TEXAS A&M AGRILIFE RESEARCH

Improving Life through Science and Technology

Restoring Soil Health & Farm Livelihoods

Canadian Forage Growers Conference
Guelph, 15th Nov, 2017

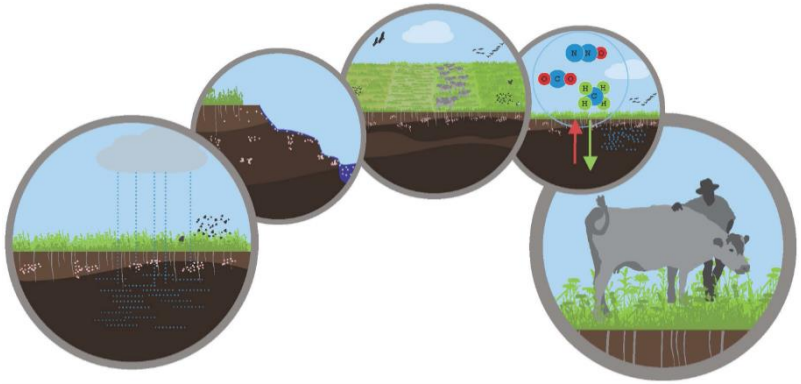
Richard Teague,
Texas A&M AgriLife Research

Research Framework and Hypothesis:

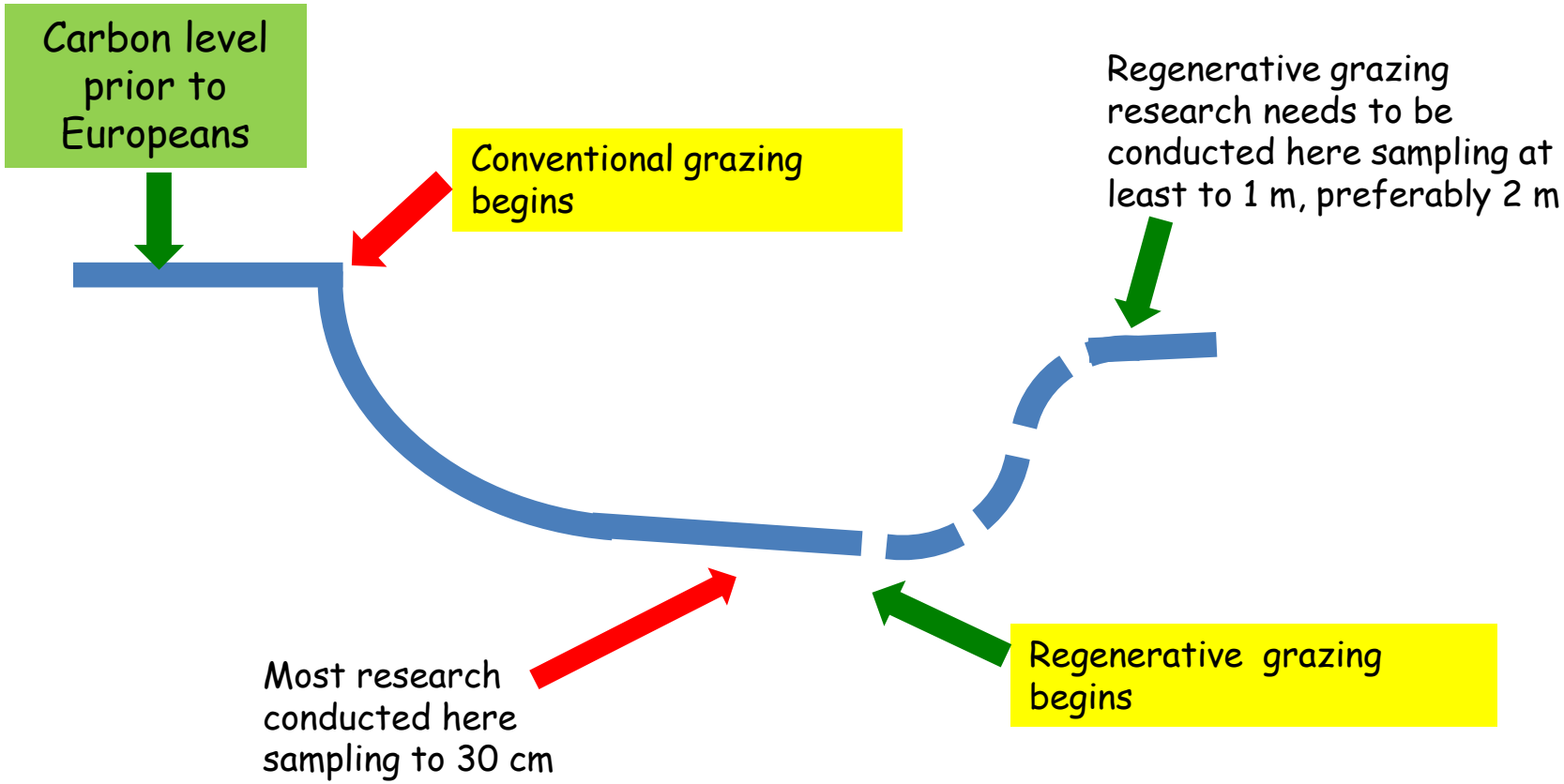
Carbon rich soil is healthy soil and beneficial for the entire ecosystem

Healthy Ecosystems function by drawing down CO_2 into the soil, *resulting in*:

- Improved water infiltration and retention;
- Improved soil nutrient status, access and retention;
- Increased diversity of fungi, microbes, plants, insects, wildlife;
- Reduced soil erosion and reduced NET GHG emissions; and
- Contributing to both improved livestock and farmer well-being.



Soil Carbon changes with human management



90% of Soil function is mediated by microbes

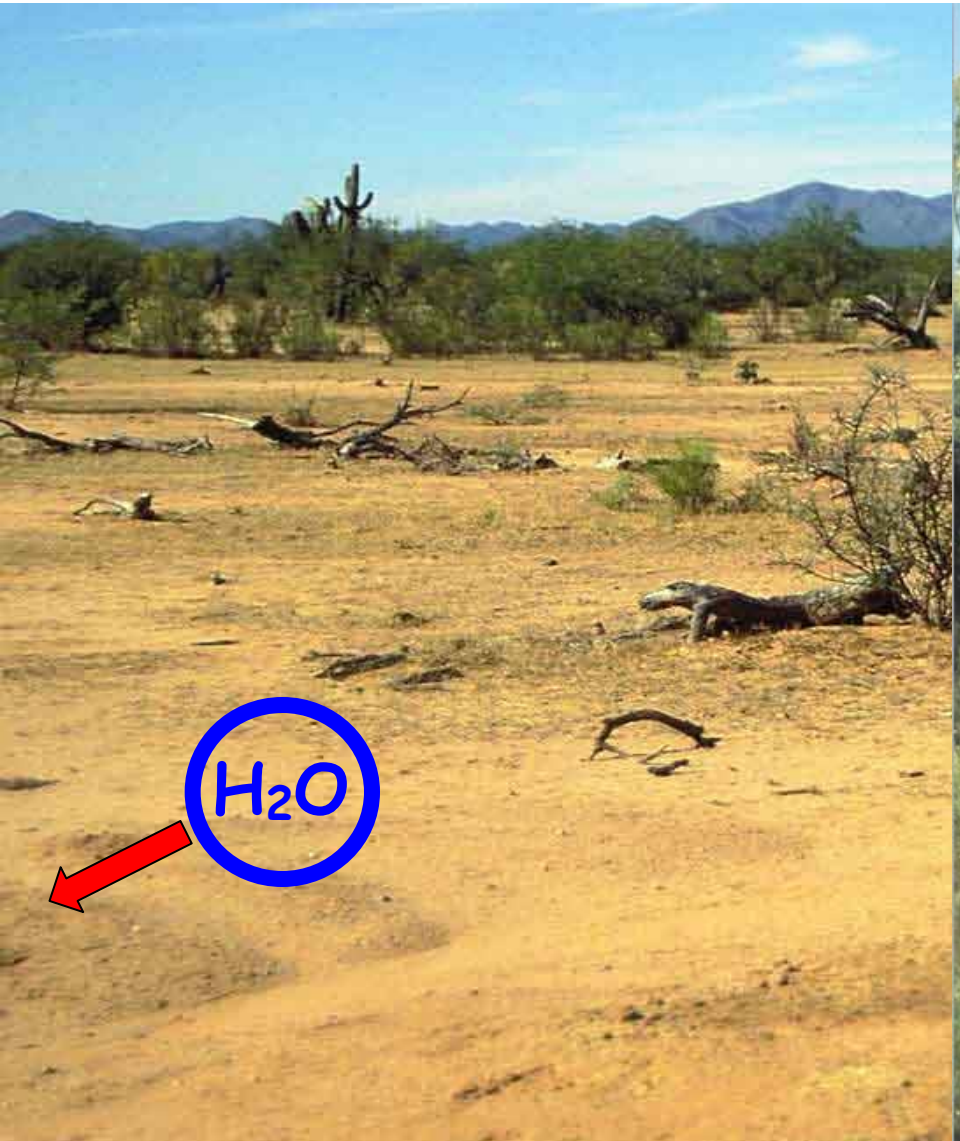
Microbes depend on plants

So how we manage plants is critical

Ingham 2000; Jones 2016; Lehman et al. 2016

Biggest limiting factor in grazing land

Water in the Soil



The Four Ecosystem Processes

1. **Energy flow** – Maximize the flow of solar energy through plants and soil.

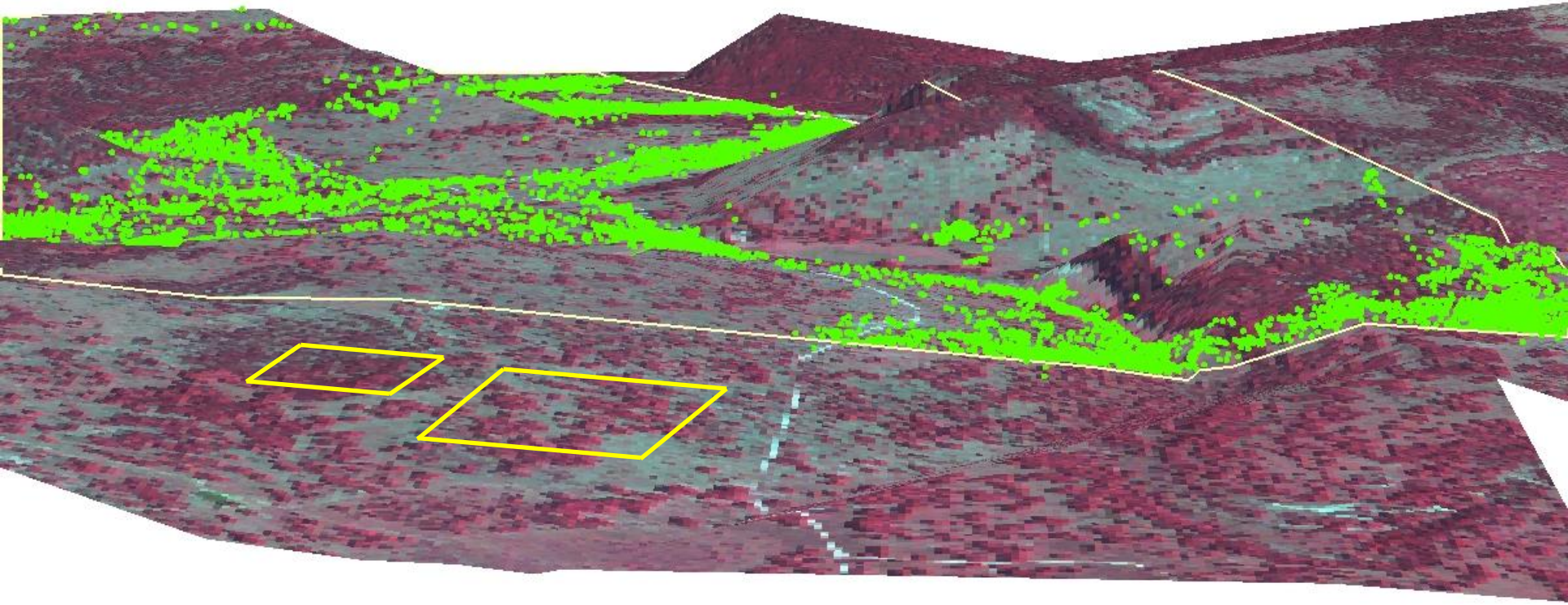
2. **Hydrological function** – Maximize capture and cycling of water through plants and soil. Reduce export and import.

3. **Mineral cycle** – Maximize cycling of nutrients through plants and soil.

4. **Community dynamics** – High ecosystem biodiversity with more complex mixtures and combinations of desirable plant species leads to increased stability and productivity

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



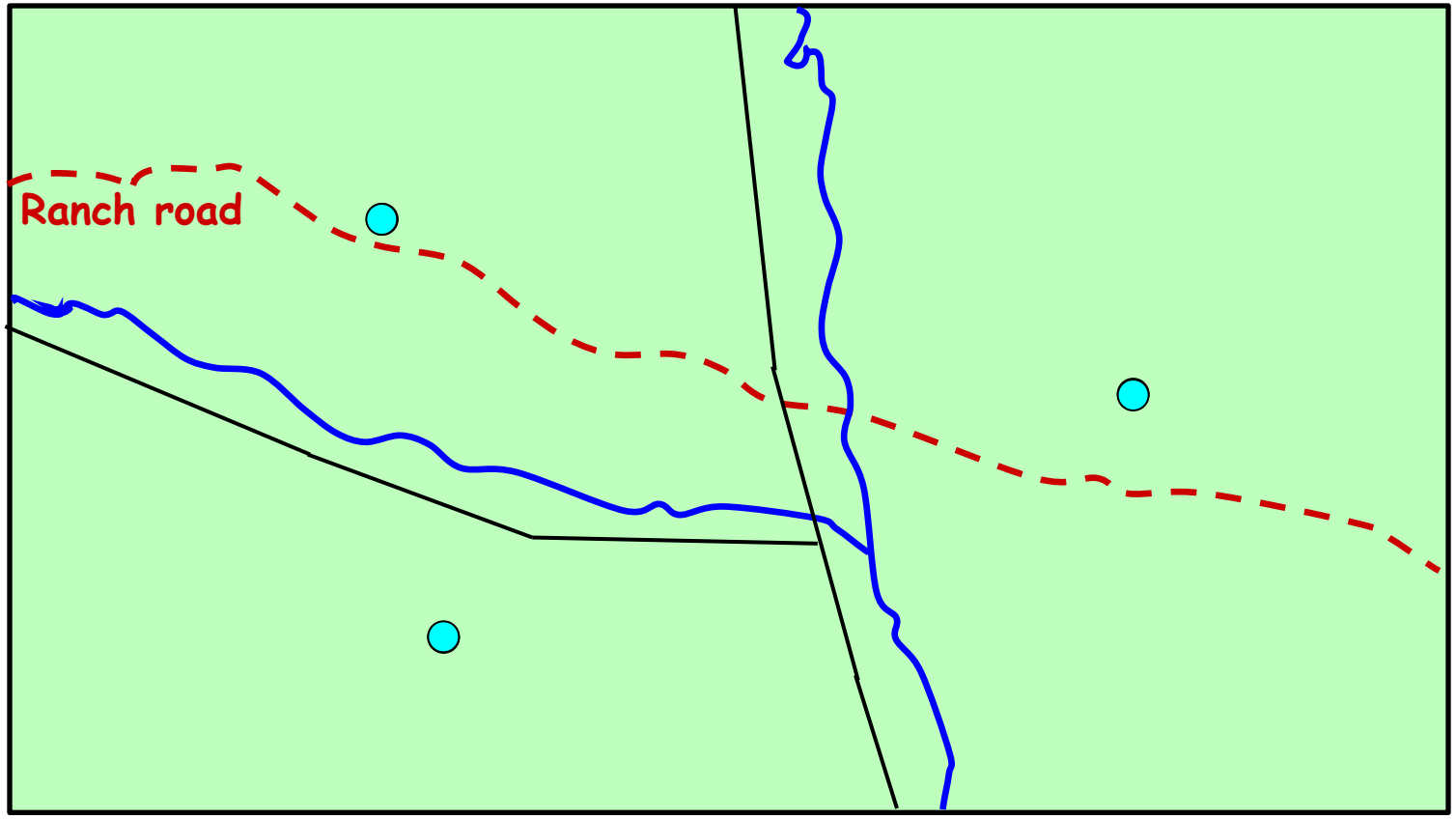
Norton 1998; Norton et al. 2013; Jakoby et al. 2014

Light continuous grazing

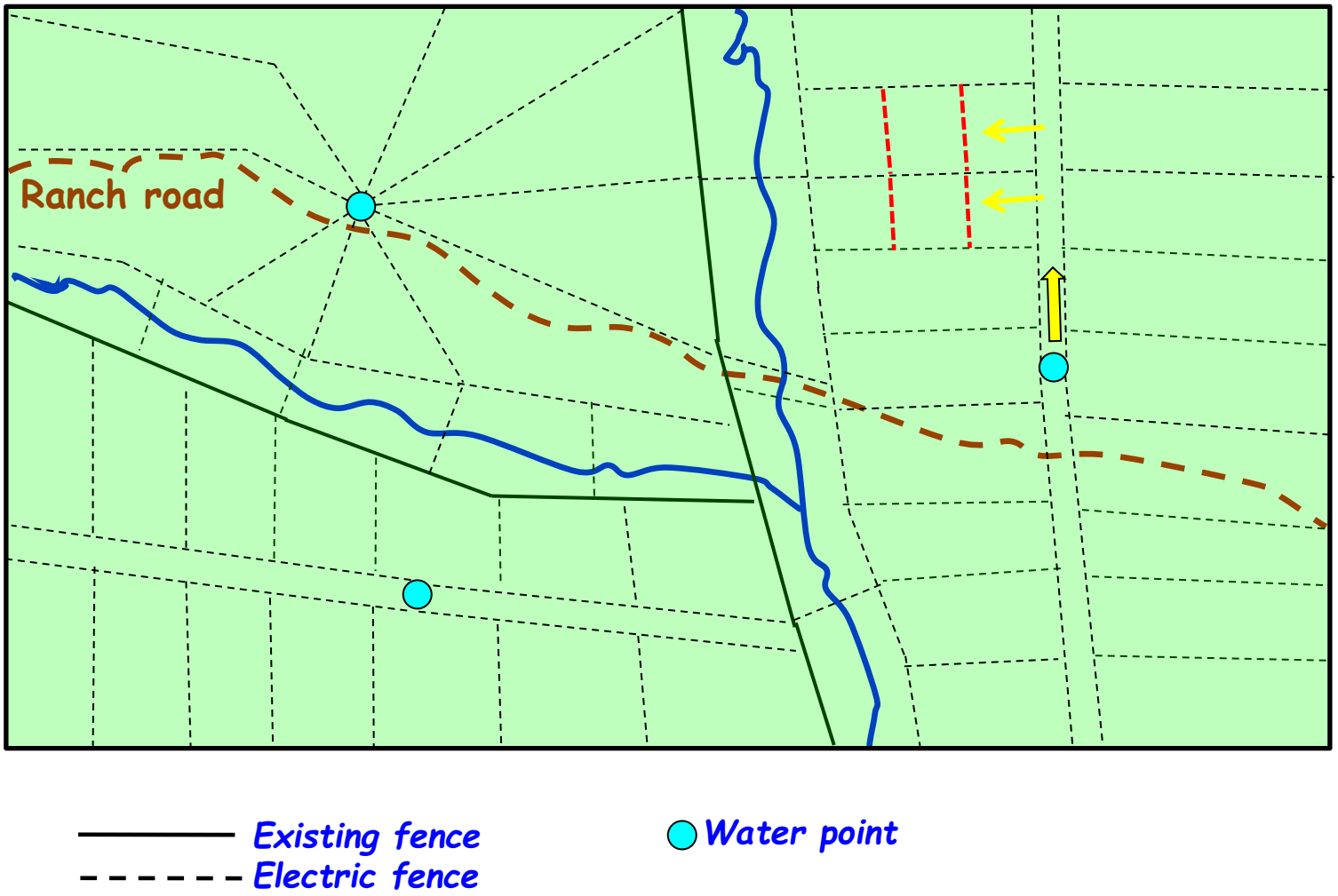
- patch selection
- no recovery

Heavy continuous grazing

Continuous Grazing



Application of AMP Grazing



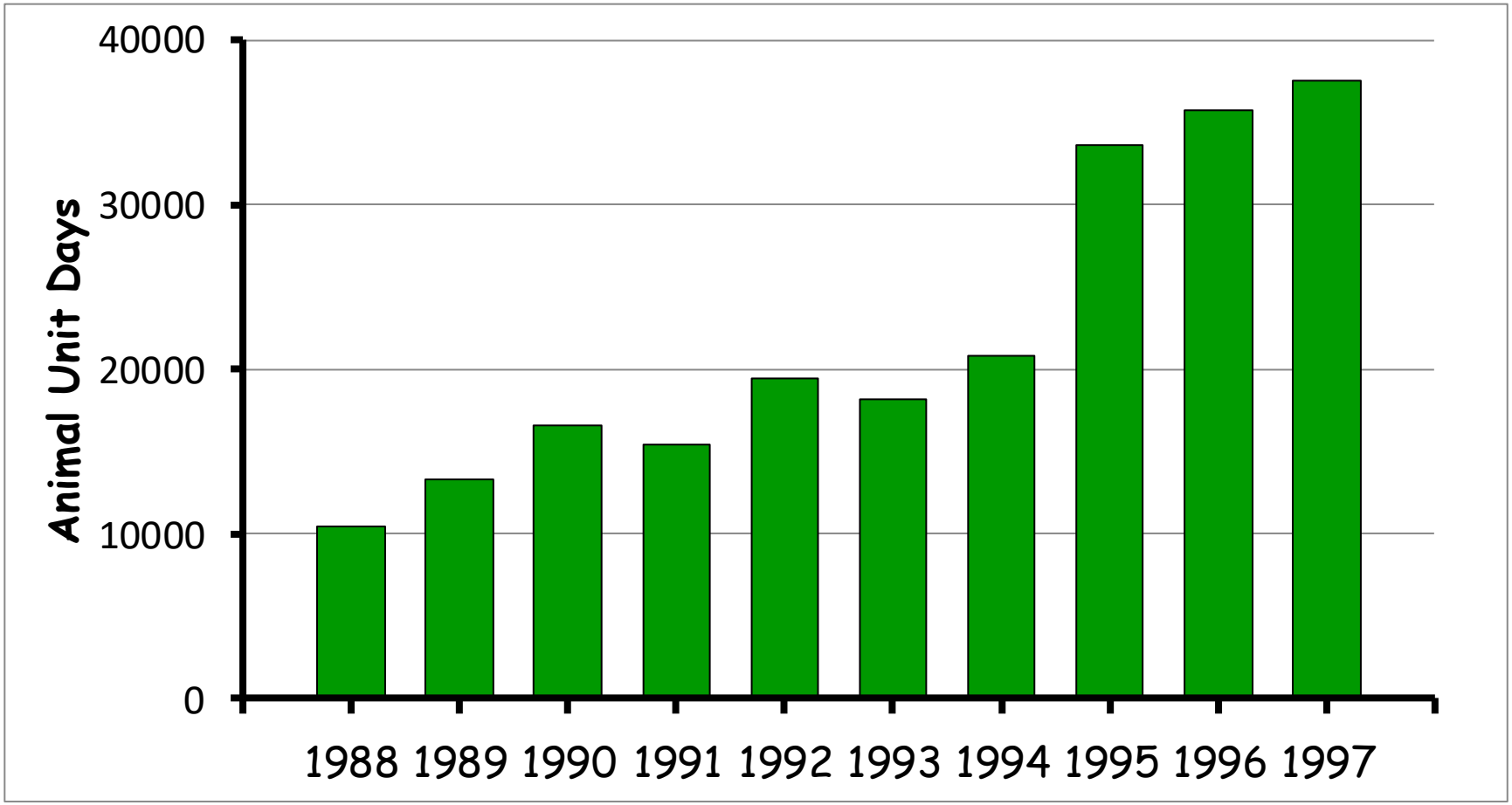
Norton et al. 2013; Jakoby et al. 2014; Teague et al. 2015

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

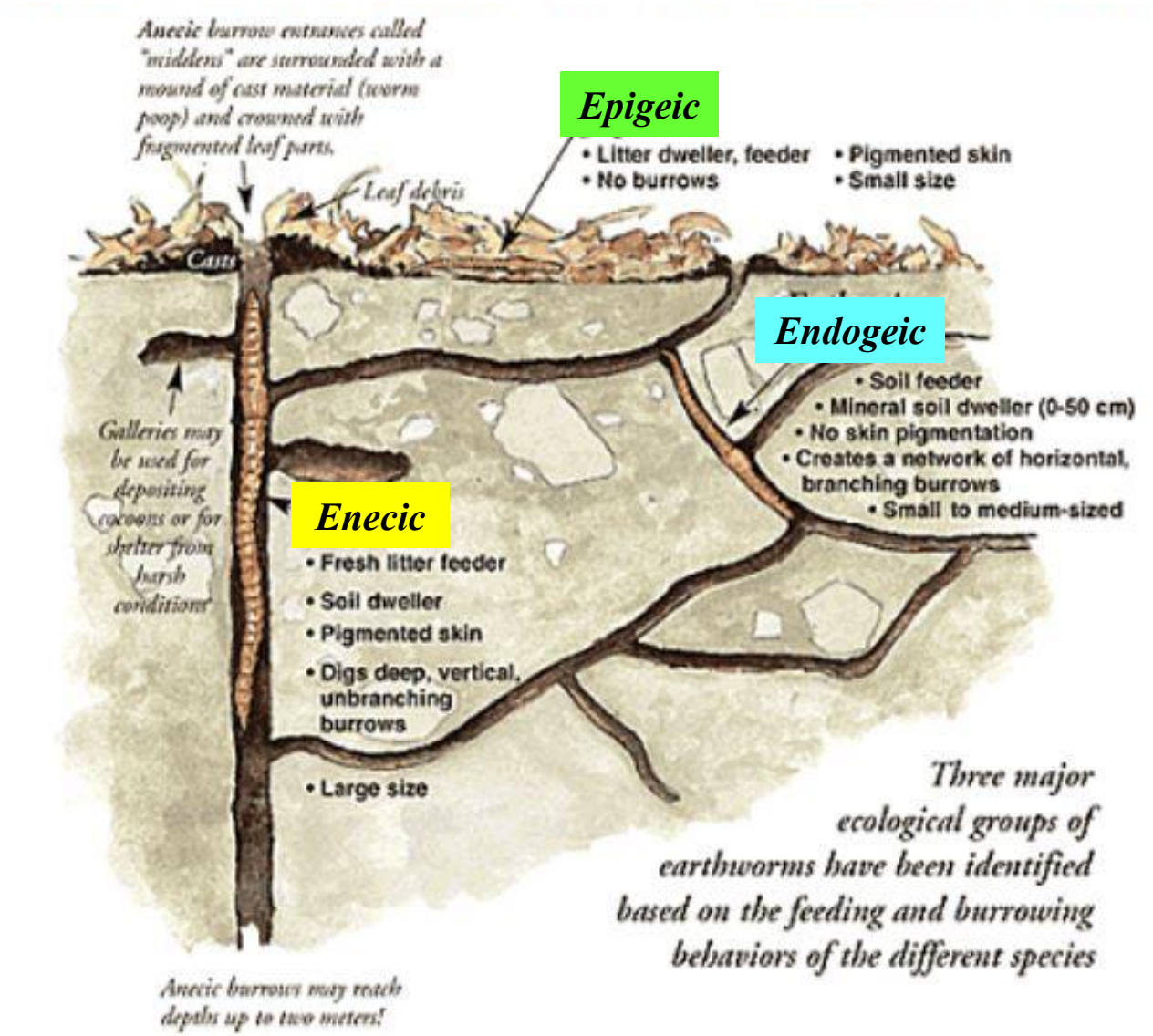
Norton et al. 2013; Jakoby et al. 2014; Teague et al. 2013; 2015

From Published Science:
Importance of Microbes and Fungi

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

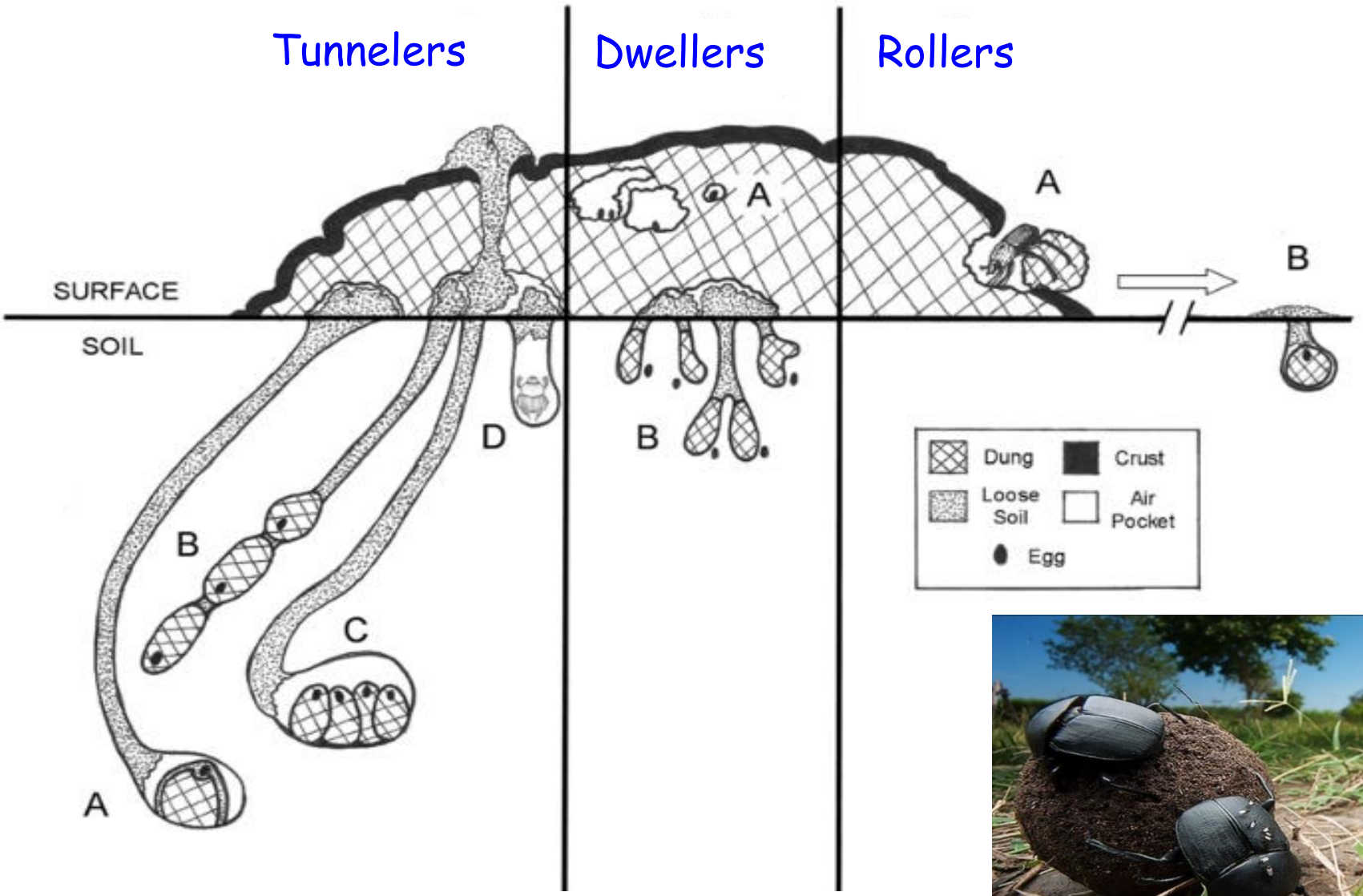
Ingham et al. 1985; Lehman et al. 2016; Montgomery 2017

Earthworms in the ecosystem



Edwards 2005; Blouin *et al.* 2013

Dung beetles in the Ecosystem

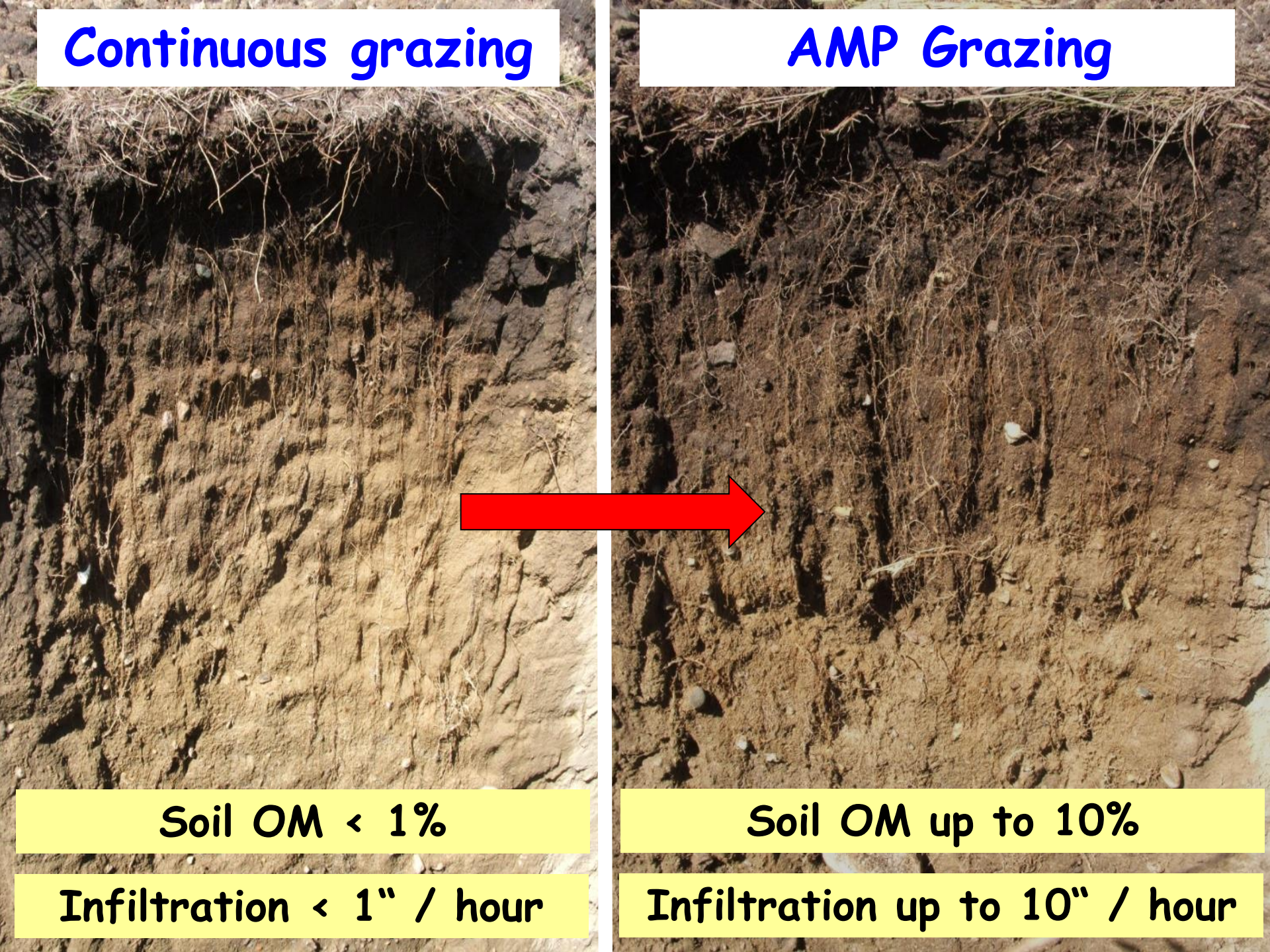


Herrick & Lal 1995; Richardson *et al.* 2000

High density Regenerative AMP grazing

200 cows drop 25 tons of dung a week

- Increase infiltration ~ 130%
- Reduce flies


Continuous grazing
AMP Grazing
Soil OM < 1%
Infiltration < 1" / hour
Soil OM up to 10%
Infiltration up to 10" / hour

Hypothesized Causal Mechanisms:

Energy Flow

Hydrological Cycle

Mineral Cycle

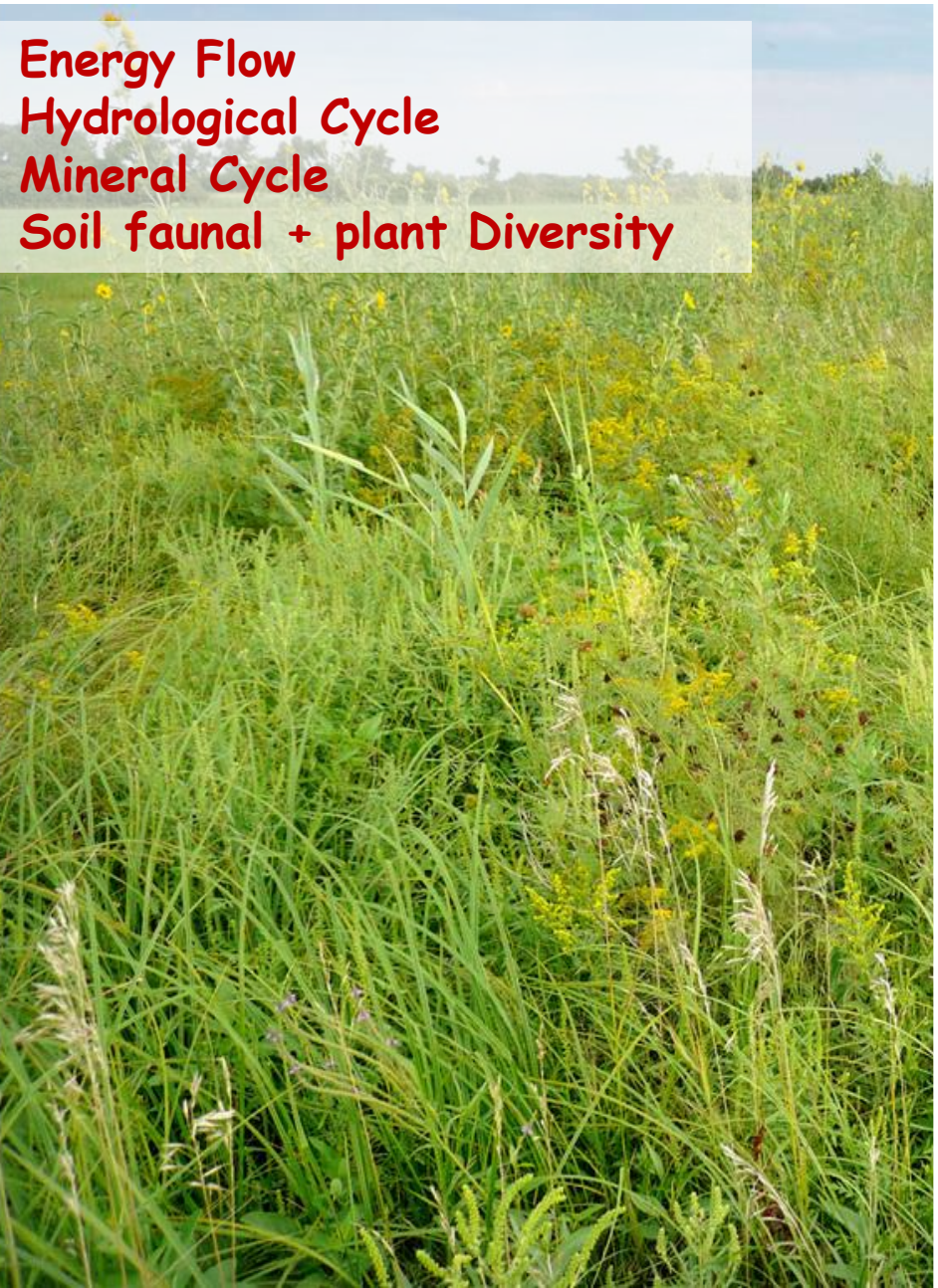
Soil faunal + plant Diversity

AMP grazing

Continuous grazing

AMP Grazing

Energy Flow
Hydrological Cycle
Mineral Cycle
Soil faunal + plant Diversity



No-grazing

Initial Texas Grazing Research

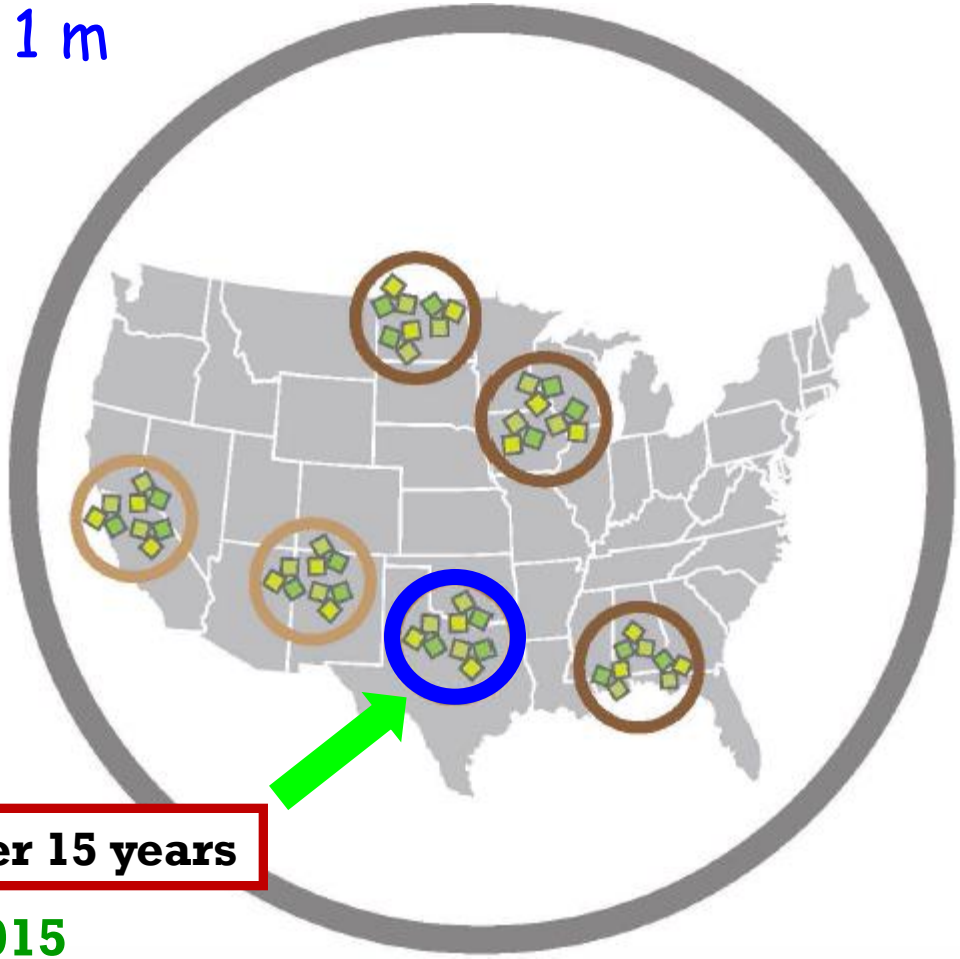
- AMP grazing gave 3 tC/ha/year ***more*** than usual heavy continuous grazing
- Decreased bare ground
- Bolstered soil fertility
- Enriched soil microbial composition
- Improved soil water holding capacity
- Improved plant species composition
- Enhanced plant productivity
- Increased livestock production

Teague et al. 2011

Published research

AMP had higher C gain/year than continuous grazing neighbors

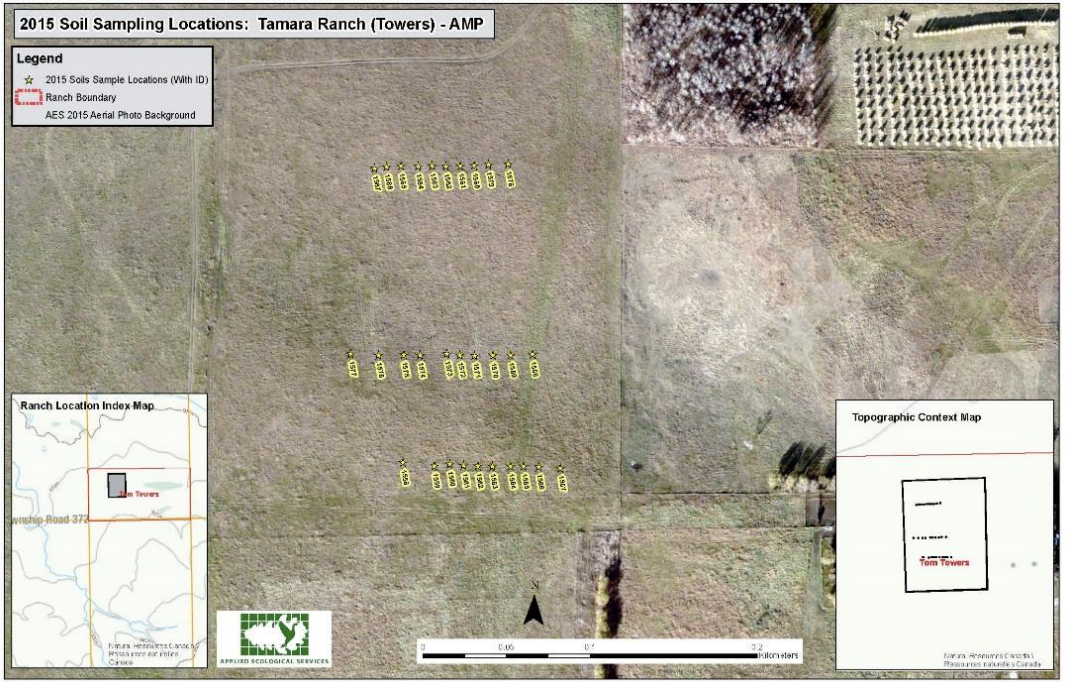
Measured to 1 m

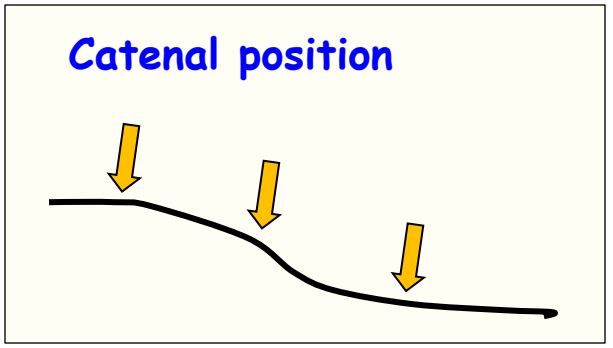


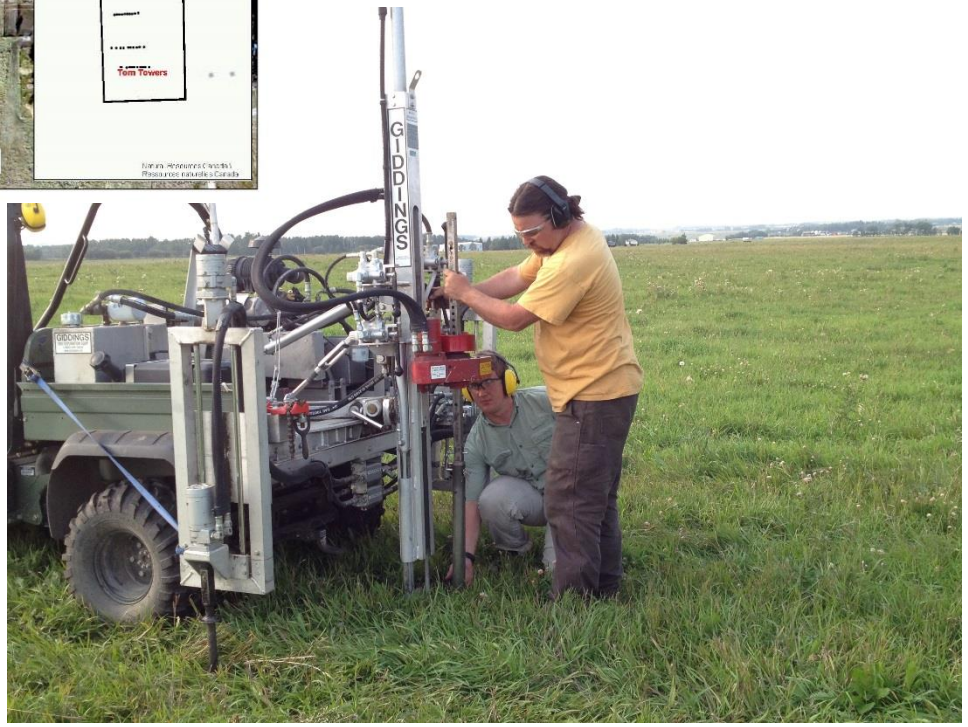
3 tC/ha/yr over 15 years

Wang et al. 2015

Paired AMP, HCG, and LCG Soil Catena Sampling

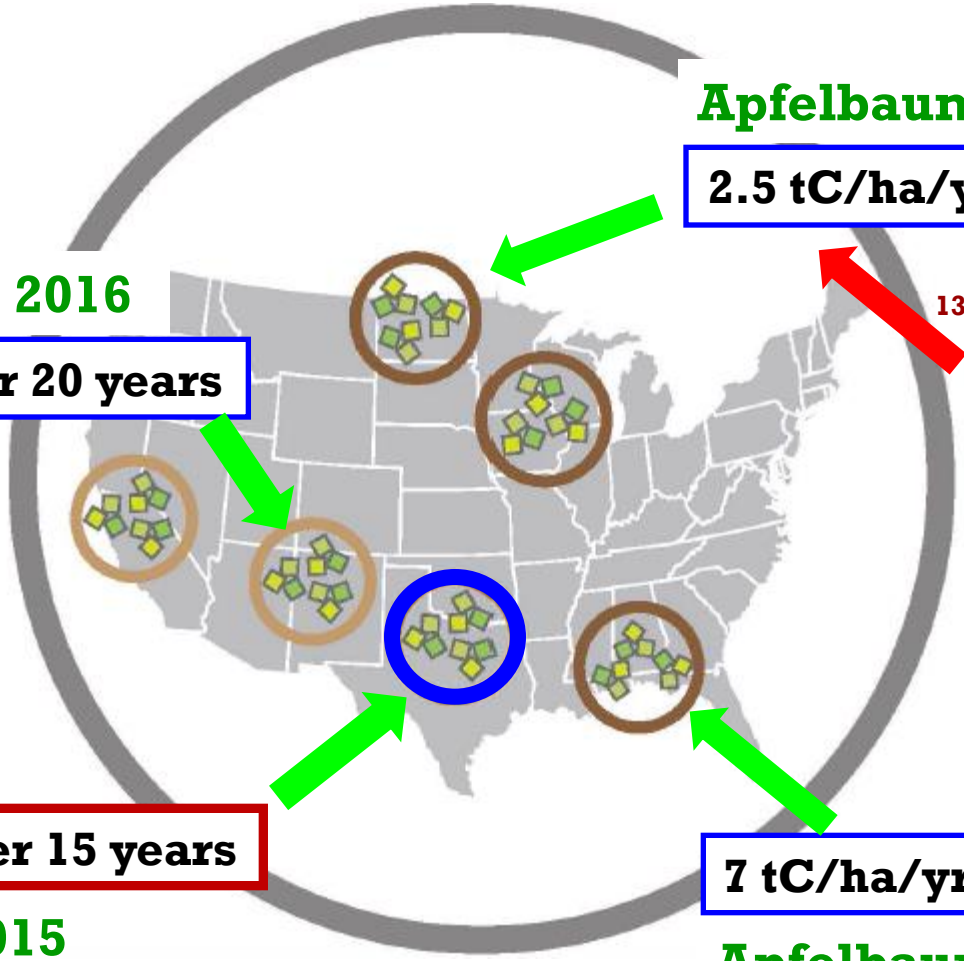






Published & Reconnaissance Sampling

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

$^{13}CO_2$ Isotope Sampling
3.0 tC/Ha/yr

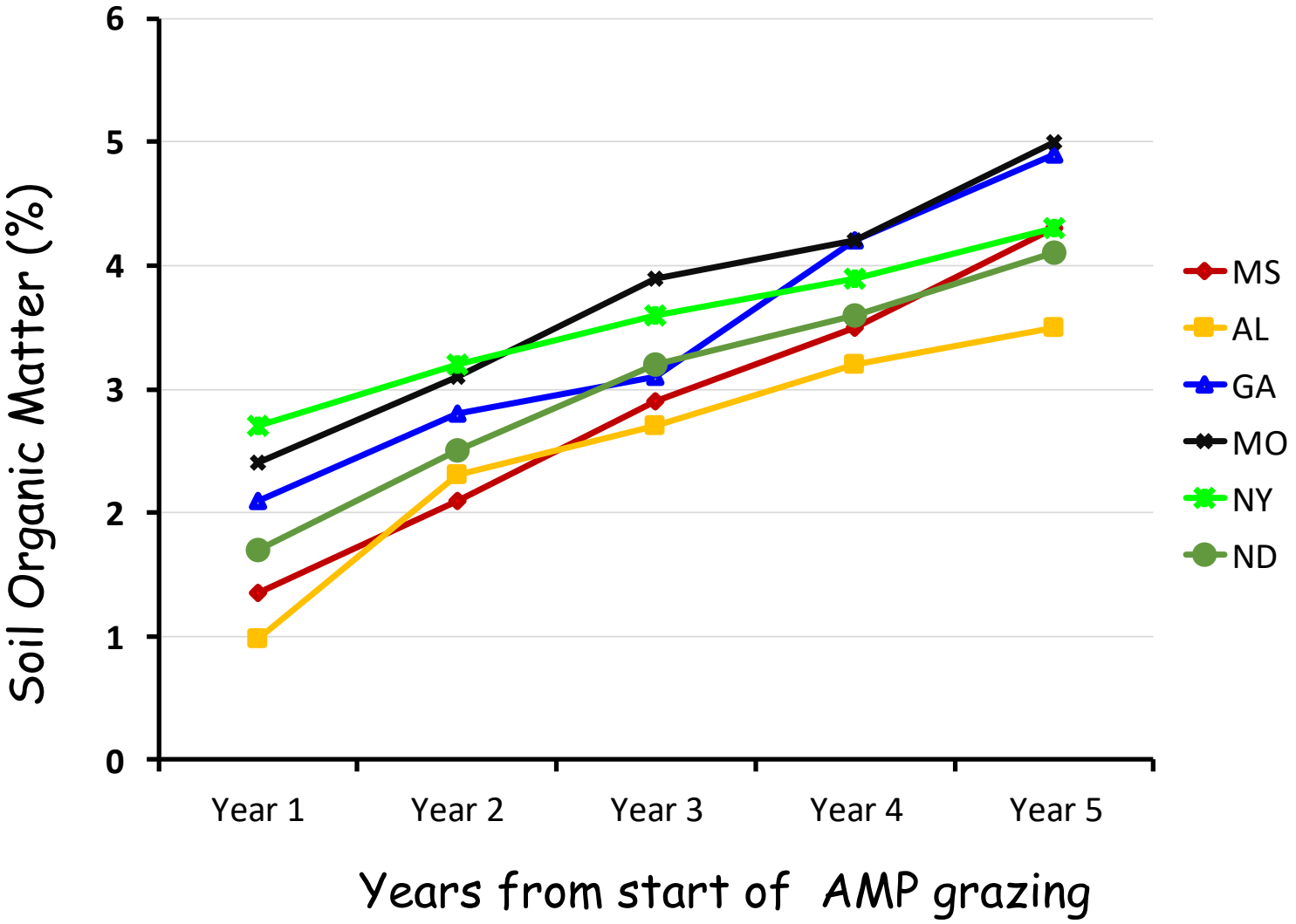
3 tC/ha/yr over 15 years

Wang et al. 2015

7 tC/ha/yr over 5 years

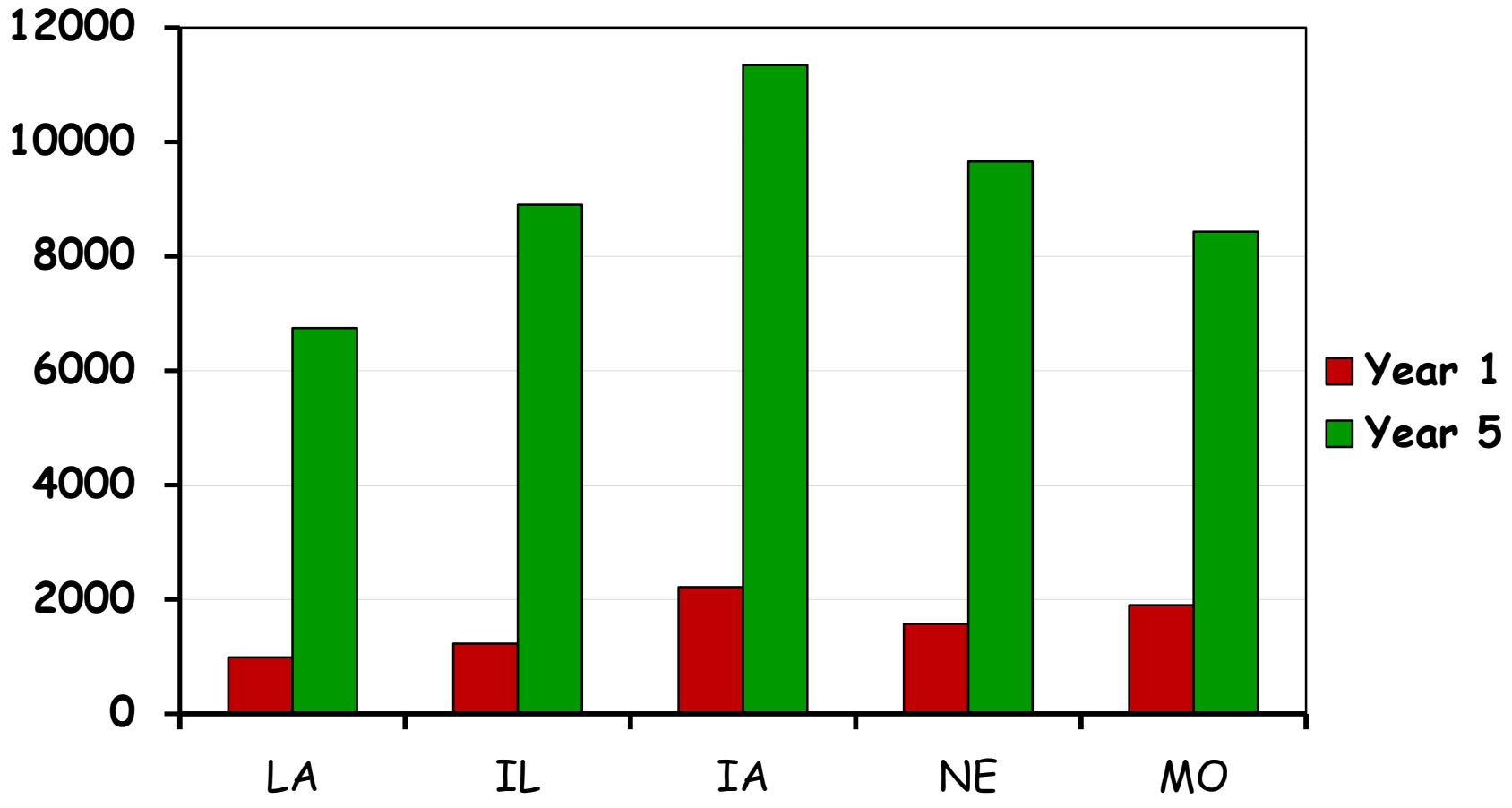
Apfelbaum et al 2015; Williams 2017

Building Soil Carbon Using AMP Grazing



Williams et al. 2017

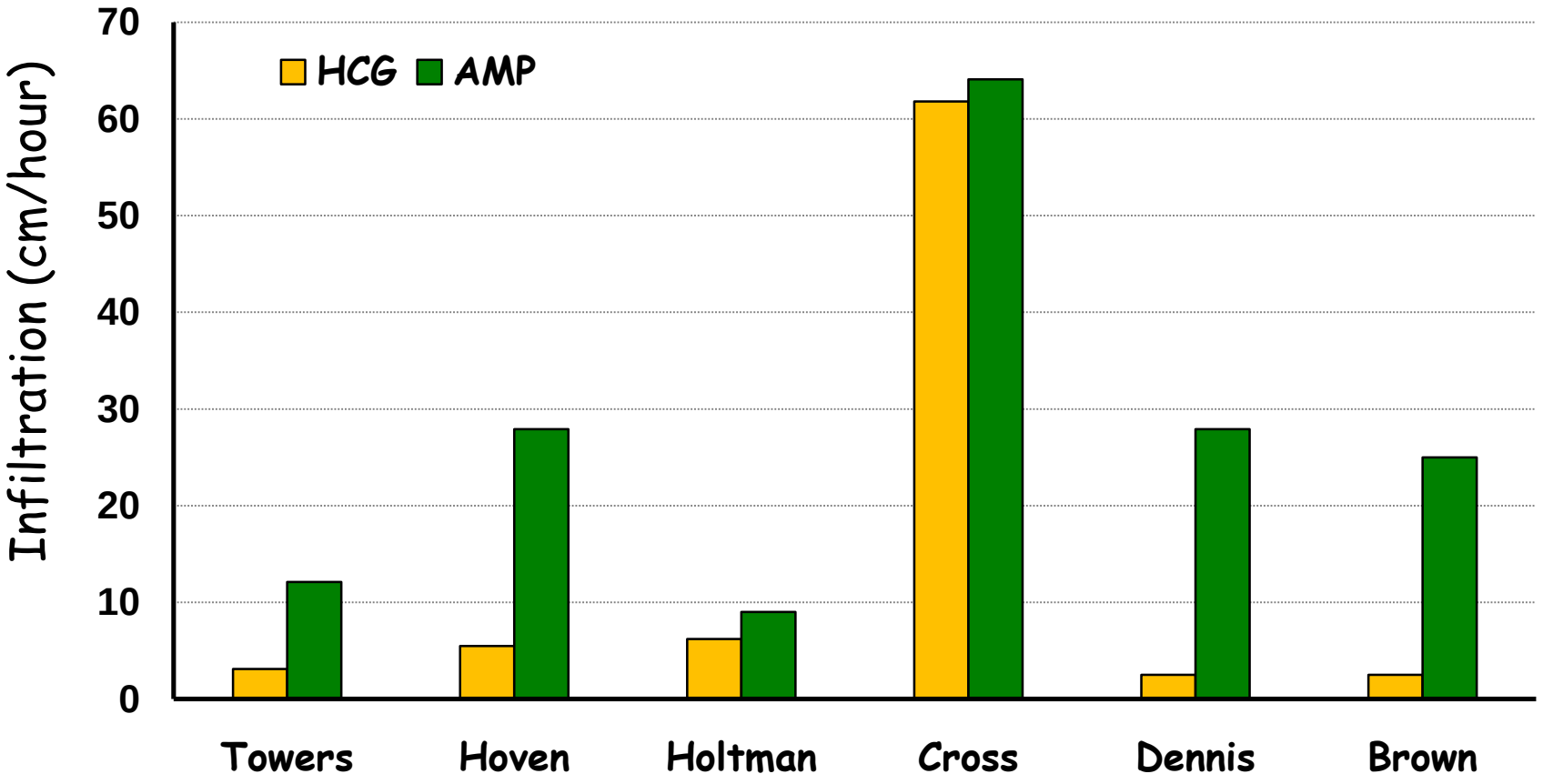
Building Microbial Biomass (ng/g of Soil)



Williams et al. 2017

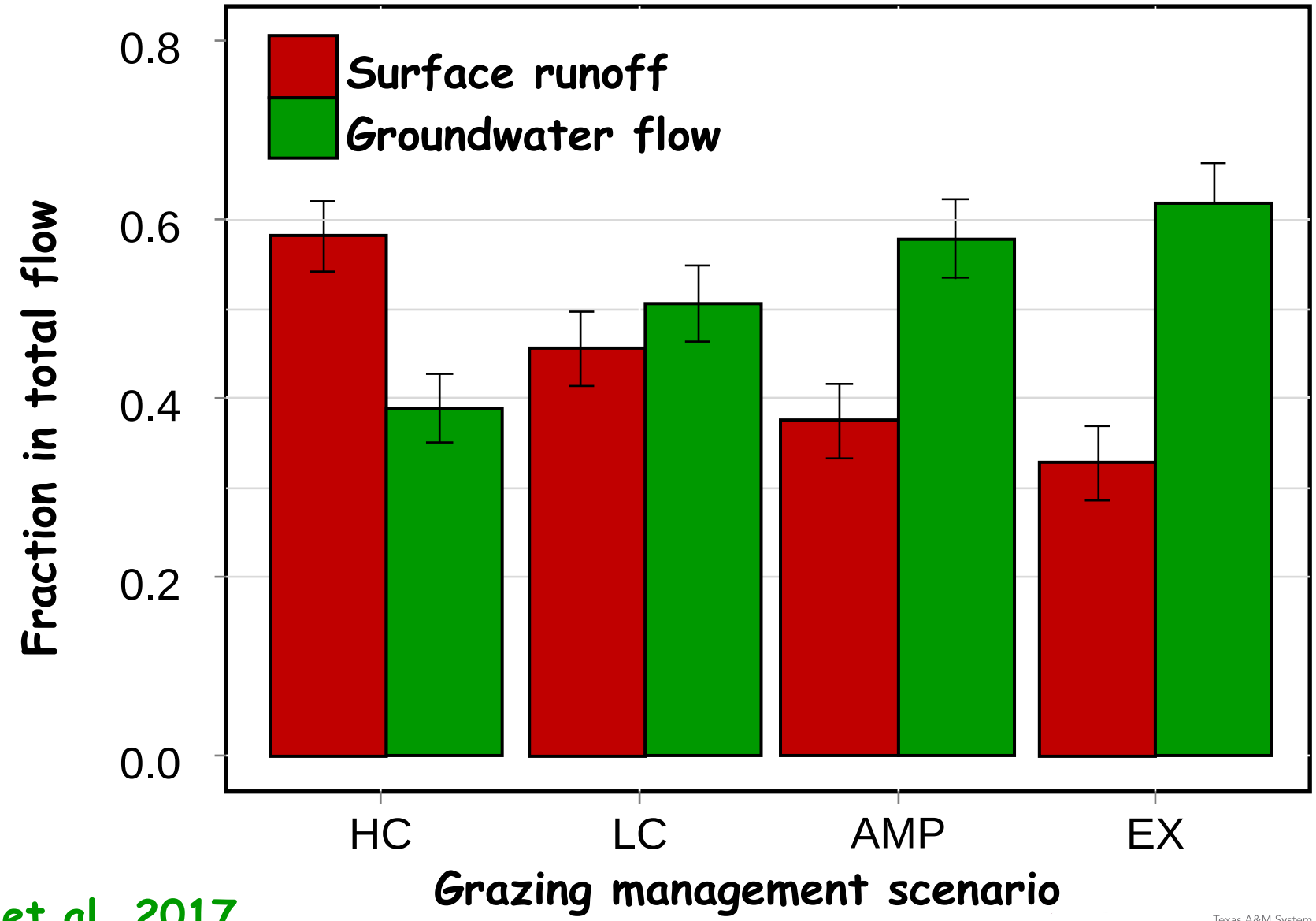
Infiltration on HCG vs. AMP grazing

Northern Great Plains



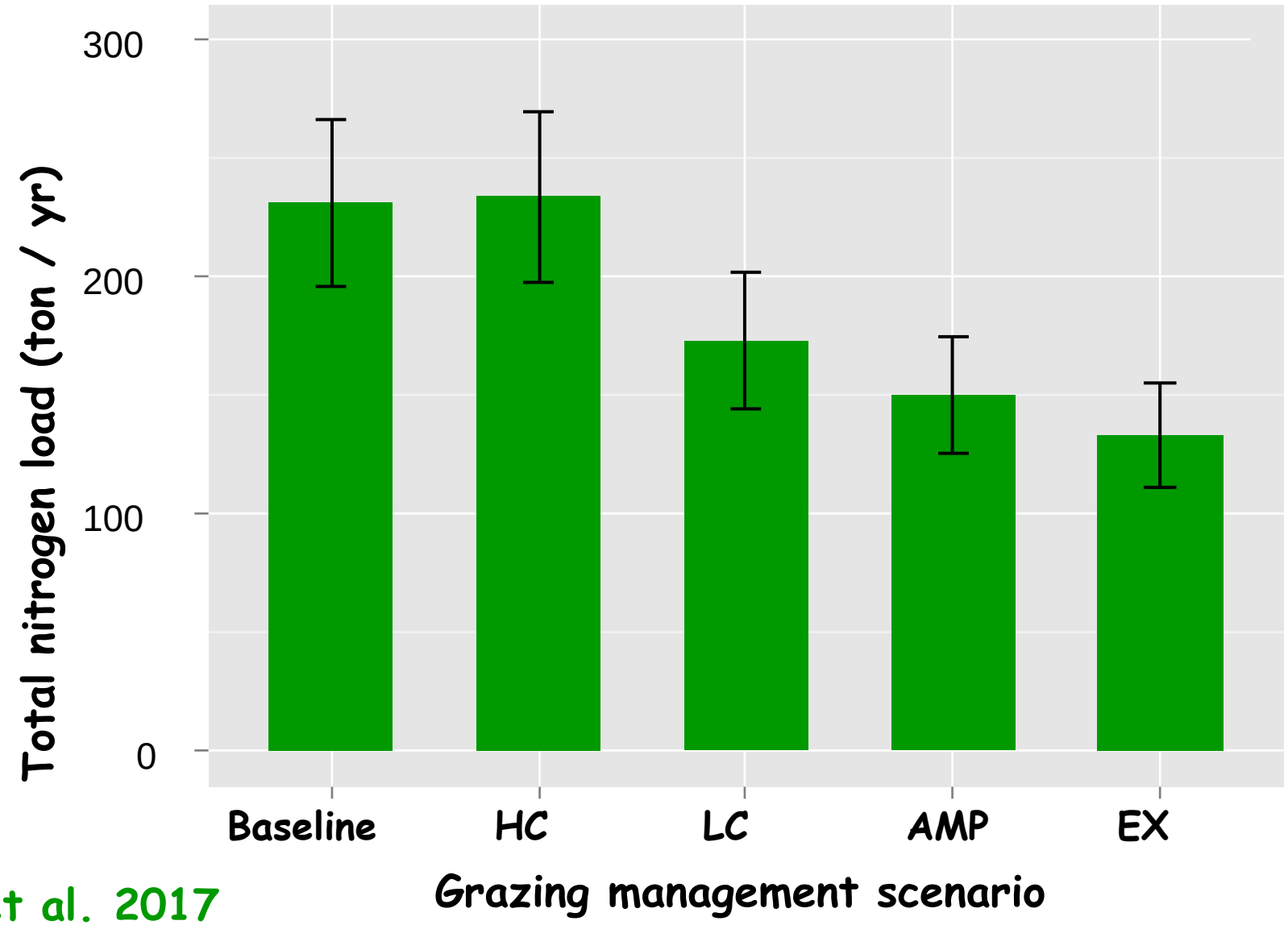
Apfelbaum et al 2016

Clear Creek watershed, North Texas



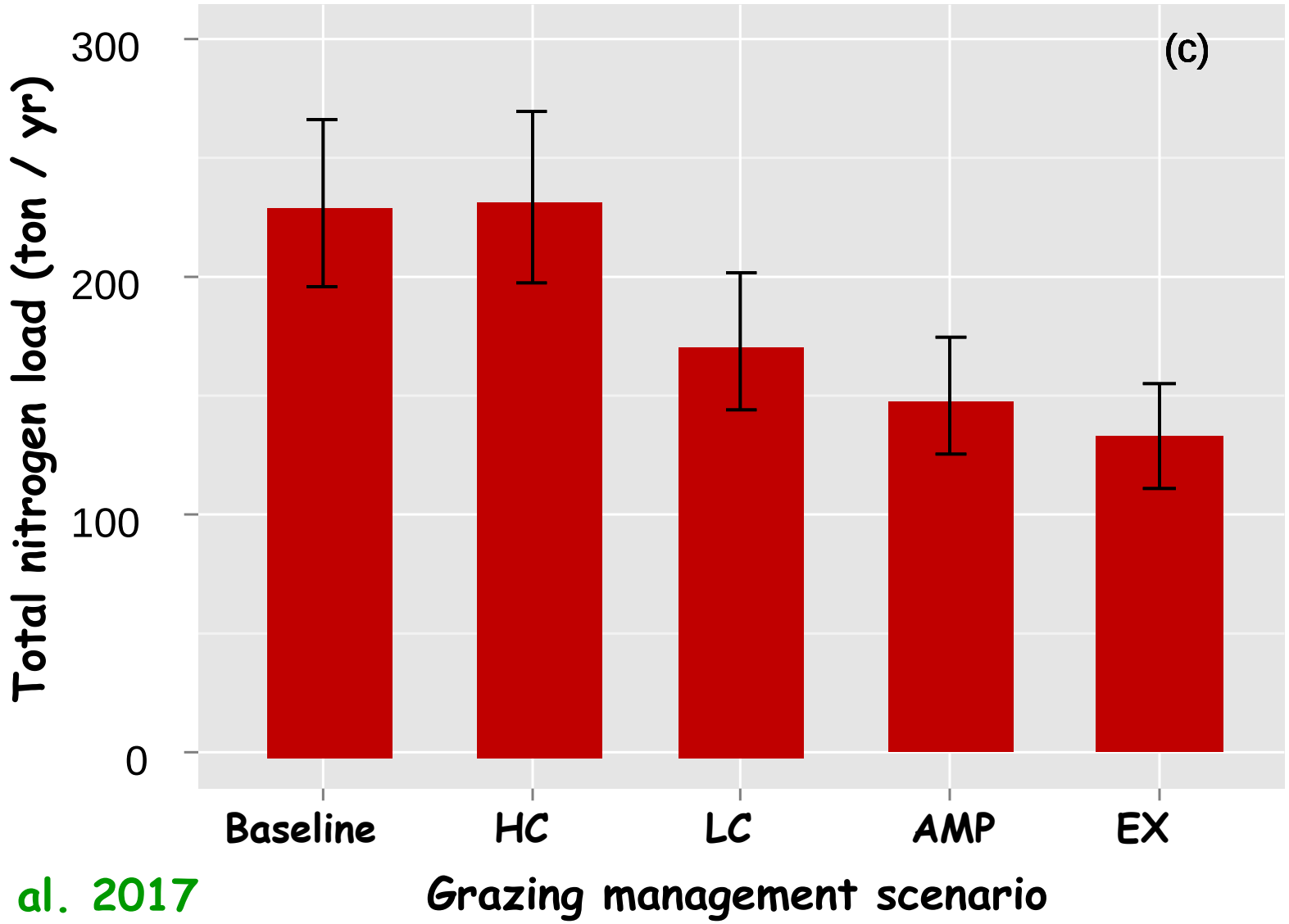
Park et al. 2017

Clear Creek – Nitrogen load



Park et al. 2017

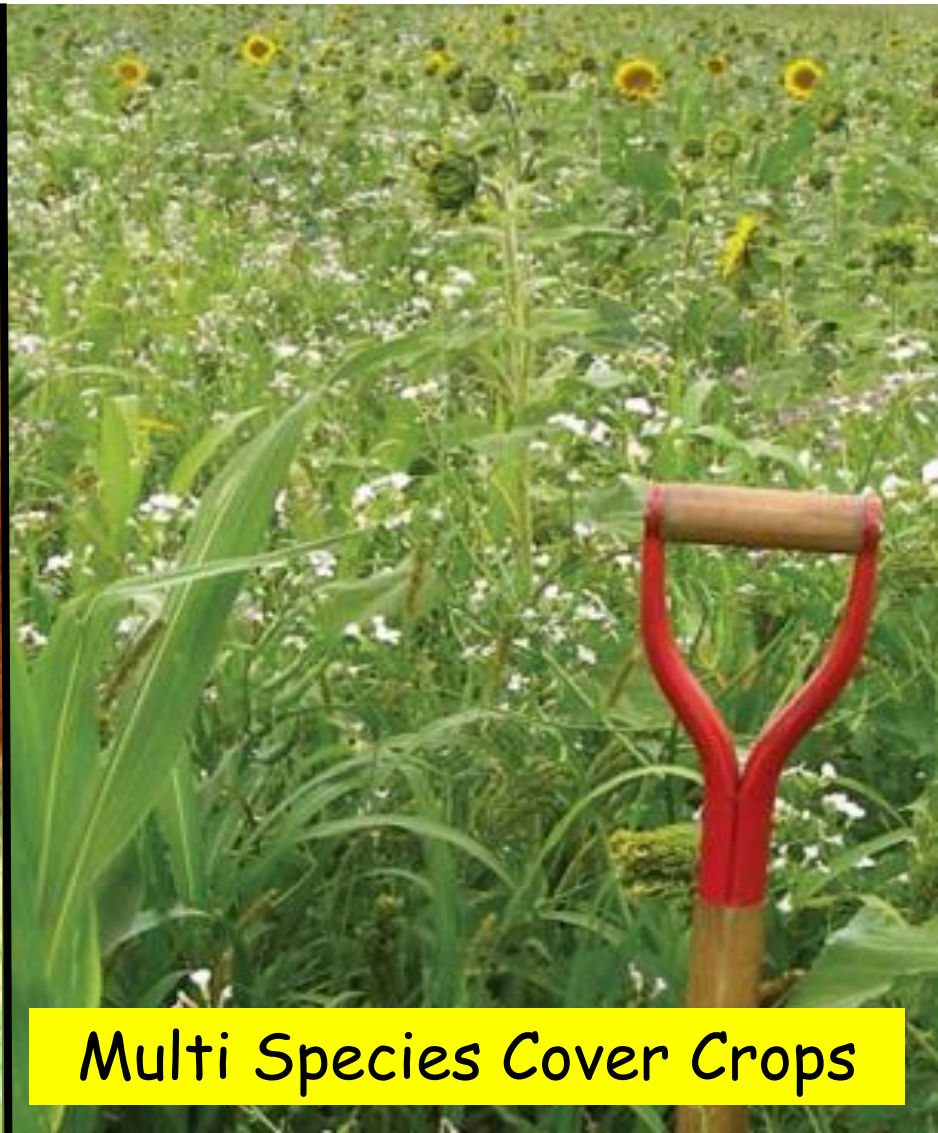
Clear Creek - Phosphorus load



Park et al. 2017

Using Cover Crops and Grazing to Boost Soil Health and Profits in Cropping Systems

High density grazing



Multi Species Cover Crops

Cover crop with 25 species


AMP grazed Cover crop

Moving to the next paddock

Is this wasted forage?

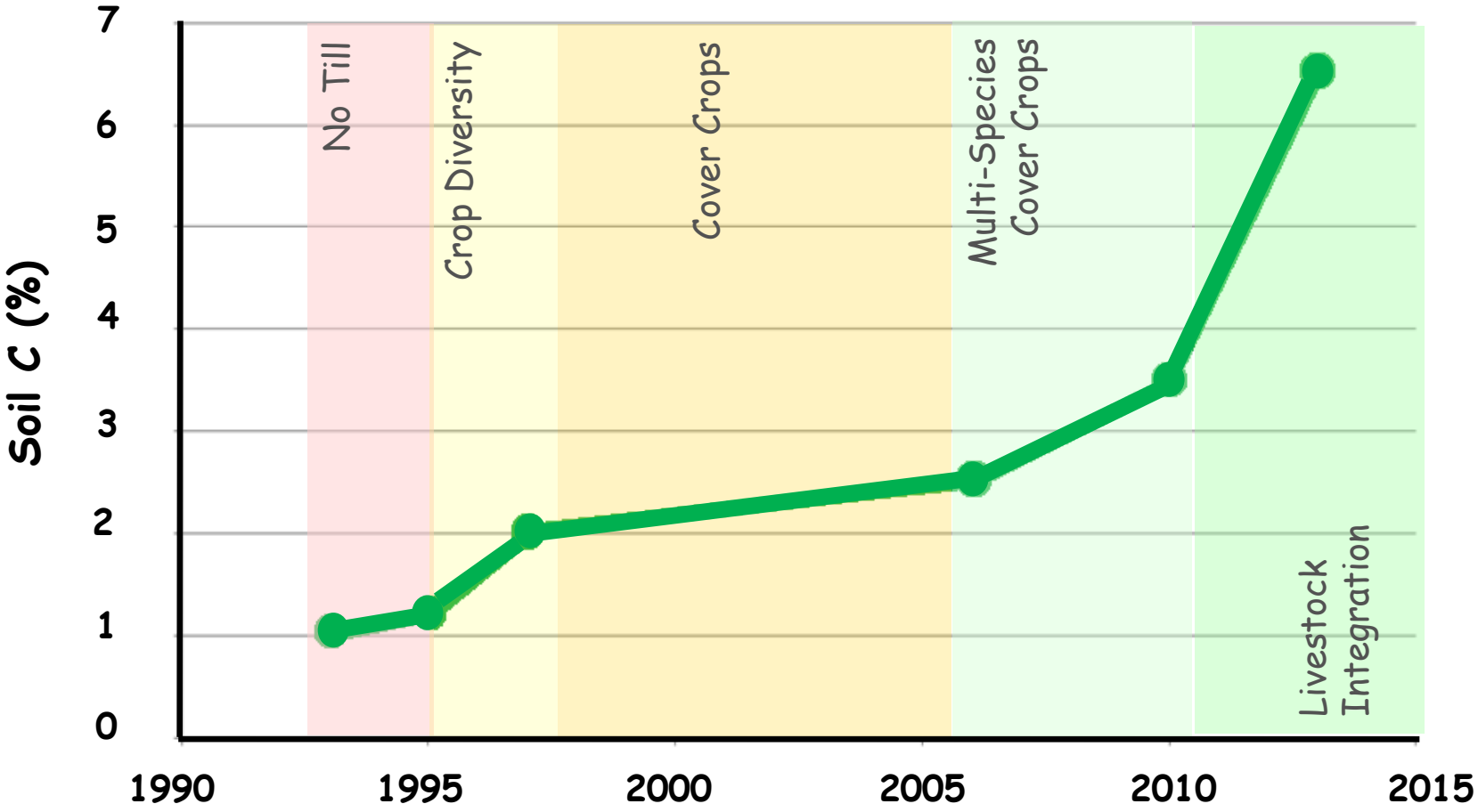
Soil Improvements with Regenerative Management

Colin Seis, New South Wales, Australia 2016

Carbon	**200%**	**Silicon**	**116%**
Water holding	**+200%**	**Nitrogen**	**103%**
Calcium	**234%**	**Phosphorous**	**102%**
Magnesium	**110%**	**Potassium**	**198%**
Zinc	**250%**	**Sulfur**	**92%**
Copper	**185%**	**Iron**	**87%**
Boron	**150%**		

Grazing and Cover Crops Boost SOC

North Dakota – 400 mm rainfall



Delgado et al 2011; Rodale 2014; Jones, 2014; Fuhrer 2015

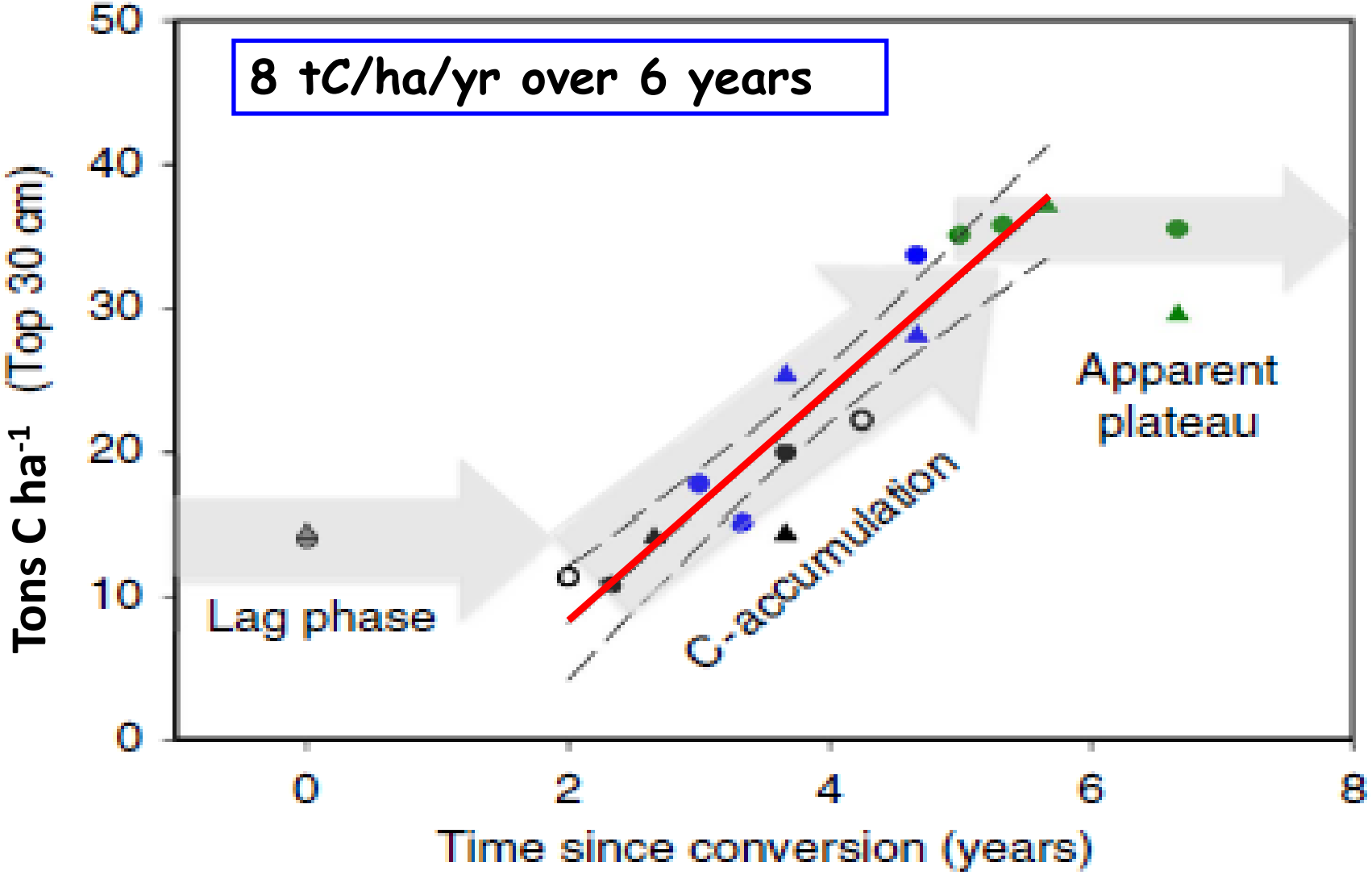
AMP Grazing on Converted Crop Fields

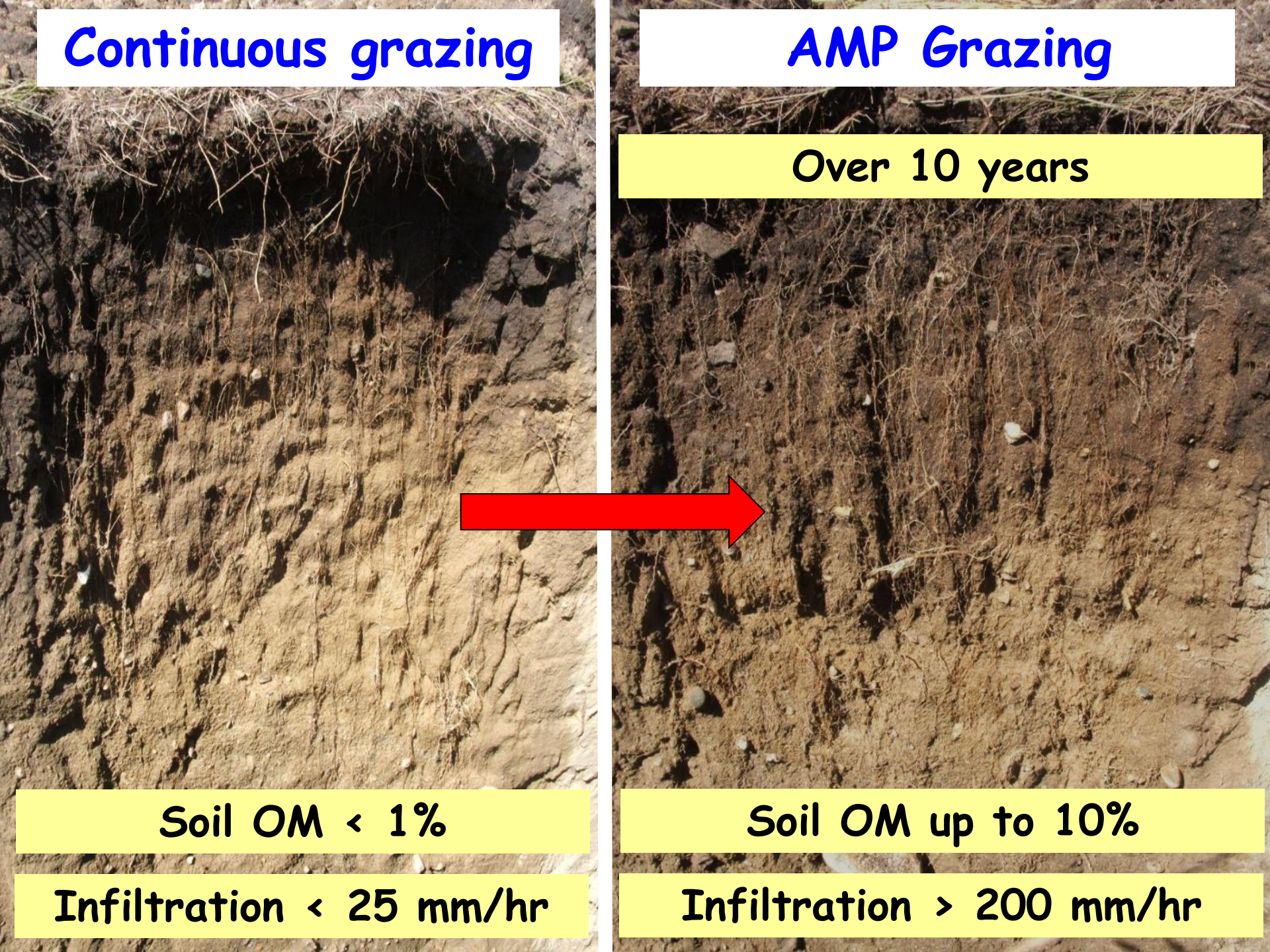
Georgia – 1,000 mm rainfall

Machmuller et al. 2015

SOC Switching from Cropping to AMP

Measured to 30 cm




Continuous grazing
AMP Grazing
Over 10 years
Soil OM < 1%
Soil OM up to 10%
Infiltration < 25 mm/hr
Infiltration > 200 mm/hr

Keys to Healthy Soil

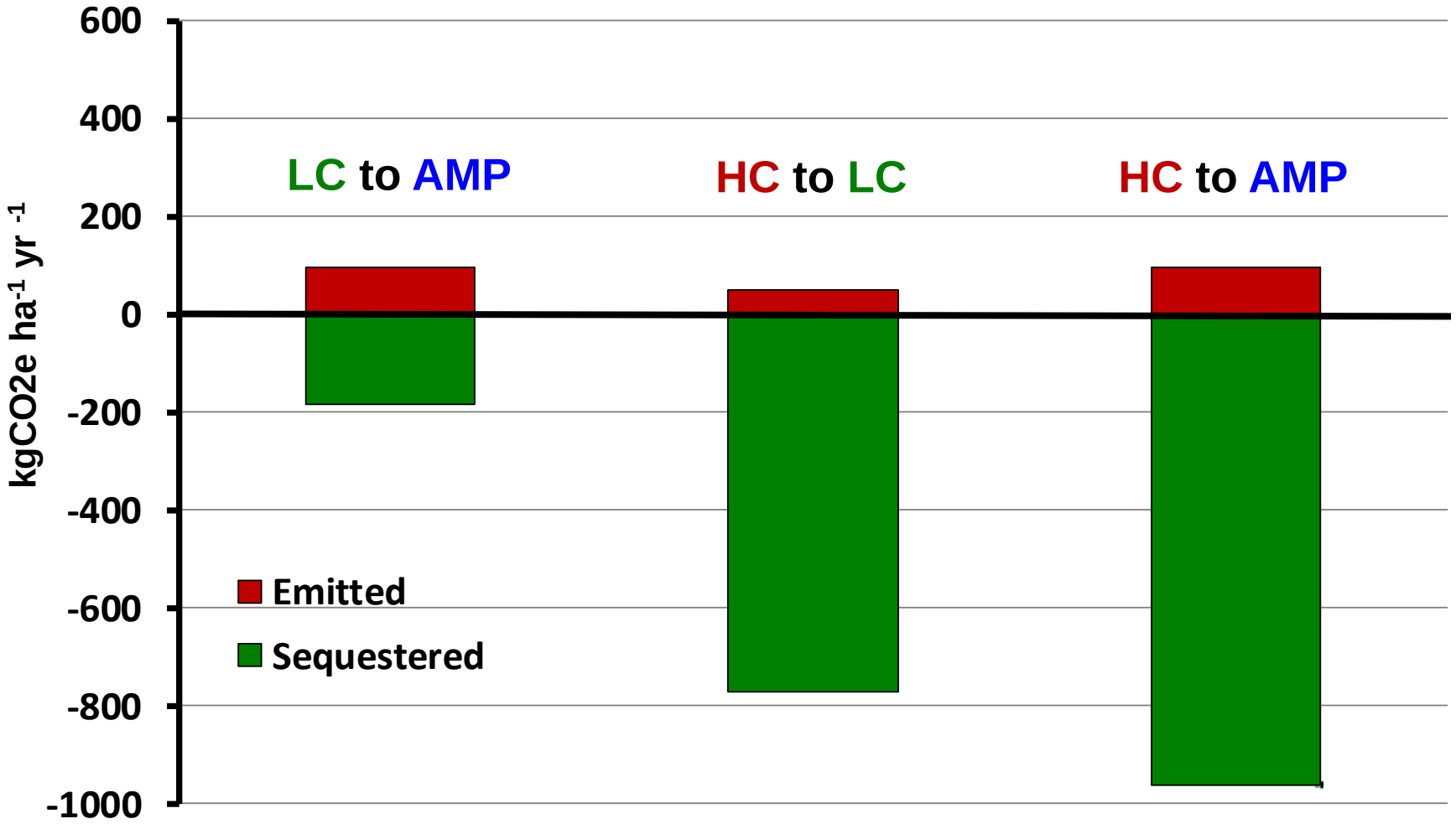
Aim to improve soil function to increase profits

- Cover the soil
- High plant diversity
- Minimise soil mechanical disturbance
- Grow plants for maximum days each year
- Manage livestock to enhance soil function
- Use organic soil amendments
- Reduce N-fertilizer use
- Incorporate livestock with regenerative grazing

Delgado et al 2011; Gattinger et al., 2012; Aguilera et al., 2013

Life Cycle Analysis of Change in Management

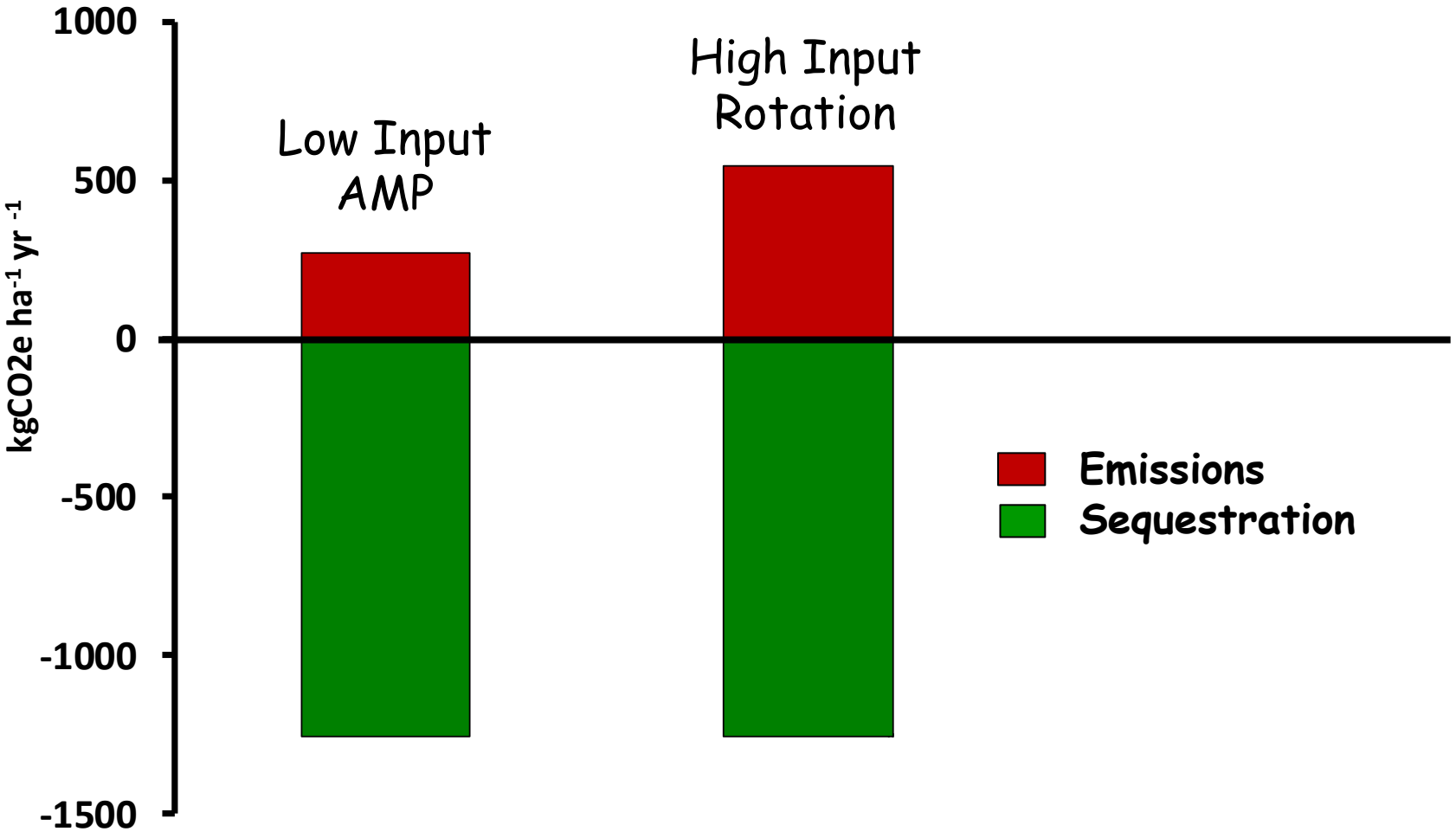
Net C Emissions on grazing only Cow-calf Operations



Wang et al. 2015

Emissions and Carbon Sinks:

Michigan Grassfed Pasture –grazing Cow-calf Operations



Rowntree et al. 2015

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

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
- Long recovery periods are critical
- Do not move to the adjacent paddock but to the paddock that has recovered the most

Walt Davis, Dave Pratt, Ranch Management Consultants

AMP Grazing Field & Modelling 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
- Fixed management protocols reduced benefits
- Profitability decreases if recovery is too short or too long
- Stocking rates can be increased without damaging ecological function as number of paddocks is increased

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

Regenerative AMP grazing can:

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

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

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

Research for Adequate Understanding

Complimentary research elements need to include:

- Field research assessing parameters relating to ecosystem functions as well as production
- Include multiple disciplines – soil, fungi, bacteria, plants, insects, wildlife, socio-economics etc.
- Adequate soil depth & spatial sampling
- Detailed CO_2 flux and $^{13}CO_2$ static chamber assessments of GHG dynamics within the context of each treatment.
- Simulation modelling to provide:
  - Mathematical hypotheses to underpin our scientific understanding,
  - Models must be corroborated with field data,
  - Assess what combinations of management decisions achieve best results?
  - Assess where different AMP configurations work most effectively.
  - What will provide best outcomes on different farms?

Teague et al. 2013; Teague et al. 2017


The Dixon Water Foundation
Thank you

Working with leading farmers

- Addresses questions at commercial scale
- Integrates component science into whole-system responses
- Identifies emergent properties
- Includes the human element essential for achieving economic and environmental goals
- Incorporates management to adaptively achieve desired goals
- Indicates how to manage adaptively
- Facilitates identifying unintended consequences
- Challenging simulation models with the field data provides a solid theoretical foundation

Van der Ploeg et al 2006; Teague et al. 2016; 2017

Regenerative Grazing Research Shows:

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- Stocking rates can be increased without damaging ecological function as number of paddocks is increased

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

Cover Crops: key to improving soil health

- Cover soil
- Build organic matter
- Build soil aggregates
- Improve water cycle
- Enhance nutrient cycling
- Enhance fertility
- Improve C/N ratio
- Provide crop diversity
- Enhance pollinators
- Wildlife habitat
- Livestock integration

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