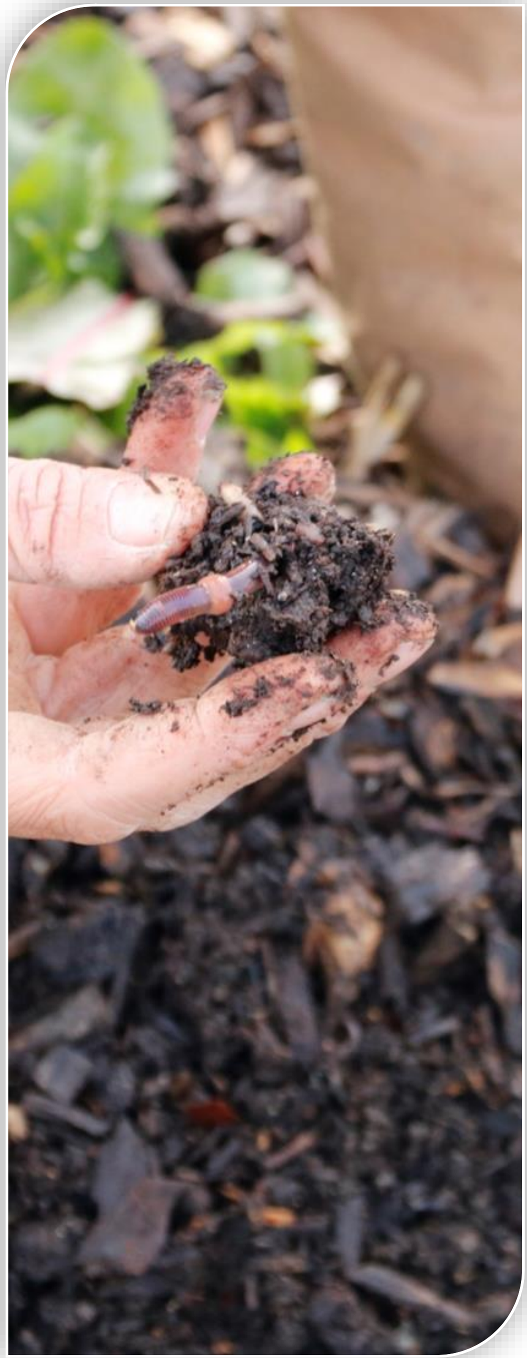


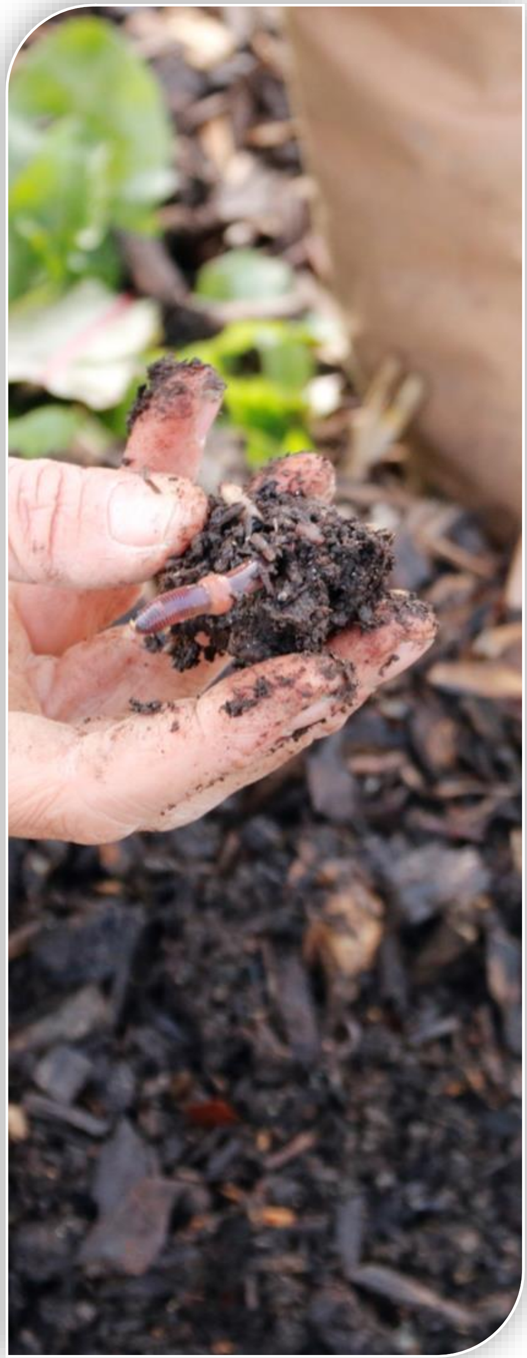
5 december 2022
Soil Health Conference

Mechanisms of soil health restoration in regenerative agriculture

Dr. Richard Teague

Texas A&M AgriLife Research – Rangeland ecologist

WERVEL · Living Lab Agro-ecologie & biologische landbouw · ILVO · VUB · Organic Forest · Soildiver Agro · agromix



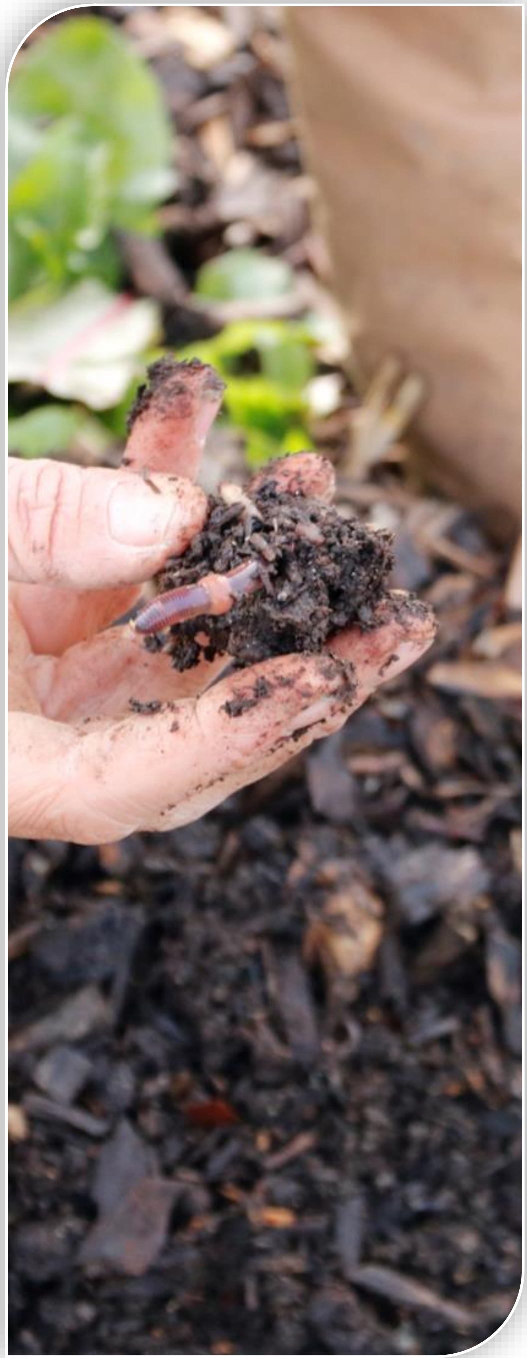
Our Framework

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:

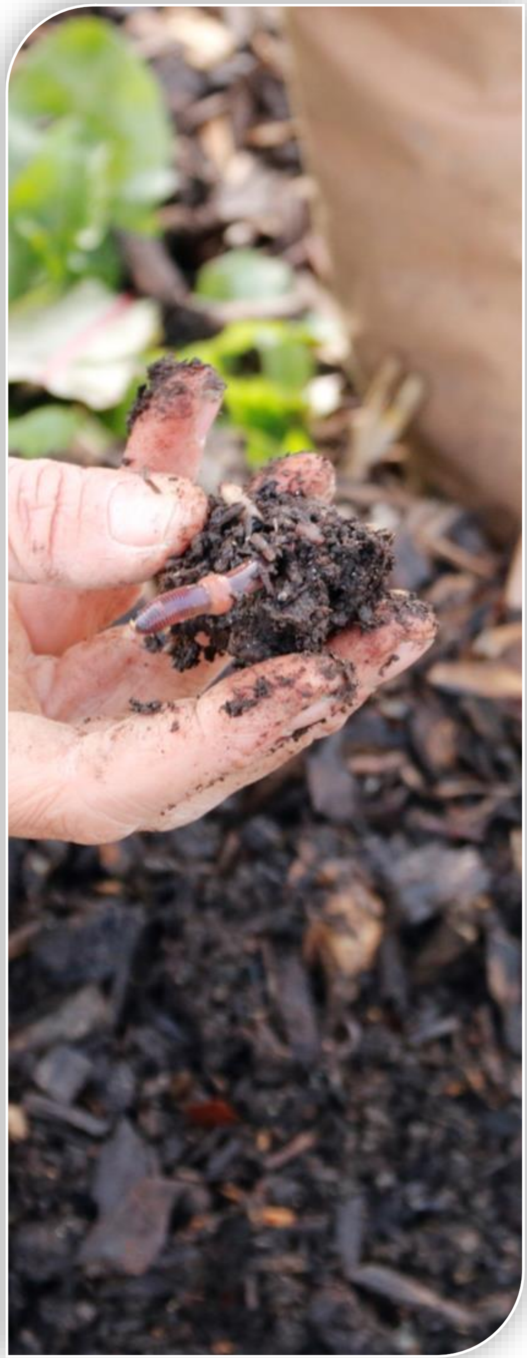
The USDA-NRCS soil mapping database identified the ranches with the highest SOC

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

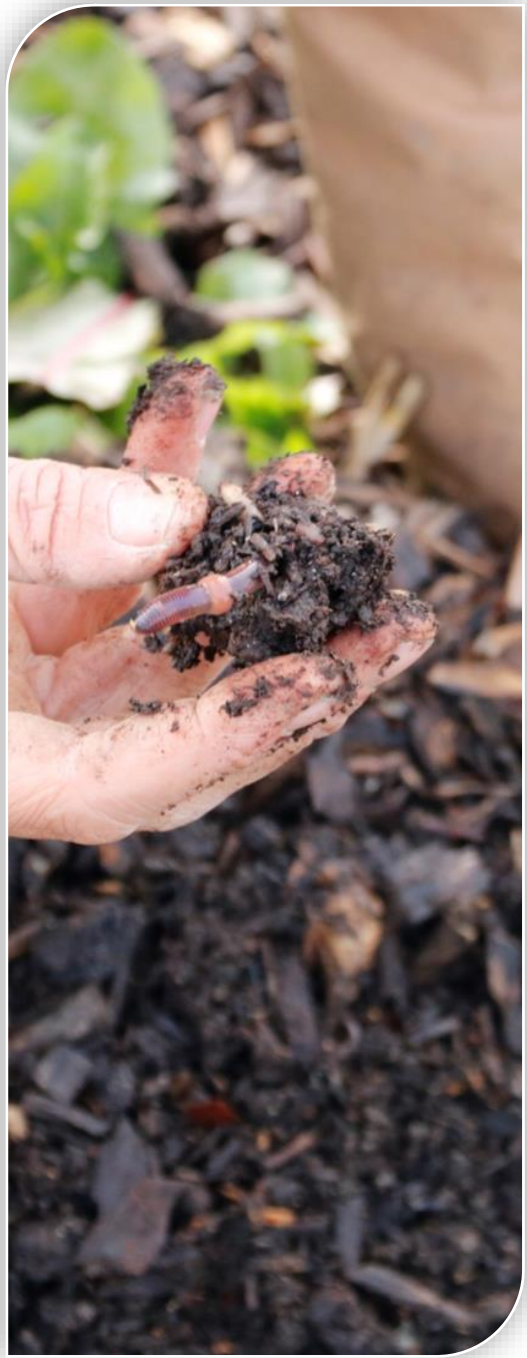
Aims at:

- 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

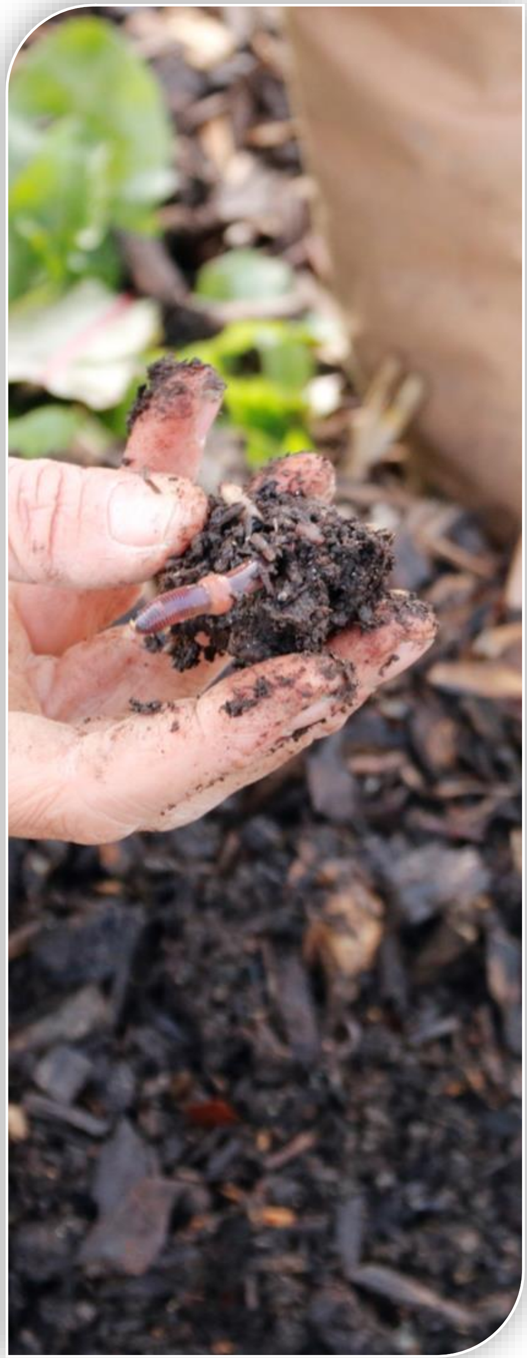
Van der Ploeg et al 2006; Savory and Butterfield 2016; Massy 2018



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

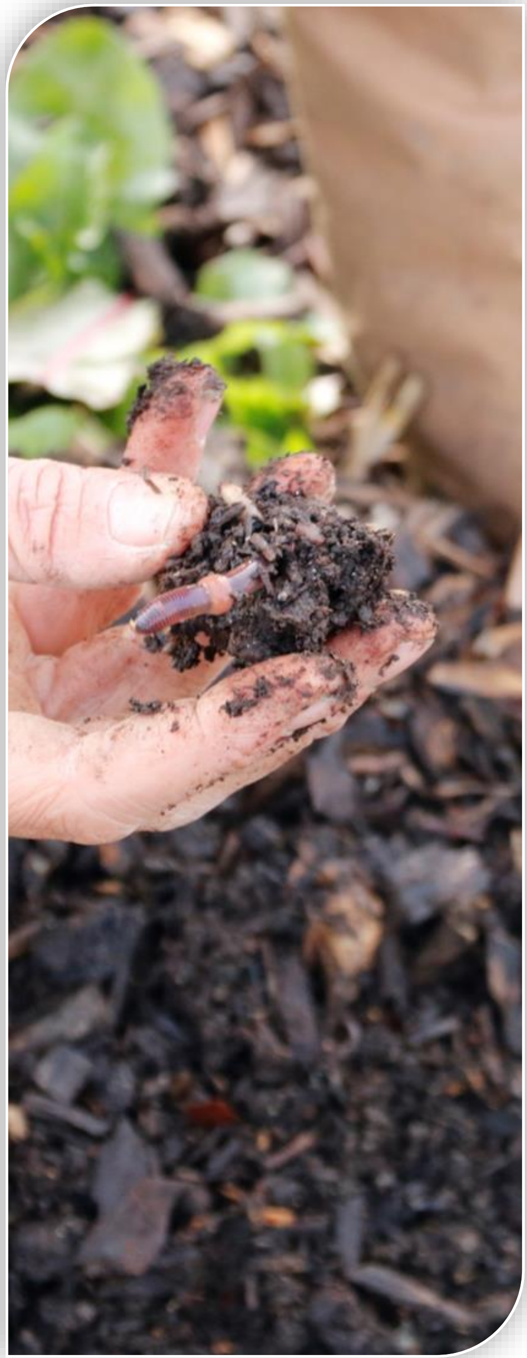
Van der Ploeg et al 2006; Teague et al. 2016; Massy 2018



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

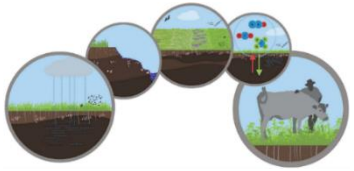
Norton et al. 2013; Jakoby et al. 2014; Teague et al. 2013; 2015



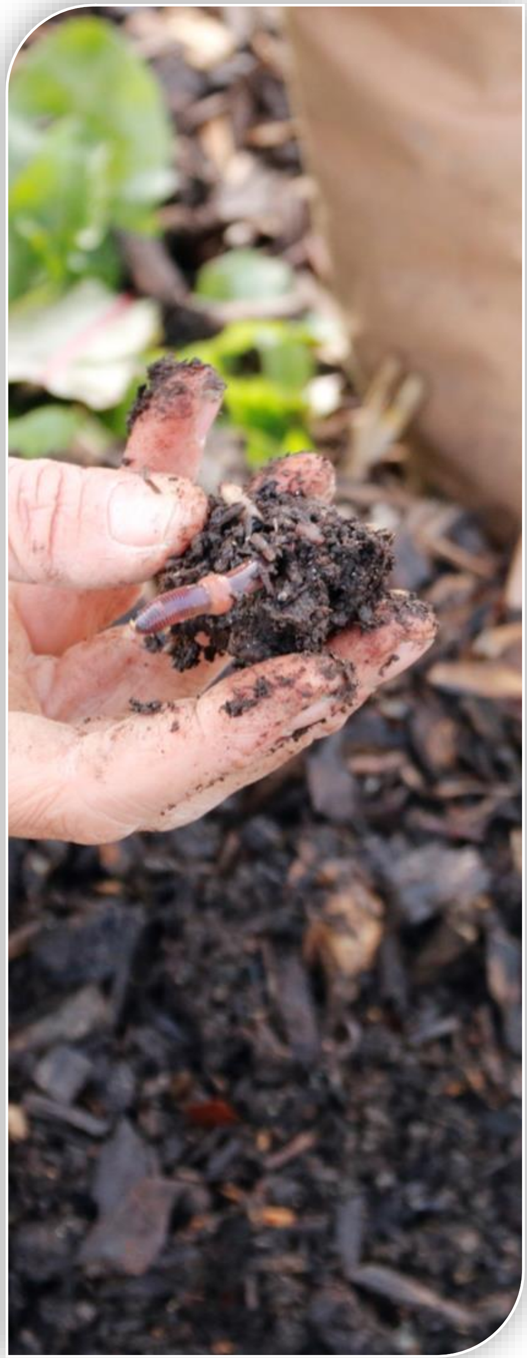
Our Research Hypothesis:

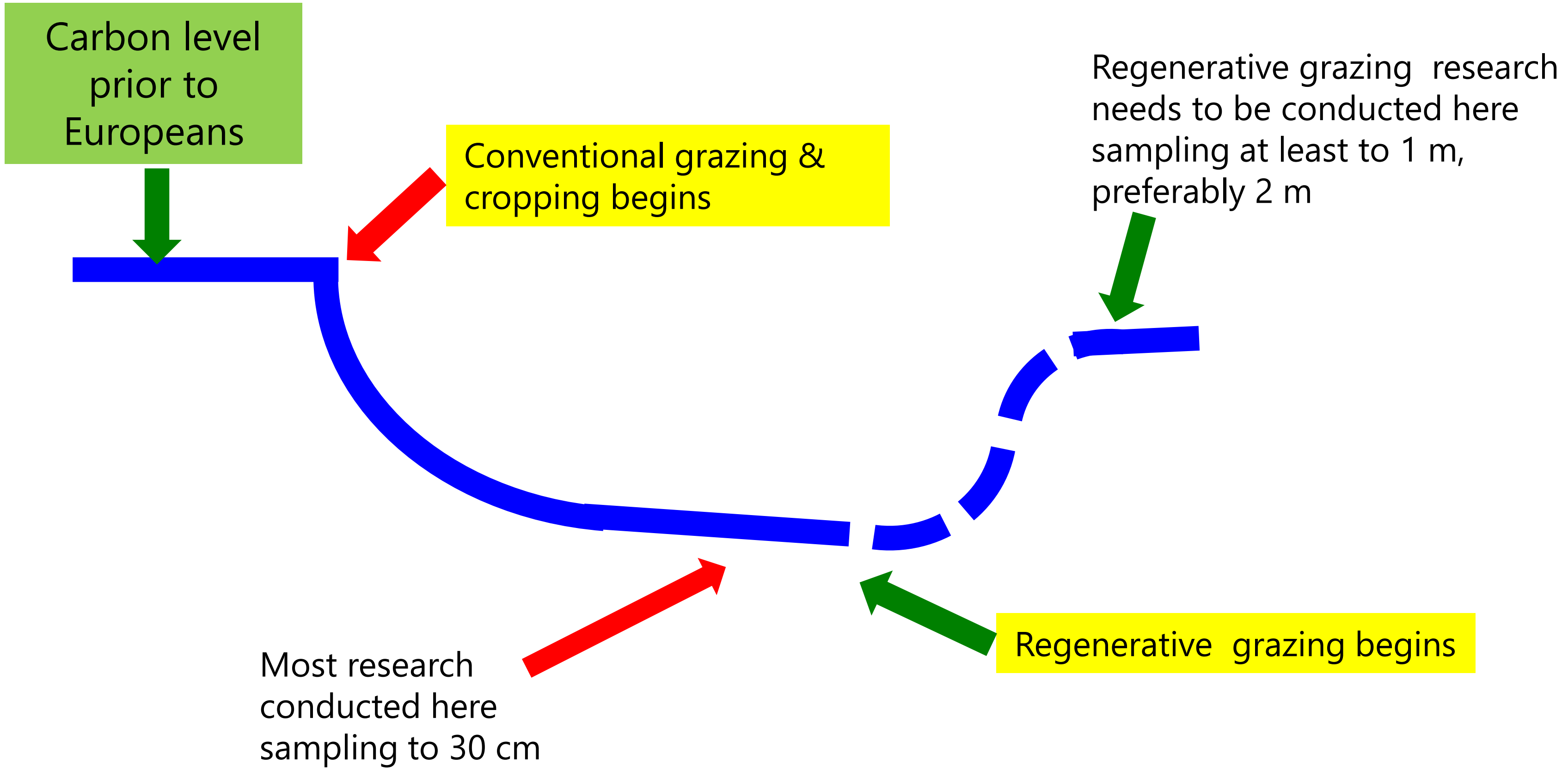
Ecosystem health is increased as soil Carbon increases, *resulting in*:

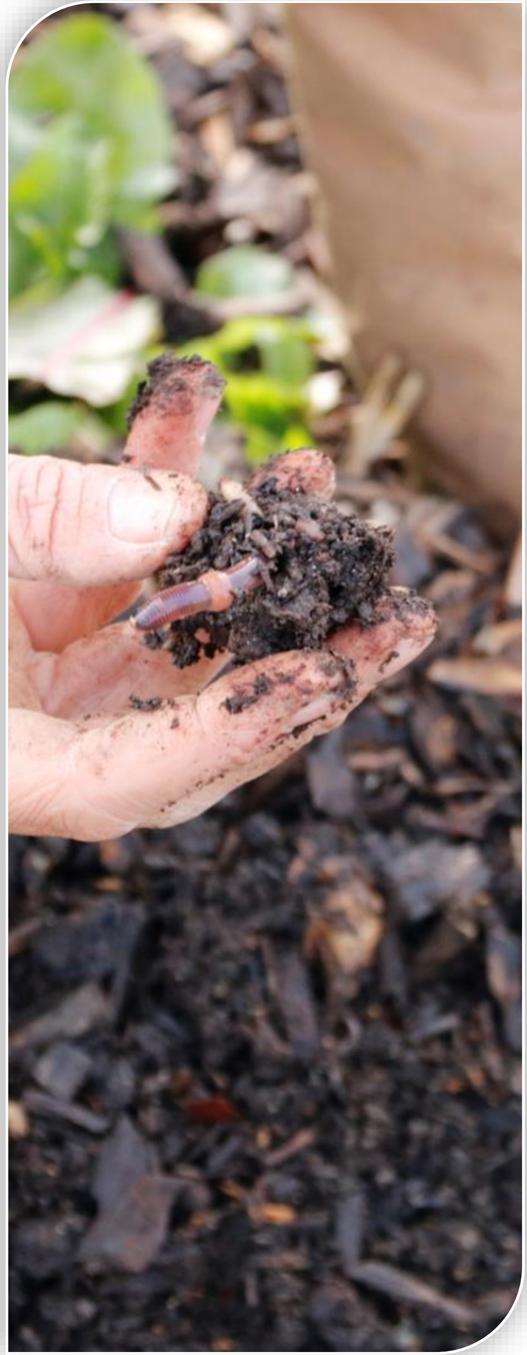
- Improves water infiltration and retention;
- Improves soil nutrient status, access and retention;
- Increases diversity of fungi, microbes, plants, insects;
- Improves wildlife diversity, nutrition and habitat;
- Reduces soil erosion and **net** GHG emissions;
- Improves livestock well-being and output;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

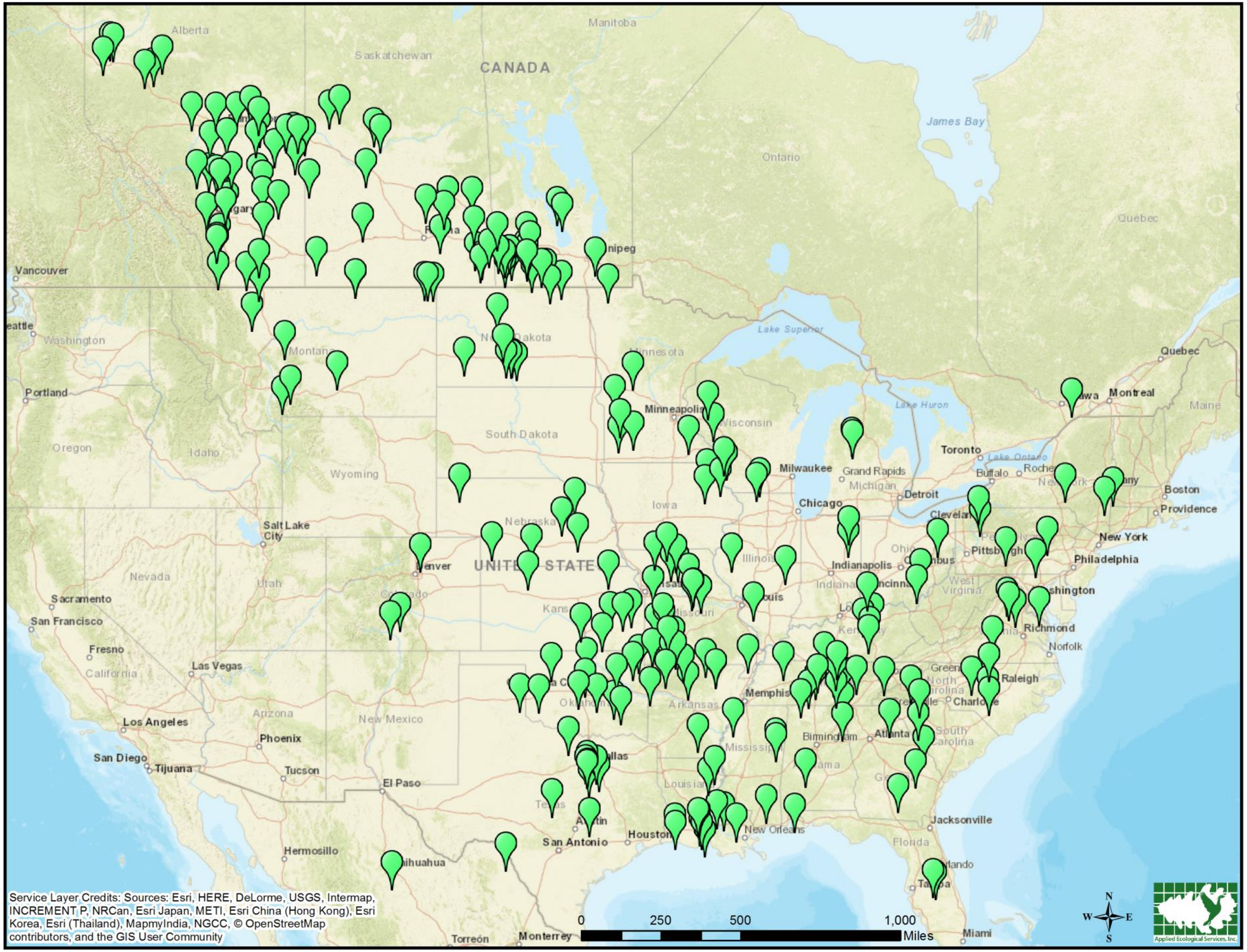


Soil Carbon changes with human management





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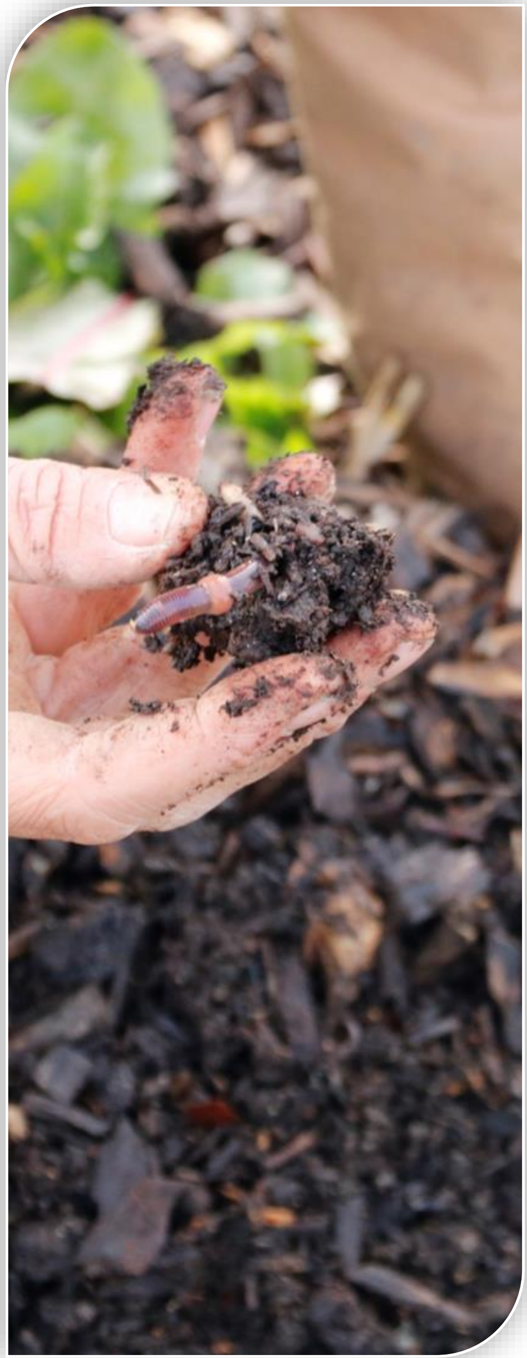
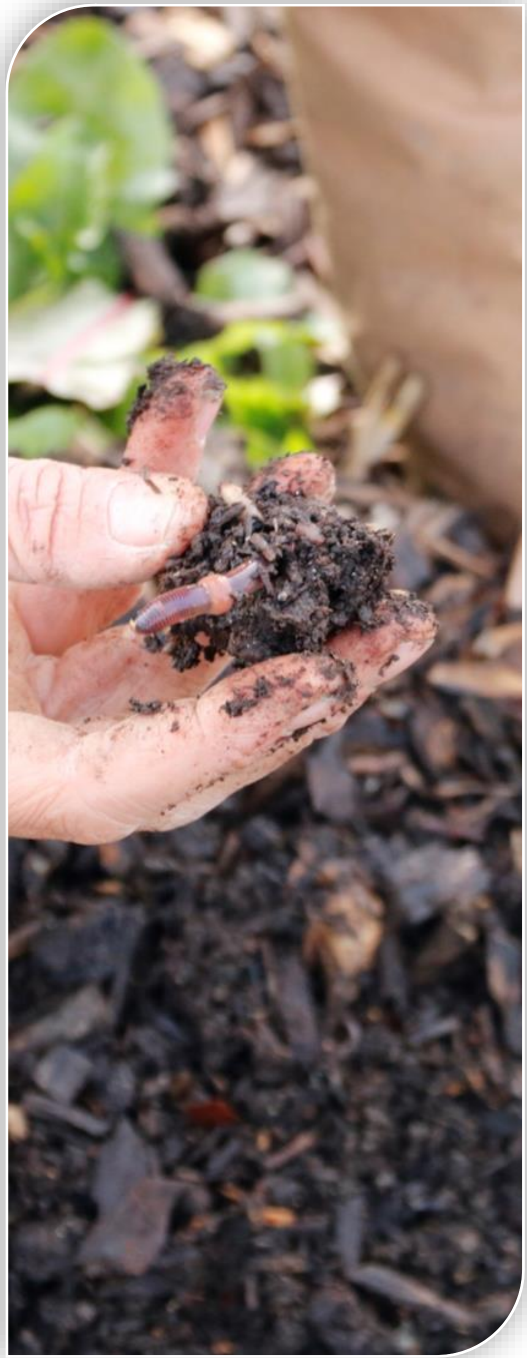
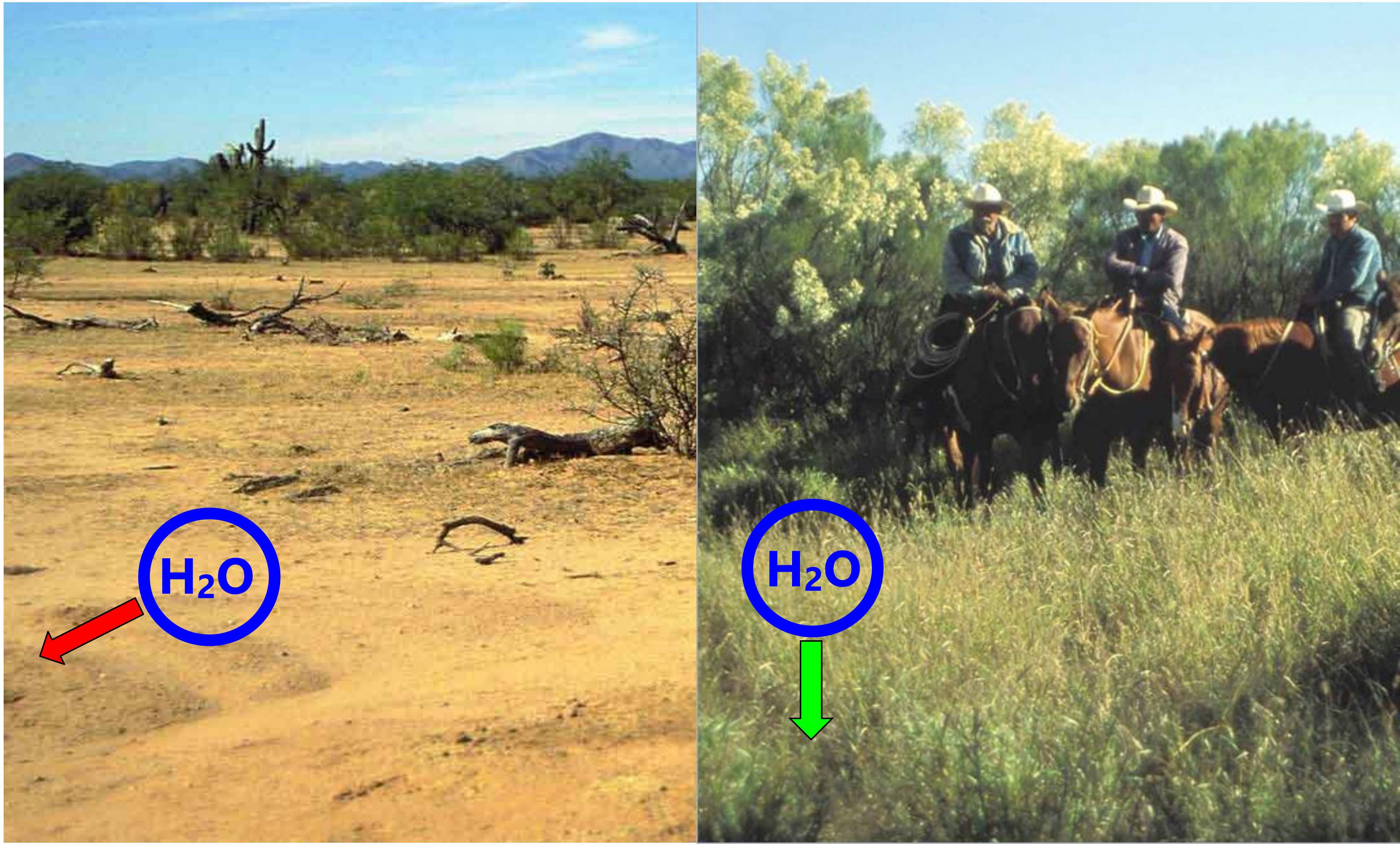


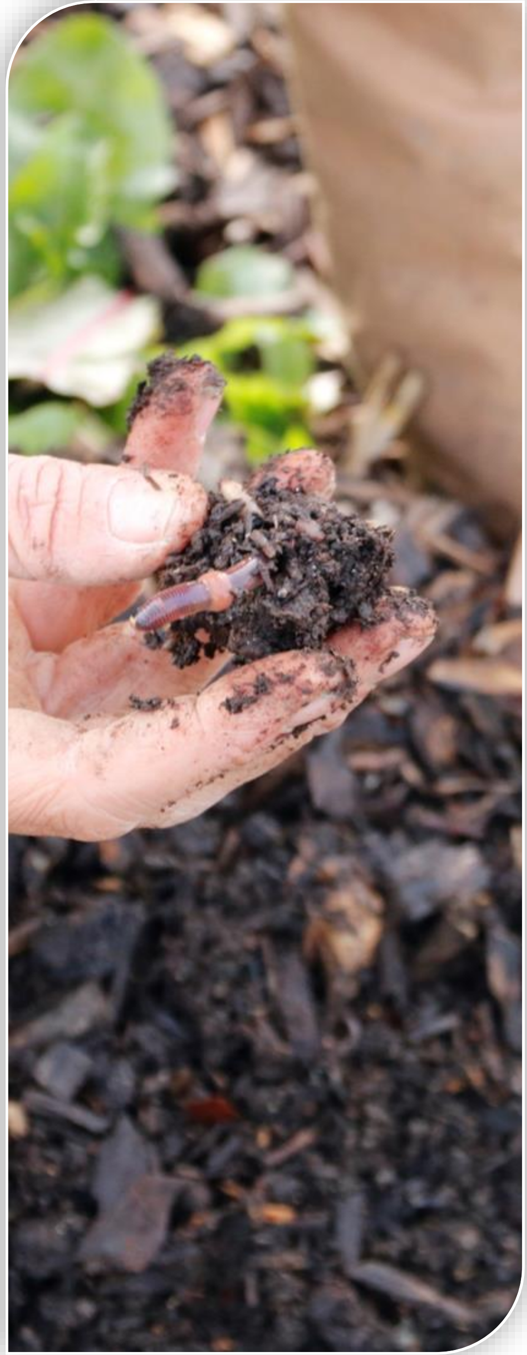
Soil biology in fully functional grazing ecosystems



Biggest limiting factor in grazing land

Water in the Soil

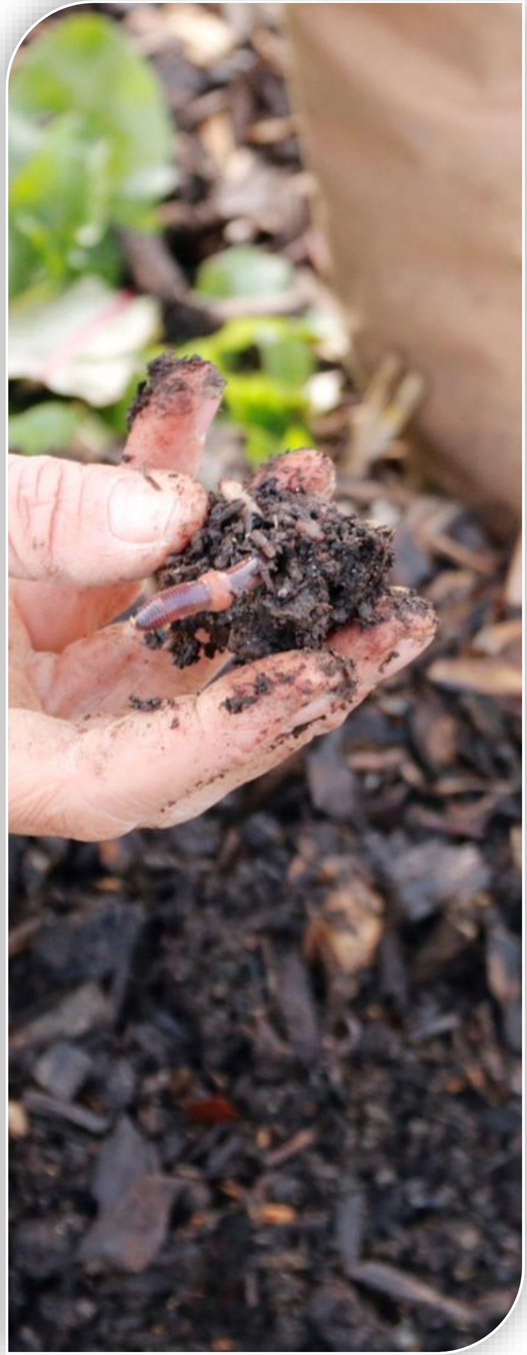




The Four Ecosystem Processes

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

Terrestrial Ecology 101; Savory and Butterfield 2016; Massy 2018

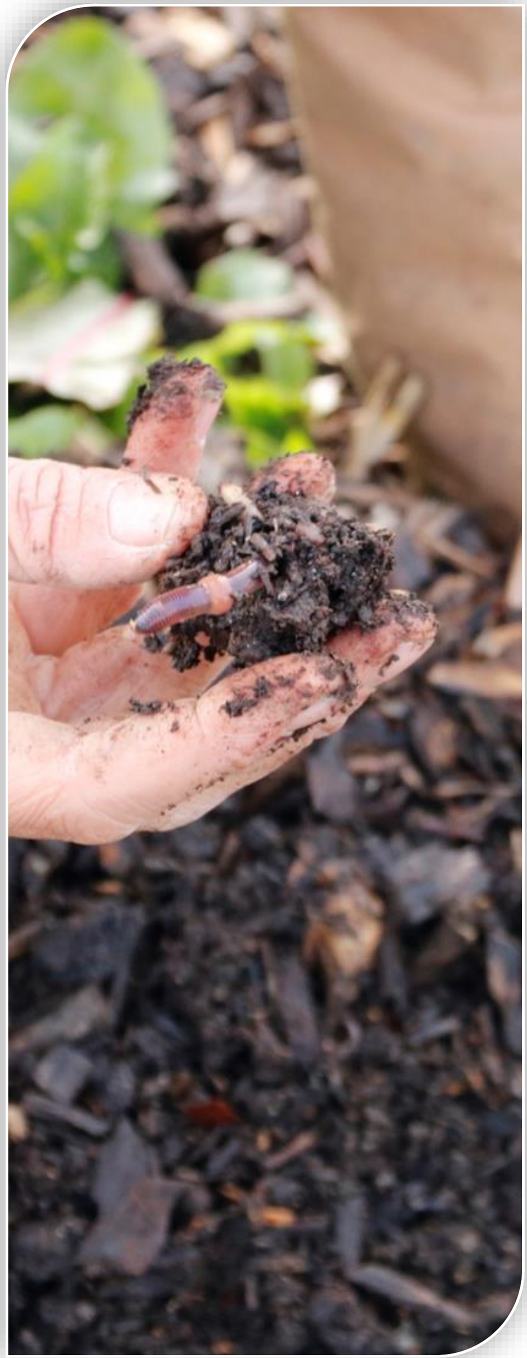


90% of Soil function is mediated by microbes

Microbes depend on plants

So how we manage plants is critical

Ingham 2000; Jones 2016; Lehman et al. 2016

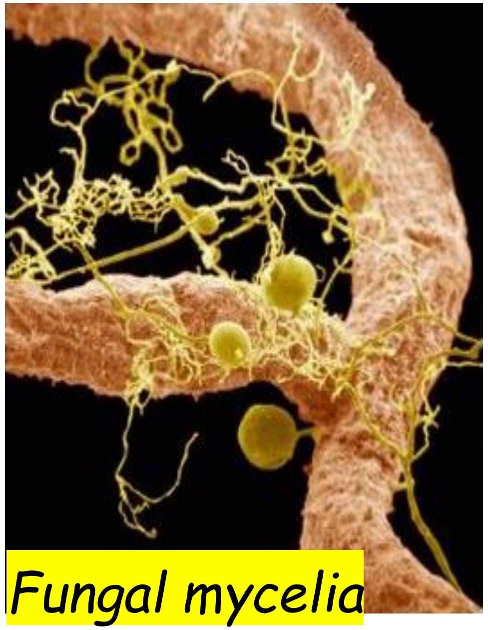


Importance of Microbes and Fungi

- 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

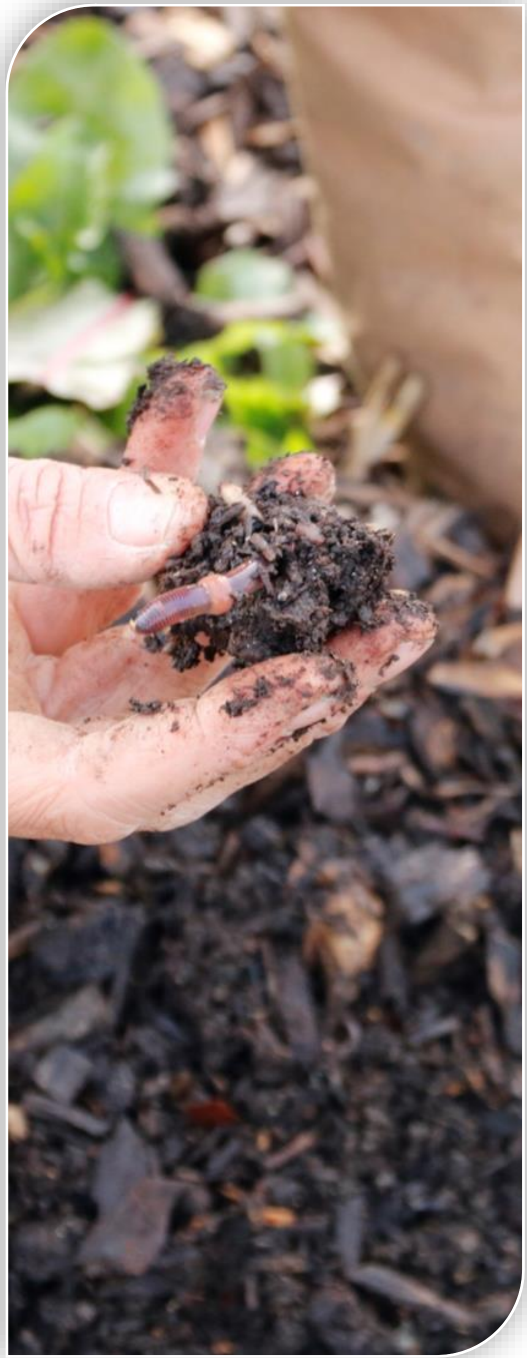
Ingham et al. 1985; Jones 2016; Lehman et al. 2016; Montgomery 2017

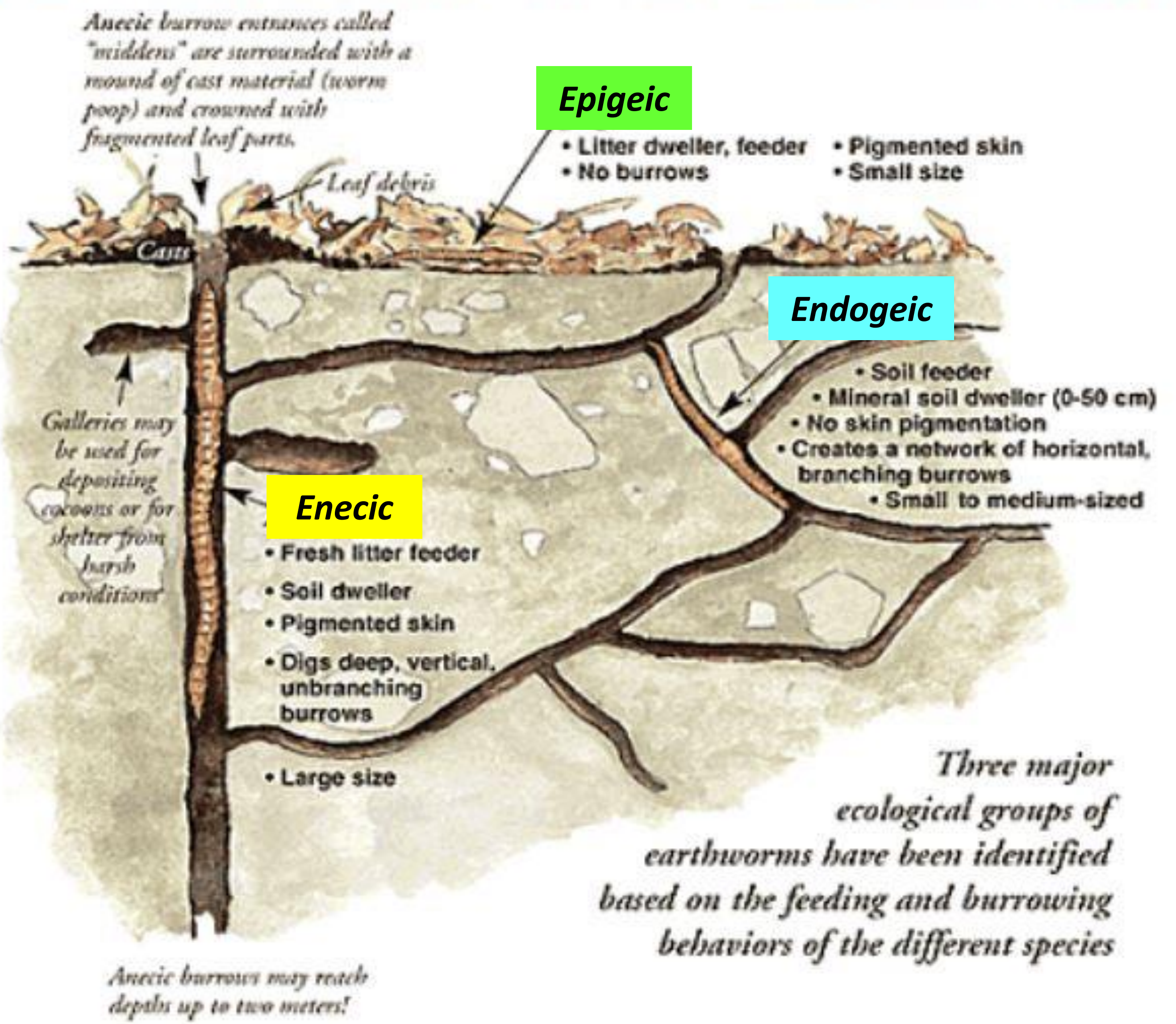


Fungal mycelia

Bacterial rhizobia

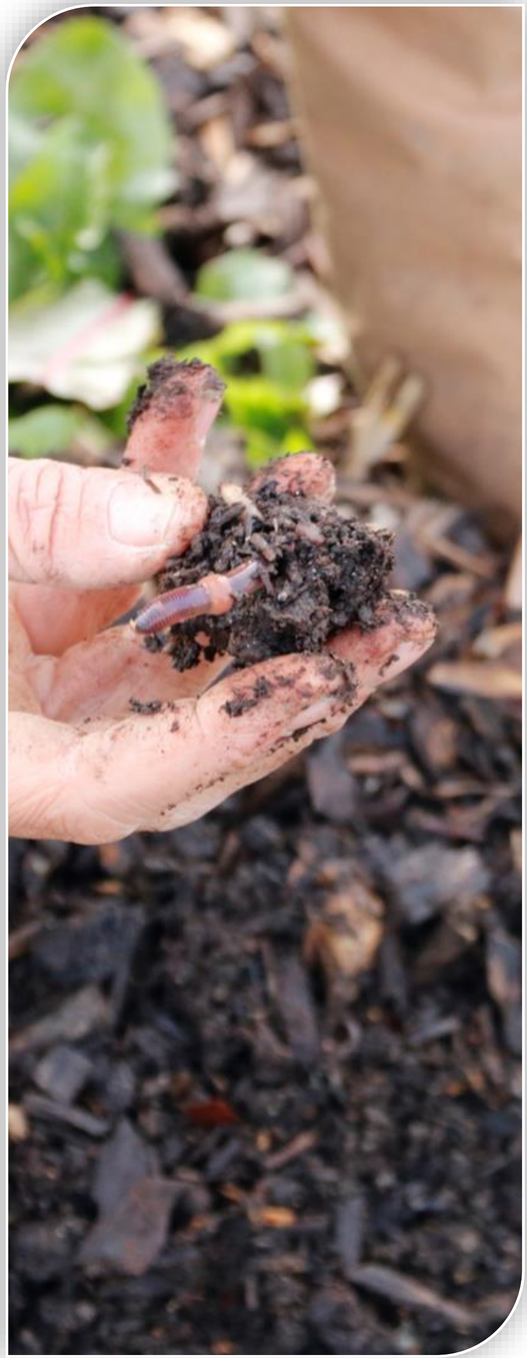
Earthworms in the ecosystem

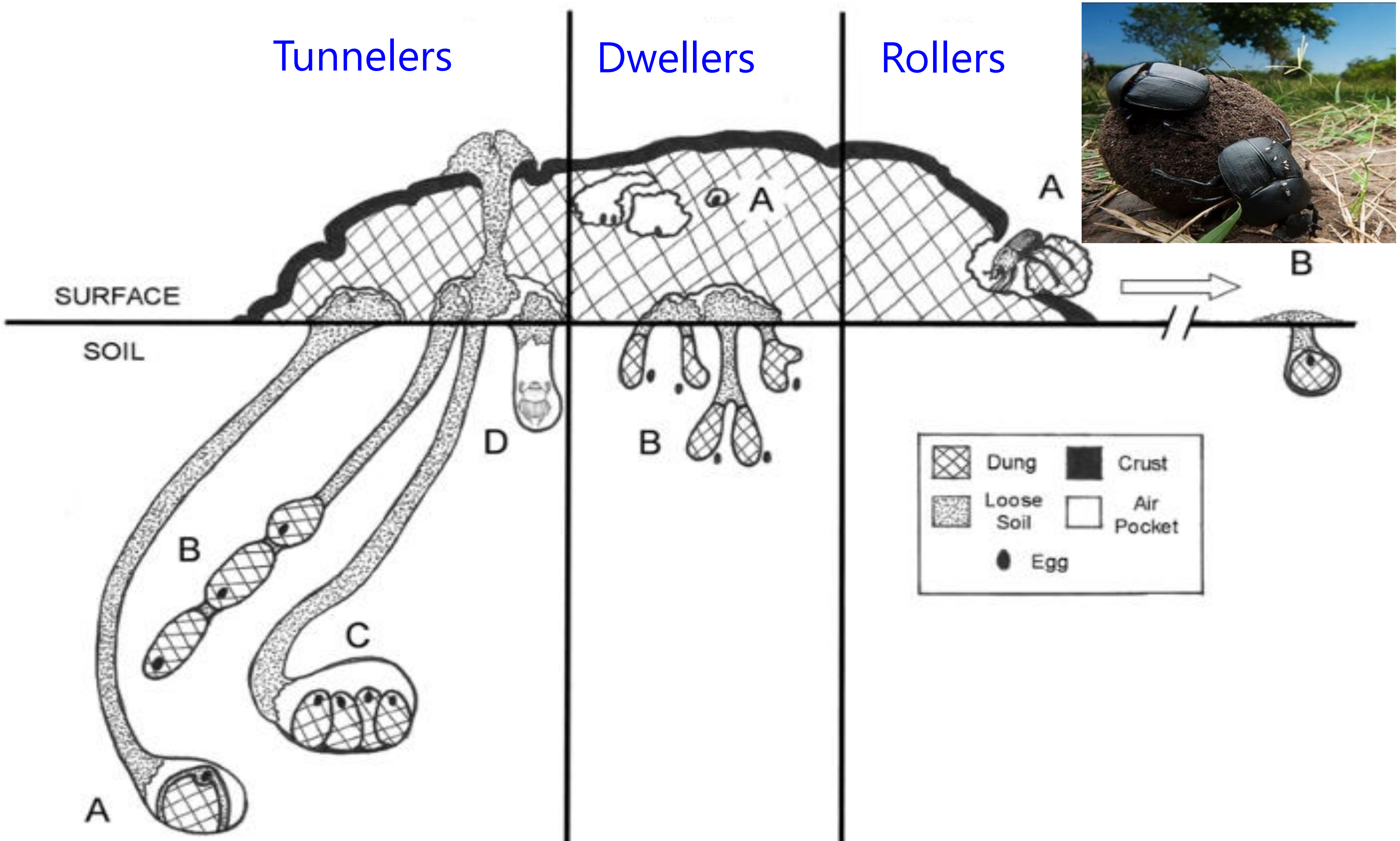




Wardle & Bardgett 2004; Blouin *et al.* 2013

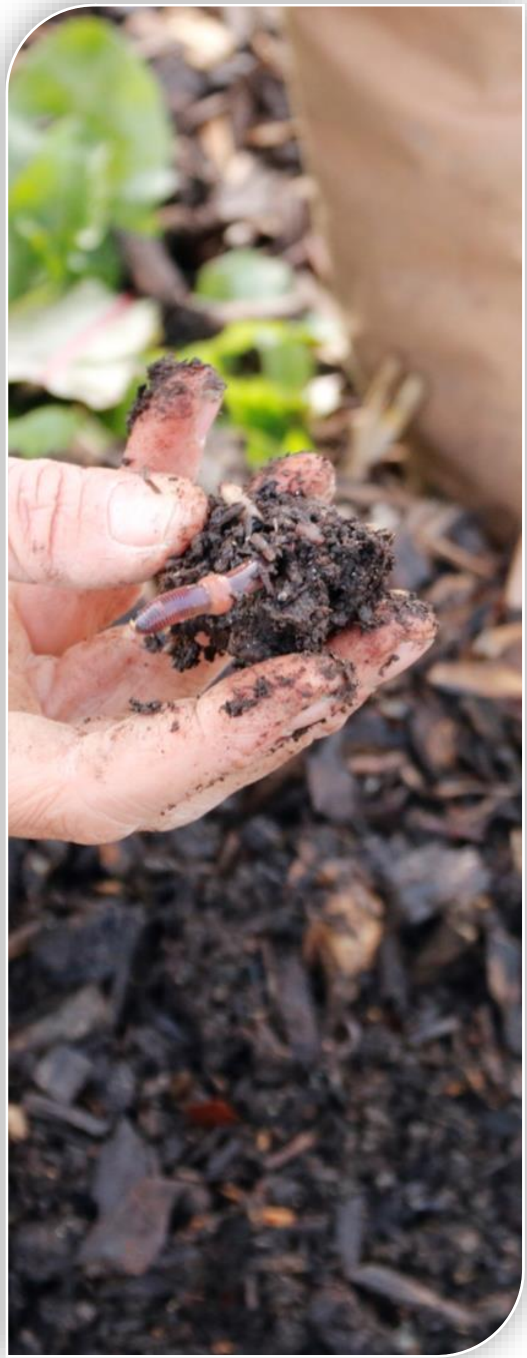
Dung beetles in the Ecosystem



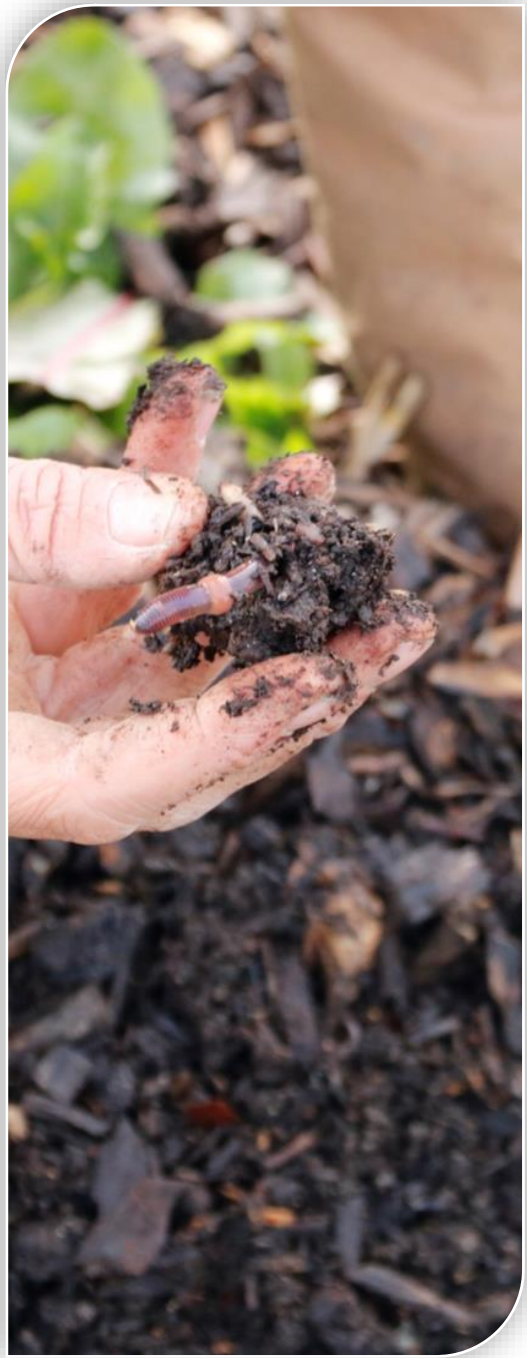


- 200 cows drop 25 tons of dung a week
- Increase infiltration ~ 130%

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

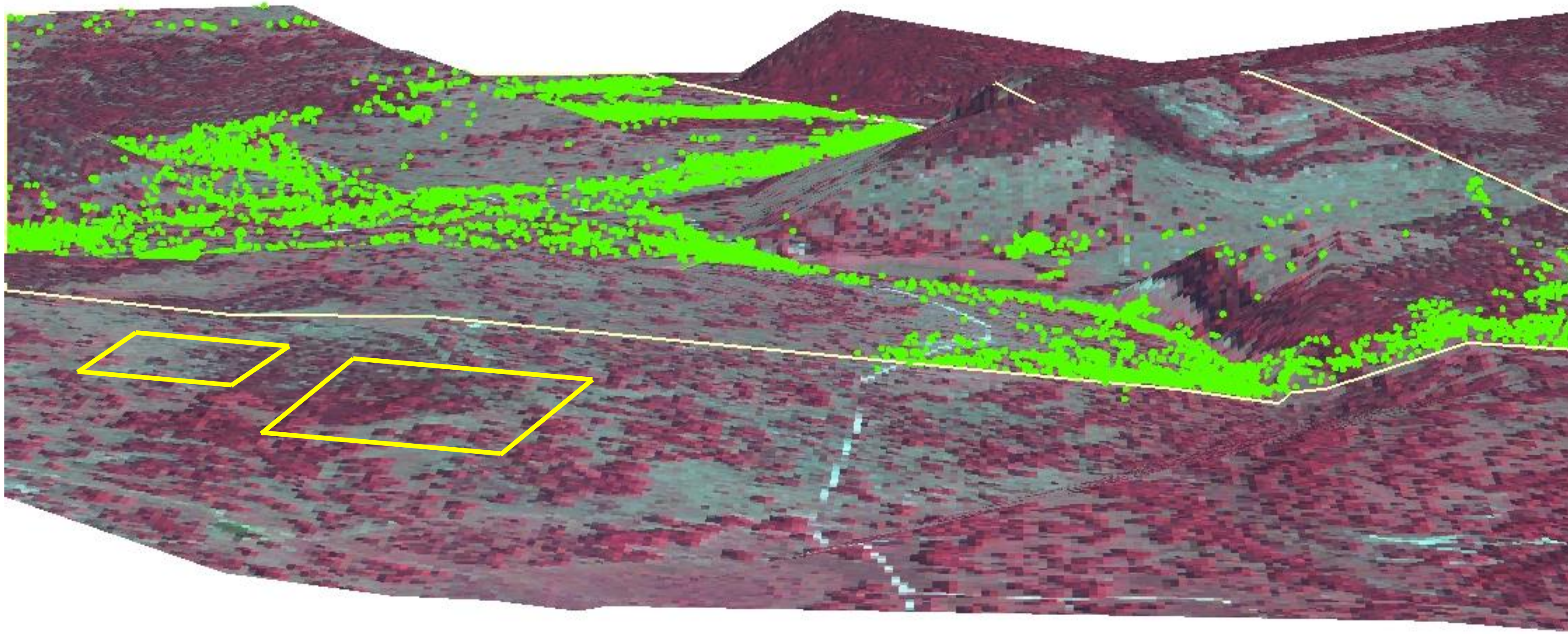


Research Results

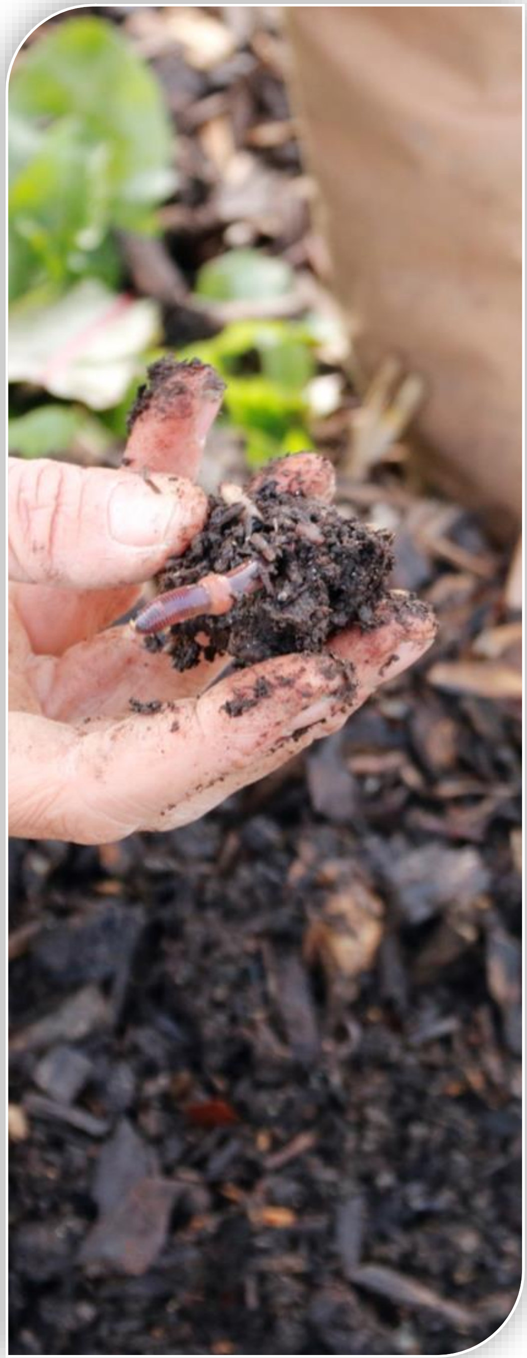


Landscape impact of continuous grazing

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

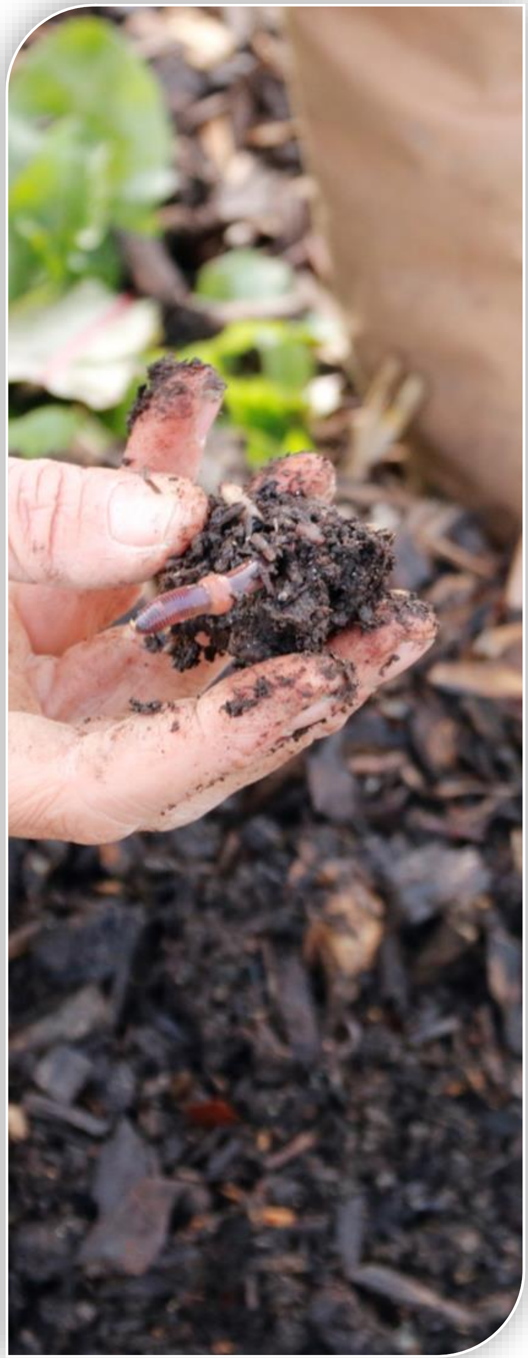


Norton 1998; Norton et al. 2013; Jakoby et al. 2014



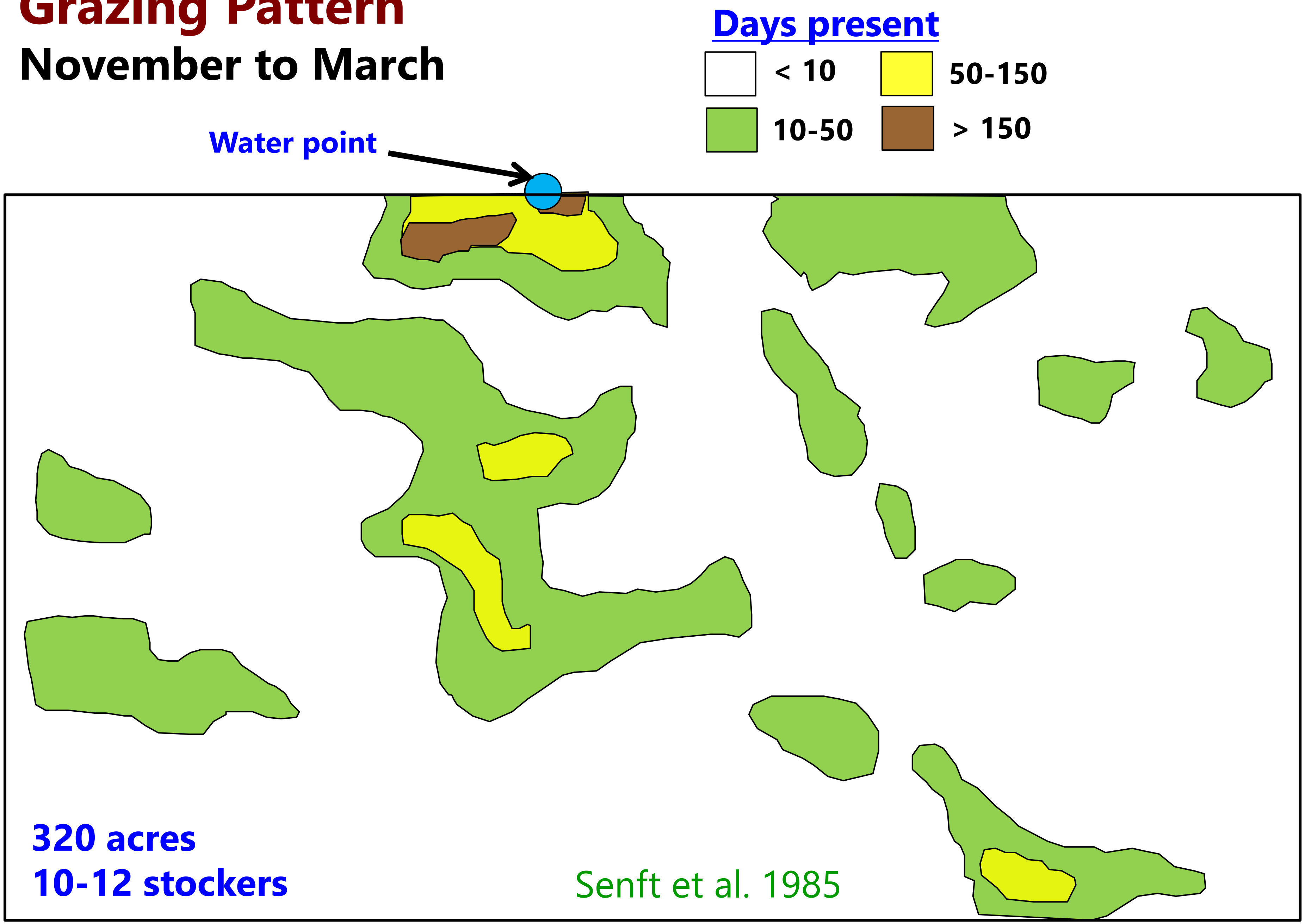

Light continuous grazing
•patch selection
•no recovery


Heavy continuous grazing

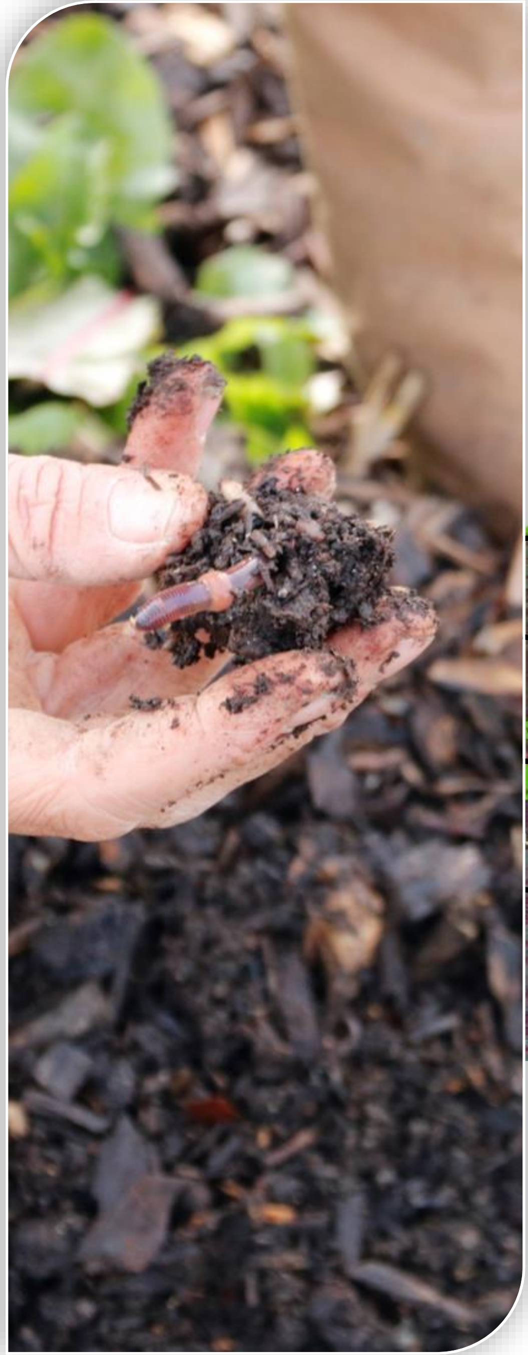


Grazing Pattern

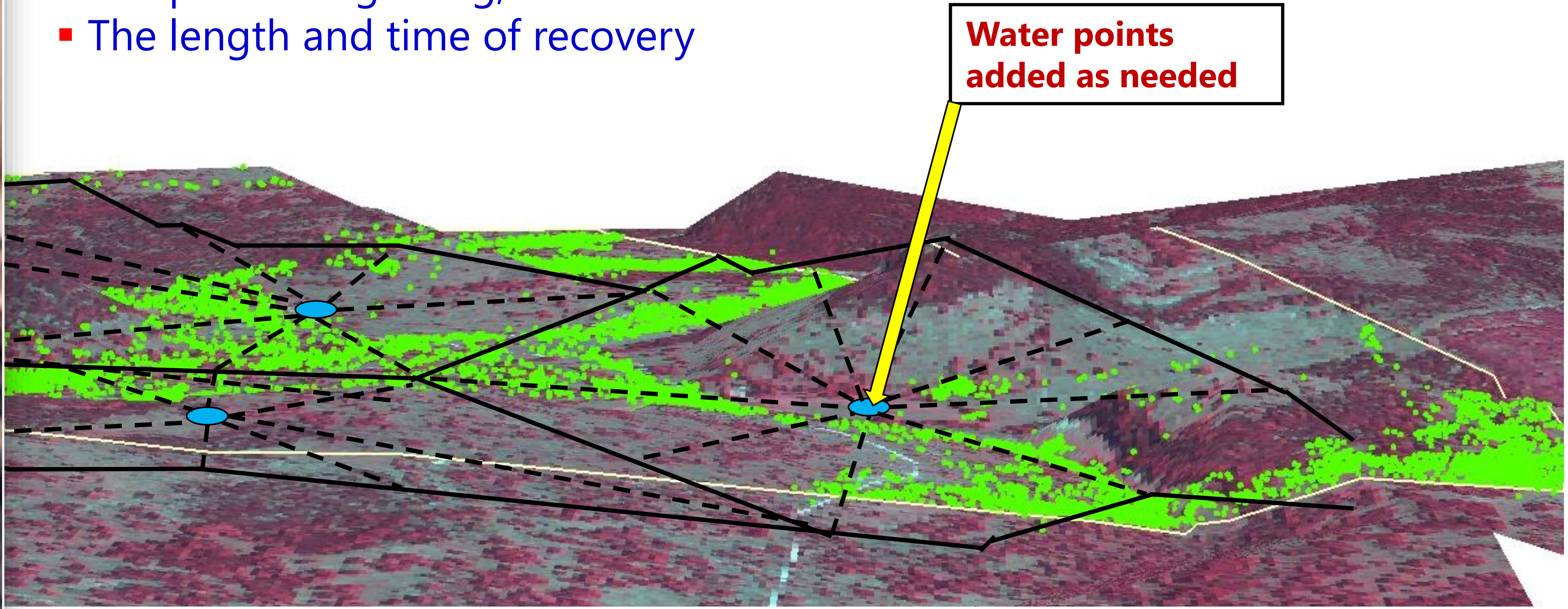
November to March



Adaptive Multi-Paddock (AMP) grazing



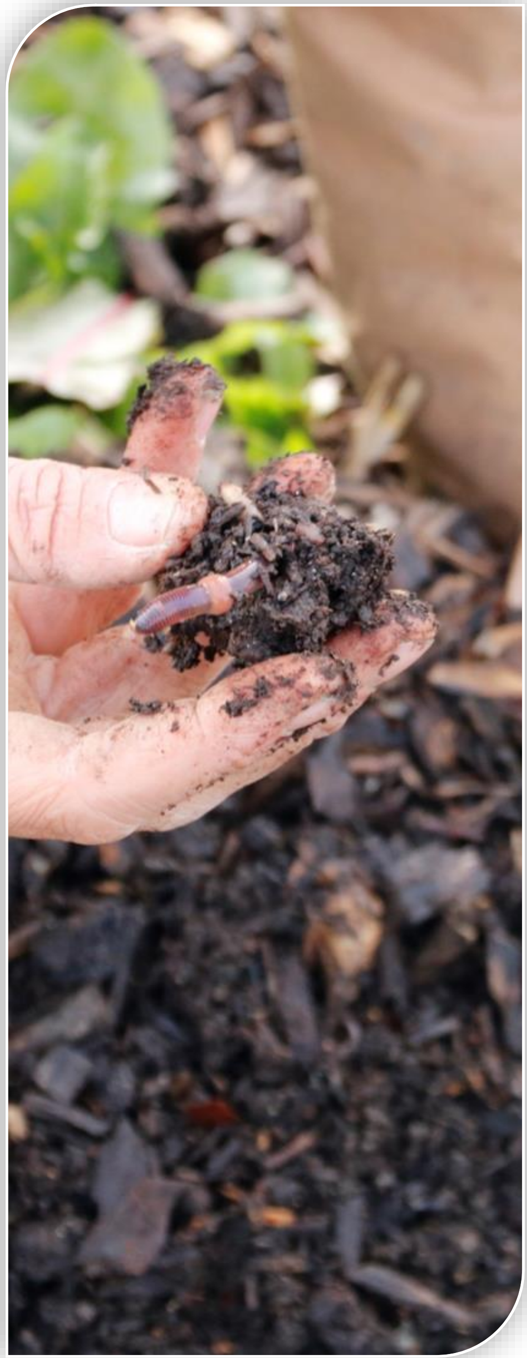
Manager can control:
- How much is grazed
- The period of grazing, and
- The length and time of recovery

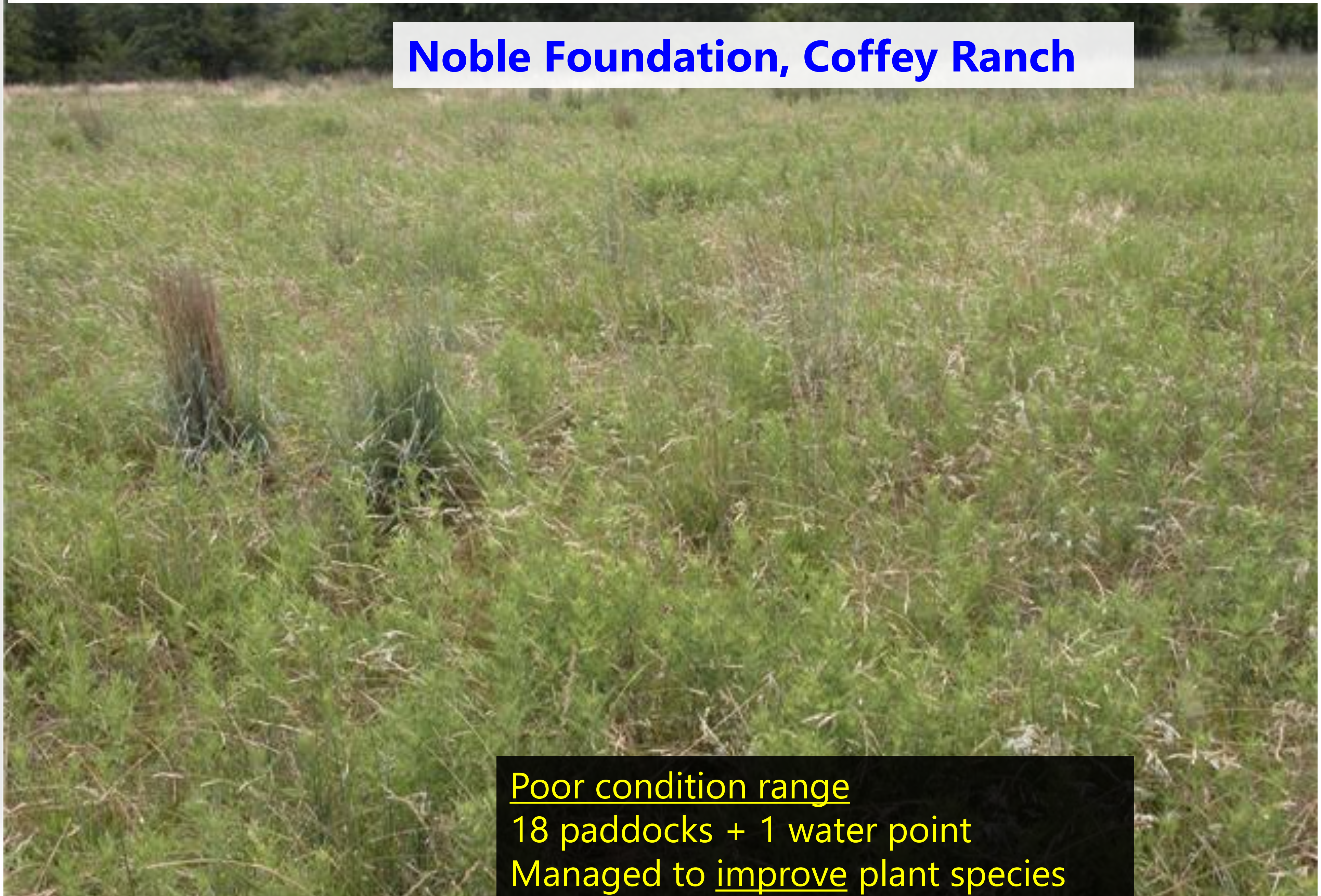


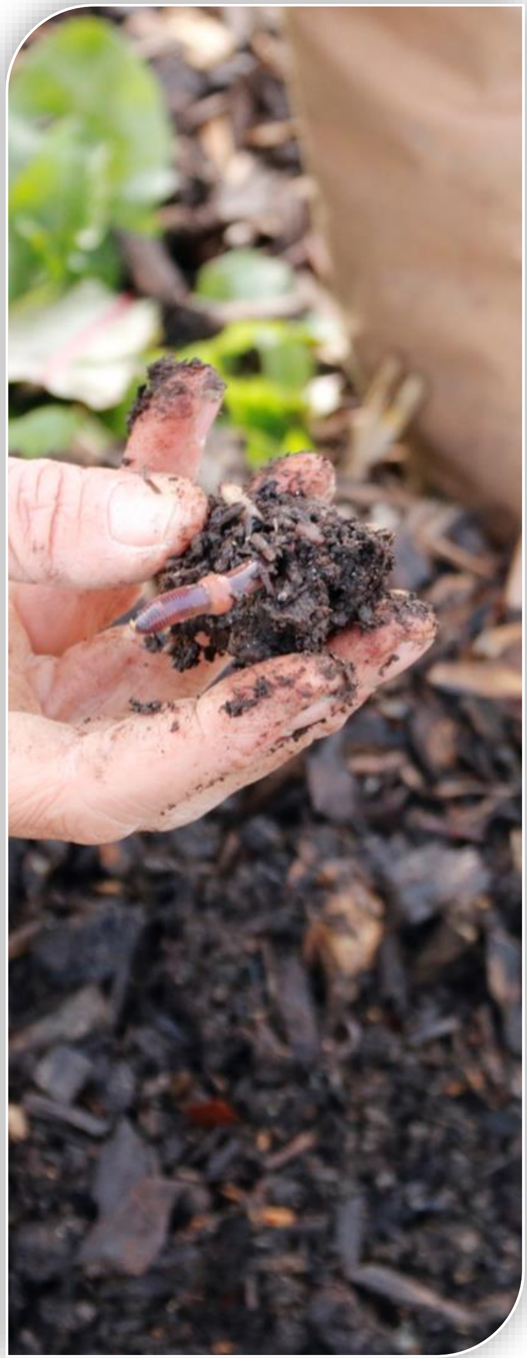
Animals:
- Graze more of the whole landscape, one paddock at a time
- Select a wider variety of plant species

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

Regenerative Grazing



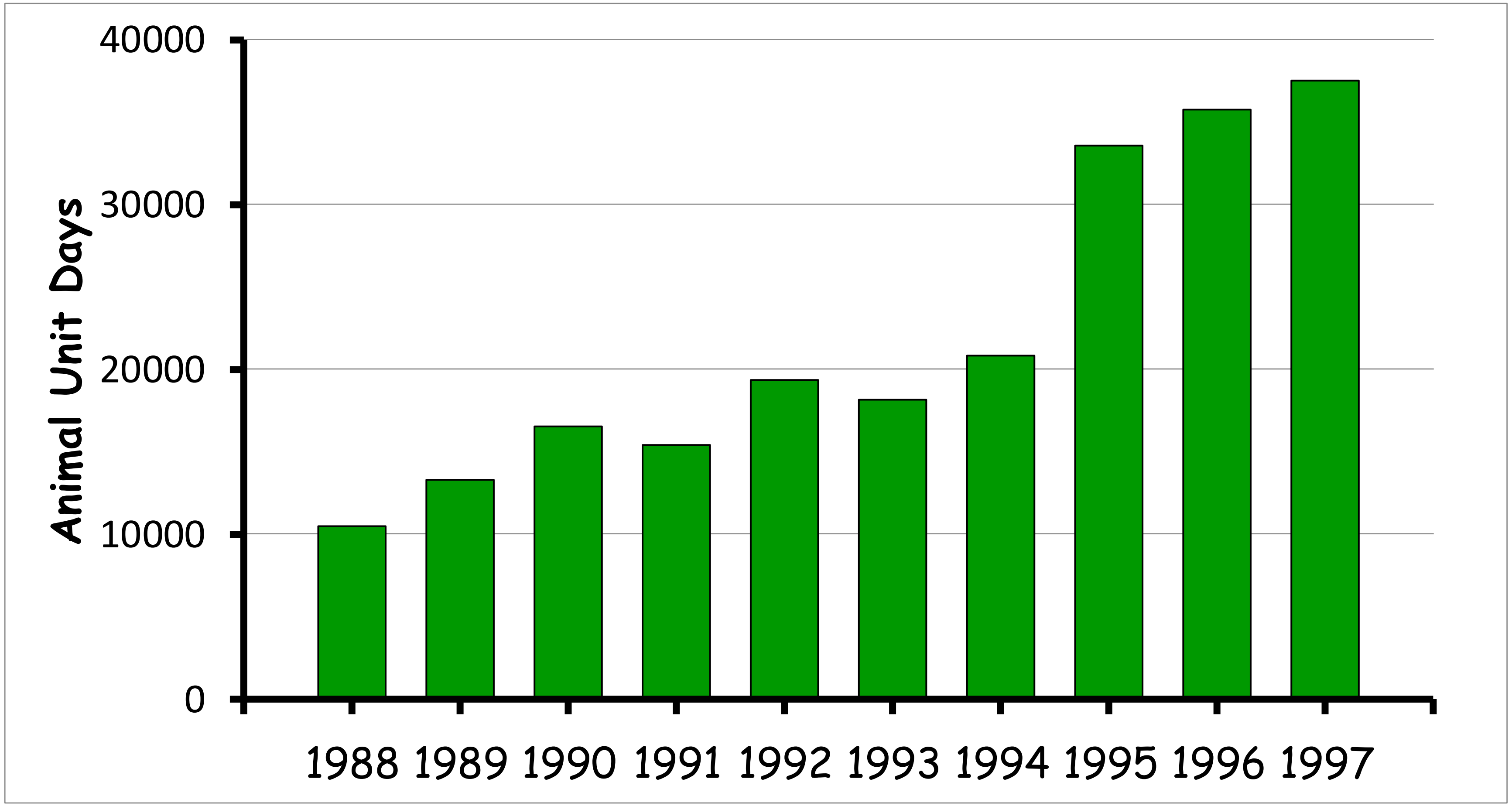


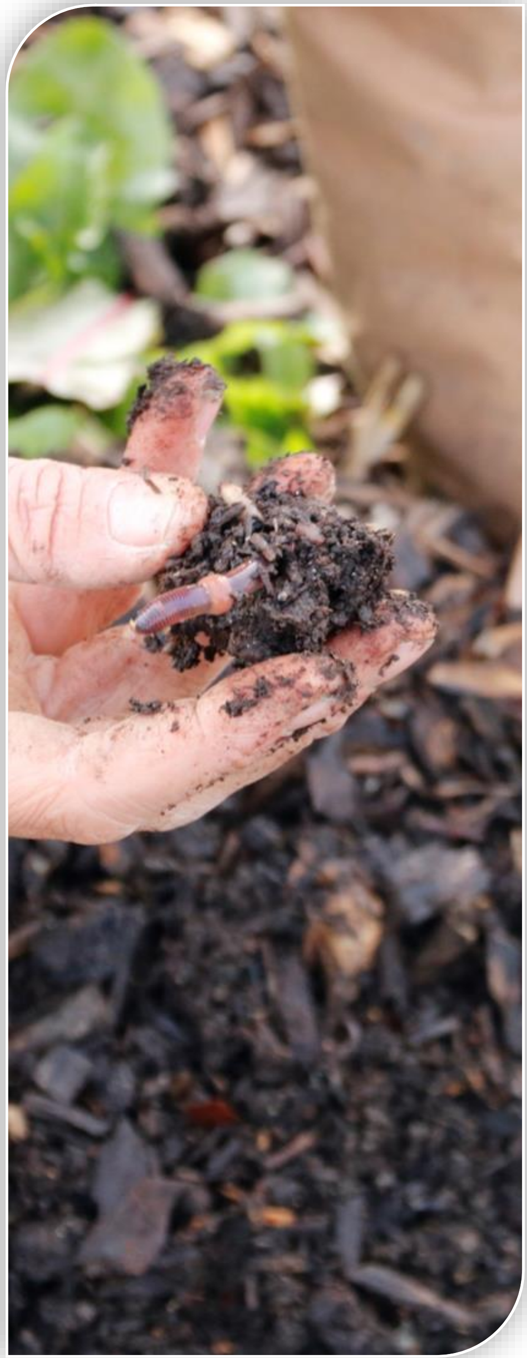


Regenerative Grazing

Noble Foundation, Coffey Ranch

Charles Griffith, Hugh Aljoe, Russell Stevens

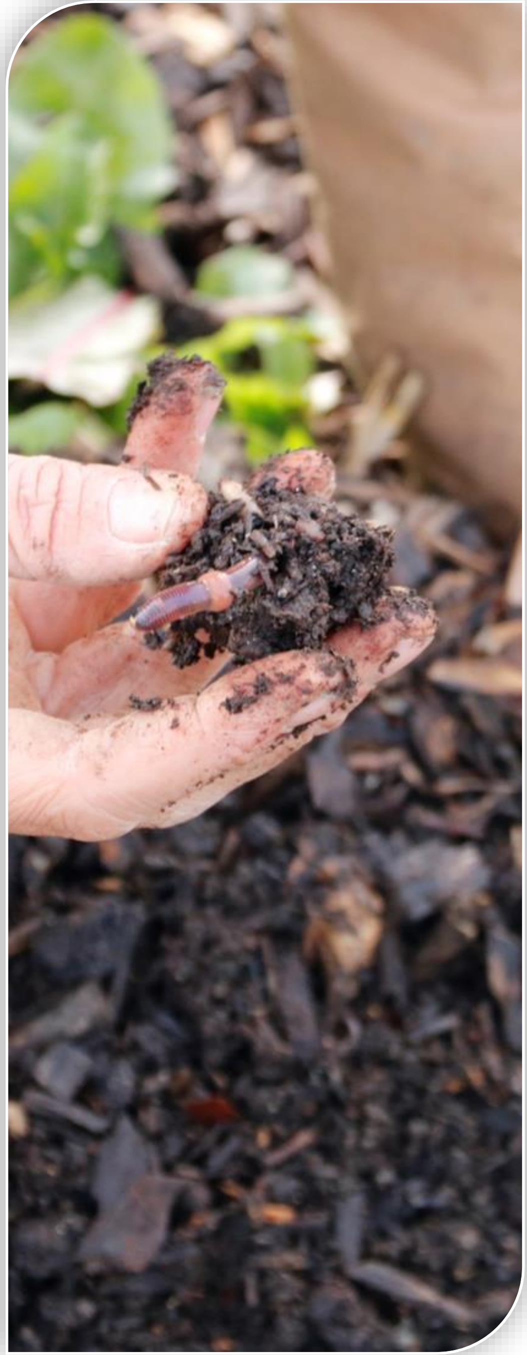




Managing AMP Grazing for Best Results

- 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

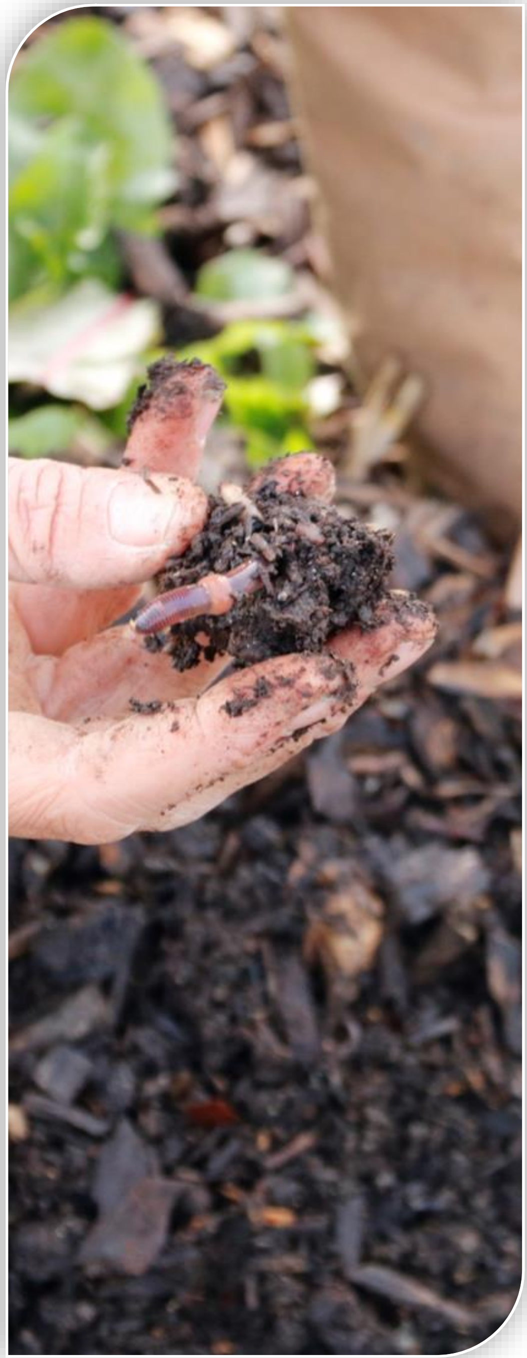
Light continuous grazing

No-grazing

Continuous grazing

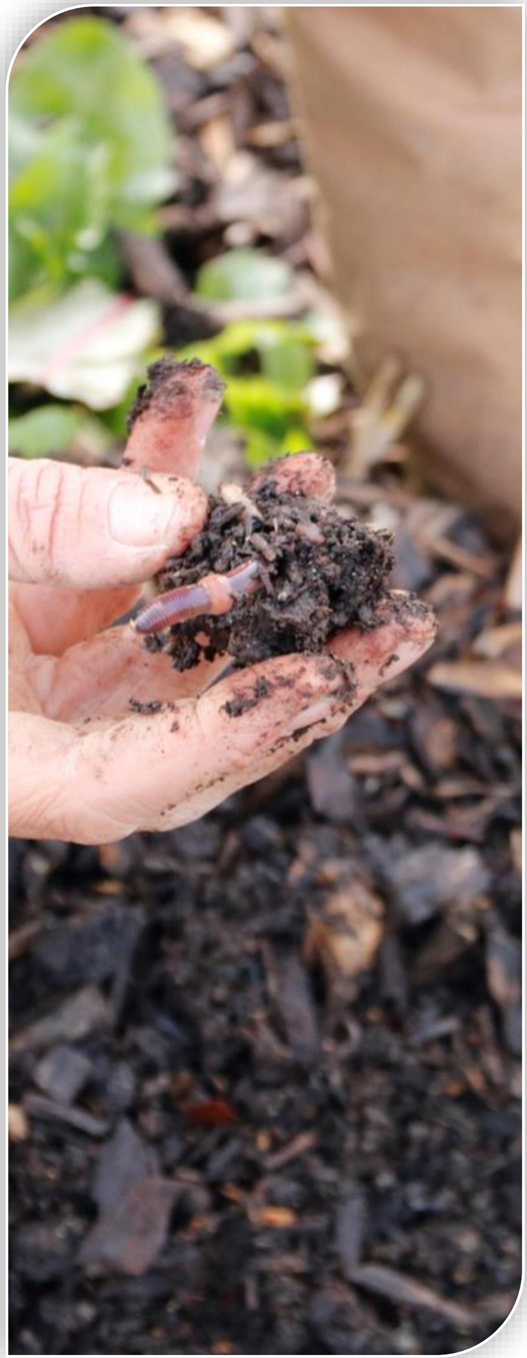
Energy Flow
Water Cycle
Mineral Cycle
Soil/Plant Diversity

Savory and Butterfield 2016; Massy 2018



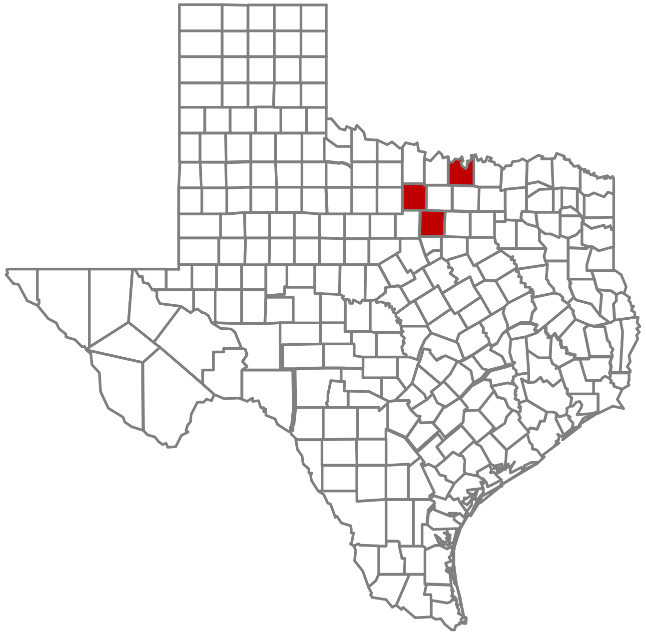
How grazing strategy impacts ecological processes

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

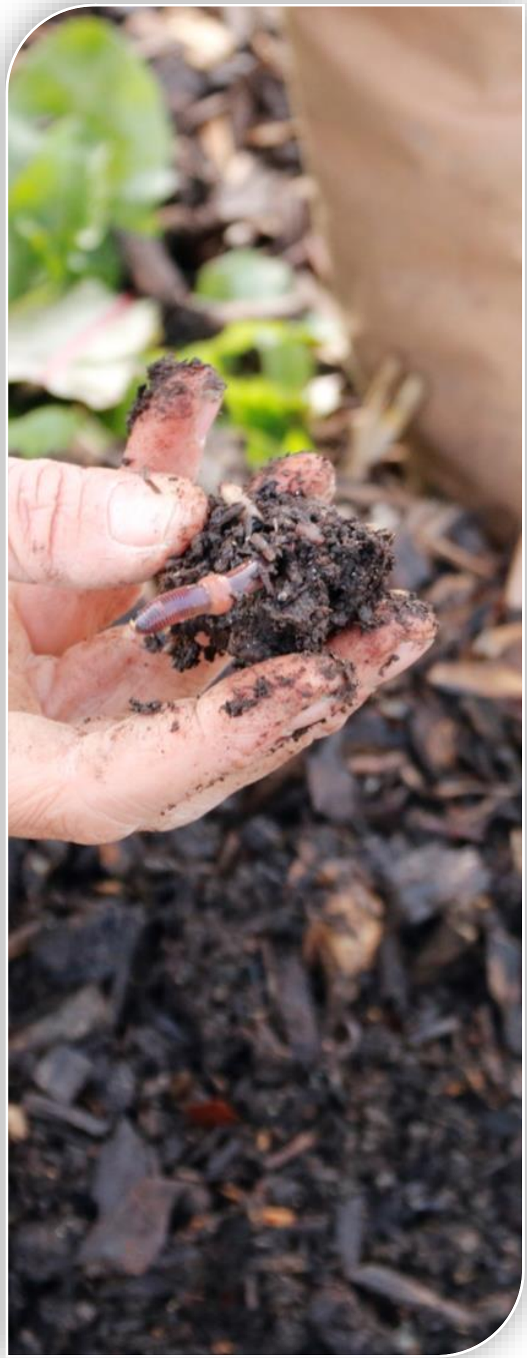


Initial Texas Grazing Research

- 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

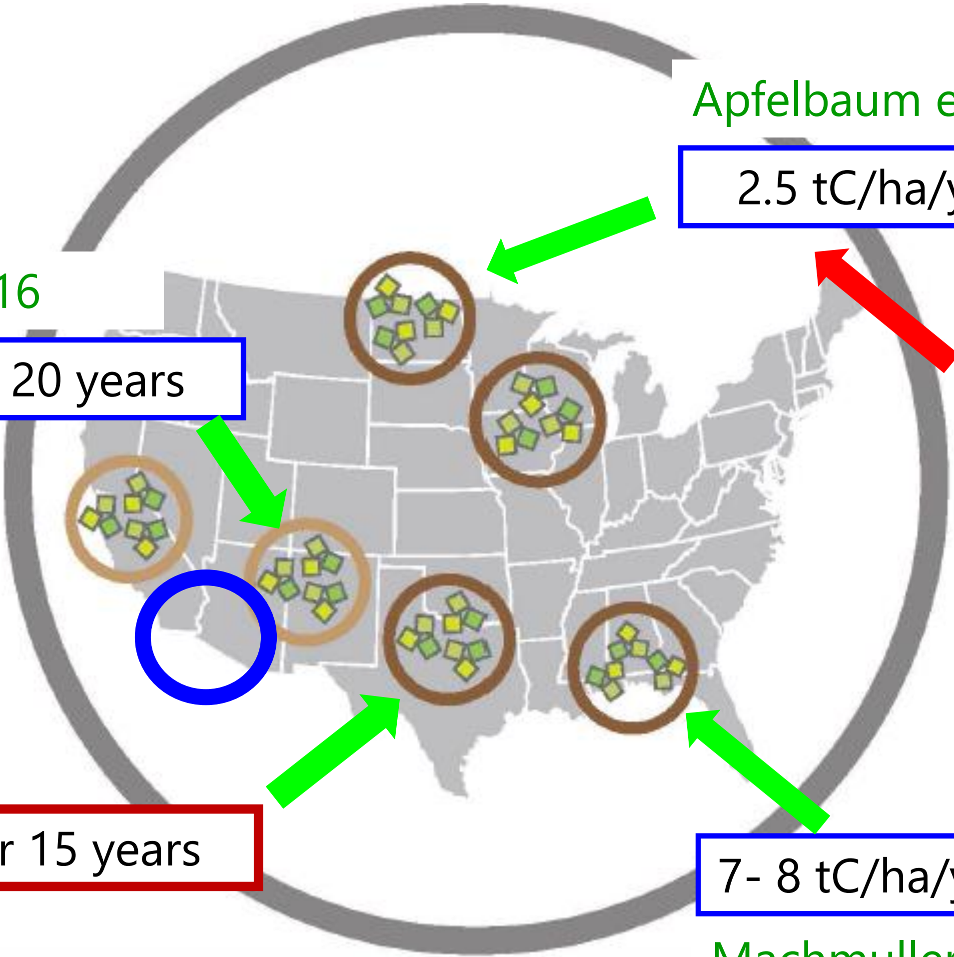


Teague et al. 2011



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

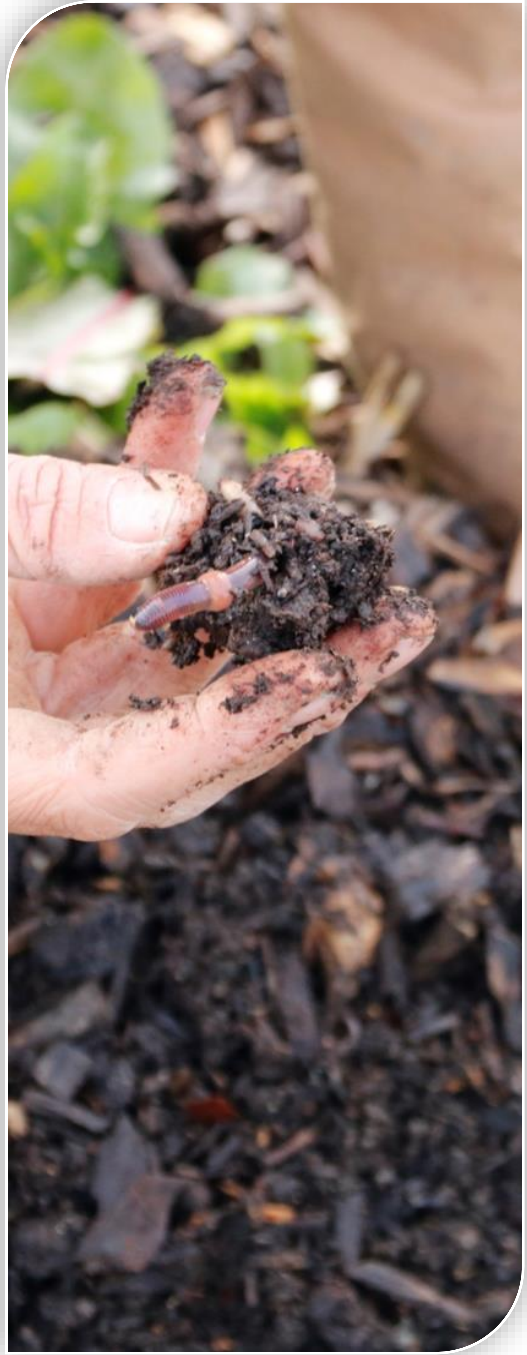
CO_2 Isotope Sampling
3.0 tC/Ha/yr

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

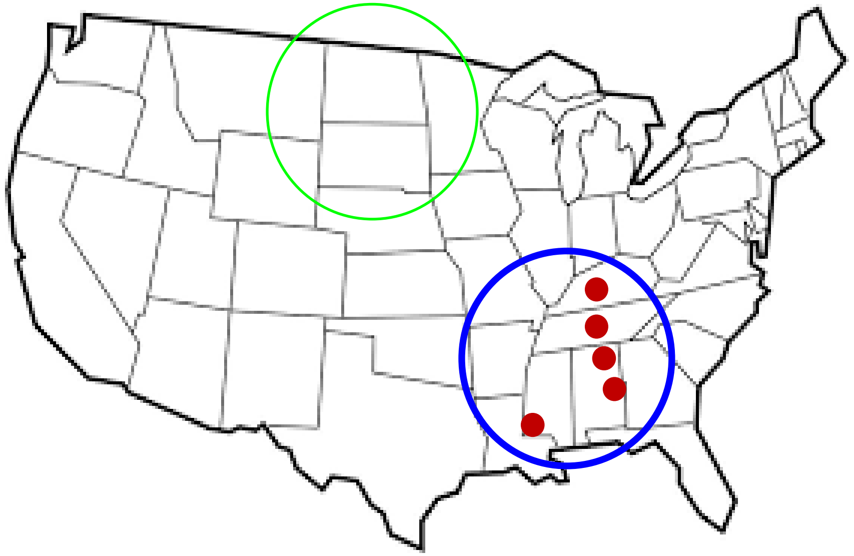
Vegetation sampling

GHG Sampling

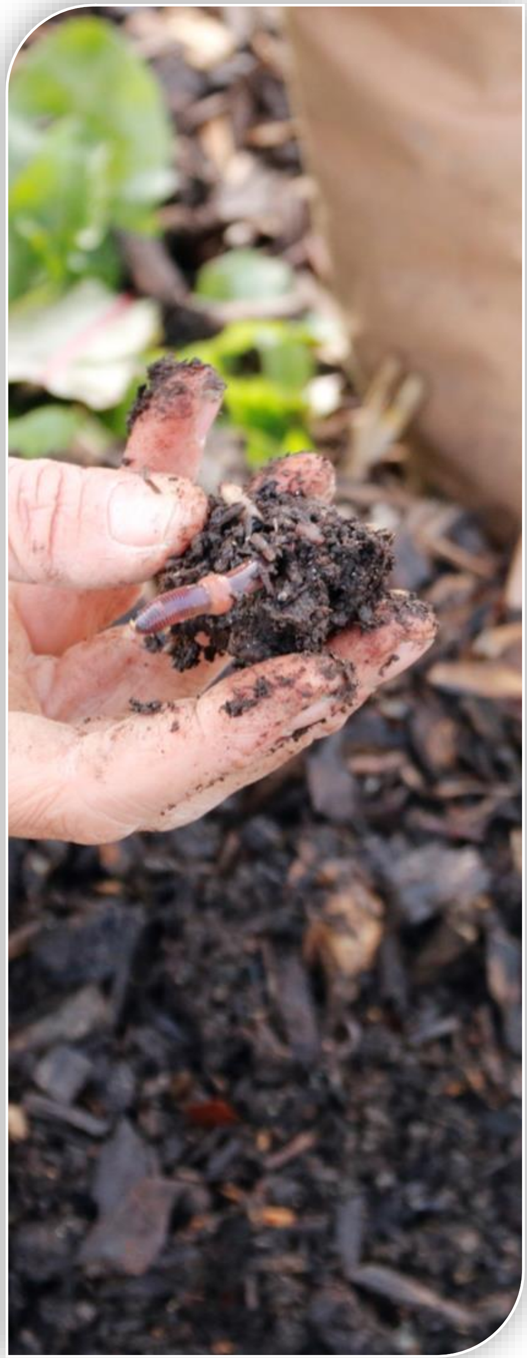
CO_2 fluxes

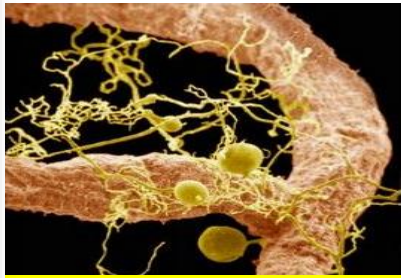
Microbiota DNA

CO_2 Isotope Fluxes



Soil and ecosystem biodiversity





Fungi

Bacteria

Earthworms

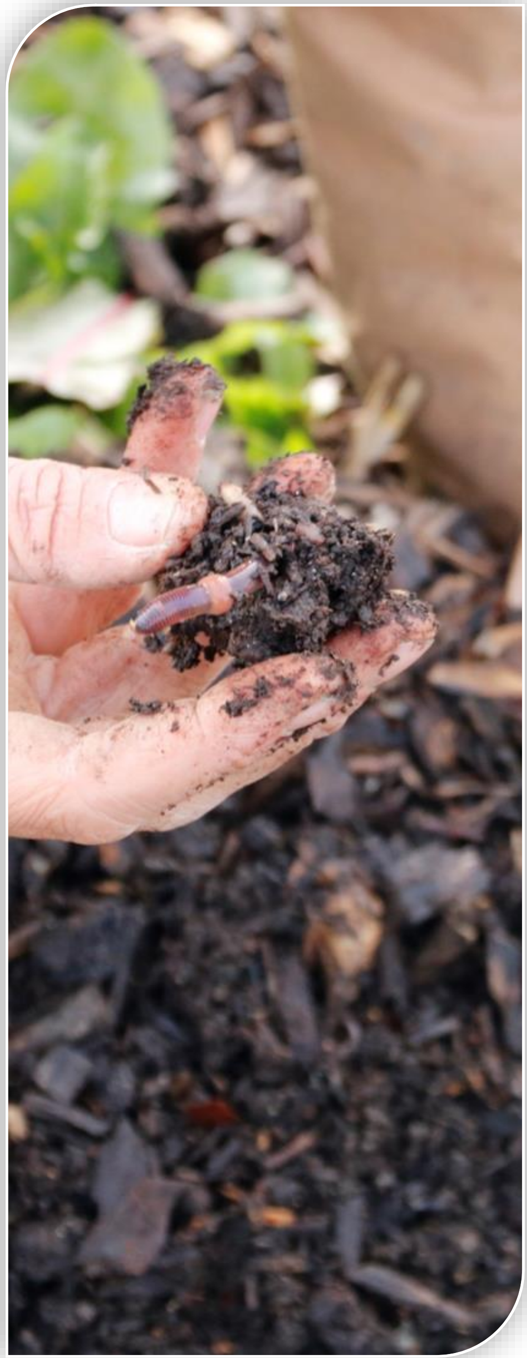
Does AMP grazing improve:

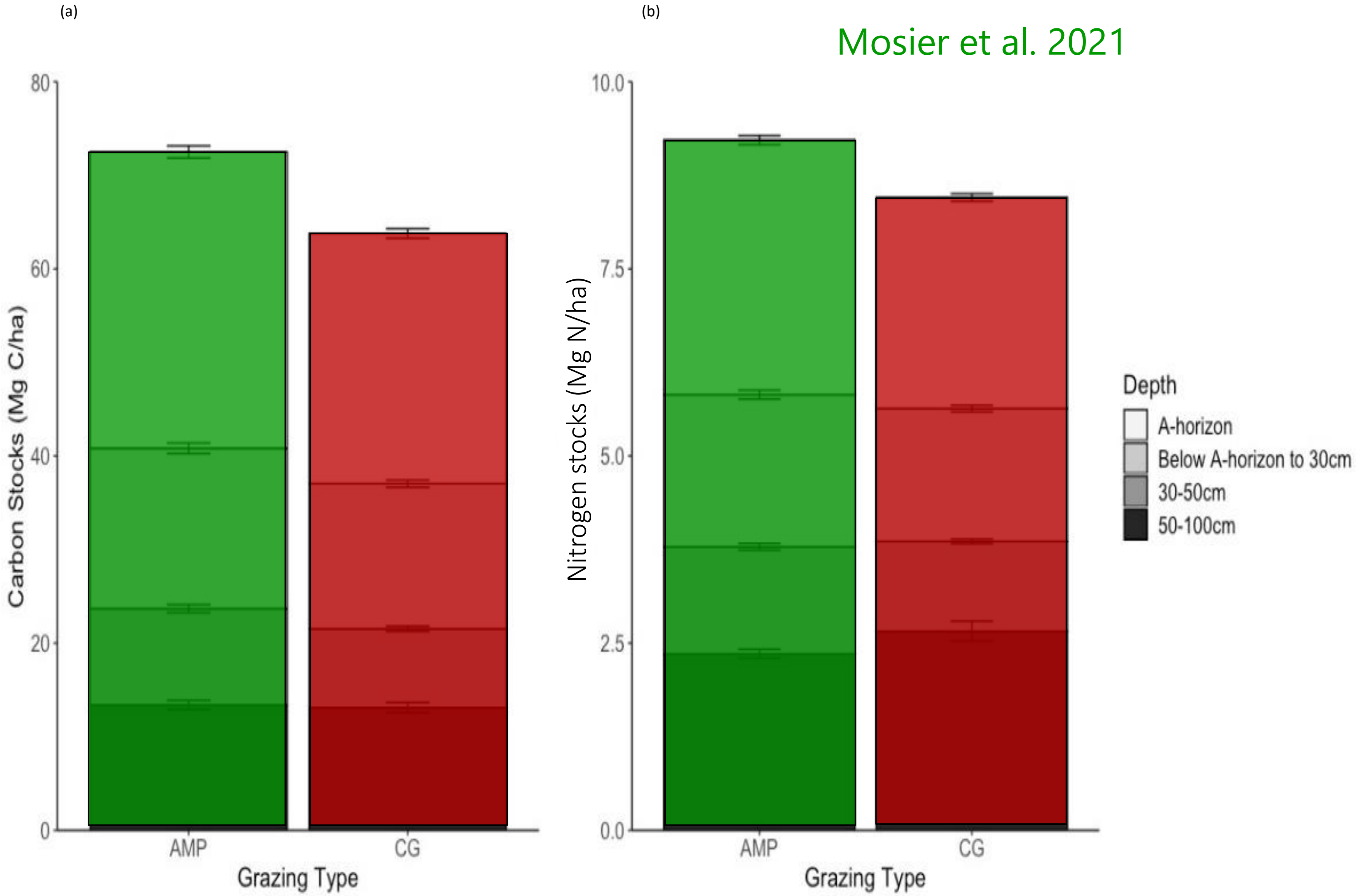
- function of soil biota;
- ecosystem biodiversity; and
- farmer livelihoods and well-being?

Dung beetles

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

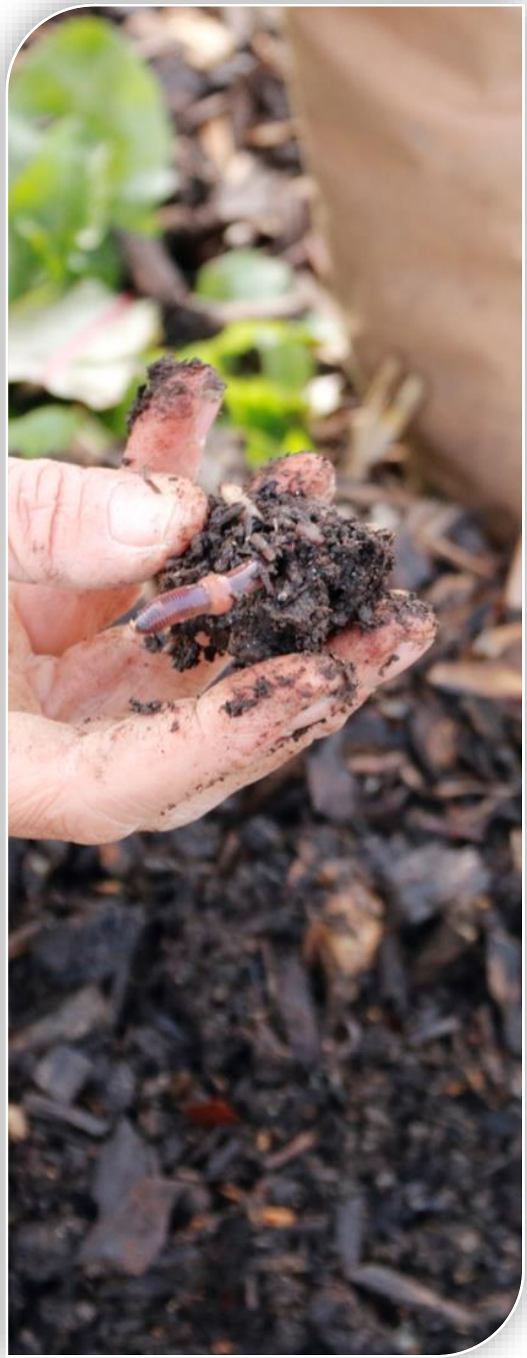
Total SOC and Soil N stocks to 1 meter





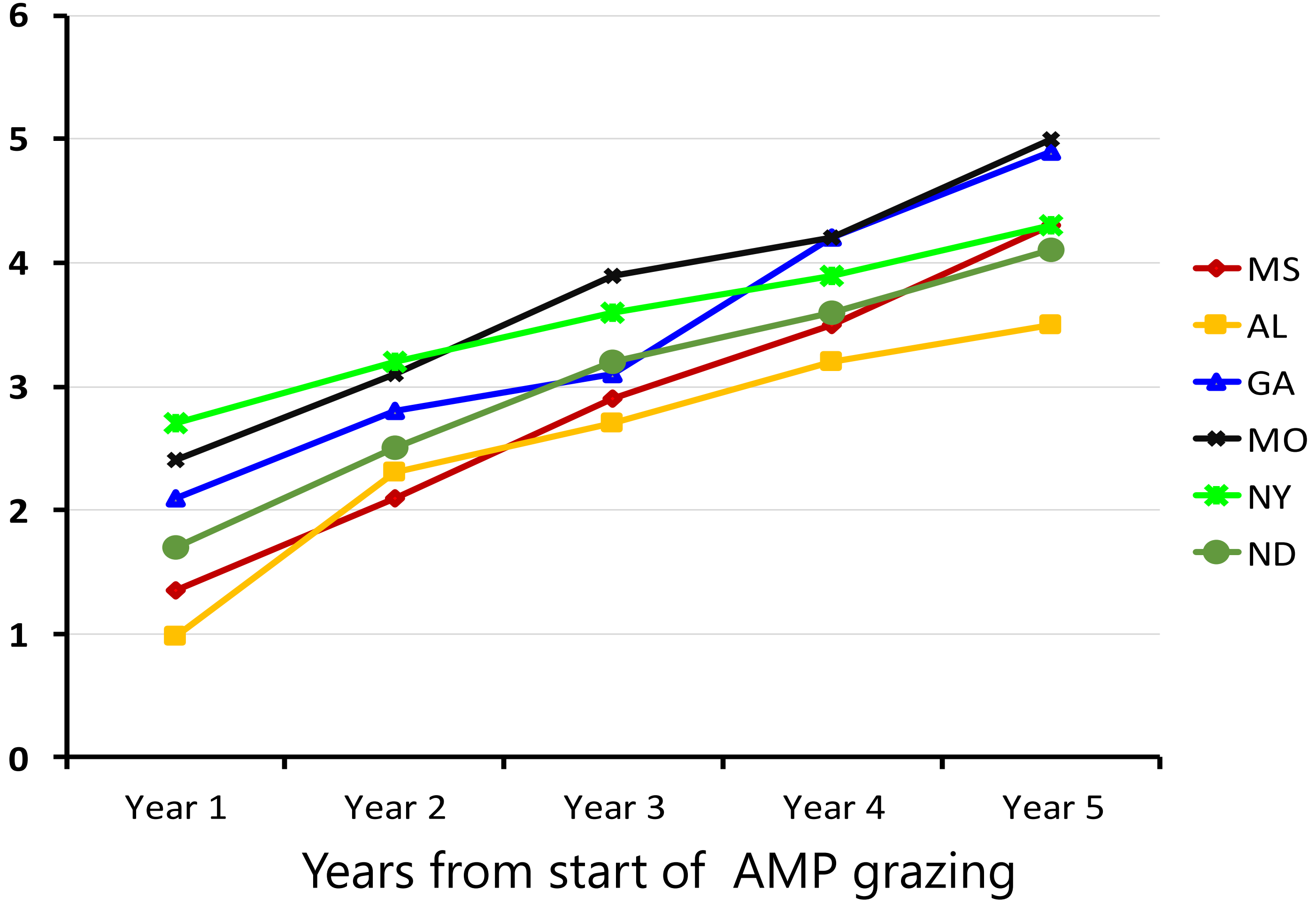
Mosier et al. 2021

AMP increased the more persistent MAOM fraction at all depths



Building Soil Carbon Using AMP Grazing

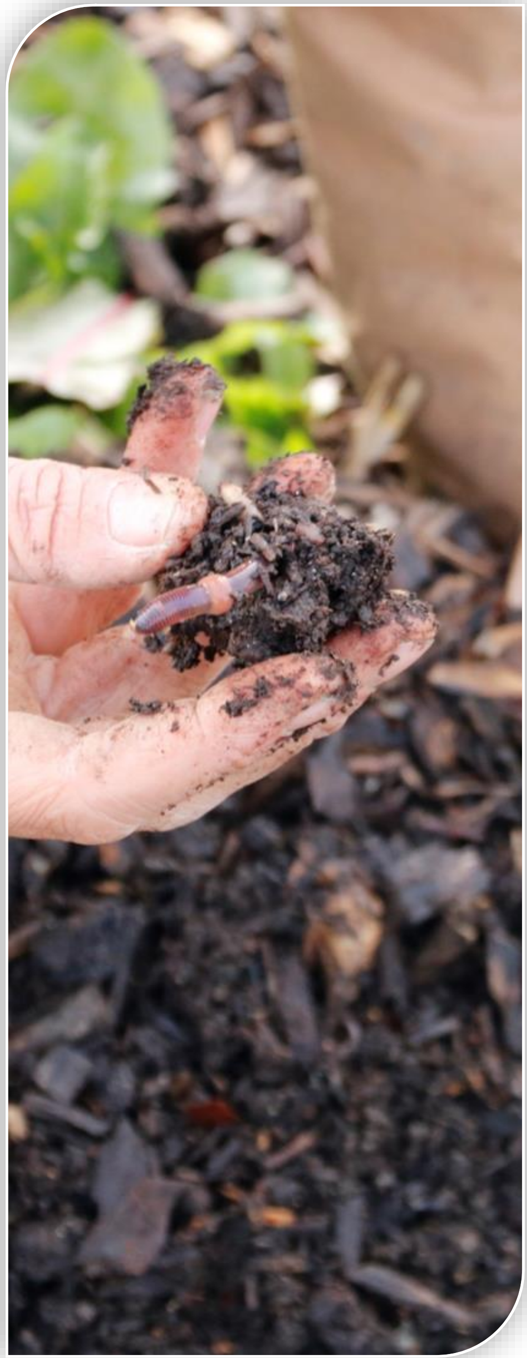
Measured to 200 mm

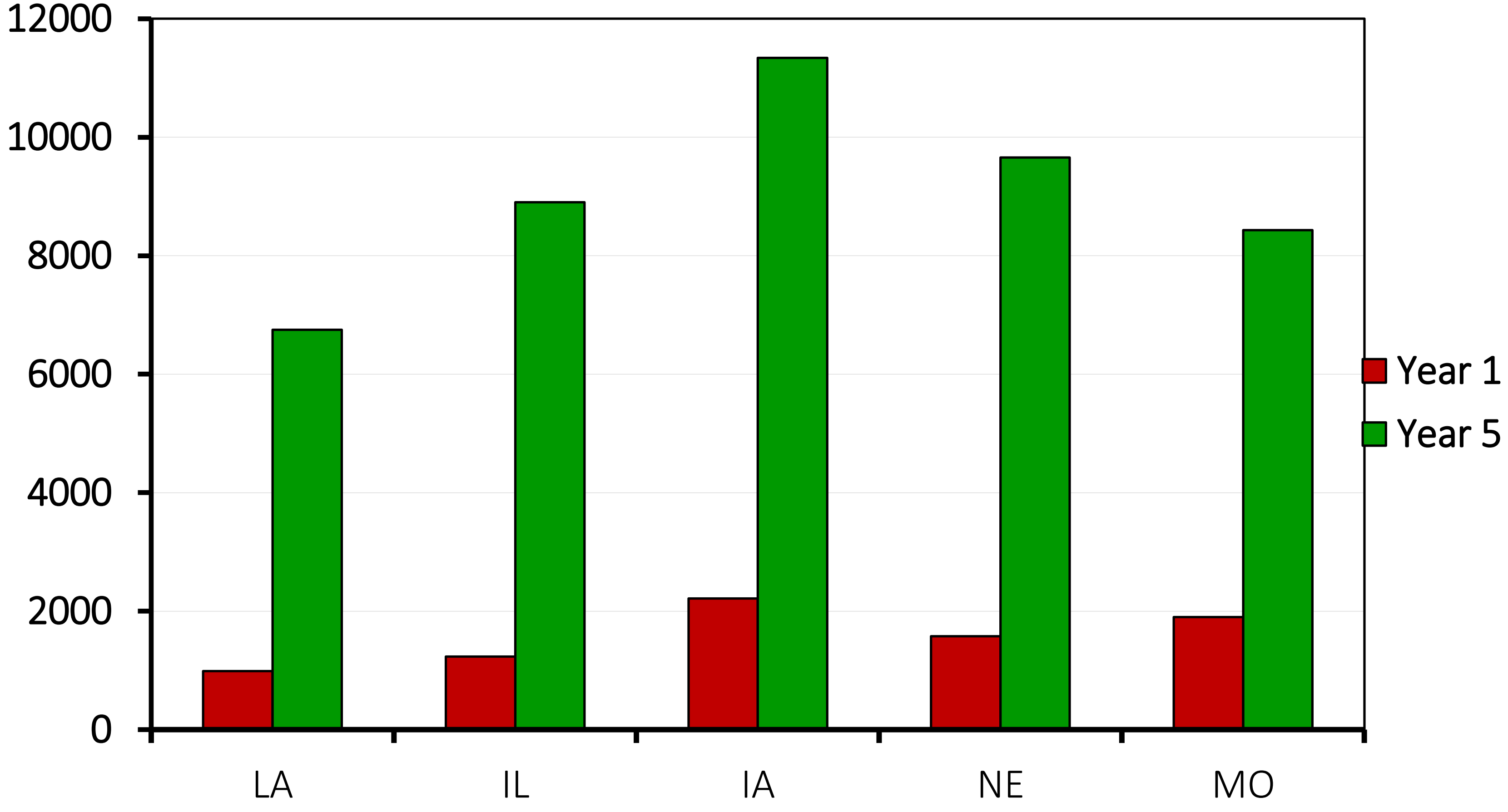


For 200 mm = mean ***increase*** of 8.6 tC ha^{-1} $year^{-1}$

Williams et al. 2017

Building Microbial Biomass (ng/g of Soil)

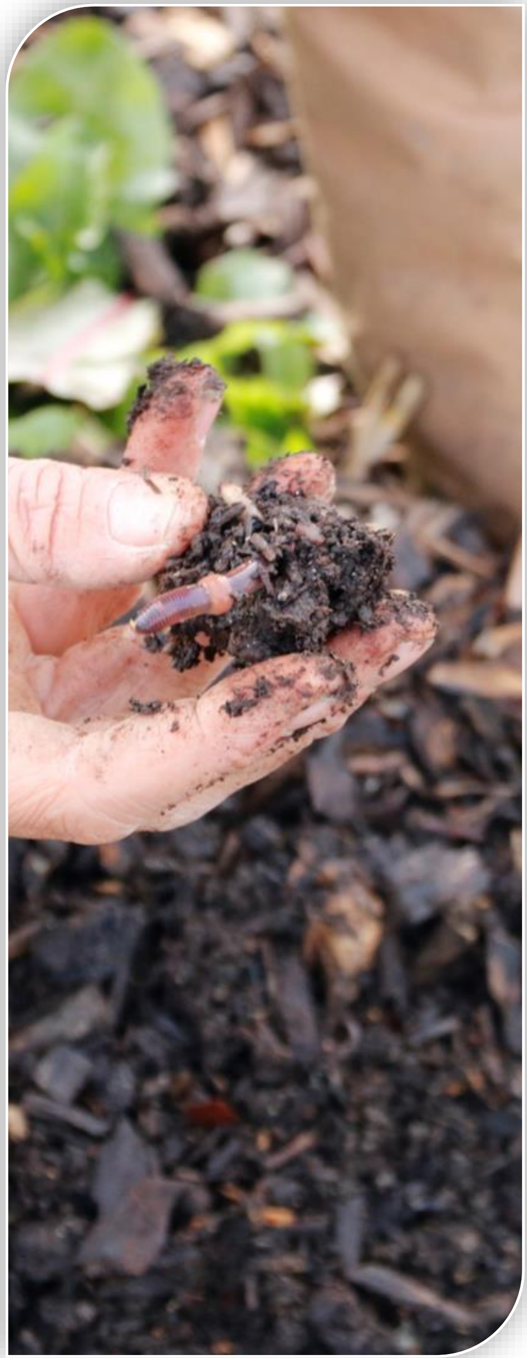


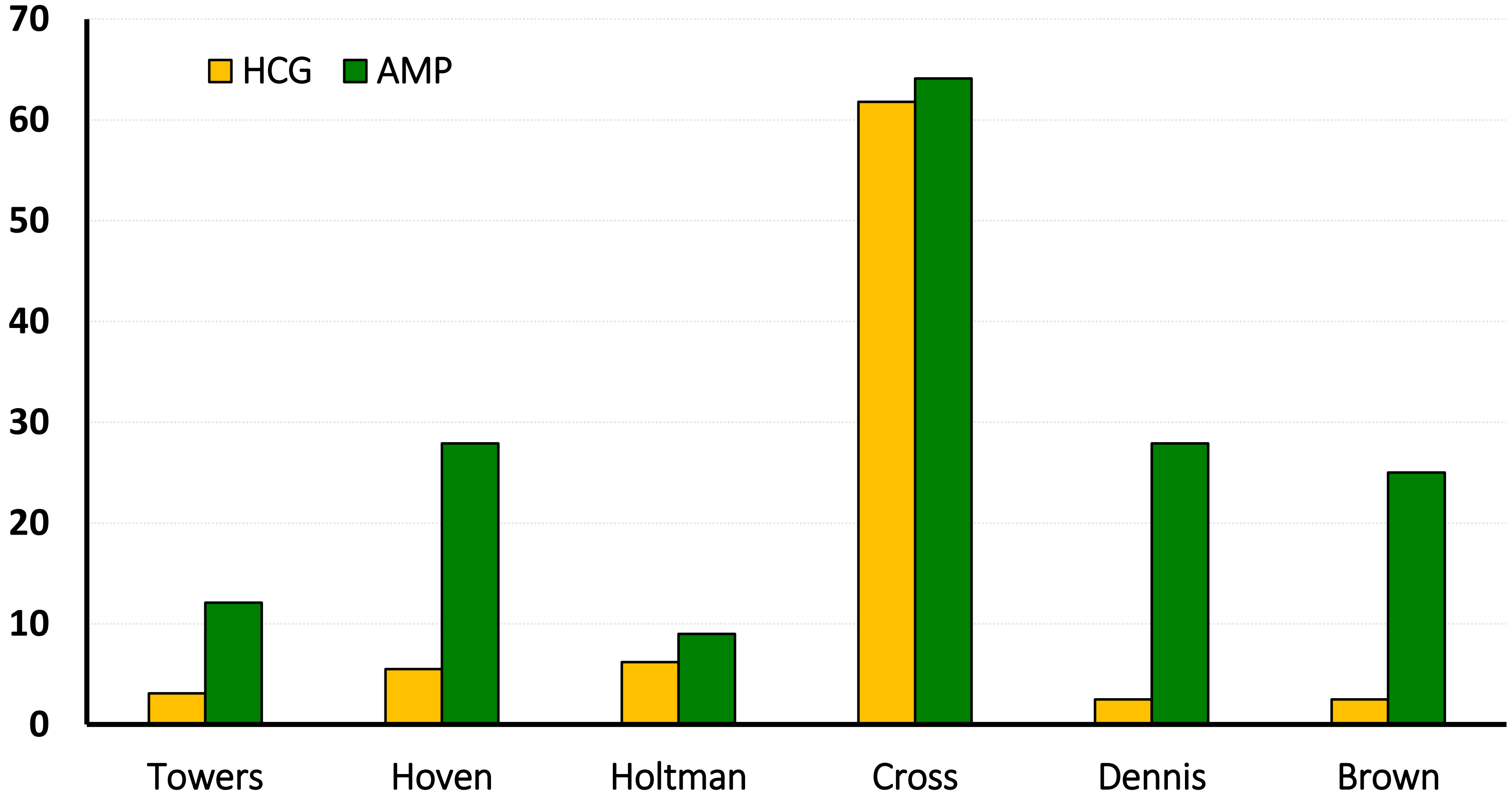


Williams et al. 2017

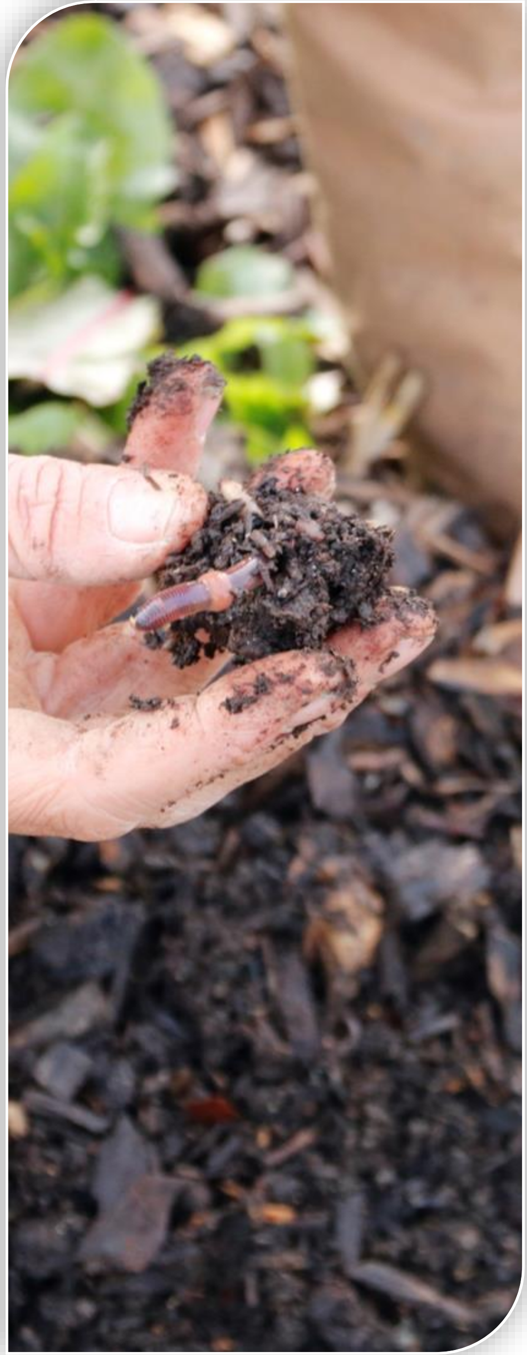
Infiltration on HCG vs. AMP grazing

Northern Great Plains





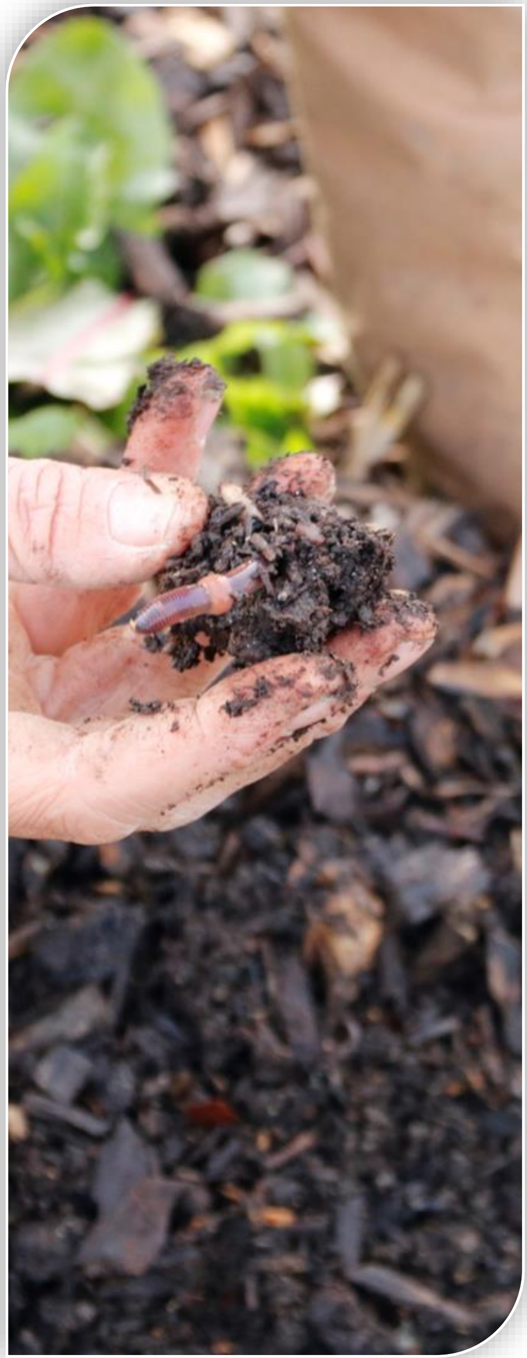
Apfelbaum et al 2016



AMP Grazing on Converted Crop Fields

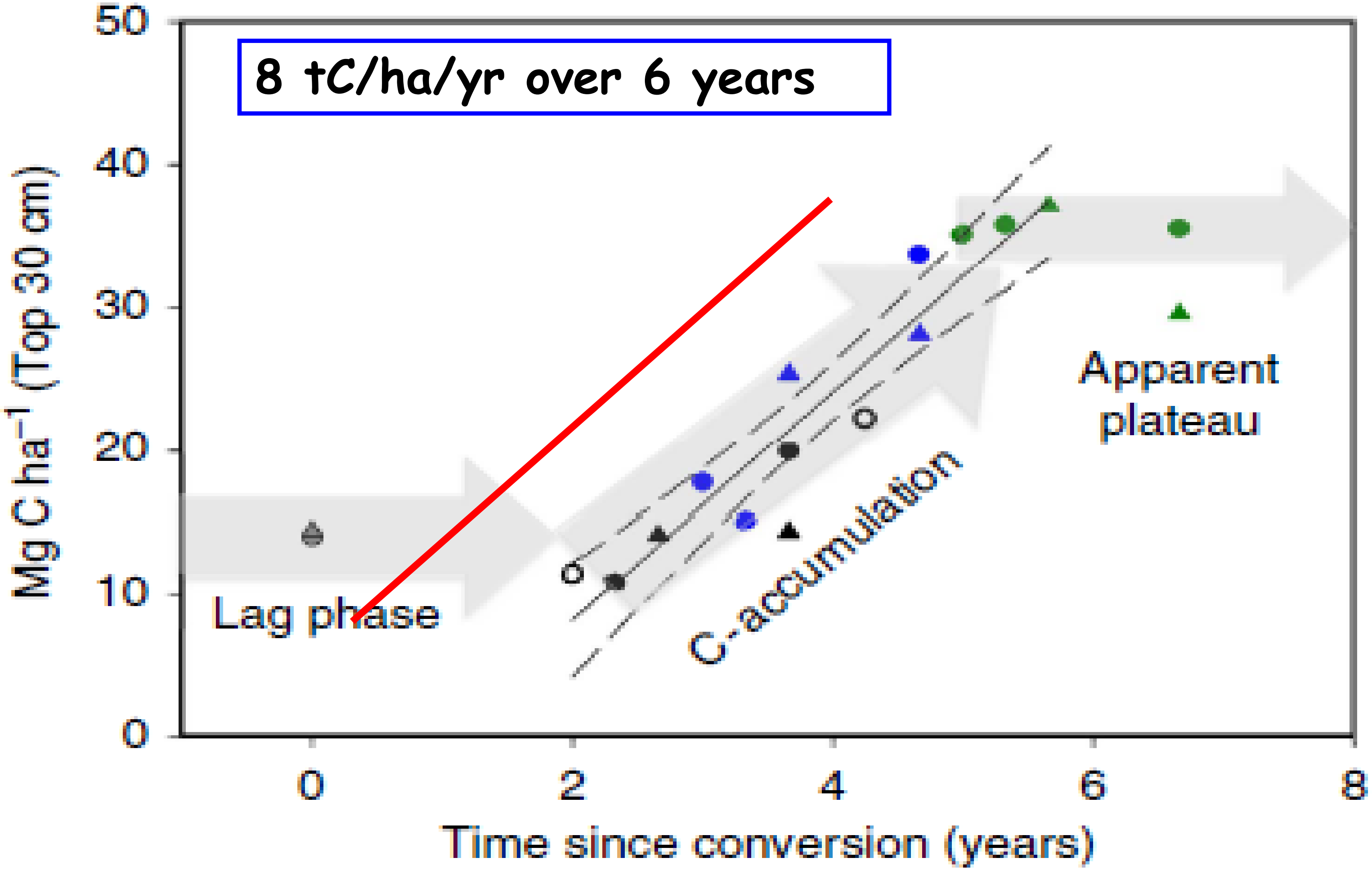
Georgia – 1,000 mm rainfall

Machmuller et al. 2015



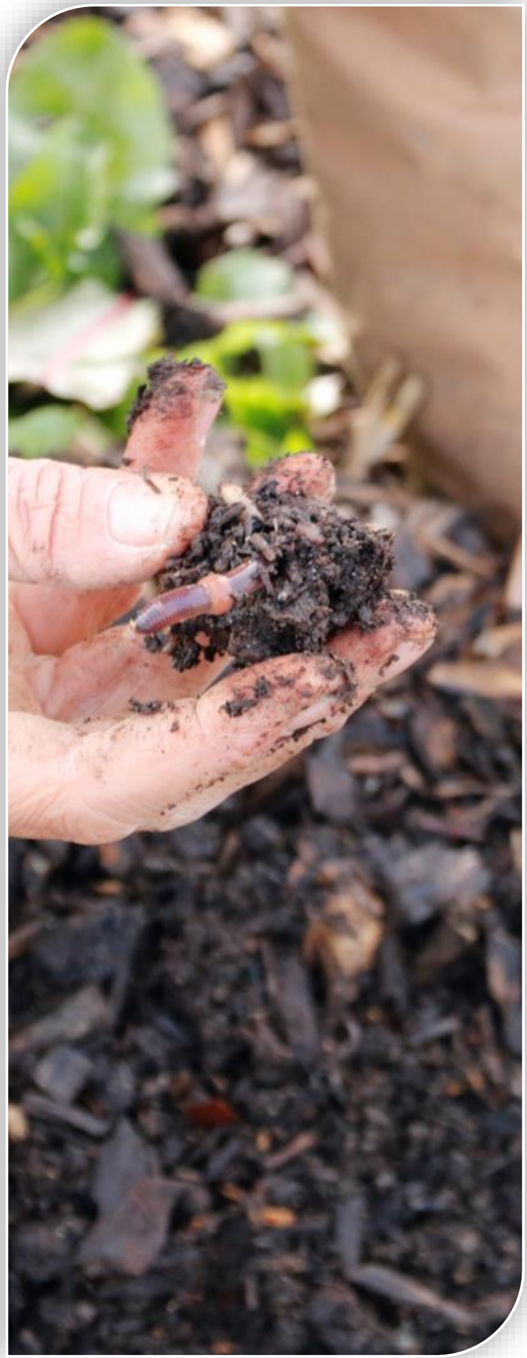
SOC Switching from Cropping to AMP

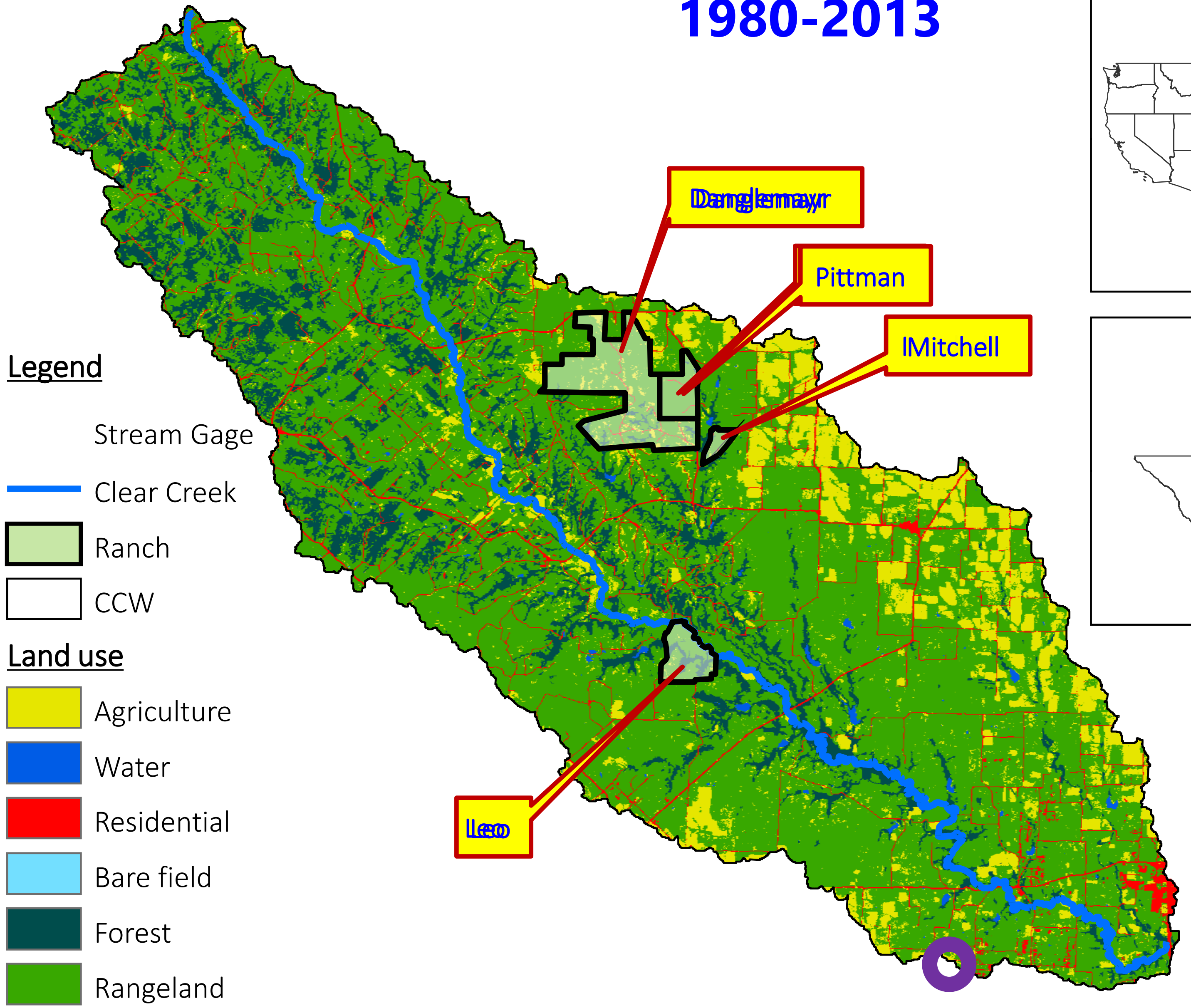
Measured to 30 cm

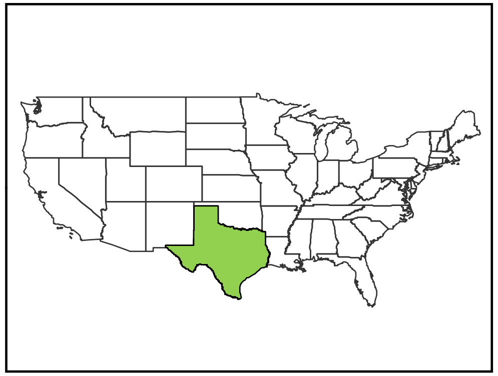


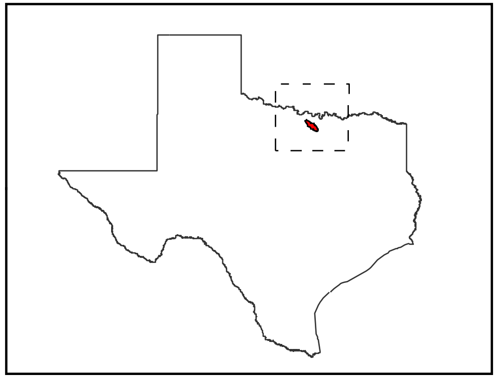
Clear Creek watershed, North Texas

1980-2013



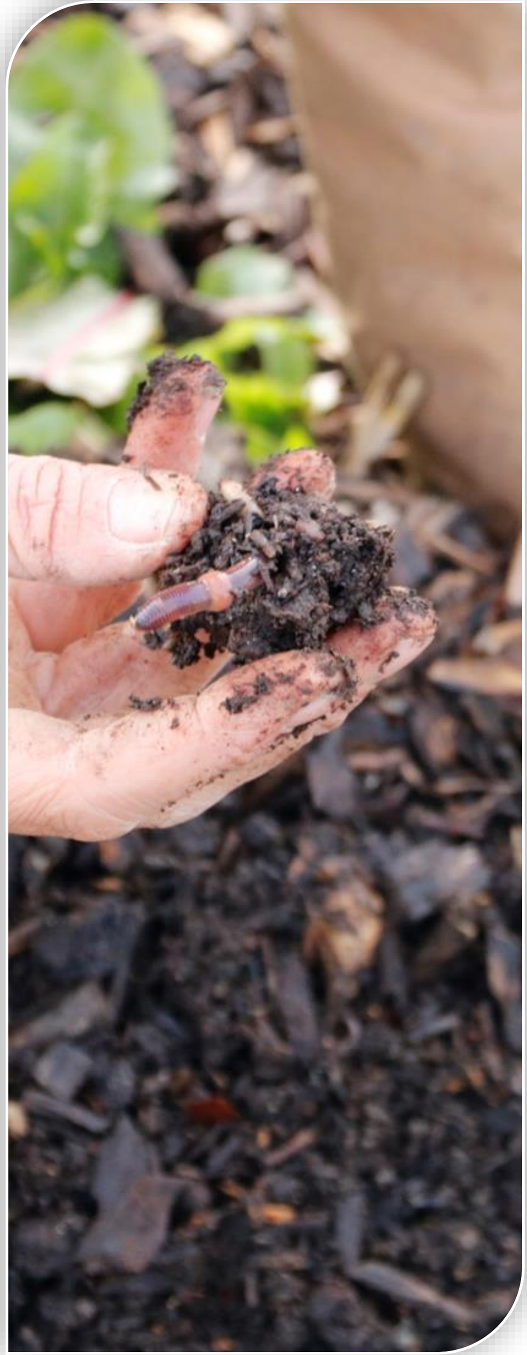


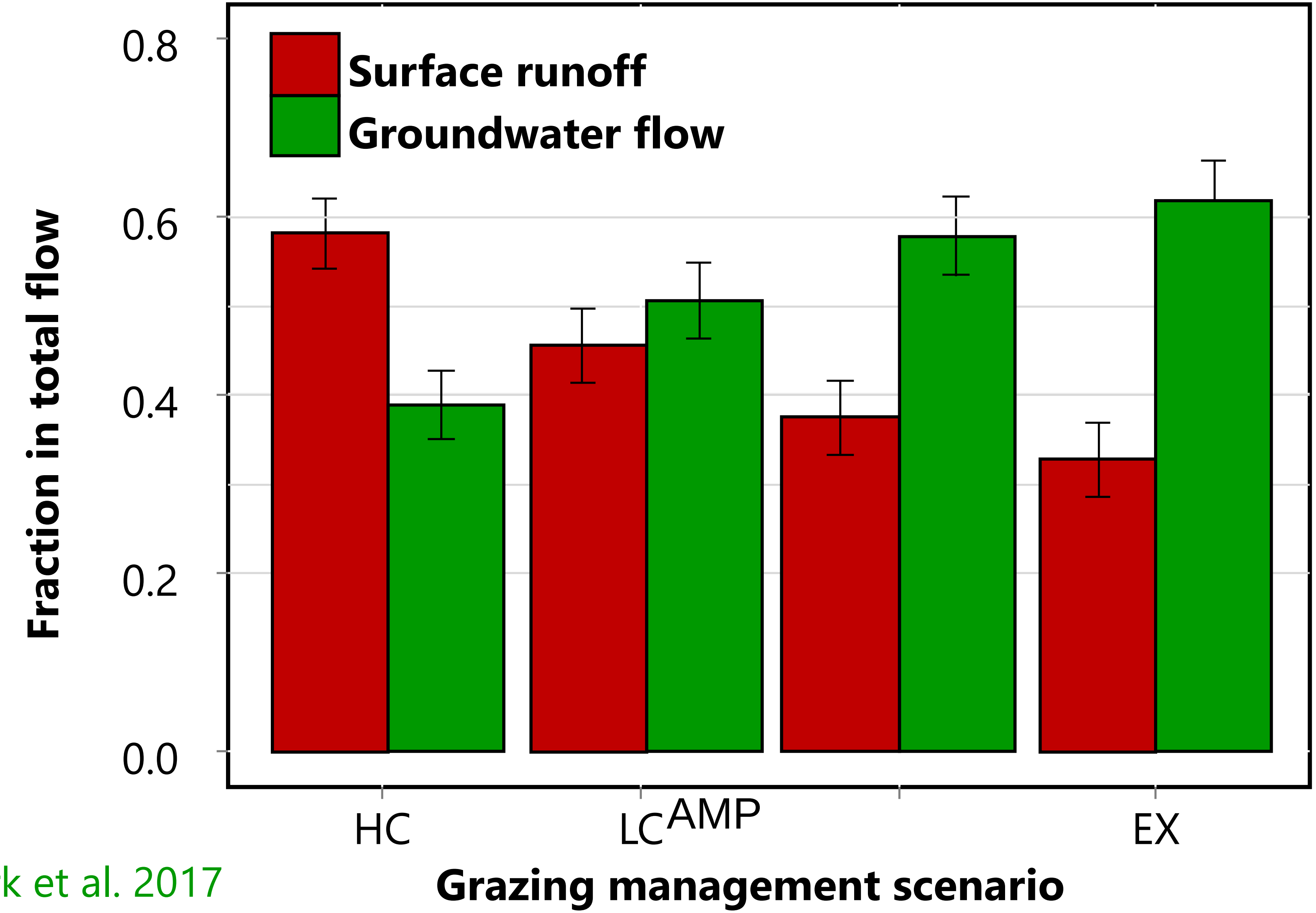




Park et al. 2017

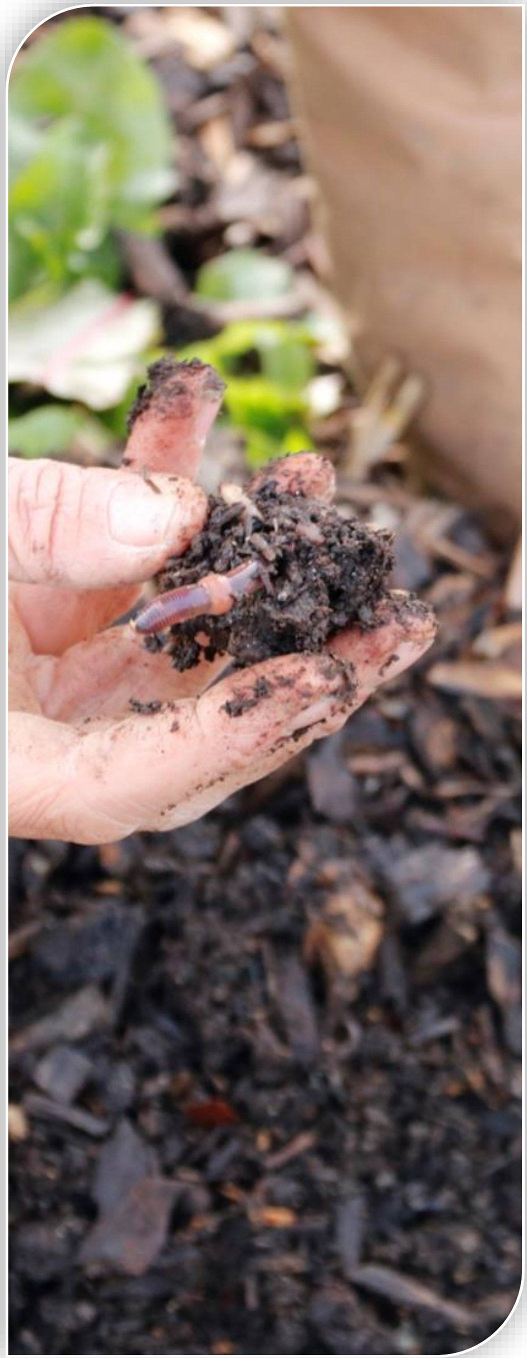
Clear Creek watershed, North Texas

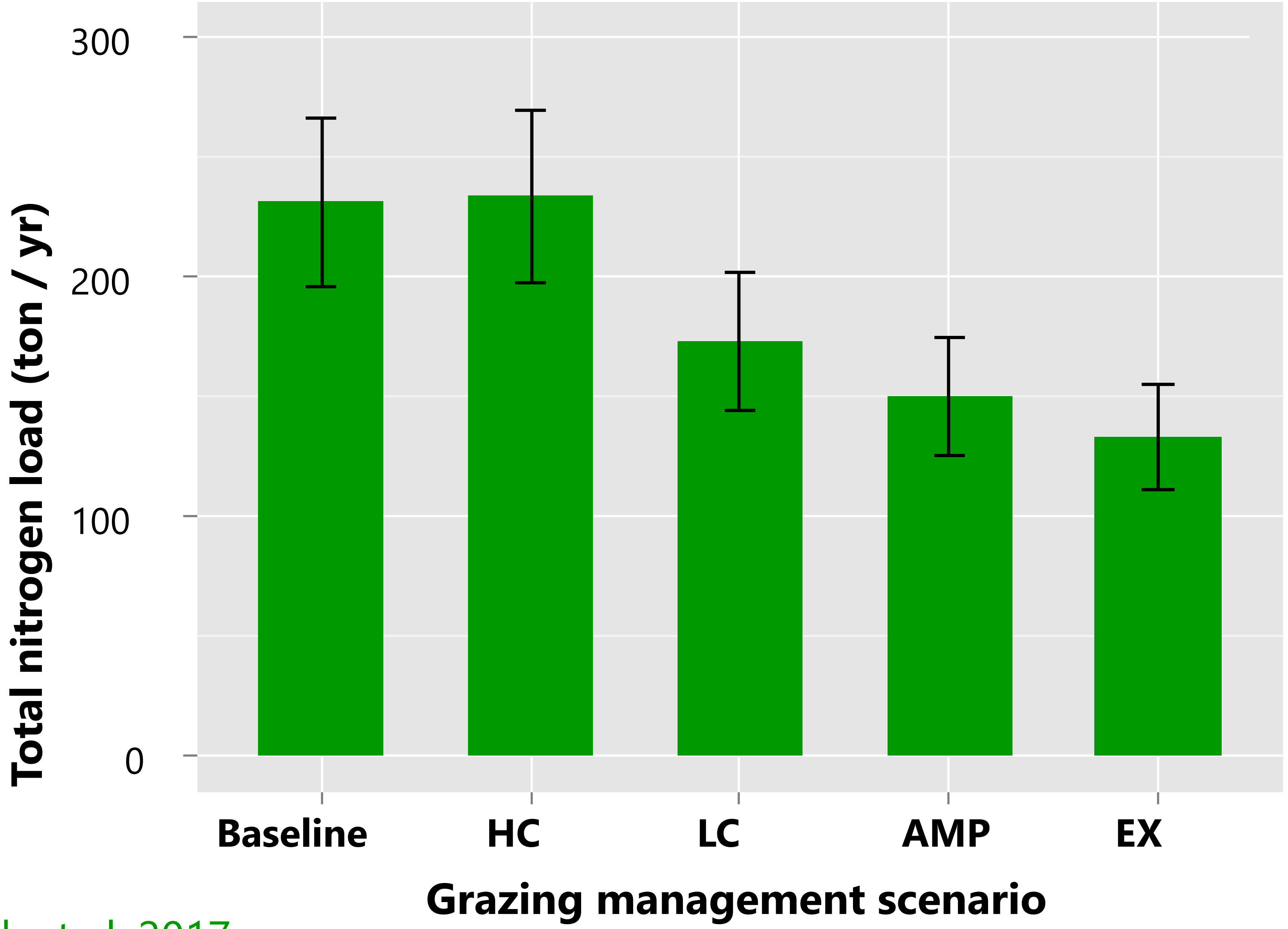




Park et al. 2017

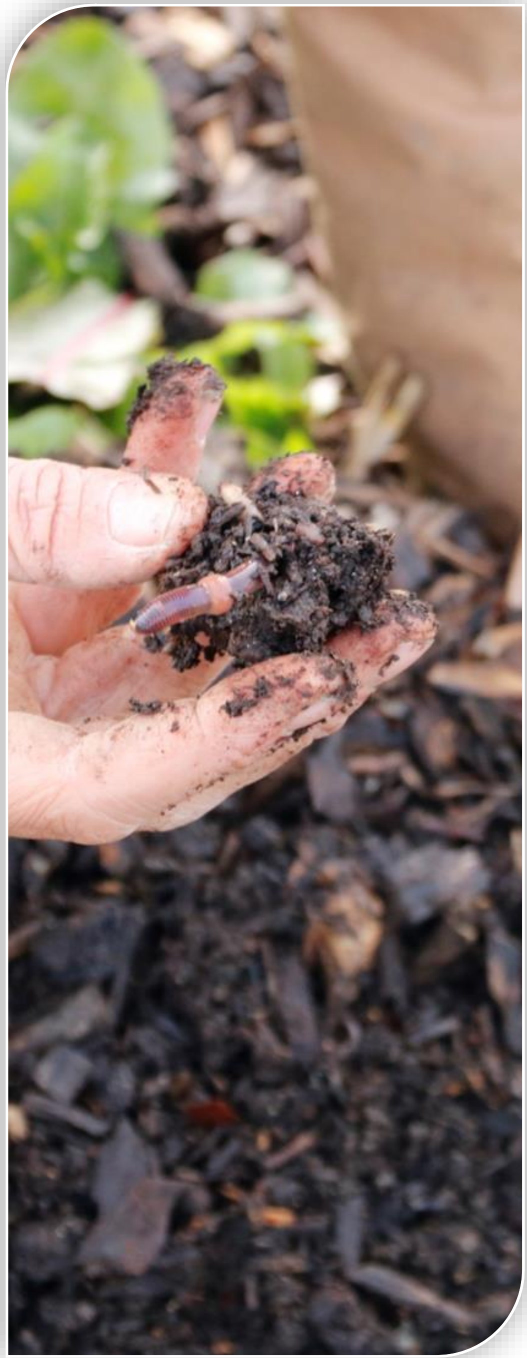
Clear Creek – Nitrogen load

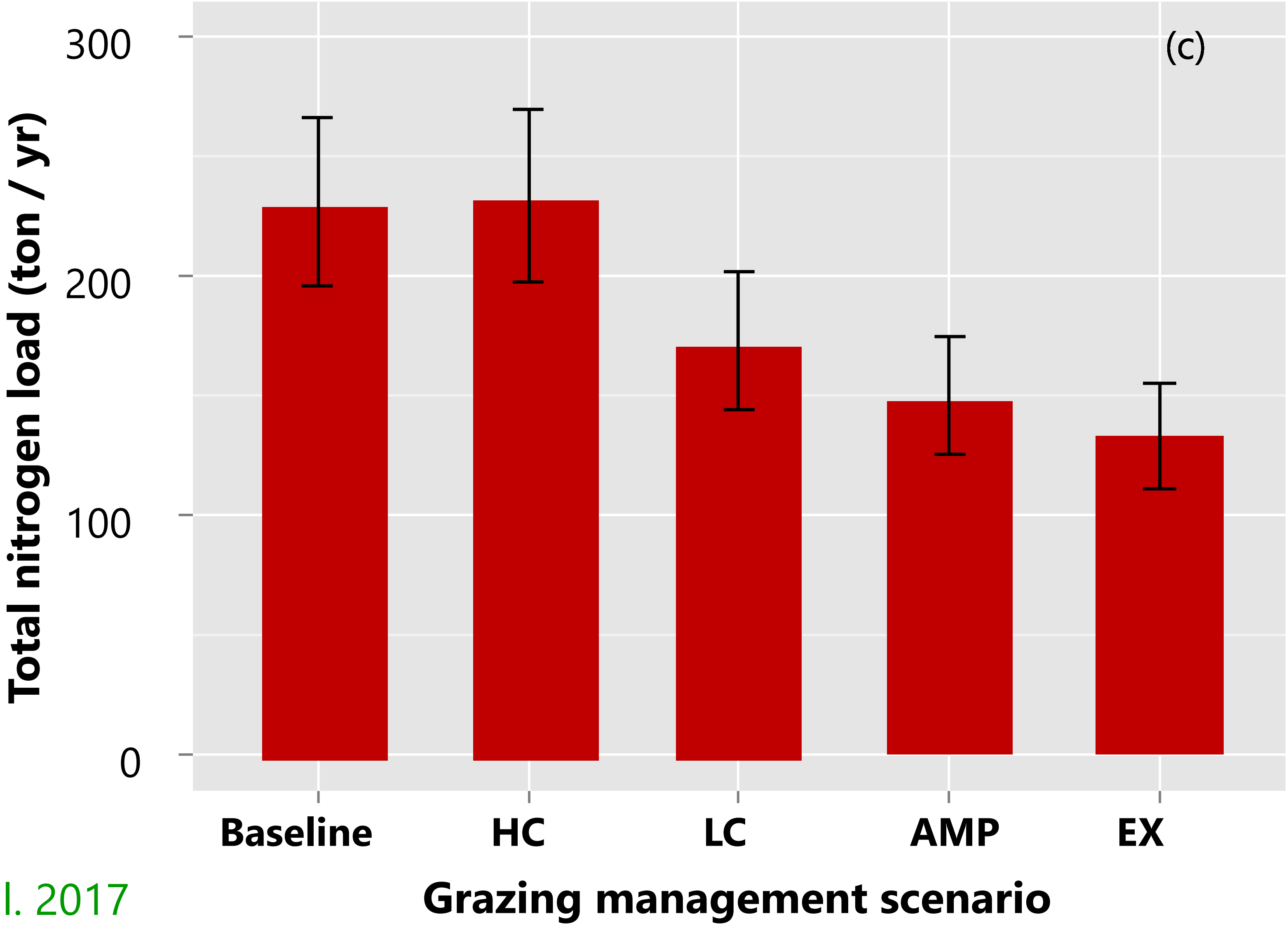




Park et al. 2017

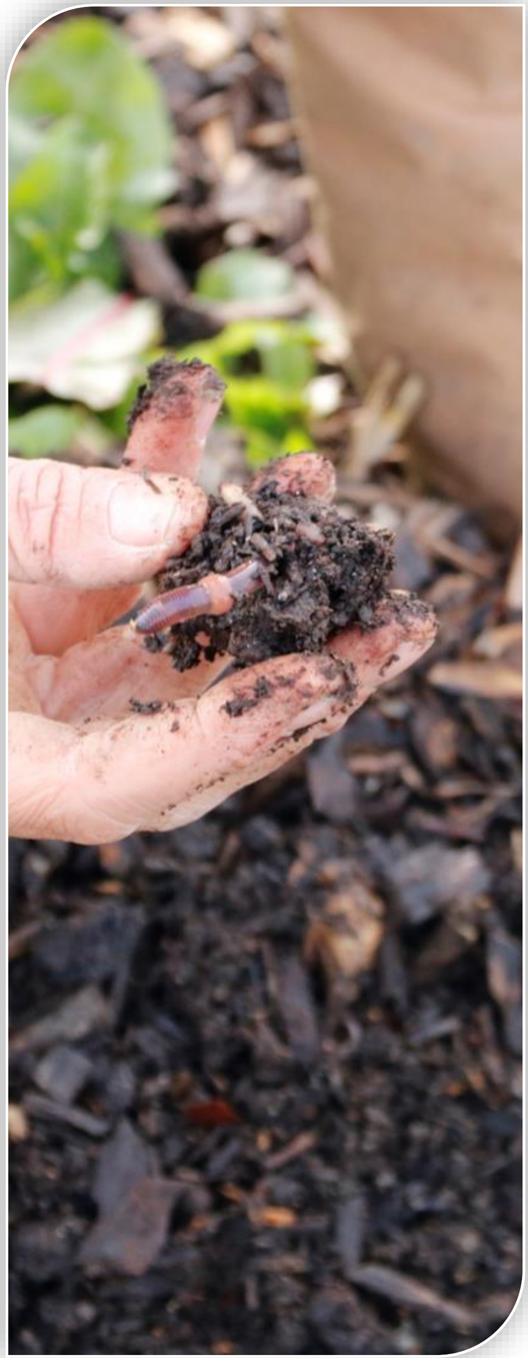
Clear Creek - Phosphorus load

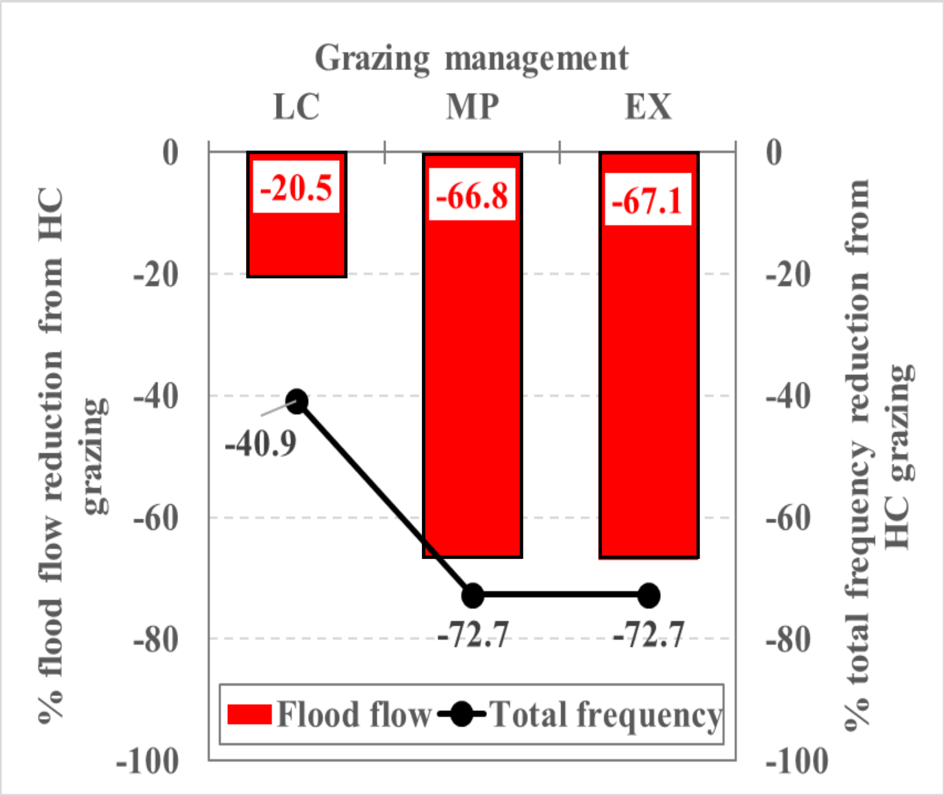




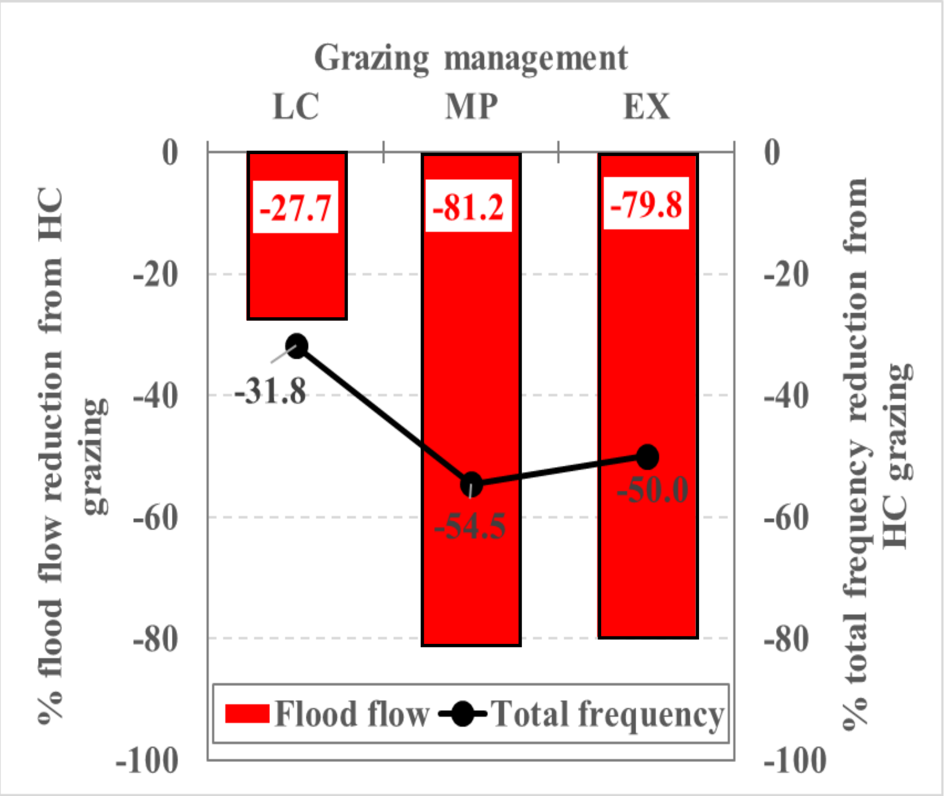
Park et al. 2017

Effect of Grazing Management on Flood Flow and Flood Frequency



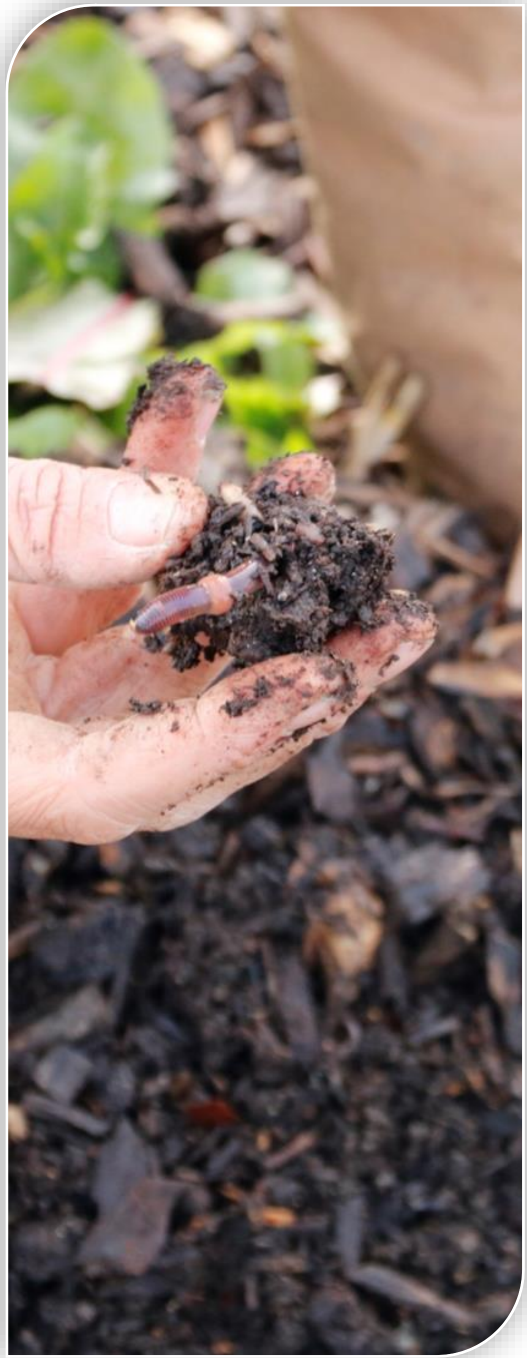


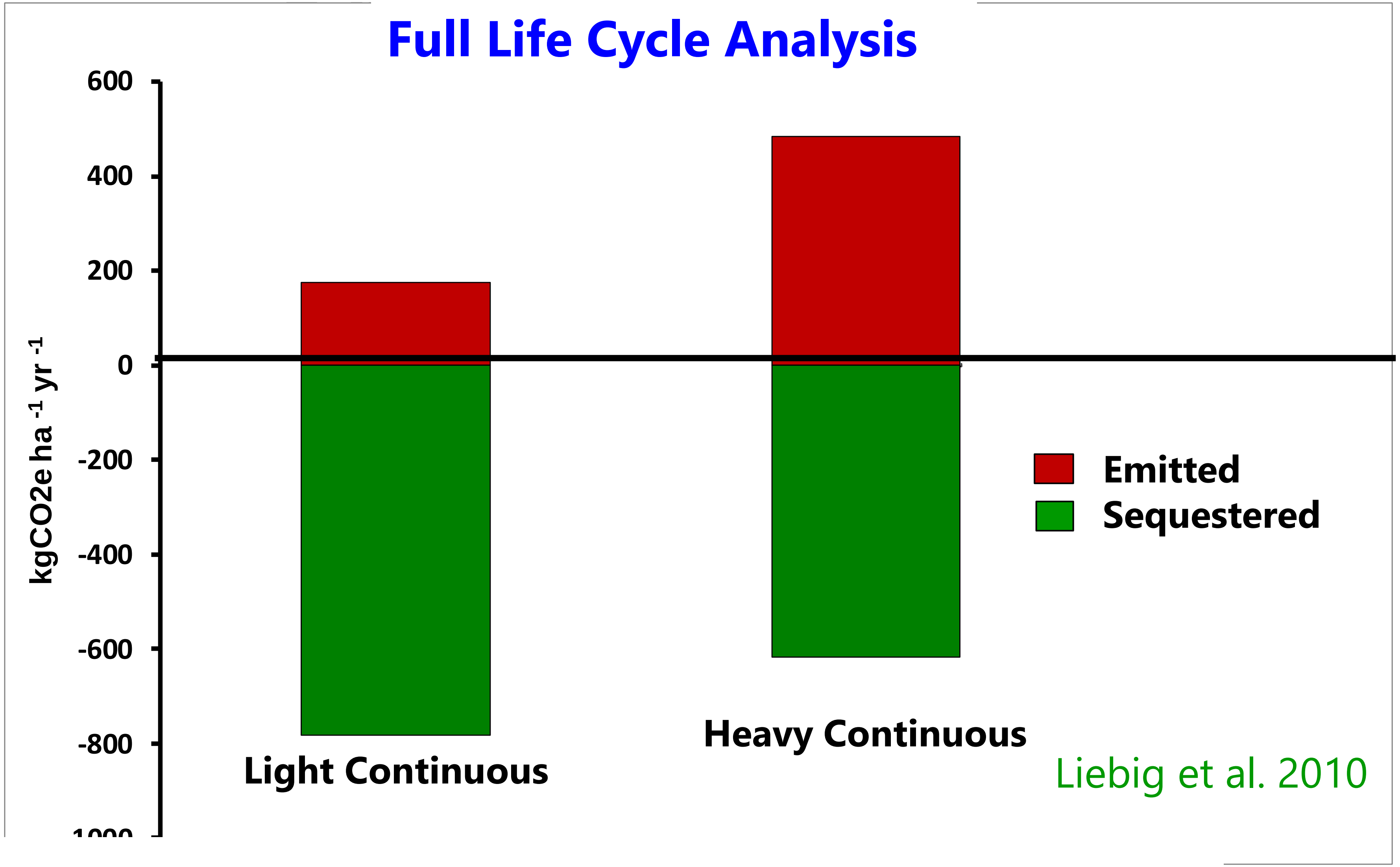
Red River Watershed, Texas

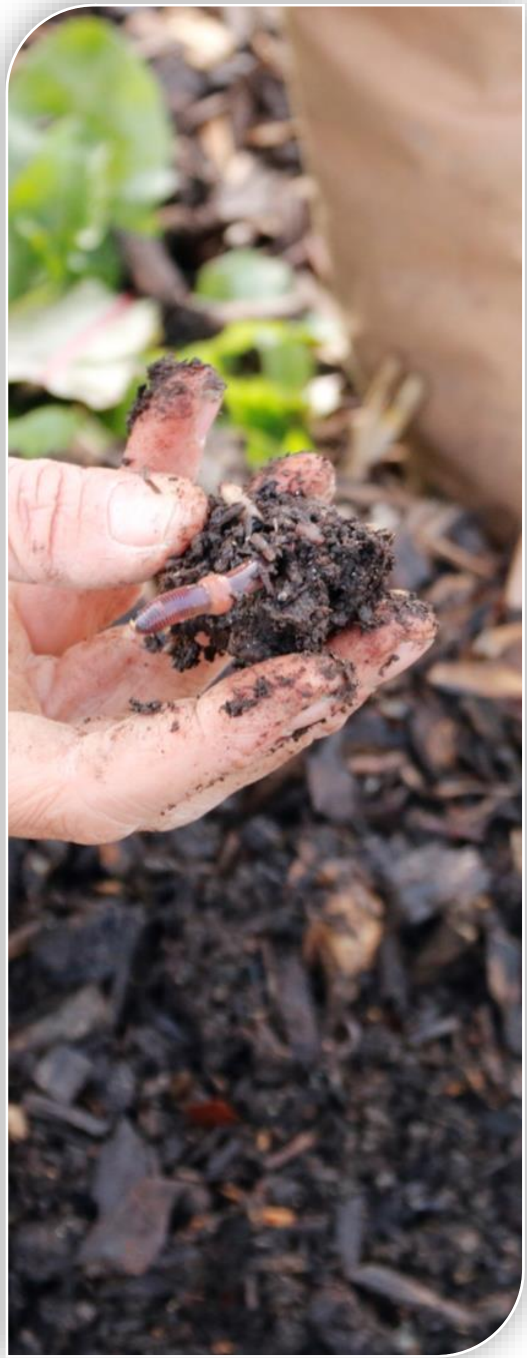


Apple Watershed, North

Carbon Sinks and Emissions:
Northern Plains rangeland grazing only Cattle Operations

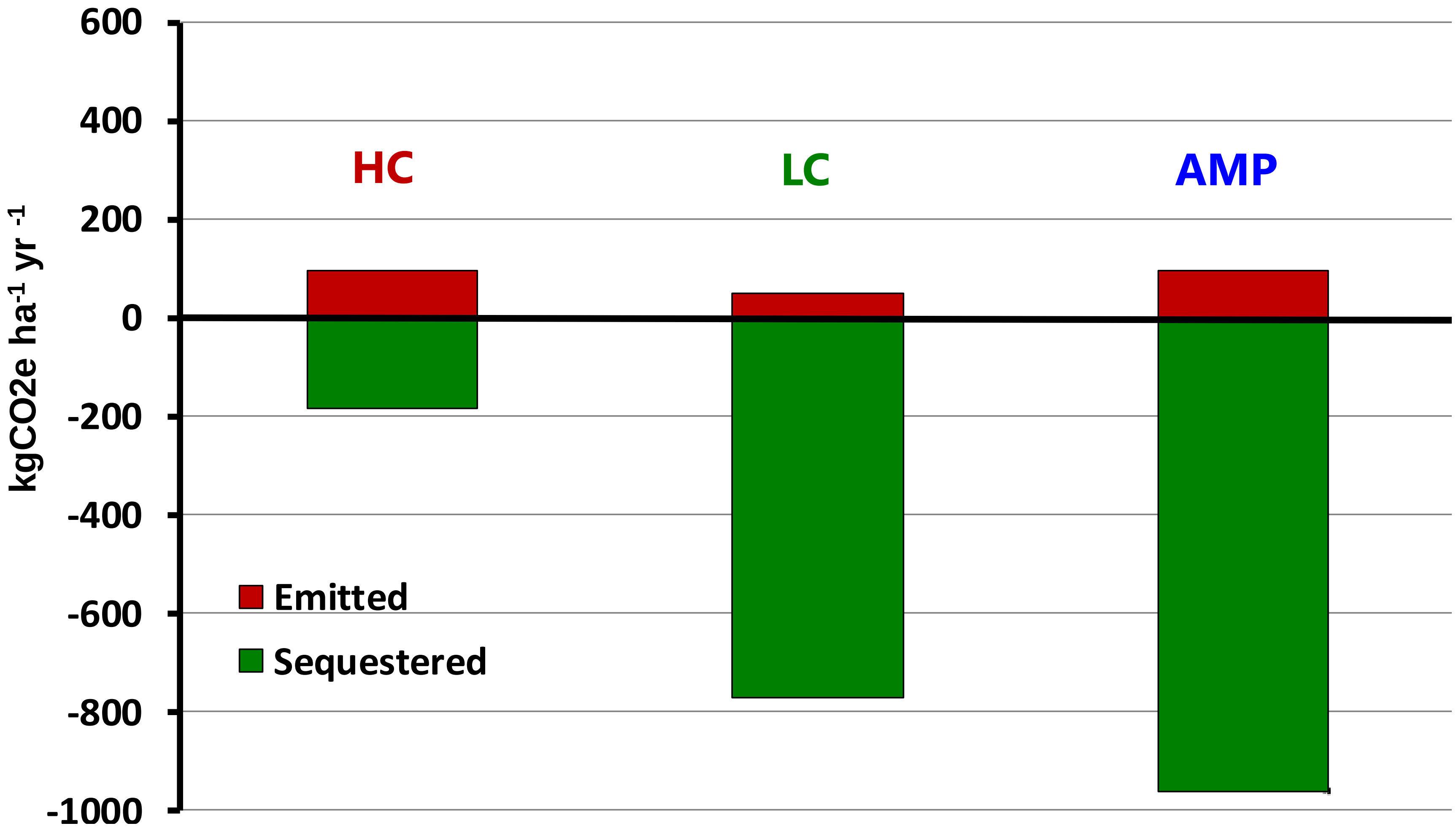




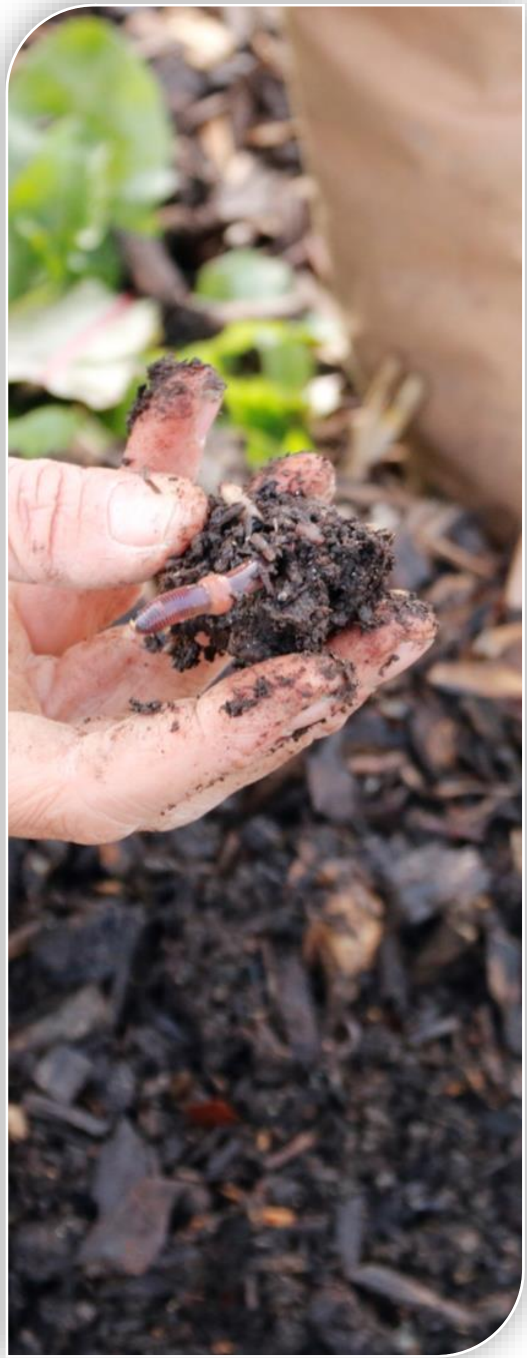


Life Cycle Analysis of Change in Management

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

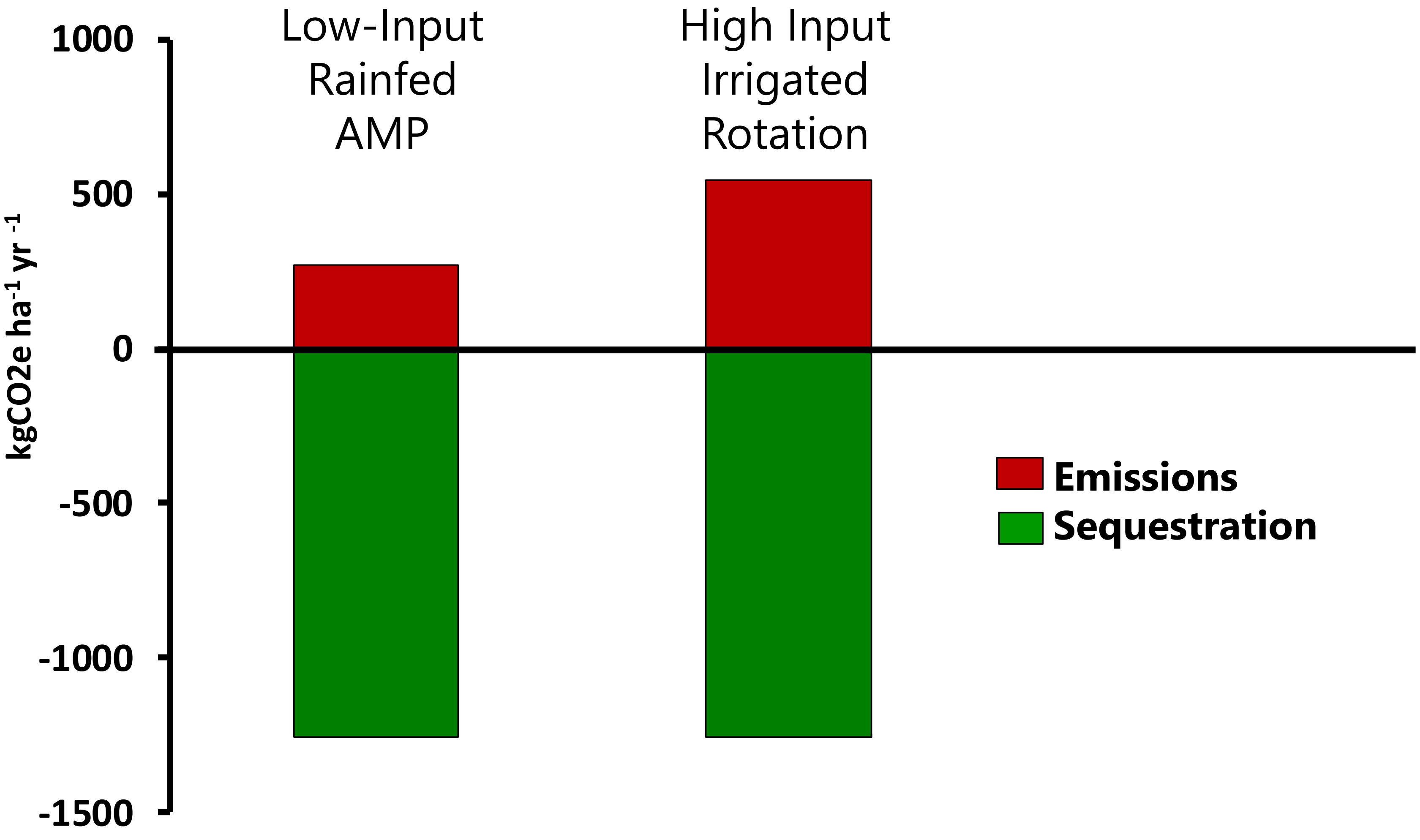


Wang et al. 2015



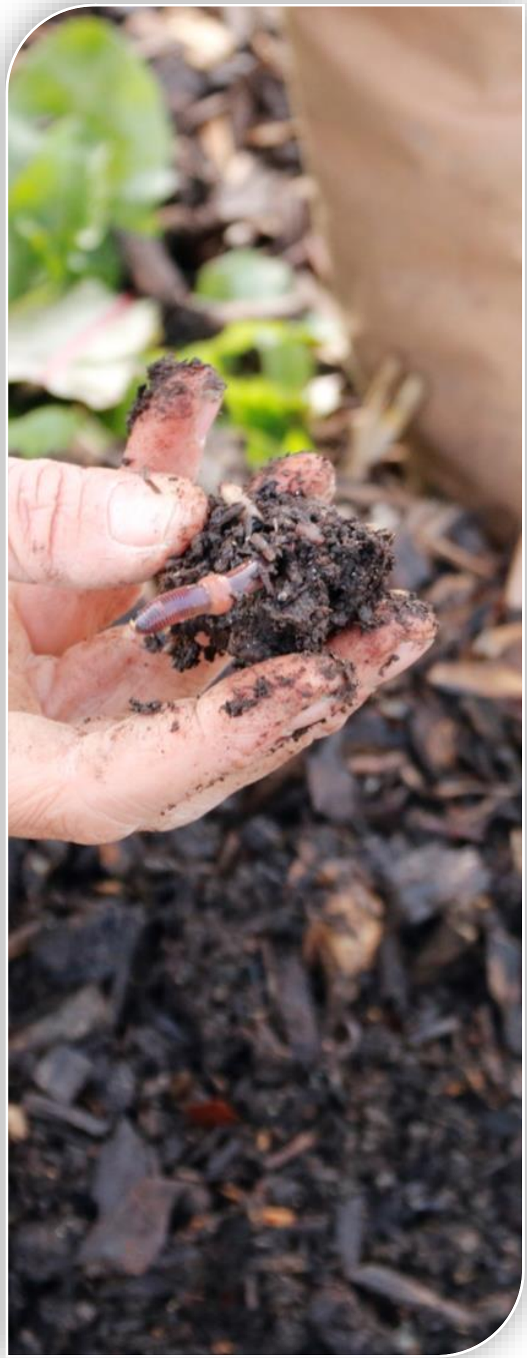
Emissions and Carbon Sinks:

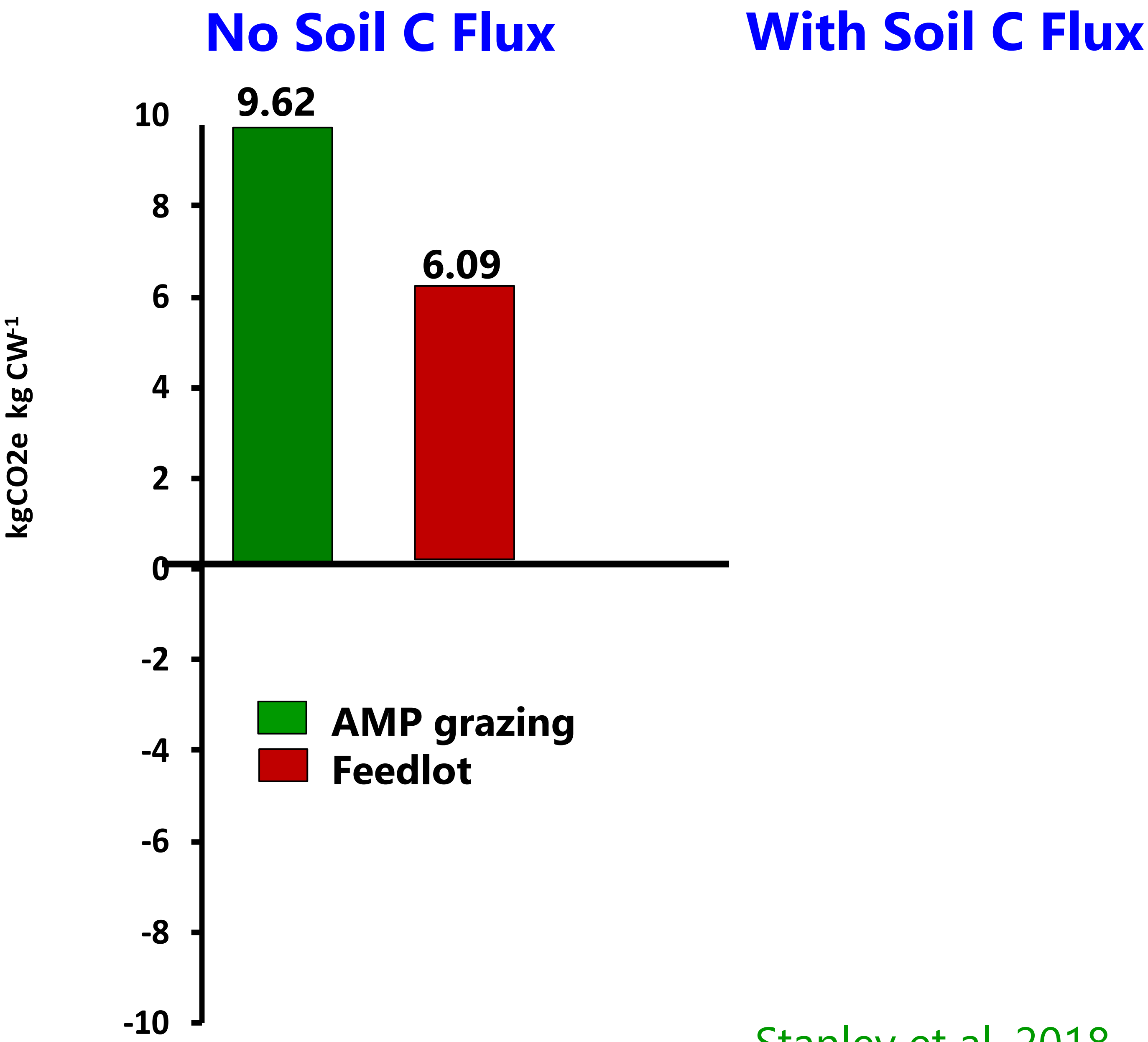
Michigan Grassfed Pasture – grazing only Cow-calf Operations



Rowntree et al. 2015

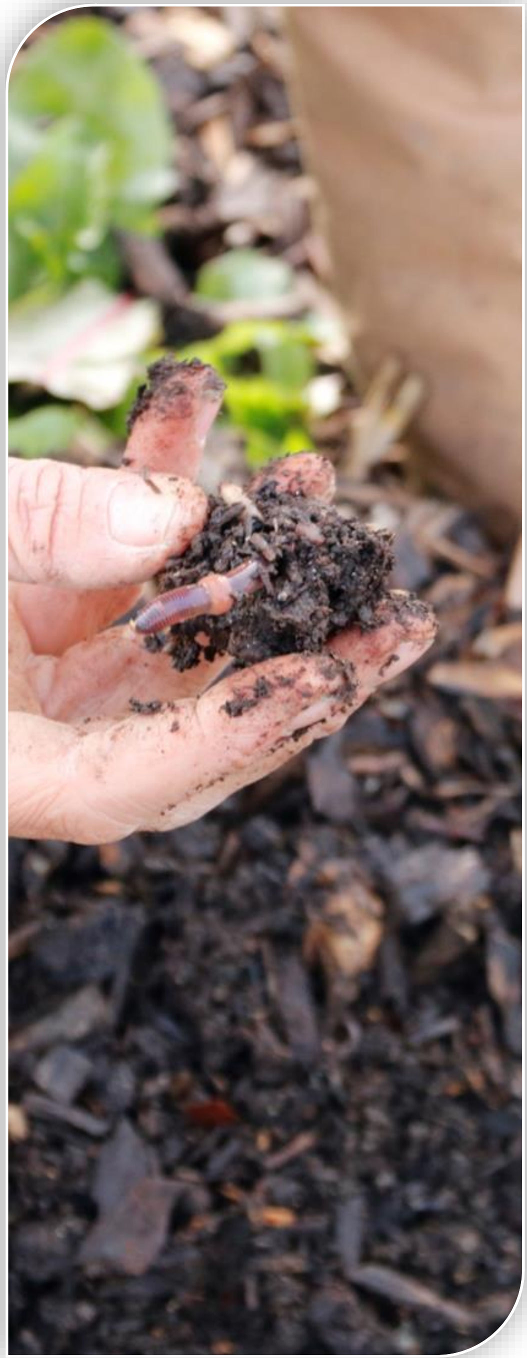
Net emissions: Feedlot vs. AMP finishing:

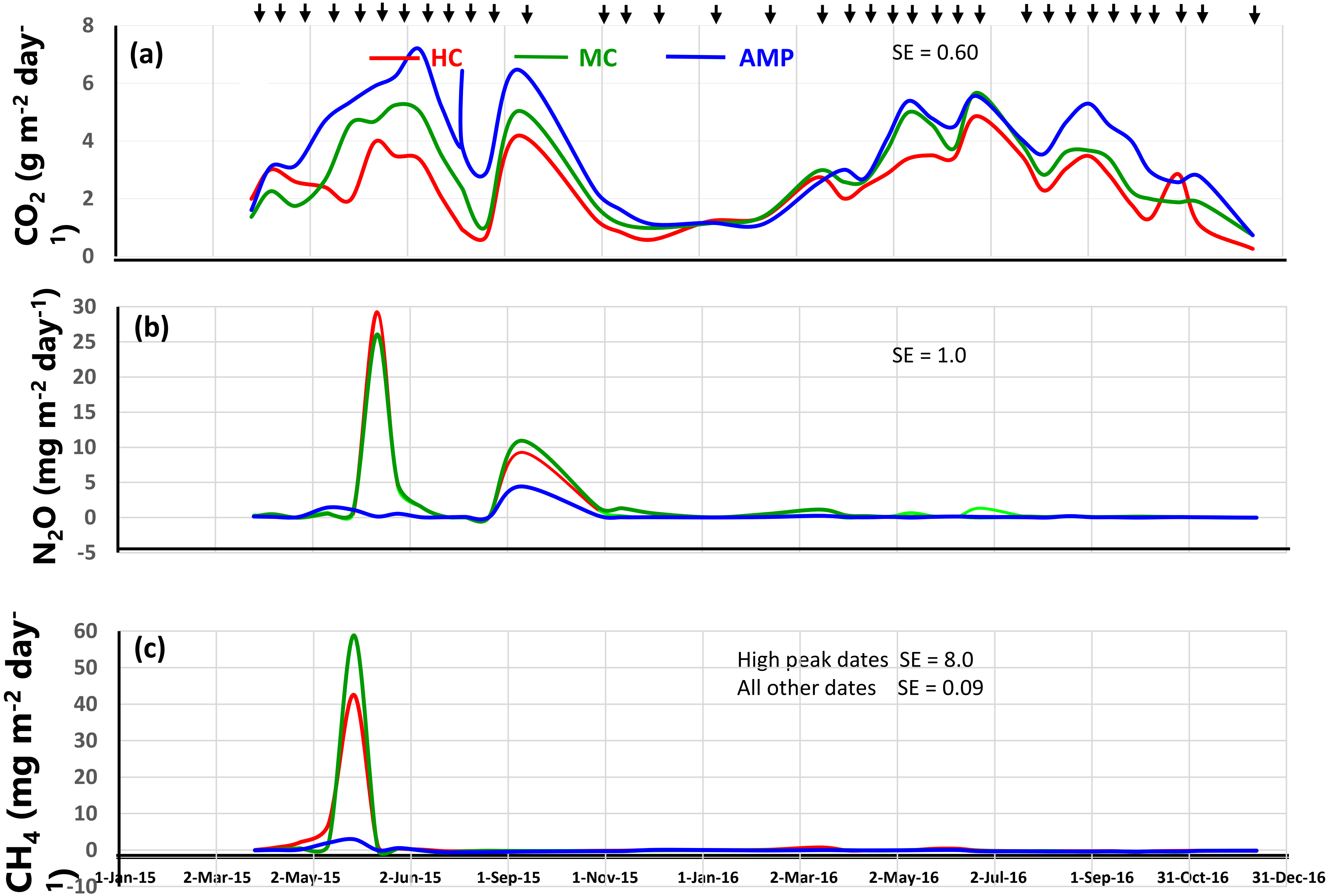


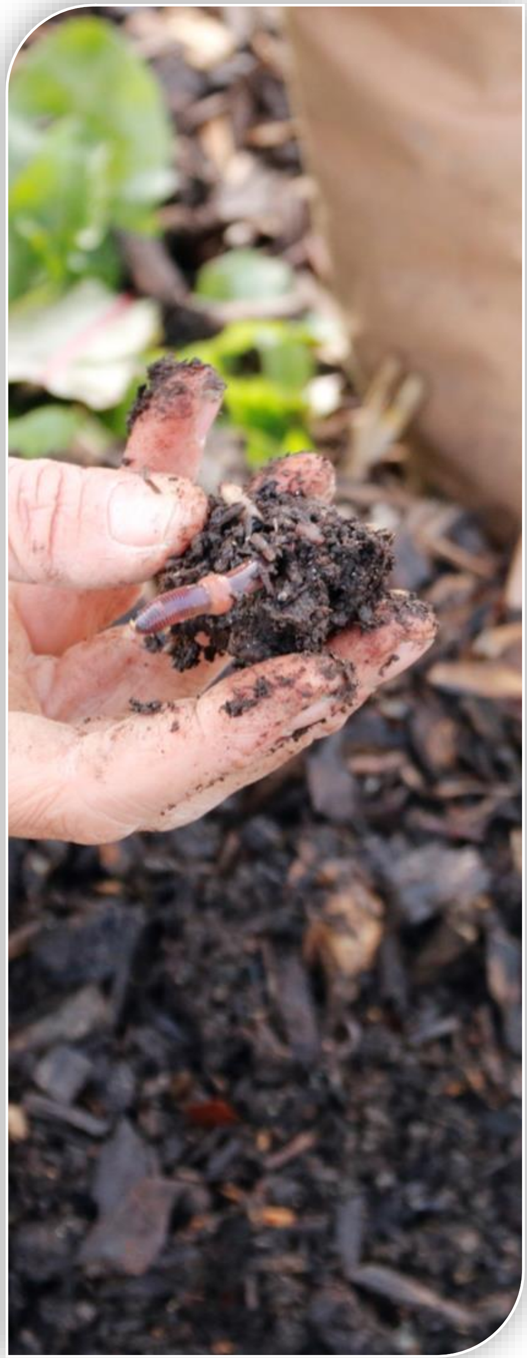


Stanley et al. 2018

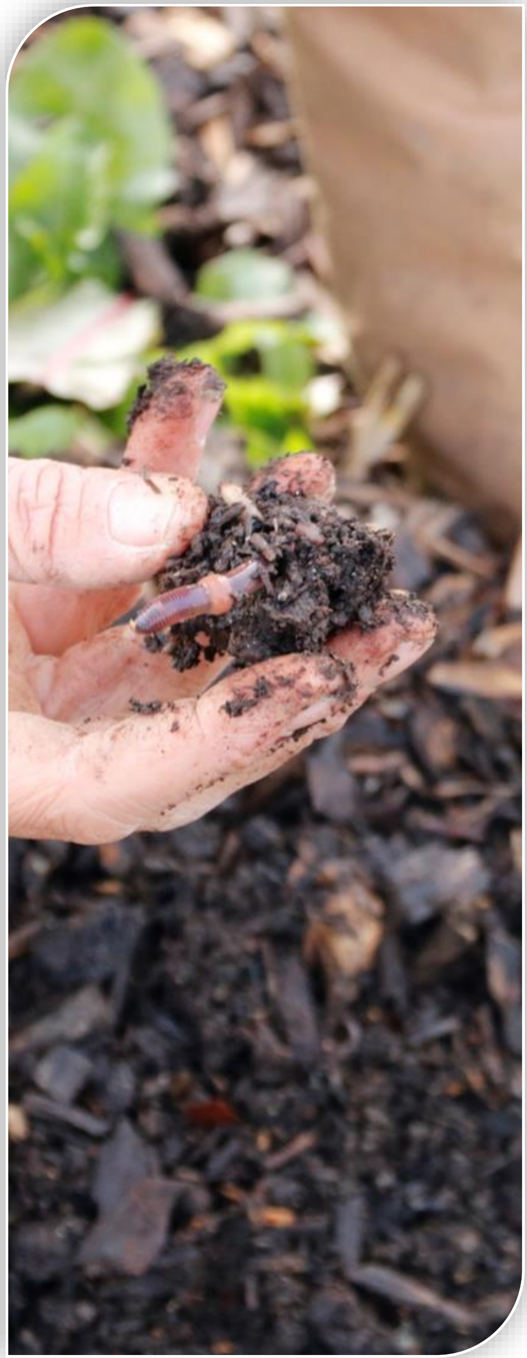
GHG Soil Surface Emissions







Managing to improve soil health and ecosystem services

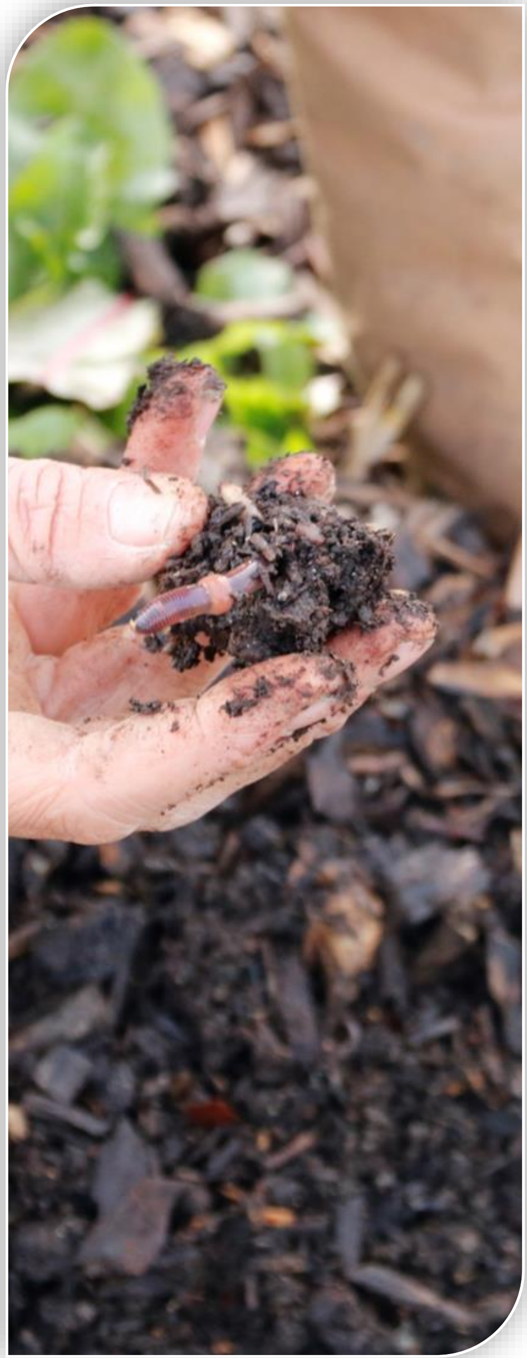


To improve Soil Health

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**

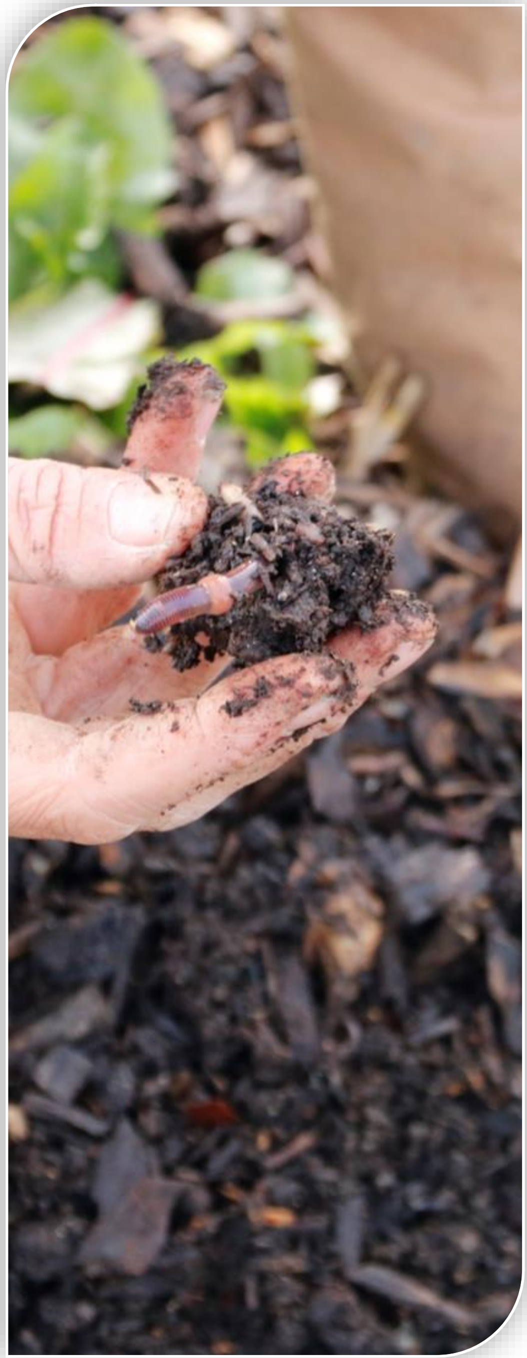
USDA-NRCS; Soil Health Institute



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

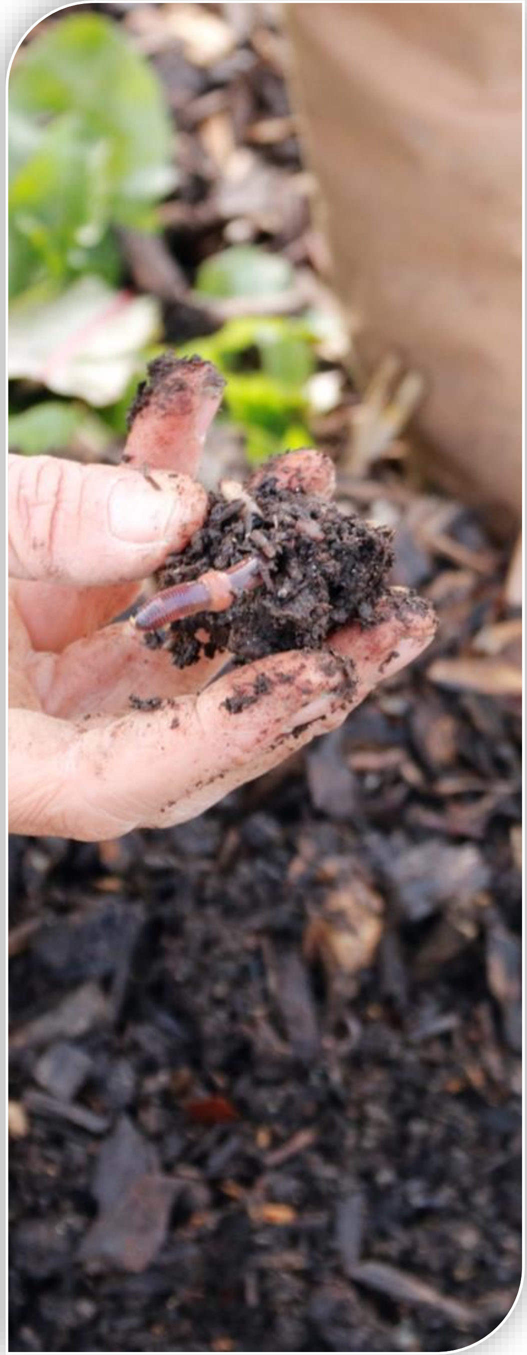
Walt Davis, Dave Pratt, Ranch Management Consultants



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

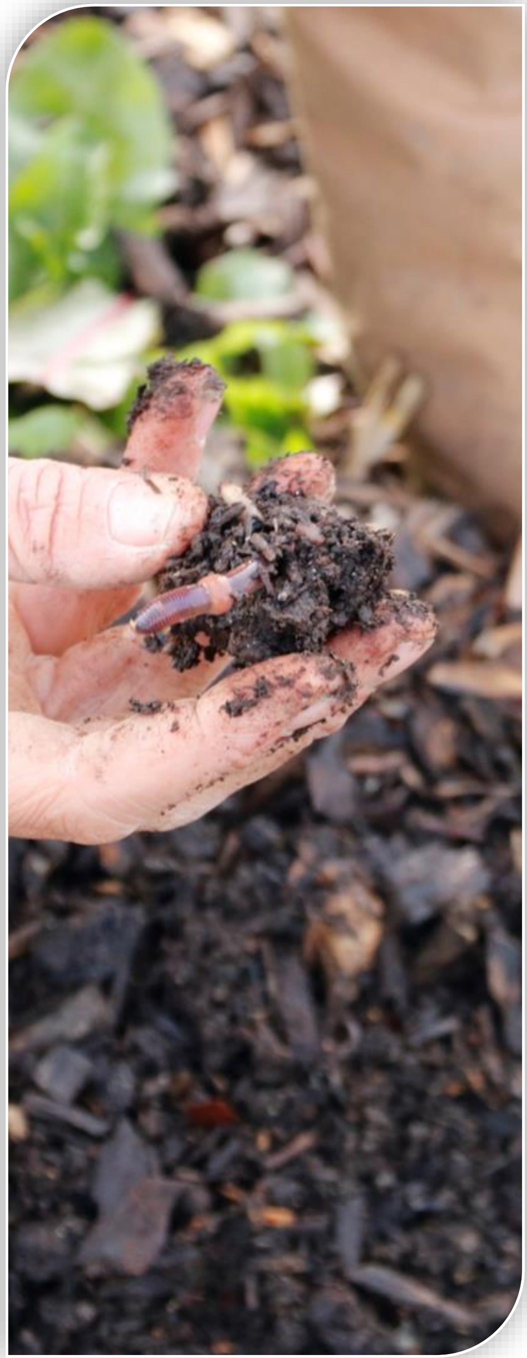
Walt Davis, Dave Pratt, Ranch Management Consultants



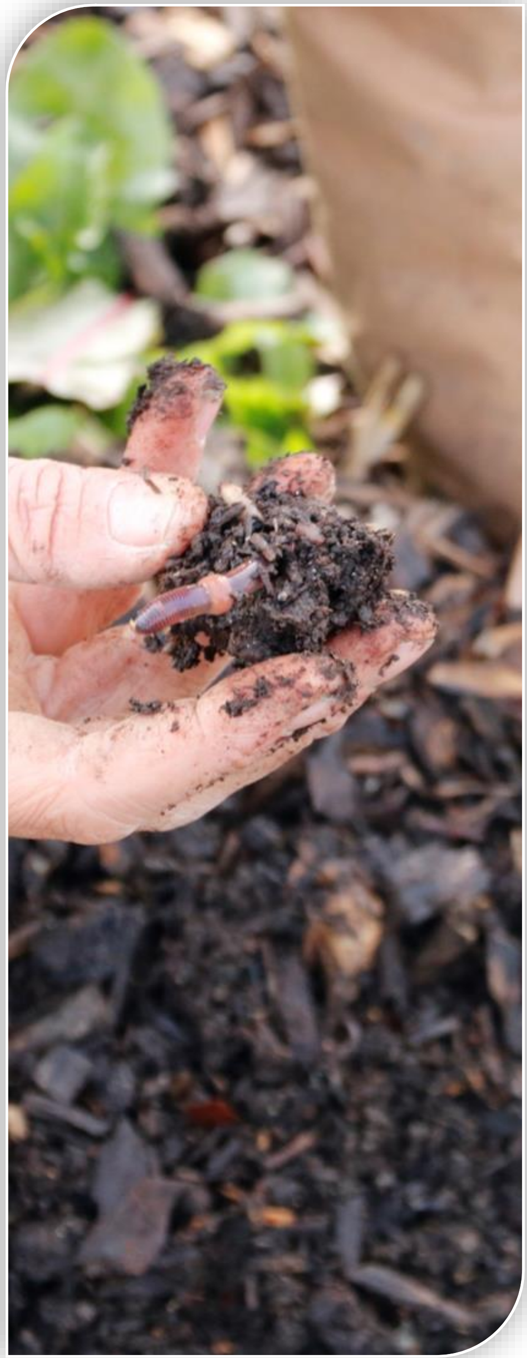
Research for Adequate Understanding

- 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

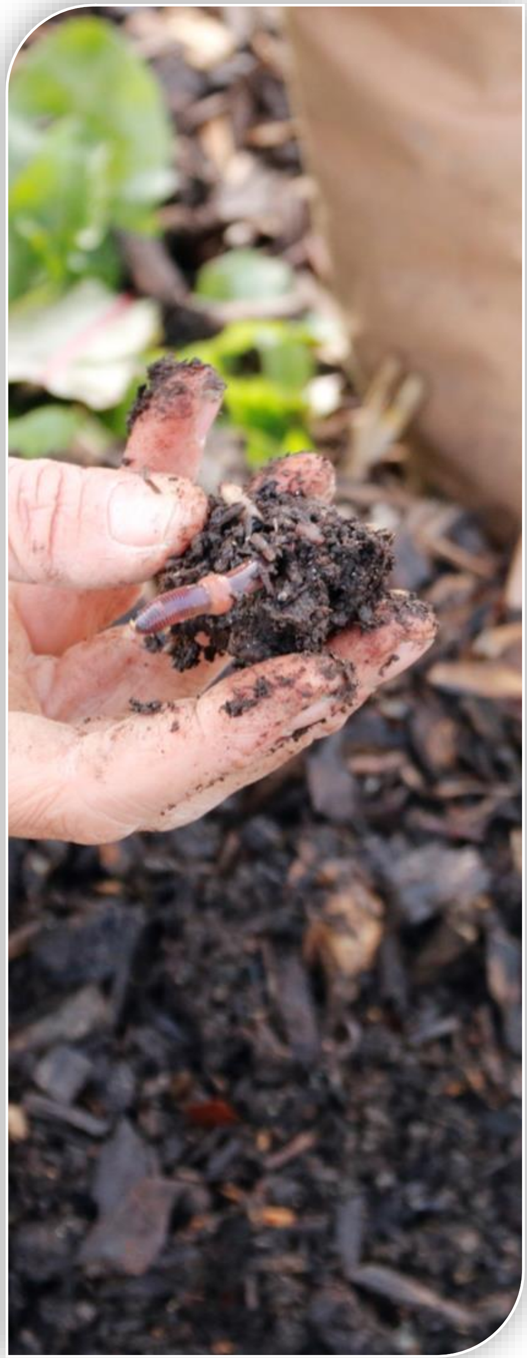


Facilitating transition to regenerative grazing

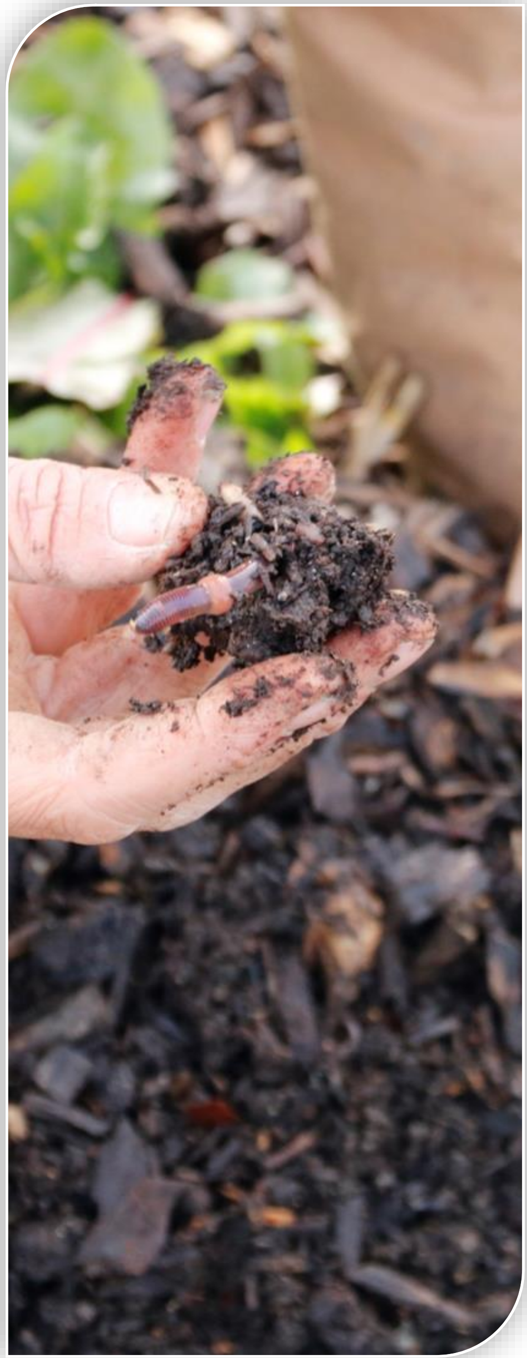


Aids to transitioning

- 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



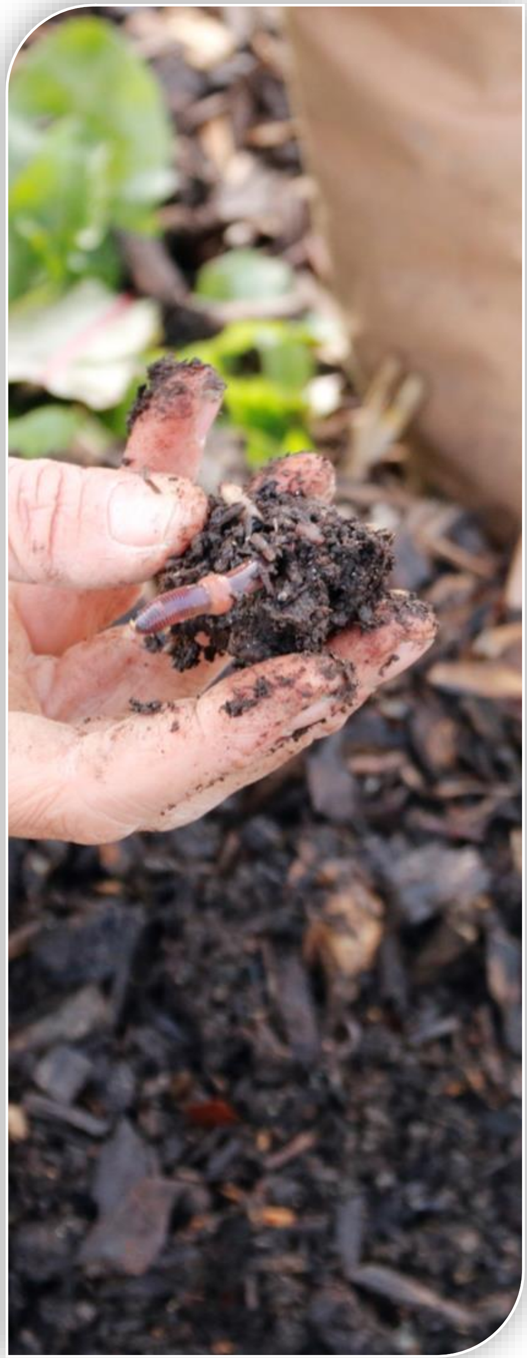
Conclusions



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

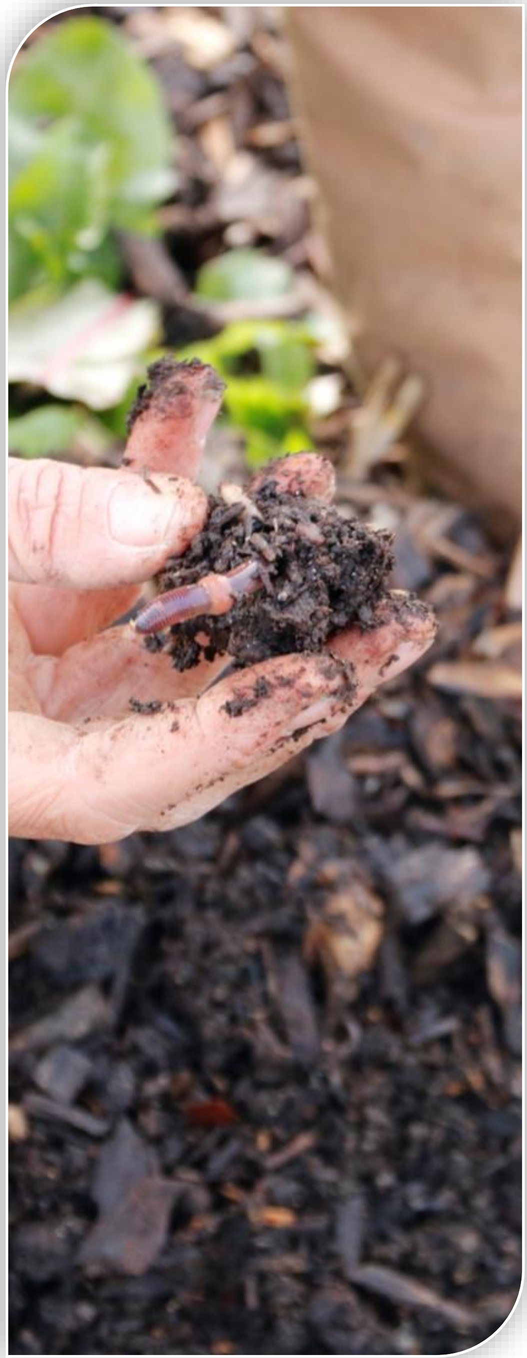
Park et al. 2017; Jakoby et al. 2014; Teague et al. 2015; Ritchie 2020; Fenster et al. 2021; Montgomery & Biklé 2022; Montgomery et al. 2021



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

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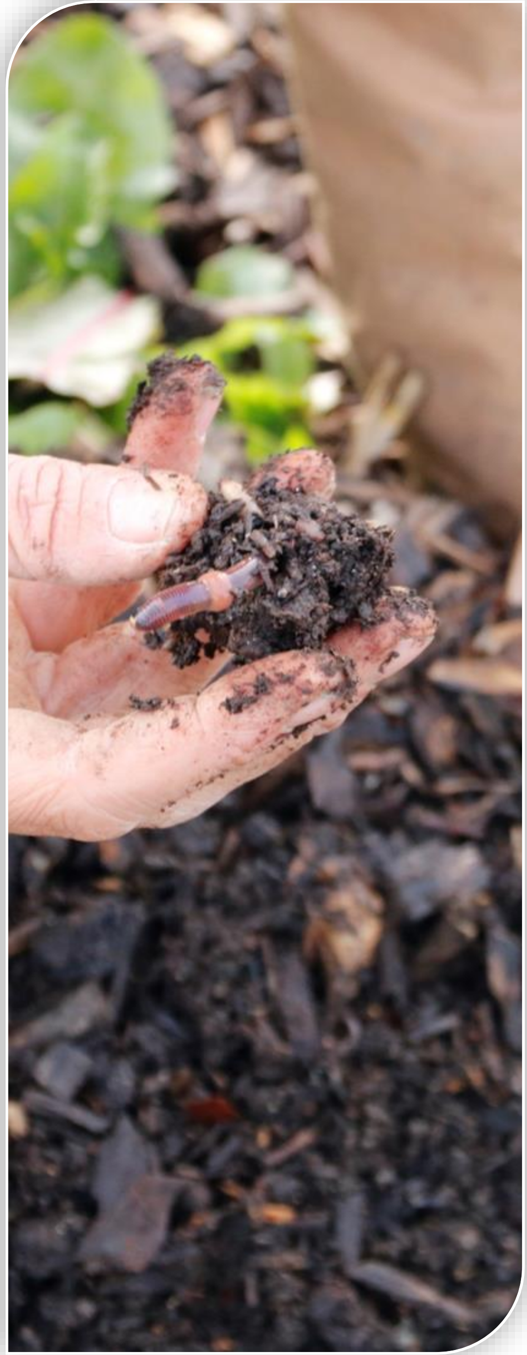
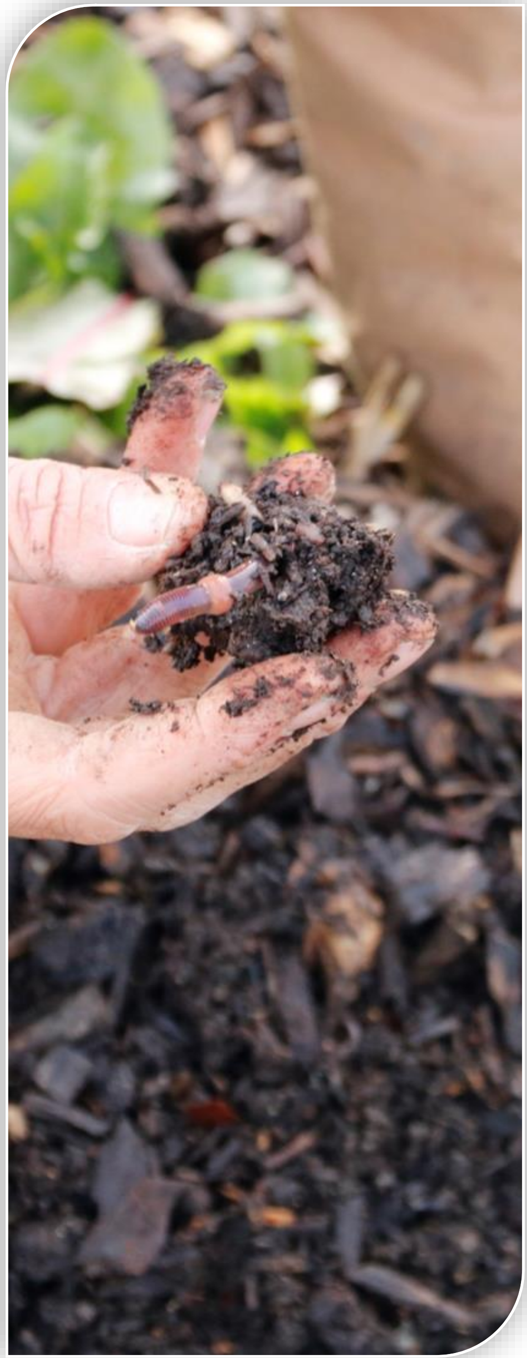


The Dixon Water Foundation

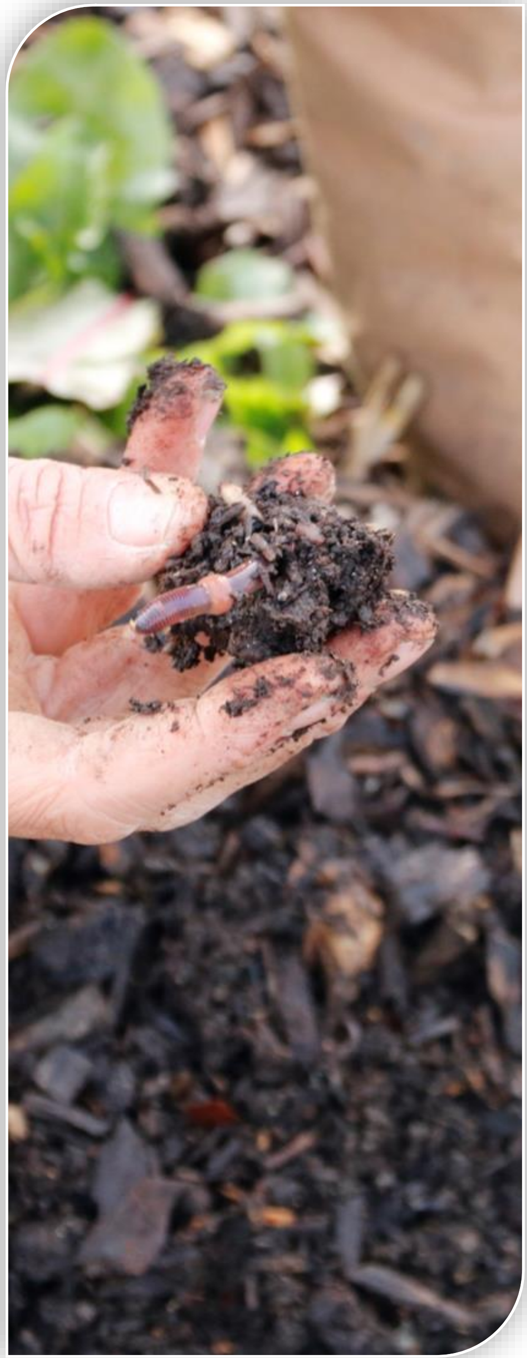
Thank you



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

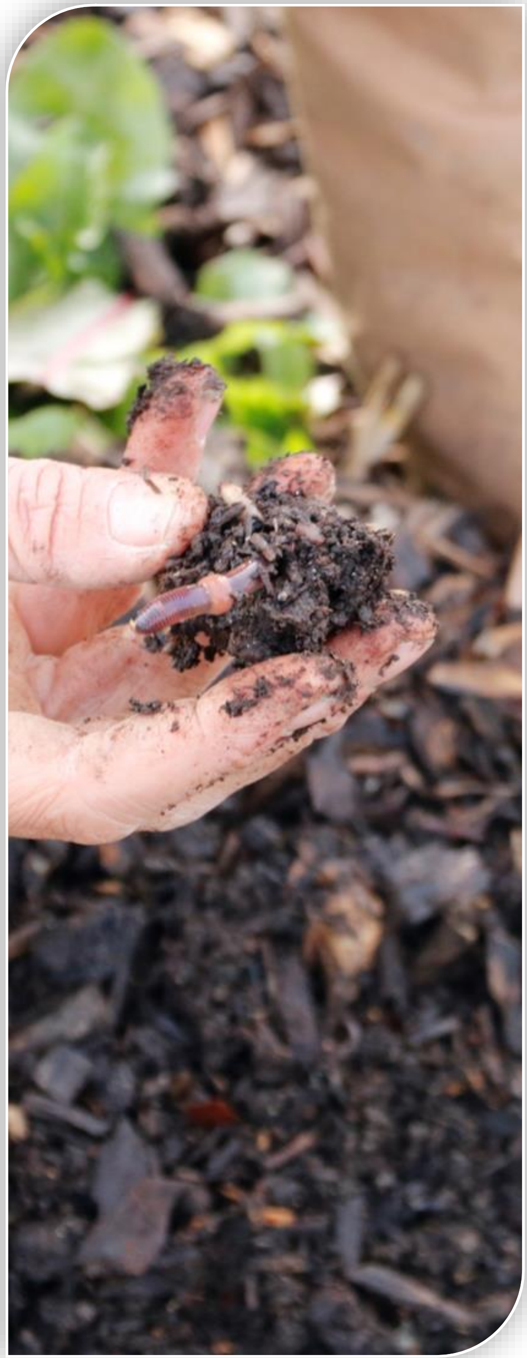
Van der Ploeg et al 2006; Teague et al. 2016; Massy 2018



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

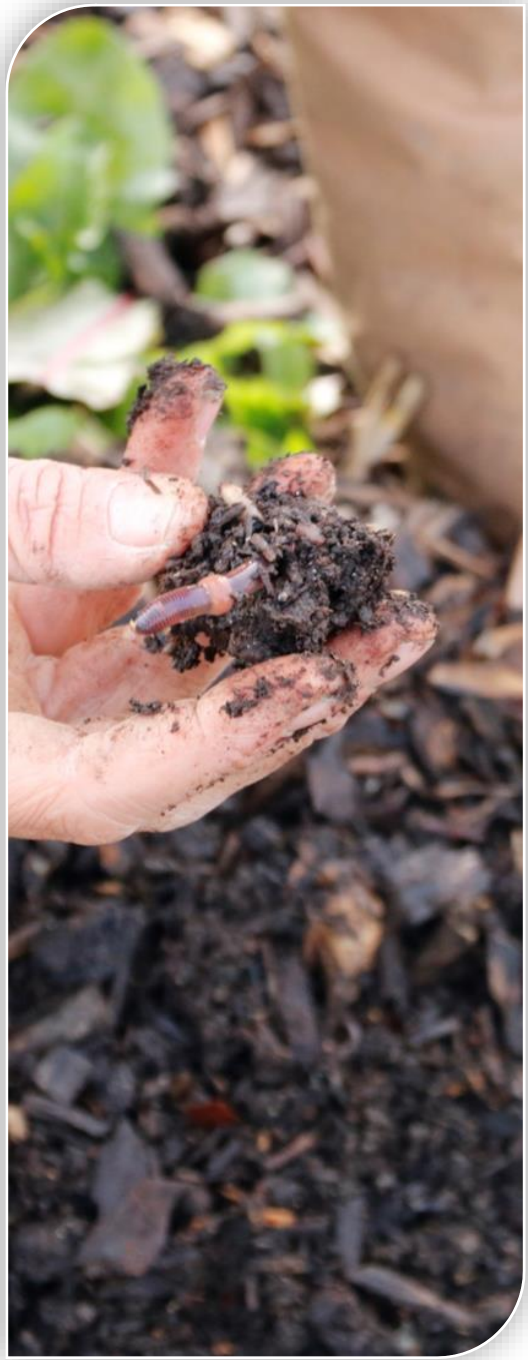
AMP vs. Continuous Grazing Research Shows:

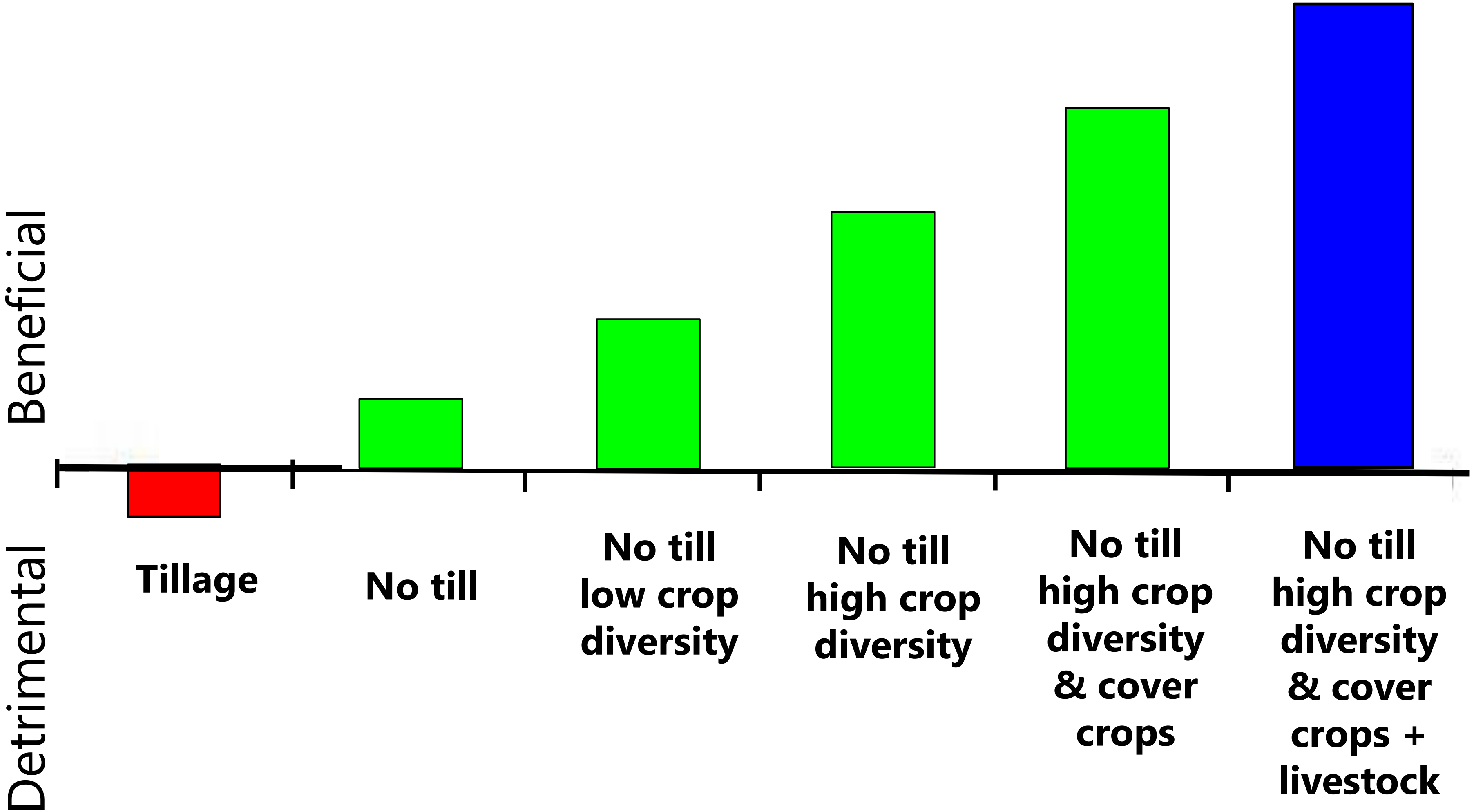
- Adaptive stocking is less sensitive to heavy stocking than fixed stocking
- As number of paddocks is increased, stocking rates can be increased while improving ecological function
- AMP advantages of over continuous grazing are more important as *paddock* and *stock* numbers increase
- Short grazing 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

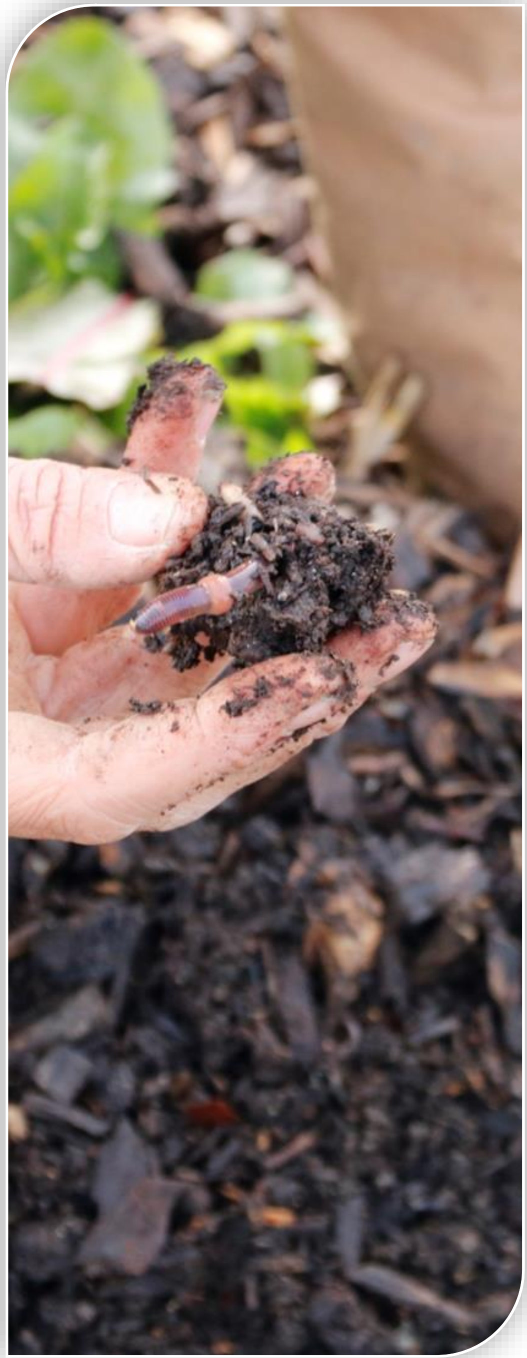
Cropland Soil Health

How different management practices influence soil health



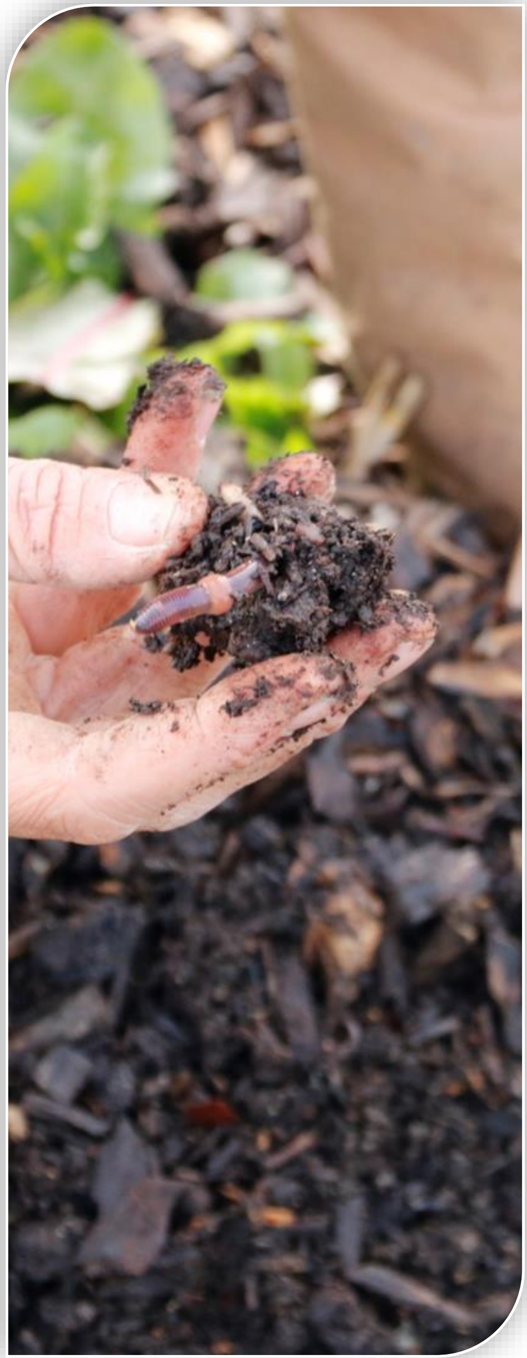


Jay Fuhrer, NRCS, North Dakota

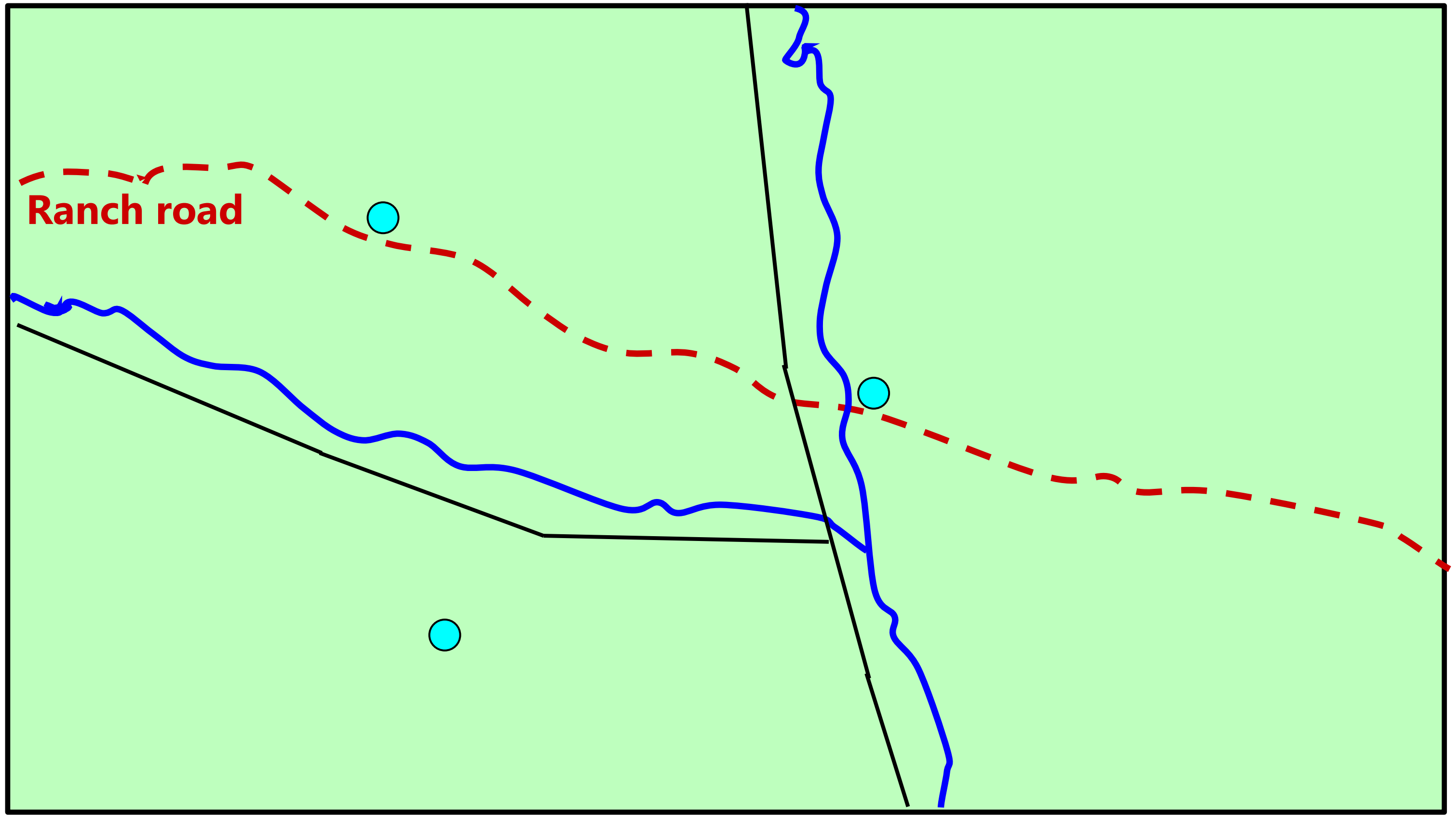


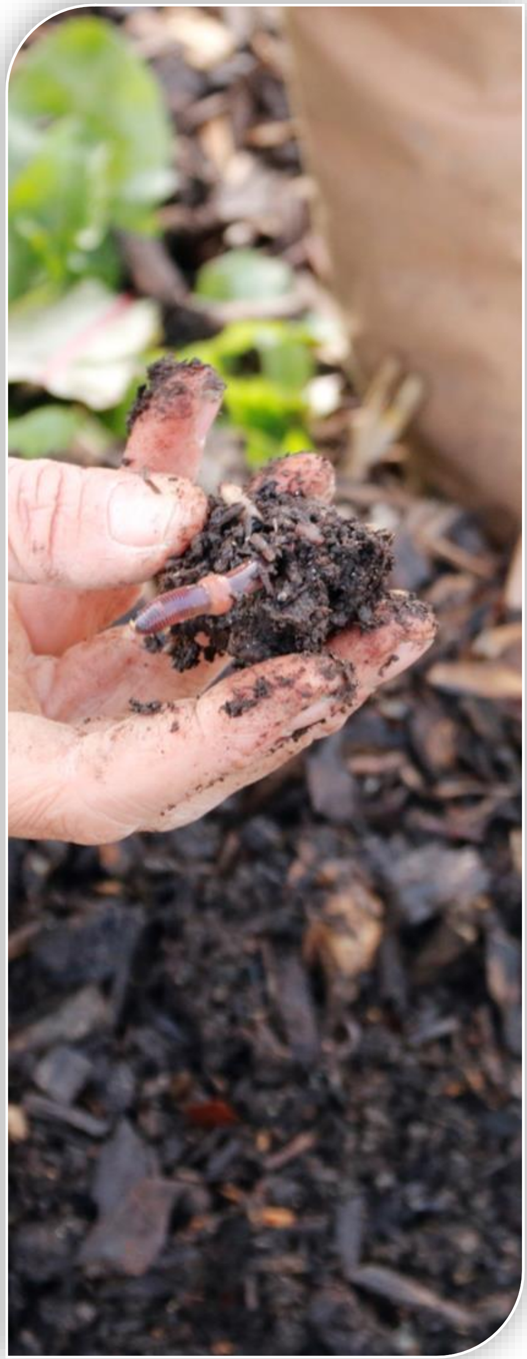
Positives with grass-based ruminants

- 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

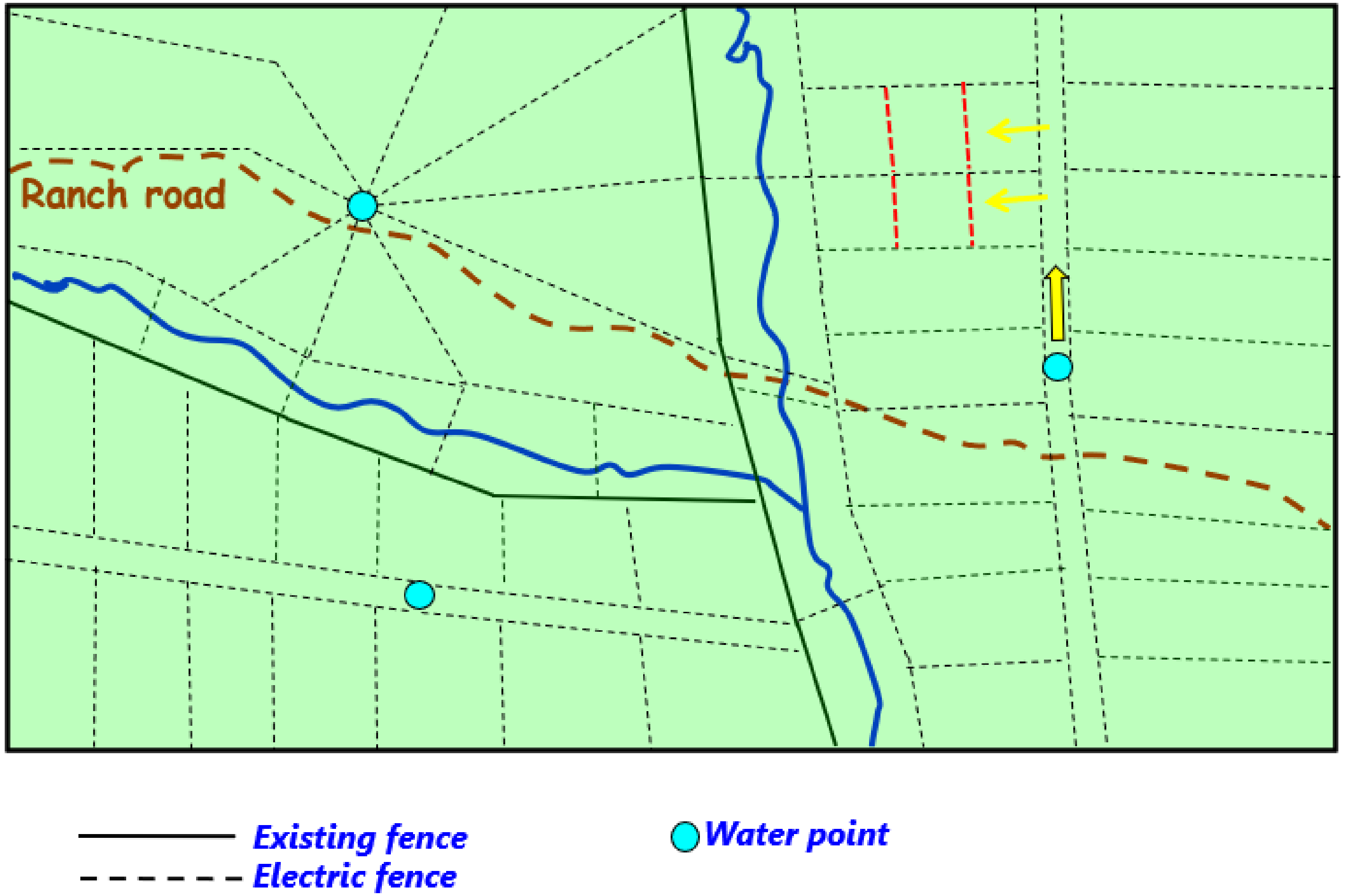


Continuous Grazing

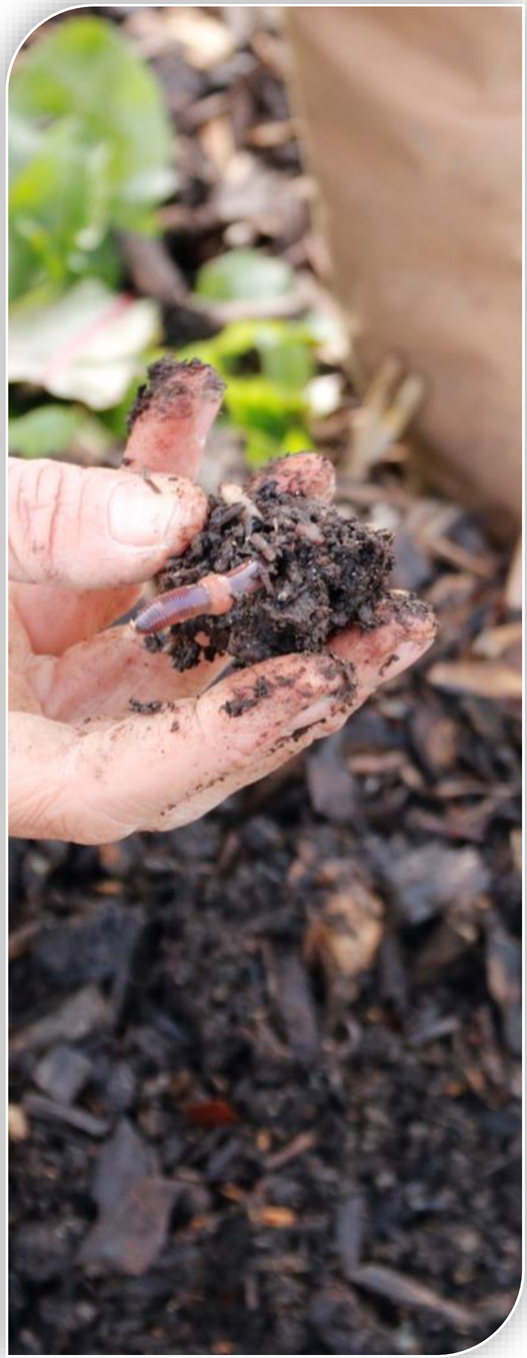




Application of AMP Grazing



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



Questions?