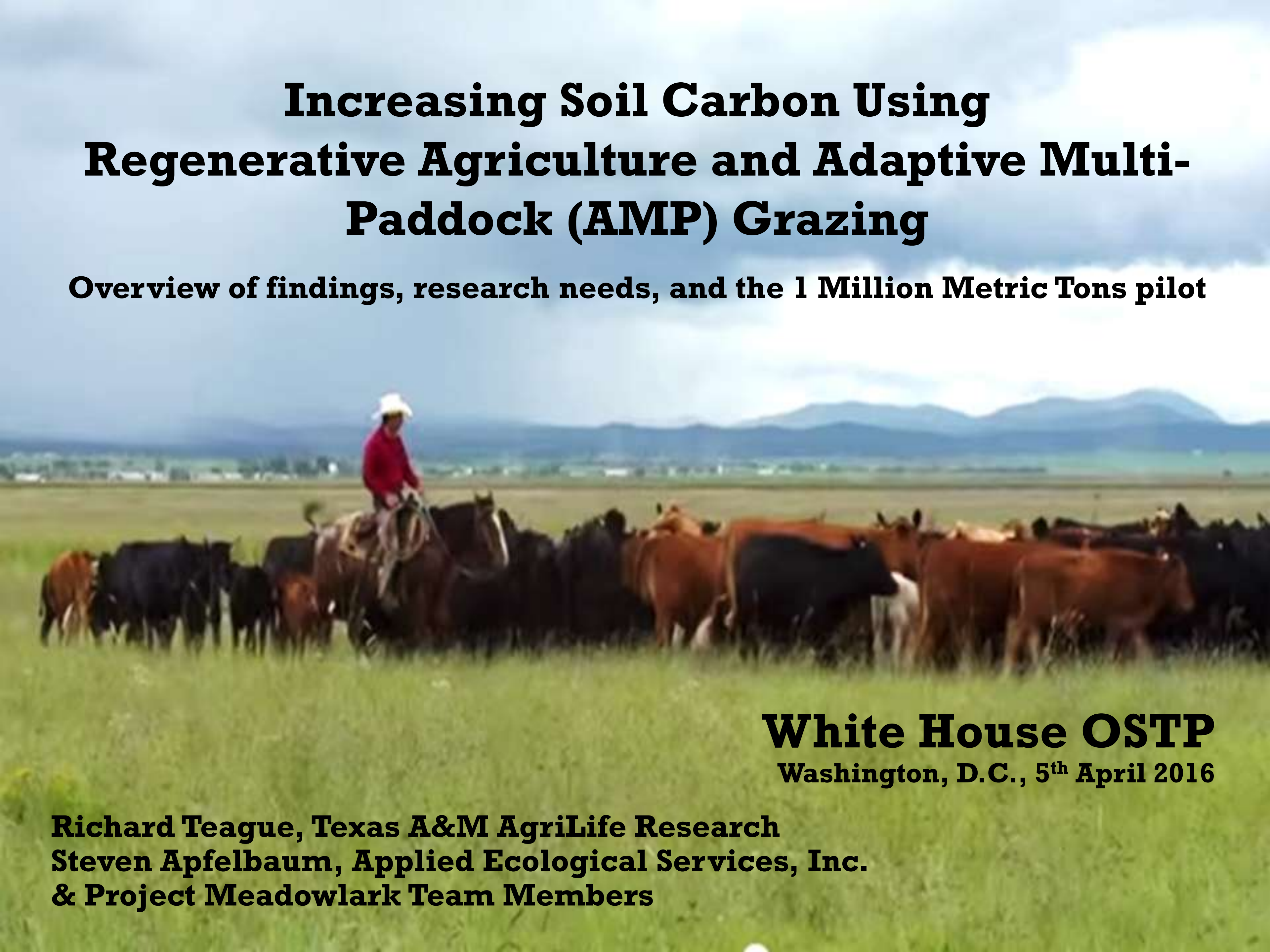
Increasing Soil Carbon Using Regenerative Agriculture and Adaptive Multi-Paddock (AMP) Grazing

Overview of findings, research needs, and the 1 Million Metric Tons pilot



White House OSTP

Washington, D.C., 5th April 2016

Richard Teague, Texas A&M AgriLife Research
Steven Apfelbaum, Applied Ecological Services, Inc.
& Project Meadowlark Team Members

Presentation Agenda

The role of re-growing soil carbon to reduce atmospheric CO_2

- Photosynthesis and soil dynamics drives the process
- Regenerative land management is the vehicle

What we have learned

- Palouse "Low Disturbance Cropping"
- North Texas and Alberta "AMP Grazing"

Data gaps---what we need to know

- Expanded systems science research understandings

How we envision addressing gaps and reaching meaningful scale quickly

- 1 Million Metric Tons pilot project with farmers/ranchers
- Coalition of industry, NGOs, and government

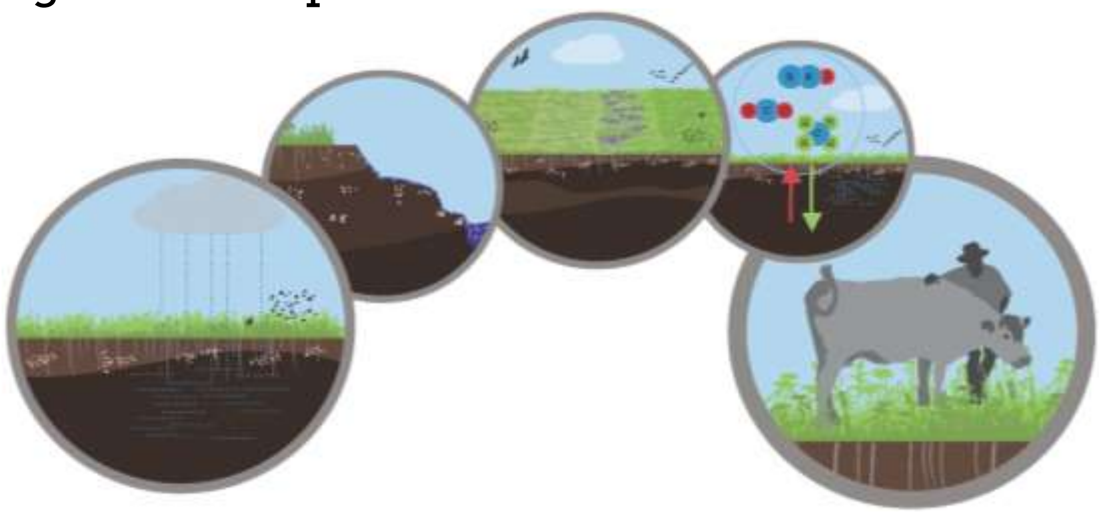
Discussions

Research Framework and Hypothesis:

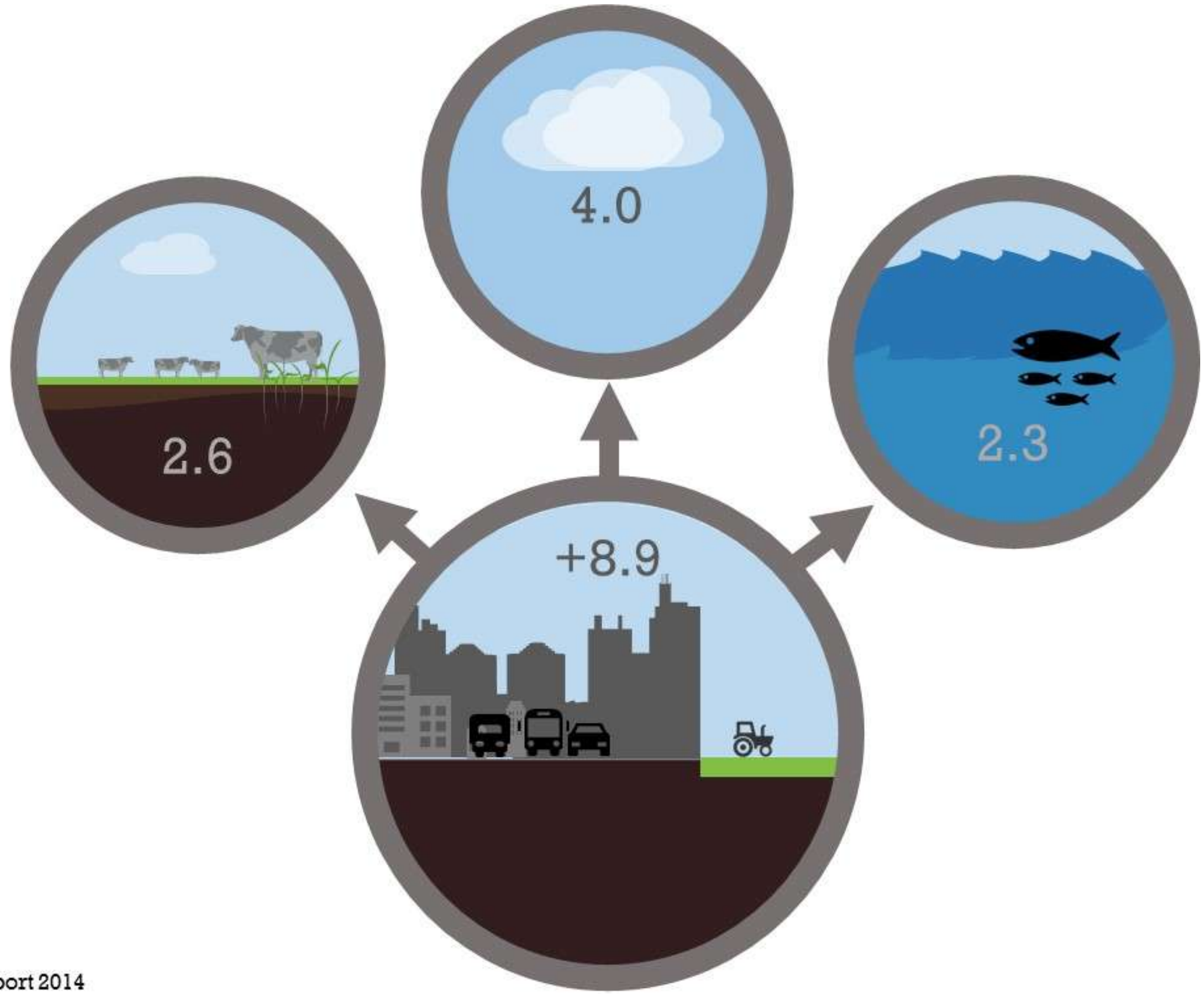
"Carbon rich soil is healthy soil, beneficial for the entire ecosystem"

Healthy Ecosystems function by:

- Drawing down CO_2 into the soil, resulting in;
- Improved water infiltration and retention;
- Increased biodiversity of fungi, microbes, plants, insects, wildlife;
- Reduced soil erosion & reduced net GHG emissions; and,
- Contributing to both improved livestock and farmer/rancher well-being.

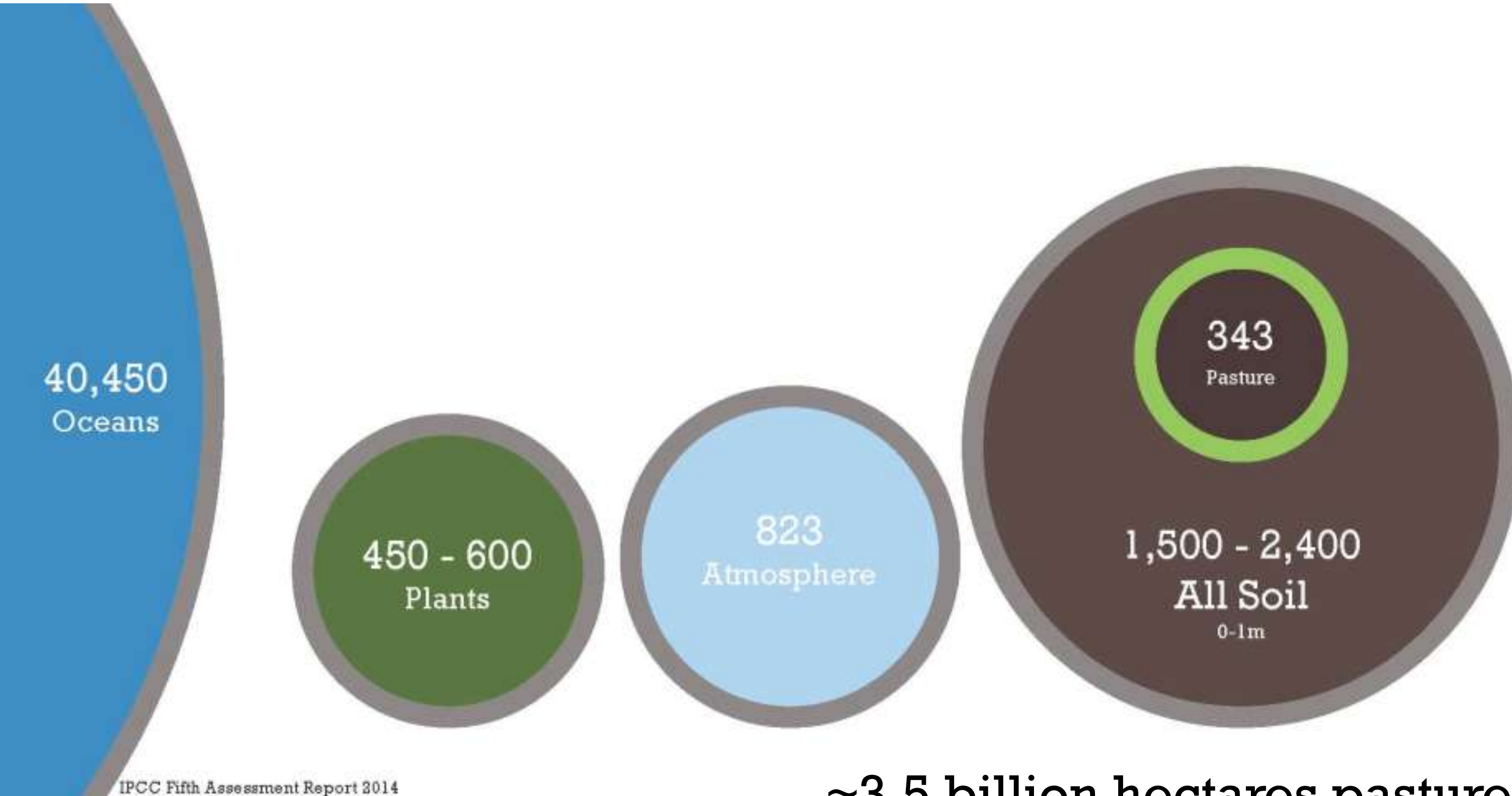


Global Fluxes – Gigatons Carbon/Year



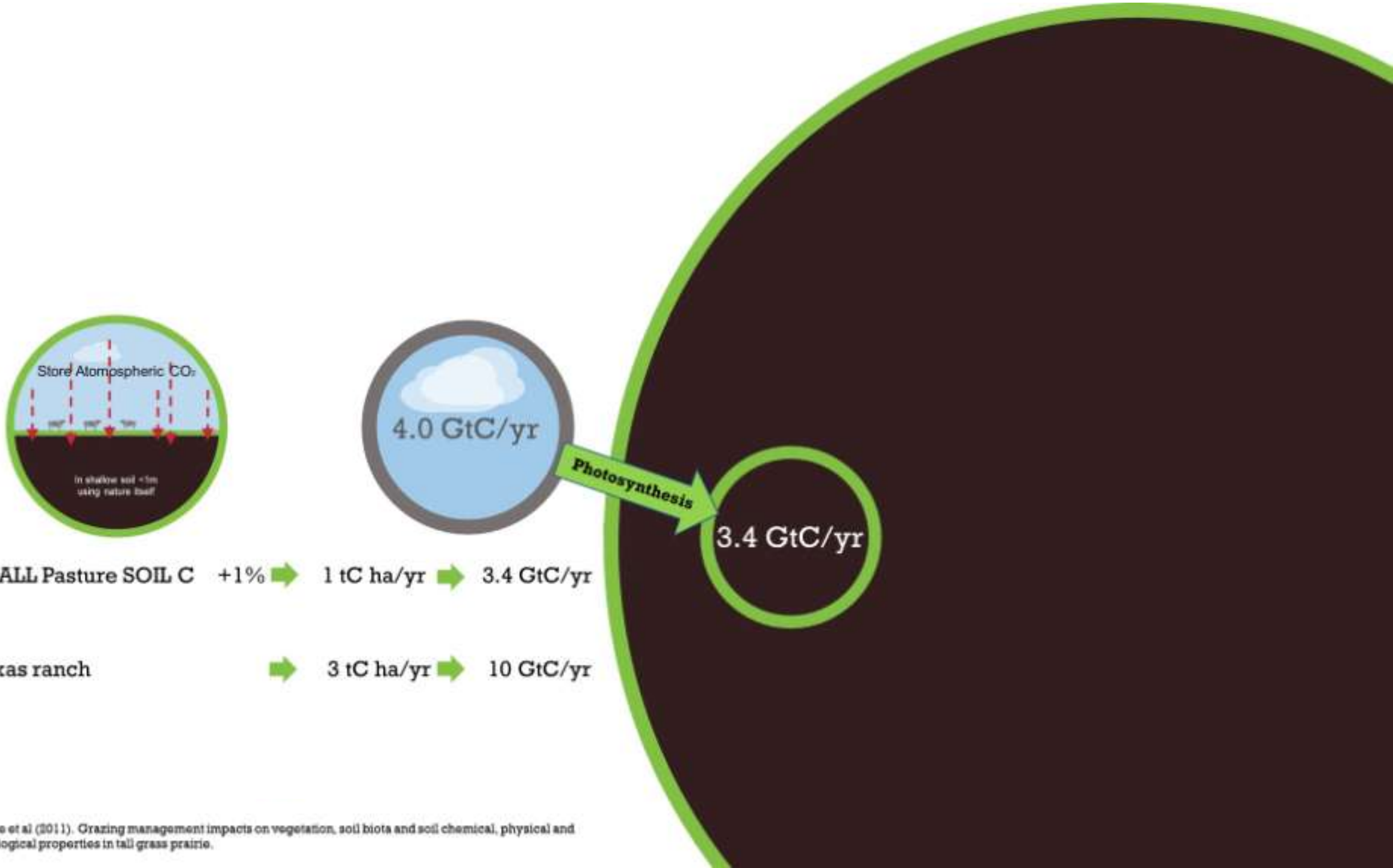
IPCC Fifth Assessment Report 2014

Global Stocks – Gigatons Carbon



~3.5 billion hectares pastures
~1 billion hectares croplands

Photosynthesis Creates Big Opportunities



IF ALL Pasture SOIL C +1% ➡ 1 tC ha/yr ➡ 3.4 GtC/yr

Texas ranch ➡ 3 tC ha/yr ➡ 10 GtC/yr

Teague et al (2011). Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie.

Palouse Low Disturbance Cropping Project

Palouse Program Goals

- Develop a soil carbon farmer partnership on 300,000+ acres
- Establish "Low Disturbance Cropping (LDC)"; one pass farming as a standard method
- Establish a low-cost farmer aggregation business model
- Showcase a soil carbon transaction
- Develop data, and templates to inform policy

Primary Program Benefits

Farmers will:

- Receive a new soil carbon revenue stream
    - Based on measured improvements in soil carbon
- Innovate to increase soil carbon/soil health

Verified Carbon Standard (VCS) Approved Soil Carbon Quantification Method

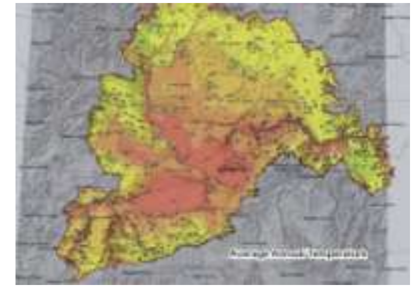
- Marketplace requirements
- Standardizes measurements, accounting and reporting

Mapping and Stratification

Region

Soils (mineralogy, history)

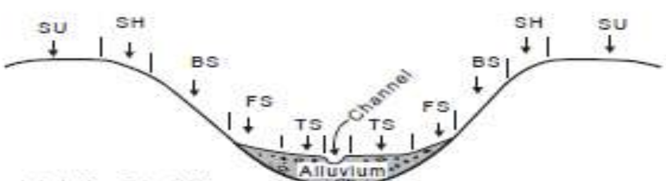
Climate zones



Precipitation

Hillslope - Profile Position (Hillslope Position in PDP) - Two-dimensional descriptors of parts of line segments (i.e., slope position) along a transect that runs up and down the slope; e.g., *backslope* or *BS*. This is best applied to transects or points, not areas.

Position	Code
summit	SU
shoulder	SH
backslope	BS
footslope	FS
toeslope	TS



(adapted from Ruhe, 1975)

USDA-NRCS *1-6* *September 2002*

Landscape position

Conducting pre-Sampling

Sample Locations by Strata-Landscape Factors

Key Factors:

- Soil management method
- Precipitation zone
- Slope position

			Direct Seed History													
			2011 or None Conventional H1		2007-2010 1-5 Yrs H2		2000-2006 6-12 Yrs H3		1992-1999 13-20 Yrs H4		1990 or earlier 21 + Yrs H5		CRP Any H6		MISC (Irrigated) H7	REFERENCE H9
Precip Zone	Slope Position	Aspect	Allocated	Sampled	Allocated	Sampled	Allocated	Sampled	Allocated	Sampled	Allocated	Sampled	Allocated	Sampled	Sampled	Sampled
P2	UP	SW		4			5	5	1	1			5	6		1
P2	UP	NE					5	5	1	1			5	5		3
P2	LO	SW		2			5	5	1	1			5	6		7
P2	LO	NE		2			5	5	1	1			5	5		11
P3	UP	SW	1	3	5	5	5	5	5	5	1	1	5	3		3
P3	UP	NE	1	5	5	5	5	5	5	5	1	1	5	5		2
P3	LO	SW	1	8	5	5	5	5	5	5	5	5	5	4		9
P3	LO	NE	1	5	5	5	5	5	5	5	5	5	5	5		8
P4	UP	SW	2	2	5	4	5	5	5	5	5	5	5	4	1	4
P4	UP	NE	2	4	5	2	5	5	5	5	5	5	5	6	1	8
P4	LO	SW	2	5	5	3	5	5	5	5	5	5	5	6	5	5
P4	LO	NE	2	3	5	4	5	5	5	5	5	5	5	5	1	4
P5	UP	SW		3	5	5	5	5	5	5	5	5	5	5		6
P5	UP	NE		7	5	5	5	5	5	5	5	5	5	7		4
P5	LO	SW		2	5	5	5	5	5	6	5	5	5	4		6
P5	LO	NE		4	5	5	5	5	5	5	5	5	5	4		7
P6	UP	SW		4	5	5	5	5	5	5			5	5		5
P6	UP	NE		6	5	5	5	5	5	5			5	5		5
P6	LO	SW		7	5	5	5	5	5	4			5	6		7
P6	LO	NE		5	5	5	5	5	5	5			5	5		4
Pre-Allocated or Sampled Plots			12	81	80	73	100	100	84	84	52	52	100	101	8	109
Target # of Plots			100		100		100		100		100		100			100

Sampling

Summary of LDC Soils Lab Analysis

Soil Management	("n")
Conventional Tillage	(81)
▪ 1-5 yrs LDC	(73)
▪ 6-12 yrs LDC	(100)
▪ 13-20 yrs LDC	(84)
▪ 21+ yrs LDC	(52)
▪ CRP	(101)
▪ Misc/Irrigated	(8)
▪ Reference Areas (109)	
TOTAL	*~800 Soil Cores (2,400 samples)*

***Then* Allocated by strata-slope position, aspect, precipitation zone**

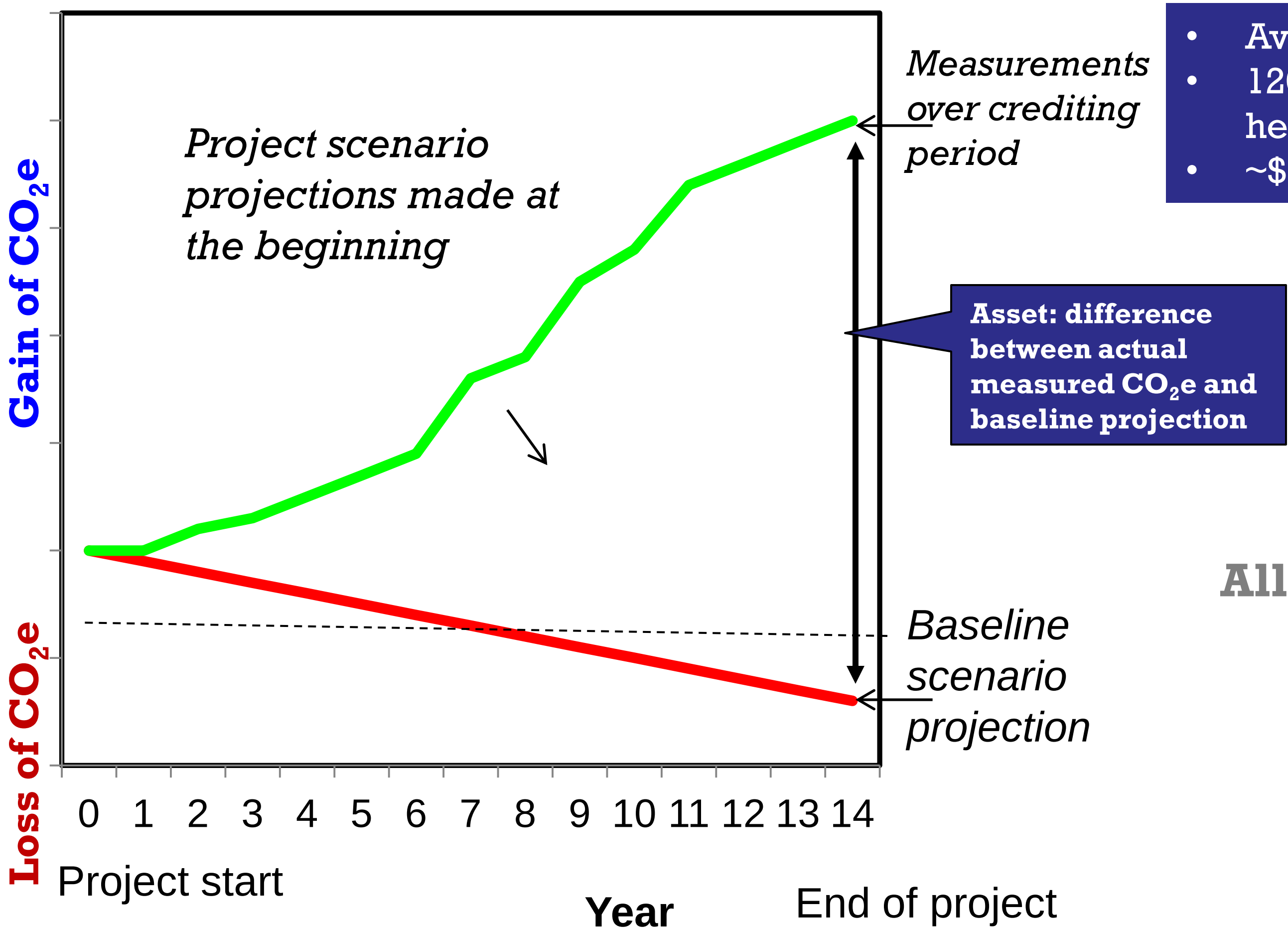
Soils Lab Analysis

- Descriptions
- Bulk Density, Fractions
- % SOC
- % SIC, pH
- % TC
- %N
- QA/QC blind splits, etc

ANOVA's/Linear Regression ---SOC Stocks vs LDC Years: Means highly significant at $P<0.05$; R-squared > 50% (n=309, including outliers).

Can Farmers Benefit?

Carbon and GHG balance, Tons of CO_2e



New Potential Revenue

- Average 3.0 tons CO_2e/ha/yr
- 120,000 tCO_2e /20yrs on 2,000 hectares
- ~$1-2 million @ $10-20/$tCO_2e$

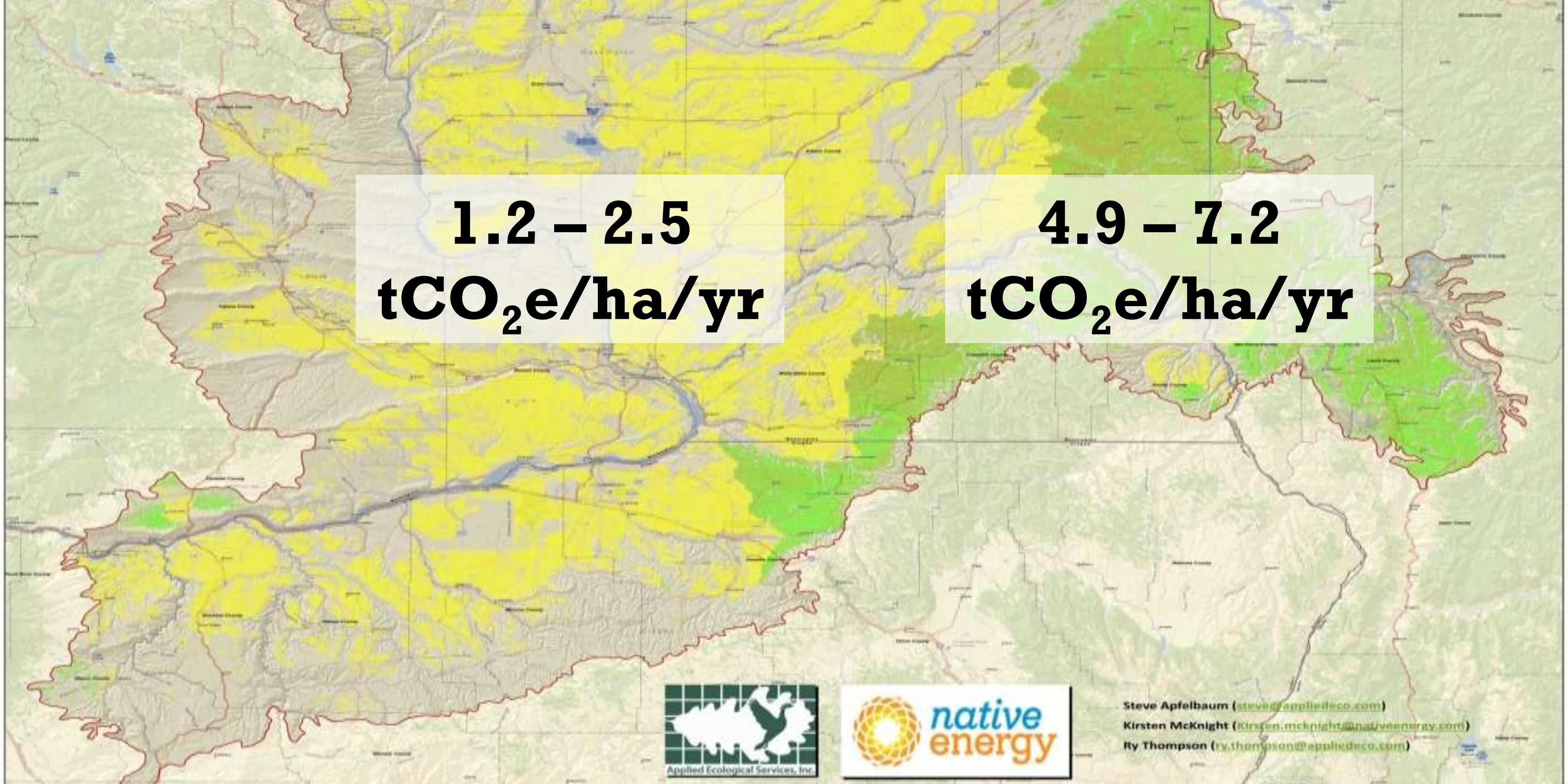
All-in Costs: ~$6/ha

Palouse Soil Carbon Project Now Enrolling New Farmers

HELP US ENROLL ANOTHER 300,000 ACRES OF PNDSA FARMLAND

JOIN THE PROCESS:

- Review farm eligibility, program guidelines and terms of agreement
- Producer enters into contract agreement.
- AES measures soil carbon improvements about every 5 years.
- Verified increases in soil carbon become salable as carbon credits.
- NativeEnergy arranges carbon credit sales on behalf of farmers.
- Please see us at BOOTH #37.



Applied Ecological Services, Inc.

native energy

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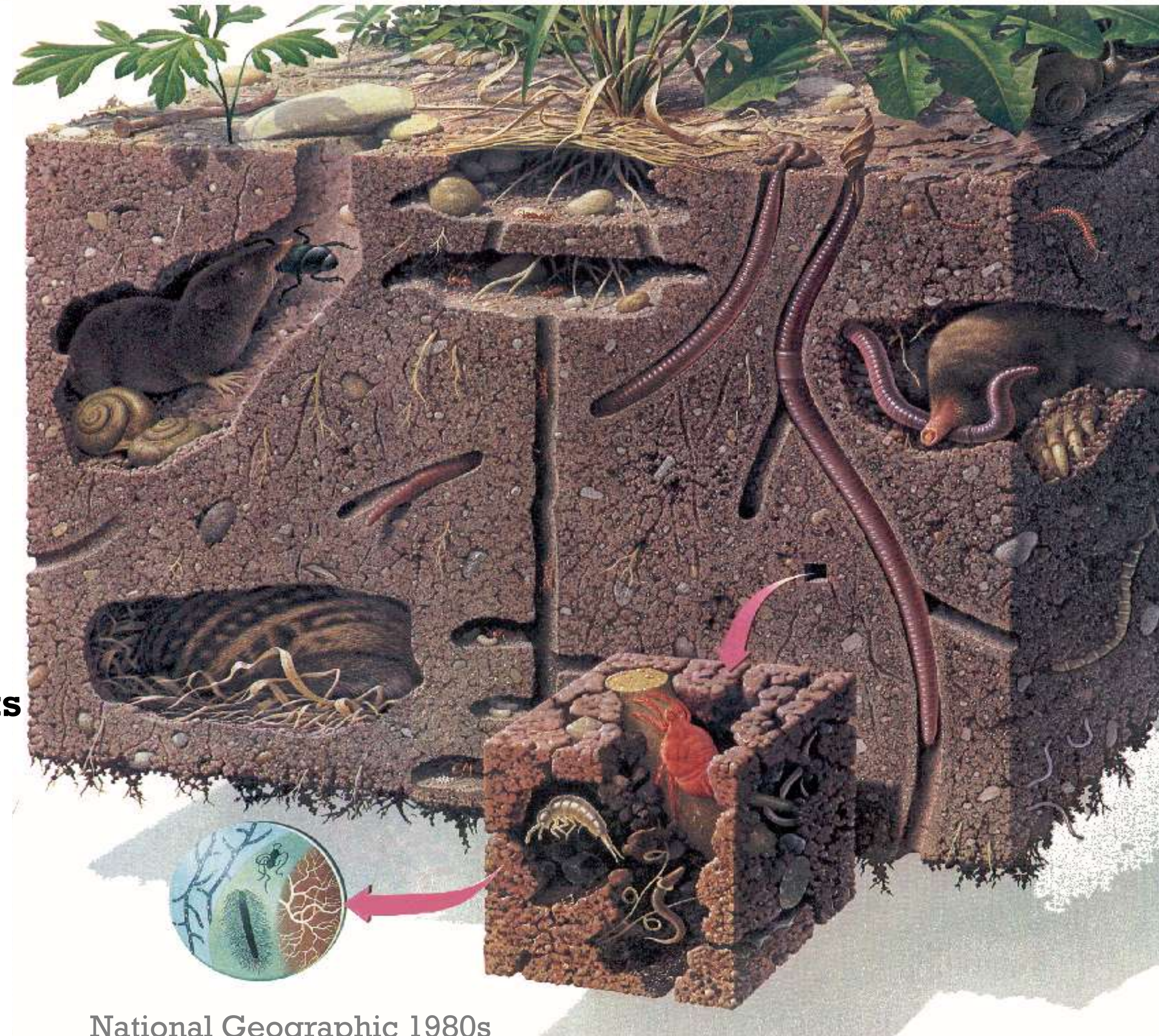
Adaptive Multi-Paddock (AMP) Grazing Studies

90% of Soil function is mediated by microbes

Microbes depend on plants

So how we manage plants is critical



National Geographic 1980s

The Four Ecosystem Processes

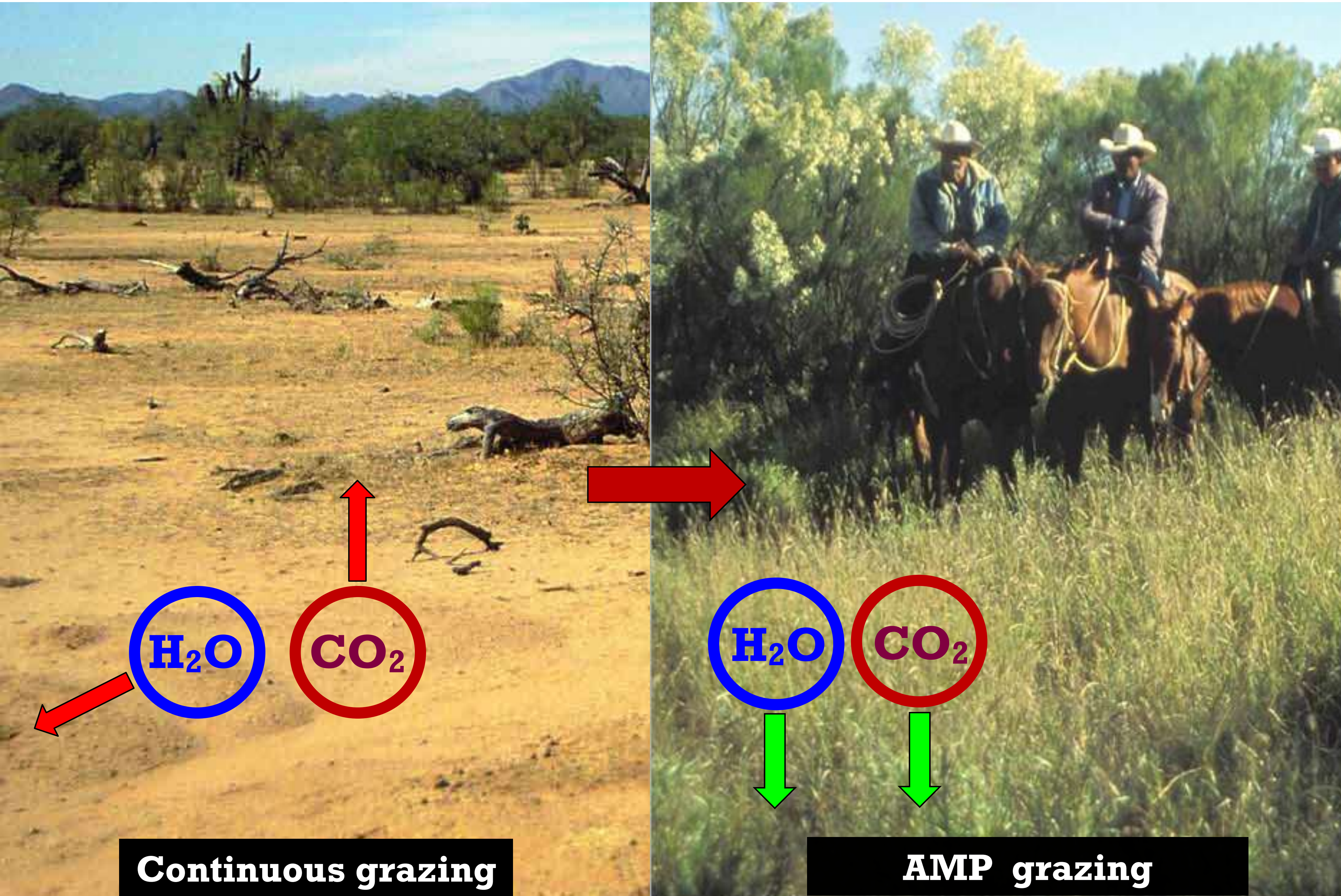
1. **Energy flow** - Maximize the flow of solar energy through plants and soil

2. **Water cycle** - Maximize capture and cycling of water through plants and soil. Reduce runoff and erosion

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, resilience and productivity

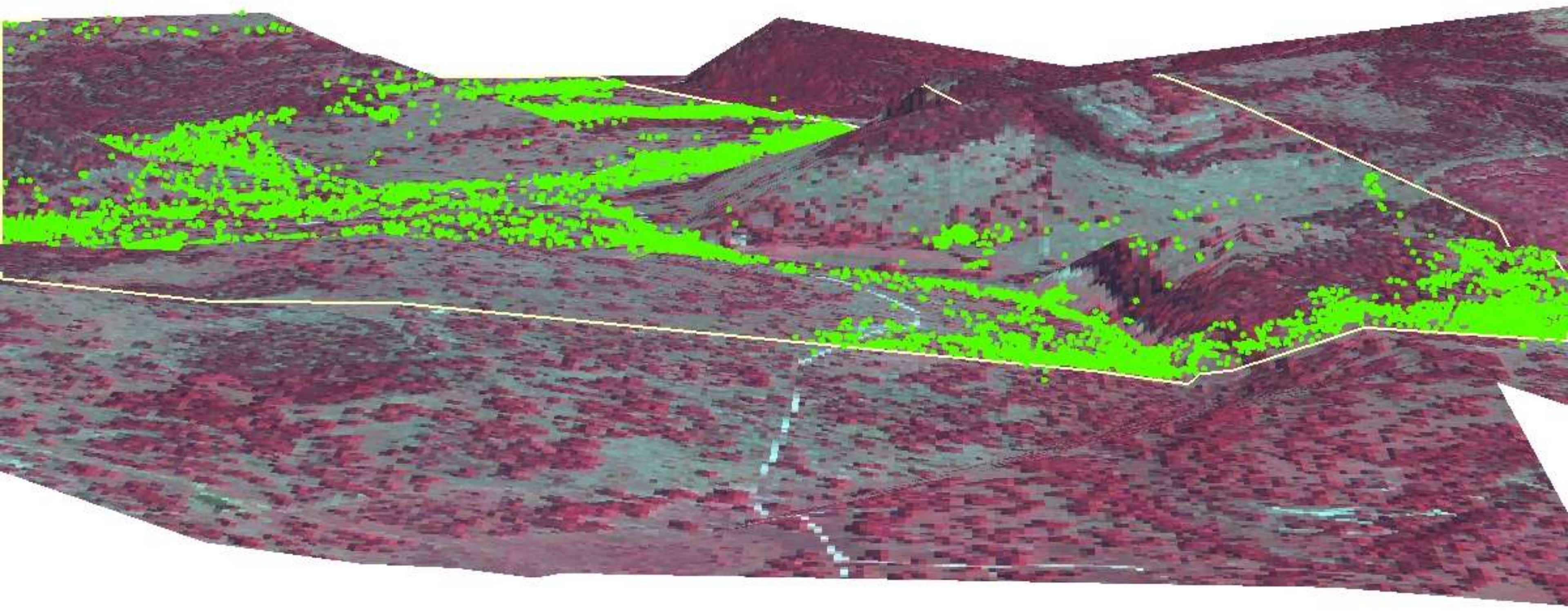
North America: Semi-Arid Rangeland



Landscape impact of continuous grazing

Edwards Plateau Ranch 3-D View w/ GPS Locations

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



Teague et al. 2013

Overgrazing

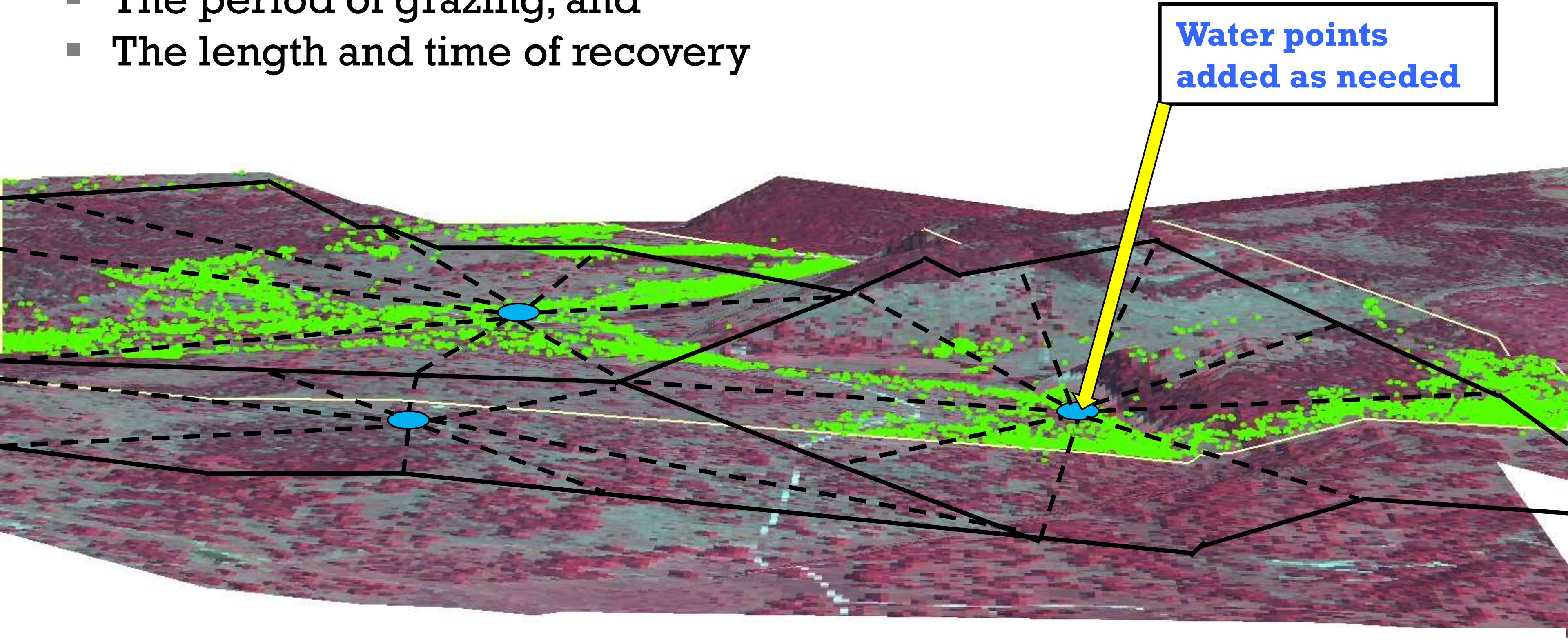
- Overgrazing has little to do with number of animals
- It has to do with the amount of time plants are exposed to the animals
- If animals remain for too long in one place, or return to the grazed plants too soon, they overgraze those plants
- One cow grazing on 10 acres all season can kill thousands of plants
- But 1000 cows grazing the same acre for 1 day will not kill a single plant

Voisin 1959; Gerrish 2004; Butterfield et al. 2006; Teague et al. 2011

Regenerative AMP grazing

Manager can control:

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



Animals:

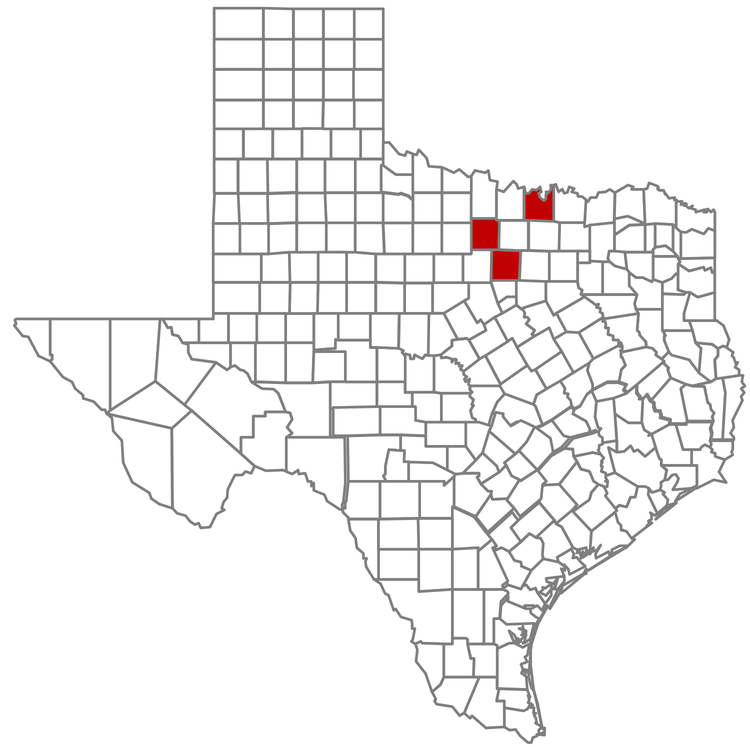
- Graze more of the whole landscape, one paddock at a time
- Select a wider variety of plant species

Teague et al. 2013

Texas AMP Research

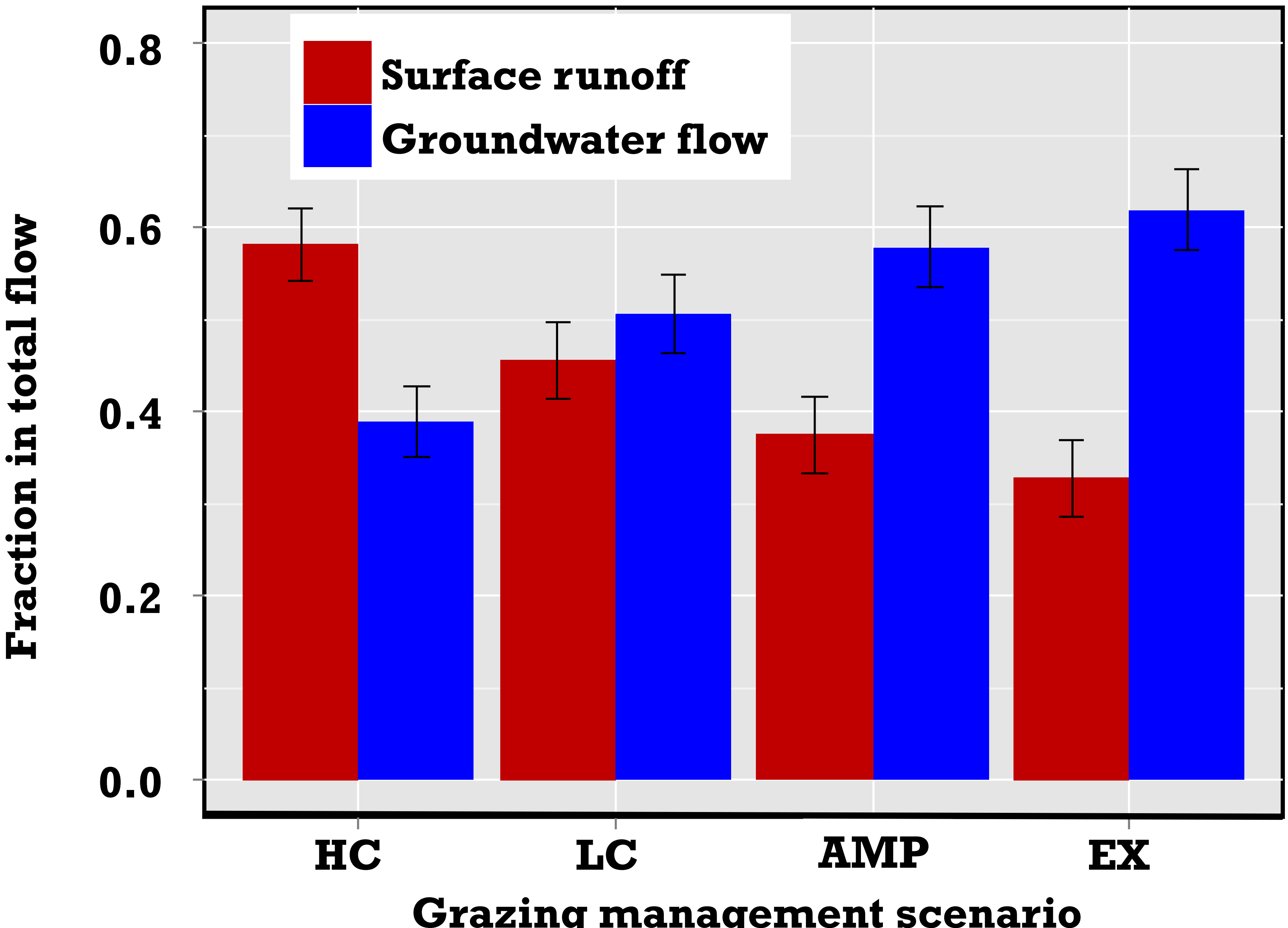
Using AMP grazing 3 Texas ranchers :

- Added 3 tons Carbon/ha/yr more than their three heavy continuously grazed neighbors
- Decreased bare ground
- Improved soil physical structure
- Bolstered soil fertility
- Enriched soil microbial composition
- Increased soil water holding capacity
- Enhanced plant productivity
- Improved plant species composition
- Increased livestock production



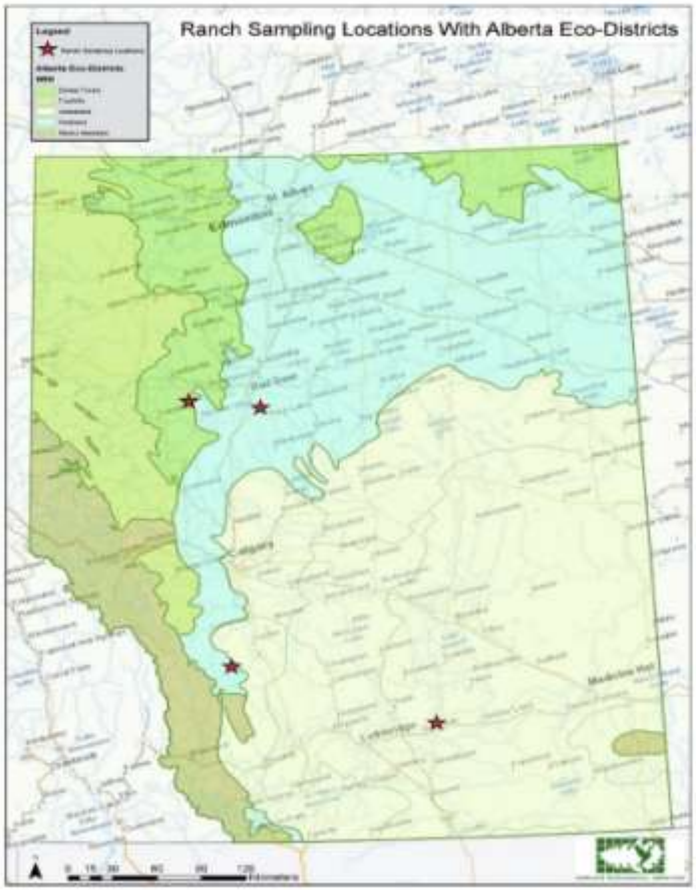
Teague et al. 2011

Clear Creek Watershed, North Texas

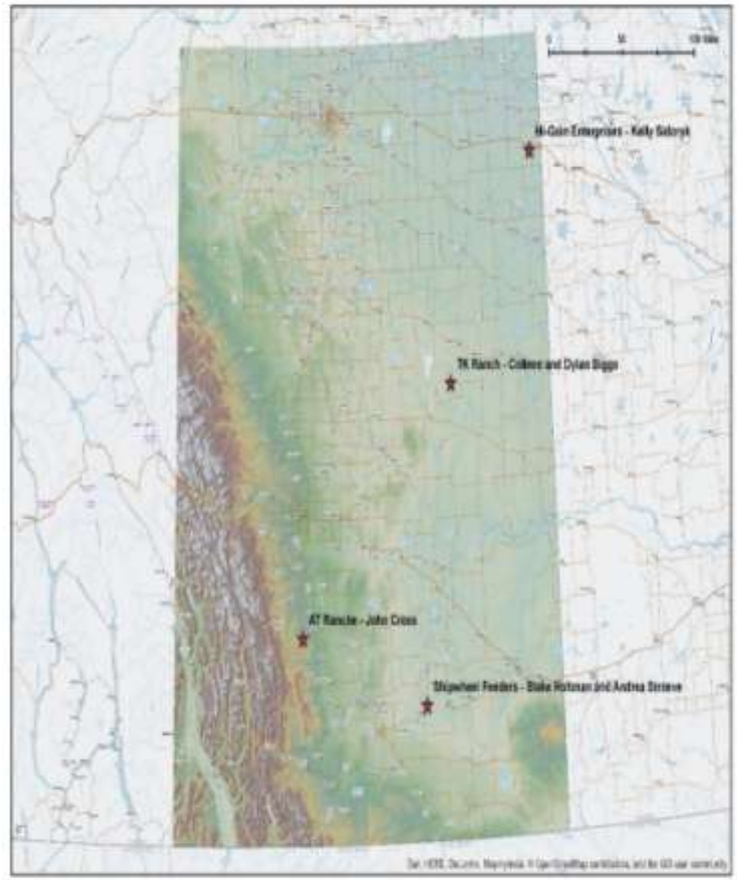


Alberta Ranches: Stratification, and Pre-sampling

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



Study Region

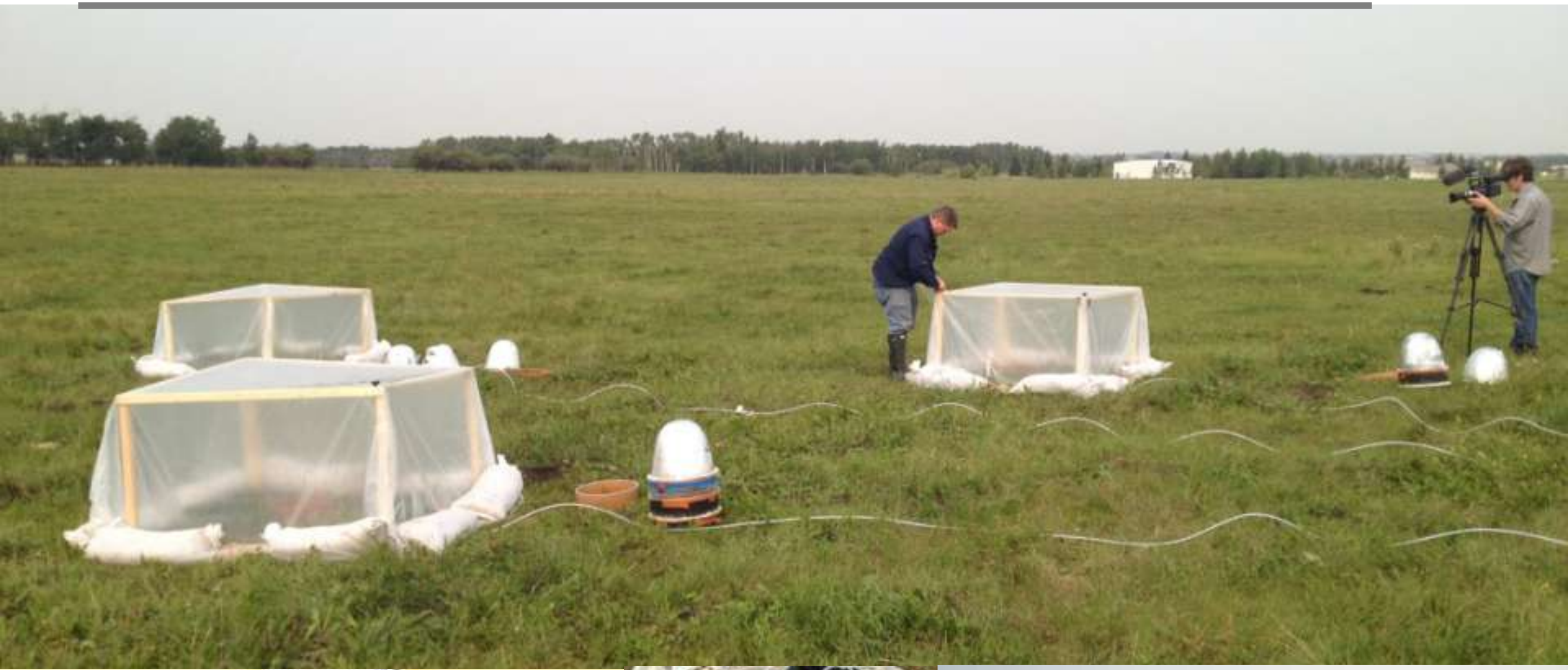


Stratification

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

Paired AMP, HCG, and LCG Soil Catena Sampling

AMP and Carbon 13 Isotope Sampling



Results

AMP grazing

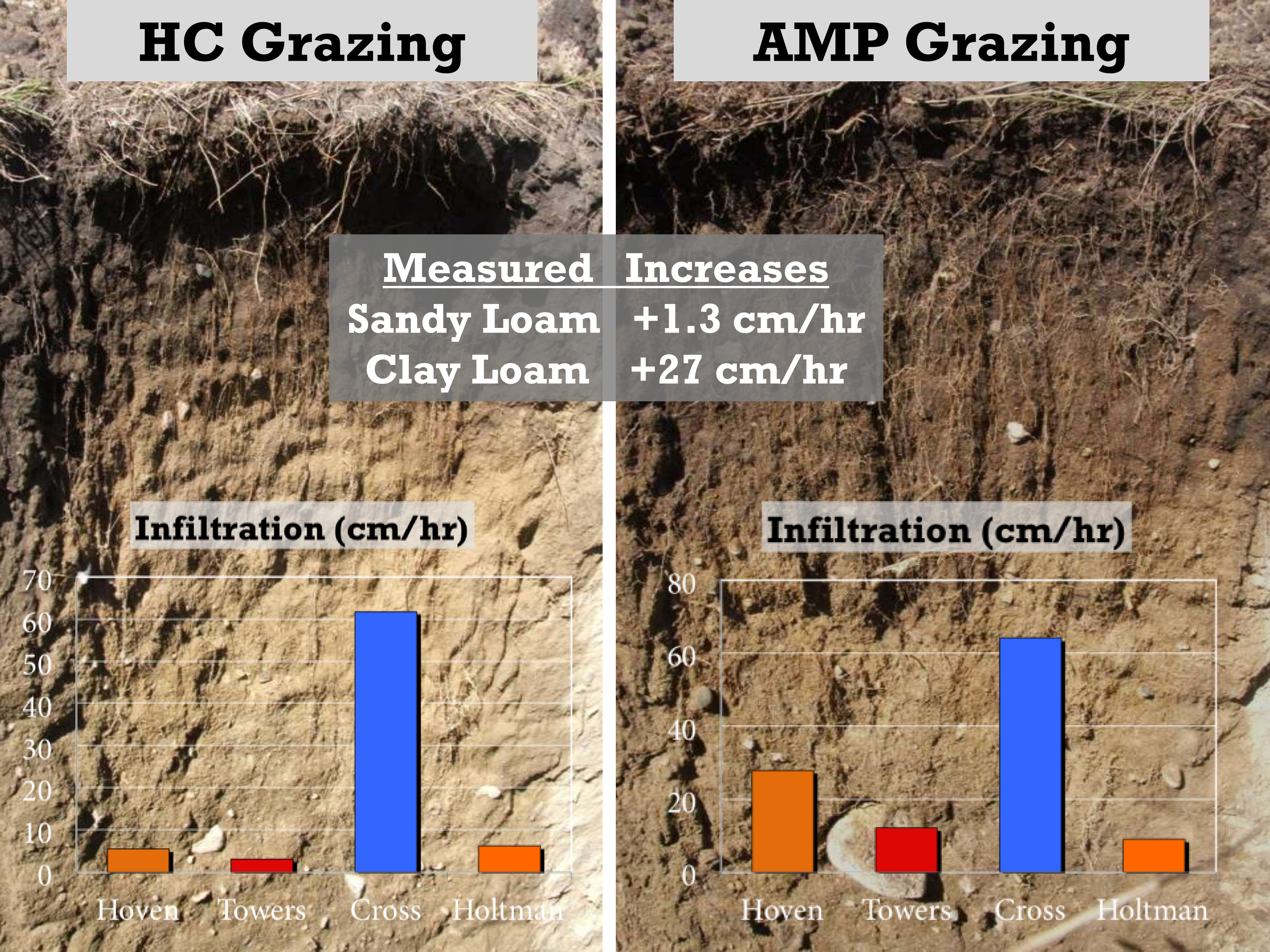
Energy Flow

Water Cycle

Mineral Cycle

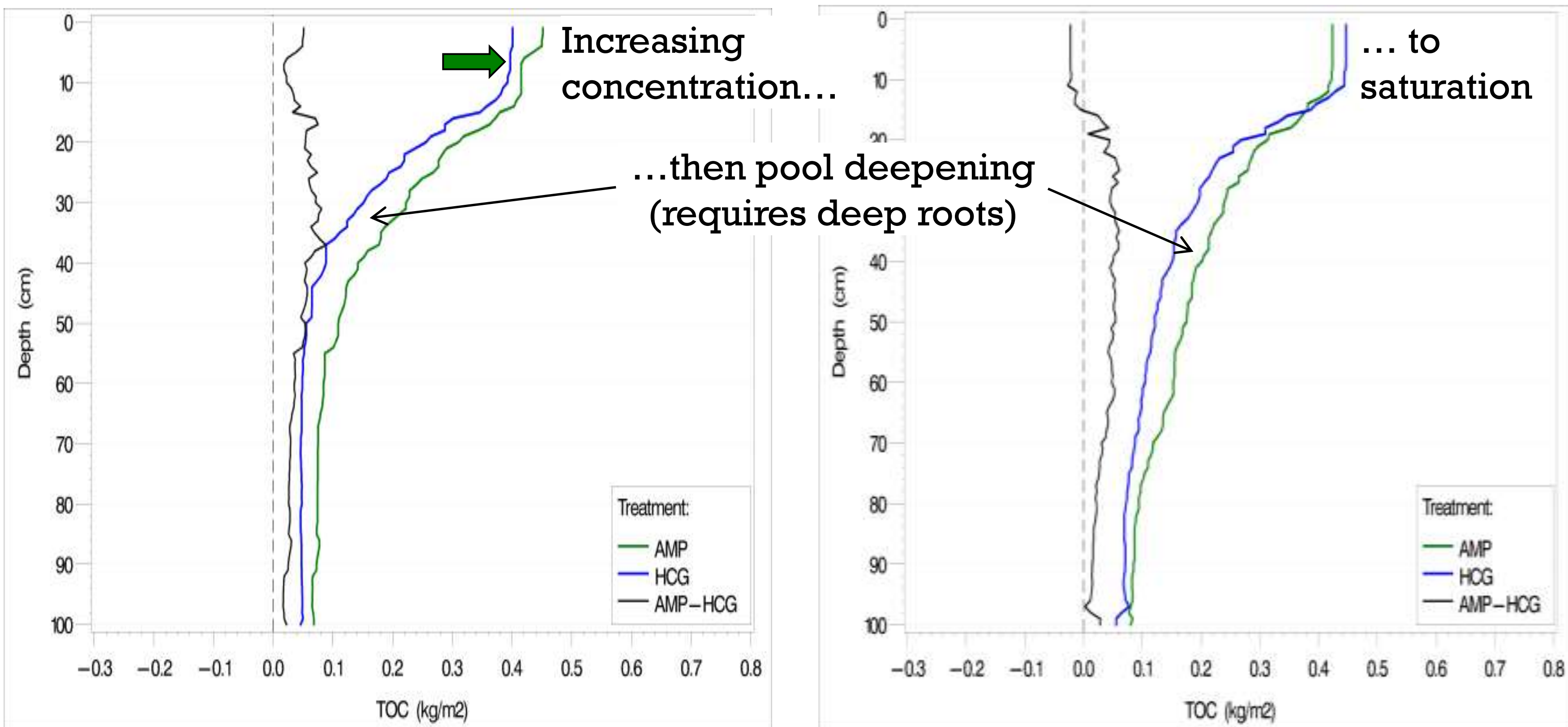
Community Dynamics

SOC accrual rates of 1.4-2.4 tC/ha/yr, Significantly higher in AMP vs HCG ($P<0.05$, $n=60$). Lowest in sandy soils, highest in clay loam soils.


HC Grazing
AMP Grazing
Measured Increases
Sandy Loam +1.3 cm/hr
Clay Loam +27 cm/hr
Infiltration (cm/hr)
70
60
50
40
30
20
10
0
Hoven
Towers
Cross
Holtman
Infiltration (cm/hr)
80
60
40
20
0
Hoven
Towers
Cross
Holtman

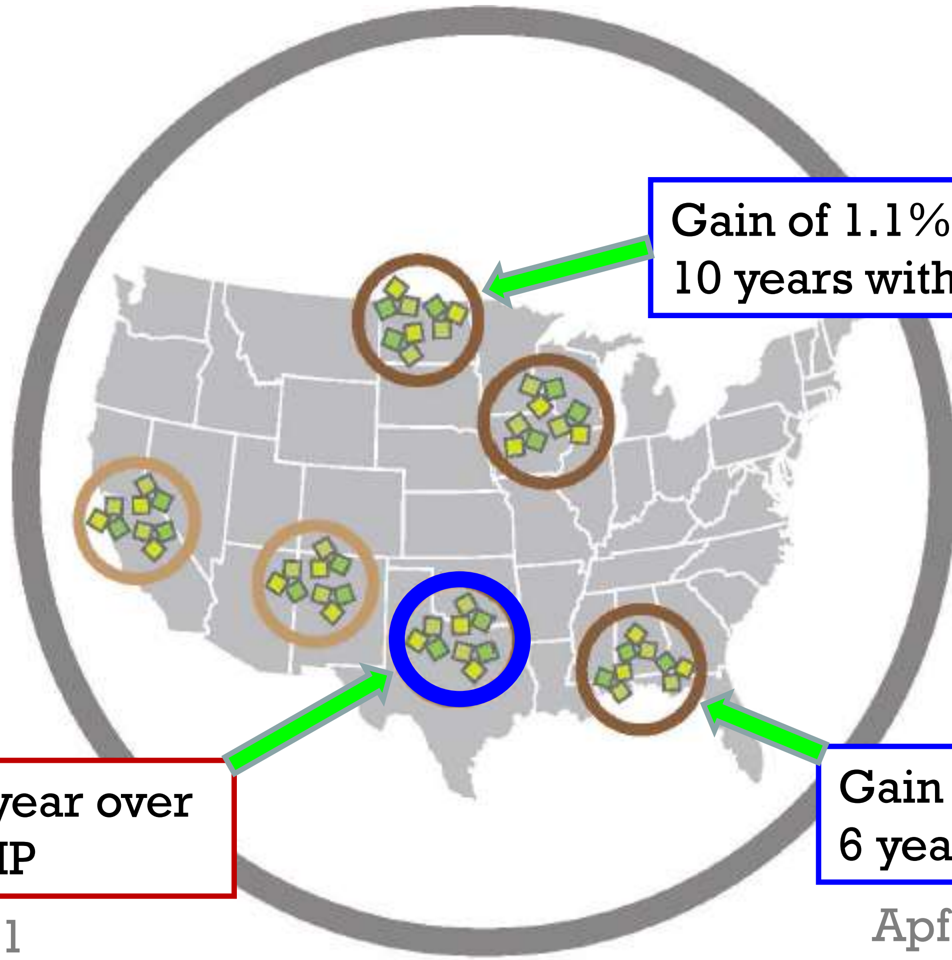
2 Dimensions Drive Total Carbon Pool

Towers – planted pastures | **Cross** – native grasses



Published & Reconnaissance Sampling

Food Security and Climate Goal - 0.4% C gain/year



Gain of 1.1% C /year over
10 years with AMP

Apfelbaum et al. 2016

Gain of 1.7% C/year over
15 years with AMP

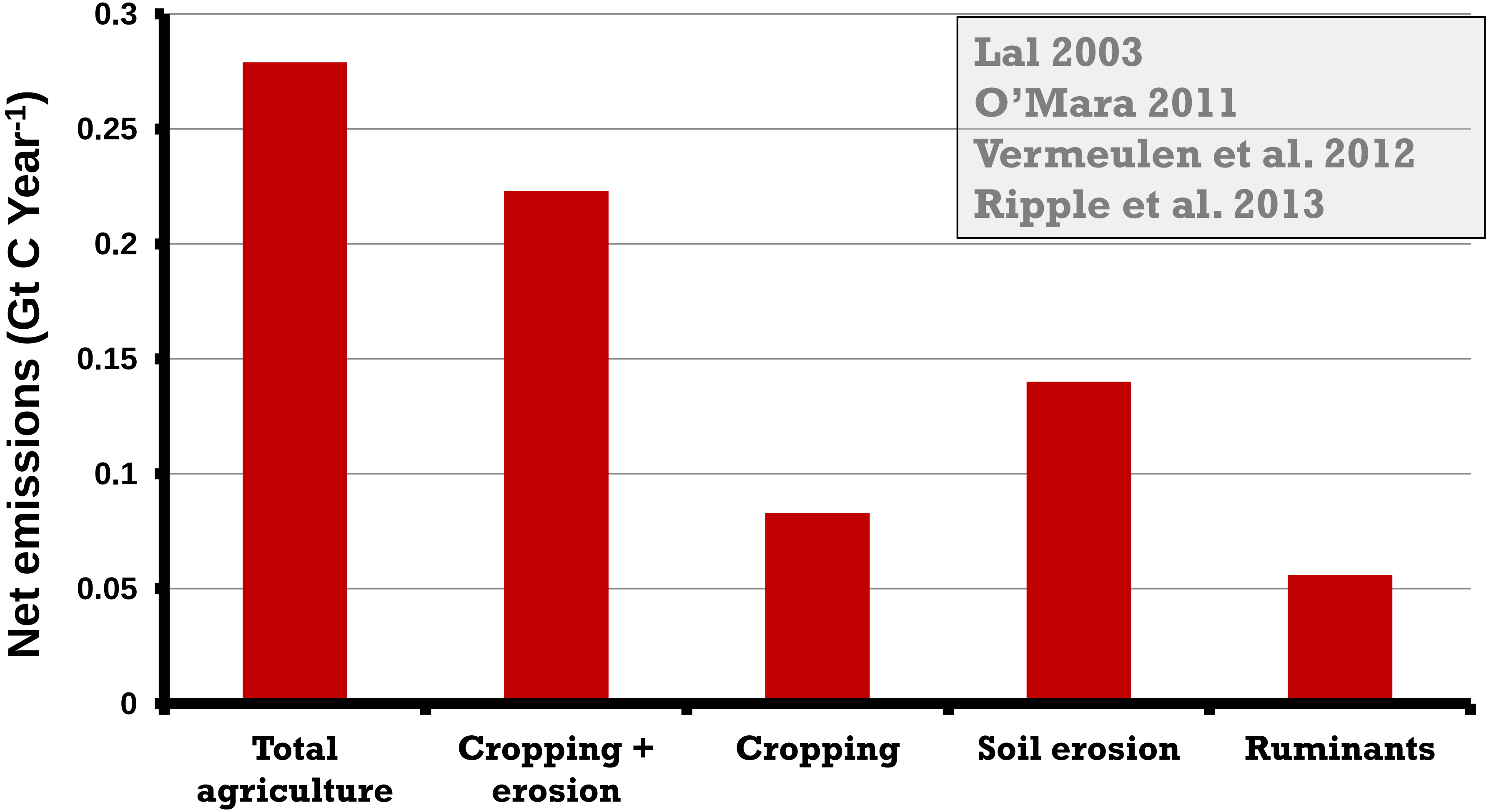
Teague et al. 2011

Gain of 2.1% C/year over
6 years with AMP

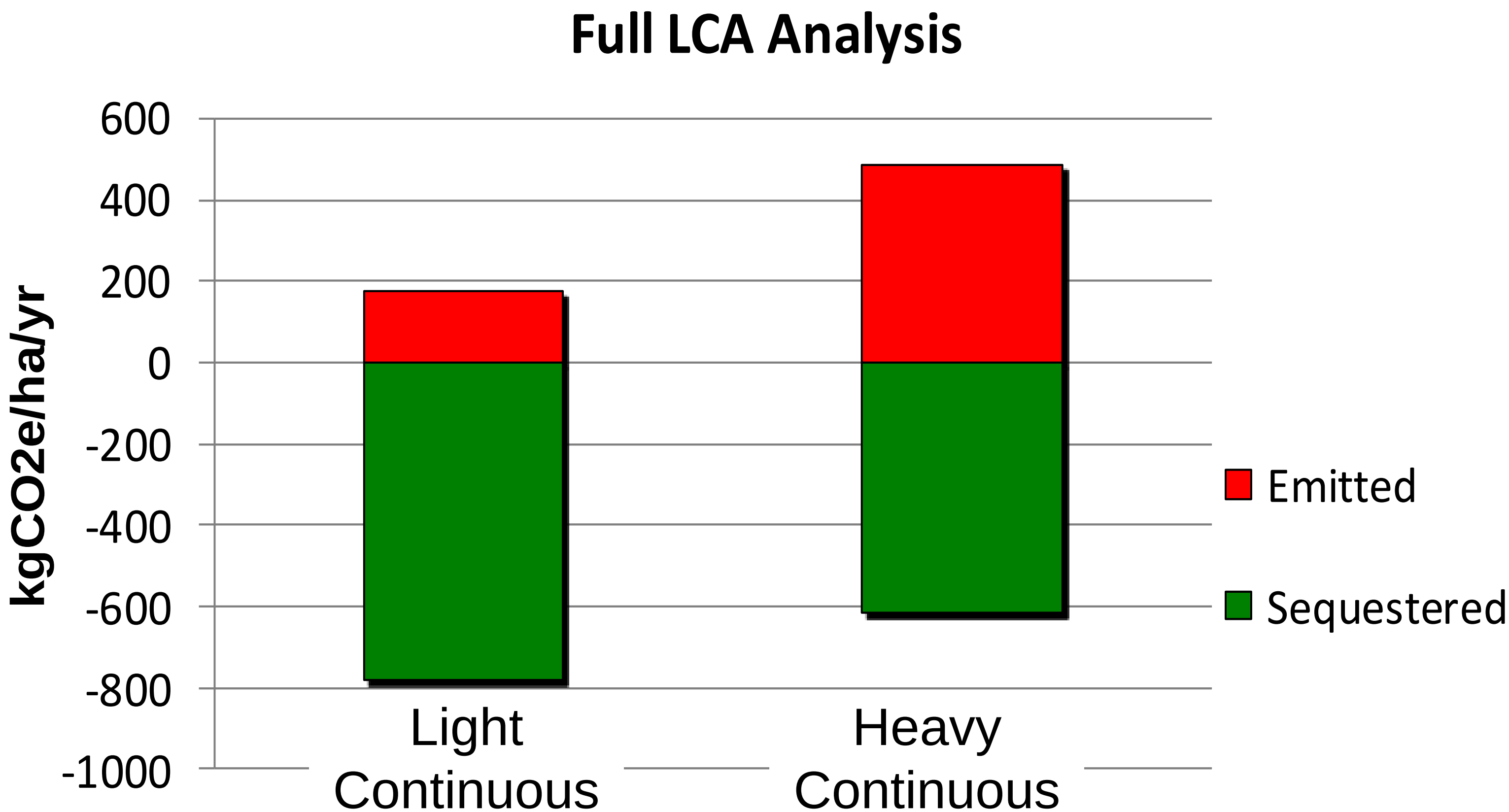
Apfelbaum et al. 2015

Importance for climate change mitigation

Agricultural Sources of Emissions: North America

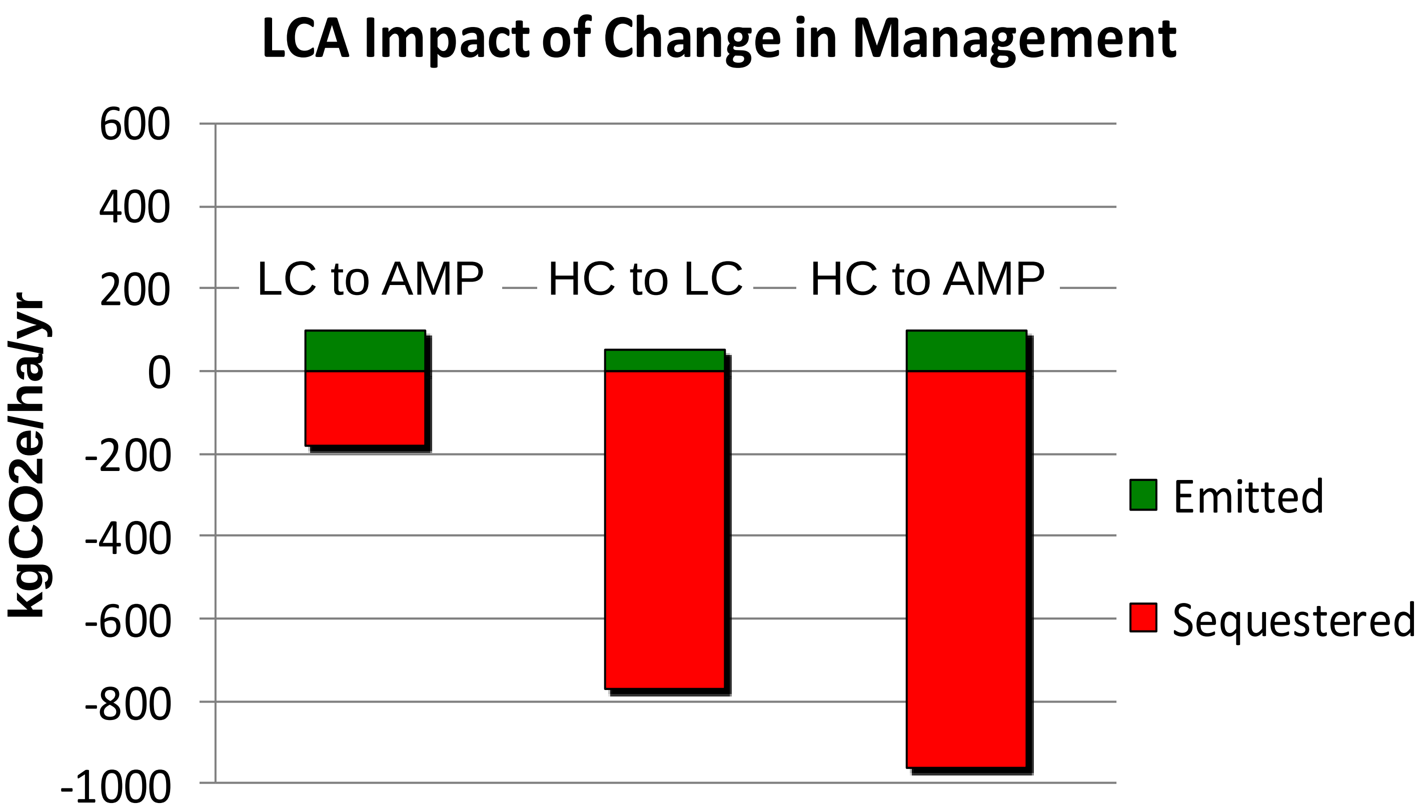


Carbon Sinks and Emissions:
Northern Plains All-grazing Cattle Operations



Liebig et al. 2010

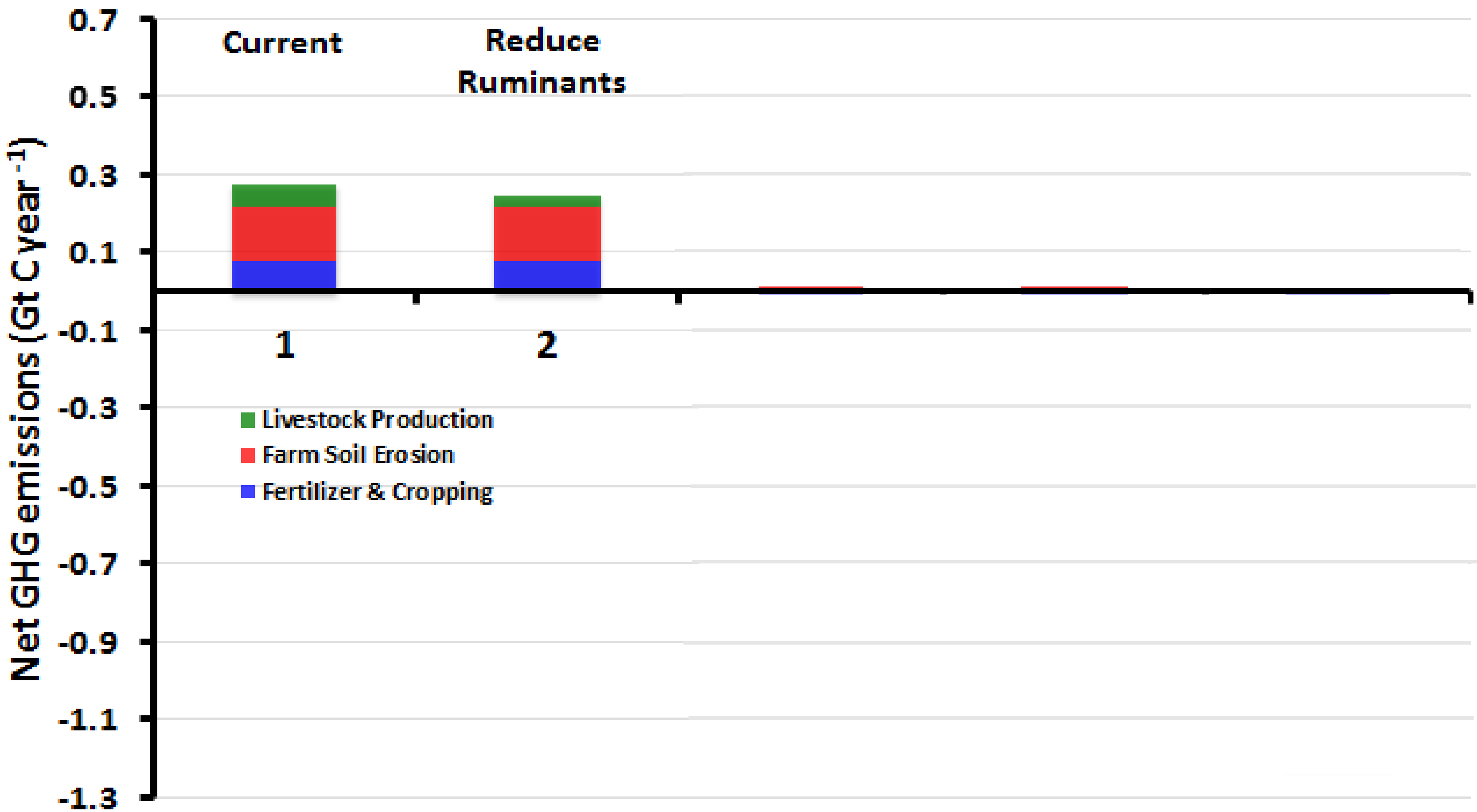
Life-Cycle-Analysis of AMP grazing:
Net C Emissions on All-grazing Cow-calf Operations



Tong et al. 2015

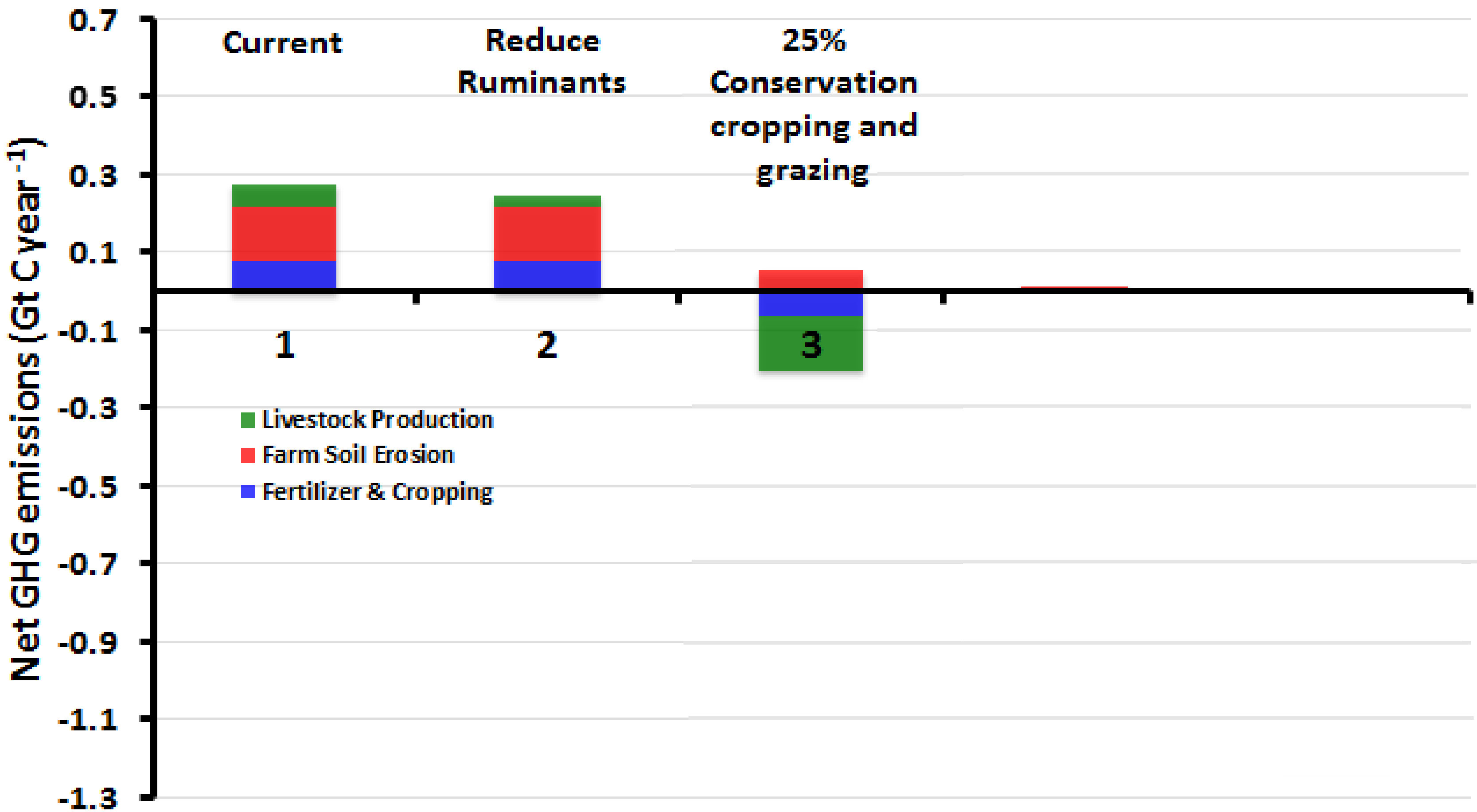
Net Emissions with Regenerative Cropping and AMP Grazing Practices

Teague et al. 2016



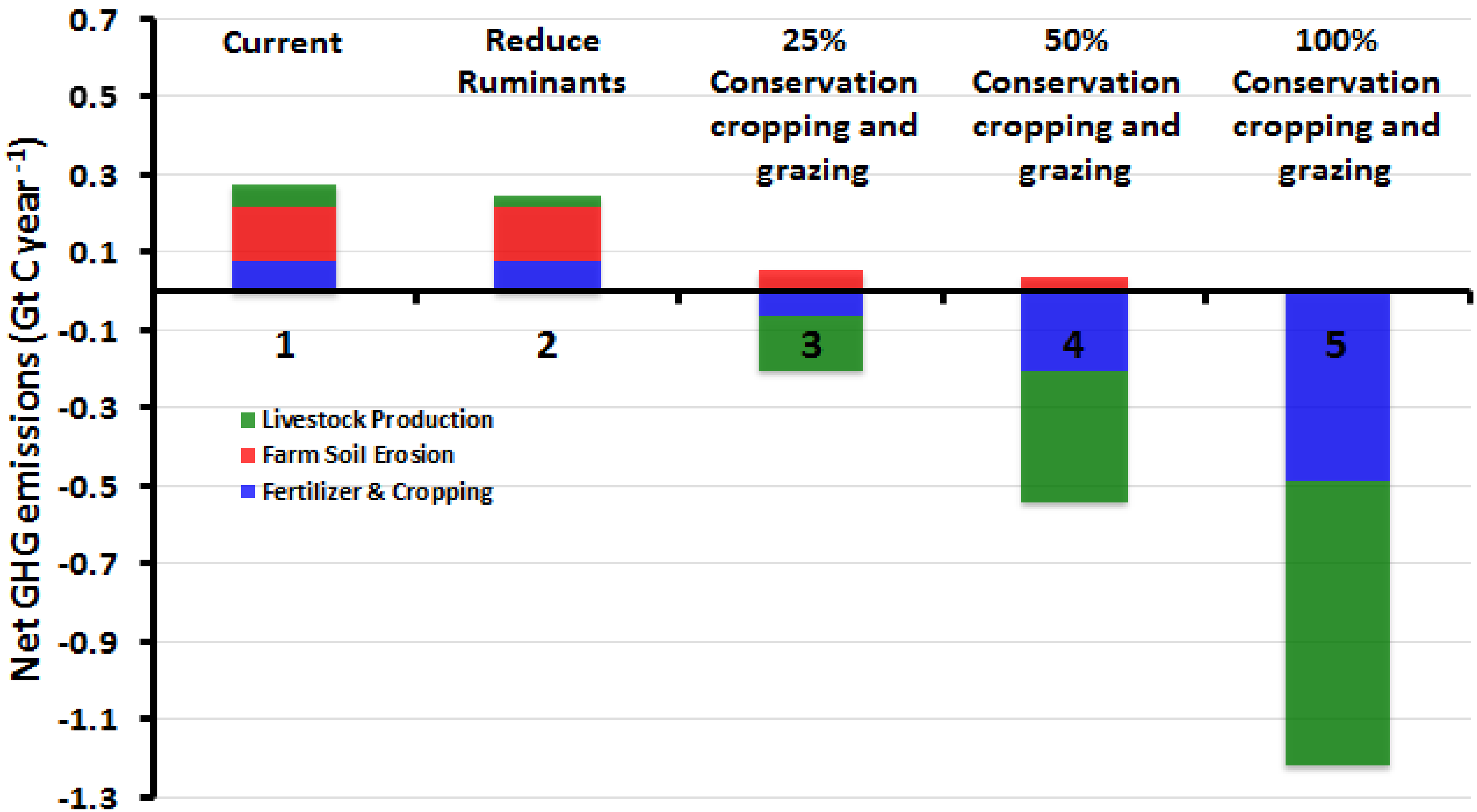
Net Emissions with Regenerative Cropping and AMP Grazing Practices

Teague et al. 2016

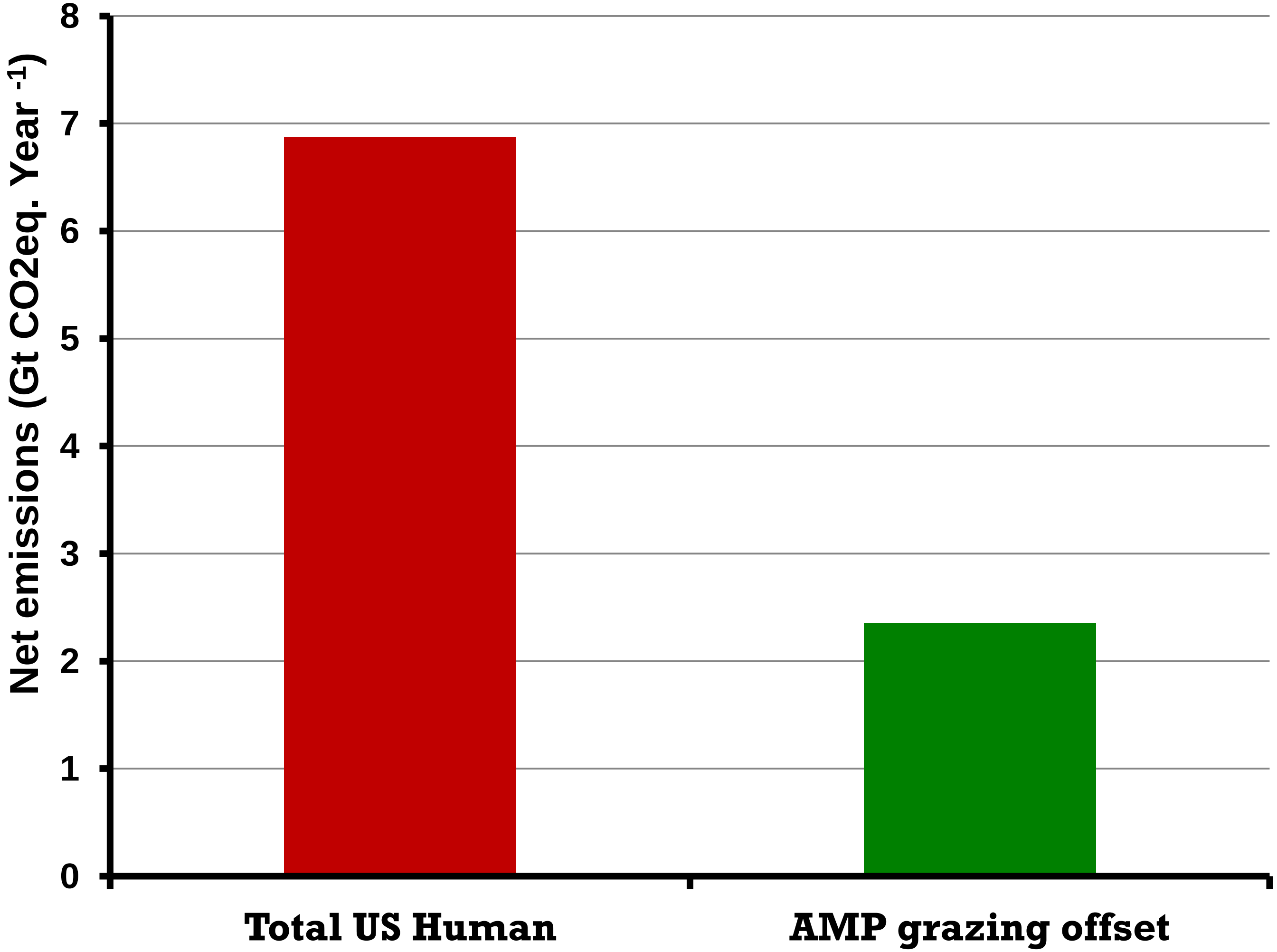


Net Emissions with Regenerative Cropping and AMP Grazing Practices

Teague et al. 2016

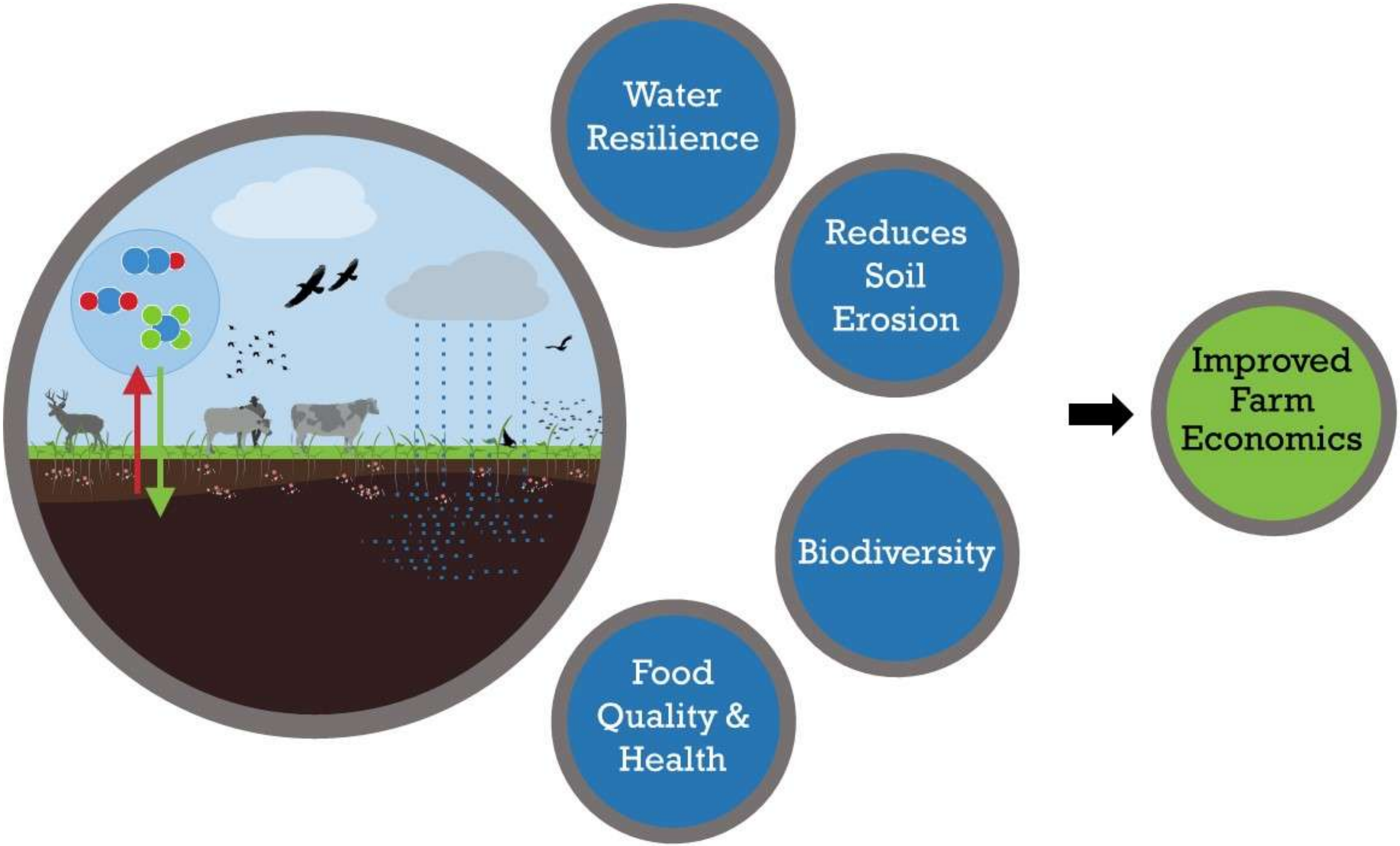


Net US Emissions vs. AMP Grazing Offsets



EPA 2014

Hypotheses: AMP Grazing Improves Ranch Economics



Data Gaps – The Need for Systems Science

Document LDC and AMP grazing benefits to soils, ecosystems and climate

- LDC and AMP grazing restoration of soils, water cycles, biodiversity and climate resiliency

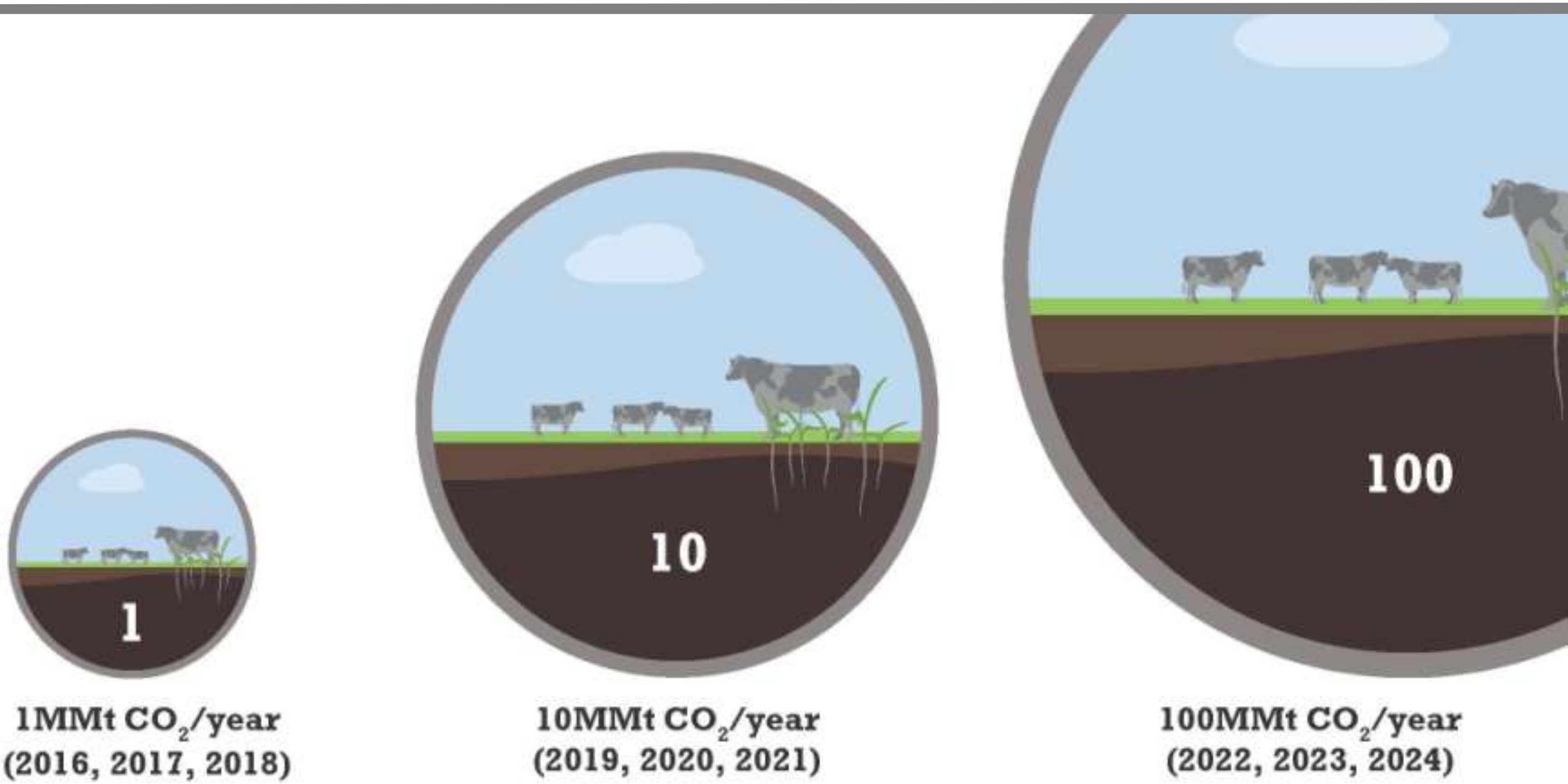
Replicate of LDC/AMP study: apply to climate and human health

- Data to characterize LDC and AMP grazing in climate modelling and national GHG accounting inventory
- Apply Eocene global cooling and grassland/ungulate evolution theory to present-day
- Landscape-scale, measurement-based GHG accounting
- Improved measurement technologies at reduced costs
- Human health nexus of LDC/AMP grazing

Create farmer/rancher incentives to support management changes

- Socio-economics of farmer & rancher willingness to change land management practices
- De-risk farmers and ranchers scaling up quickly – support and incentives, coaching, insurance, other tools, and perhaps policies

1 Million Metric Tons (1MMt) Pilot



Three strategies to get soil carbon storage to large-scale:

1. **Systems science** – create the foundational data
2. **Farmer & rancher aggregation** – expand AMP grazing through communication
3. **Policy development** – create incentives for AMP grazing

Summary

What we think we know

- Regenerative land management practices (LDC & AMP grazing) can significantly increase soil carbon (1.2 – 11 tCO_2e/ha/yr)
- If AMP grazing is executed at scale, it appears it can quickly, reliably and affordably store billions of metric tons (gigatons) of CO_2e/yr
- LDC & AMP grazing can help address climate resilience

What we need to know

- Systems understanding of LDC & AMP grazing effects on soils, ecosystems, climate and human health
- Farmer & rancher triggers for participation

What we need now

- Continue building the coalition of industry supporters, NGOs and government agencies
- Funding systems science at scale
- Incentives for farmers & ranchers to participate in sequestering 100 MM tCO_2/yr by 2022
- ***Achieving soil carbon storage improvements at scale!***

NM State University

Texas A&M AgriLife Research

University of Hawai'i

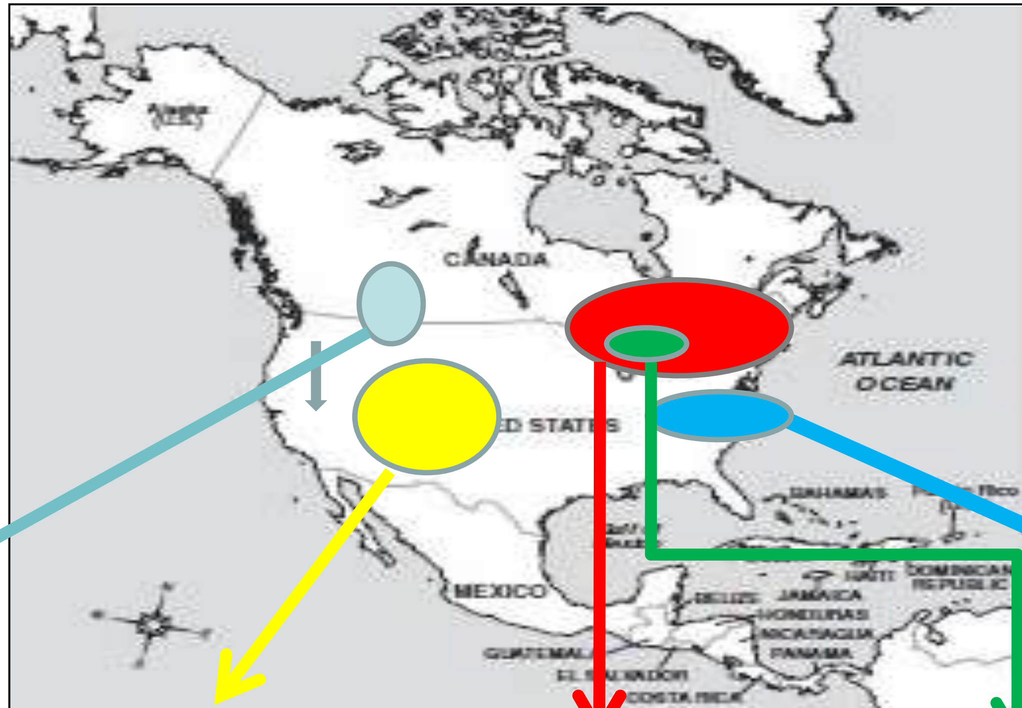
Applied Ecological Services, Inc.

carbon nation

ASU

Michigan State University | AgBioResearch

Soil Carbon Durability (Years)



Semi-arid:

Soil Depth	Average Carbon Age (yrs)
.1 m	30-60
1m	47,000
2m	120k-130k
3m	>200k

Retallack, 2013

Arid West, New Mexico

Soil Depth	Average Carbon Age (yrs)
.1 m	100-200
.2 m	30,000+
>.2-.5 m	3-5 million

Monger, C. NMSU

Wisconsin glacial till plain

Uplands

Soil Depth (m)	Average Carbon Age (yrs)
.1	100-200
1-2	1500-12k
>2	>12k

Peat

Soil Depth (m)	Average Carbon Age (yrs)
.1	100-200
.1 to 1	1500-12k
>2	>80k

Futuma, UM

Unglaciated

Soil Depth (m)	Average Carbon age (yrs)
.1	100-300
.1 to 1	500-2k
1-2	>30k
>2	>200k

Estimated

Global Cooling, Soil Carbon and Grassland Ecosystems
Archaeological Evidence

From Retallack, G. 2013 Global cooling by grassland soils of the geological past and near future. Annu. Rev. Earth Planet. Sci 41:69-86)

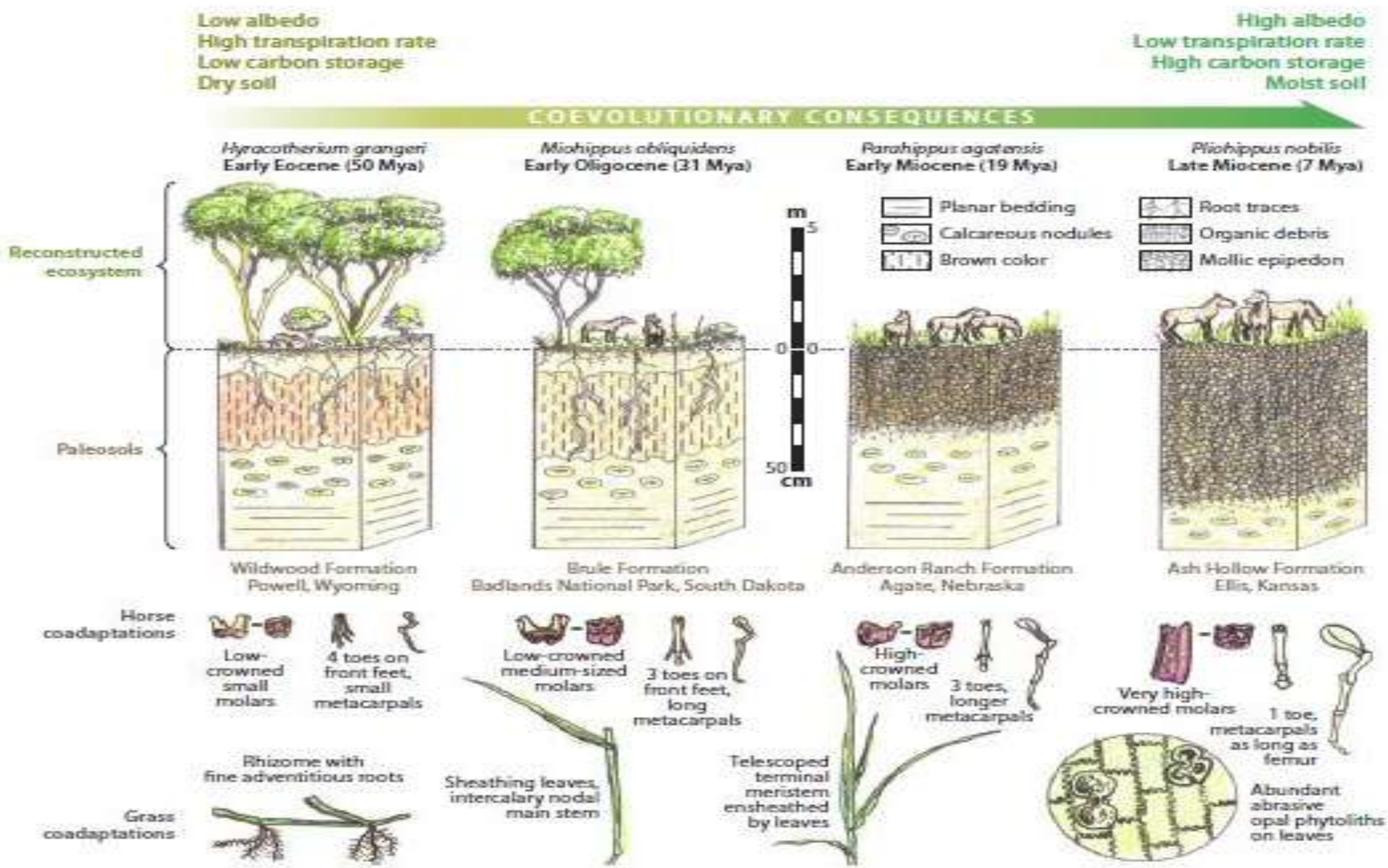


Figure 1

Coevolution of grassland grazers, grasses, and soils (from Retallack 2007b, with permission from Elsevier).

Did Global Cooling Co-occur with Grassland/Ungulate Evolution?

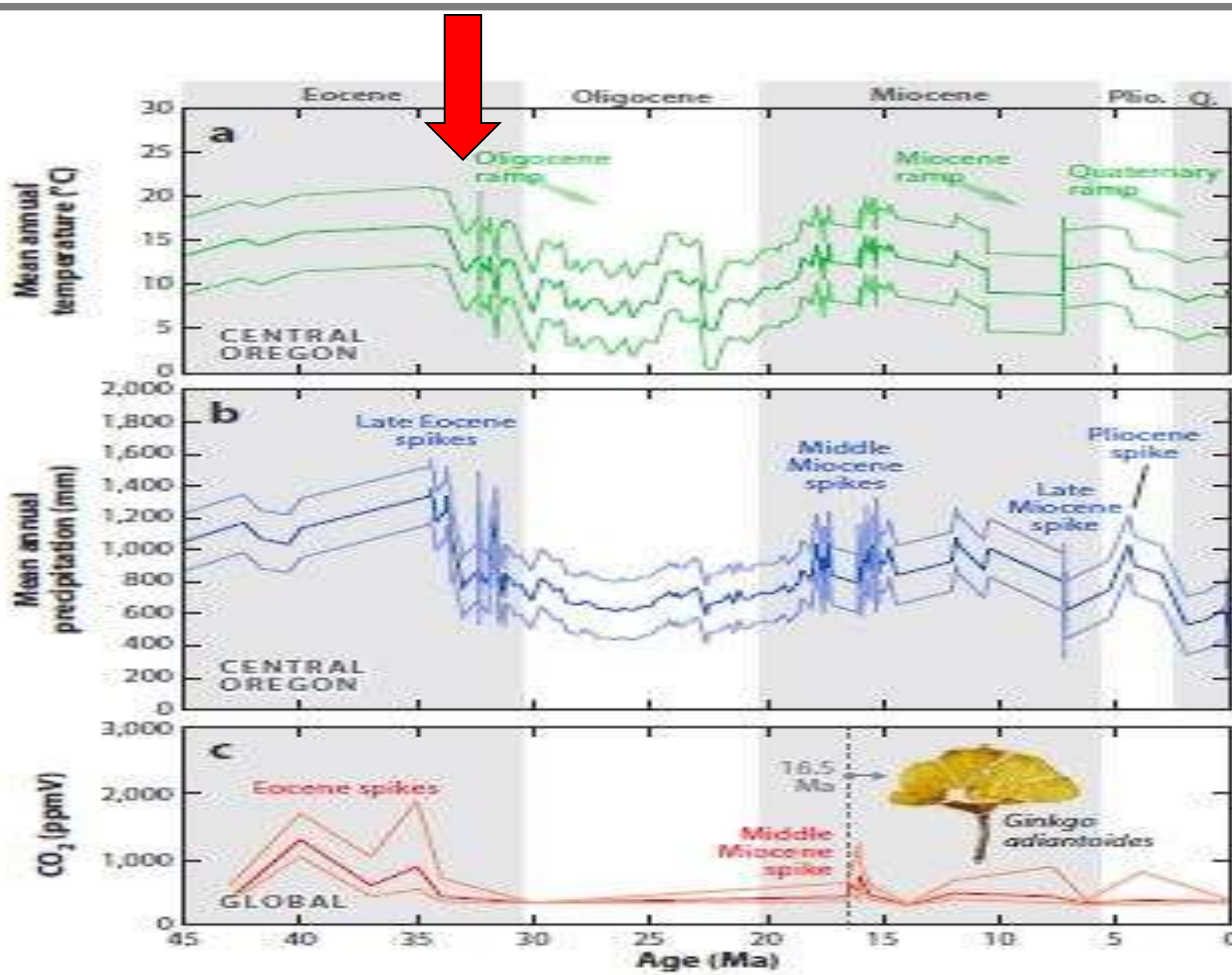
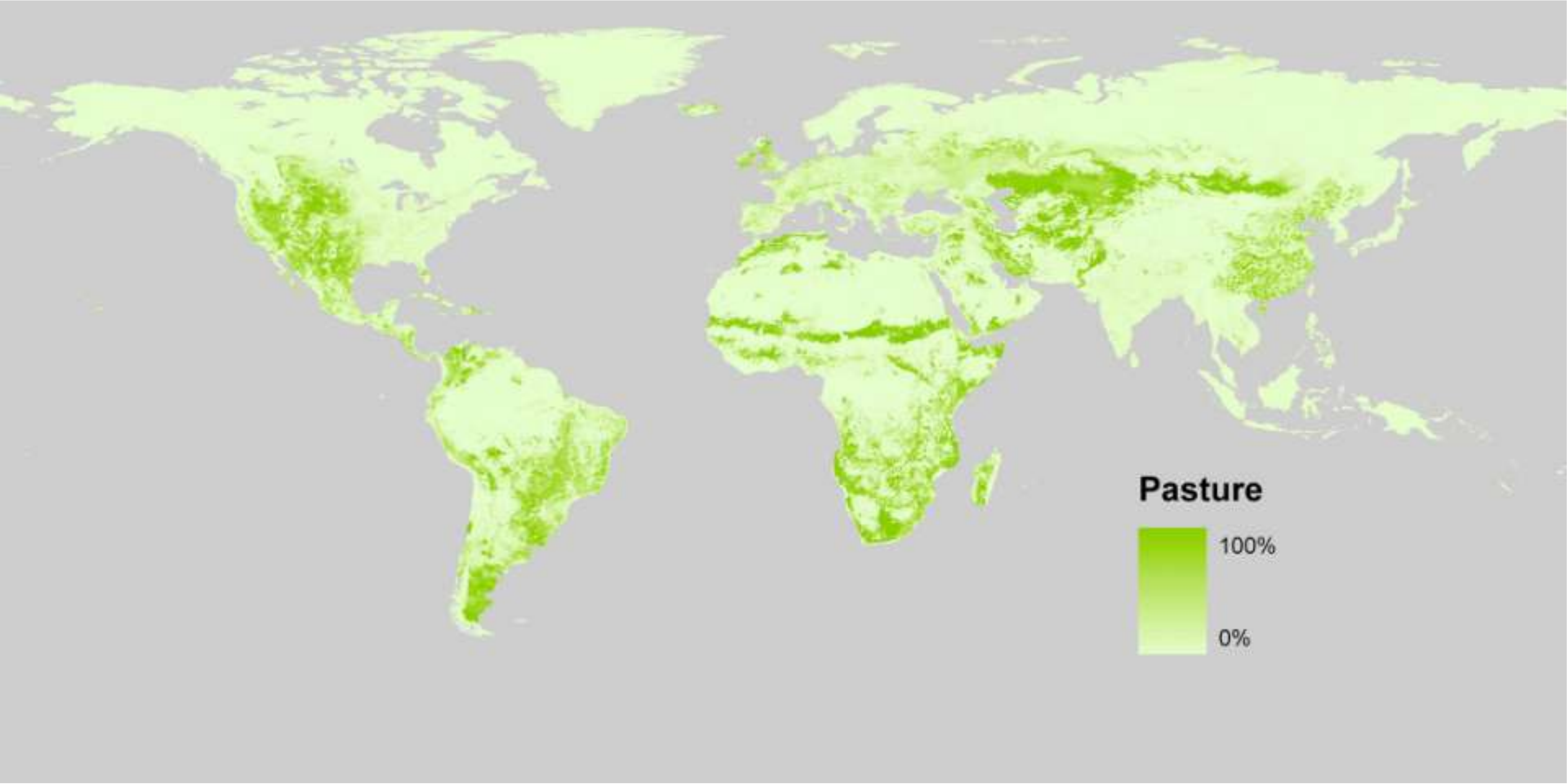


Figure 5

Time series of (*a*) paleotemperature and (*b*) paleoprecipitation from the chemical composition of paleosols in Oregon (Retallack 2007a) and atmospheric CO_2 from the fossil *Ginkgo* stomatal index (Retallack 2009a) both suggest a role for CO_2-greenhouse control of Cenozoic paleoclimate. The fossil leaf (*c*) is middle Miocene (16.5 Mya) *Ginkgo adiantoides* from below the Grande Ronde Basalt, near Wieppe, Idaho (described by Retallack & Rember 2011). Abbreviations: Plio., Pliocene; Q., Quaternary.

Global Pasture Distribution



Global Cropland Distribution