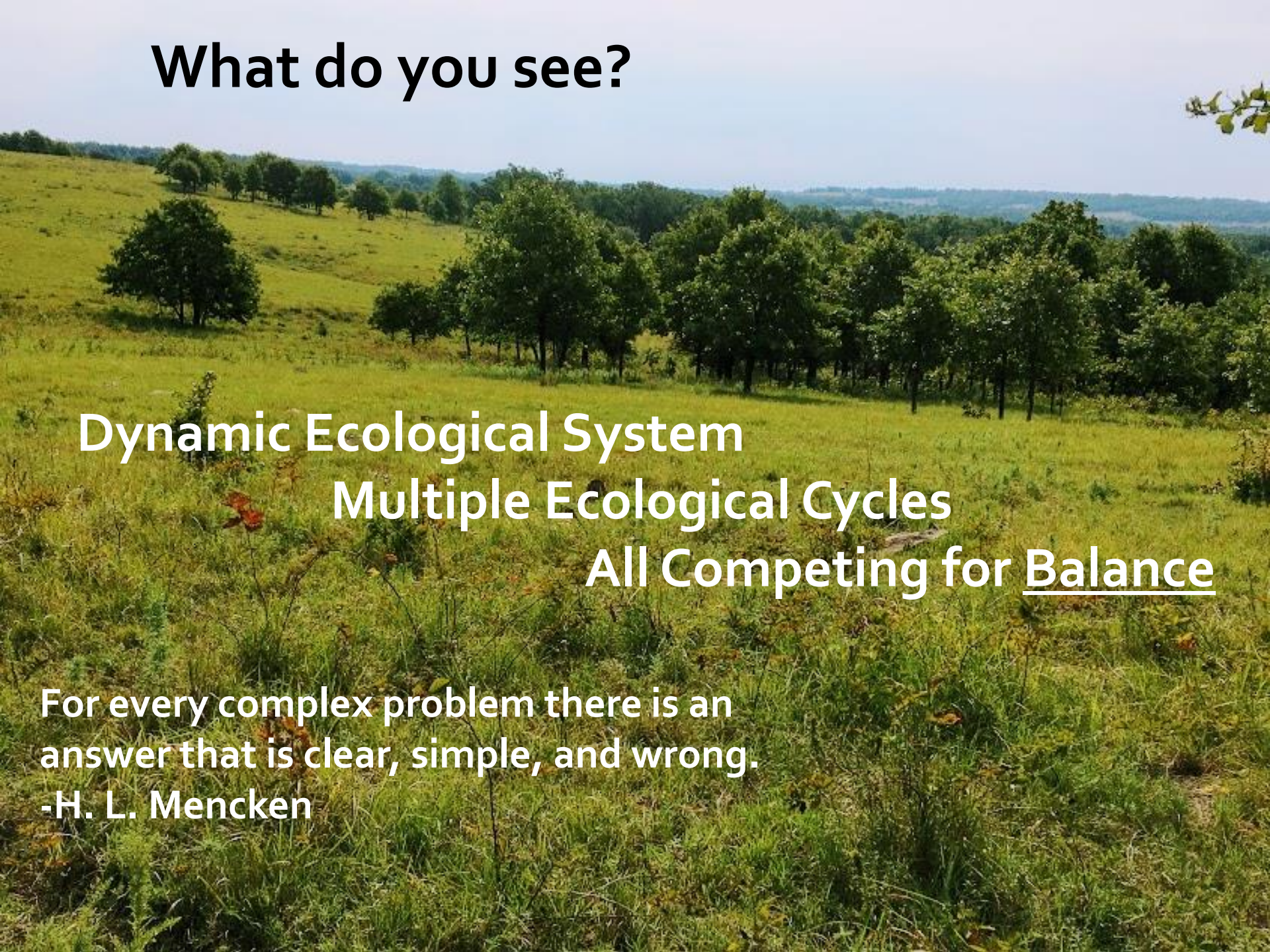
Grazing Land Soil Health:
Concerns, Experiences, and Outlook

Main Issues

- Concerns
- Experiences
- Outlook

What do you see?



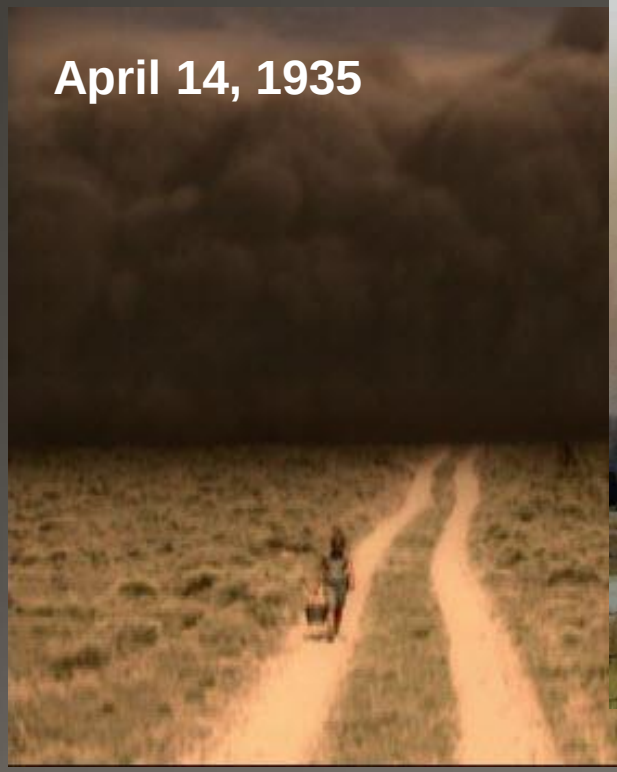
Dynamic Ecological System

Multiple Ecological Cycles

All Competing for Balance

For every complex problem there is an answer that is clear, simple, and wrong.
-H. L. Mencken

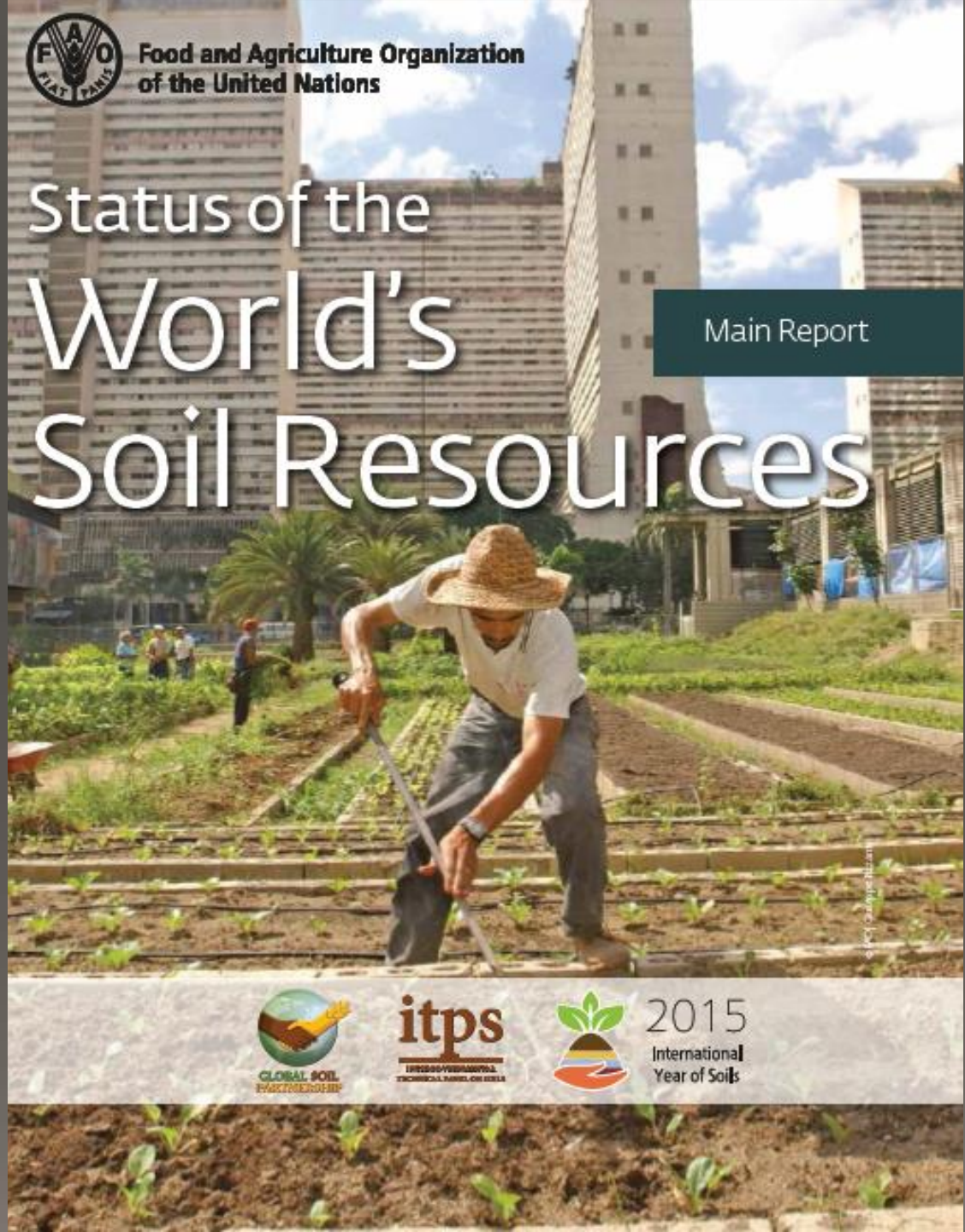
Have we fixed all of our problems in 82 years?



United Nations- FAO

"The overwhelming conclusion from the report is that the majority of the world's soil resources are in only fair, poor or very poor condition. "

-Over 200 technical scientist in the field of soil resources and soil change.

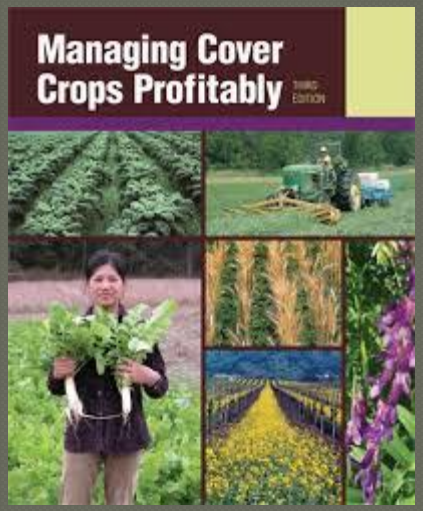


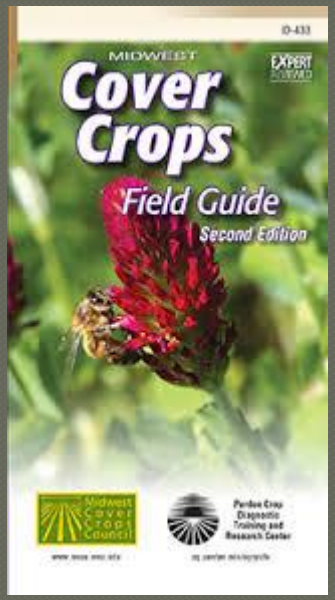
I WANT
EVERYTHING
NOW

FAST
FOOD

Concerns: Good Intentions- Cover Crops

Where is our Focus?





Consistent Message

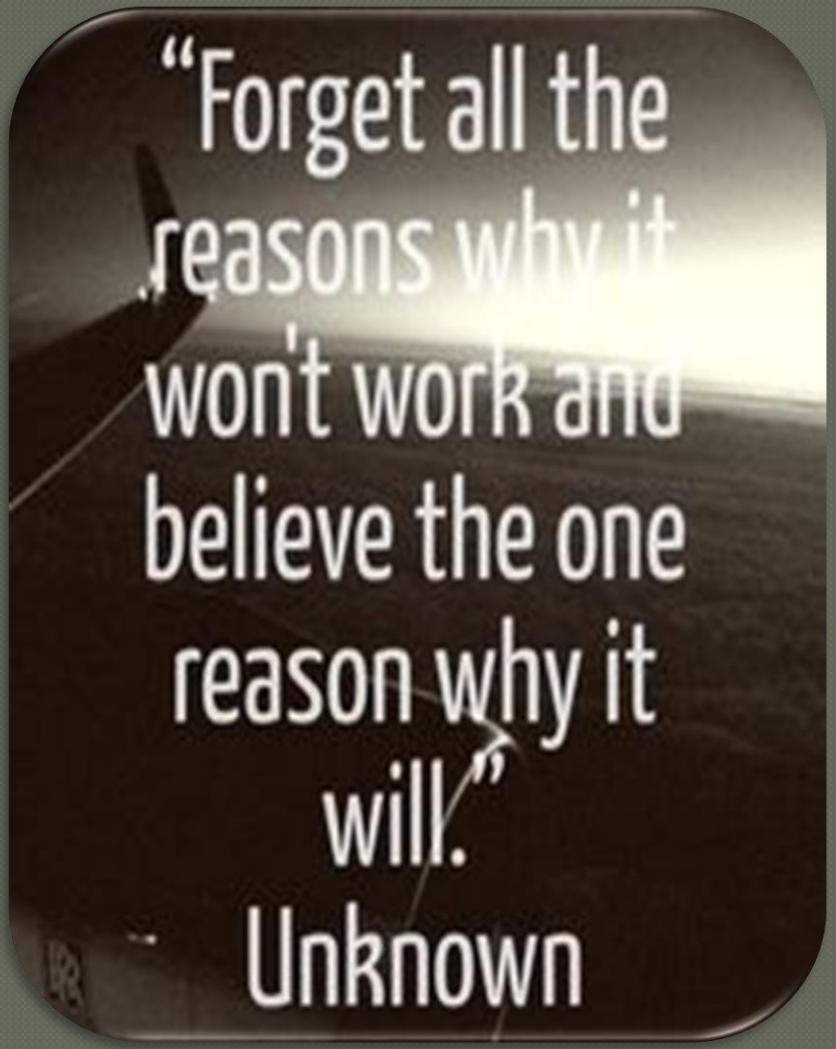
SOIL HEALTH PRINCIPLES

1. Keep the soil covered
2. Minimize soil disturbance
3. Increase crop diversity
4. Keep living roots in the soil
5. Integrate livestock

Learn more at www.sfa-mn.org

"You will loose all soil aggregation in one year if "all" soil health principles are not followed" -
Facebook Post 2016

Soil Health Management Needs Balance



The Soil Food Web

First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators

Soil and Water Conservation Society (SWCS). 2000. Soil Biology Primer. Rev. ed. Ankeny, Iowa: Soil and Water Conservation Society.

Bacteria

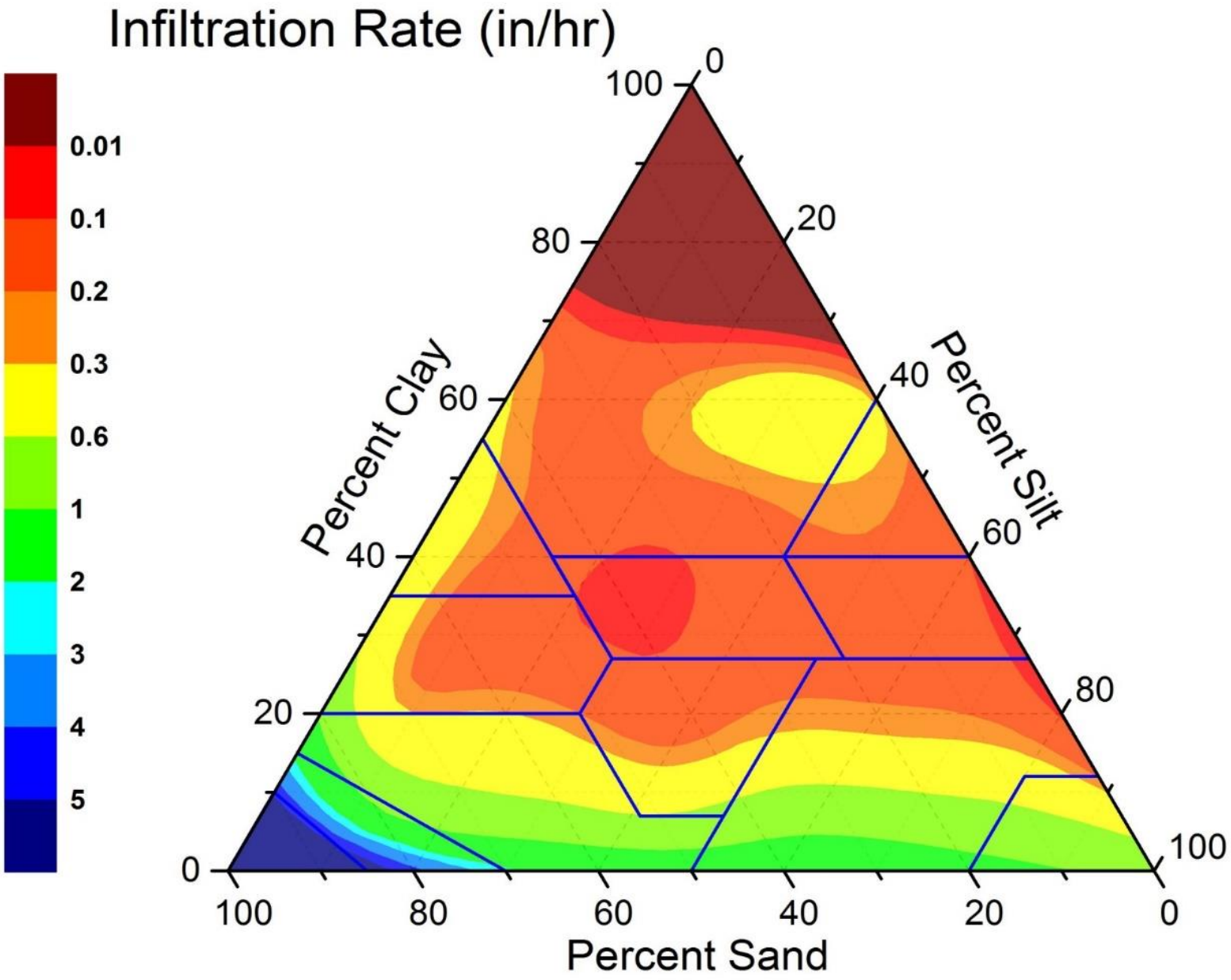
Bacterial Services

- Decomposition of OM
- Nutrient cycling
- Nitrogen fixation
- Nitrification
- Denitrification
- Disease Suppression
- Breakdown of hard to decompose compounds

It's an exchange: the plant provides Carbon, the bacteria help to cycle nutrients like N

Soil Health

- What is the most limiting factor in the Soils of our area? Water…Soil Fertility?
- (Infiltration and storage)
- Its not about how much *Rain* you get.



http://i.imgur.com/wzev3zY.jpg -- see also calculator @
http://hydrolab.arsusda.gov/SPAW/Index.htm

Organic Matter

- ↑ Organic Matter* ↑ Water Holding Capacity
- Better Soil Structure = Better Water Holding Capacity
- Facilitates soil aggregate development
- Provides 90% to 95% of nitrogen in unfertilized soils
  - How do prairies produce anything?
- DRIVES and FEEDS the entire biological system

* 1% OM in 6 inches of soil can hold up to 19,000 gallons of water.

Soil Carbon and Water

Relationship between soil organic carbon and soil water holding capacity (0-30 cm) From Jones 2006

Change in SOC concentration	Change in OC stock (kg/m^2)	Extra water holding (litres/ha)	CO_2 sequestered (t/ha)
1%	4.2	168,000	154
2%	8.4	336,000	308
3%	12.6	504,000	462
4%	16.8	672,000	616

Soil Carbon, Nutrients and Water

Relationship between soil organic carbon and soil water holding capacity (0-30 cm) Teague 2013

Parameter	Heavy Continuous	Light Continuous	Multi-paddock
Soil Organic Carbon	3.1b	4.4b	4.86a
Cation Exchange Capacity	24.6b	23.7b	27.4a
Water holding (Gal/acre)	55,700	79,059	87,324

Five Principles to Improve Soil Health

1. Keep the Soil Covered
2. Minimize Disturbance
3. Plant Diversity (4 Crop Types)
4. Keep a Living Root Year Round
5. Livestock Integration

Armor-What is it?

- Physical Protection covering the Soil Surface
  - Residue
  - Living Plants

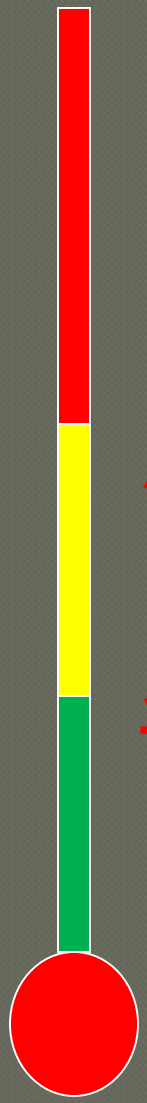
Yes

No

Armor- Why is it important?

- Prevents Erosion
- Limits Water Loss from Evaporation
- Reduces Hoof-Action Compaction
- Carbon to build Organic Mater
- Food for Microbes
- Fuels the Nutrient Cycle
- Manages Soil Temperatures

When soil temperature reaches...



140 F — Soil bacteria die

130 F — 100% moisture is lost through evaporation and transpiration

113 F — Some bacteria species start dying

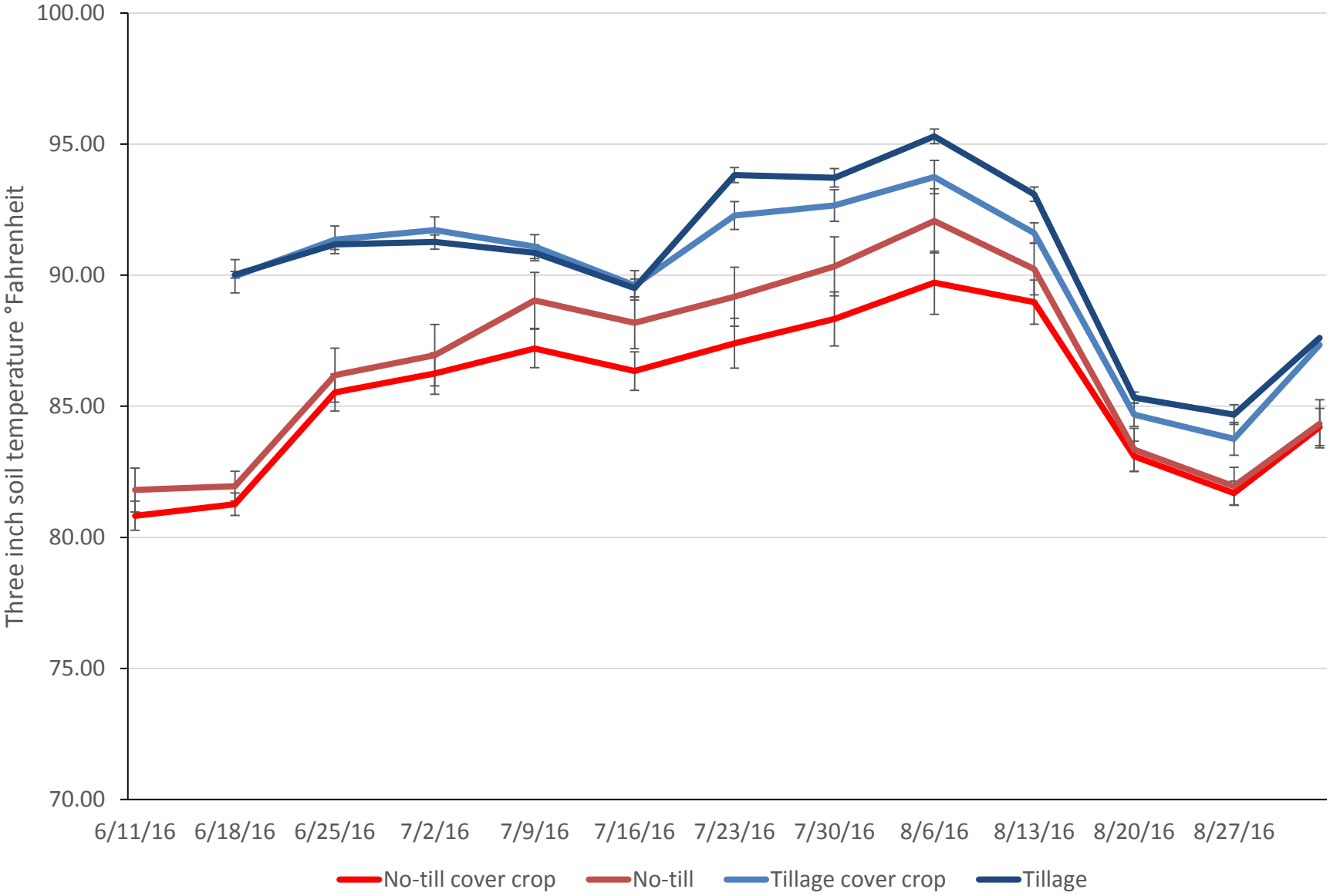
100 F — 15% of moisture is used for growth
85% moisture lost through evaporation and transpiration

95 F

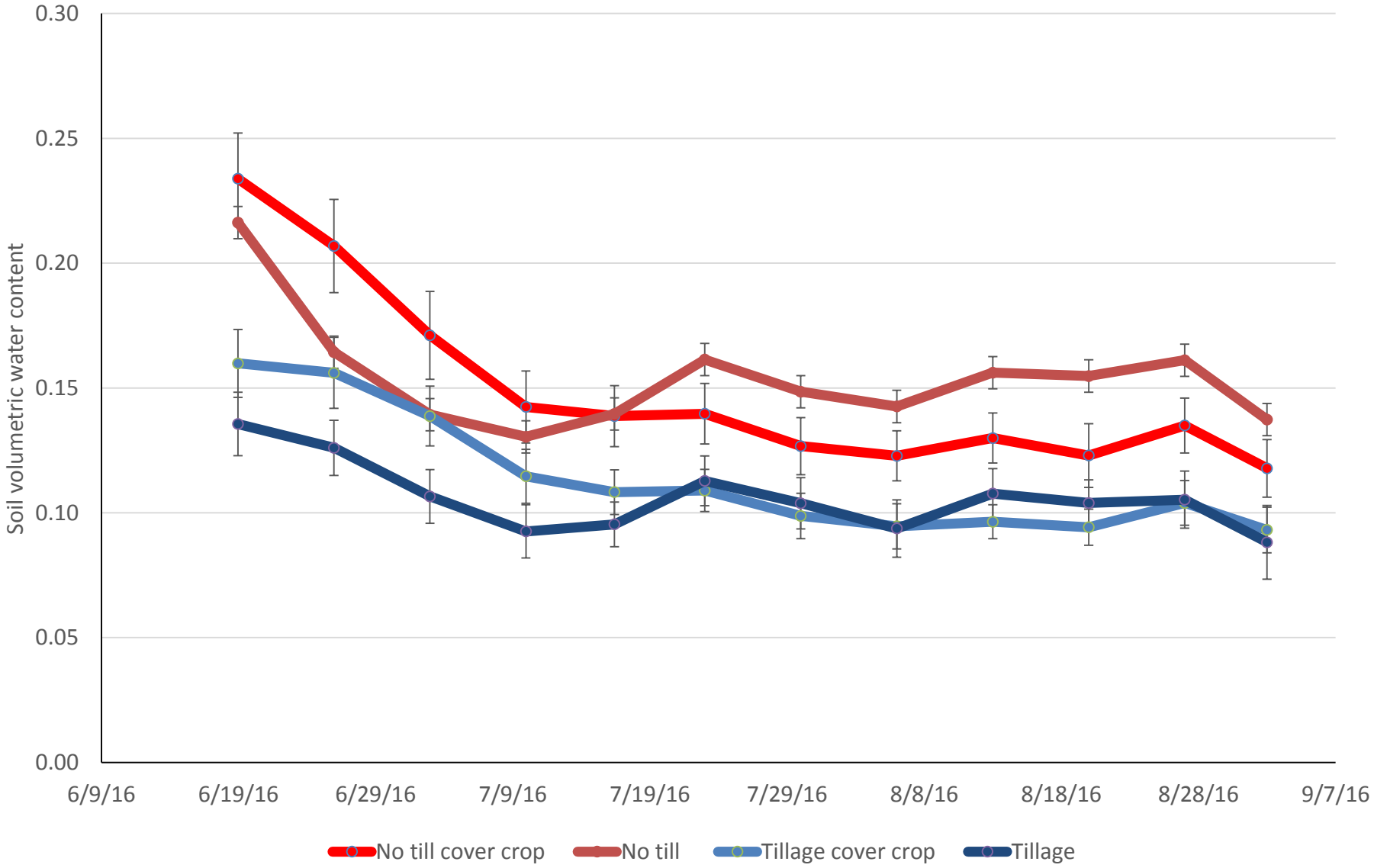
70 F — 100% moisture is used for growth

J.J. McEntire, WUC, USDA SCS, Kerrville TX, 3-58 4-R-12198. 1956

Treatment weekly summer mean three inch soil temperatures °F



Mean tillage (± cover crop) and no-till (± cover crop) three inch summer 2016 volumetric soil moisture content



Minimizing Disturbance-What is it?

- Goal is to Minimize the Physical, Chemical, or Biological disturbance of the Soil.
- Optimize is better
- Examples of Disturbances:

Physical	Chemical	Biological
Tillage	Fertilizing	Herbicides/ Pesticides
Overgrazing	Irrigating (low quality water)	Fungicides
Compacting	Pesticides	Overgrazing

Min. Disturbance-Why is it important?

- Healthy Soils have "good" structure, balanced fungal/bacteria populations, plentiful earthworms, and organic matter.

Large Blocks

Small Blocks

Crumb

Plant Diversity-What is it?

- 4 Components to Plant Diversity
  - Warm Season Grasses
  - Warm Season Broadleaves
  - Cool Season Grasses
  - Cool Season Broadleaves

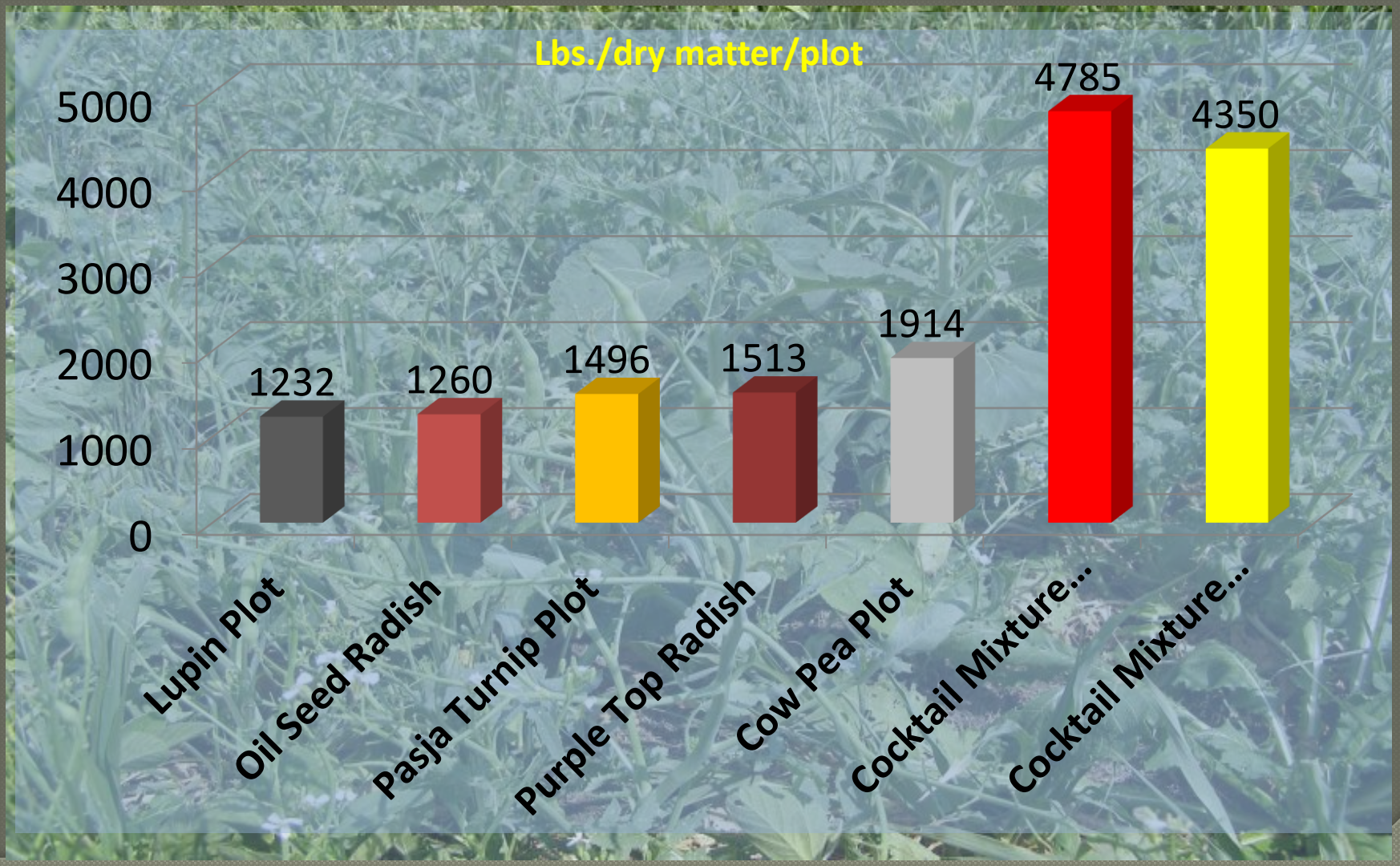
Cover Crop Enhancement

Turnip

Oilseed radish

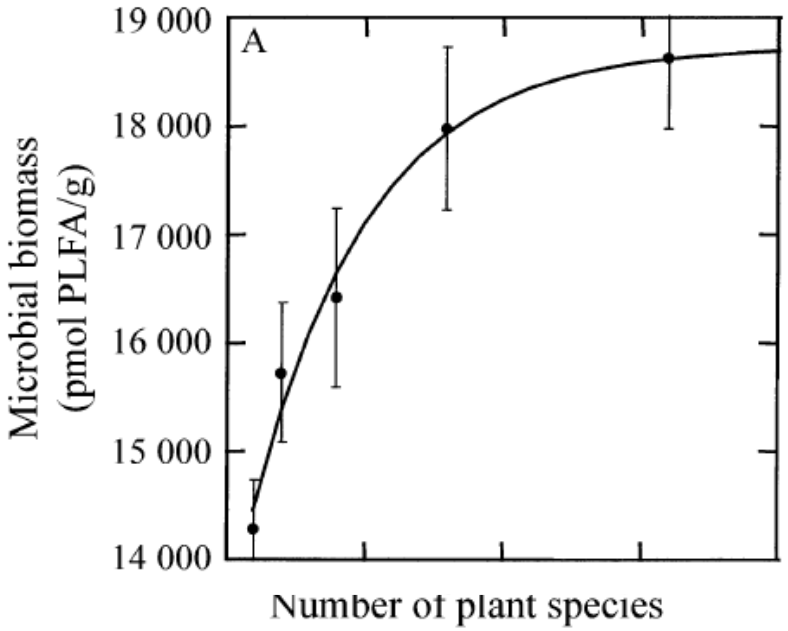
Cocktail

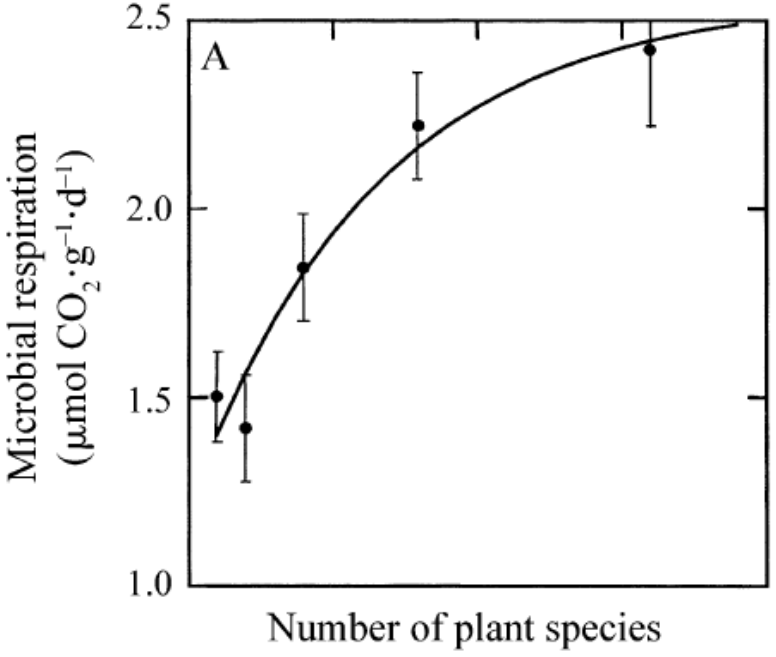
Utilize energy efficiently- understand the power of diversity: Collaboration is more apparent than Competition: ND case study: 2006 Production On Burleigh District Plot with 1.8 in. of rain



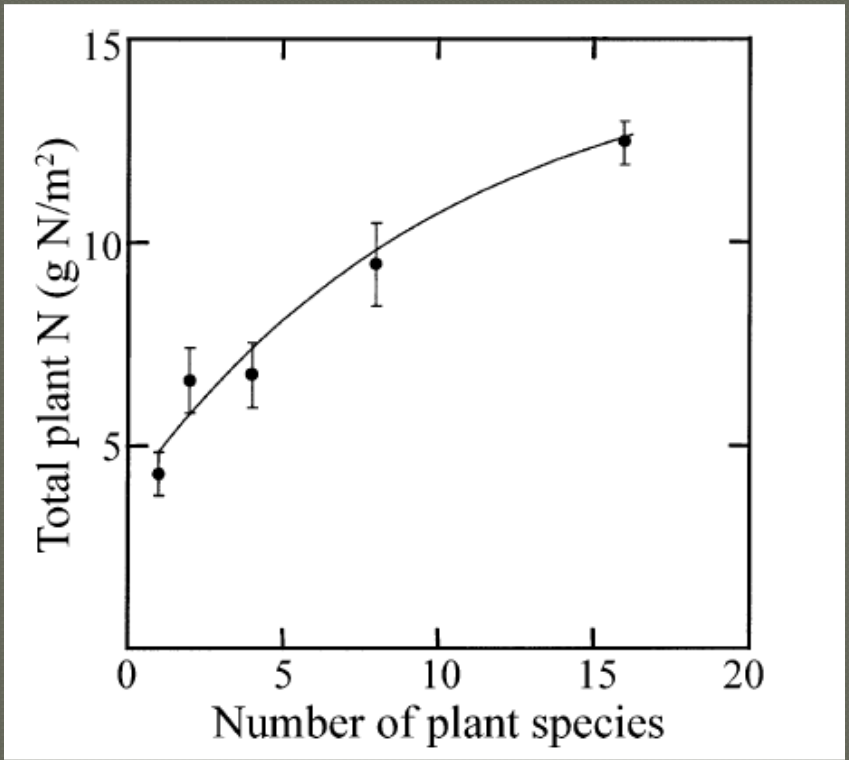
Plant Diversity Increases Microbial Productivity

Adapted from Zak et.al 2003





Plant Diversity Increases Total N Production



Adapted from Zak et.al 2003

Plant Diversity-Why is it important?

- Plants attract Microbiology with root exudates
  - Legumes/Rhizobium, Big Bluestem/Mycorrhizae
- Each plant species exude diff. root exudates
  - Attracts billions of microbes
- Increased Microbiology=Increased Soil Health
- 20% to 50% more carbon enters the rhizosphere from root exudates and exfoliates (sloughed cells and root hairs) than actually is present as fibrous roots at the end of the growing season. (Pg. 39, 1st paragraph – Fundamentals of Soil Ecology by D.C. Coleman (Second Edition)).

Living Root Year Round-What is it?

- Healthy Soils need living plants with Actively growing roots 365 days a year.

Nodulated Legume roots to fix Nitrogen

Fibrous Grass roots to build Structure

Brassica Tap roots to increase Porosity

While attracting and sustaining billions of microbe species

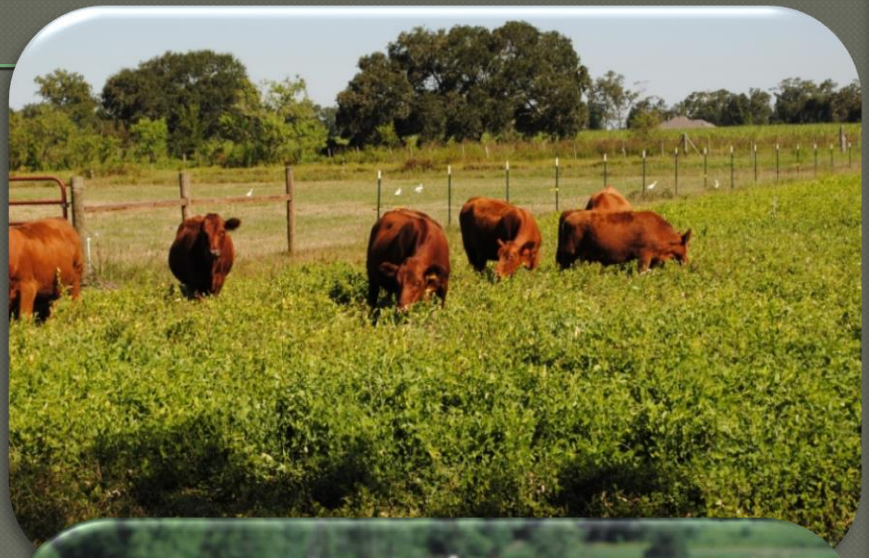
- As microbes grow and die they release nutrients, the nutrient cycle is working year round

Living Roots Year Round

- Jastrow (1987) and Miller and Jastrow (1990) indicated that the formation of water-stable aggregates can be related to the biomass of roots as well as the composition of the plant community.
- Roots of different species also vary in the composition of exudates and their rates of deposition. (Beare et.al. 1995)
- Mycorrhizal associations influence characteristics of root exudates that shape the composition and activity of the rhizosphere community (e.g. Meyer and Linderman, 1986).

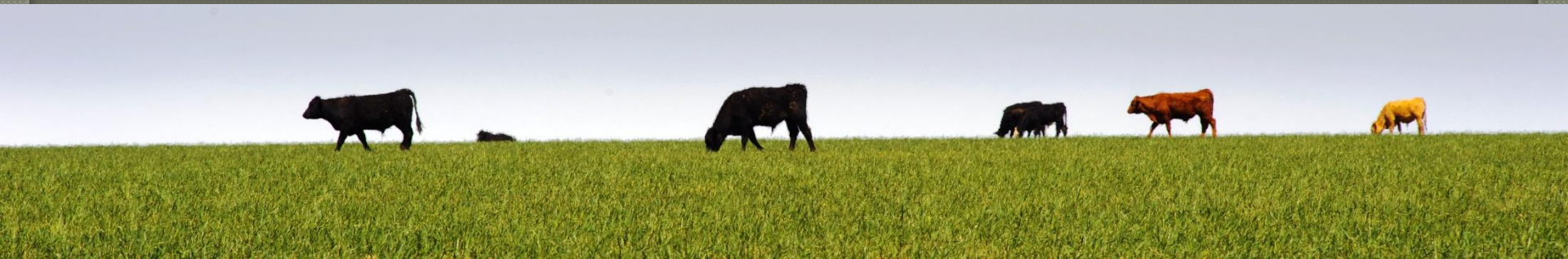
Livestock Integration

- Livestock Integration is the use of Livestock to accomplish ***Specific Objectives***.
  - Assist with the Termination of a Cover Crop
  - Trample plant material
  - Add Biological Diversity
  - Manage Plant Communities



Integrating Livestock

- Economic driver with variation depending on management and markets.
- Adding cattle to a legume–grain crop rotation doubled the rate of soil C accumulation, because of the manure additions (Drinkwater et al., 1998).
- Recycling of crop C through manure and decomposing residues improves soil C sequestration (Singh et al., 1998; Ma¨der et al., 1999; Soussana et al., 2004).



Increase grazing distribution

- Keep livestock together as much as possible, combine herds where possible
- High Density grazing will increase grazing distribution ensuring better pasture utilization and most of all increase the recovery periods of other pastures.

Does all this work in Practice?

Experiences

Building Soil Health with Grazing Management

USDA
United States Department of Agriculture
Agricultural Research Service

TXGLC
TEXAS GRAZING LAND COALITION

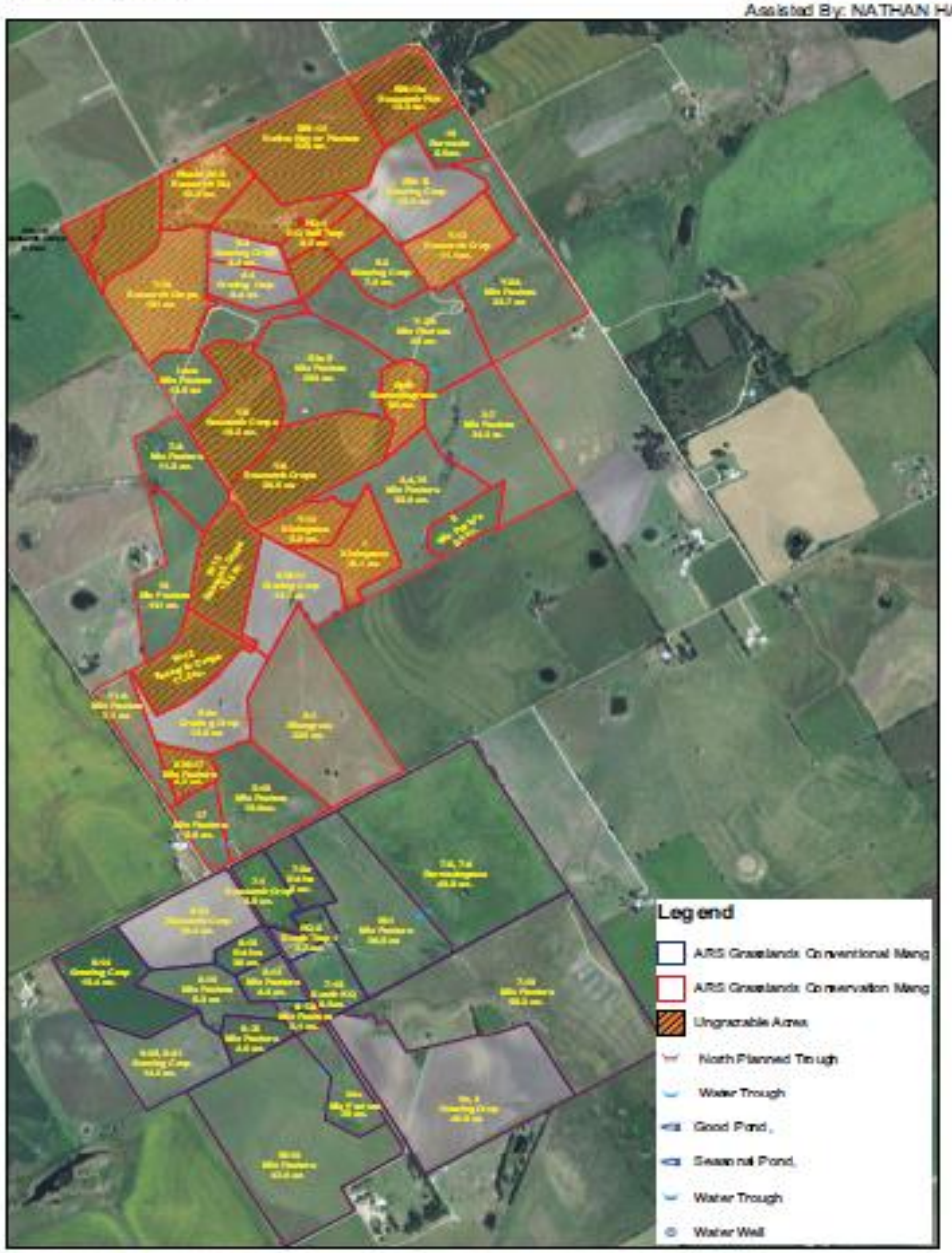
USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

ARS Grassland Research Station

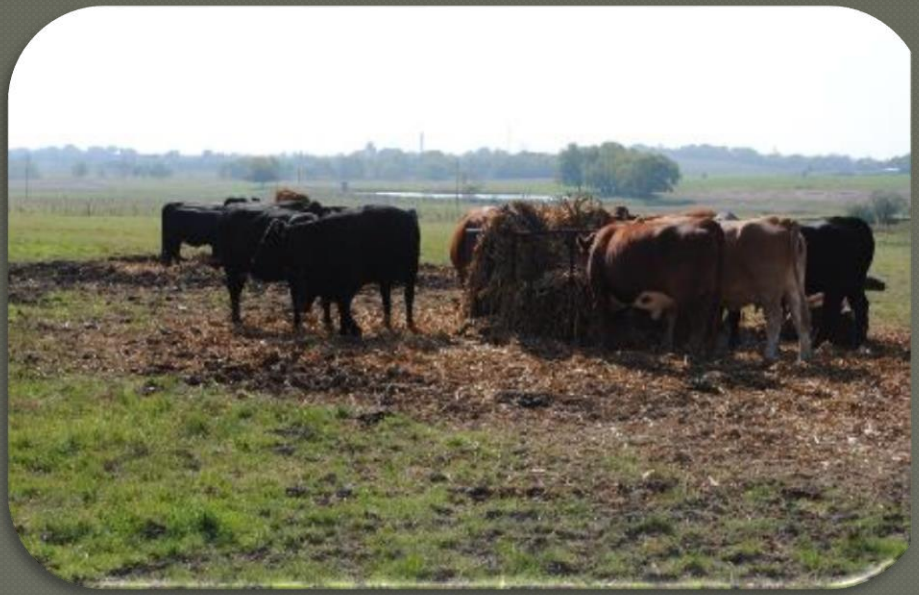
Customer(s): USDA-ARS

Agency: USDA-NRCS

Assisted By: NATHAN HAILE



Starting Point…



Riesel: What Did We Do?

NORTH RANCH

- Attained Forage Animal Balance
- Increased Grazing Distribution
- Increased Recovery Periods
- Integrated Diversity on Cropland
- Reduced Inorganic Inputs
- Reduced/Eliminated Winter Substitution Feeding

SOUTH RANCH

- Traditional Season Long Grazing
- No Rest or Deferment
- Increased Inorganic Fertilizer
- Continued Winter Oat Program
- Increased Substitution Feeding
- Minimal Management

Riesel: What Did We Measure?

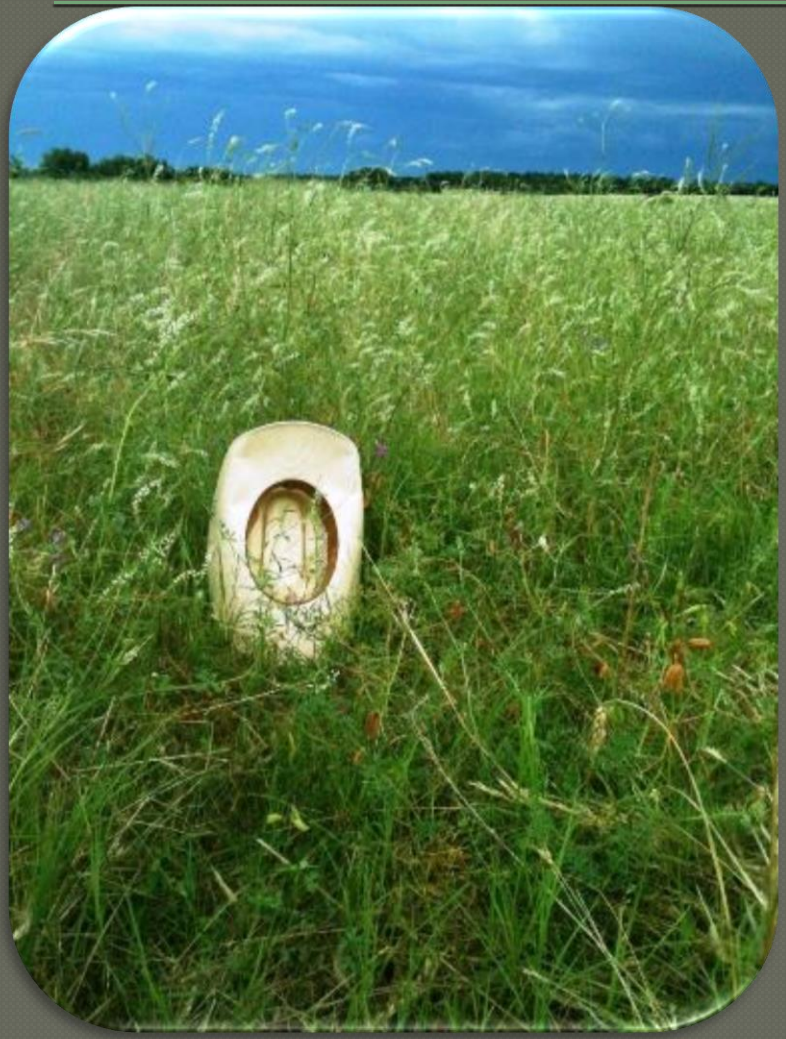
BOTH NORTH AN SOUTH DIVISIONS

- **Forage Responses**
  - Biannual Forage Inventories
  - Grazing Exclosures
- **Livestock Responses**
  - Body Condition Score
  - Fecal NIR Data (%CP, DOM)
- **Soil Health**
  - Slovita CO^2 Respiration
  - Water Extractable Organic Carbon
  - Water Extractable Nitrogen
- **Economics**
  - Every Dollar Spent

Cool Season Multi Species Cover Crops over Degraded Bermudagrass

- Seeded on Dec 7, 2011
  - Wheat, oats, rye, barley
  - Alfalfa, Austrian Winter Pea, Hairy Vetch, Madrid, Hubam and Crimson Clover
  - Turnips, Rape
- On April 18th produced **5,500 lbs of forage with no fertilizer**
- 5 acres were grazed with 30 Cow/calf pairs for 10 days…that is a rate of 6 cows/acre

June 12th 60 day recovery



Closing Forage Supply Gaps

Grazed again for 15 days with 30 cows

- 5 acres supported 30 head for 25 days at a stocking rate of 6 AU/Ac during the early spring

2014 70% Co

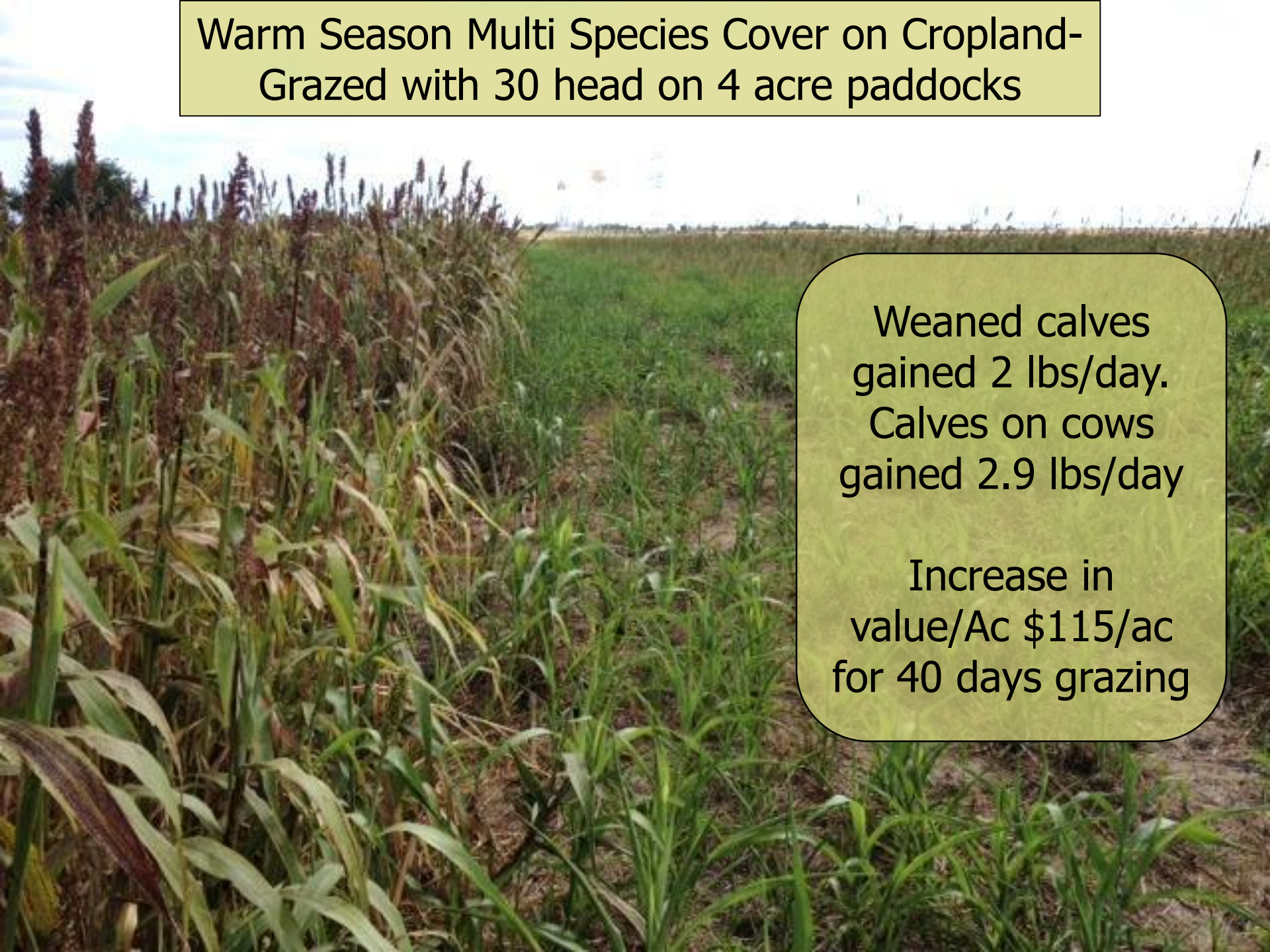
2012 Warm Season Cover on Oat Fields

- No-till seeded 88 Acres on May 10, 2012
  - Brown Top and German Millet
  - Buckwheat
  - Iron and Clay Cow Pea
  - Forage Soybean
  - Sesame

- ~ $32/Acre seed cost

Warm Season Multi Species Cover on Oat Cropland- Grazed with 30 head on 4 acre Paddocks

Warm Season Multi Species Cover on Cropland-
Grazed with 30 head on 4 acre paddocks

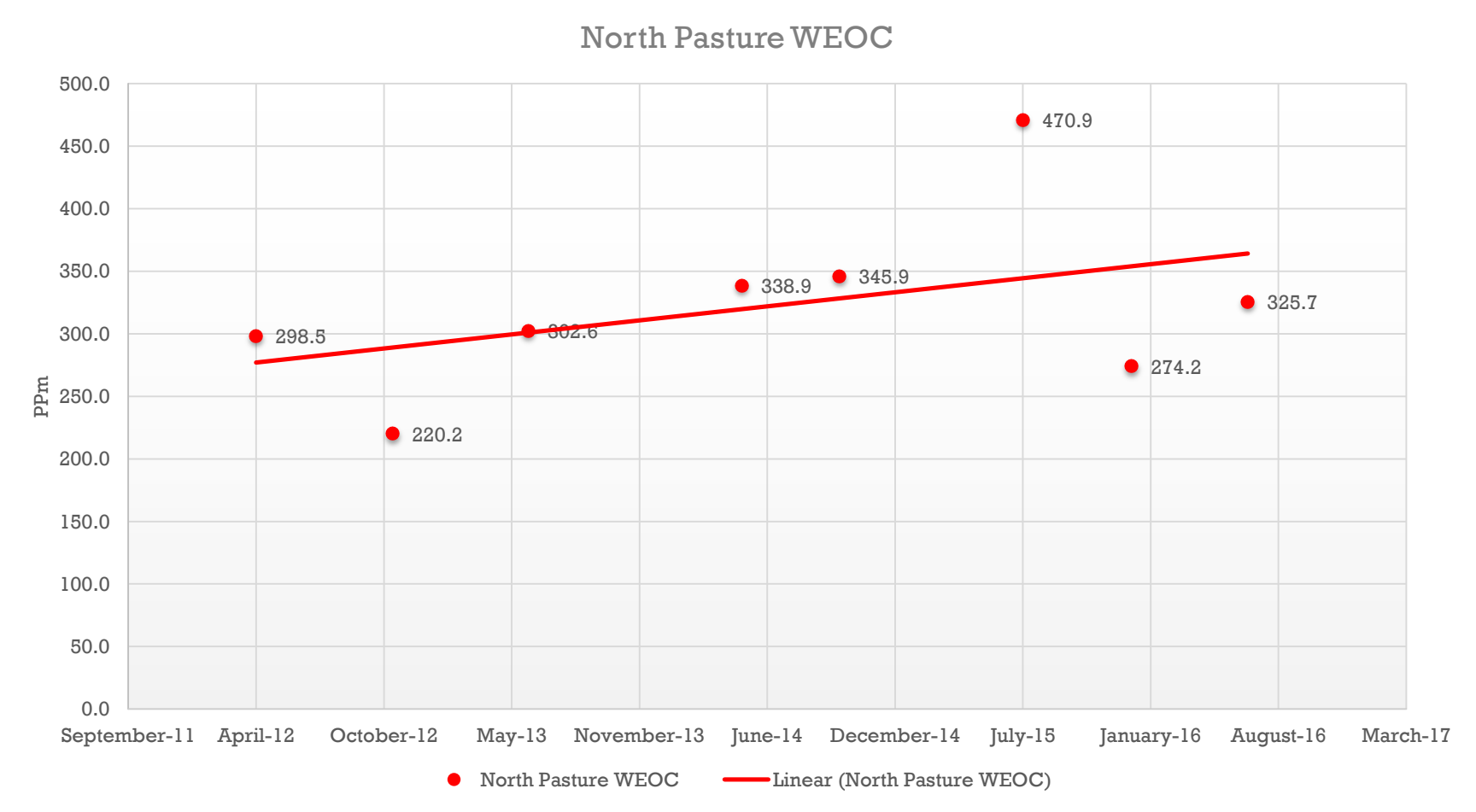


Weaned calves gained 2 lbs/day. Calves on cows gained 2.9 lbs/day

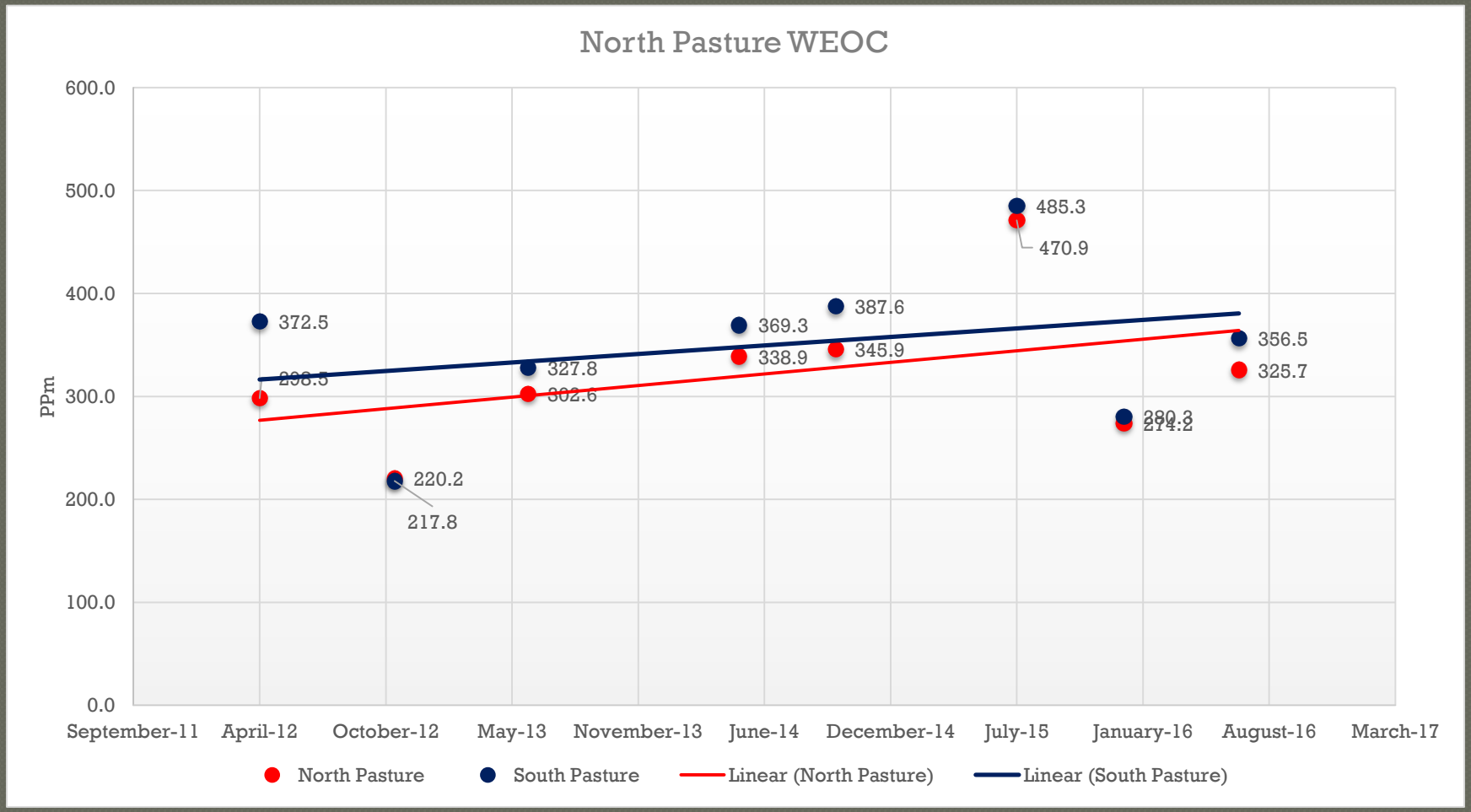
Increase in value/Ac $115/ac for 40 days grazing

What about Soil Health?

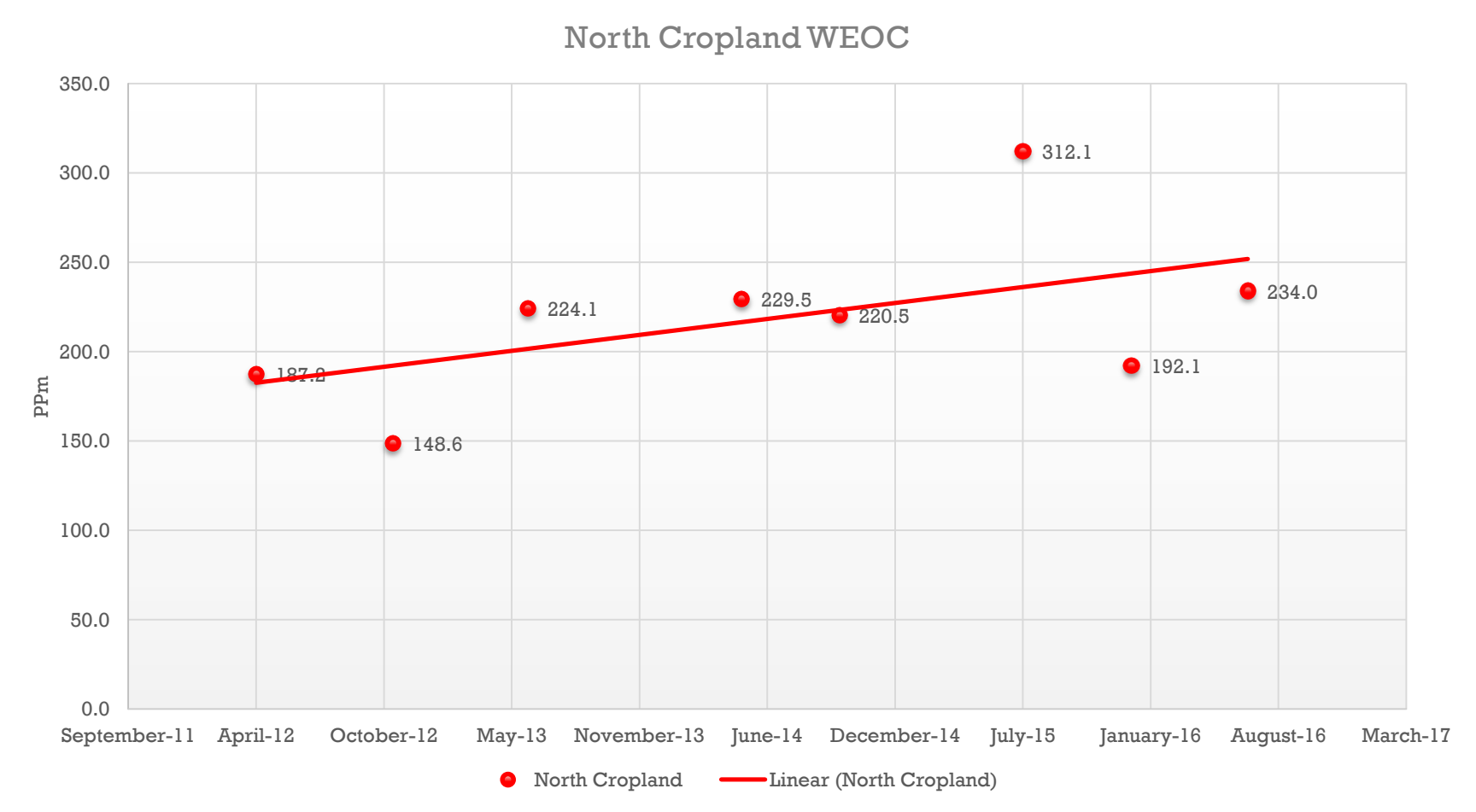
North Pasture: Water Extractable Organic Carbon



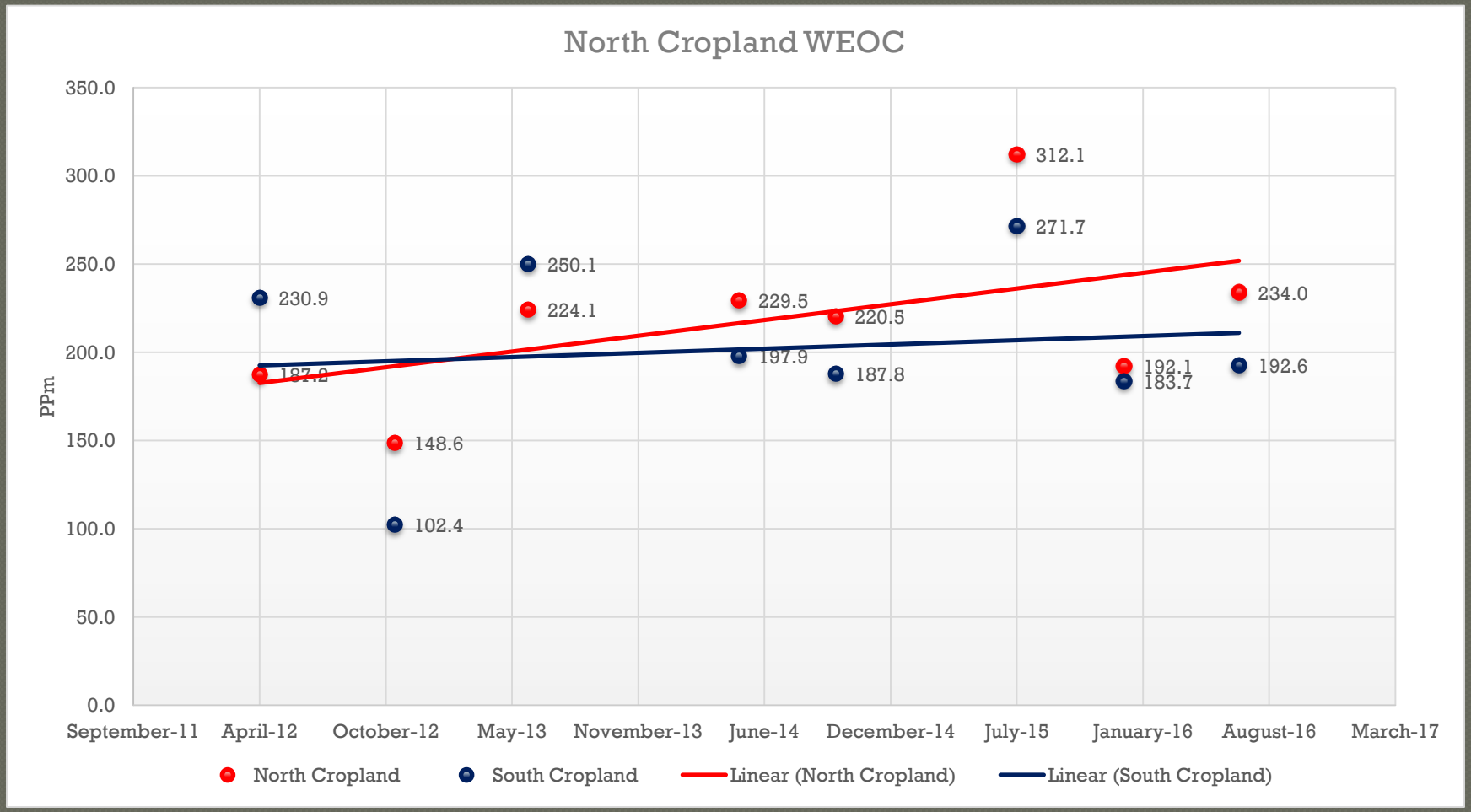
Perennial Pasture: Water Extractable Organic Carbon



North Cropland: Water Extractable Organic Carbon

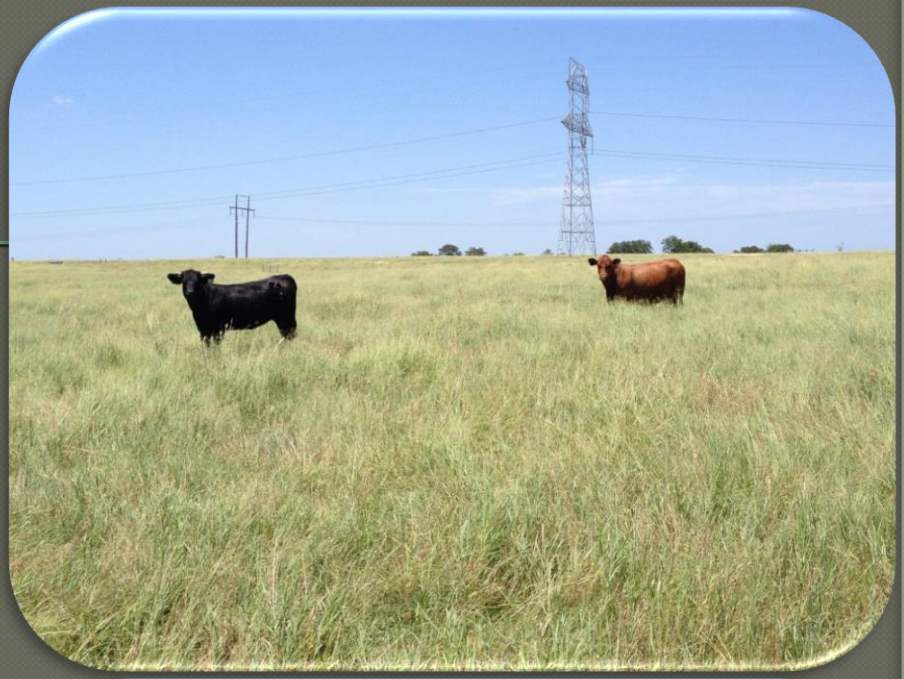


Cropland:
Water Extractable Organic Carbon



Klein Grass

- Kliengrass was extremely degraded
- Increased Stock Density currently @ 13,0080 Lbs. Live weight/Ac on 3 Ac paddocks
- Future Plans to go to ½ Ac/day @ 78,480 Lbs. Live weight/Ac



Riesel Case Study

North Division FALL Clipping Data

North – weights are air dry			
Enclosure lbs/ac	Pasture (lbs/ac)	Percentage left	Percentage grazed
3421	1614	47%	53%
3813	3791	99%	1%
4419	2368	54%	46%
3029	3071	101%	-1%
4348	1934	56%	44%
5246	3717	71%	29%

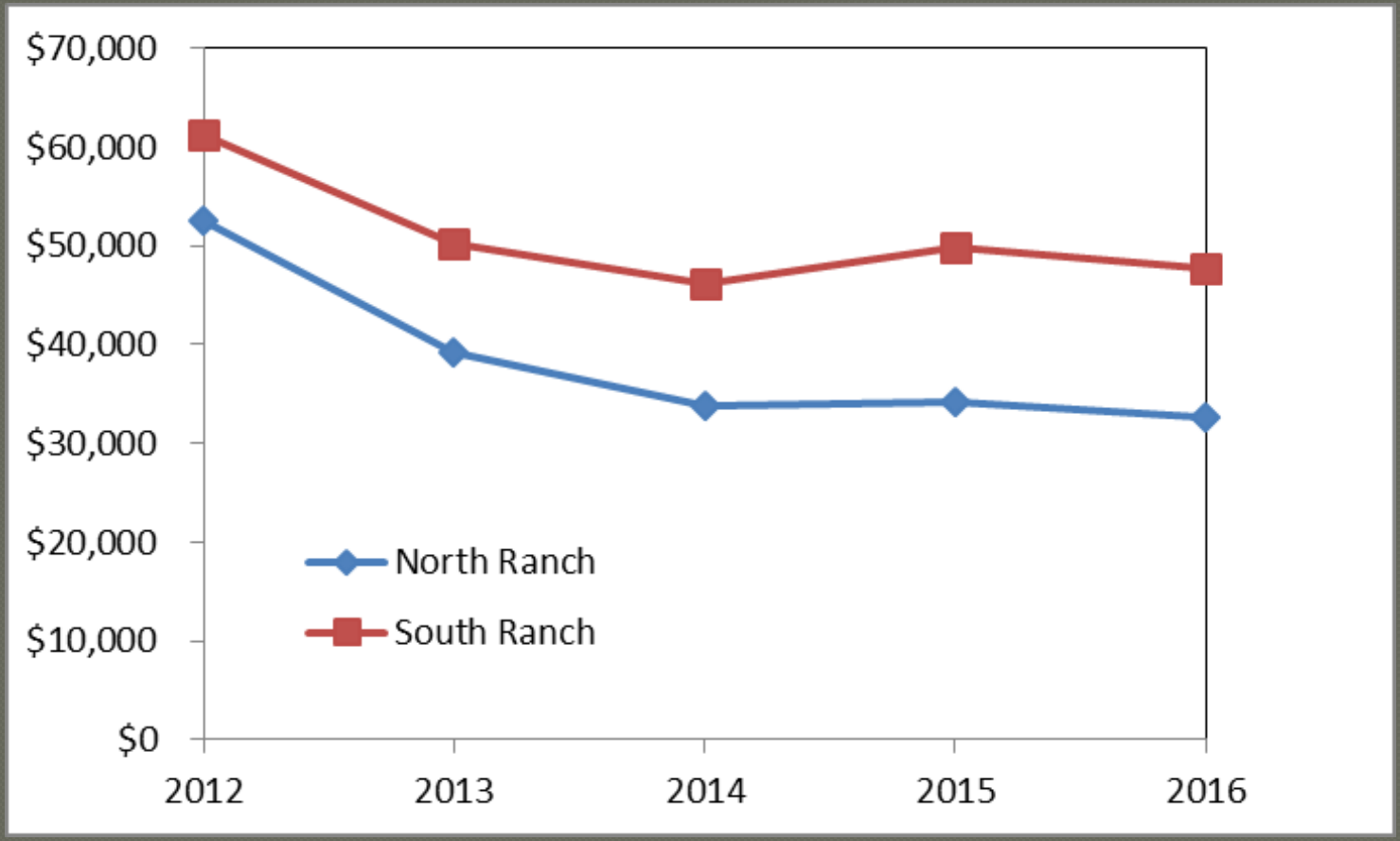
Riesel Case Study

South Division FALL Clipping Data

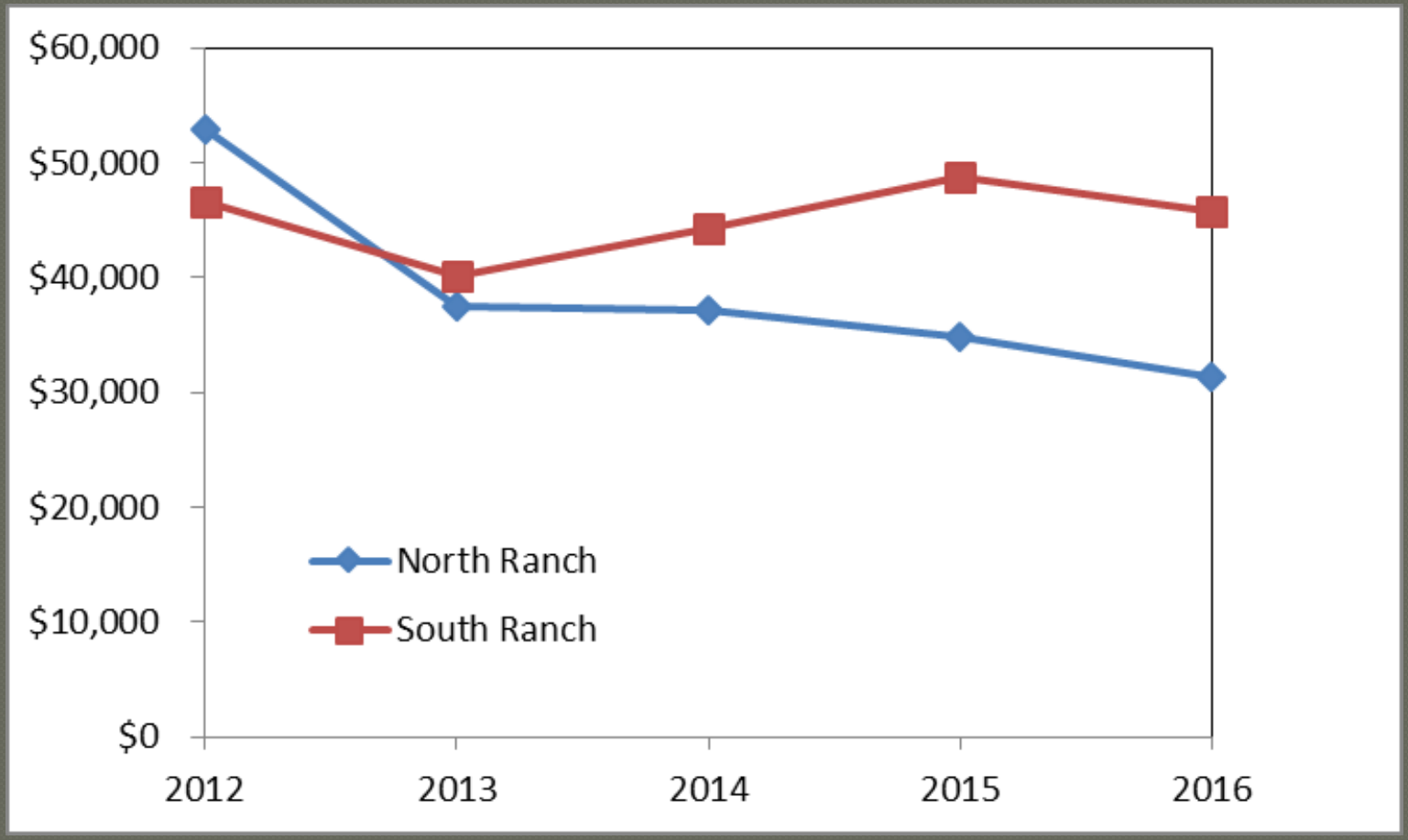
South – weights are air dry			
Enclosure lbs/ac	Pasture (lbs/ac)	Percentage left	Percentage grazed
3492	630	18%	82%
6058	470	8%	92%
1104	396	36%	64%
3065	813	27%	73%
2886	565	20%	80%

Show me the Money….

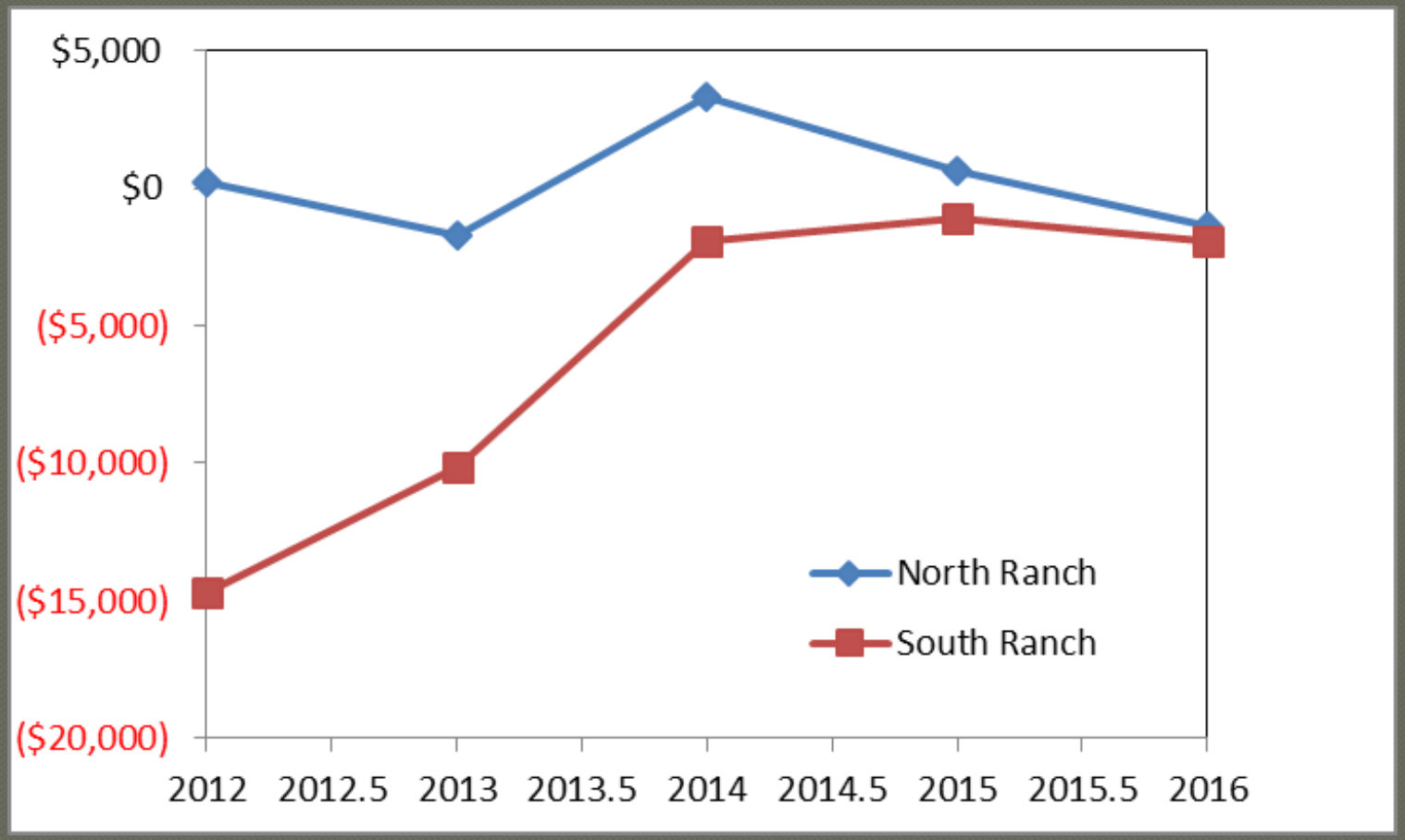
Ranch Costs


$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
2012
2013
2014
2015
2016
North Ranch
South Ranch

Ranch Revenue



Ranch Profitability

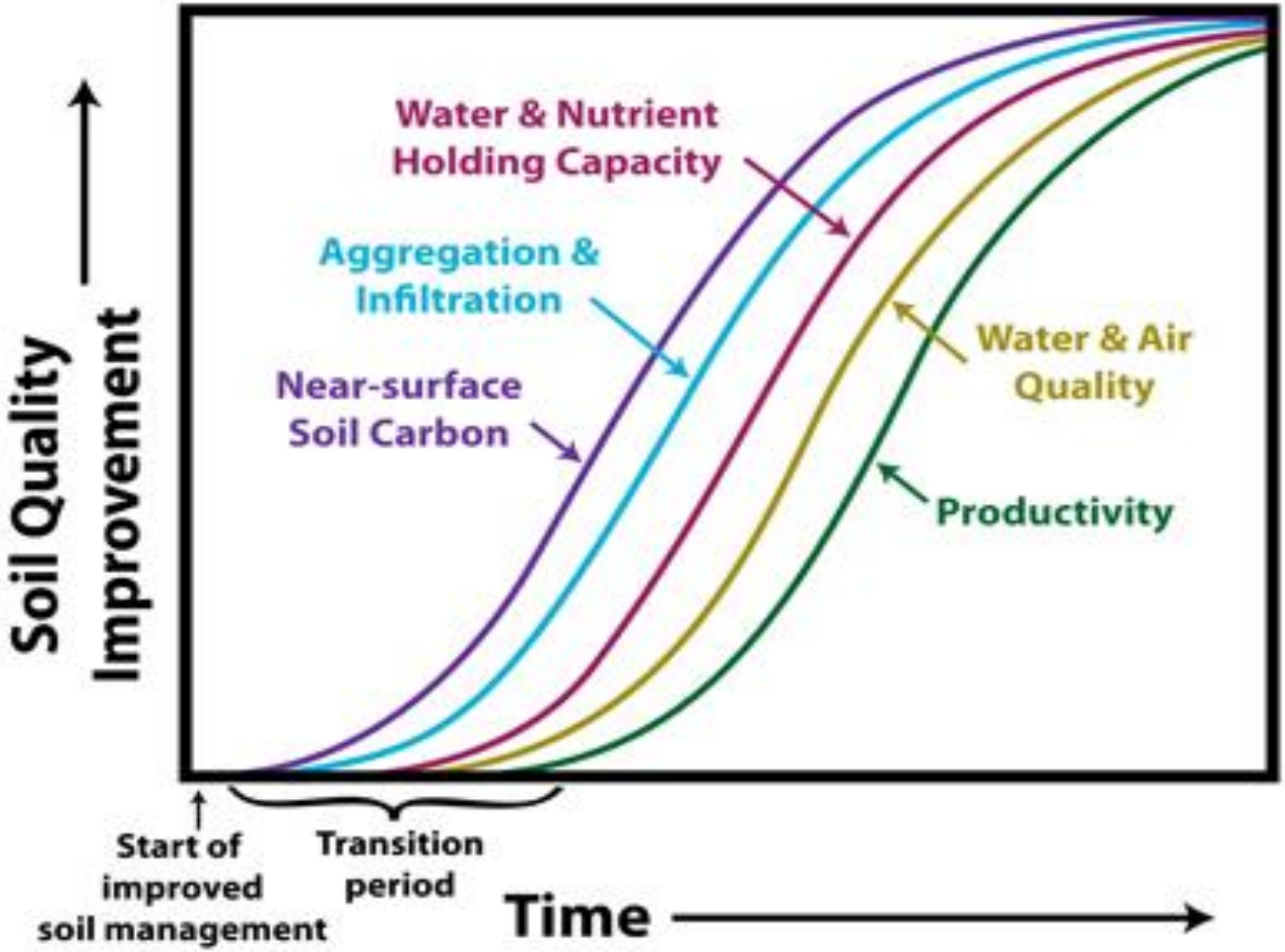


Economic Summary

Five year averages (2012-2016)				
North Ranch (enhanced)			South Ranch (traditional)	
Costs			Costs	
Labor	$1,980		Labor	$3,862
Feed	$4,774		Feed	$12,494
Vet.	$558		Vet.	$777
Misc.	$425		Misc.	$123
Sampling	$609		Sampling	$0
Capital	$2,417		Capital	$0
Buy Cattle	$7,840		Buy Cattle	$12,600
Mach./Fuel	$3,390		Mach./Fuel	$6,241
Seed	$5,107		Seed	$1,968
Fertilizer	$4,981		Fertilizer	$8,859
Chemical	$596		Chemical	$714
Total Costs	$32,677		Total Costs	$47,638

Processing Thoughts…

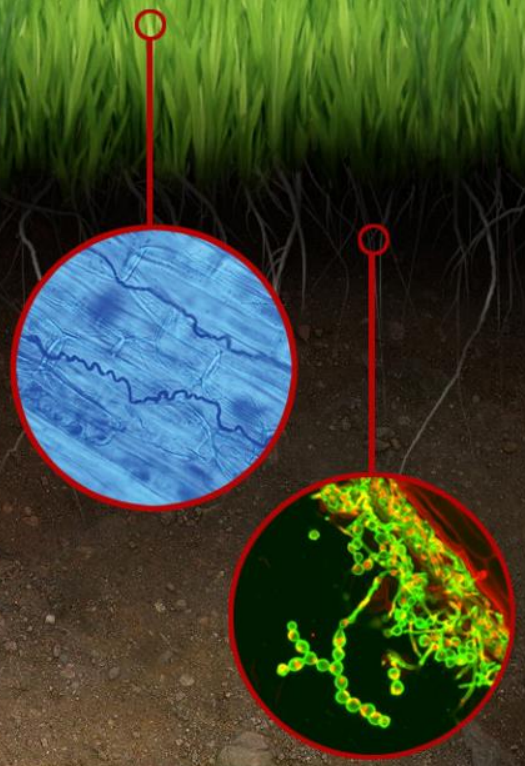
- Capitalize on rewards when they arise.
  - Remember our job is to convert sunlight into a marketable product.
  - Restocking or adding stockers
- Timely applications of inorganic fertilizer should be considered
- Progress towards spring calving.
- Be Patient. Resilience requires it.
  - Carbon Bank


Soil Quality
Improvement
Water & Nutrient
Holding Capacity
Aggregation &
Infiltration
Near-surface
Soil Carbon
Water & Air
Quality
Productivity
Start of
improved
soil management
Transition
period
Time

Source: NRCS

Outlook for the Future

Harnessing the Microbiome for Agricultural Sustainability in Bioenergy-based Systems

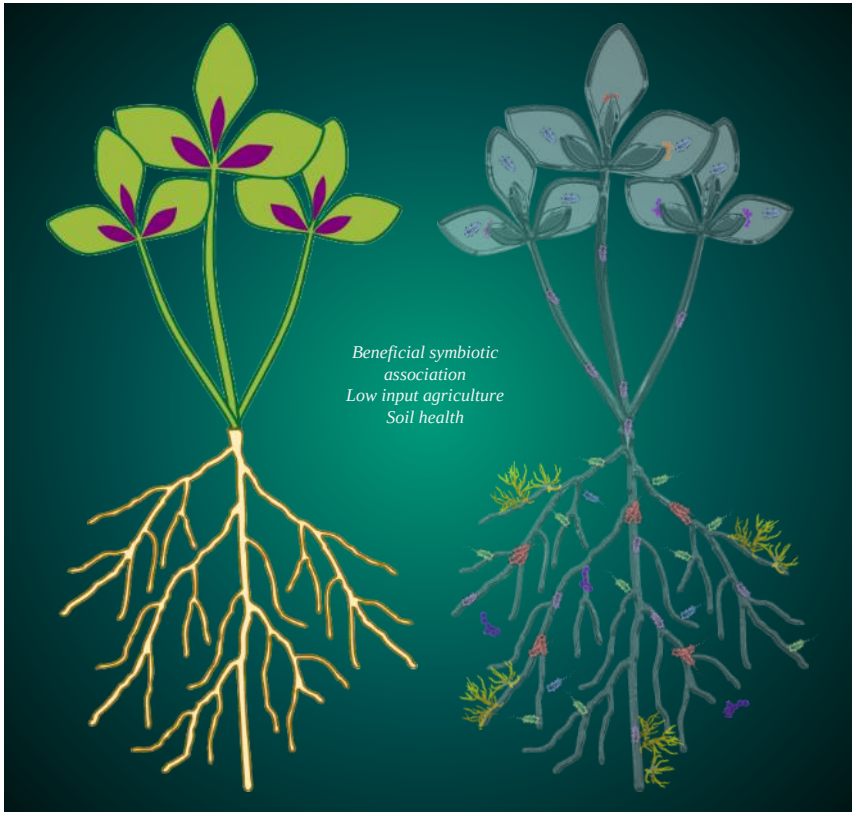


Kelly D. Craven Ph. D

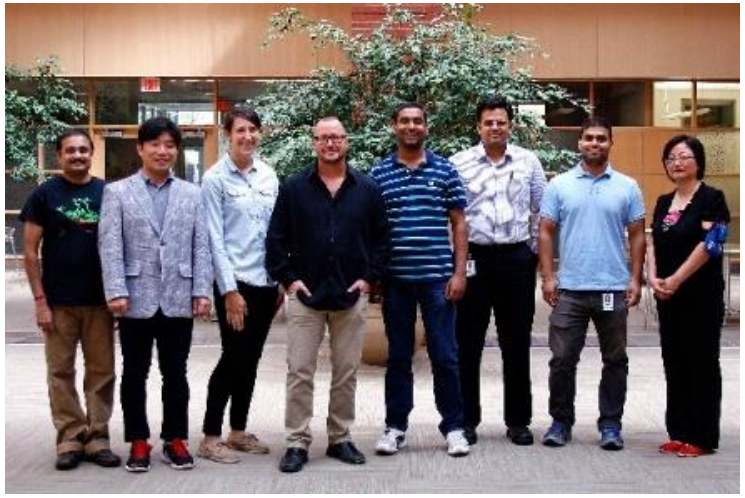
THE SAMUEL ROBERTS
NOBLE
FOUNDATION

Your Microbes, Your Health

Plant Microbes, Plant Health



Symbiosis for Sustainability Group

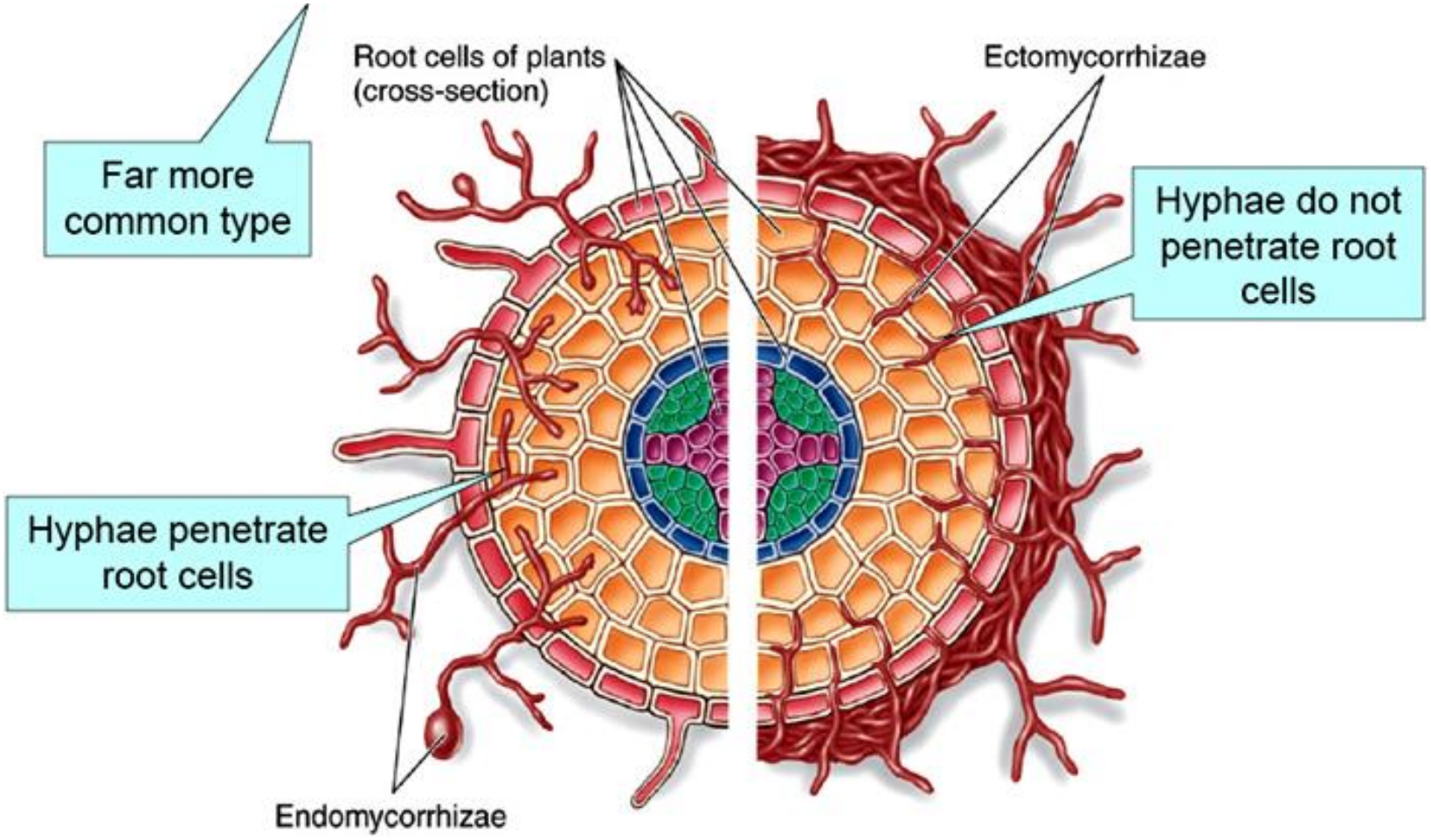


Rationale: Plants depend on diff. types of symbionts in ALL natural environments, esp. challenging ones (i.e. nutritionally deficient soils, extreme temps, etc)

Overarching goal: Find symbiotic microbes to promote plant growth under a **sustainable, low-input strategy**

****Optimize the Plant Phytobiome****

Endomycorrhiza and Ectomycorrhiza



Source

The Sebacinales

(artificial infections)

- Unlike AM mycorrhizae, these fungi can be cultured on artificial media

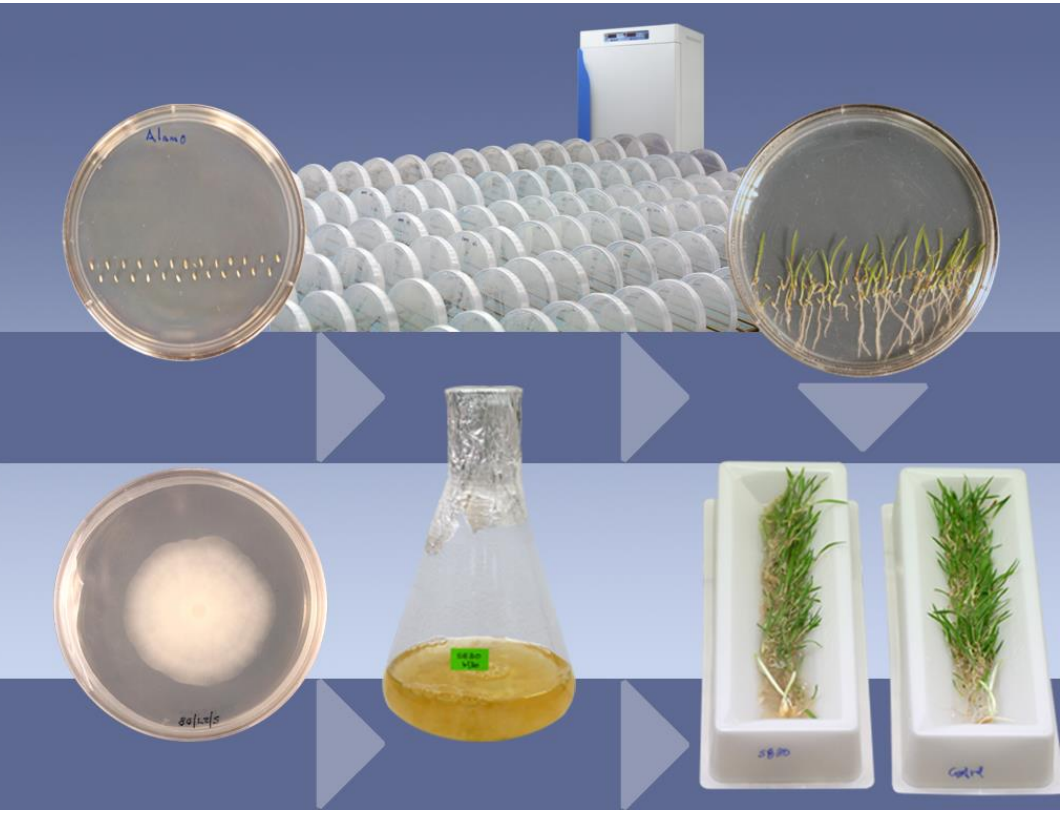
- 15 isolates collected from orchids in SW Australia

Warcup, J.H., The mycorrhizal relationships of Australian orchids, New Phytologist, 87(2), 371-381, 1981

- *Piriformospora indica* and *Sebacina vermifera* could be artificially inoculated onto the root systems of an extraordinary diversity of plant hosts (Singh et al, 2001; Varma et al, 2001)

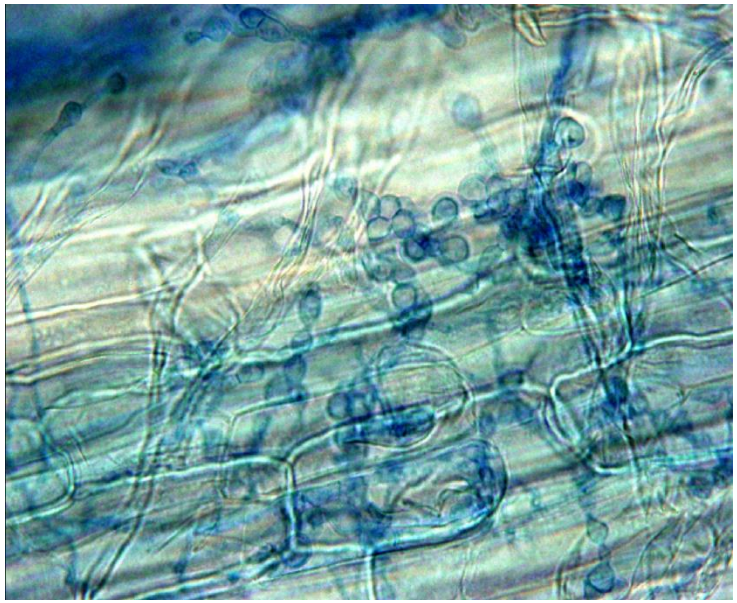
- Artificially inoculated plants often showed pronounced growth effects and stress tolerances (above; Waller et al., 2005)

- **Obtained *S. vermifera* orchid isolates for plant growth promotion studies**



2 month old seedlings screened
(WGA-AF 488, lactophenol blue)

94 - 100% infection!!

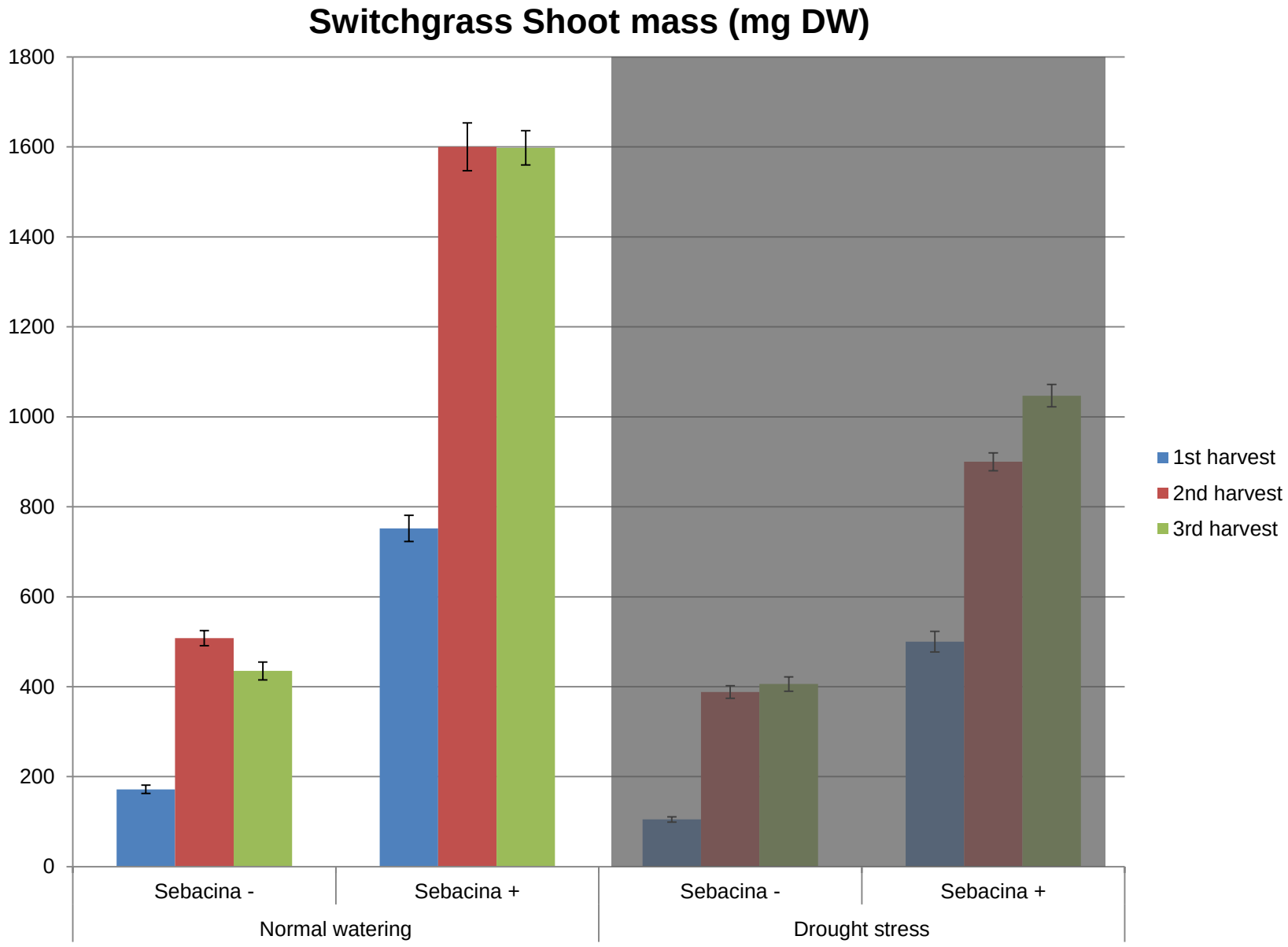


Plant Performance Study

- NF/GA-993 genotype of Switchgrass cultivar Alamo (lowland)
- 6 isolates of *Sebacina vermifera* (AUS orchid)
- 10 day old seedlings were inoculated (3hr)

Effect of *Sebacina vermifera* (AUS) inoculation on switchgrass

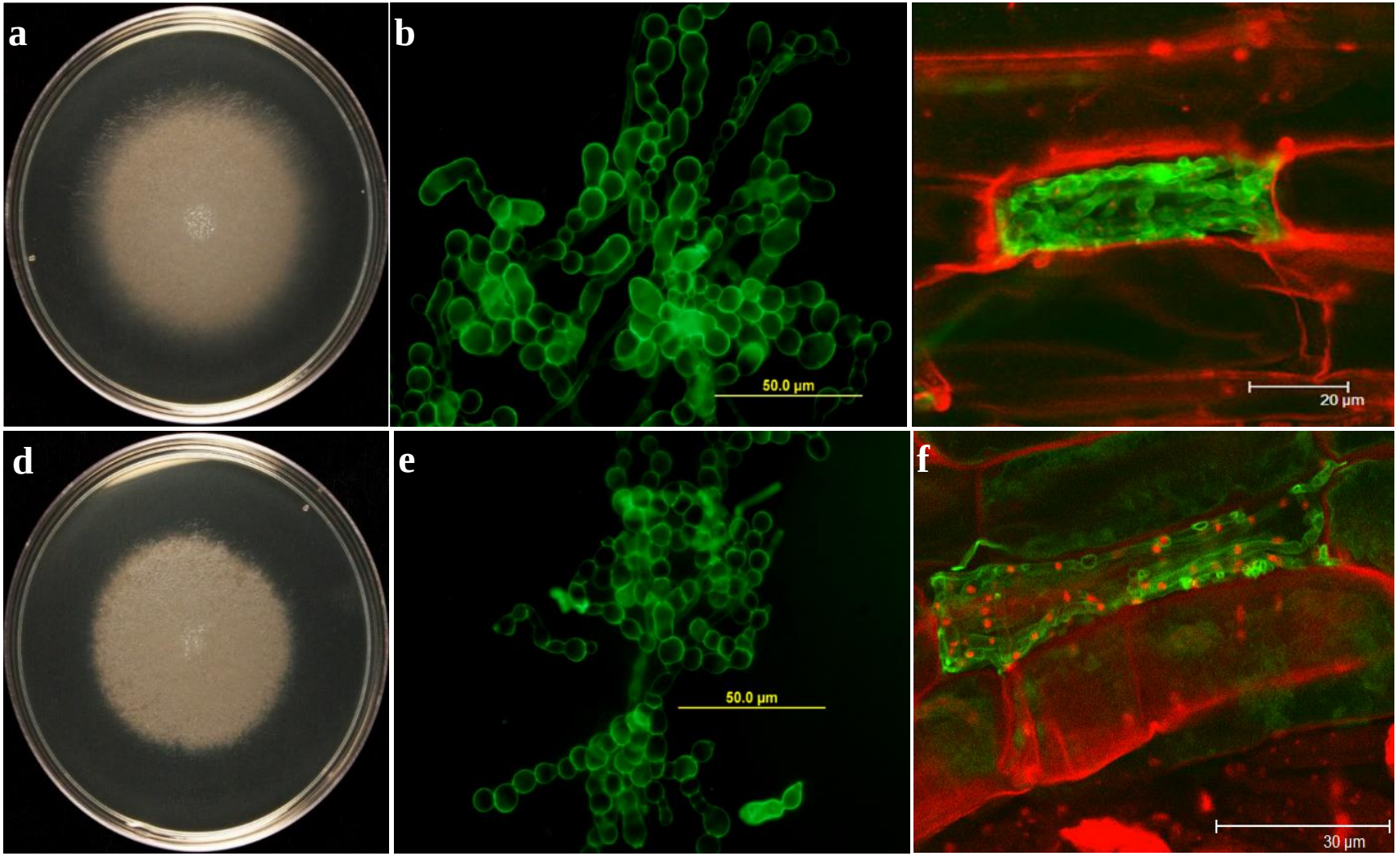
Ghimire et al., 2009. Bioenerg Res. 2: 51-58.



1st, 2nd, 3rd harvest = 2, 3.5, 7 months, respectively

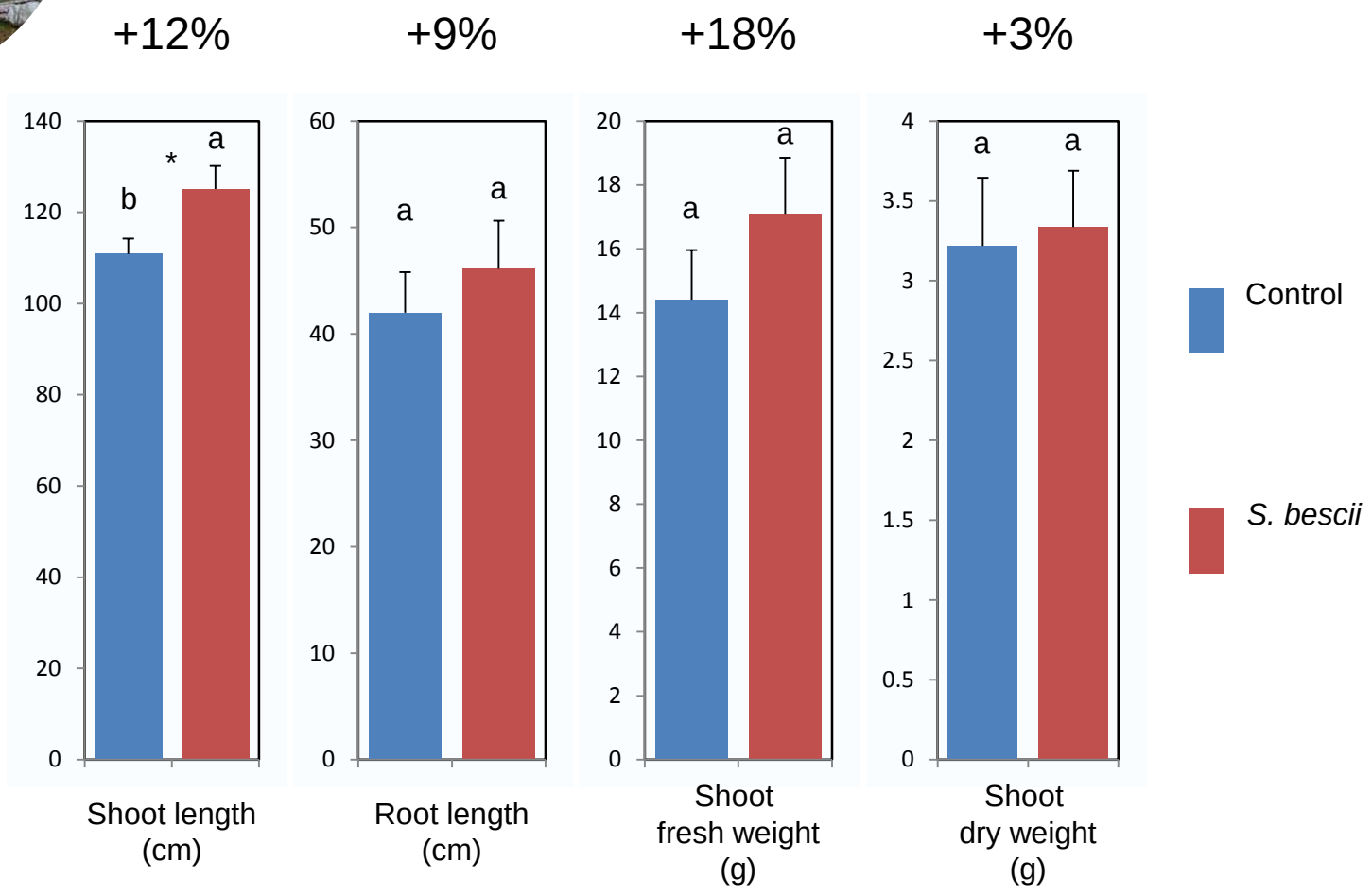
Ghimire & Craven 2011
Appl . Envir. Microbiol. 77: 7063-7067

First N. American strain of *Sebacina* (=*Sebacina bescii*)!



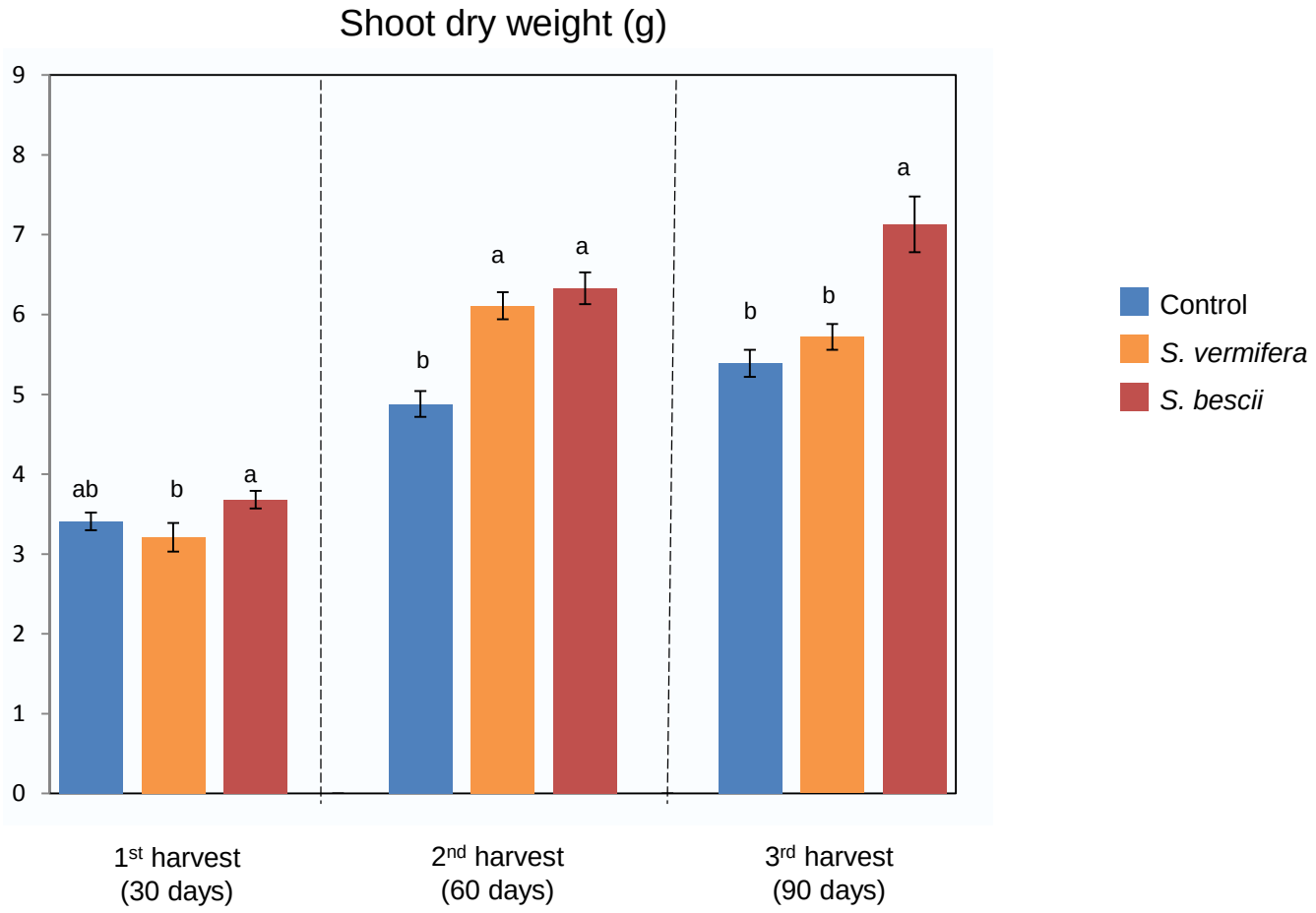
Biomass increase in Switchgrass

8 weeks after colonization **of seedlings**



Effect of *S.bescii* colonization on forage biomass of Switchgrass (Alamo). Bars with different letter indicate significant difference between treatments at p ≤0.05.

Biomass increase in winter wheat



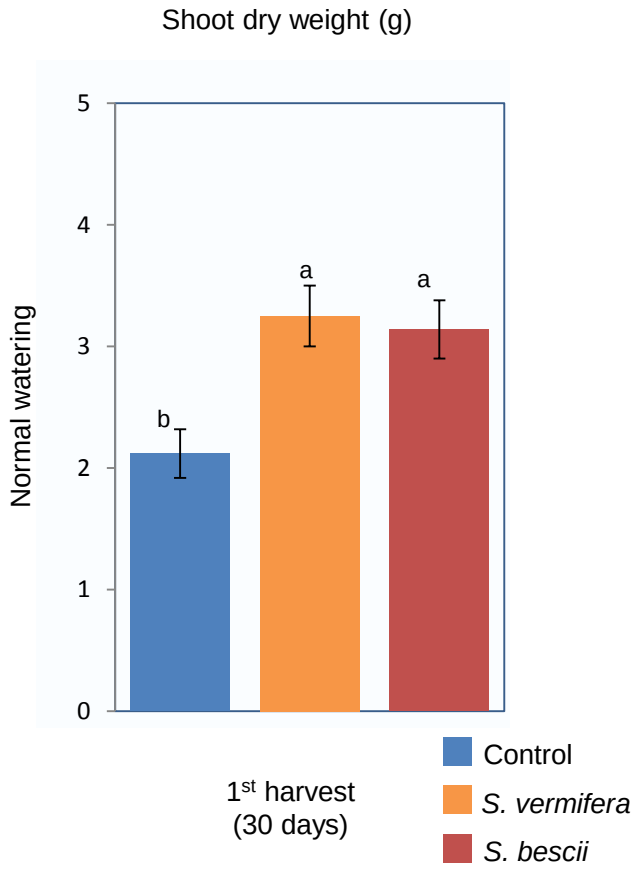
Effect of *S. vermifera* MAFF305830 and *S.bescii* colonization on forage biomass of winter wheat (NF101) under normal and water stress condition. Bars with different letter indicate significant difference between treatments at p ≤0.05.

Biomass increase in Alfalfa

Control

S. vermifera

S. bescii



Effect on forage biomass of Alfalfa (NECS-141) colonized with *Sebacina bescii* and *Sebacina vermifera* respectively, with respect to control under normal and drought conditions three weeks after initiation of drought treatment.

We’ve got an exciting future…

Jeff Goodwin
Range and Pasture Consultant
Office 580-224-6469
djgoodwin@noble.org

THE SAMUEL ROBERTS

NOBLE

FOUNDATION