Managing Grazing and Cropping to Regenerate Soil Carbon and Ecosystem Services

University of Alberta, Edmonton
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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

Many graziers use Adaptive Multi Paddock (AMP) grazing successfully.

Most conservation winners use MP grazing.

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

Adaptive MP grazing

$\text{H}_2\text{O}$ $\rightarrow$ $\text{CO}_2$

$\text{H}_2\text{O}$ $\rightarrow$ $\text{CO}_2$
Adaptive multi-paddock grazing

Planned multi-paddock grazing

- Ranch road
- Existing fence
- Electric fence
- Water point
Restoration using Adaptive MP grazing

Noble Foundation, Coffey Ranch

Poor condition range
18 paddocks + water points
Managed to improve plant species
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
AMP grazing

Energy Flow
Water Cycle
Mineral Cycle
Soil/plant Composition
Continuous grazing

Infiltration < 1" / hour
Soil Carbon < 1%

AMP Grazing

Infiltration = > 8" / hour
Soil Carbon > 10%

Neil Dennis, Saskatchewan
After 10 years
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

Anecic burrow entrances called "middens" are surrounded with a mound of cast material (worm poop) and crowned with fragmented leaf parts.

Leaf debris

Epigeic
- Litter dweller, feeder
- No burrows
- Pigmented skin
- Small size

Endogeic
- Soil feeder
- Mineral soil dweller (0-50 cm)
- No skin pigmentation
- Creates a network of horizontal, branching burrows
- Small to medium-sized

Anecic
- Fresh litter feeder
- Soil dweller
- Pigmented skin
- Digs deep, vertical, unbranching burrows
- Large size

Galleries may be used for depositing cocoons or for shelter from harsh conditions

Three major ecological groups of earthworms have been identified based on the feeding and burrowing behaviors of the different species.

Anecic burrows may reach depths up to two meters!
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

The diagram illustrates the fraction of total flow attributed to surface runoff and groundwater flow under different grazing management scenarios: HC, LC, AMP, and EX. The data shows varying contributions across these scenarios, with HC having the highest surface runoff fraction and EX having the highest groundwater flow fraction. The error bars indicate the variability in these measurements.
Clear Creek - Streamflow

Grazing management scenario

- Baseline
- HC
- LC
- AMP
- EX

Streamflow (mm / yr)
Clear Creek - Nitrogen load

Grazing management scenario

Baseline, HC, LC, AMP, EX
Clear Creek - Phosphorus load

Total nitrogen load (ton / yr)

Grazing management scenario

Baseline    HC    LC    AMP    EX

0            100    200    300     (c)
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

Catenal position
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.
Infiltration on HCG vs. AMP Grazing - Alberta 2015

Infiltration (cm hr$^{-1}$)
2 Dimensions Drive Total Carbon Pool

**Towers - planted pastures**

![Graph showing Tower's carbon pool depth against TOC concentration.](image1)

Increasing concentration...

then pool deepening

(needs deep roots)

**Cross - native grasses**

![Graph showing Cross's carbon pool depth against TOC concentration.](image2)

... to saturation
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

Gabe Brown, North Dakota
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

<table>
<thead>
<tr>
<th>Element</th>
<th>Increase (%)</th>
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<tbody>
<tr>
<td>Carbon</td>
<td>200%</td>
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<tr>
<td>Water holding</td>
<td>+200%</td>
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<tr>
<td>Silicon</td>
<td>116%</td>
</tr>
<tr>
<td>Calcium</td>
<td>234%</td>
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<tr>
<td>Nitrogen</td>
<td>103%</td>
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<tr>
<td>Phosphor</td>
<td>102%</td>
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<tr>
<td>Magnesium</td>
<td>110%</td>
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<tr>
<td>Potassium</td>
<td>198%</td>
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<tr>
<td>Zinc</td>
<td>250%</td>
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<tr>
<td>Sulfur</td>
<td>92%</td>
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<tr>
<td>Copper</td>
<td>185%</td>
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<tr>
<td>Iron</td>
<td>87%</td>
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<tr>
<td>Boron</td>
<td>150%</td>
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Soil Improvements with Regenerative Management
Gabe Brown, North Dakota 2016
No fertilizer since 2007

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

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 vs. No-till + cover crop

NRCS, Tennessee
Cropland Soil Health
How different cropping practices affect soil health

- Tillage: Detrimental
- Direct seeding
- No till with low crop diversity
- No till with high crop diversity
- No till with high crop diversity & cover crops
- No till with high crop diversity & cover crops and livestock

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

- Wang et al. 2015: 7 tC/ha/yr over 5 years
- Apfelbaum et al. 2015: 3 tC/ha/yr over 15 years
- Apfelbaum et al. 2016: < 0.5 tC/ha/yr over 20 years
- Apfelbaum et al. 2016: 2.5 tC/ha/yr over 20 years

Wang et al. 2015

Apfelbaum et al. 2015

Apfelbaum et al. 2016

< 0.5 tC/ha/yr over 20 years

3 tC/ha/yr over 15 years

7 tC/ha/yr over 5 years
Carbon Sinks and Emissions: Northern Plains grazing only Cattle Operations

Full Life Cycle Analysis

- Emitted
- Sequestered

Light Continuous

-1000
-800
-600
-400
-200
0
200
400
600
kg CO2e ha\(^{-1}\) yr\(^{-1}\)

Heavy Continuous

-1000
-800
-600
-400
-200
0
200
400
600
kg CO2e ha\(^{-1}\) yr\(^{-1}\)

Liebig et al. 2010
Life Cycle Analysis of Change in Management

Net C Emissions on grazing only Cow-calf Operations

LC to AMP  HC to LC  HC to AMP

Emitted  Sequestered

Wang et al. 2015
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

Net Emissions with Current Practices and Reduced Ruminants
Net Emissions with Current Cropping and Regenerative Grazing Practices

![Net GHG emissions (Gt C year⁻¹)]

- **Current**
- **Reduce Ruminants**
- **Current cropping and 25% grazing**
- **Current cropping and 50% grazing**
- **Current cropping and 100% grazing**

Categories:
- Livestock Production
- Farm Soil Erosion
- Fertilizer & Cropping

Values:
- 1
- 2
- 3
- 4
- 5
Net Emissions with **Regenerative Cropping** and **Regenerative Grazing** Practices

Teague et al. 2016
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
Questions?