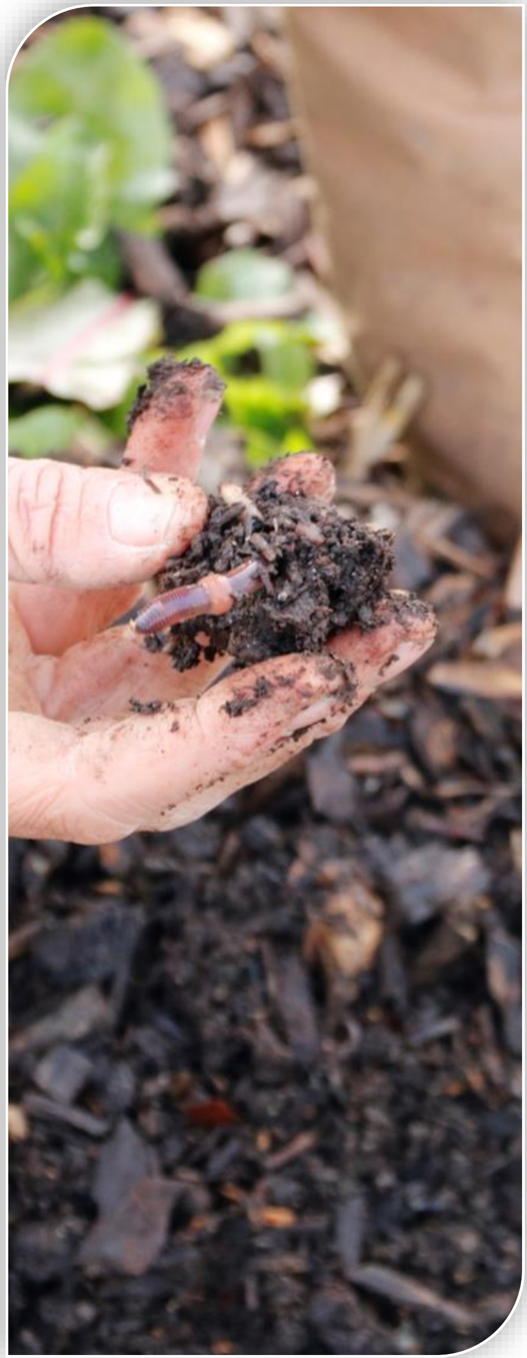
Towards a sustainable system of regenerative agriculture and livestock farming



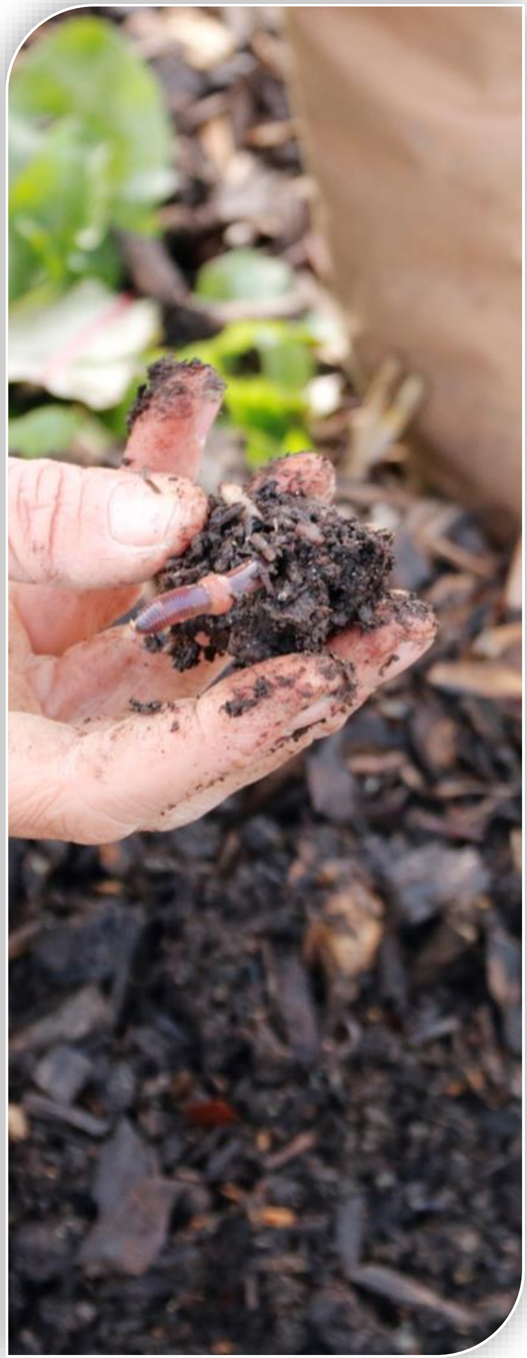
310
2017-03-25 Hans Humusbauer beste Grünland
www.organic-forest.eu
Pflanzensaftanalyse
Datum der Probenahme: 25.03.2017
0
100
4 Monaten vor Probenahme
1000 kg steenmeel
gestrooid
3 Wochen vor Probenahme
10 Tonnen /ha Gülle
1 bovengronds (emissie-arme mest)
CO₂ - Dungung 233
0 25 50 75 100
78
2,1
18
schnelle Salze ▲
100% gebunden ± 365 kg/ha
0% ungebunden ± 0 kg/ha
Zusammen ± 365 kg/ha
schwache Rotte
Atmung 23 CO₂
Versauerung -0,30 pH
Mineralisation 85 kg/ha
lemiger Sand
optimal feucht
pH-H2O = 6,80
O2-Druck = 27,1
0% Steine
5 % Ton
Ca/Mg = 68 / 12
K = 3,5
6% org. Subst.
Ntot = 5000
C/N =
Symbionten ▲
Atmung 210 CO₂
Versauerung -1,2 pH
Nährst. Nachlieferung 1 617 kg/ha
HA
Ton-Humuskomplex ▲ KAK = 12
Bodenanalyse von (2017)
viel zu hoch: 5 optimaal
etwas hoch: 6 ruim voorzien
optimal: 6 ruim voorzien
leichte Mangel: 4 bijna optimaal
Riesenmangel: 3 licht gebrek
74
1,4
7
18
schnelle Salze ▼
72% gebunden ± 263 kg/ha
28% ungebunden ± 102 kg/ha
im Wurzelbereich ± 365 kg/ha
Symbionten ▼
Atmung 164 CO2
Versauerung -1,4 pH
Nährst. Nachlieferung 1 064 kg/ha
Sand
etwas feuchter wie ▲
pH-H2O = 7,00
O2-Druck = 24,1
0% Steine
Ton-Humuskomplex ▼ KAK = ± 7,5
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Vanhoof Test (v. 2022-14) © Organic Forest Polska
- 1 -
2017-03-25 VT Hans Humusbauer beste Grünland de



Robuuste koeien
veel weiden
Afkalven in voorjaar
Hoge gehaltes,
Ureum te hoog, nu OK.
Licht alcalisch
Half zacht water
Geen klauwproblemen
Emissie-
arme mest
Licht alcalisch
halfzacht water
Evenwichtig
rantsoen
Weinig brok
(Kali, sporenelementen)
matig kuilvoer
Geen chemie
Geen spoelwater
Mest van weidende koeien
Injecteren
Drijfmest
Geen Lacto-
gesteentemeel
Te zwak
bodemleven
kunstmest
Weinig
sporenelementen
te nat
te veel kali



Chemical analysis
= determination of the quantity of building materials

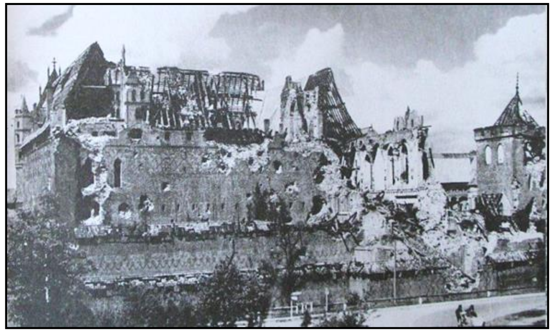


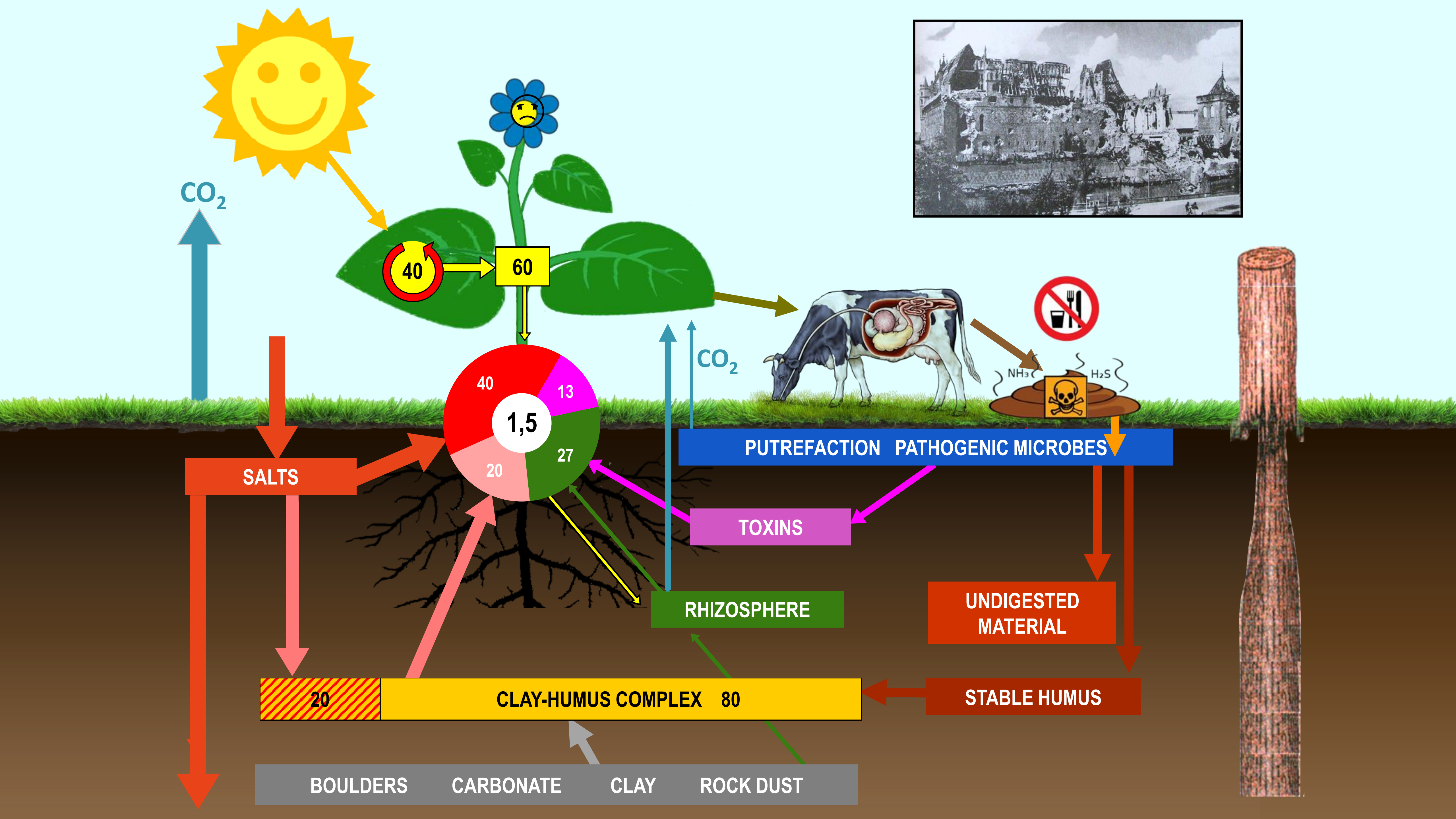
What kind of life / conditions do we need?

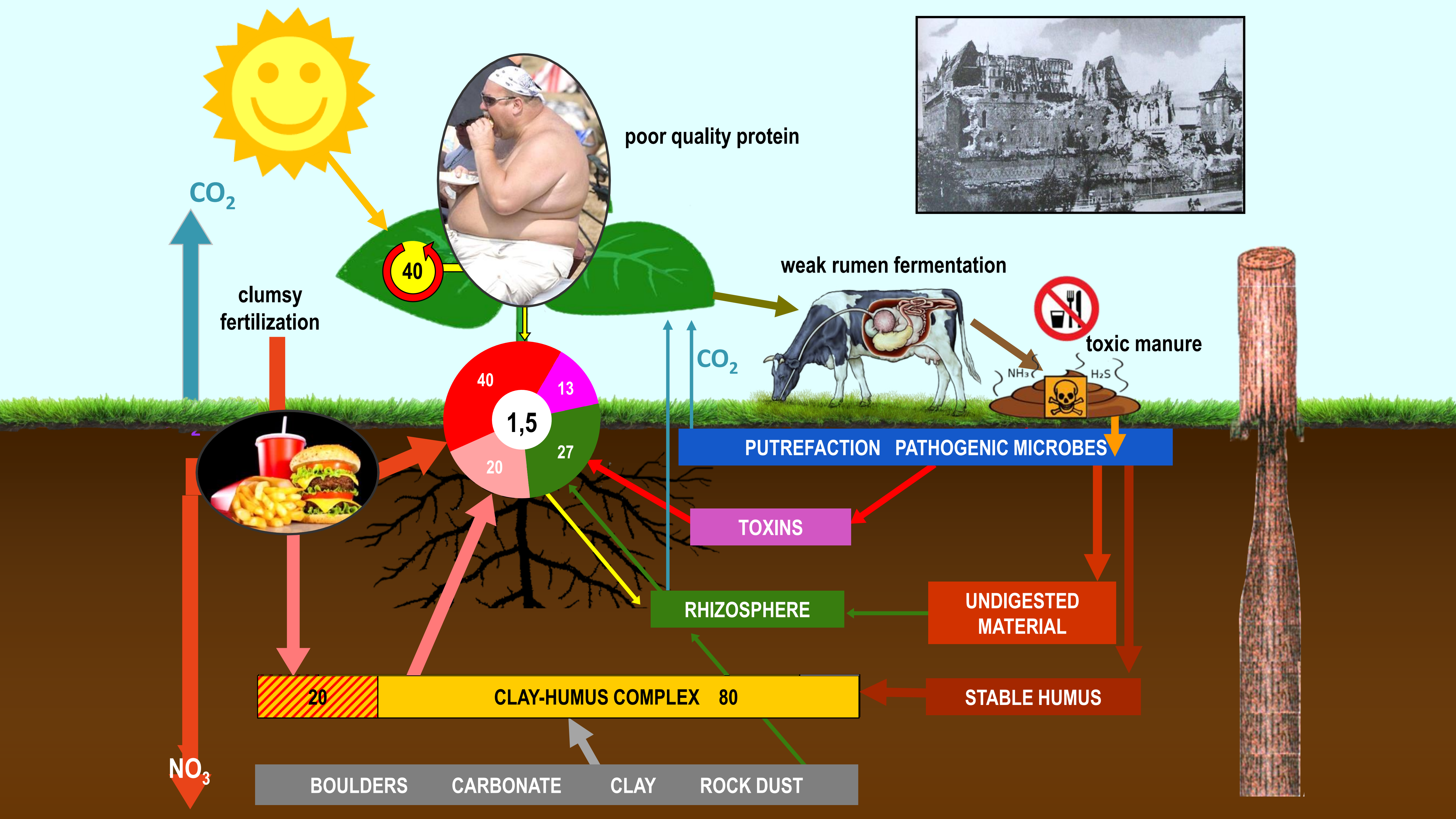
quantity of life

quality of life

a place to live

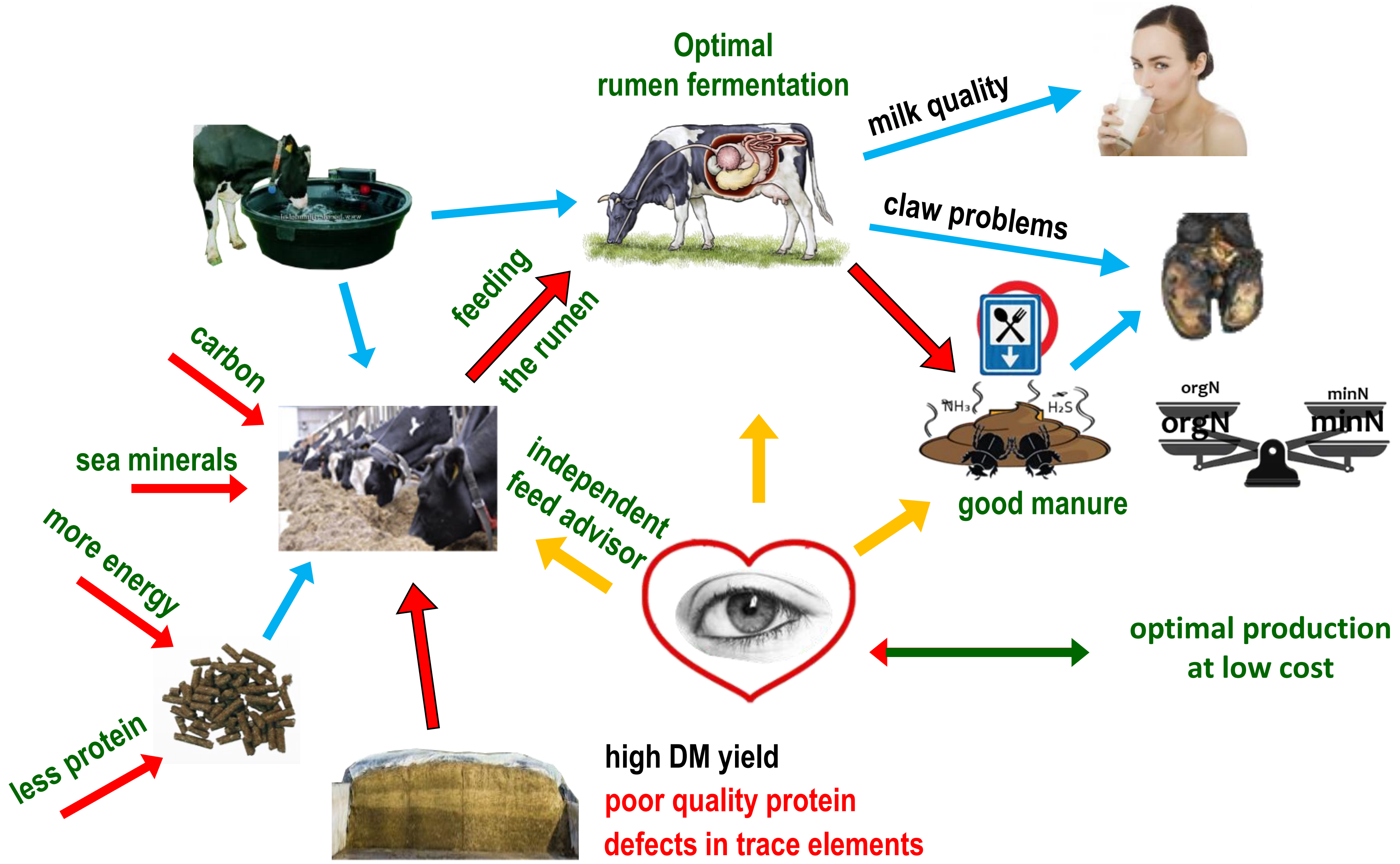



CO_2
40
60
40
13
1,5
27
20
CO_2
NH_3
H_2S
PUTREFACTION PATHOGENIC MICROBES
SALTS
TOXINS
RHIZOSPHERE
UNDIGESTED MATERIAL
20
CLAY-HUMUS COMPLEX 80
STABLE HUMUS
BOULDERS
CARBONATE
CLAY
ROCK DUST



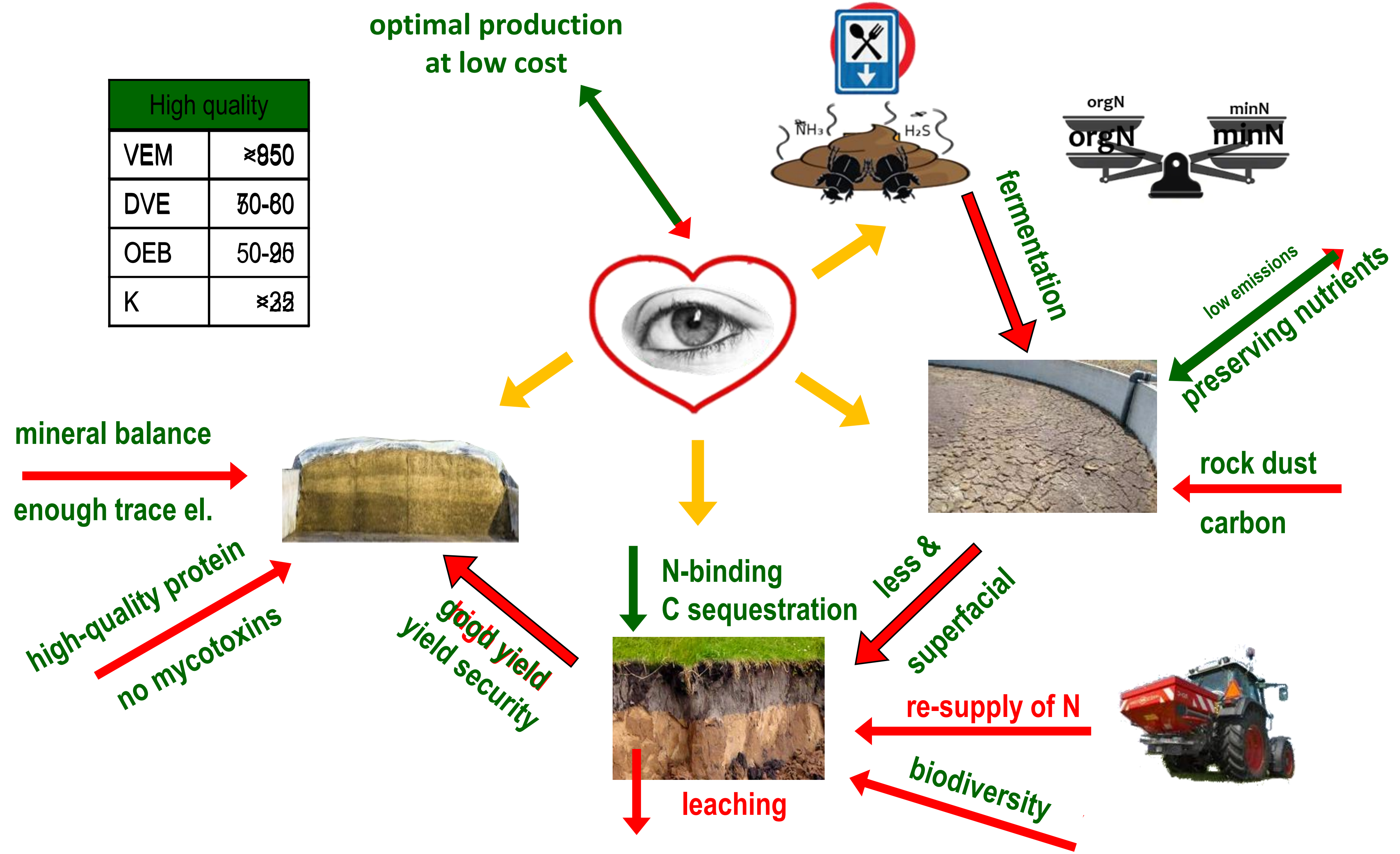
poor quality protein
CO_2
40
clumsy fertilization
weak rumen fermentation
toxic manure
NH_3
H_2S
CO_2
40
13
1,5
27
20
PUTREFACTION PATHOGENIC MICROBES
TOXINS
RHIZOSPHERE
UNDIGESTED MATERIAL
STABLE HUMUS
20
CLAY-HUMUS COMPLEX 80
NO_3
BOULDERS CARBONATE CLAY ROCK DUST

SHORT-TERM APPROACH

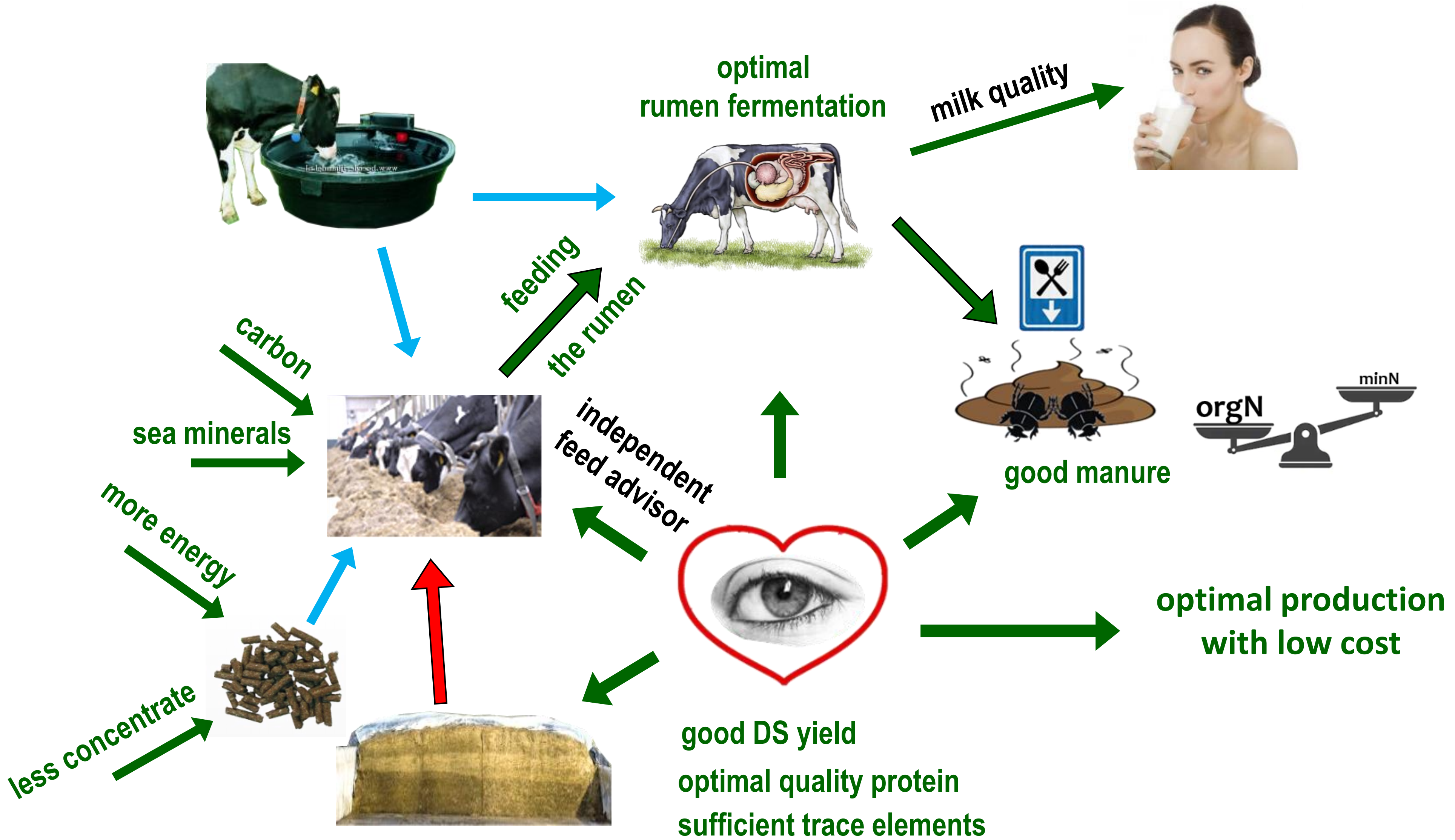


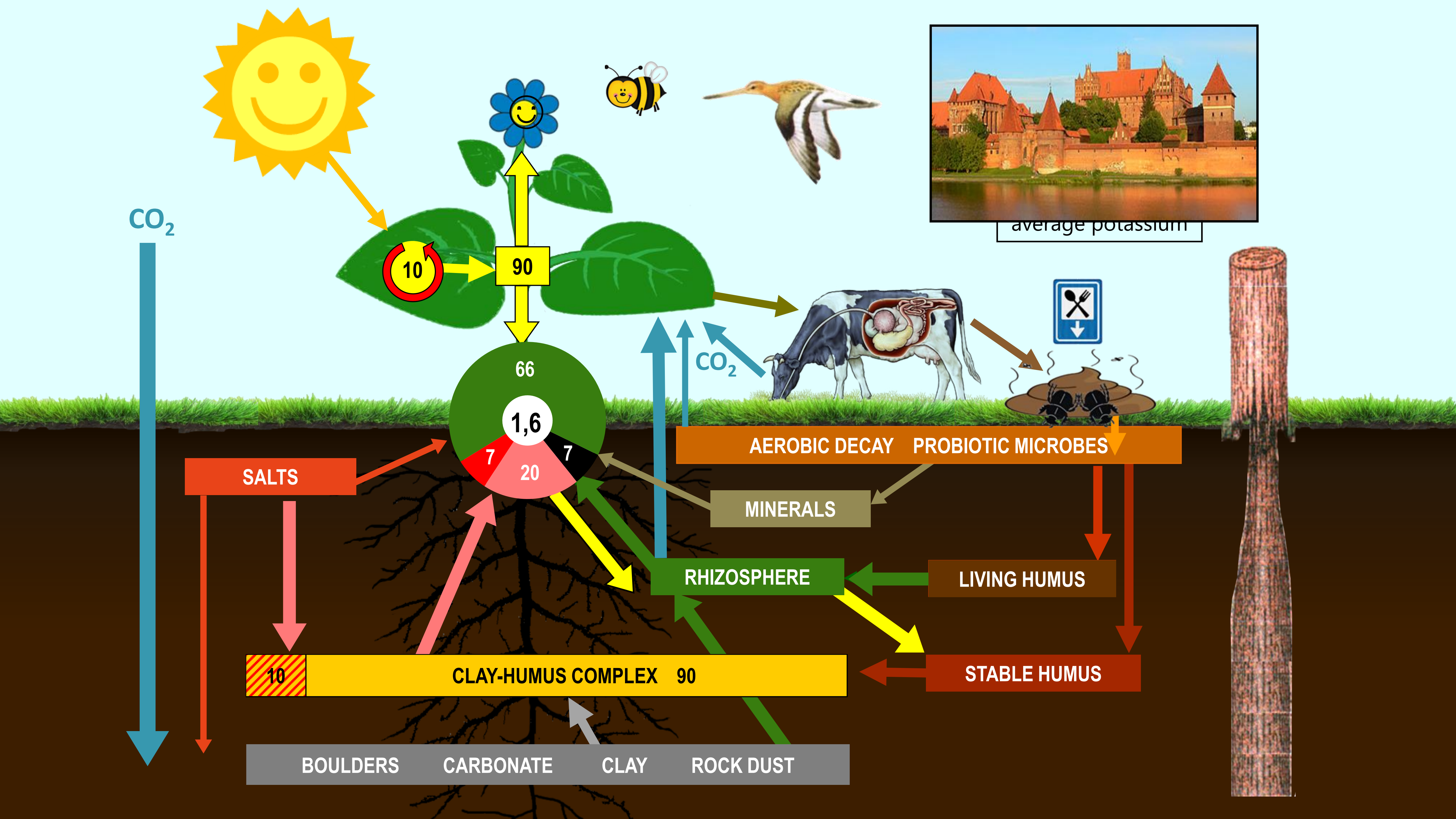
LONGER-TERM APPROACH

High quality	
VEM	≥850
DVE	70-80
OEB	50-26
K	≤32



LONGER-TERM APPROACH





CO_2
10
90
66
1,6
7
20
7
CO_2
average potassium
AEROBIC DECAY
PROBIOTIC MICROBES
SALTS
MINERALS
RHIZOSPHERE
LIVING HUMUS
10
CLAY-HUMUS COMPLEX 90
STABLE HUMUS
BOULDERS
CARBONATE
CLAY
ROCK DUST

Trends in
Plant Science

CellPress

Feature Review

The decline of plant mineral nutrition under rising CO_2: physiological and molecular aspects of a bad deal

Alain Gojon,[1] Océane Cassan,[1] Liên Bach,[1] Laurence Lejay,[1] and Antoine Martin[1,*]

The elevation of atmospheric CO_2 concentration has a strong impact on the physiology of C3 plants, far beyond photosynthesis and C metabolism. In particular, it reduces the concentrations of most mineral nutrients in plant tissues, posing major threats on crop quality, nutrient cycles, and carbon sinks in terrestrial agro-ecosystems. The causes of the detrimental effect of high CO_2 levels on plant mineral status are not understood. We provide an update on the main hypotheses and review the increasing evidence that, for nitrogen, this detrimental effect is associated with direct inhibition of key mechanisms of nitrogen uptake and

Highlights

Elevated [CO_2] (eCO_2) has a negative impact on key physiological mechanisms of nutrient acquisition and assimilation in C3 plants. The reasons are largely unknown.

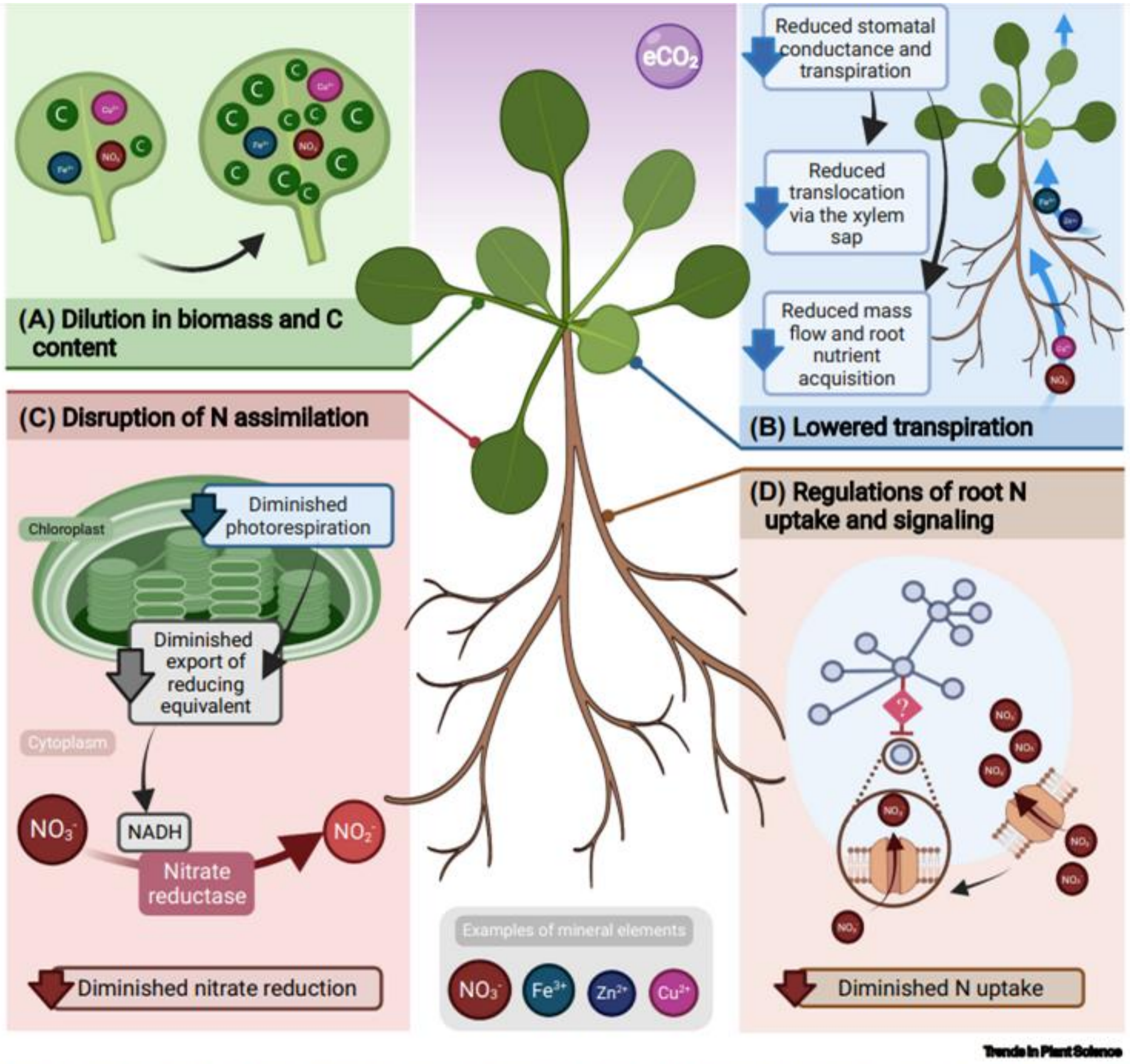
eCO_2 particularly lowers nitrogen content of plants tissues, possibly through

We see the opposite in daily practice

Box 2. Genetic manipulations to improve the response of plants to eCO_2

Nature & farmers don't need any genetic manipulations

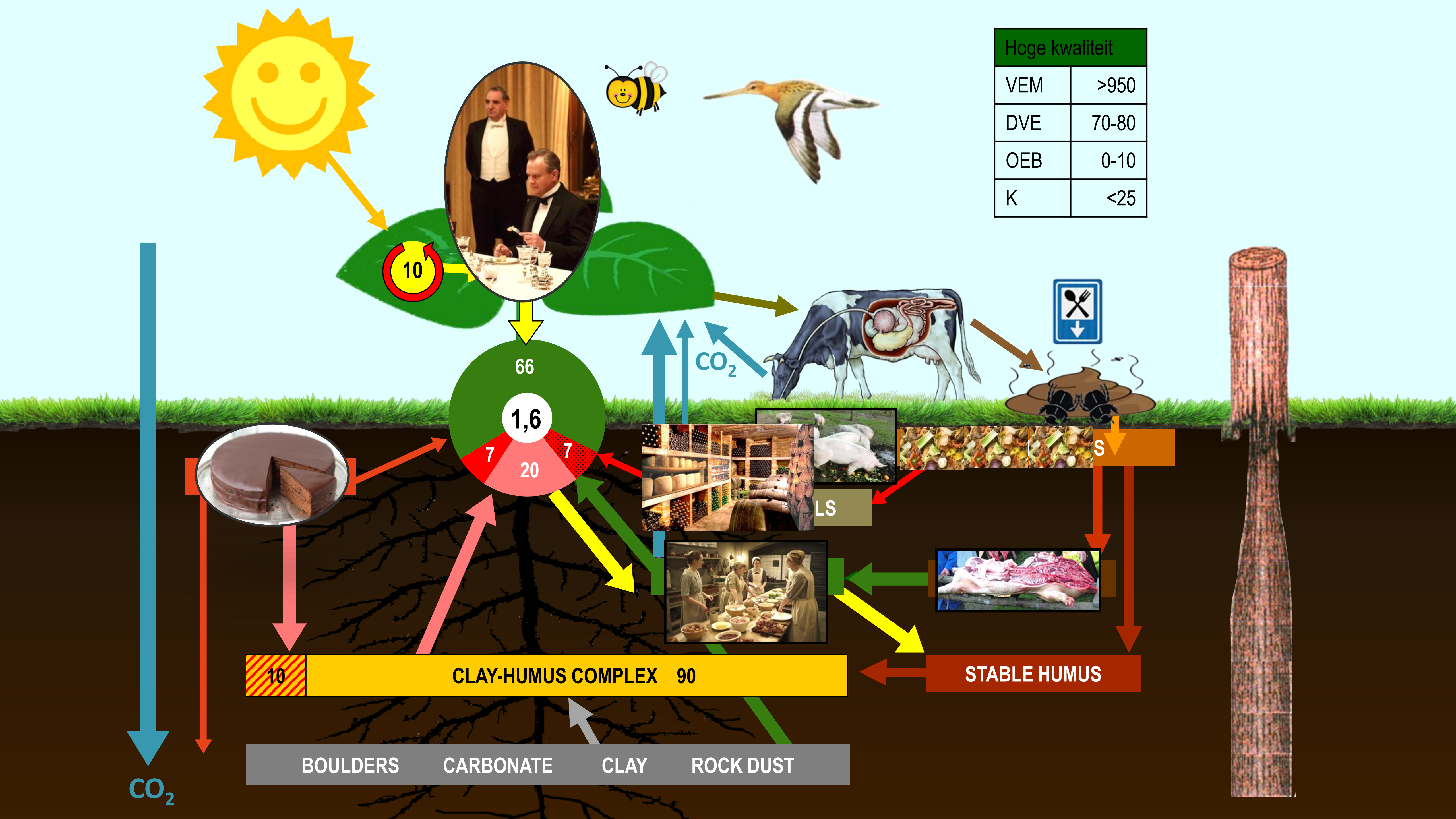
Box 3. Impaired N nutrition efficiency as a main cause of the acclimation of photosynthesis to eCO_2

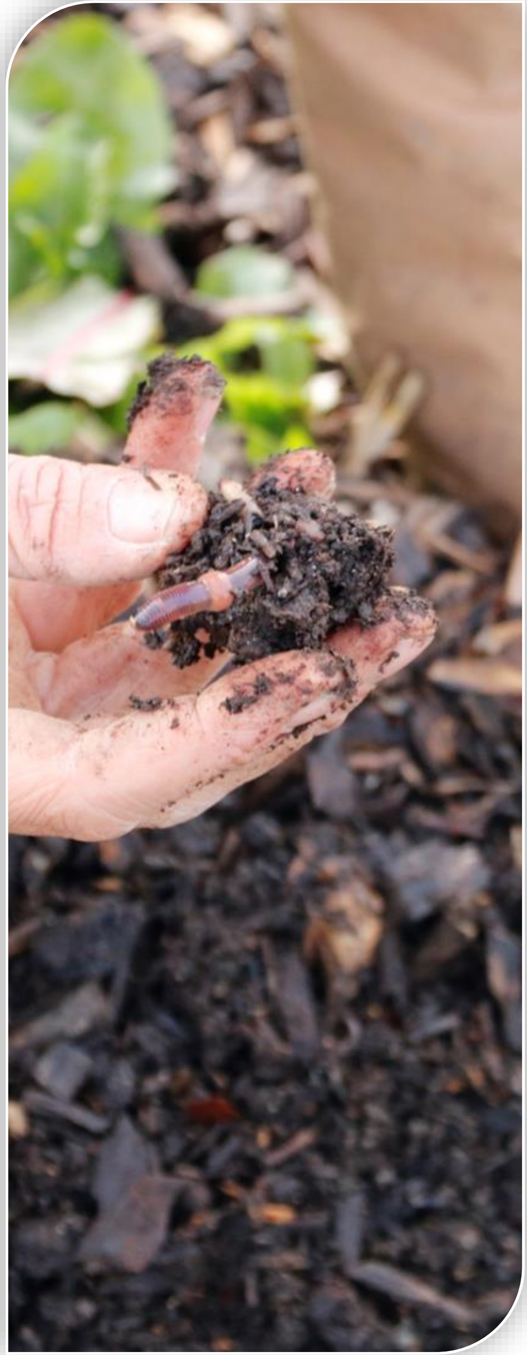


Abstract

The elevation of atmospheric CO_2 concentration has a strong impact on the physiology of C3 plants, far beyond photosynthesis and C metabolism. In particular, it reduces the concentrations of most mineral nutrients in plant tissues, posing major threats on crop quality, nutrient cycles, and carbon sinks in terrestrial agro-ecosystems. The causes of the detrimental effect of high CO_2 levels on plant mineral status are not understood. We provide an update on the main

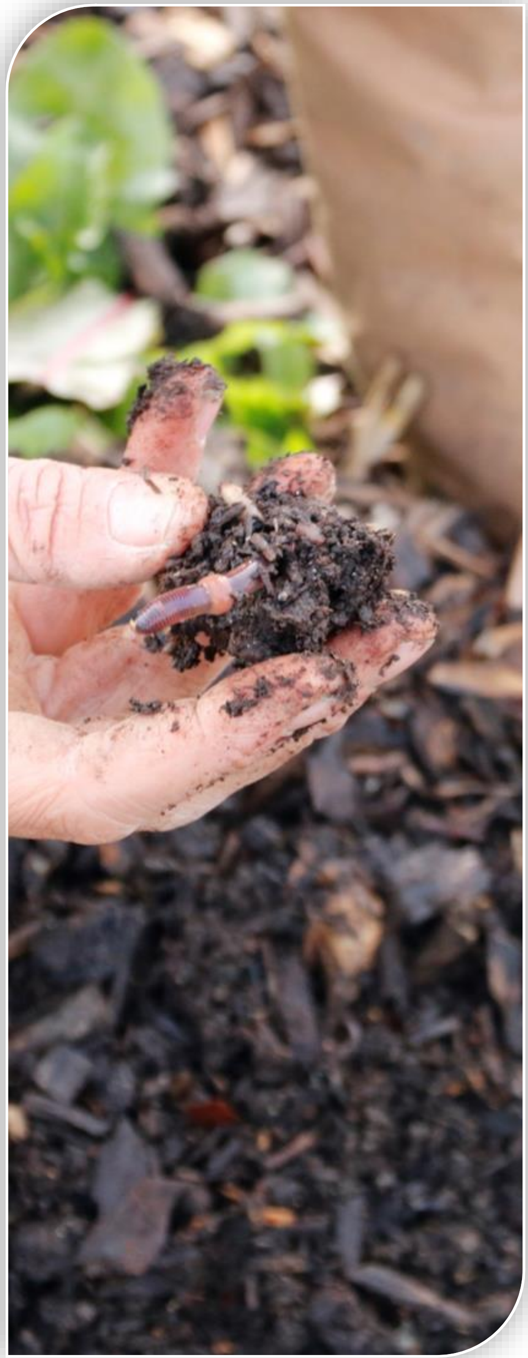
scientists/policy makers should work together with farmers (= experts by experience)


Hoge kwaliteit
VEM >950
DVE 70-80
OEB 0-10
K <25
10
66
1,6
7
20
7
CO_2
LS
S
10
CLAY-HUMUS COMPLEX 90
STABLE HUMUS
BOULDERS
CARBONATE
CLAY
ROCK DUST
CO_2



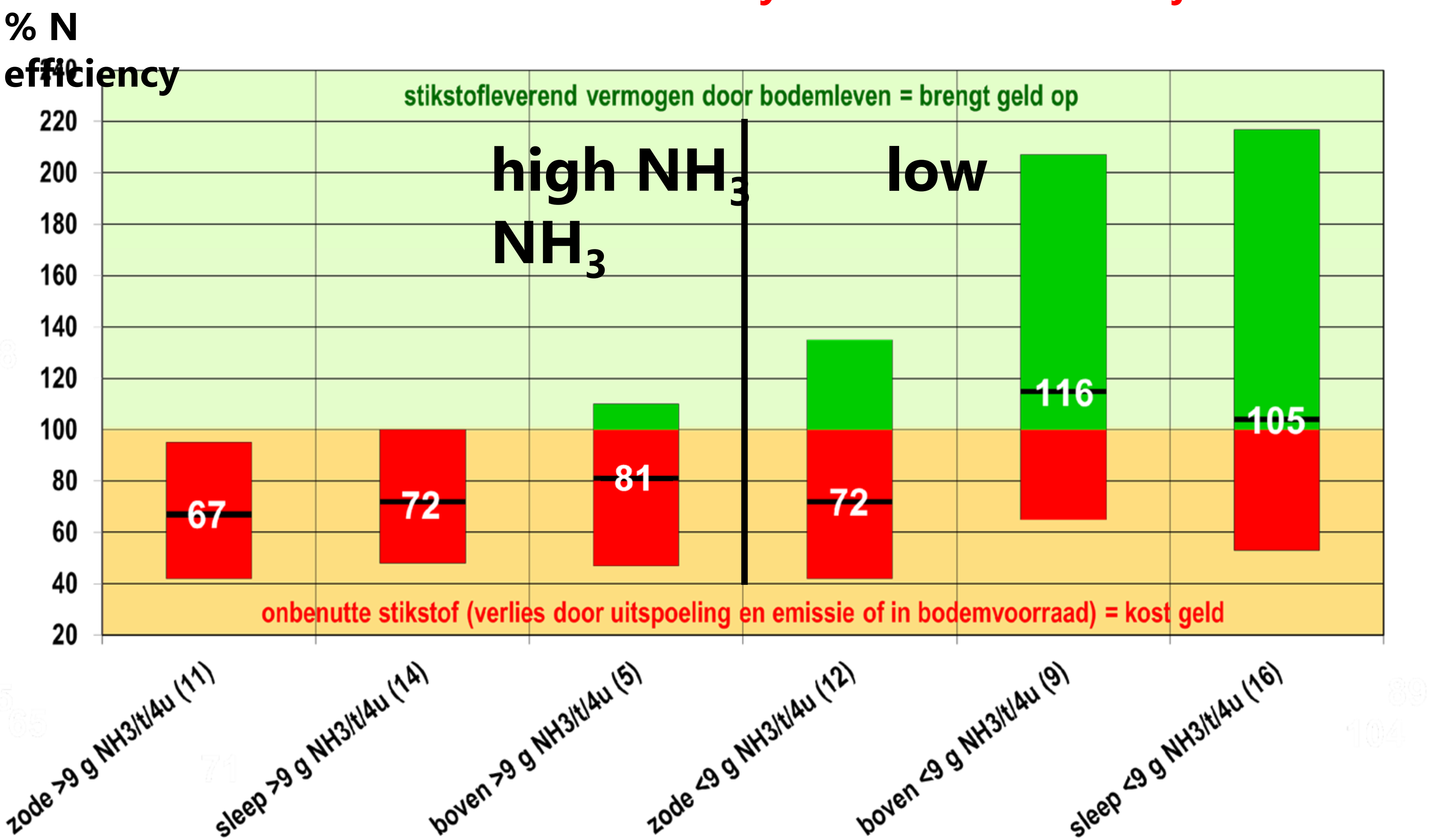
Research in 2019 on 135 dairy farms

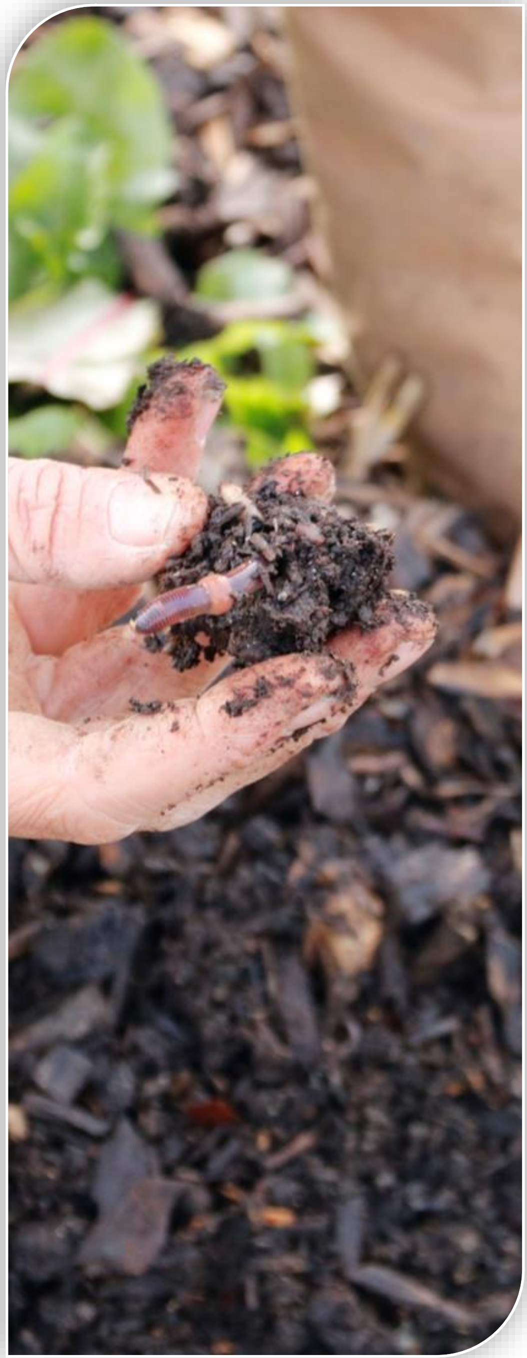
Together to a system of regenerative agriculture and livestock farming



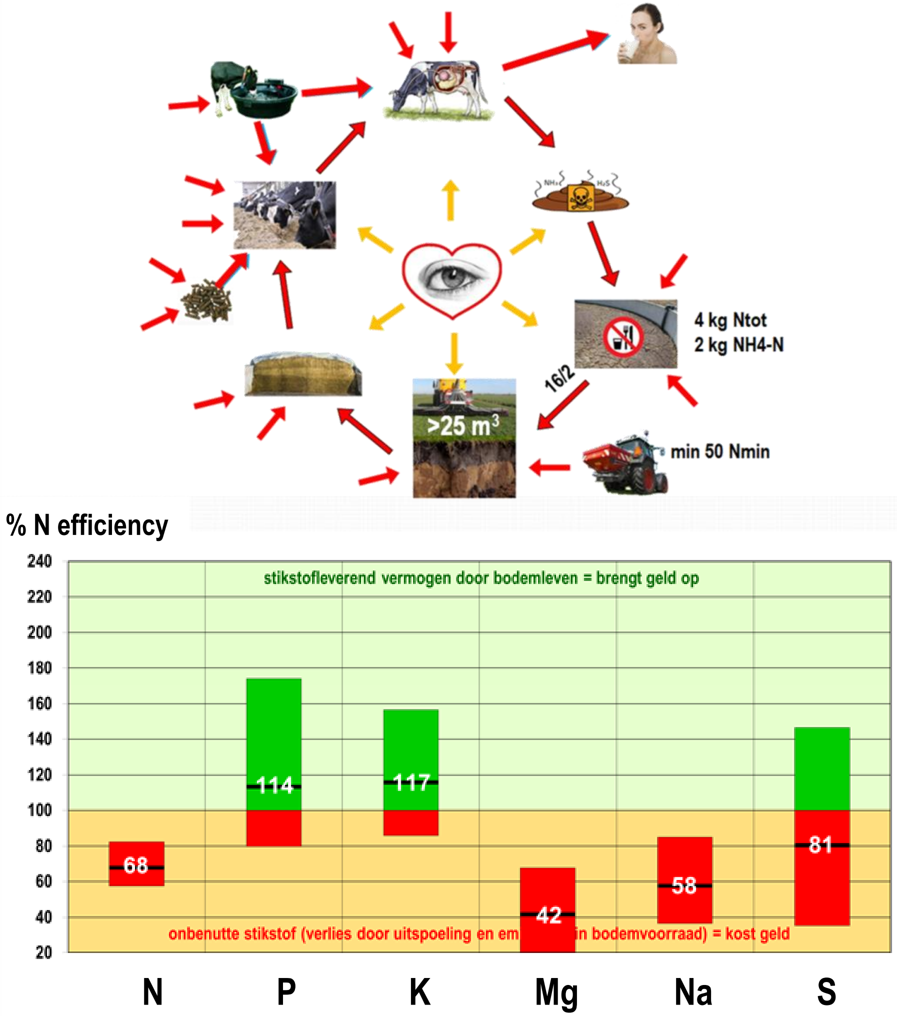
NH3 emissions and way of fertilising

high-emission manure always gives poor efficiency
low-emission manure is clearly less efficient when injected

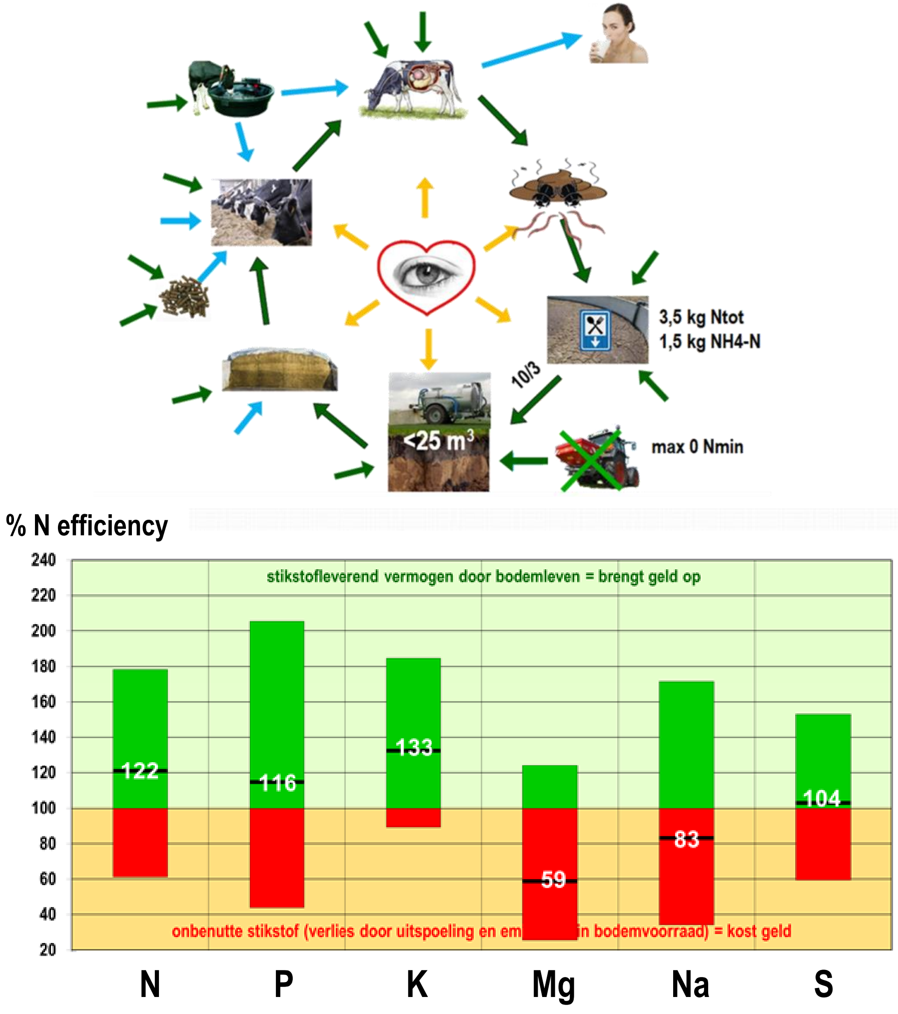




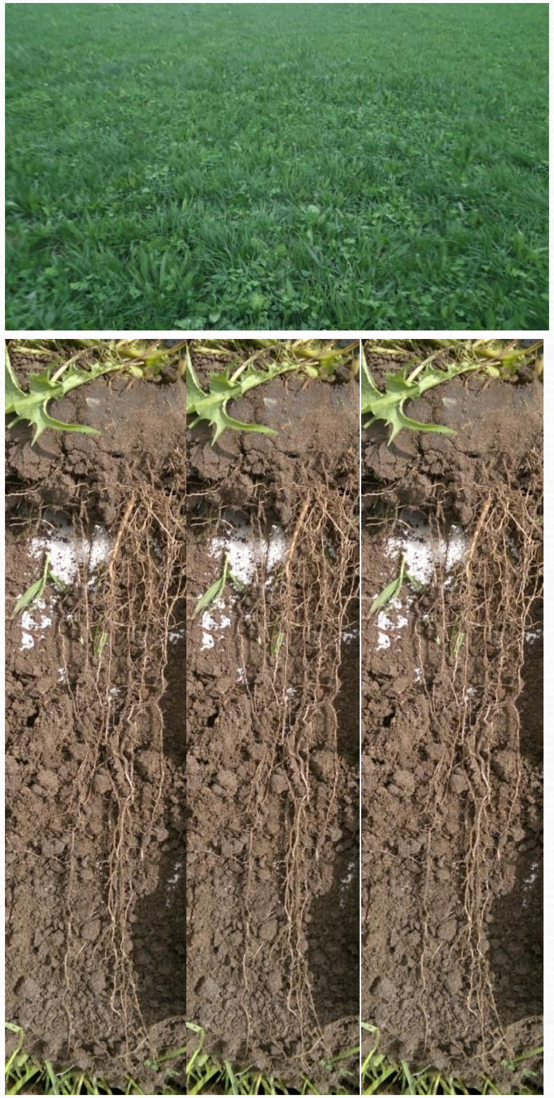
conventional



regenerative



N-efficiency and rootdepth

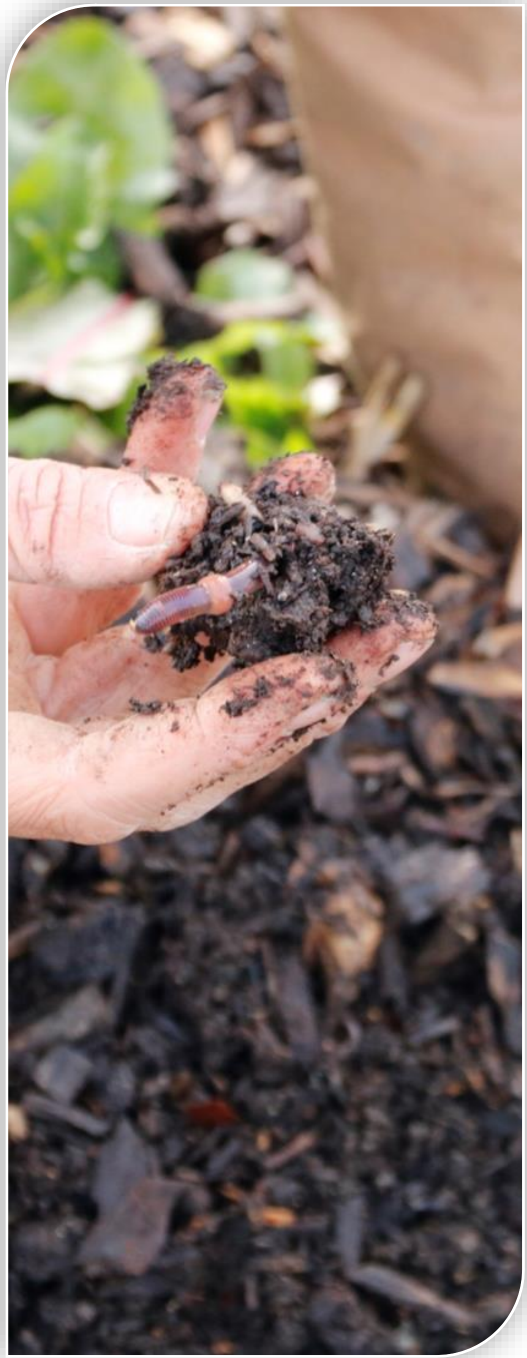


REDUCING COSTS THROUGH A POWERFUL BIOLOGY!

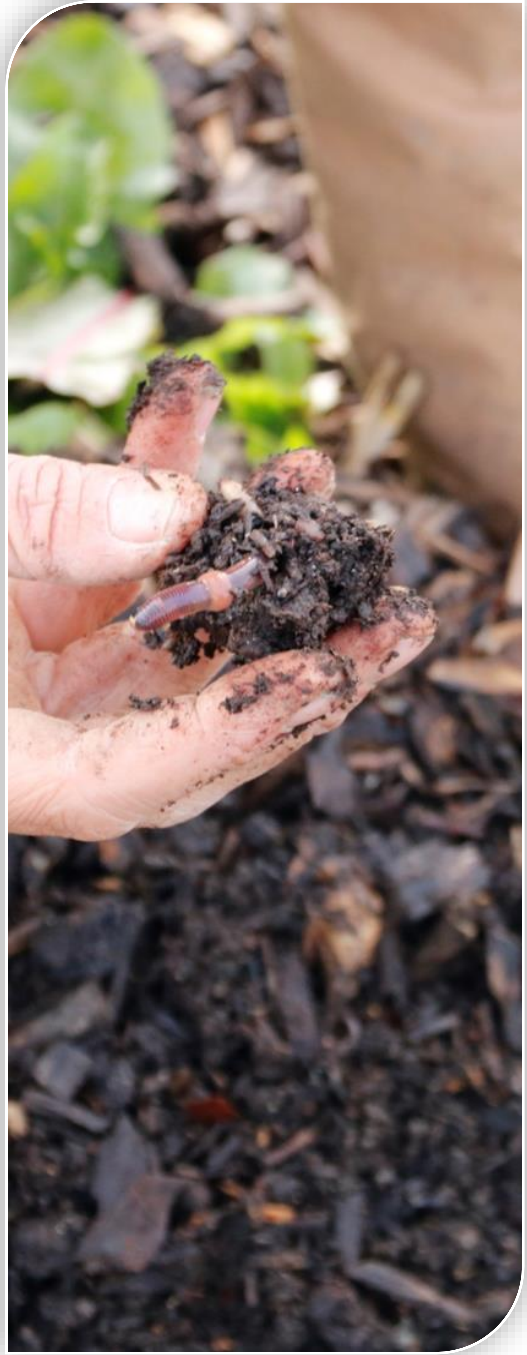
Towards a sustainable system of regenerative agriculture and livestock farming

Organic Forest

www.organic-forest.eu



Questions?

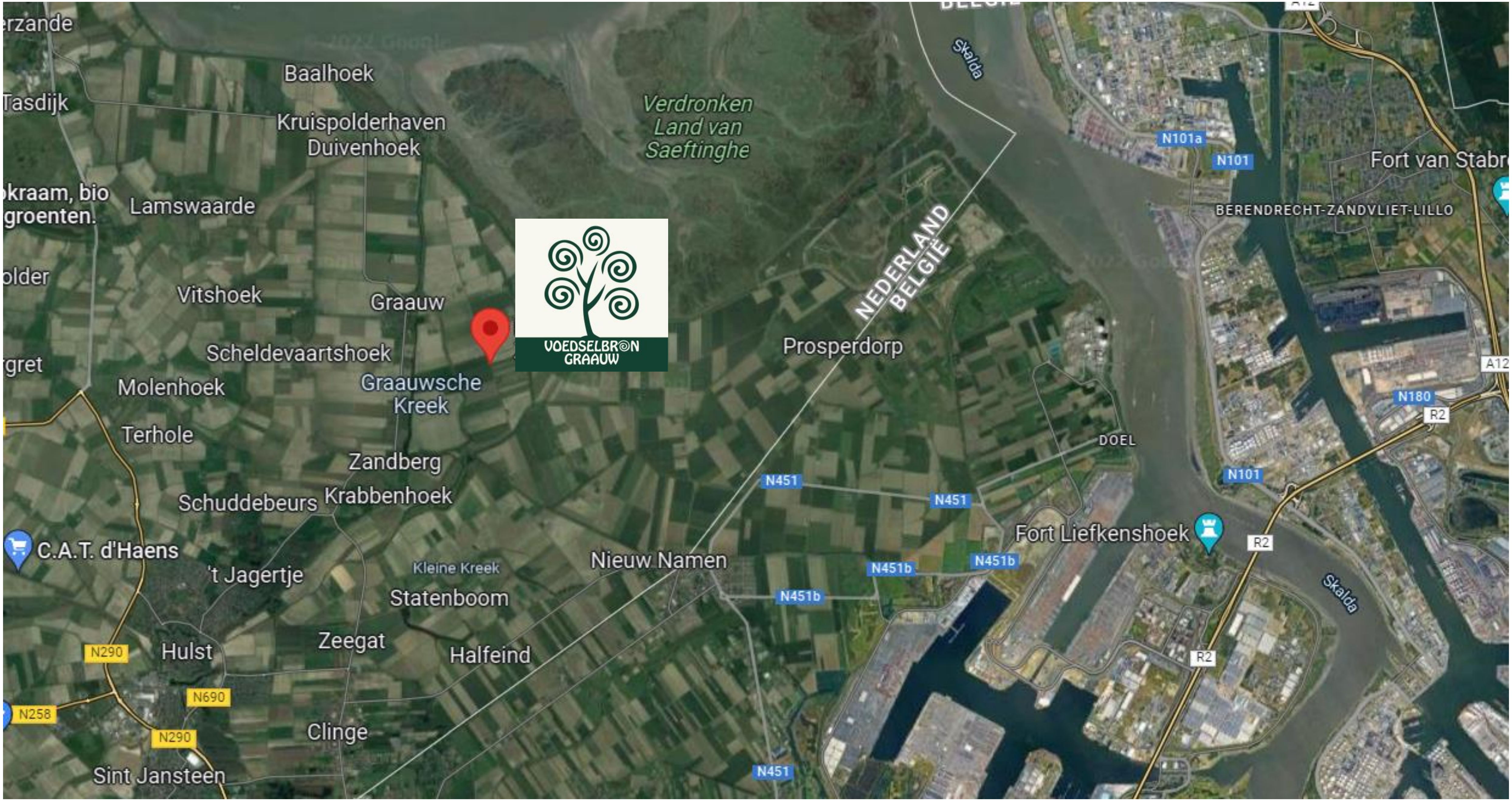


What can regenerative agriculture deliver for farmers?

Emiel van de Vijver

DE ZEEUWSE AKKER
My organic farm

Emiel van de Vijver,
Graauw (NL)



Baalhoek
Kruispolderhaven
Duivenhoek
Verdronken Land van Saeftinghe
Lamswaarde
Vitshoek
Graauw
Scheldevaartshoek
Molenhoek
Graauwsche Kreek
Terhole
Zandberg
Schuddebeurs
Krabbenhoek
C.A.T. d'Haens
't Jagertje
Kleine Kreek
Statenboom
Nieuw Namen
Hulst
Zeegat
Halfeind
Clinge
Sint Jansteen
N290
N690
N258
VOEDSELBRON GRAAUW
NEDERLAND
BELGIË
Prosperdorp
Skalda
N101a
N101
Fort van Stabr
BERENDRECHT-ZANDVLIET-LILLO
A12
N180
R2
DOEL
N451
N451b
Fort Liefkenshoek

Healthy soil, healthy plants

Same soil type

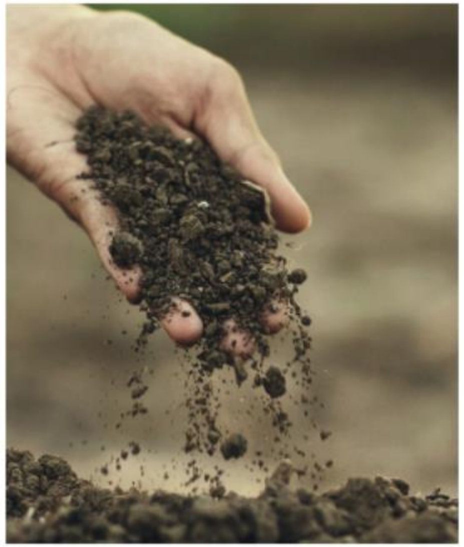
3rd year agroforestry

2nd year agroforestry

First year agroforestry

compost

ZWARTE SPECHT
gangmaker van de rhizosfeer



BASISGANGMAKER COMPOST

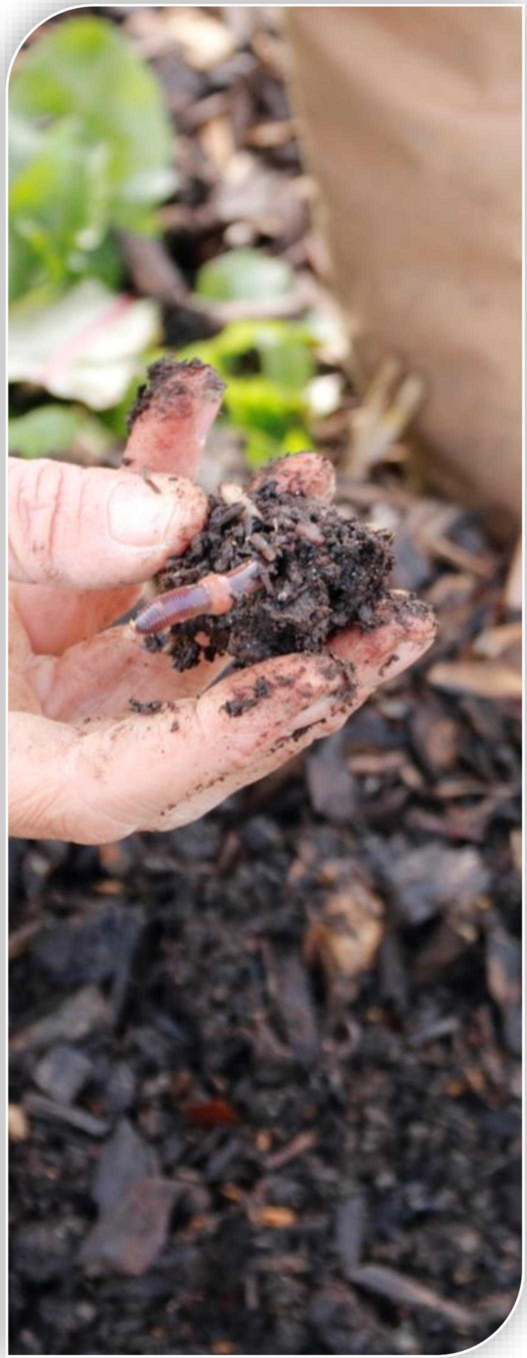
BESTE BASIS VOOR BODEMVERBETERING

- Optimaal ontwikkelde compost
- Stimuleert het bodemleven
- 100% biologisch, ook voor gangbaar
- Goede resultaten in akkerbouw en fruitteelt

GECOMPOSTEERDE KIPPENMESTKORRELS

VOOR EEN OPTIMAAL WERKENDE EN GEZONDE BODEM

- 100% biologisch
- A-meststof
- Werkt al na 2 weken
- Hoge stikstofefficiëntie

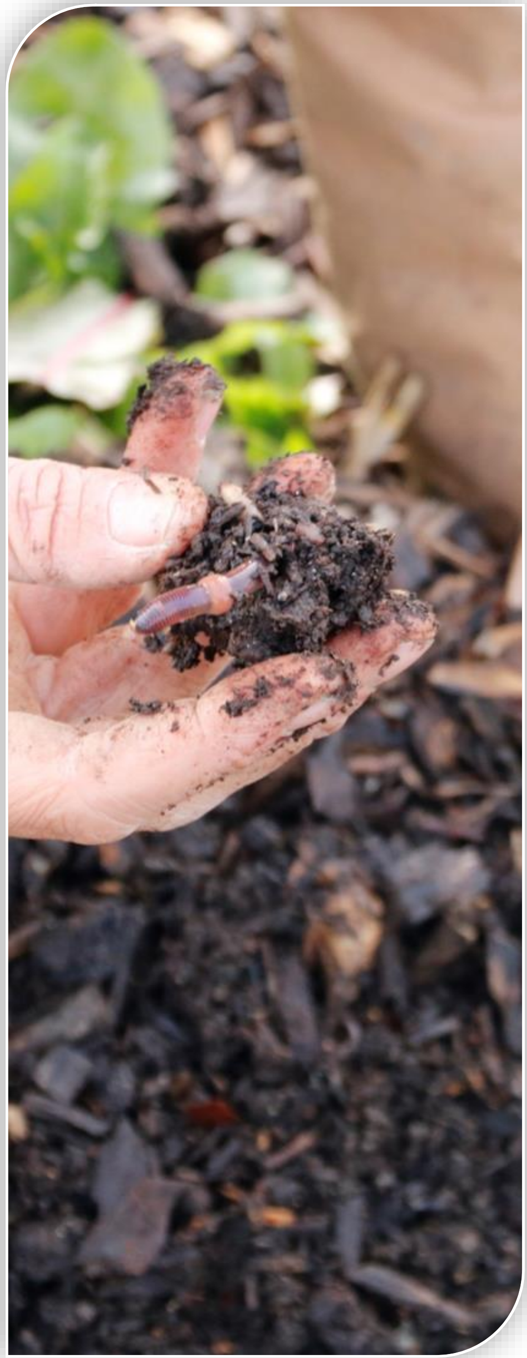


Fertilization = nutrition soil life

- Fertilization autumn:
  - compost of wood chips and poplar bark
  - Miscanthus compost
- Fertilization spring:
  - Dried organic chicken manure in pellets

Broccoli

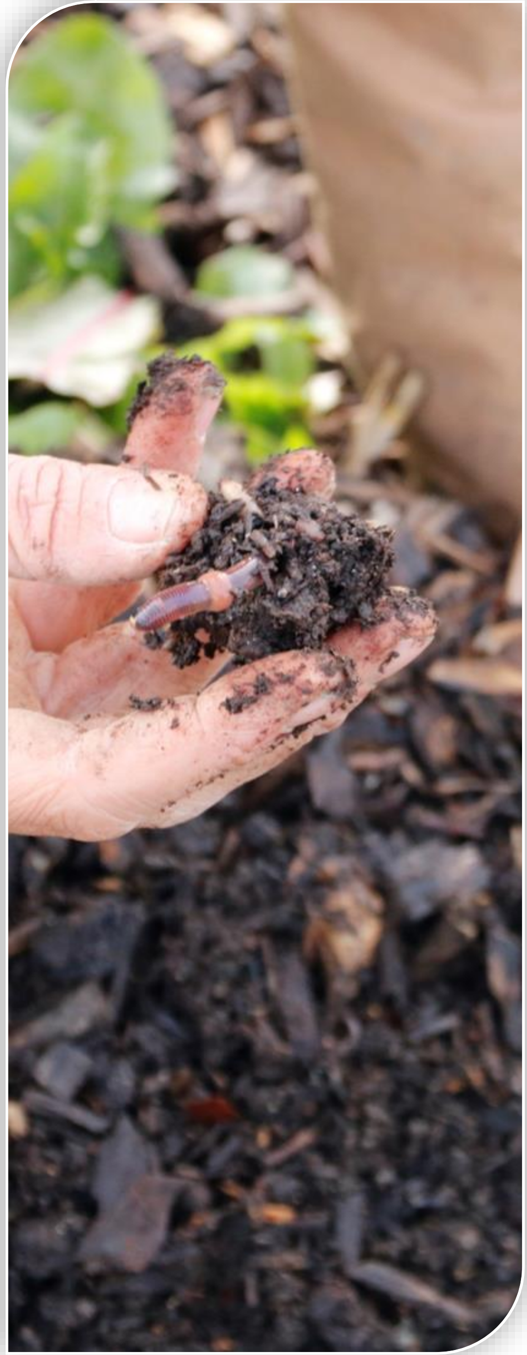
Broccoli



Broccoli old system: too much NA

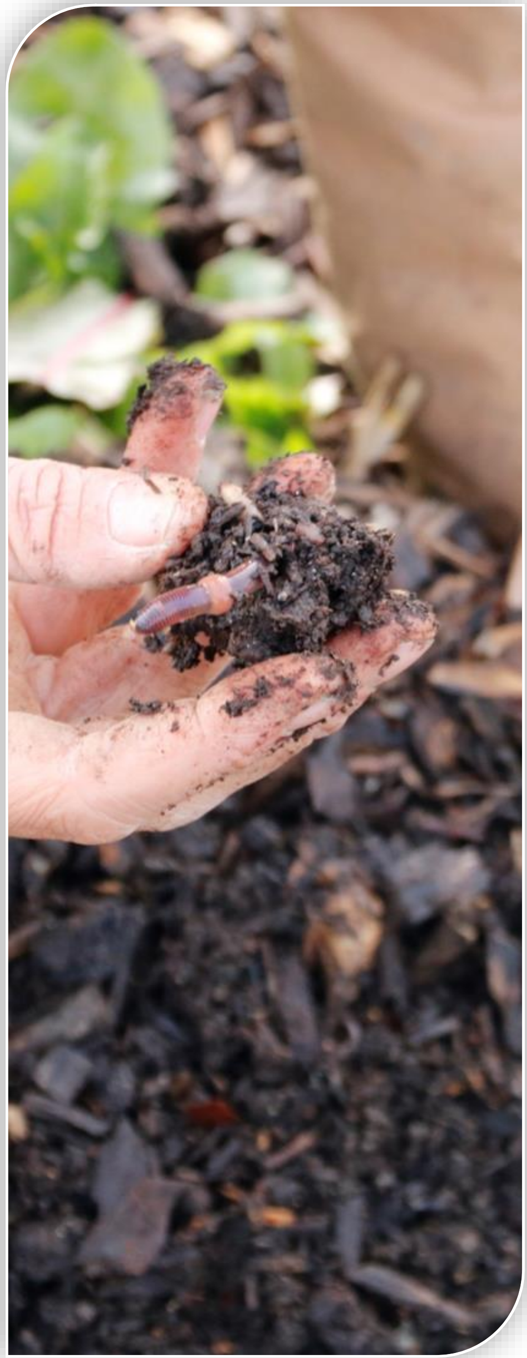
Mineraal		Huidig niveau	
Suikers	%	6,2	1
	%	5,1	2
pH		6,3	1
		6,0	2
EC	mS/cm	9,9	1
	mS/cm	12,5	2
K - Kalium	ppm	2101	1
	ppm	1808	2
Ca - Calcium	ppm	2677	1
	ppm	4827	2
K / Ca		0,78	1
		0,37	2
Mg - Magnesium	ppm	152	1
	ppm	233	2
Na - Natrium	ppm	251	1
	ppm	543	2
NH4 - Ammonium	ppm	66	1
	ppm	40	2
NO3 - Nitraat	ppm	<20	1
	ppm	<20	2
N uit Nitraat	ppm	<5	1
	ppm	<5	2
N - Stikstof totaal	ppm	1039	1
	ppm	631	2
Cl - Chloride	ppm	683	1
	ppm	1649	2
S - Zwavel	ppm	2220	1
	ppm	2595	2
P - Fosfaat	ppm	190	1
	ppm	139	2
Si - Silicium	ppm	10,3	1
	ppm	9,1	2
Fe - IJzer	ppm	1,74	1
	ppm	1,27	2
Mn - Mangaan	ppm	1,38	1
	ppm	1,32	2
Zn - Zink	ppm	3,11	1
	ppm	1,61	2
B - Borium	ppm	2,72	1
	ppm	4,13	2
Cu - Koper	ppm	0,26	1
	ppm	0,16	2
Mo - Molybdeen	ppm	0,39	1
	ppm	0,38	2
Al - Aluminium	ppm	<0,50	1
	ppm	0,54	2

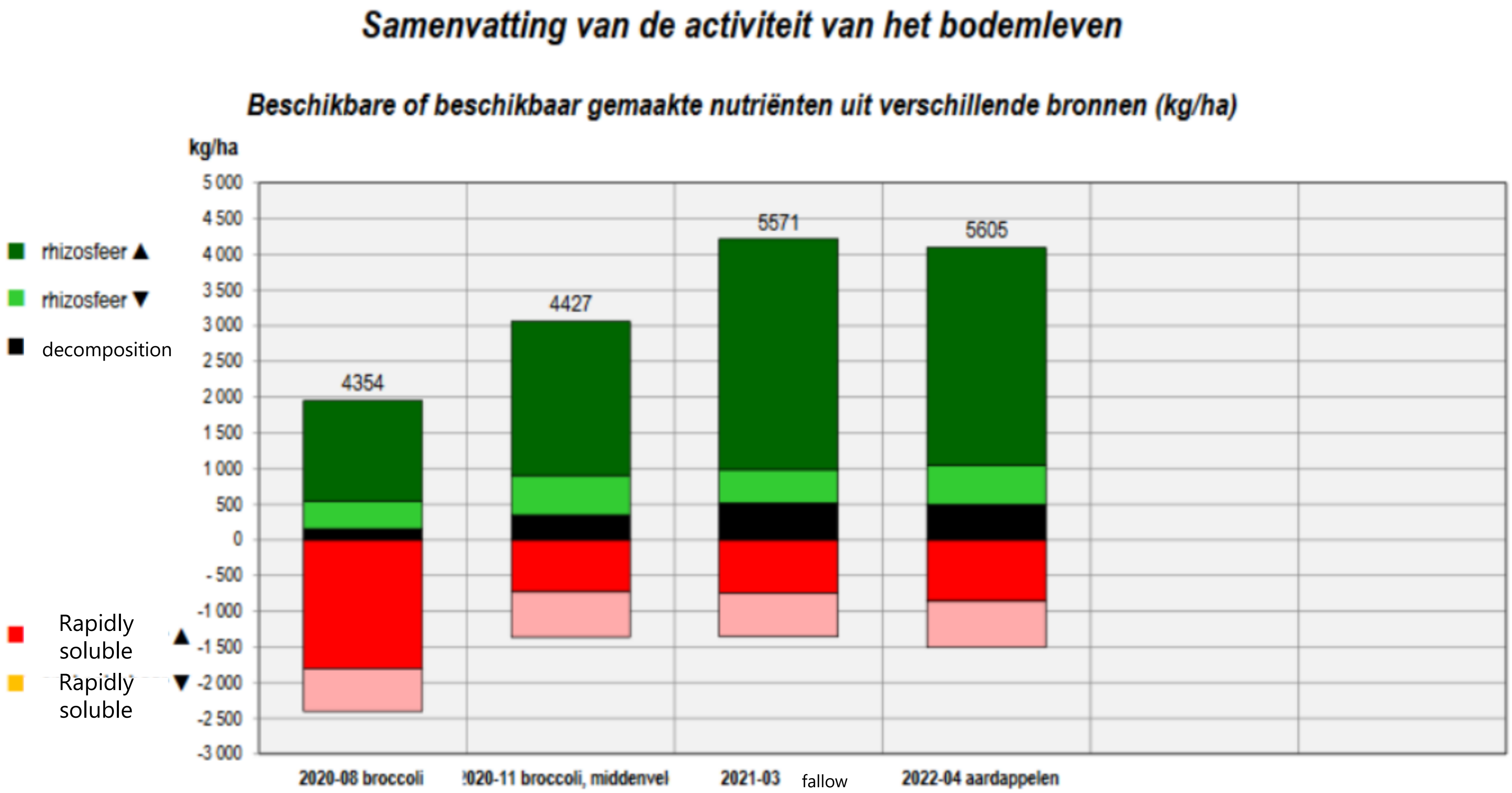
Plant juice analysis broccoli - Zwarte Specht concept



Mineraal		Huidig niveau	Optimum	
Suikers	%	2,7	0,6 - 1,9	1
	%	3,0		2
pH		5,9	6,2 - 6,6	1
		6,1		2
EC	mS/cm	7,1	11,9 - 16,1	1
	mS/cm	12,6		2
K - Kalium	ppm	1867	3625 - 5775	1
	ppm	4200		2
Ca - Calcium	ppm	1655	1225 - 4300	1
	ppm	3342		2
K / Ca		1,13		1
		1,26		2
Mg - Magnesium	ppm	83	280 - 510	1
	ppm	143		2
Na - Natrium	ppm	27	66 - 161	1
	ppm	42		2
NH4 - Ammonium	ppm	62	140 - 470	1
	ppm	81		2
NO3 - Nitraat	ppm	<20	70 - 910	1
	ppm	<20		2
N uit Nitraat	ppm	<5	16 - 205	1
	ppm	<5		2
N - Stikstof totaal	ppm	735	1630 - 3110	1
	ppm	1202		2
Cl - Chloride	ppm	276	740 - 1780	1
	ppm	951		2
S - Zwavel	ppm	1155	1130 - 1730	1
	ppm	2305		2
P - Fosfaat	ppm	208	230 - 610	1
	ppm	313		2
Si - Silicium	ppm	4,8	2,6 - 7,5	1
	ppm	6,4		2
Fe - IJzer	ppm	0,77	1,50 - 2,45	1
	ppm	2,73		2
Mn - Mangaan	ppm	1,14	2,20 - 6,20	1
	ppm	1,30		2
Zn - Zink	ppm	0,82	2,30 - 5,35	1
	ppm	1,81		2
B - Borium	ppm	0,70	2,60 - 5,20	1
	ppm	1,69		2
Cu - Koper	ppm	0,15	0,25 - 0,50	1
	ppm	0,31		2
Mo - Molybdeen	ppm	0,51	0,20 - 0,60	1
	ppm	1,92		2
Al - Aluminium	ppm	<0,50	<0,50 - <0,50	1
	ppm	0,51		2

Measurement report Peter Vanhoof then and now





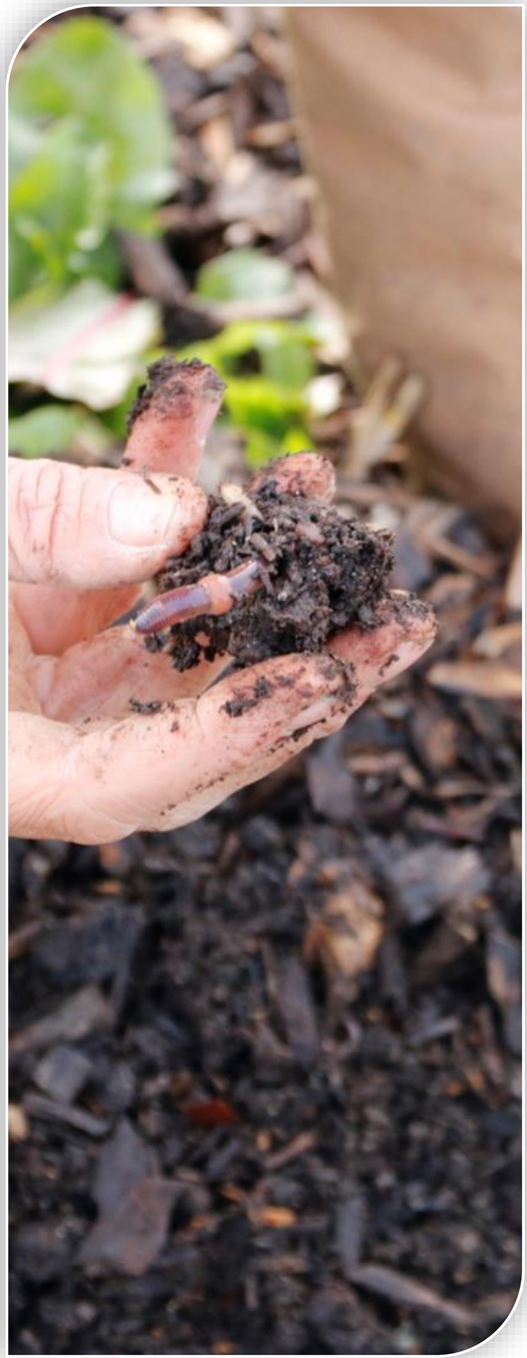


Potatoes

Knolselder
Cellery



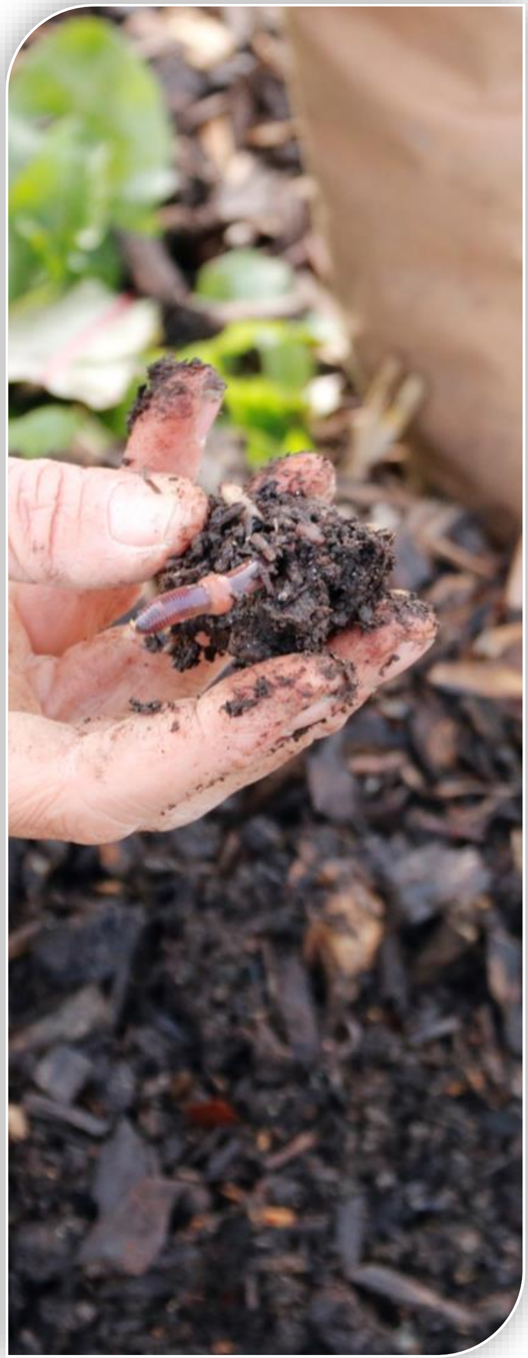
TREATED WITH ZWARTE SPECHT CONCEPT
NOT TREATED

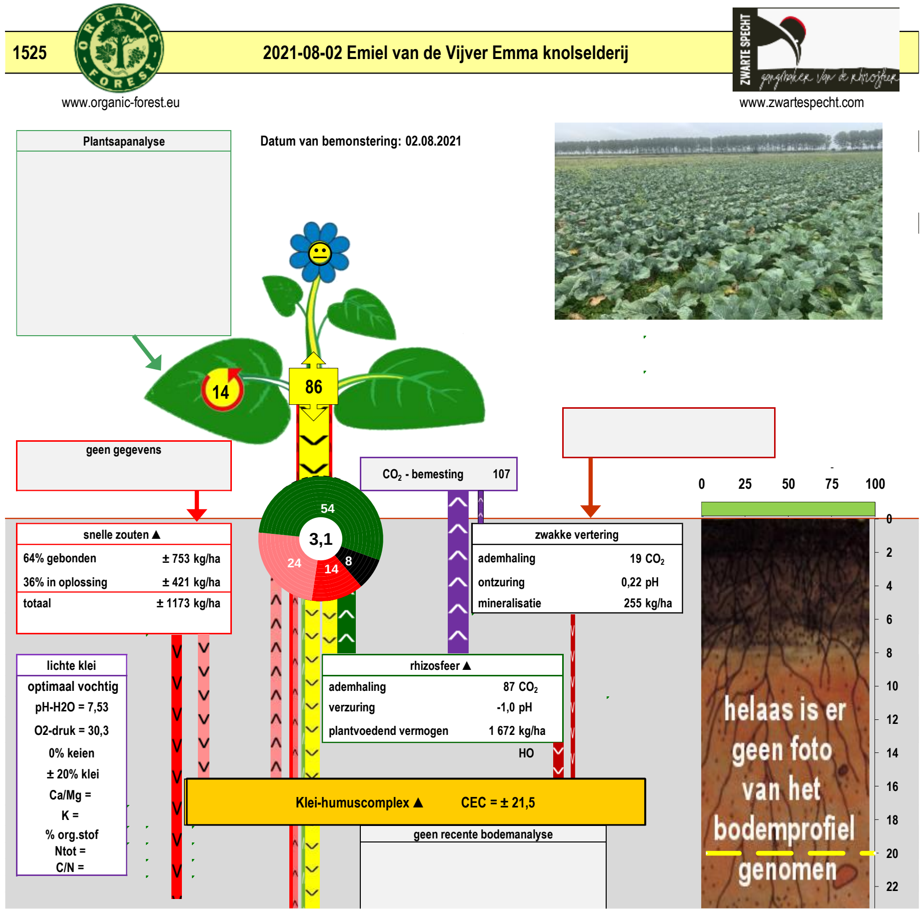


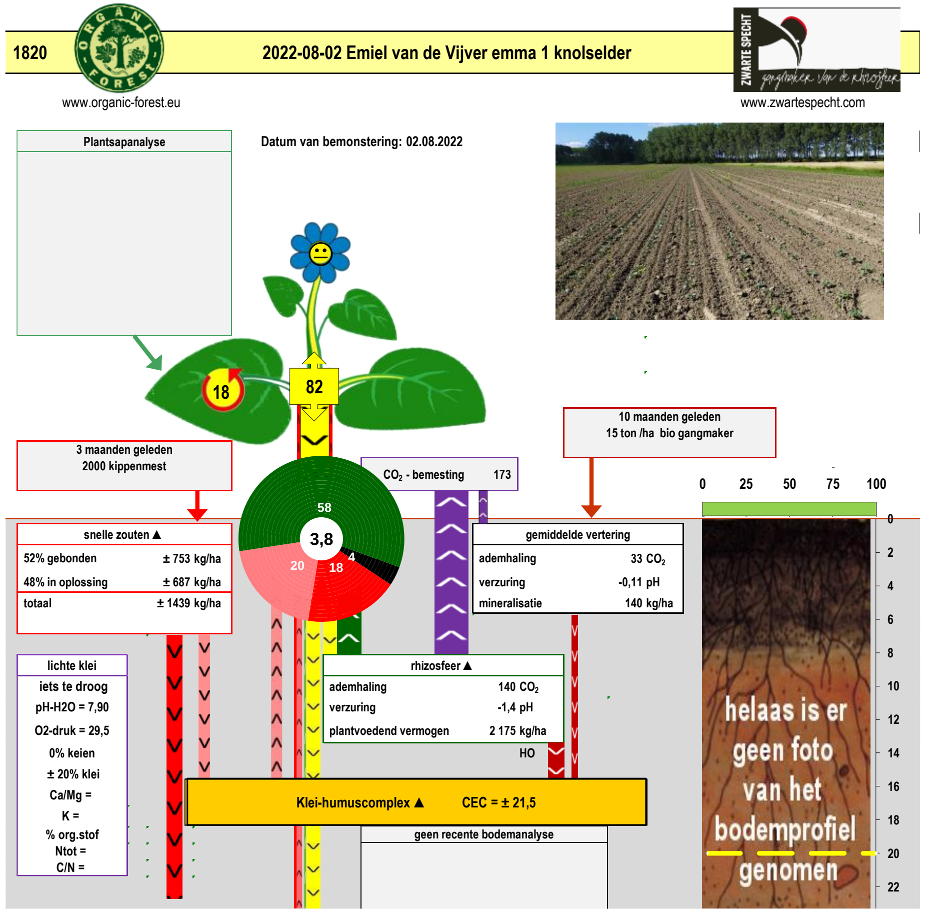
Plant juice analysis

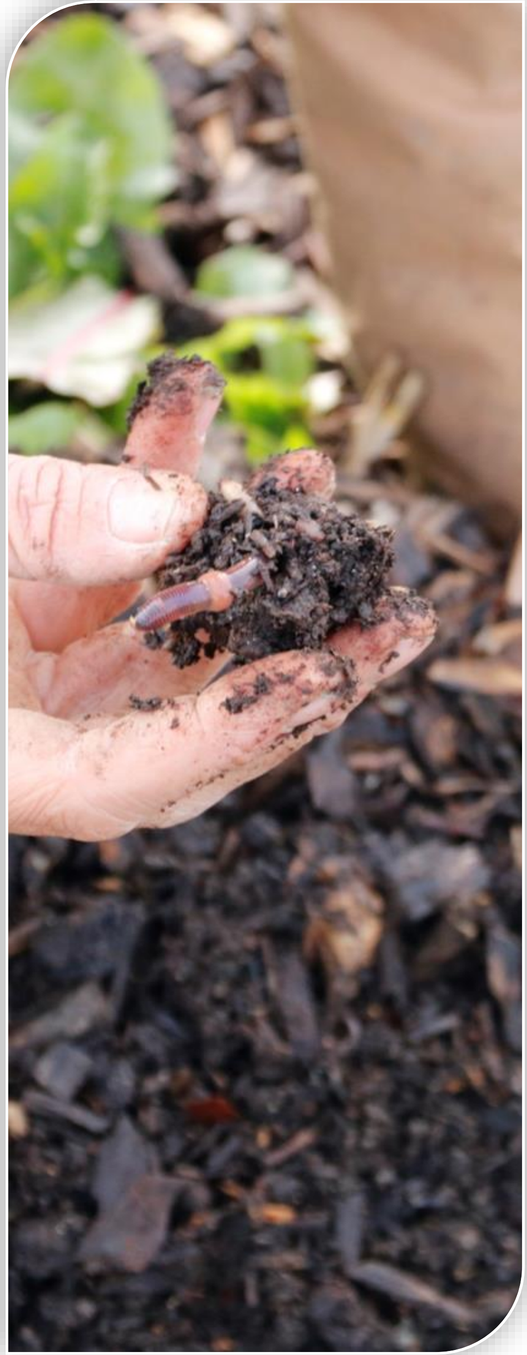
Mineraal		Huidig niveau	Optimum	
Suikers	%	0,5	0,6 - 1,2	1
	%	0,4		2
pH		5,6	5,7 - 6,0	1
		5,8		2
EC	mS/cm	20,9	15,7 - 19,7	1
	mS/cm	20,2		2
K - Kalium	ppm	7808	3675 - 5925	1
	ppm	5436		2
Ca - Calcium	ppm	3466	1175 - 8075	1
	ppm	5541		2
K / Ca		2,25		1
		0,98		2
Mg - Magnesium	ppm	610	360 - 570	1
	ppm	651		2
Na - Natrium	ppm	801	611 - 1237	1
	ppm	1012		2
NH4 - Ammonium	ppm	38	60 - 120	1
	ppm	41		2
NO3 - Nitraat	ppm	1204	280 - 1420	1
	ppm	2378		2
N uit Nitraat	ppm	272	63 - 321	1
	ppm	537		2
N - Stikstof totaal	ppm	1305	930 - 1640	1
	ppm	1404		2
Cl - Chloride	ppm	3053	1790 - 3790	1
	ppm	3950		2
S - Zwavel	ppm	2291	690 - 2470	1
	ppm	2044		2
P - Fosfaat	ppm	555	110 - 340	1
	ppm	126		2
Si - Silicium	ppm	10,8	2,3 - 4,7	1
	ppm	14,5		2
Fe - IJzer	ppm	3,34	2,25 - 5,15	1
	ppm	7,31		2
Mn - Mangaan	ppm	3,49	3,80 - 11,00	1
	ppm	6,64		2
Zn - Zink	ppm	6,81	4,45 - 6,80	1
	ppm	8,57		2
B - Borium	ppm	2,32	0,40 - 1,50	1
	ppm	1,14		2
Cu - Koper	ppm	1,12	0,55 - 0,90	1
	ppm	0,62		2
Mo - Molybdeen	ppm	0,16	0,10 - 0,35	1
	ppm	0,70		2
Al - Aluminium	ppm	2,58	<0,50 - 1,33	1
	ppm	3,57		2

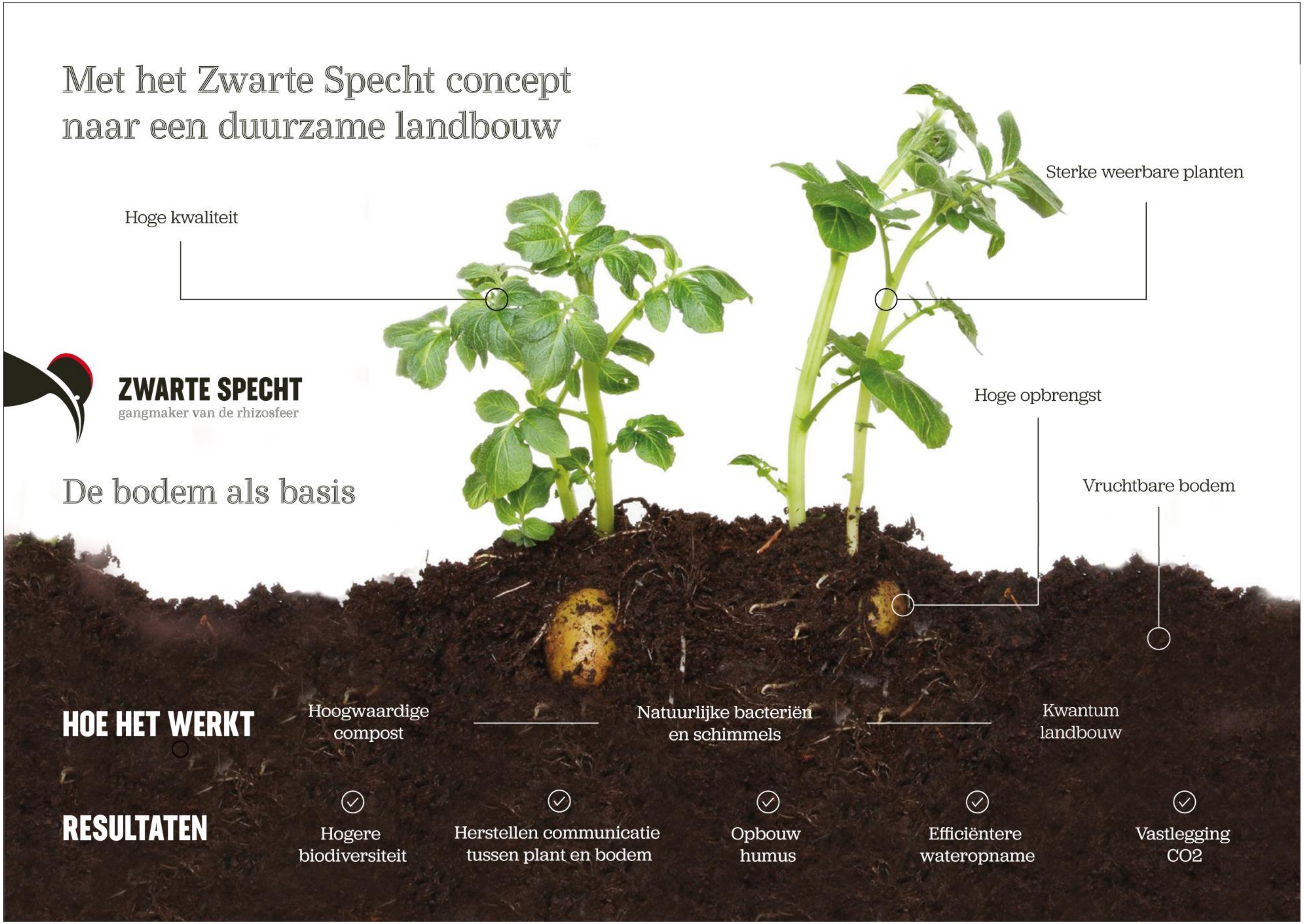
Measurement report then and now



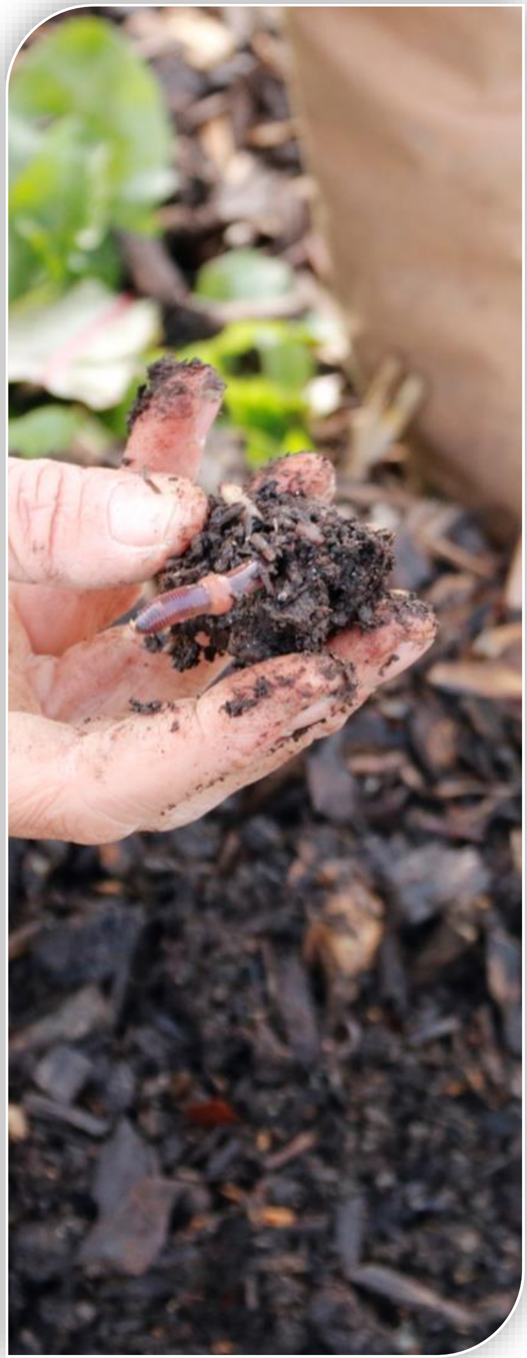








Met het Zwarte Specht concept
naar een duurzame landbouw
Hoge kwaliteit
Sterke weerbare planten
ZWARTE SPECHT
gangmaker van de rhizosfeer
Hoge opbrengst
De bodem als basis
Vruchtbare bodem
HOE HET WERKT
Hoogwaardige compost
Natuurlijke bacteriën en schimmels
Kwantum landbouw
RESULTATEN
Hogere biodiversiteit
Herstellen communicatie tussen plant en bodem
Opbouw humus
Efficiëntere wateropname
Vastlegging CO2



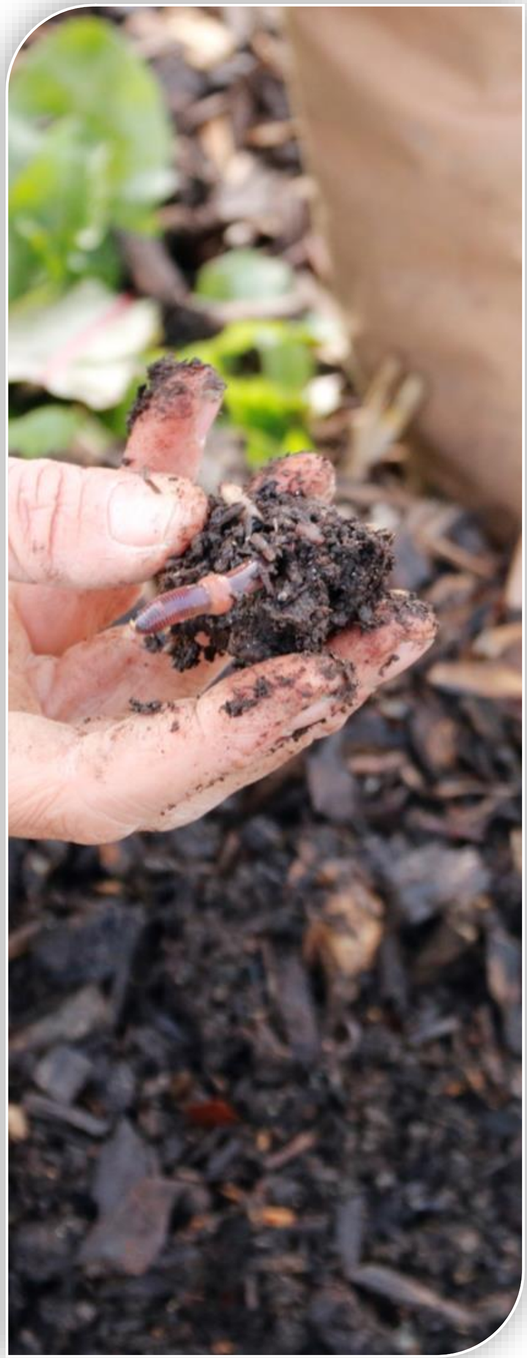
Thank you for your attention

Questions?

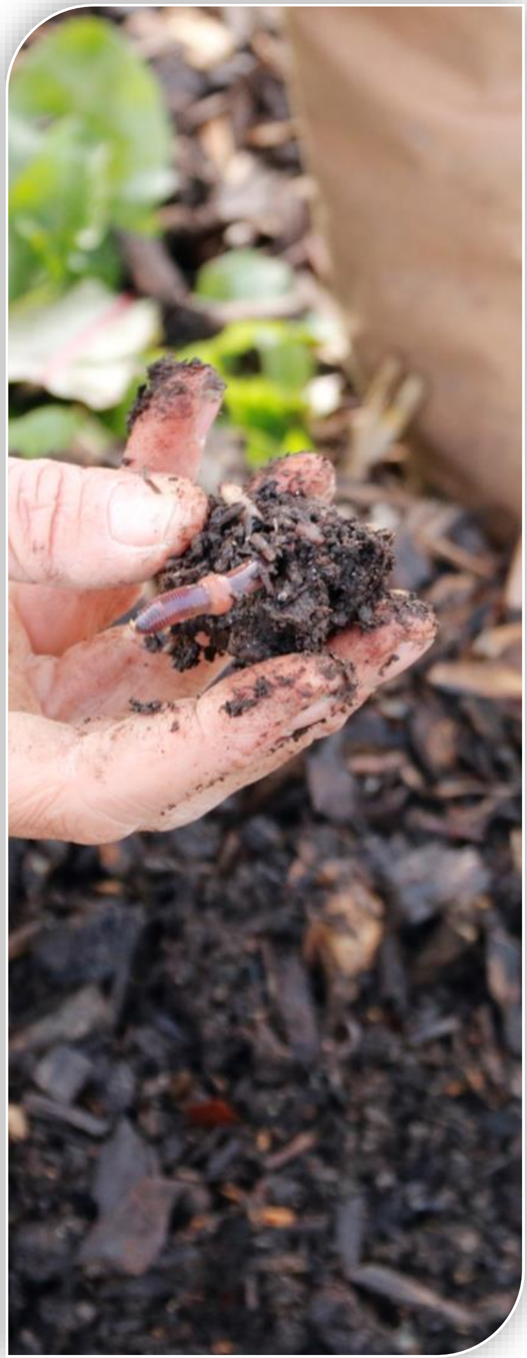
- emiel@vdvijver.eu - 0626098949
- zeeuwseakker.nl - voedselbrongraauw.nl
- zwartespecht.com

ZWARTE SPECHT

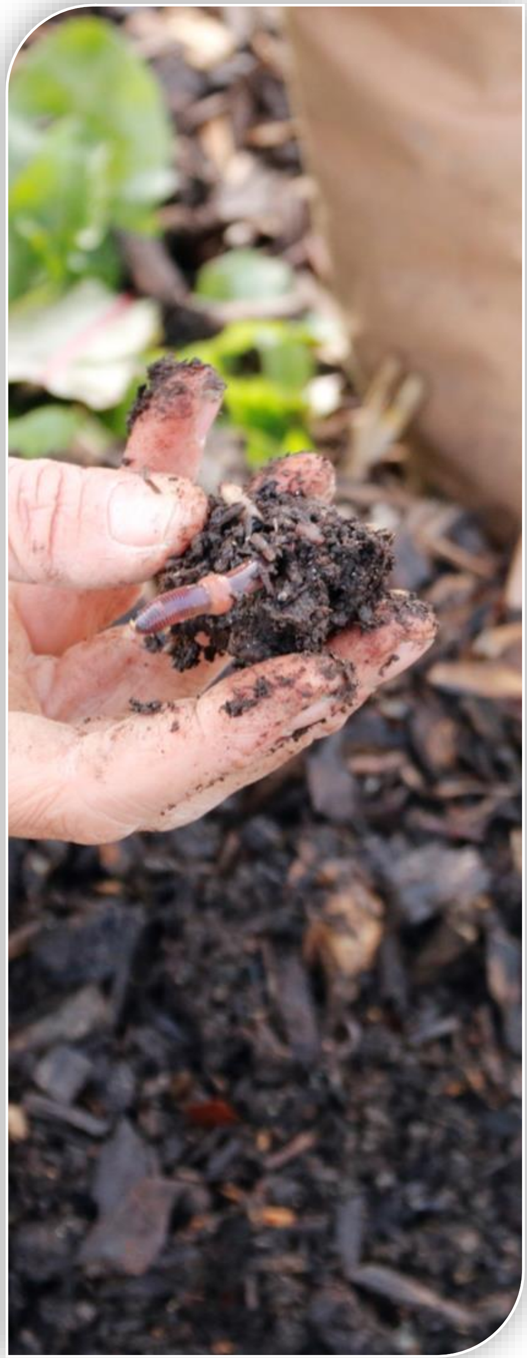
gangmaker van de rhizosfeer



Questions?

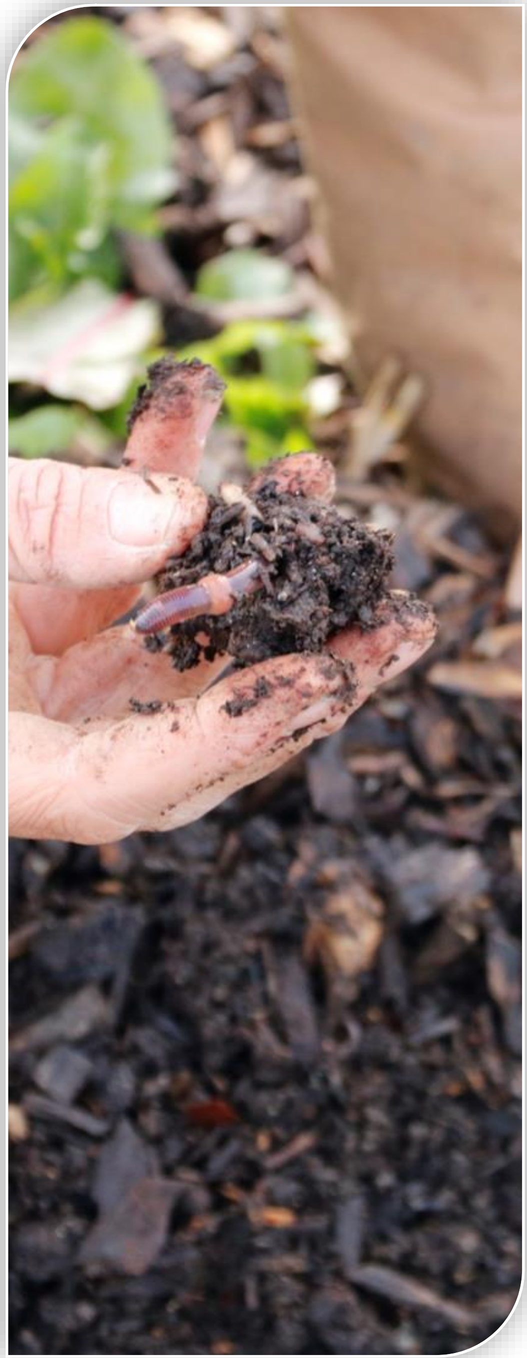


Discussion

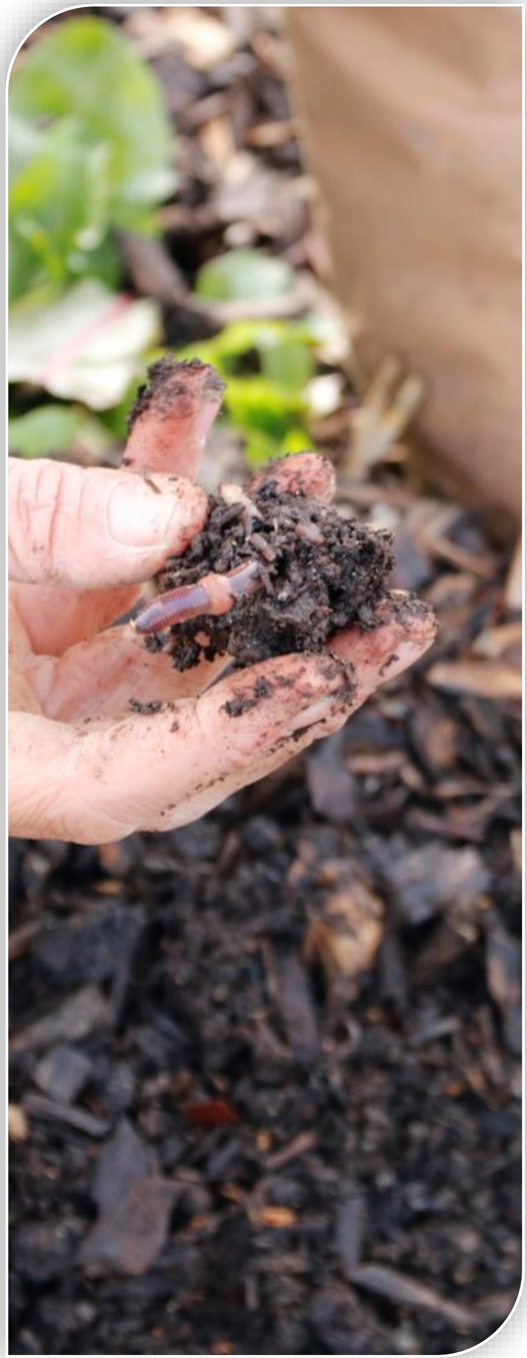


Coffee Break

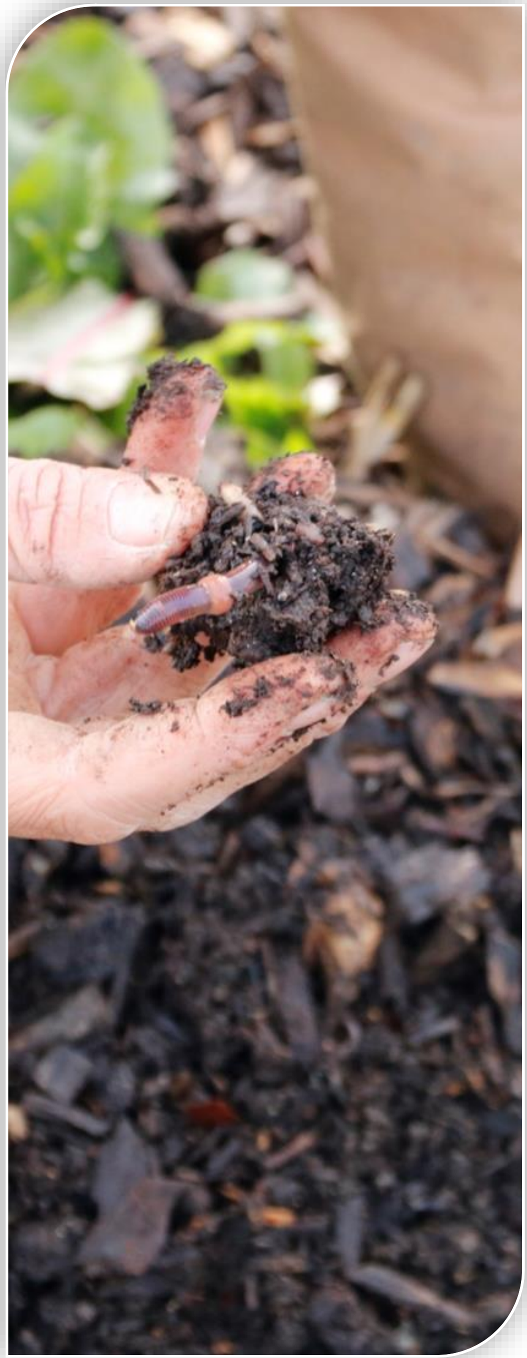
Till 15h30



Panel Discussion



Questions?



A special thanks to

&

Raschad Al Khafaji
Annemie Elsen
Martine Swerts
Anette Scheengans