Managing Grazing and Cropping to Regenerate Soil Carbon and Ecosystem Services

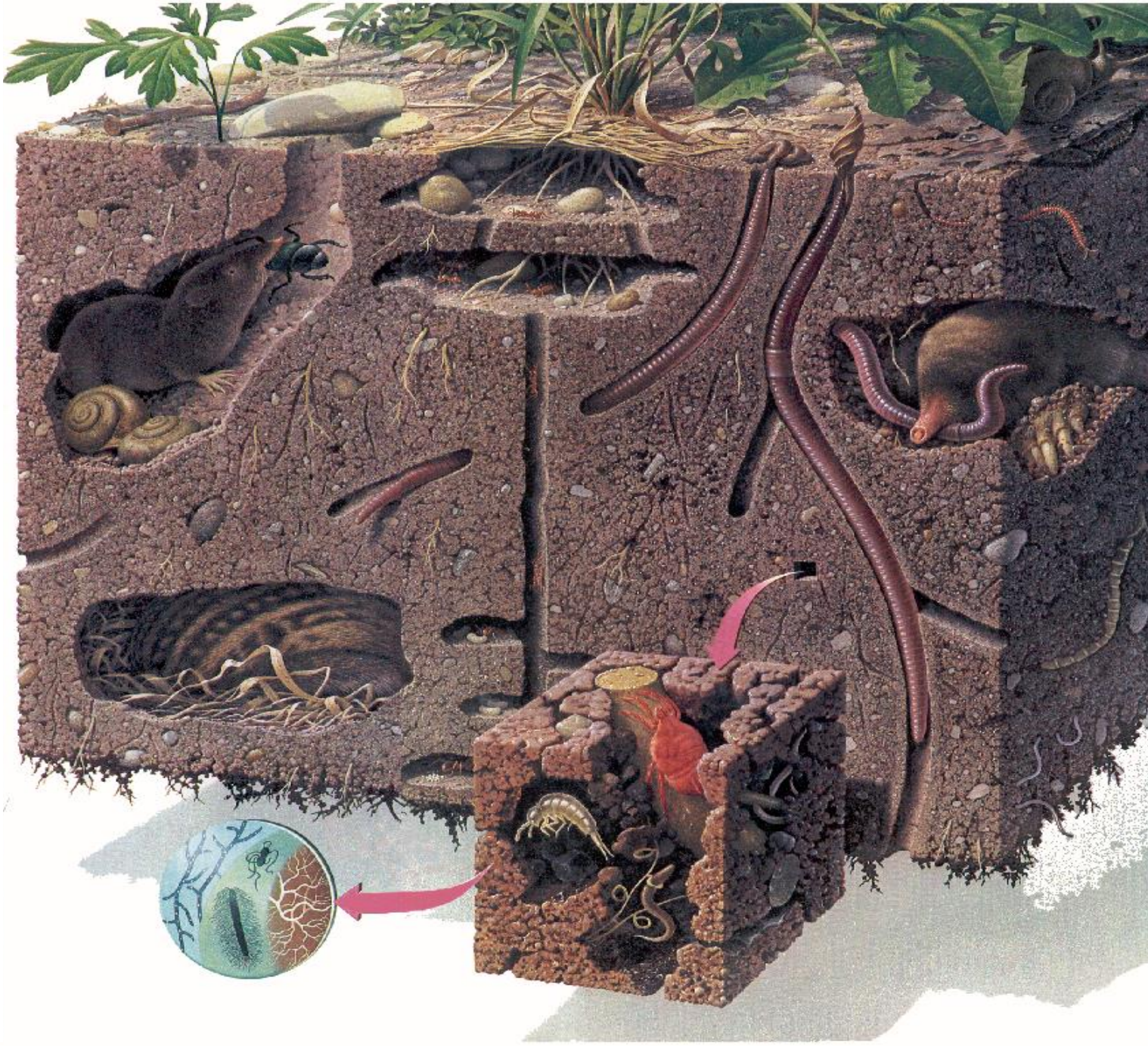
University of Alberta, Edmonton
15th February, 2017

Richard Teague,
Texas A&M AgriLife Research, Vernon

90% of Soil function is mediated by microbes

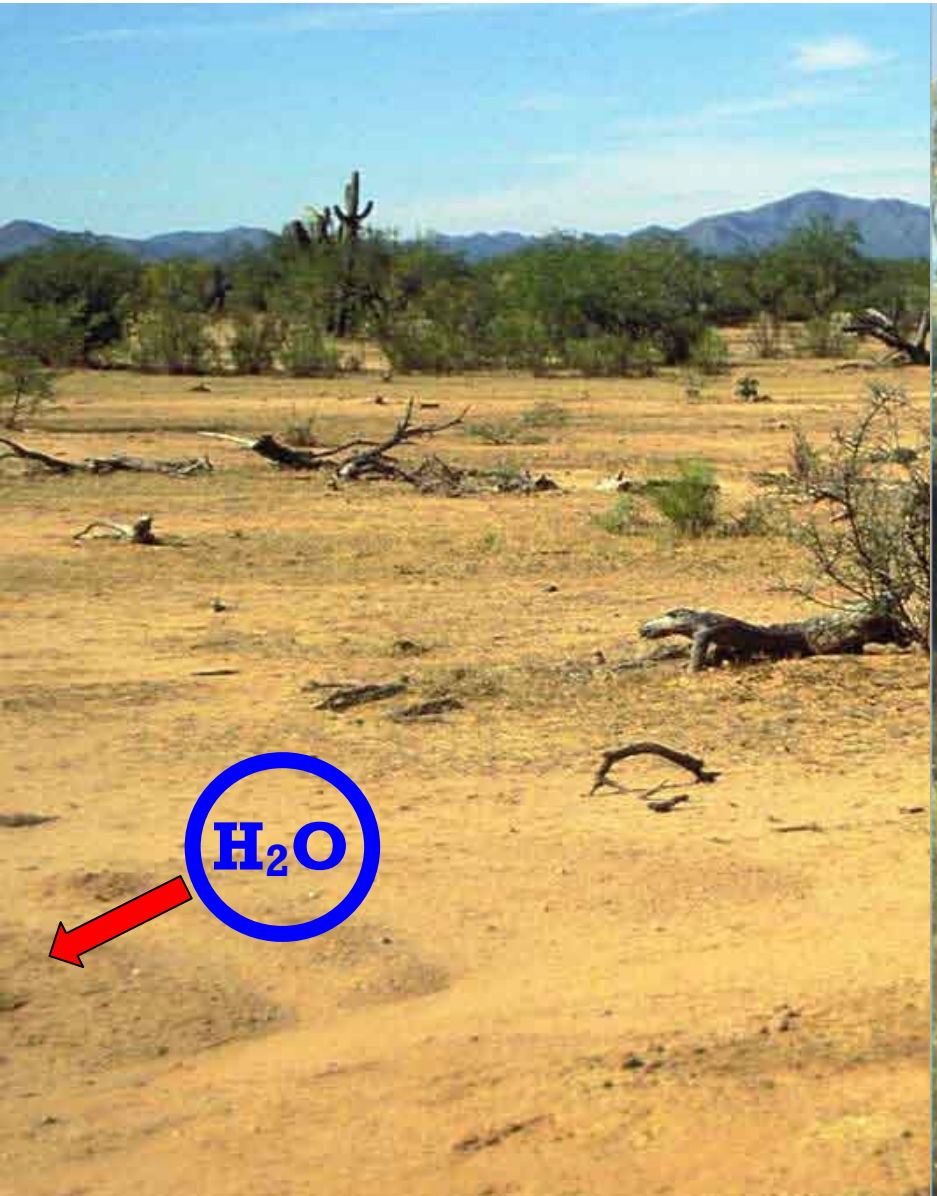
Microbes depend on plants

So how we manage plants is critical



Biggest limiting factor in Rangeland

Water in the Soil



The Four Ecosystem Processes

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

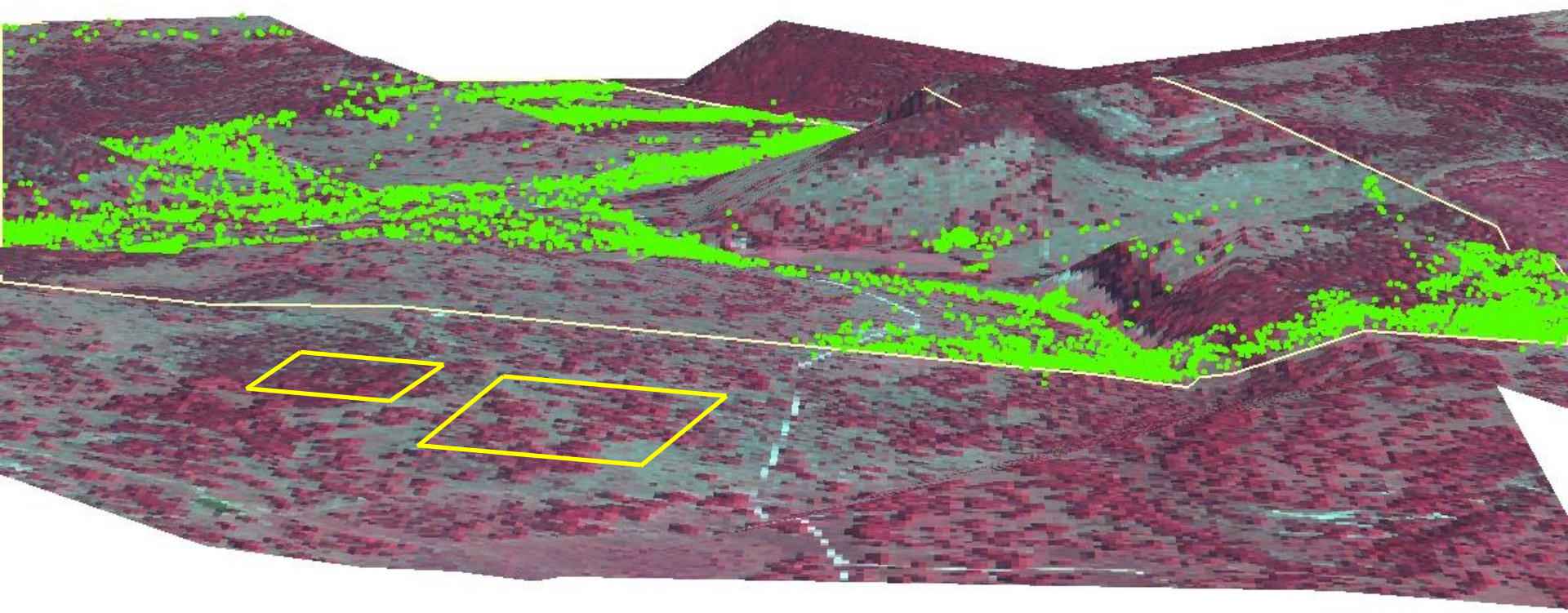
2. **Water cycle** – Maximize capture and cycling of water through plants and soil. Reduce export and import.

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

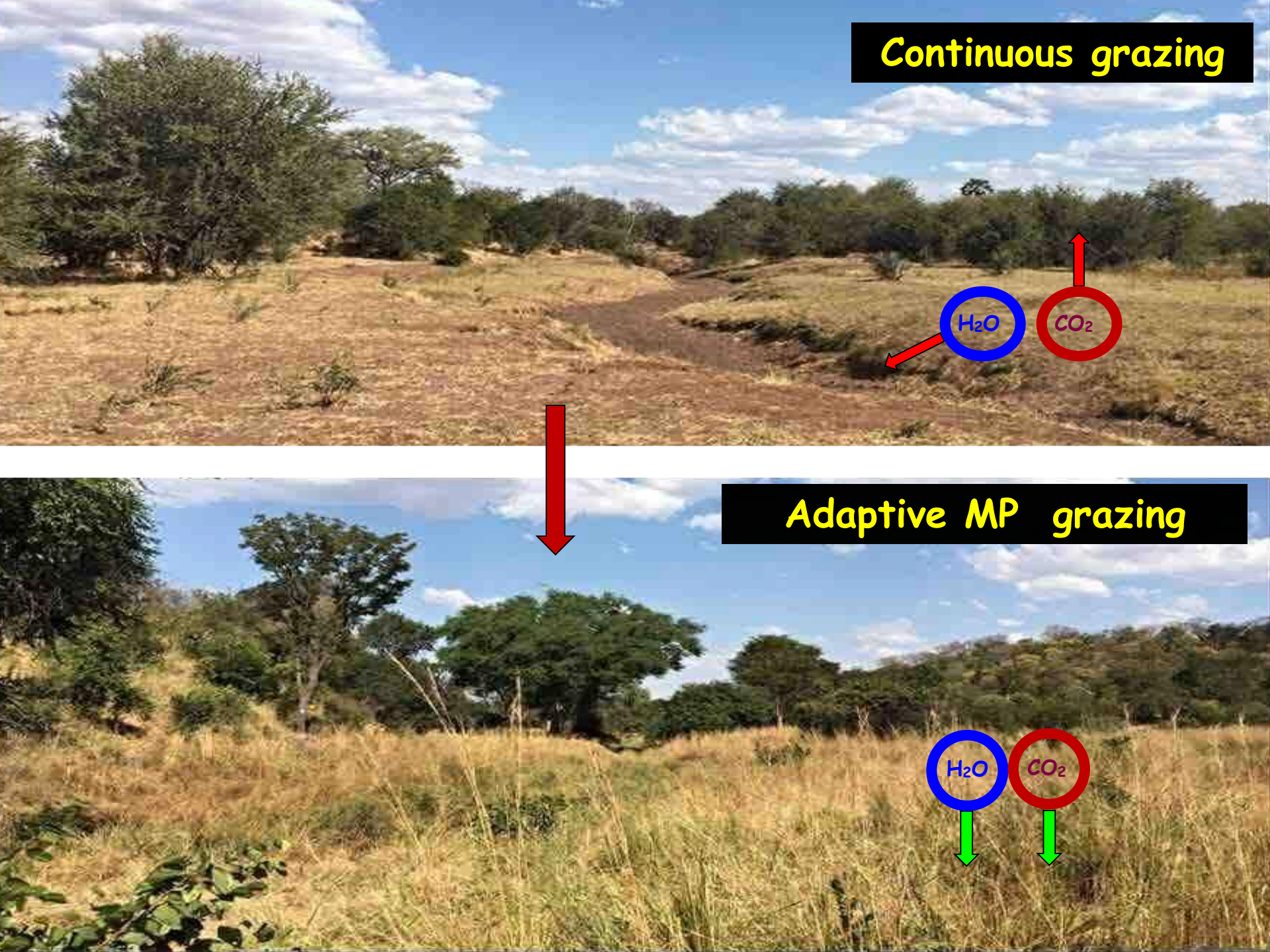


Norton 1998; Norton et al. 2013; Jakoby et al. 2014 .

Many graziers use Adaptive Multi Paddock (AMP) grazing successfully

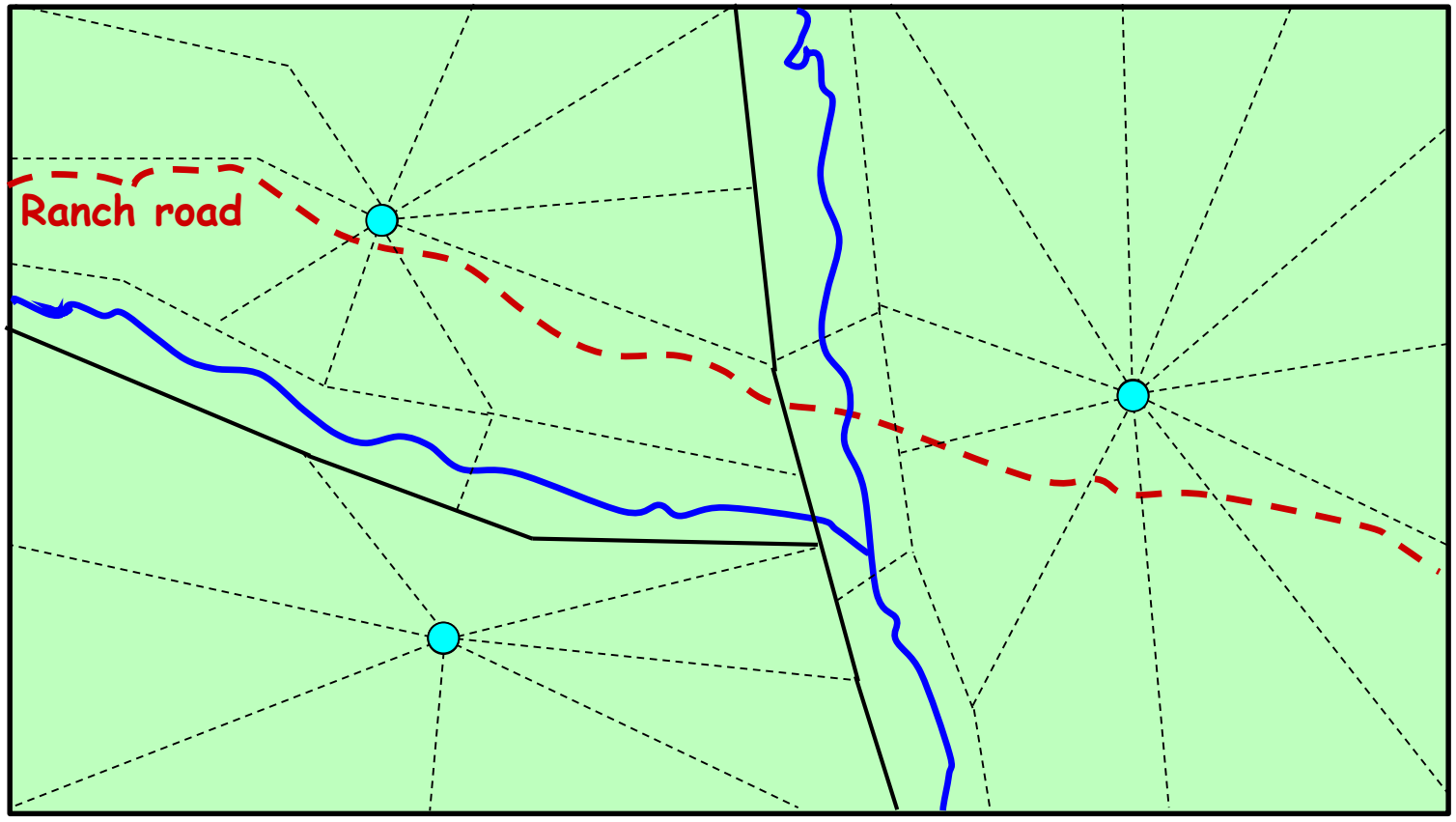
Most conservation winners use MP grazing

- Overgrazing has little to do with number of animals.
- But with the amount of time plants are exposed to animals.

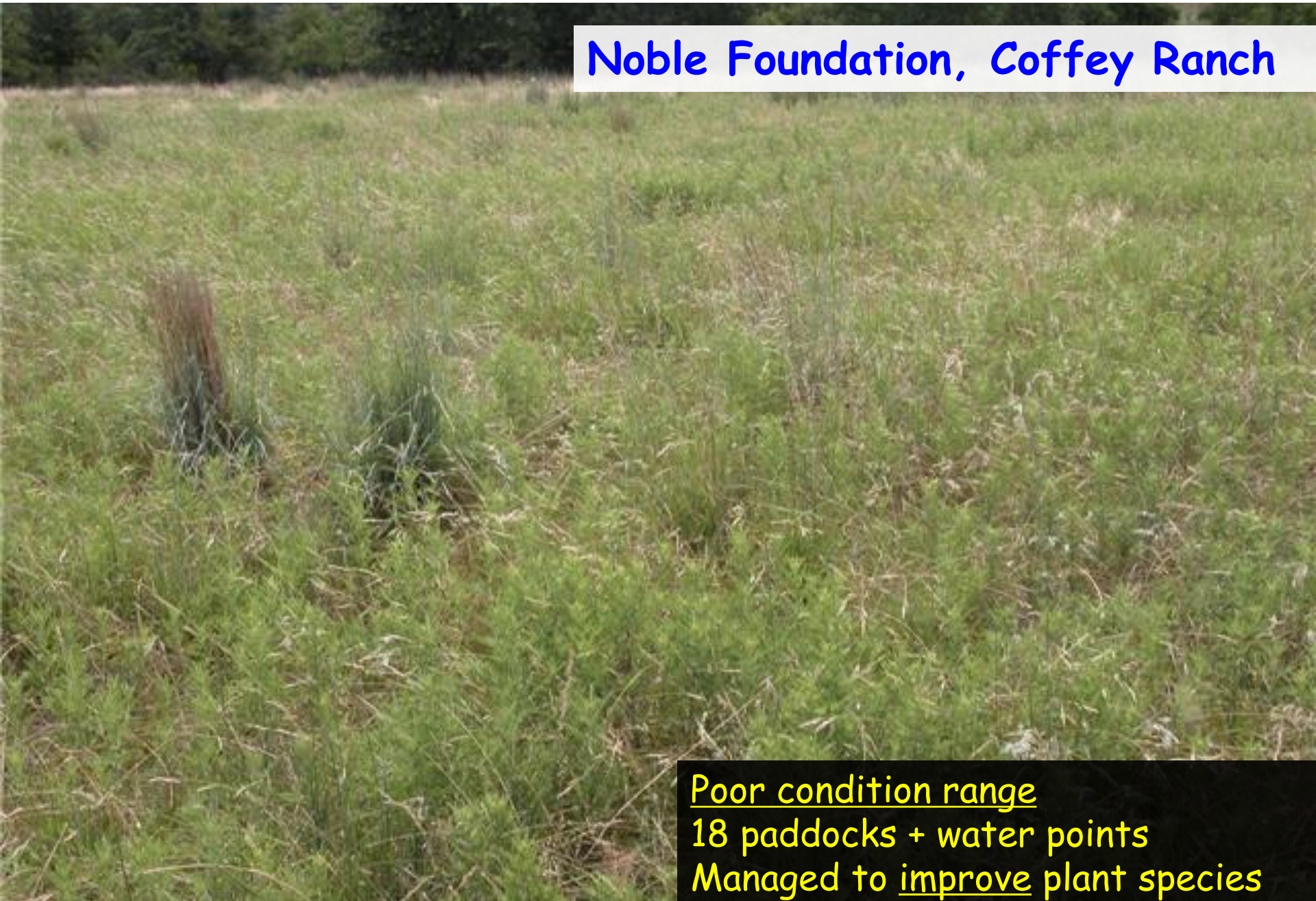

Continuous grazing
H2O
CO2
Adaptive MP grazing
H2O
CO2

Adaptive multi-paddock grazing

Planned multi-paddock grazing



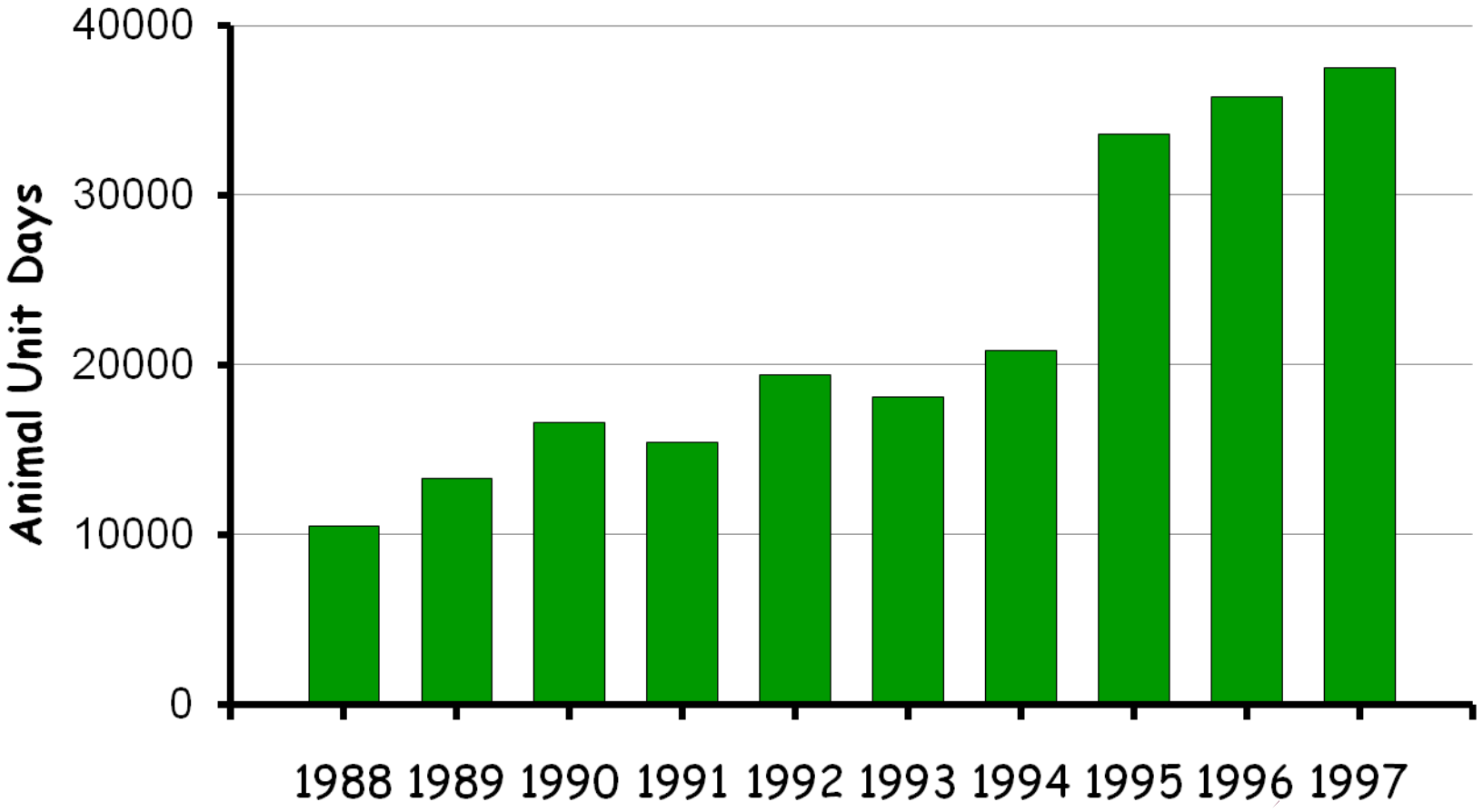
Restoration using Adaptive MP grazing



Restoration using Adaptive MP grazing

Noble Foundation, Coffey Ranch

Charles Griffith, Hugh Aljoe, Russell Stevens



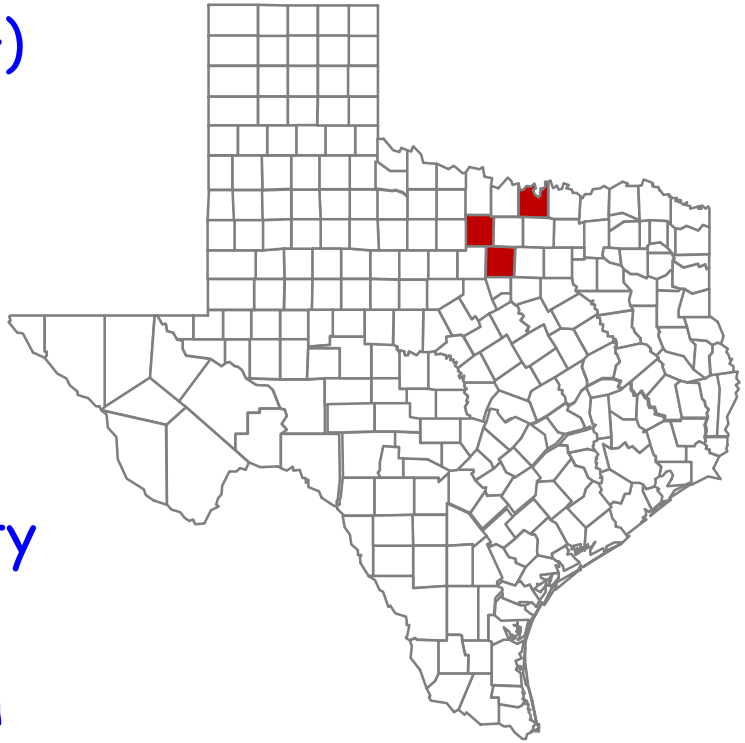
Managing for Desired Outcomes

- Flexible stocking to match forage availability and animal numbers
- Rotate paddocks to spread grazing over whole ranch one paddock at a time
- Defoliate moderately in growing season
- Use short grazing periods
- Adequate recovery before regrazing
- Adaptively change with changing conditions

Texas Grazing Research

Using AMP grazing 3 Texas ranchers:

- Added 3 tons Carbon /ha/year **more** than their 3 heavy continuous (HCG) grazing neighbors
- Decreased bare ground
- Improved soil physical structure
- Bolstered soil fertility
- Enriched soil microbial composition
- Improved soil water holding capacity
- Enhanced plant productivity
- Improved plant species composition
- Increased livestock production



Teague et al. 2011

Causal Mechanisms

Continuous grazing

Adaptive MP grazing

AMP grazing

Energy Flow

Water Cycle

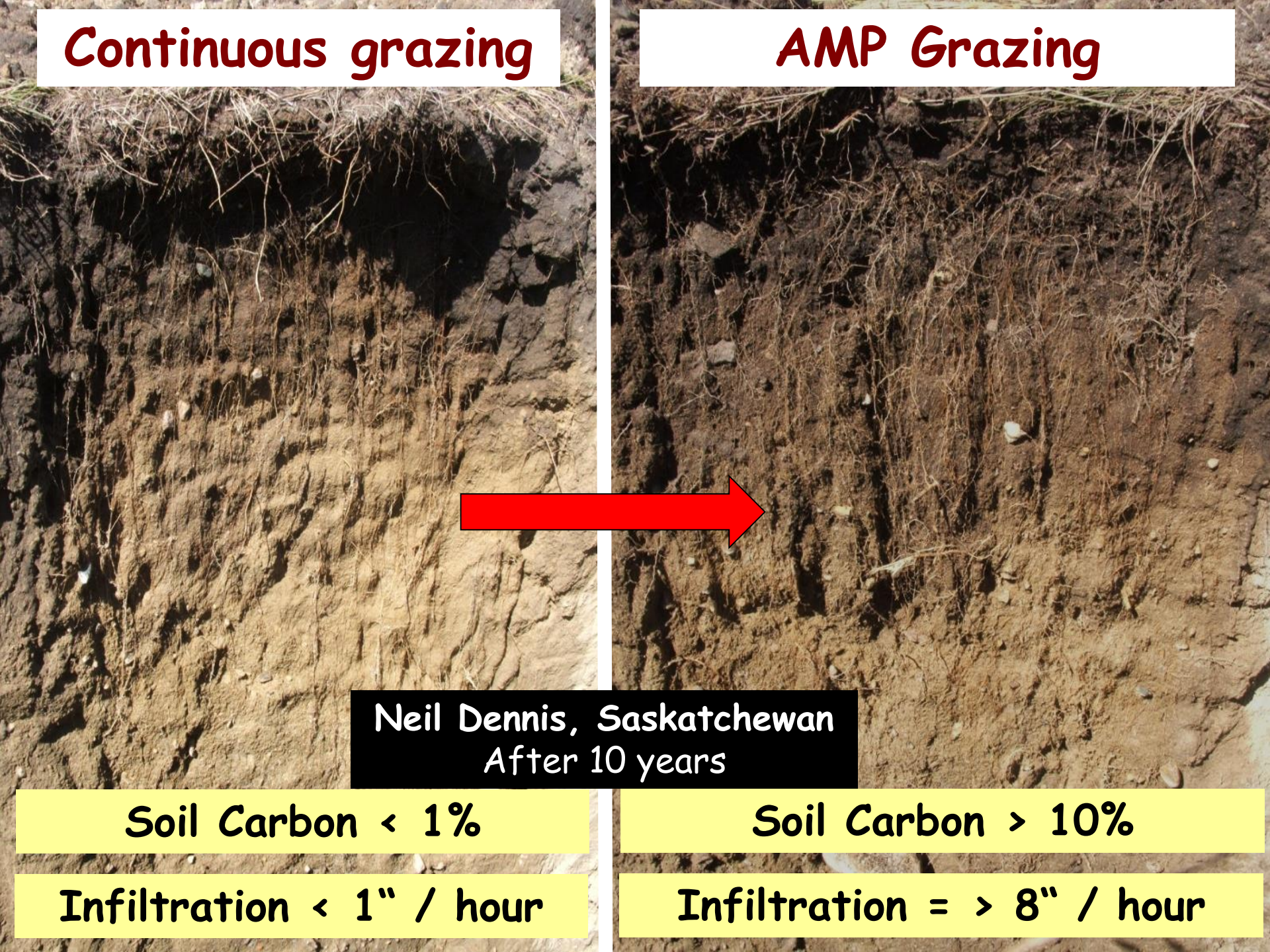
Mineral Cycle

Soil/plant Composition

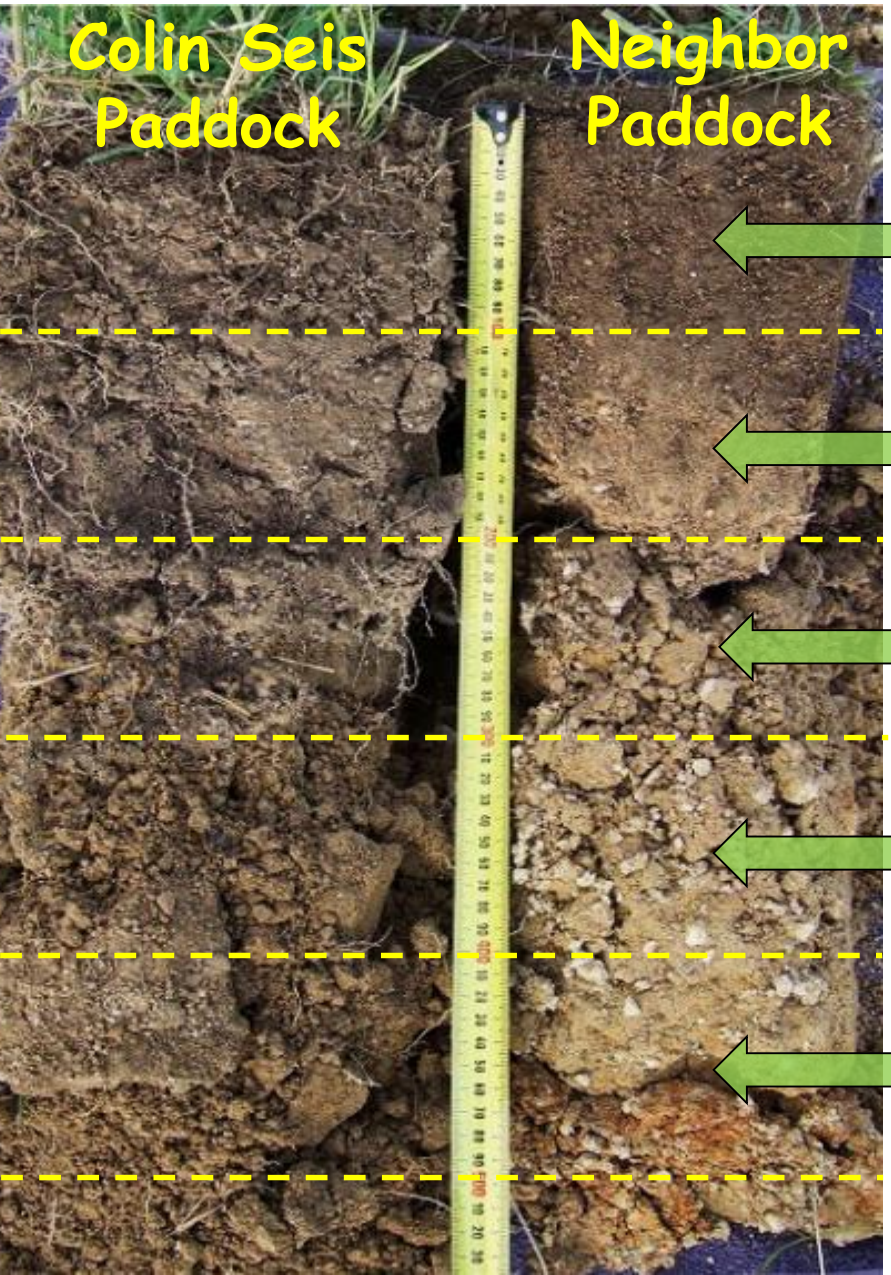
Continuous grazing

AMP Grazing

No-grazing


Continuous grazing
AMP Grazing
Neil Dennis, Saskatchewan
After 10 years
Soil Carbon < 1%
Soil Carbon > 10%
Infiltration < 1" / hour
Infiltration = > 8" / hour

Soil health differences due to management



Research from 2008-2010

0 - 10cm – 150% ↑

10 - 20cm – 243% ↑

20 - 30cm – 317% ↑

30 - 40cm – 413% ↑

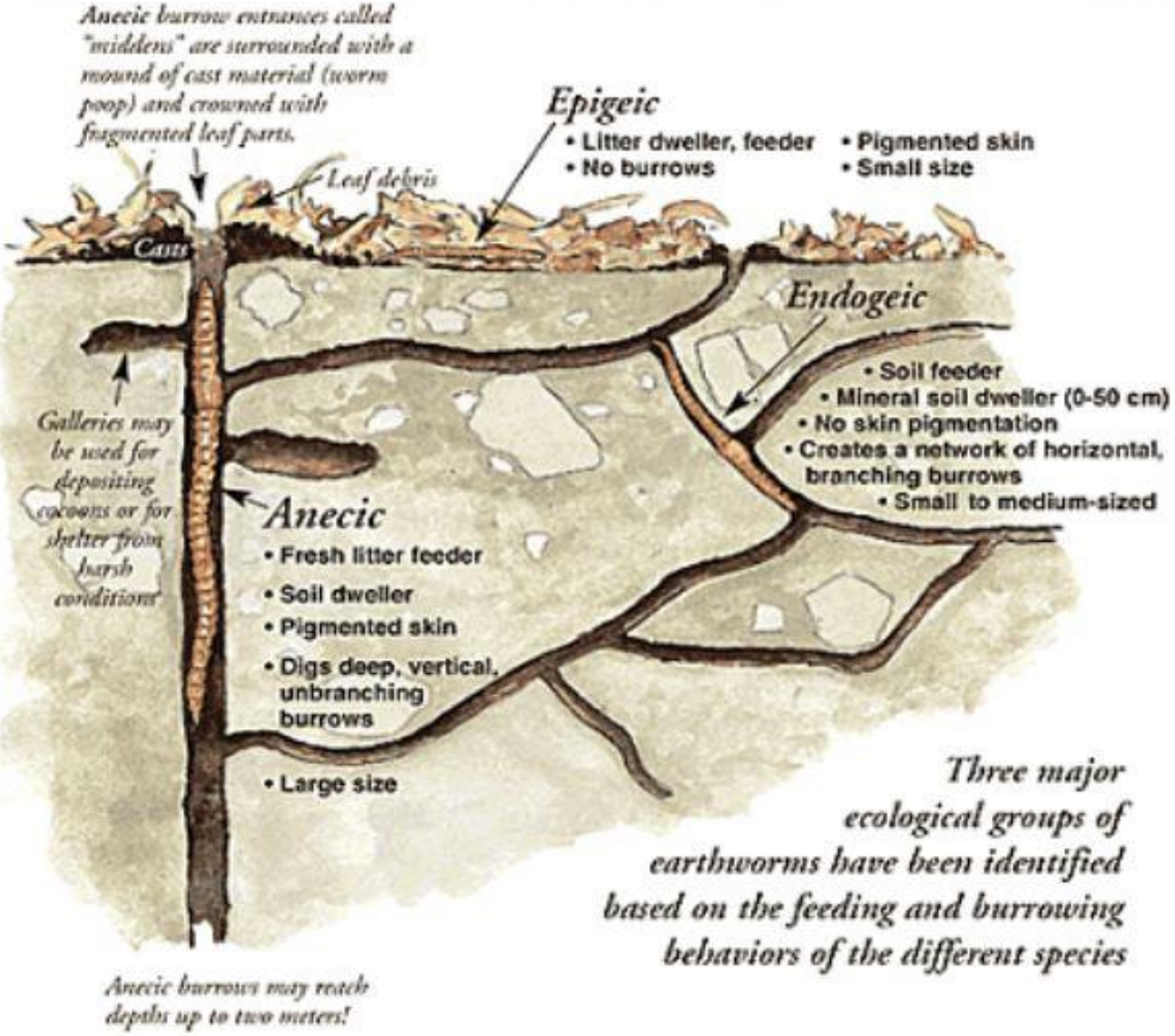
40 - 50cm – 157% ↑

Christine Jones, 2014

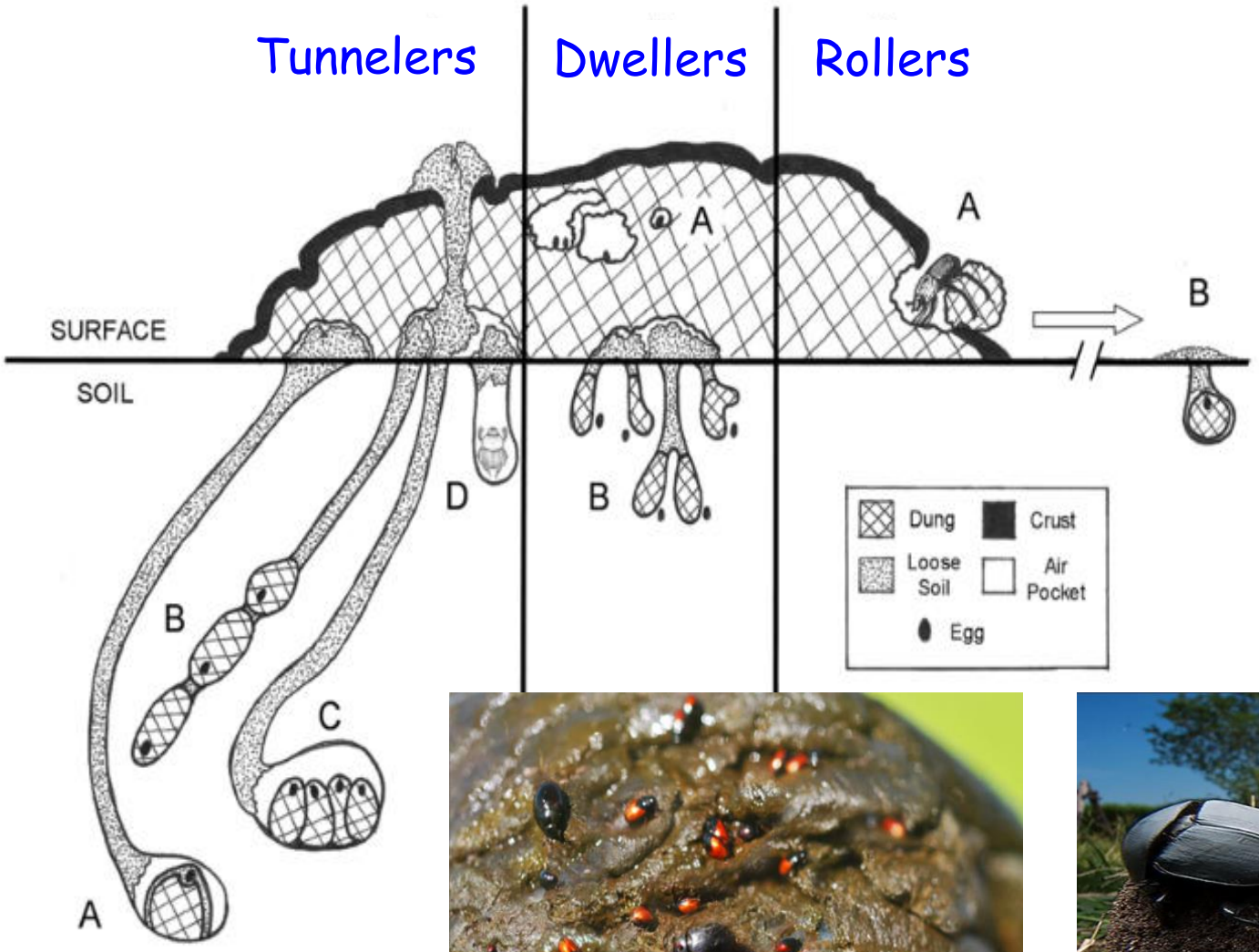
Importance of Microbes and Fungi

- Improve soil structure
- Access and transport nutrients to plants
- Extend root volume and depth
- Produce exudates to enhance soil C
- Mycorrhizal fungi are prime source of stable soil carbon
- Increase water and nutrient retention
- Increase drought resistance
- Fend off pests and pathogens
- Plant growth highest with highest fungal to bacterial ratio

Earthworms in the ecosystem



Dung beetles in the Ecosystem



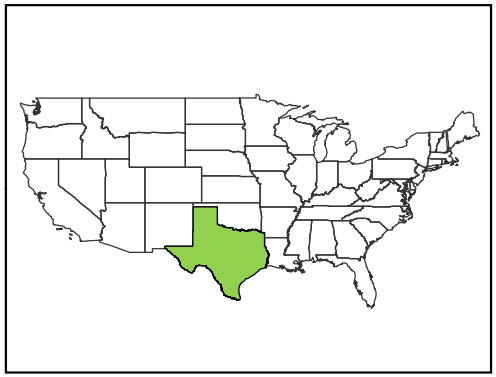
Estimated value ± $2 Billion per year

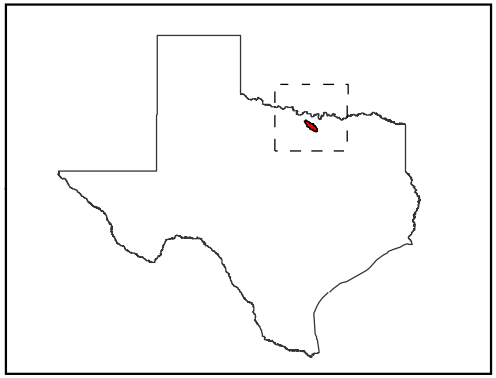
High density Regenerative AMP grazing

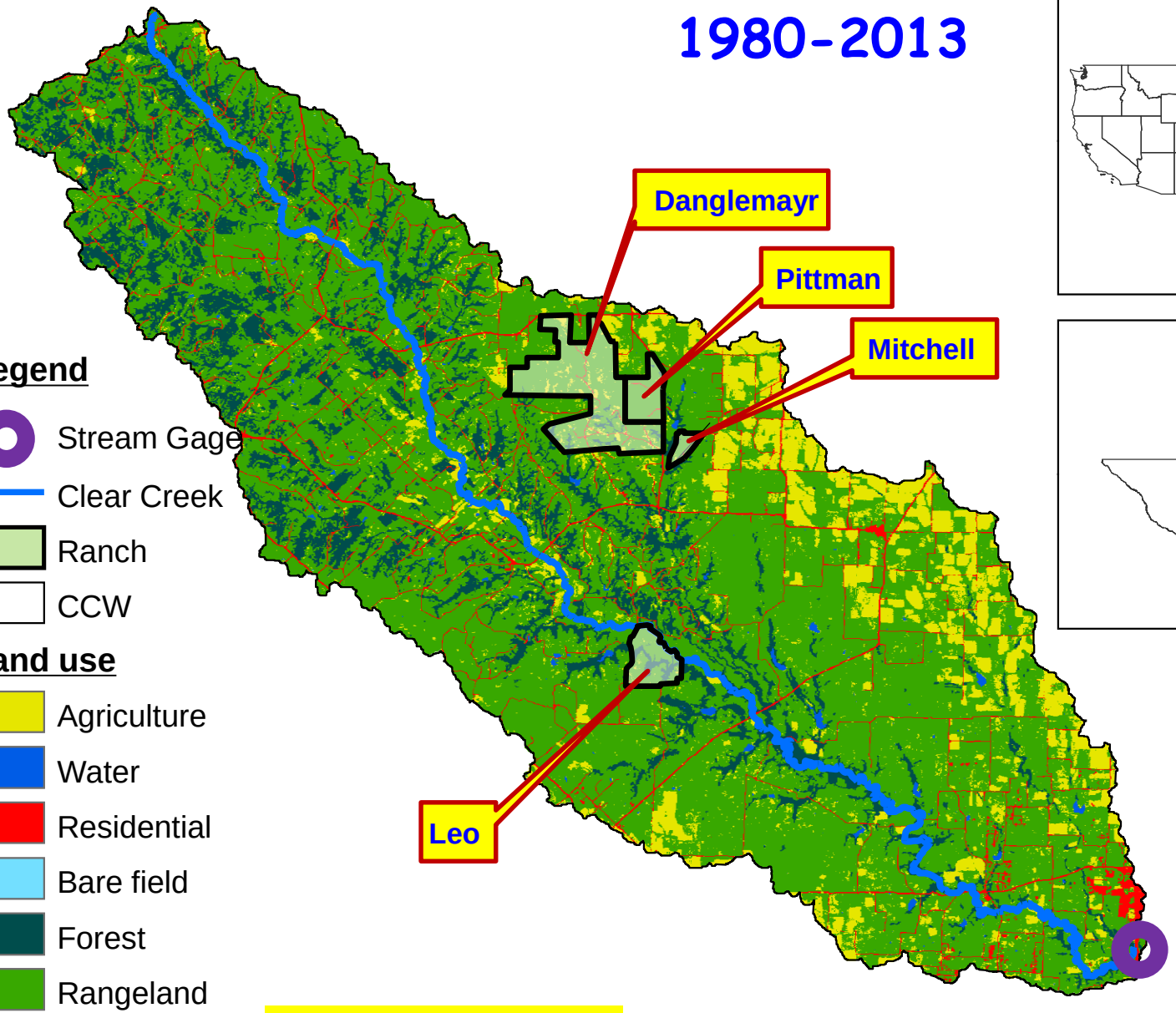
- 200 cows drop 25 tons of dung a week
- Increase infiltration ~ 130%

Clear Creek watershed, North Texas

1980-2013







Legend

- Stream Gage
- Clear Creek
- Ranch
- CCW

Land use

- Agriculture
- Water
- Residential
- Bare field
- Forest
- Rangeland

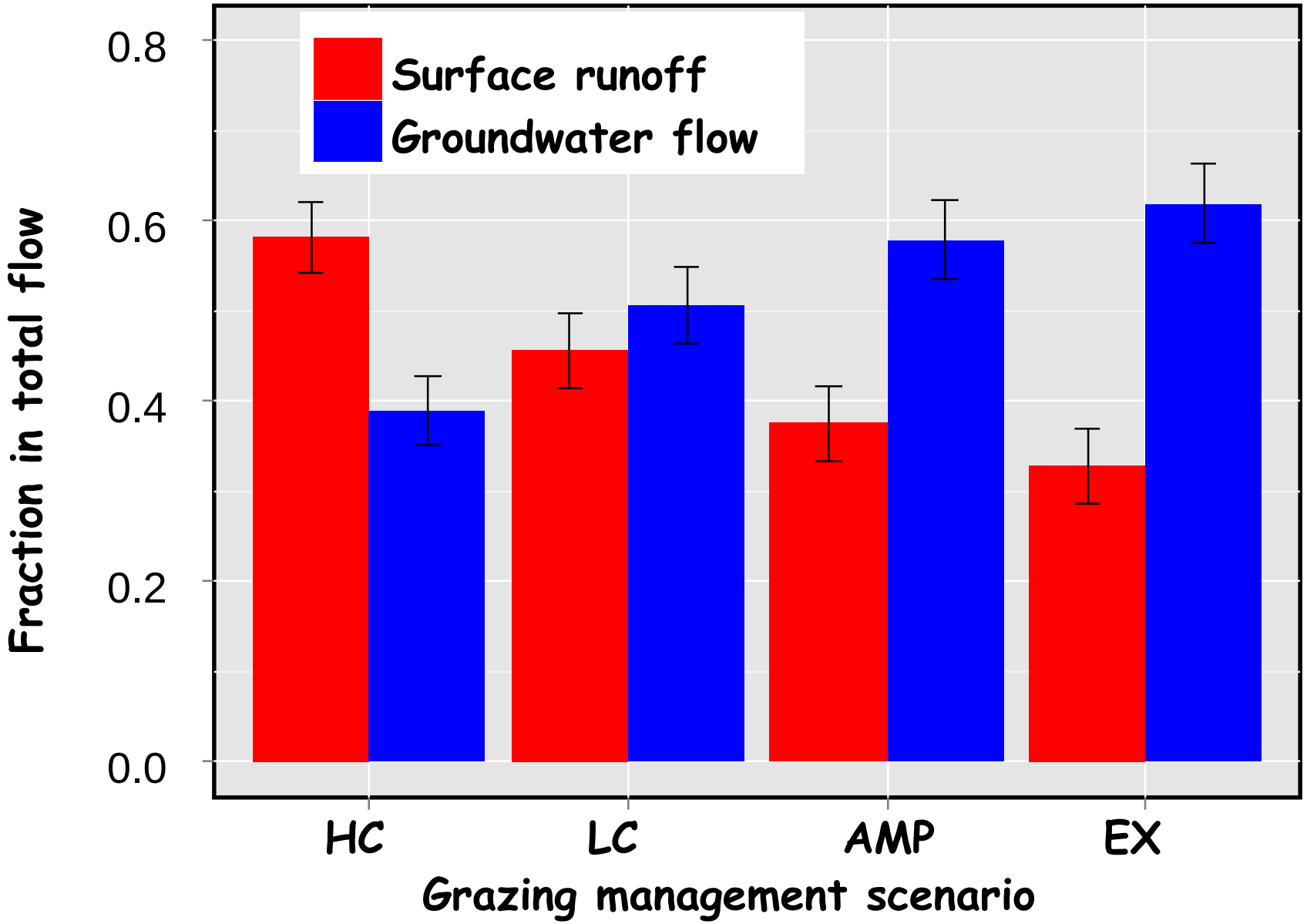
0 2.5 5 10

Kilometers

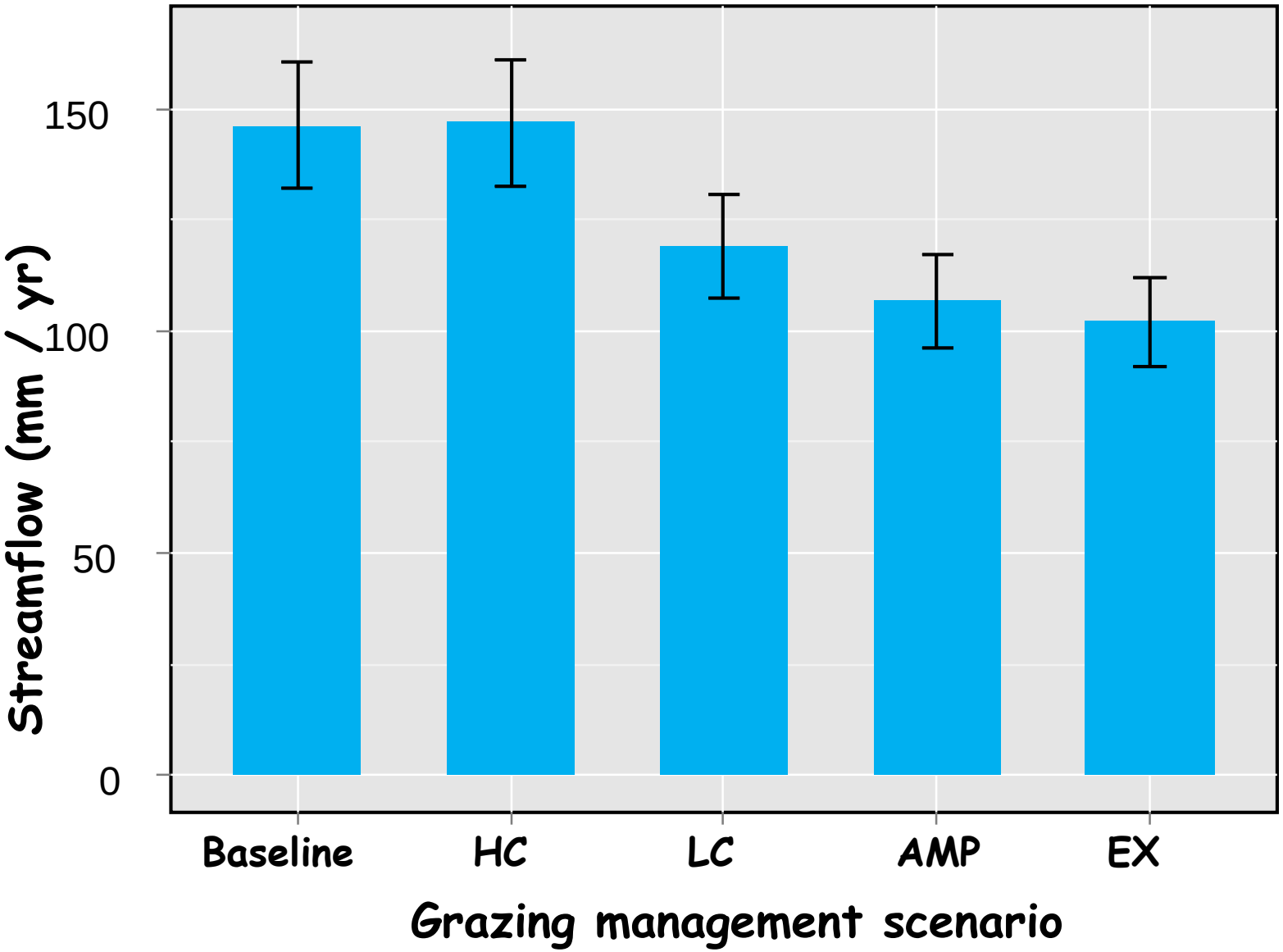
Park et al. 2017

Texas A&M System

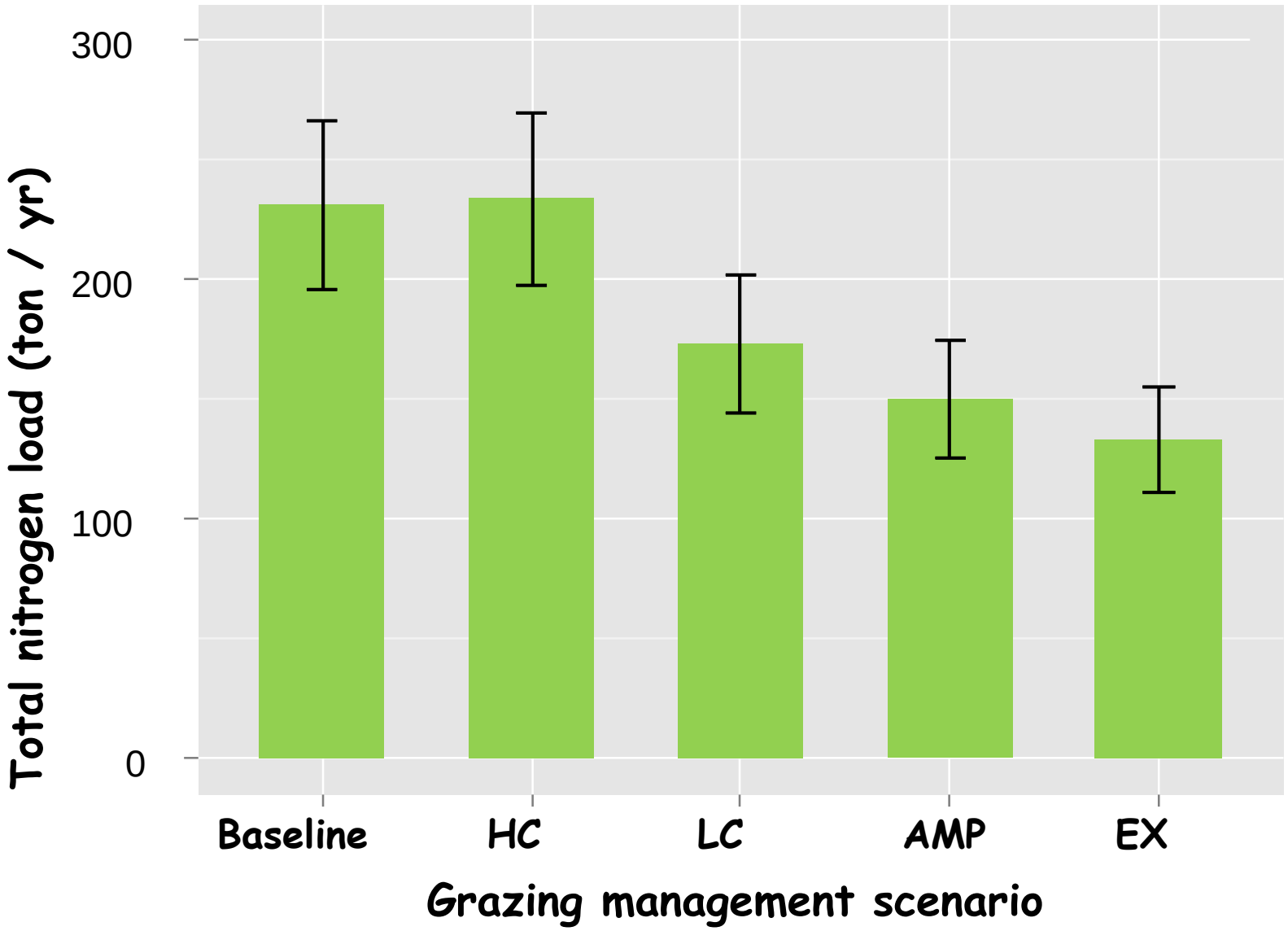
Clear Creek watershed, North Texas



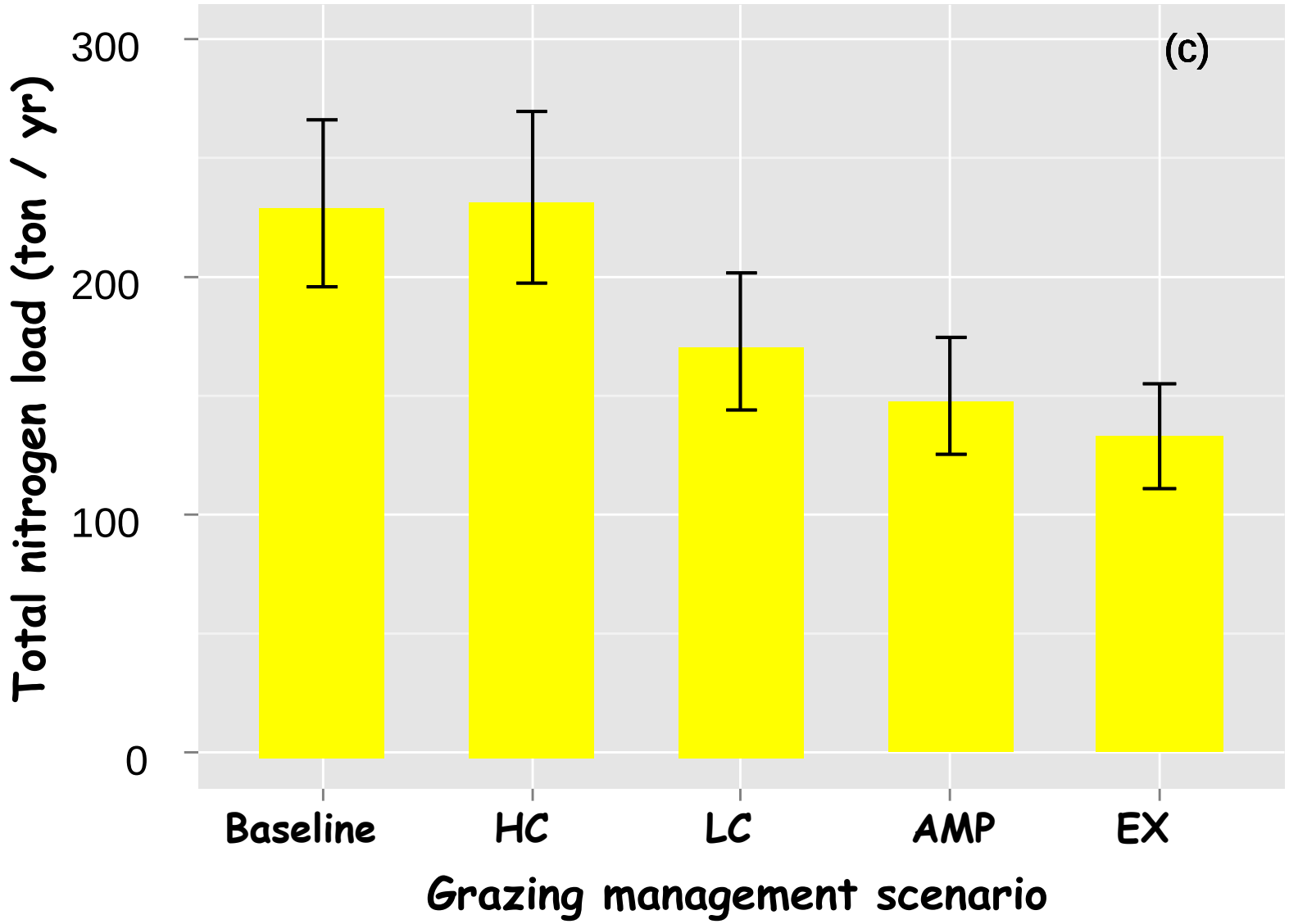
Clear Creek - Streamflow



Clear Creek – Nitrogen load

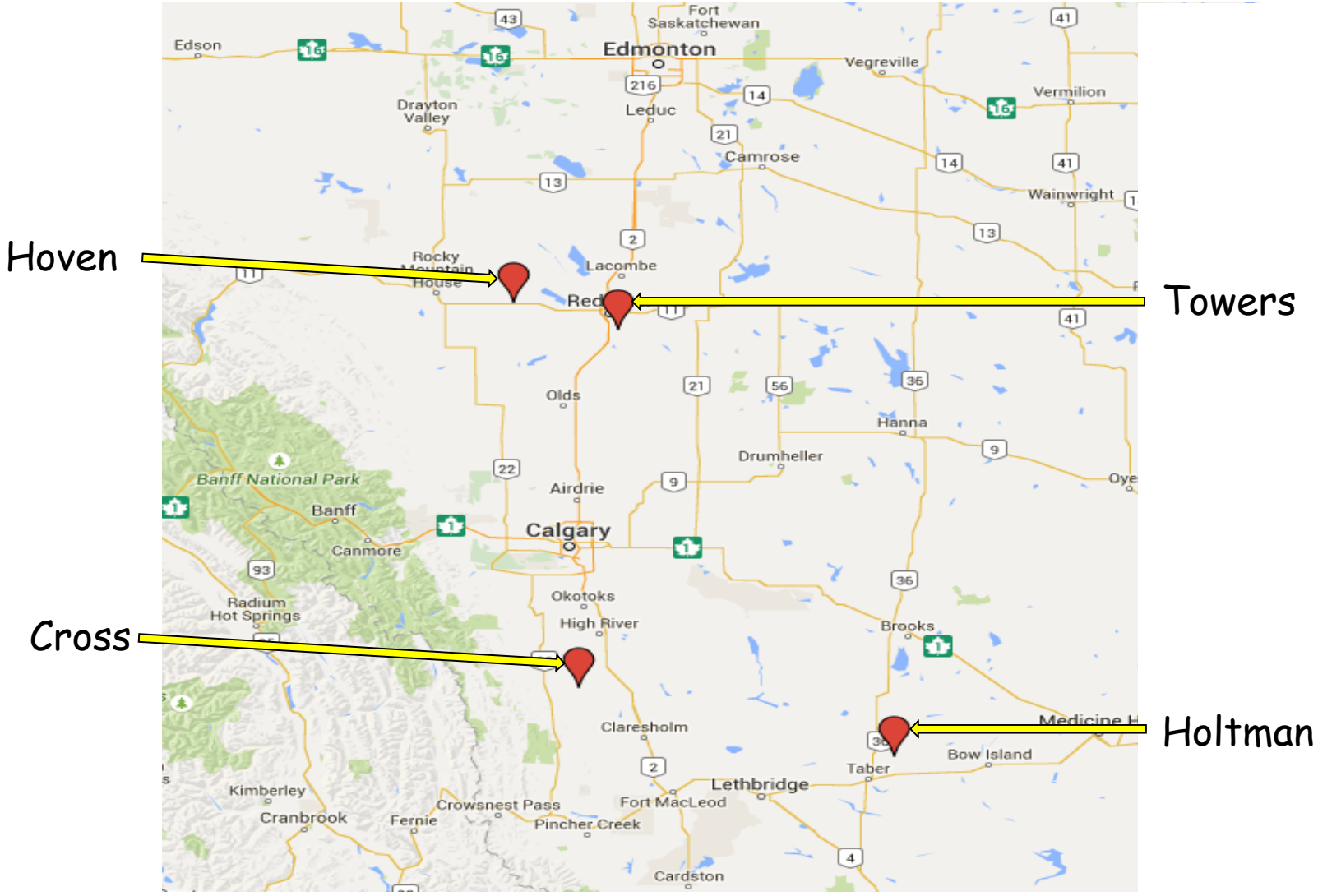


Clear Creek - Phosphorus load



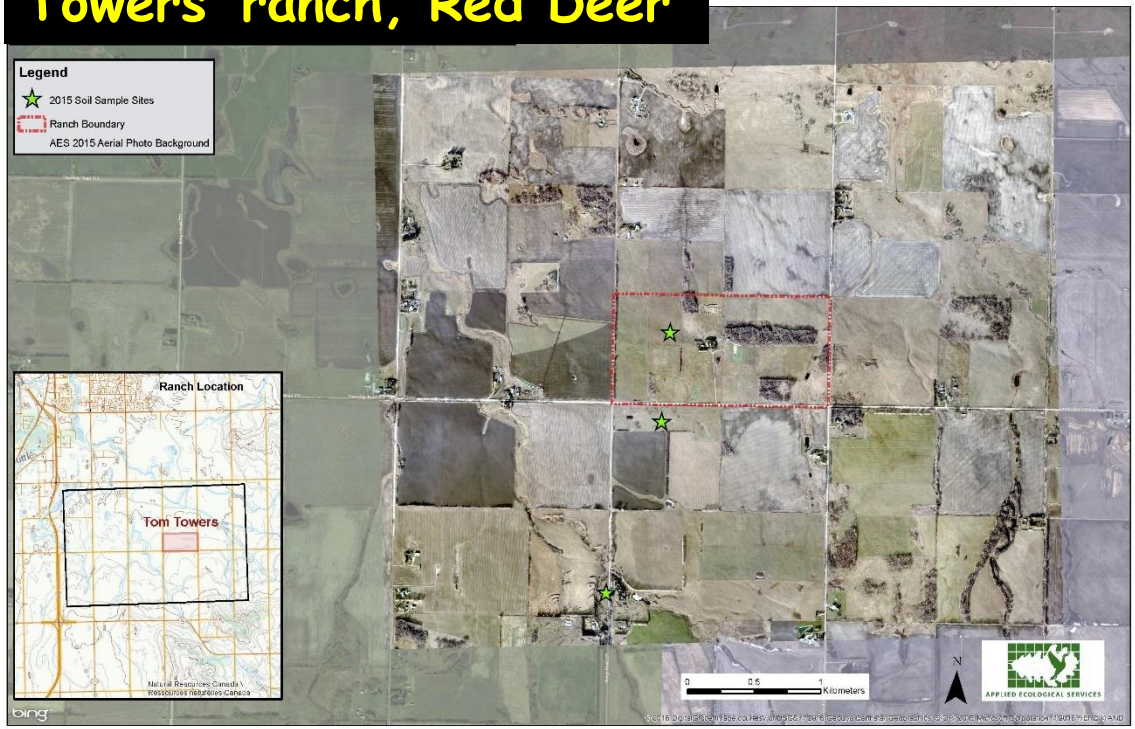
Alberta Ranches: Stratification, and Pre-sampling

Goal: Measure SOC, water infiltration, and vegetation biodiversity in AMP vs. HCG/LCG managed rangelands.

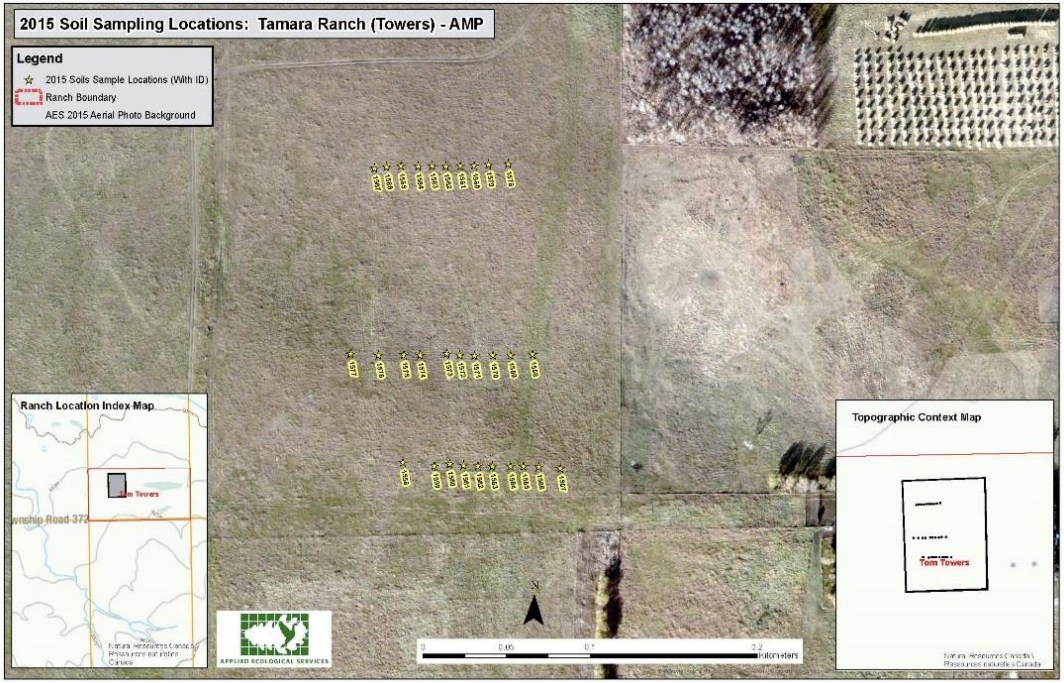


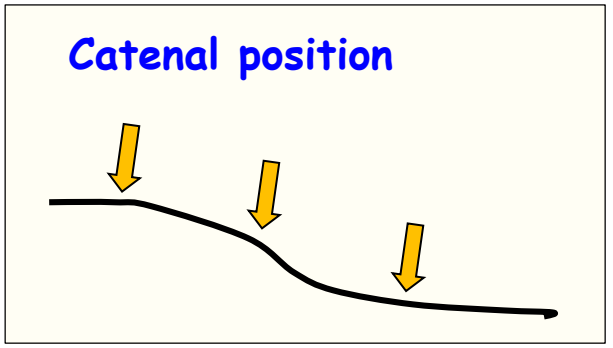
AMP, HCG, and LCG Site Selection and Pre-Sampling

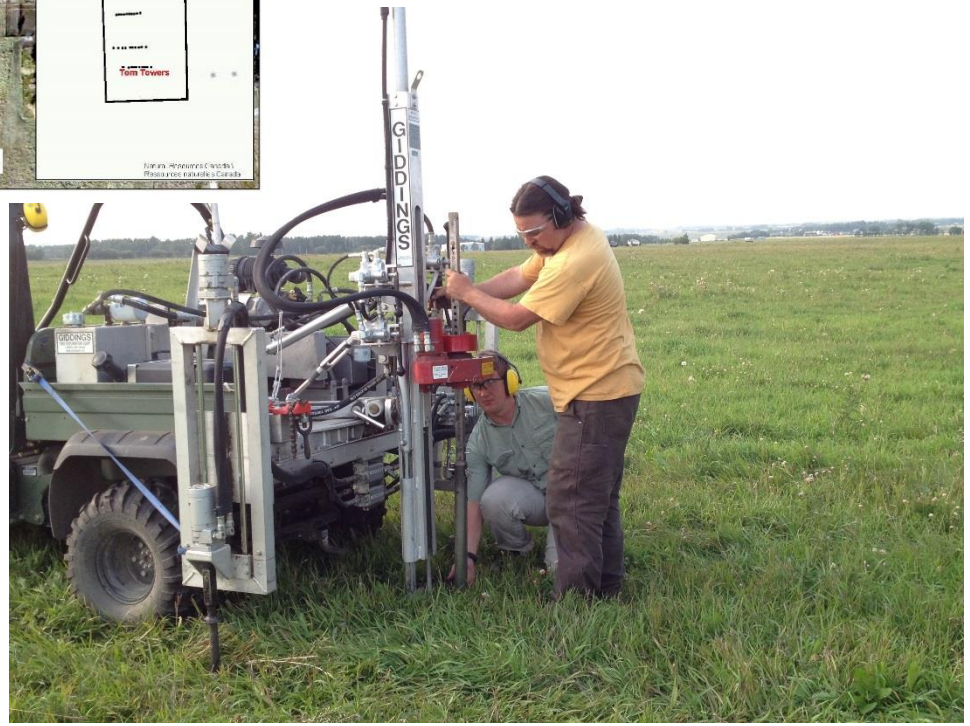
Towers' ranch, Red Deer



Paired AMP, HCG, and LCG Soil Catena Sampling







AMP and Carbon 13 Isotope Sampling

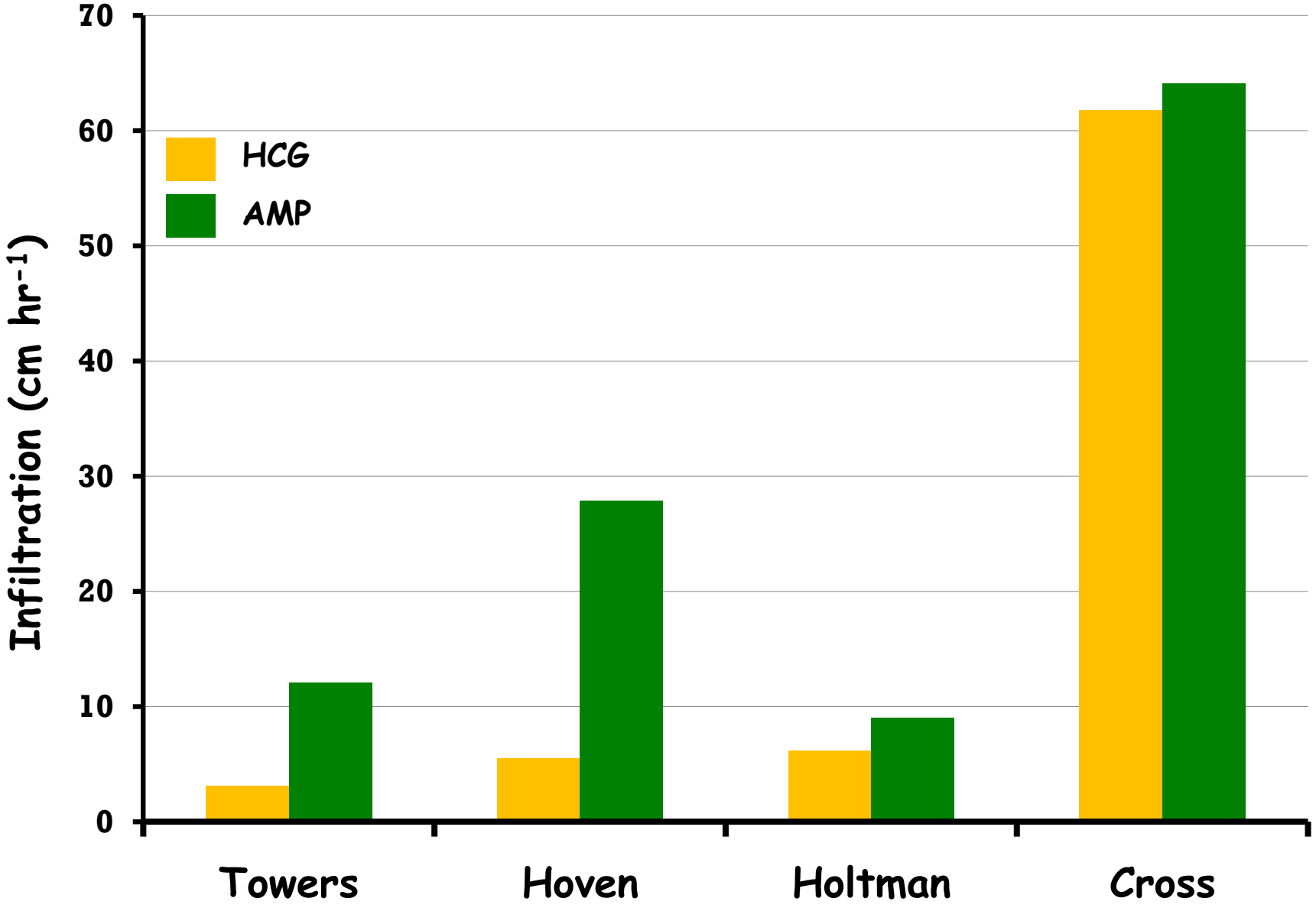
Results

- Soil Organic Carbon accrual rates of 1.4 -2.5 tC/ha/yr, higher in AMP vs HCG ($P > 0.05$, $n=60$).
- Lowest in sand, highest in clay loam soils.

AMP grazing

LCG/HCG

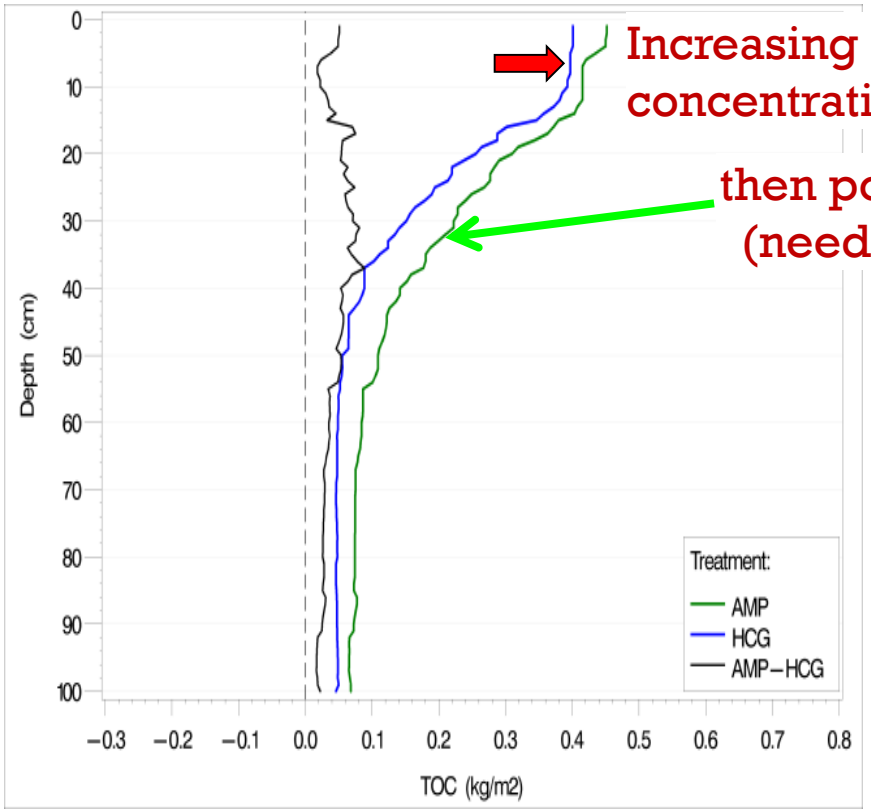
Infiltration on HCG vs. AMP Grazing – Alberta 2015

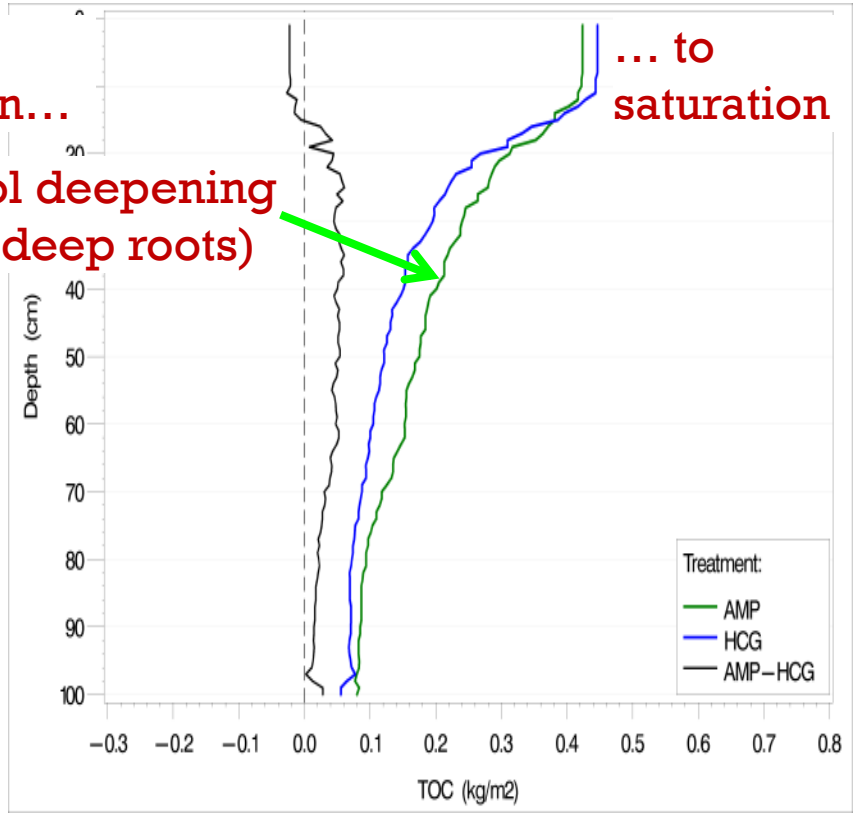


2 Dimensions Drive Total Carbon Pool

Towers – planted pastures

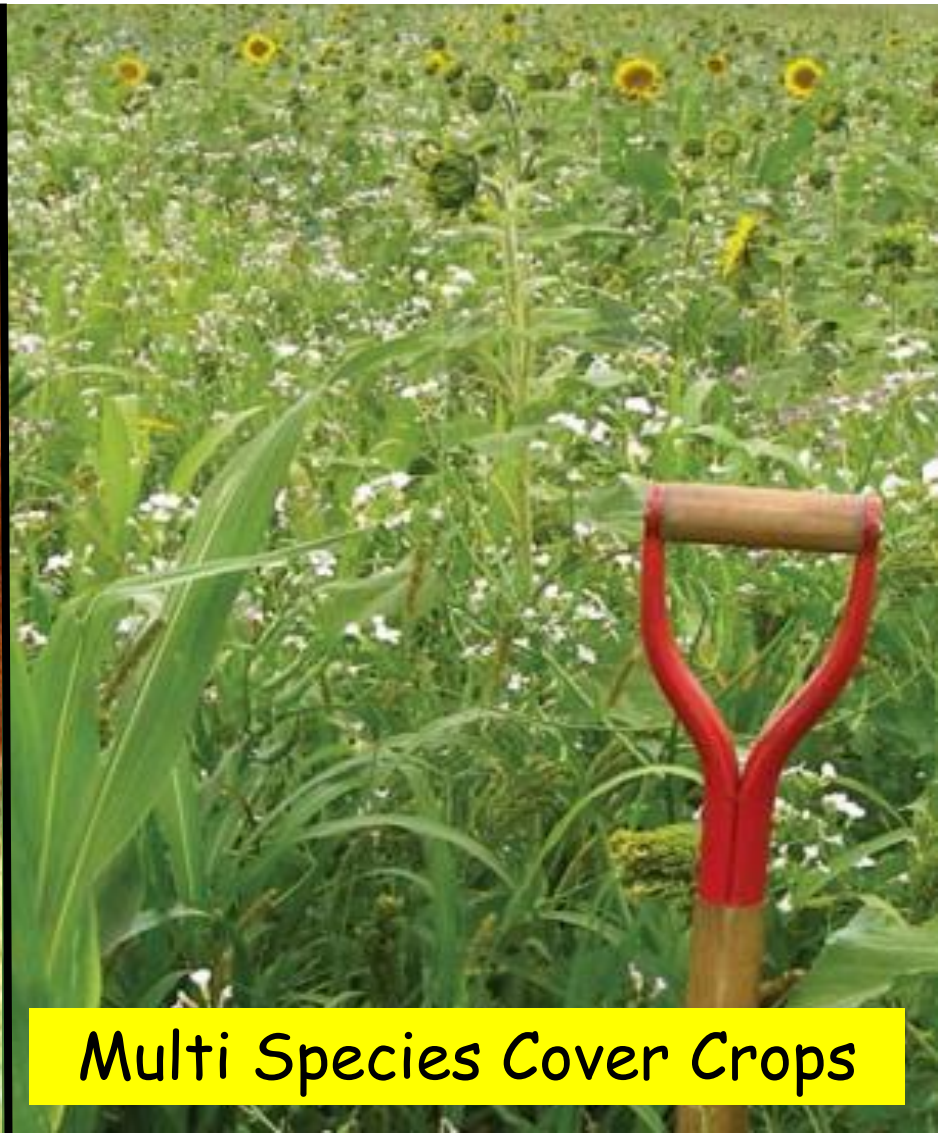
Cross – native grasses





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

High density grazing



Multi Species Cover Crops

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

Cover crop with 25 species


Mob 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%**		

Soil Improvements with Regenerative Management

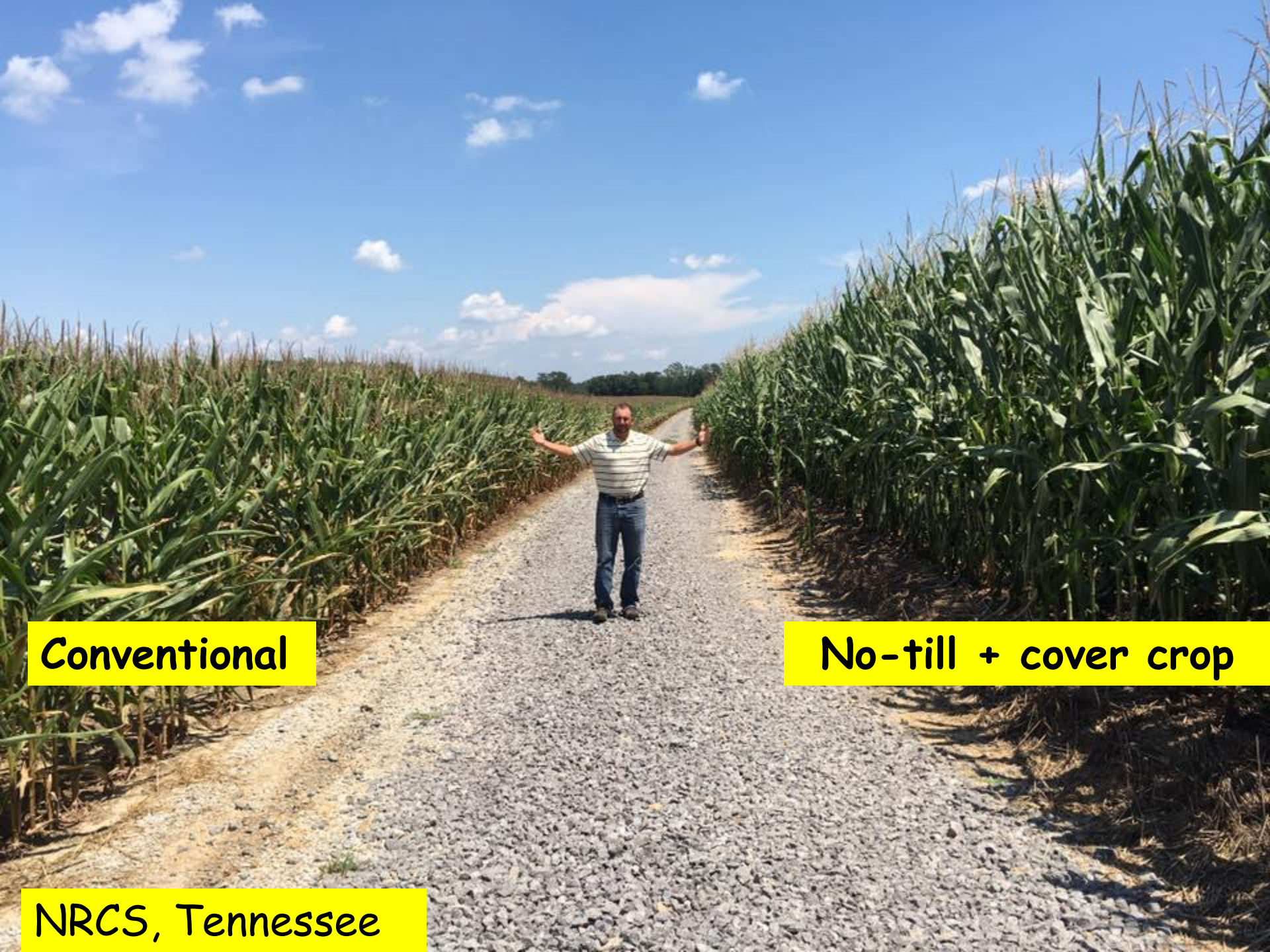
Gabe Brown, North Dakota 2016

No fertilizer since 2007

Management	N	P	K	WEOC
		Kg/ha		
Organic	2	174	106	261
No-till, low diversity	30	273	152	268
No-till, MD, high syn.	41	243	223	293
No-till, HD, livestock	**315**	**1127**	**1959**	**1226**

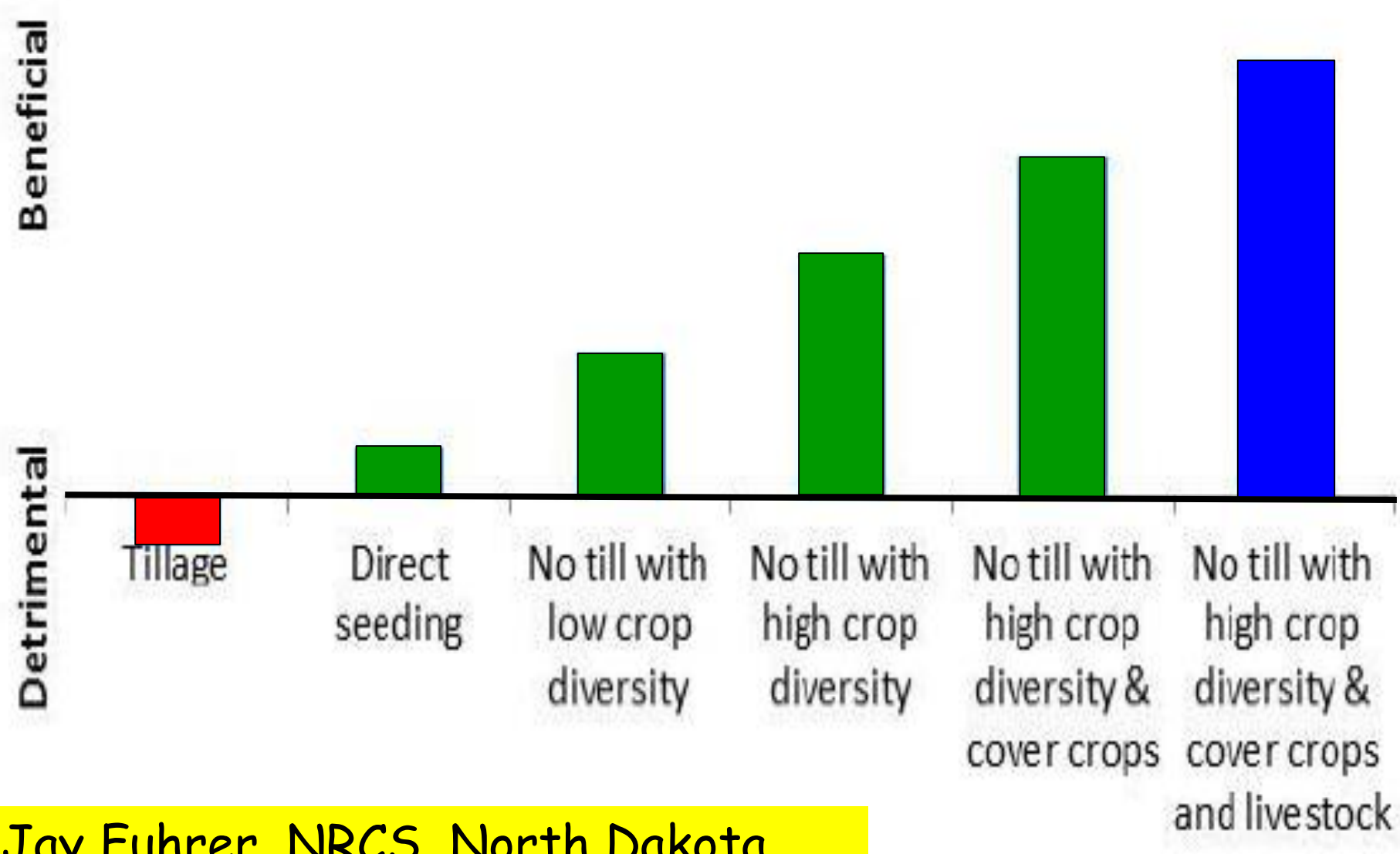
Soil test by Dr. Rick Haney, USDA-ARS, Temple Texas

MD = Medium diversity cover crops
High syn. = High synthetic fertilizer
HD = High diversity cover crops
Livestock = Regenerative livestock grazing
WEOC = Water Extractable Organic Carbon


Conventional
No-till + cover crop
NRCS, Tennessee

Cropland Soil Health

How different cropping practices affect soil health



Jay Fuhrer, NRCS, North Dakota

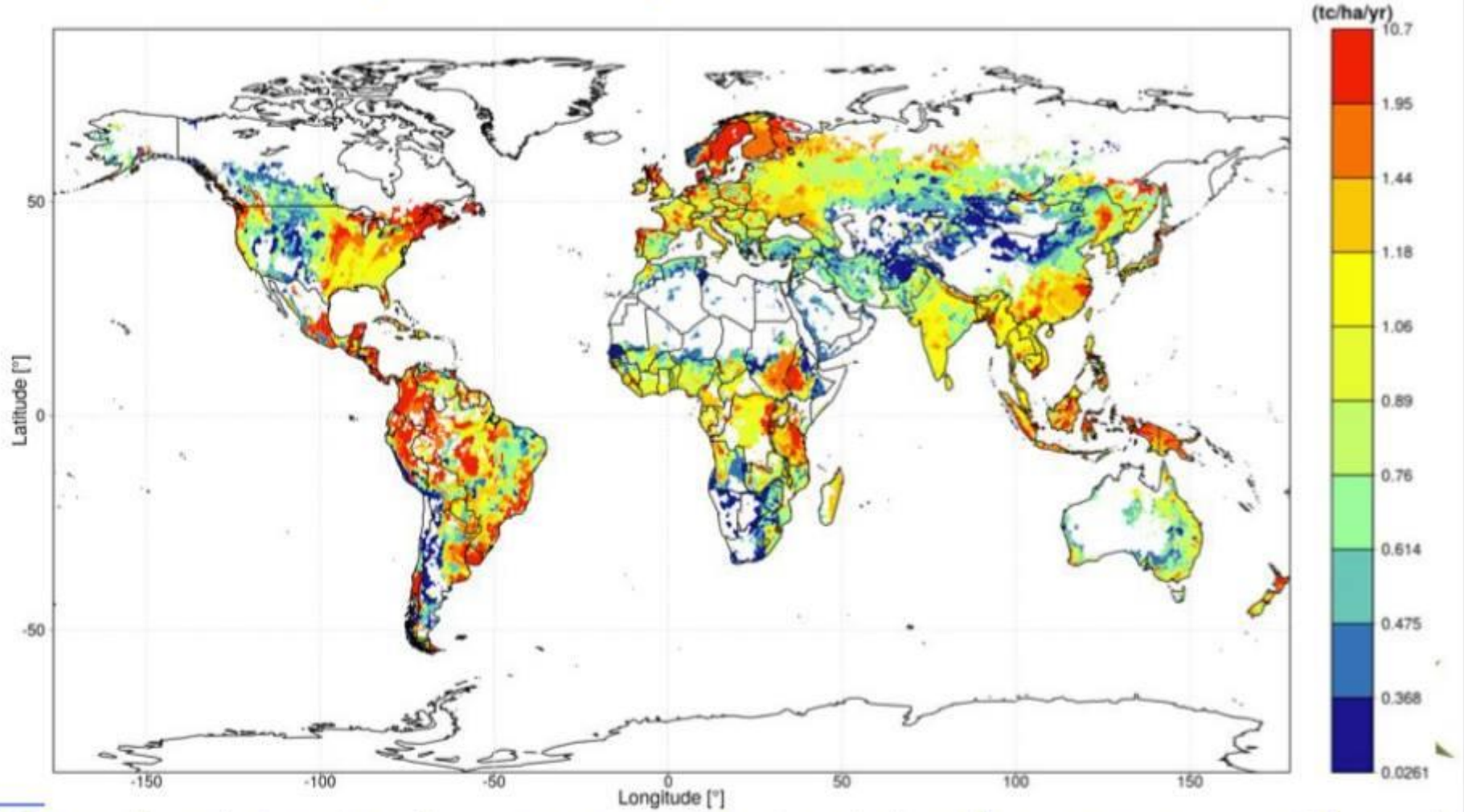
Keys to Healthy Soil

- 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

Marrakech 17th November - 1st FORUM of PARTNERS

Additional organic carbon returns to soils with 4 per 1000 compared to current baseline

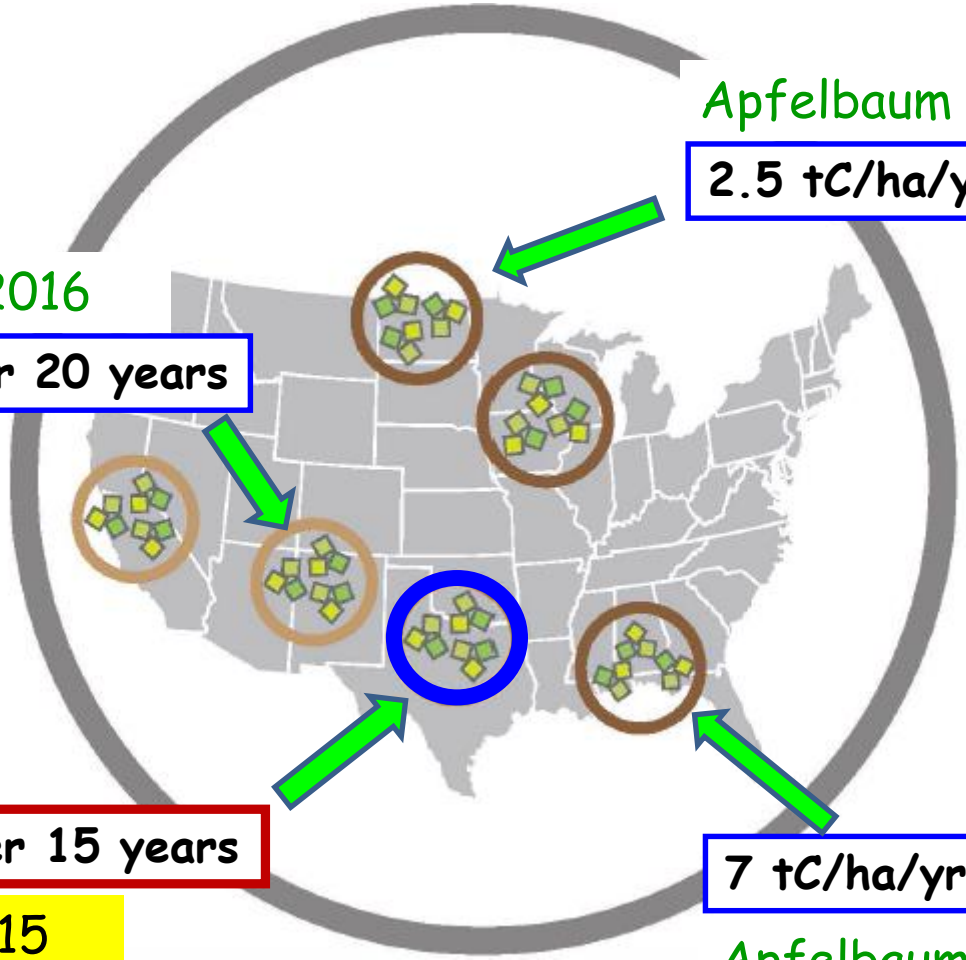


Median: +0.89 tC /ha/ yr, that is +2 tDM

(RothC model, inverse mode, bias correction. IIASA, INRA)

Published and Reconnaissance Sampling

AMP Carbon stock gain/year relative to continuous grazing



Apfelbaum et al 2016

2.5 tC/ha/yr over 20 years

Apfelbaum et al 2016

< 0.5 tC/ha/yr over 20 years

3 tC/ha/yr over 15 years

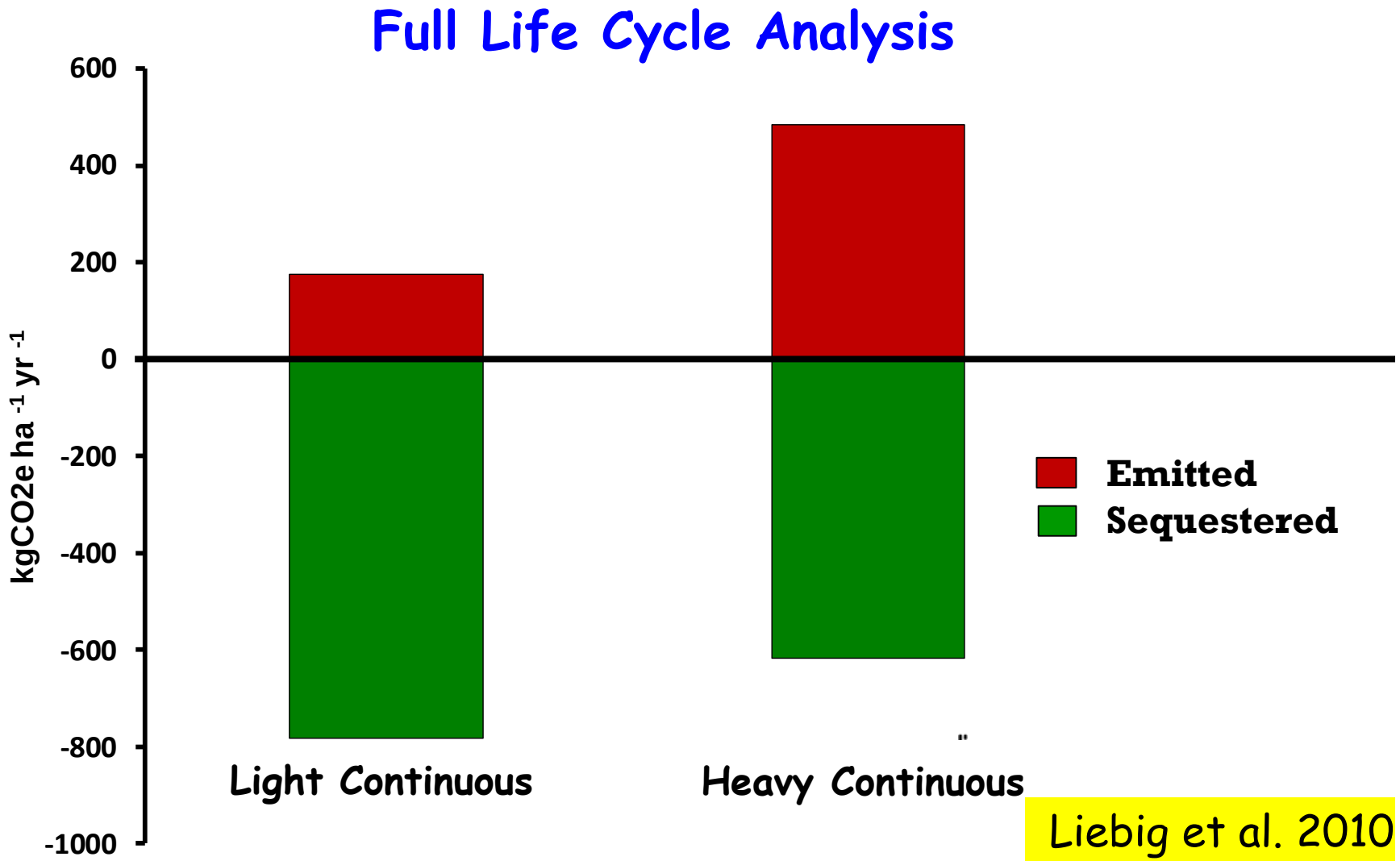
Wang et al. 2015

7 tC/ha/yr over 5 years

Apfelbaum et al 2015

Carbon Sinks and Emissions:

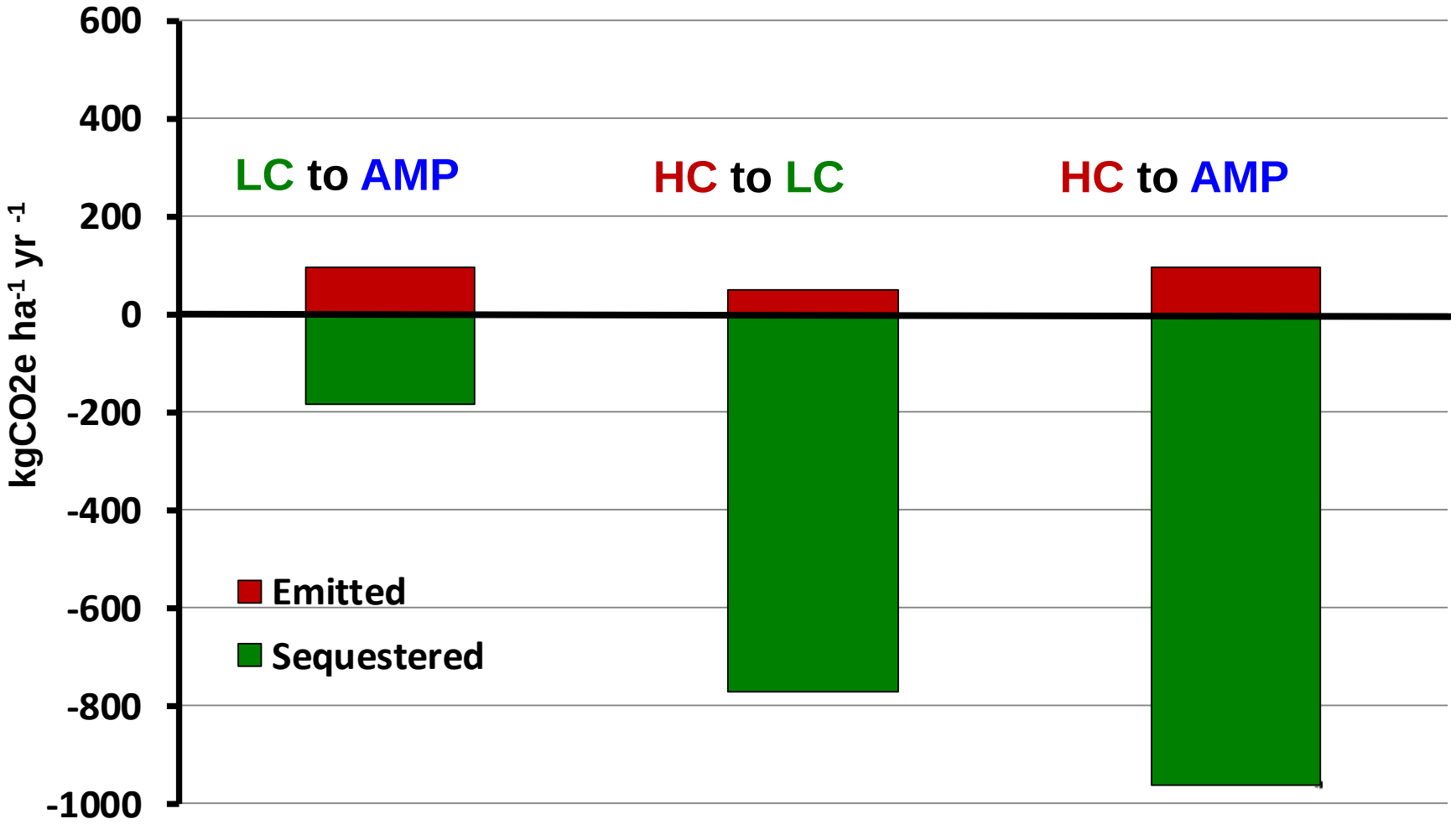
Northern Plains grazing only Cattle Operations



Liebig et al. 2010

Life Cycle Analysis of Change in Management

Net C Emissions on grazing only Cow-calf Operations



Wang et al. 2015

Grass-fed Cultivated Pasture LCA

Using AMP grazing

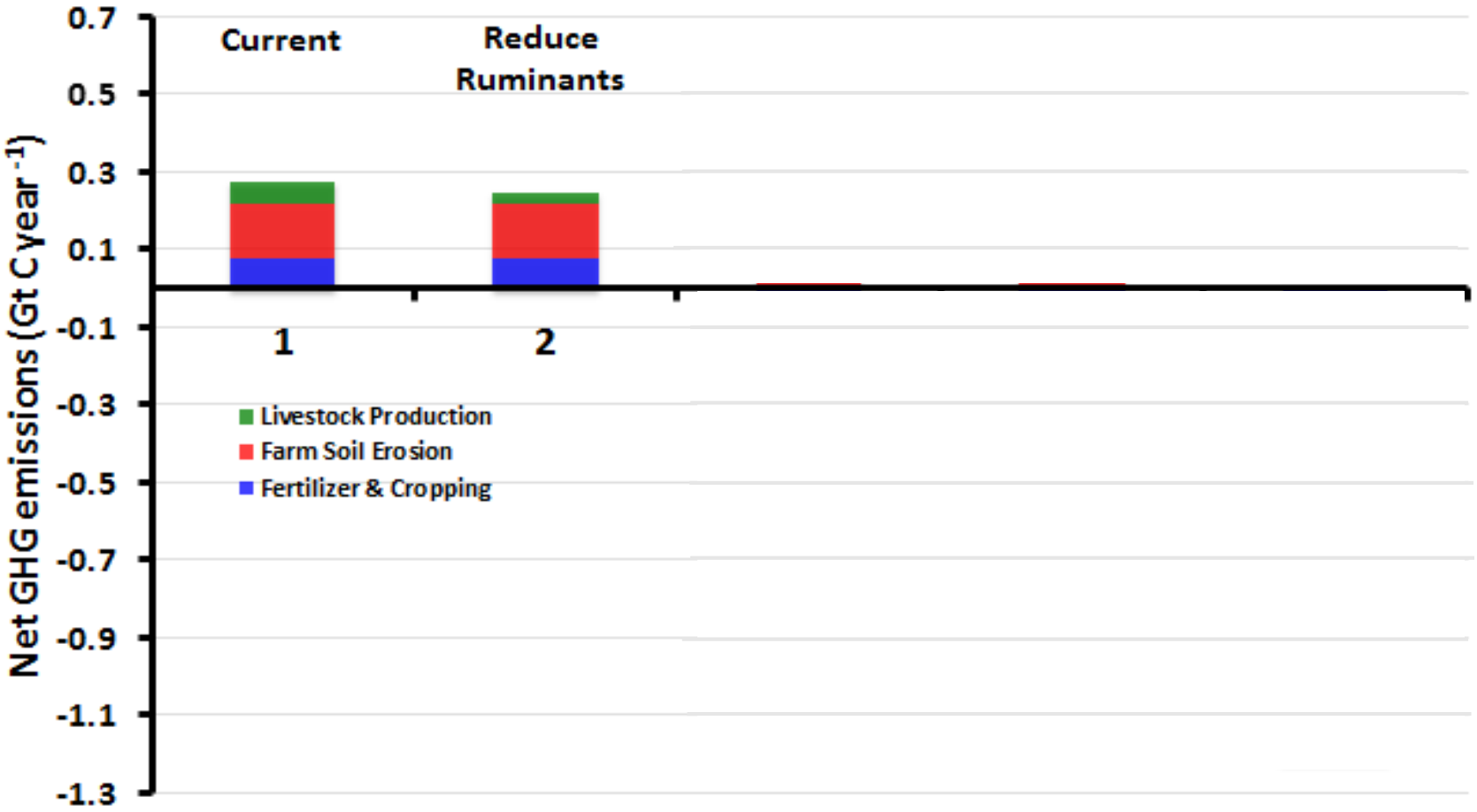
Low input system: Breakeven = 1.0 tons Carbon /ha/year

High input system: Breakeven = 2.0 tons Carbon /ha/year

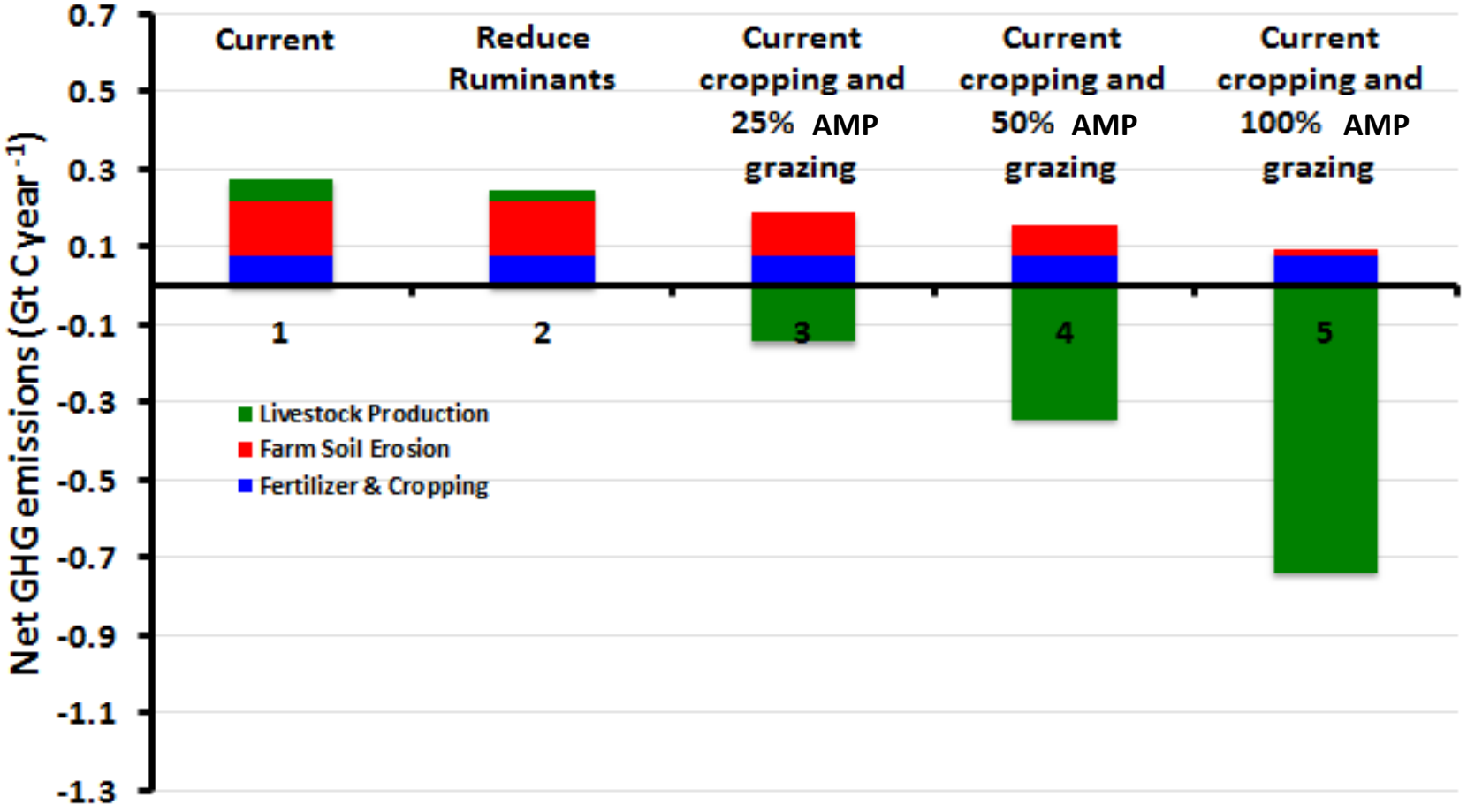
C sequestration in these pastures ~ 3 tons Carbon /ha/year

Rowntree et al. 2017.

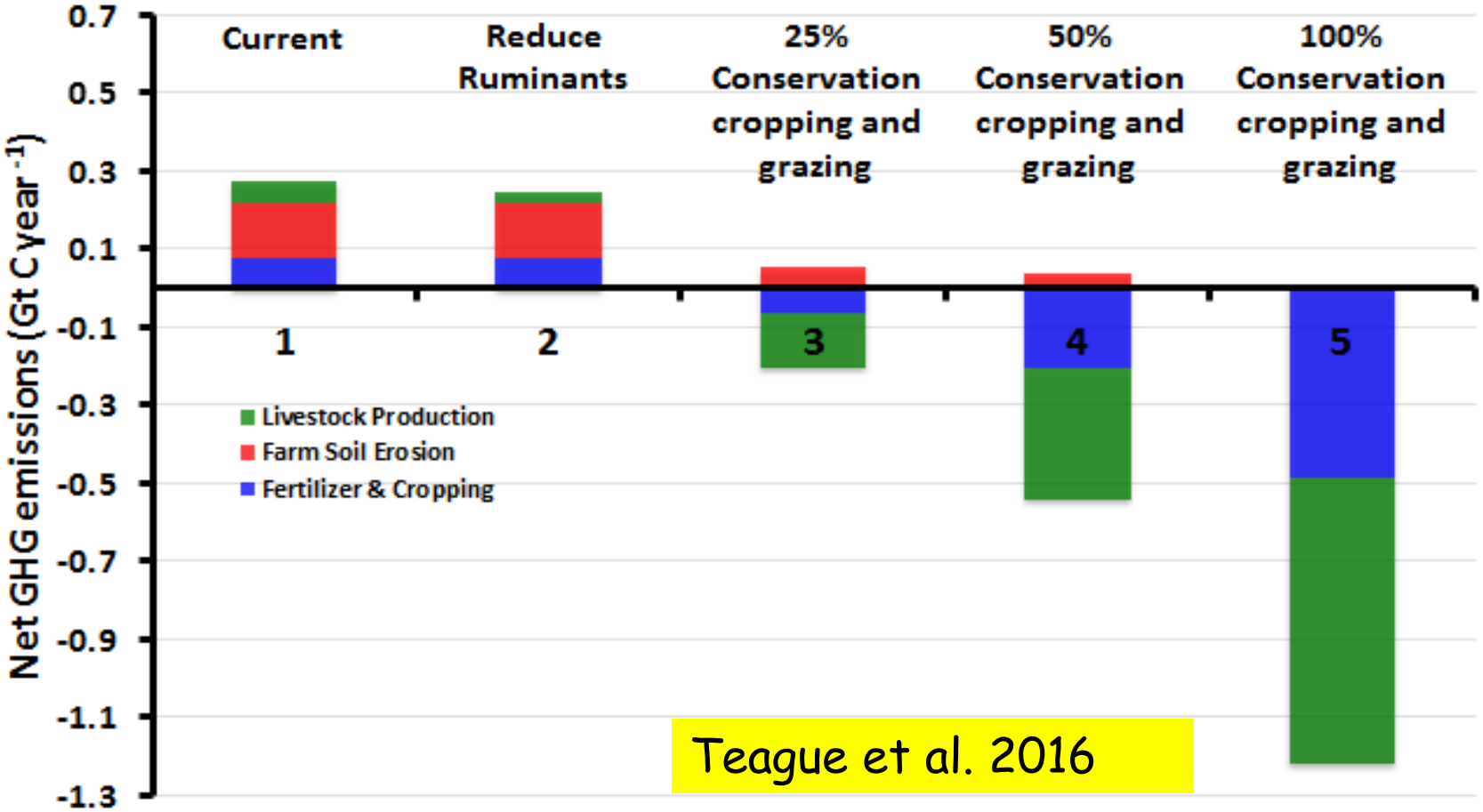
Net Emissions with Current Practices and Reduced Ruminants



Net Emissions with Current Cropping and Regenerative Grazing Practices

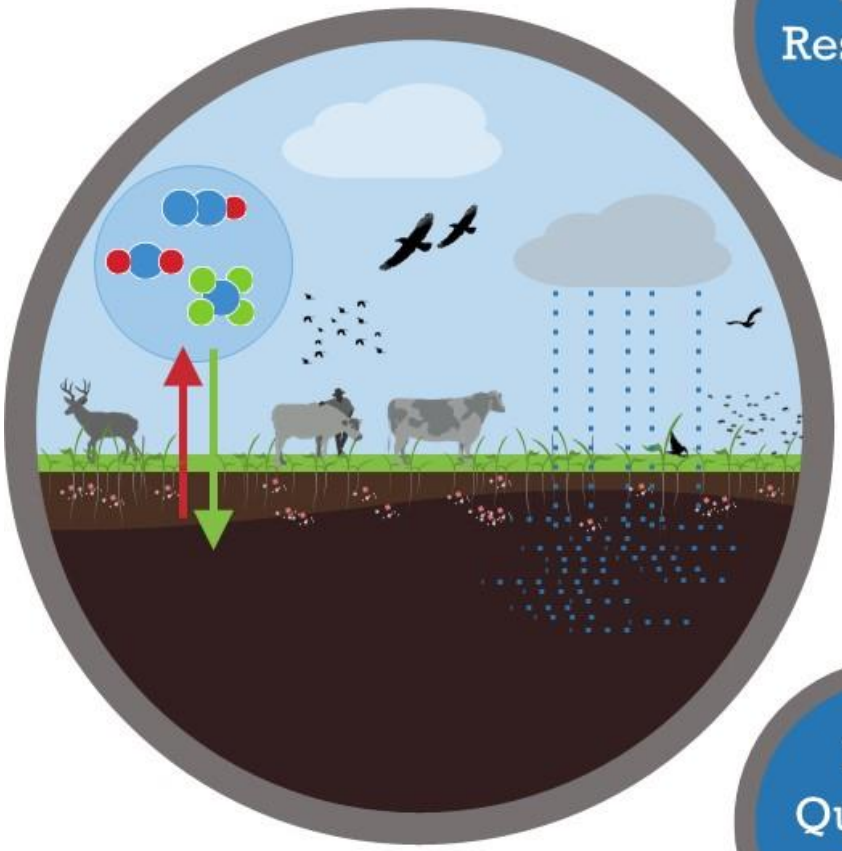


Net Emissions with Regenerative Cropping and Regenerative Grazing Practices



Hypothesis:

Regenerative Agriculture Improves Farm Economics



Water Resilience

Reduces Soil Erosion

Biodiversity

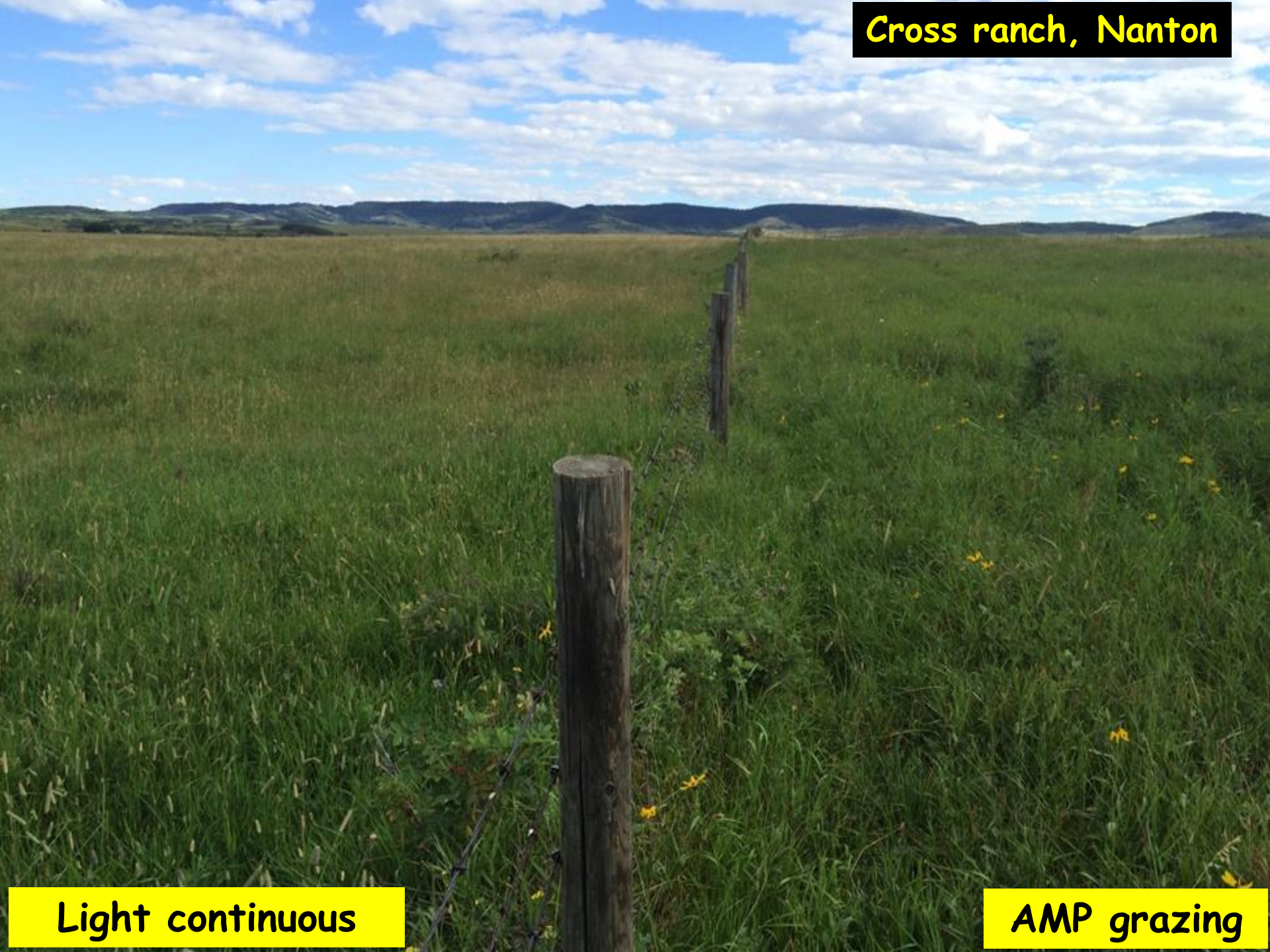
Food Quality & Health

Improved Farm Economics


Hoven ranch, Red Deer


Light continuous


AMP grazing


Cross ranch, Nanton
Light continuous
AMP grazing

Holtman ranch, Taber


Questions?