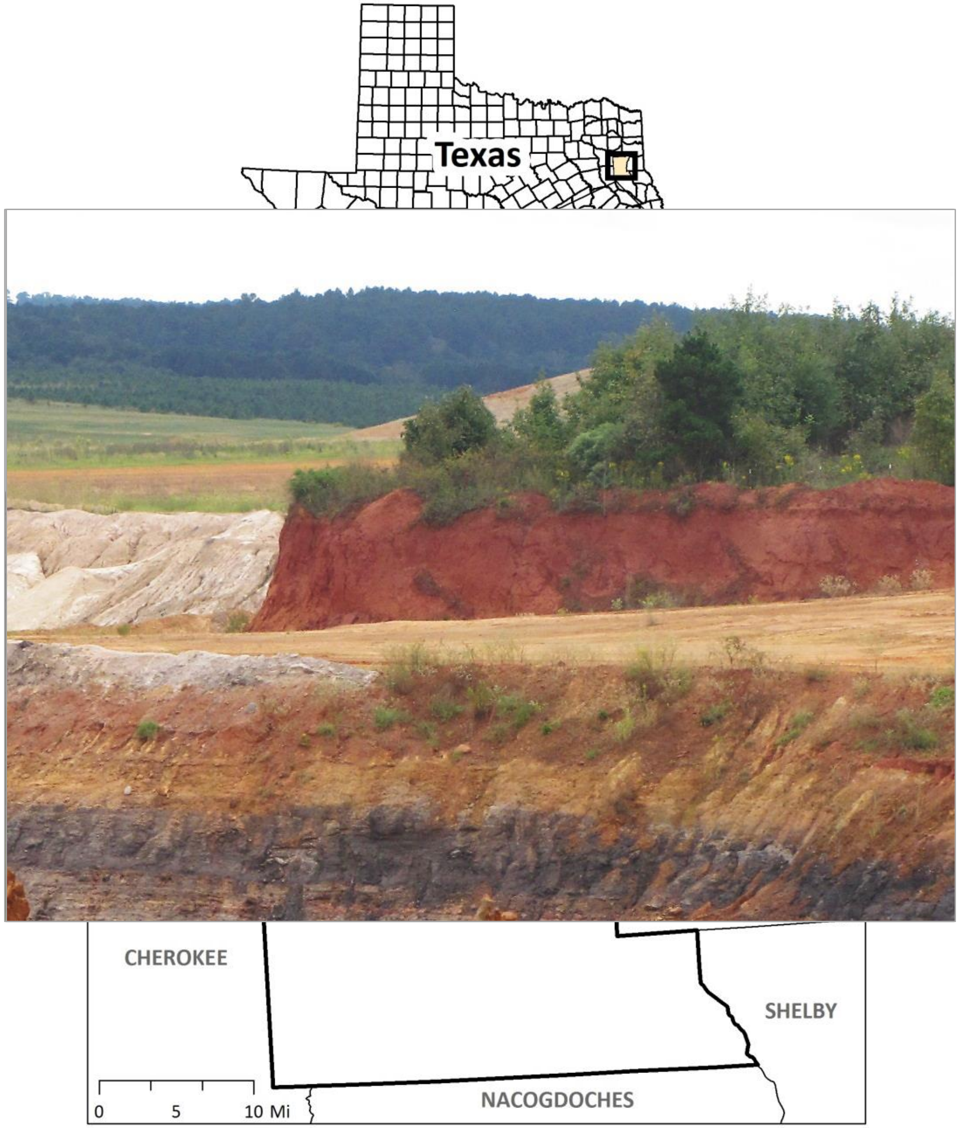
Surface and Subsurface Tillage Effects on Soil Properties and Vegetation at an East Texas Lignite Surface Mine

Hannah Angel
H. Williams, J. Stovall, K. Farrish, L. Young
Stephen F. Austin State University
Presented at ASMR, Morgantown
April 10, 2017

Luminant

Research Location

- Luminant Oak Hill Mine
  - 10,000 ha
  - Martin Lake Power Plant
- Area Mining Method
  - Dragline Operation
- Reclamation Approach
  - Oxidized Material Haulback



Oxidized Material Haulback Methodologies

Truck-Shovel Combination

Tractor Pulled Scraper Pans

Literature Overview

- Similar productivity levels to unmined lands in East Texas
  (Priest et al., 2015)

- Mine soil compaction indicated
  (Yao & Wilding, 1994; Barth & Hossner, 2000)

- Alleviating soil compaction improves tree growth
  (Burger & Evans, 2010; Powers et al., 1999)

Oak Hill Mine Reforestation

Research Questions

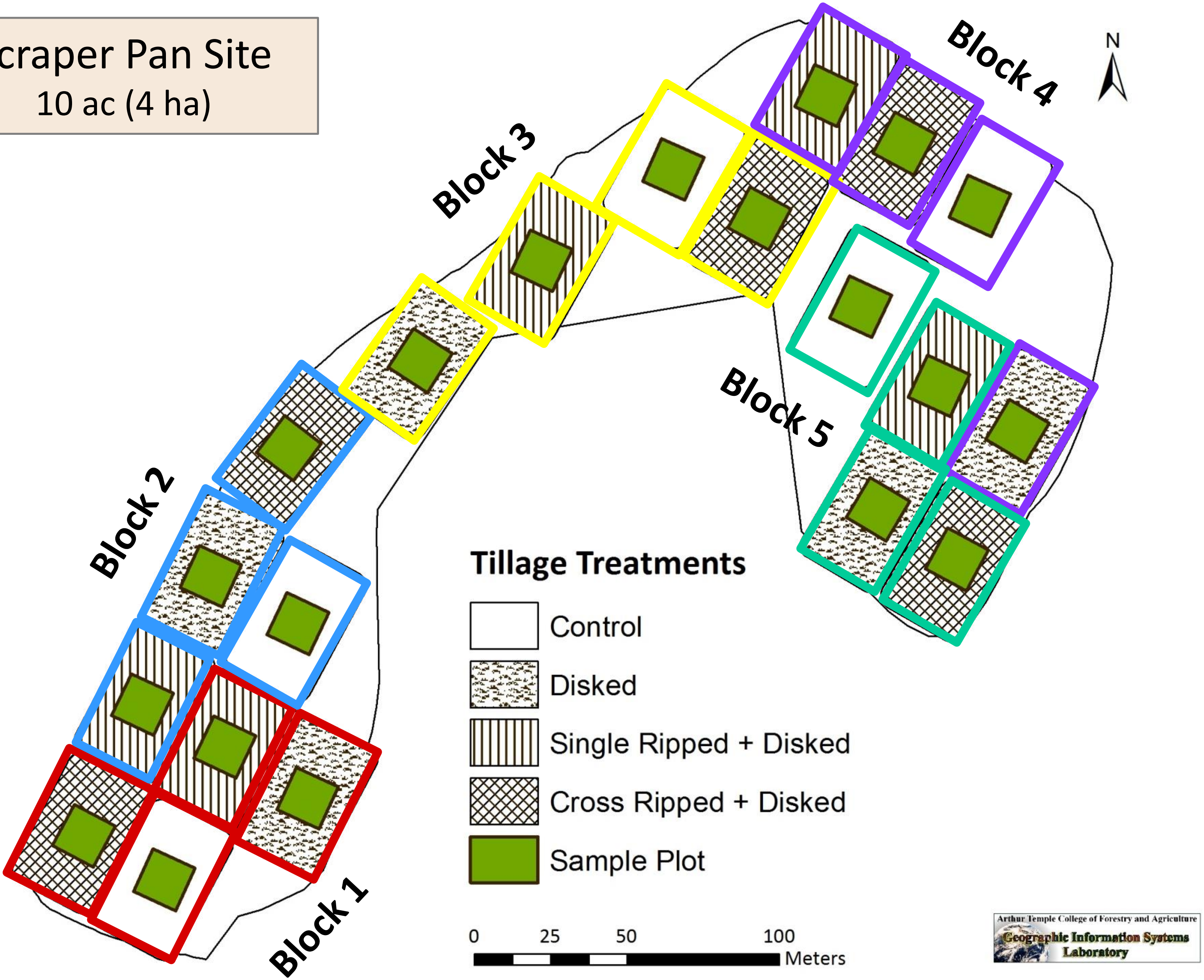
- Can mine soil compaction be alleviated using different surface and subsurface tillage techniques?

- How do tillage techniques influence mine soil properties and vegetative response?

Experimental Design

Scraper pan site

Scraper Pan Site
10 ac (4 ha)



Treatments

Surface Tillage Treatment

Control (no till) vs Disk (30-35 cm depth)

Subsurface Tillage Treatment

Single vs Cross-Ripping (90 cm depth)

Subsurface Tillage Treatment

Single **or** Cross-Ripped + Disked

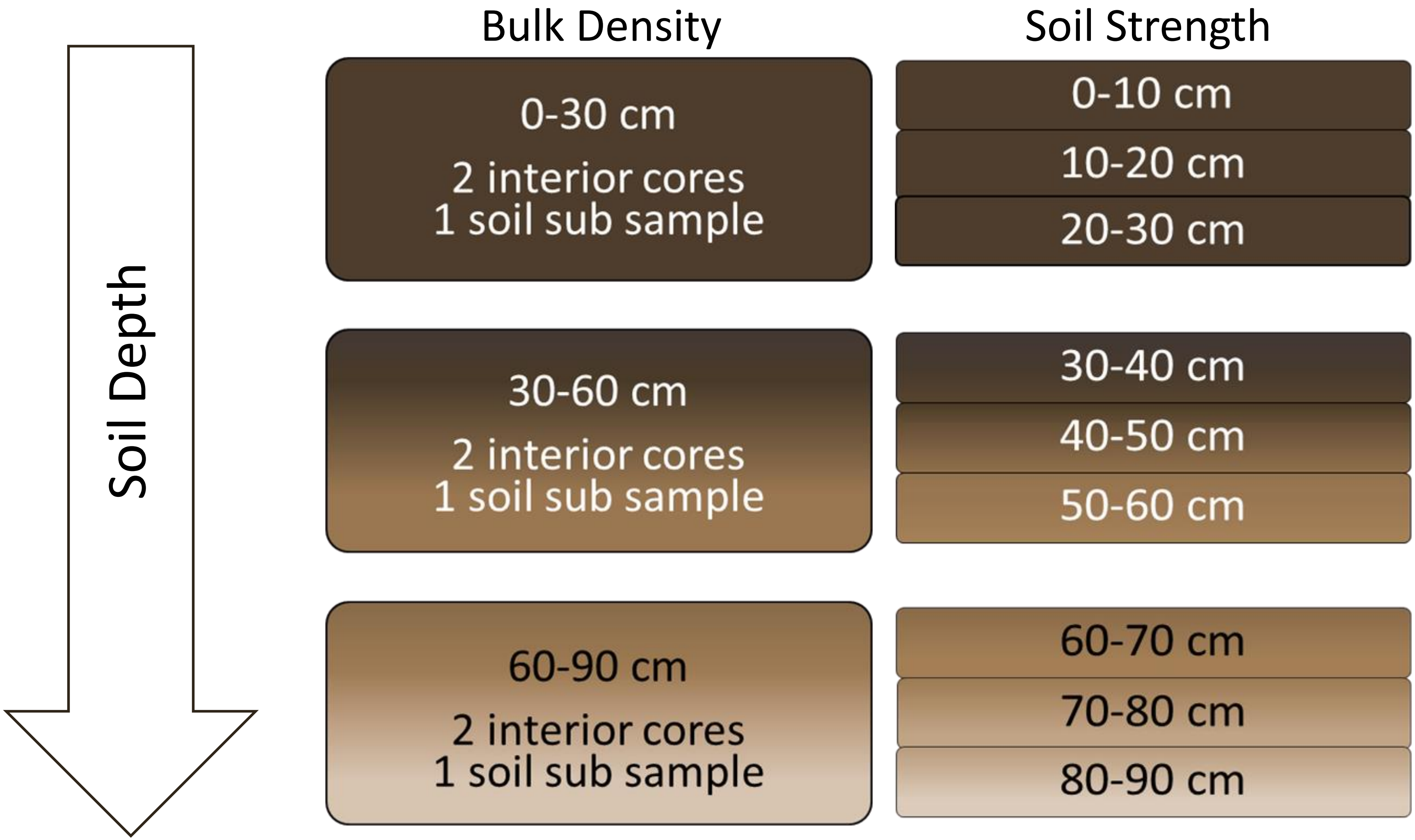
Site Preparation: November 2015

Tree Planting: January 2016

Loblolly pine (*Pinus taeda*) 1-0 bare-root seedlings at 2 m x 3 m spacing

Methods

Soil Test Pit Sampling



Methods
Soil Physical Properties

- Soil Bulk Density (Db)
  - Slide hammer method
  - Total of 40 soil test pits

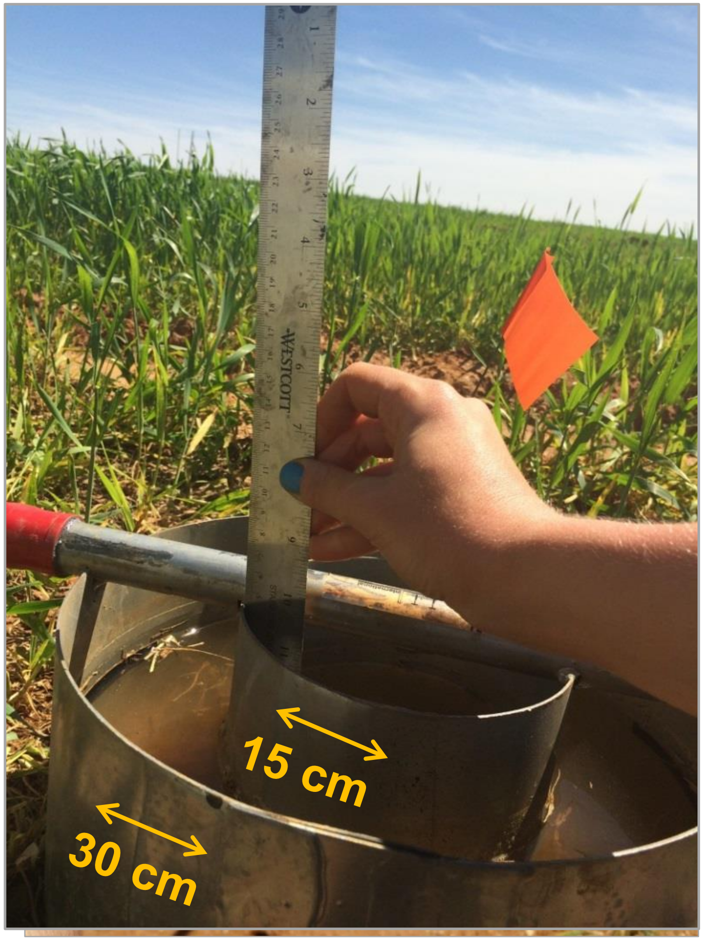
Pit Size Approx.
4.0’L x 4.0’ W x 3.5’D

Methods
Soil Physical Properties

- Two Interior Db Cores:
  - Volumetric water concentration
  - Total porosity
  - Particle density
  - Field capacity
  - Permanent wilting coefficient

Methods
Soil Physical Properties

- Soil strength
  - Hand-held electronic cone penetrometer
- Surface water concentration
  - One time measurement
  - 0-30 cm depth
  - Soil auger
- Saturated infiltration rates
  - Double-ring infiltrometer



Methods

Soil Lab Analyses

- **Texture**
  - Standard hydrometer method
- **pH**
  - Glass electrode pH meter
- **Elemental concentration**
  - C, N – CHN628 series
  - Ca, Mg, K, P – ICP analyzing unit
- **Particle density, pore space**
- **Water Relations**
  - Field capacity (-0.03 MPa)
  - Permanent wilting coefficient (-1.5 MPa)

Texture analysis

Methods
Tree Seedlings

- Sampling plot = 44 trees
  - Height (HT)
  - Ground-line diameter (GLD)
  - Seedling volume index
- First year survival and growth
  - October 2016
- First year biomass production
  - Above and belowground
  - Model: $Y = \beta_0 * (GLD^{\beta_1}) * (HT^{\beta_2})$

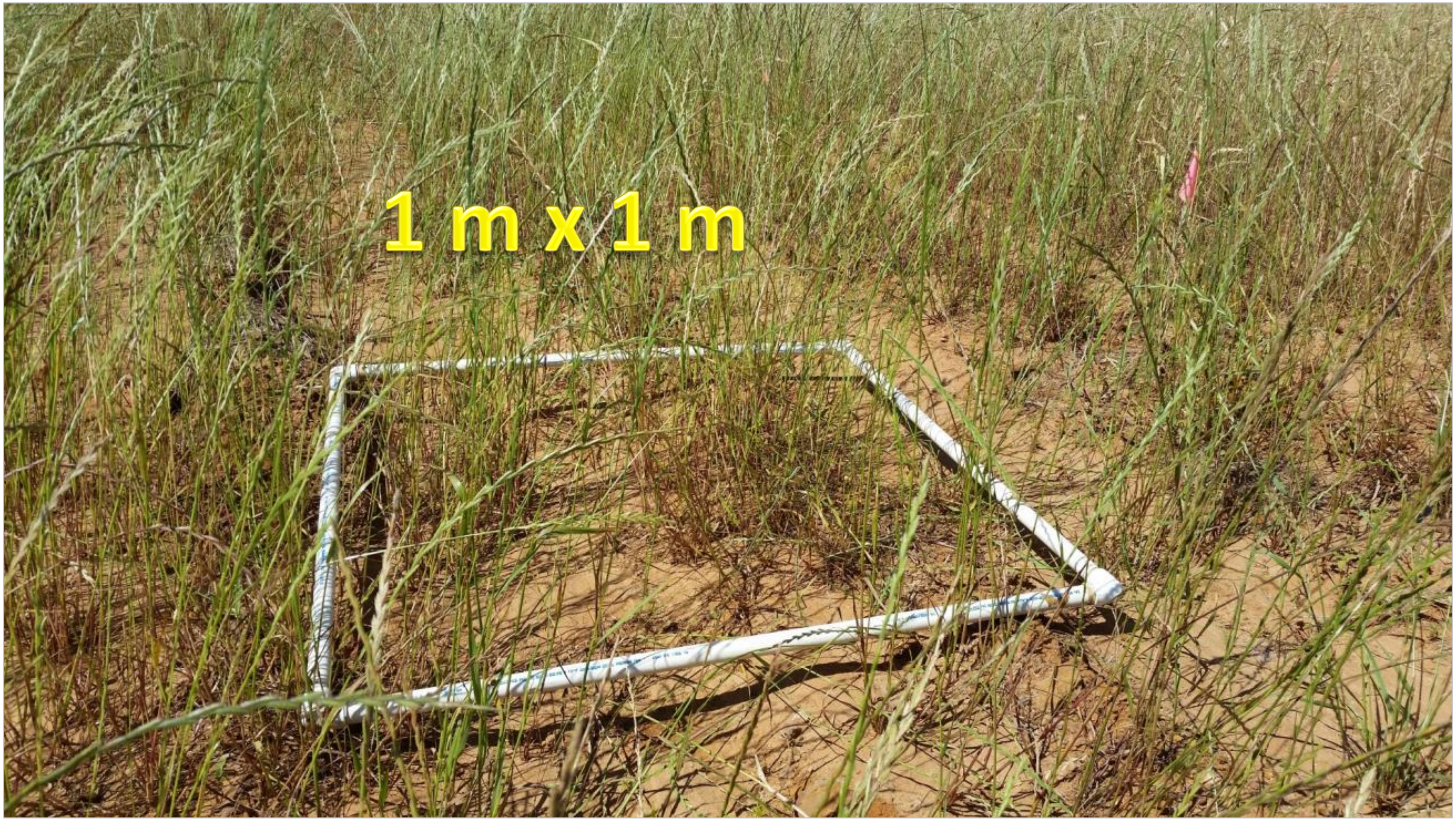
Methods

Tree Seedlings

Samples = 80 aboveground, 24 belowground

Methods

Herbaceous Aboveground Biomass



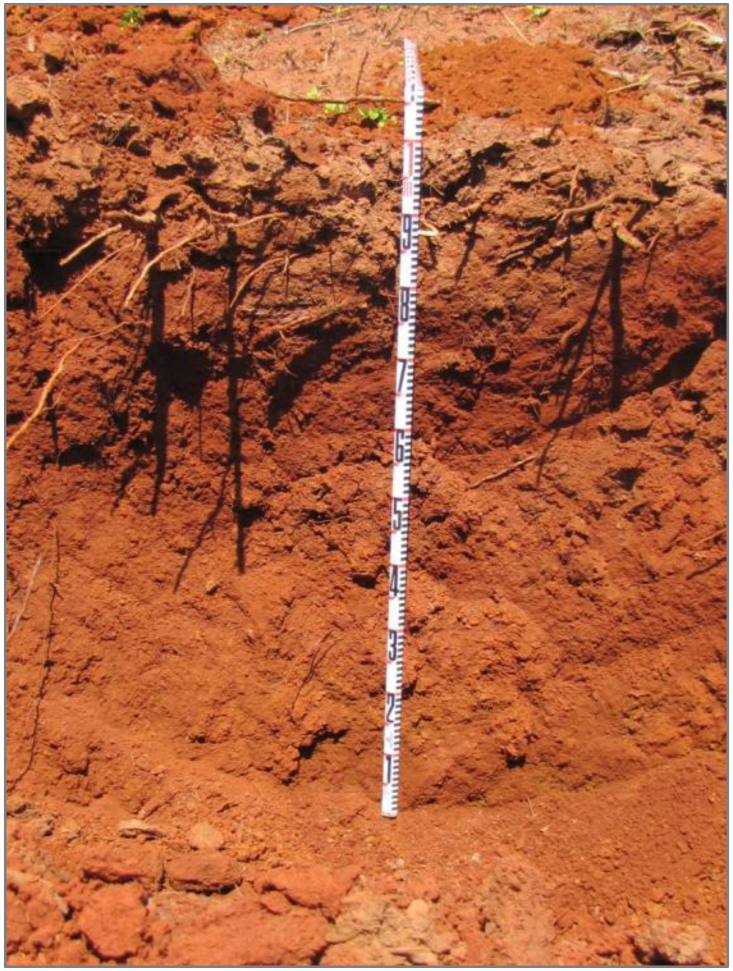
Statistical Procedure

- **Analysis of Variance**
  - SAS
  - PROC MIXED, PROC NLIN
  - Least square means test ($\alpha = 0.1$)

Results

Soil Response to Tillage

Reference Site



Redsprings Soil Series

Depth	% SAND	% SILT	% CLAY	Texture Class
0-30 cm	60	9	31	sandy clay loam
30-60 cm	44	11	45	clay
60-90 cm	46	10	44	sandy clay

Soil Depth (cm)	Bulk Density (Mg/m^3)
0-30	1.38
30-60	1.22
60-90	1.31

Baseline Information: Soil Chemical Properties

Site	Depth (cm)	pH	C	N	P	K	Ca	Mg	Na	CEC (cmol kg^{-1})	Base Sat (%)
			------ % ------		------------ mg kg^{-1} ------------						
Scraper Pan	0-30	8.0	0.95	0.11	1.6	63	3855	304	52	14.5	76
	30-60	8.0	0.88	0.11	0.9	62	4044	350	57	15.4	76
	60-90	8.0	1.01	0.12	0.6	58	4461	322	57	16.4	78

Soil Texture*

Depth	% SAND	% SILT	% CLAY	Texture Class
0-30 cm	60a	12a	28a	sandy clay loam
30-60 cm	56ab	11a	33b	sandy clay loam
60-90 cm	53b	14a	33b	sandy clay loam

$p < 0.10$

*Averaged across tillage treatments

No Tillage

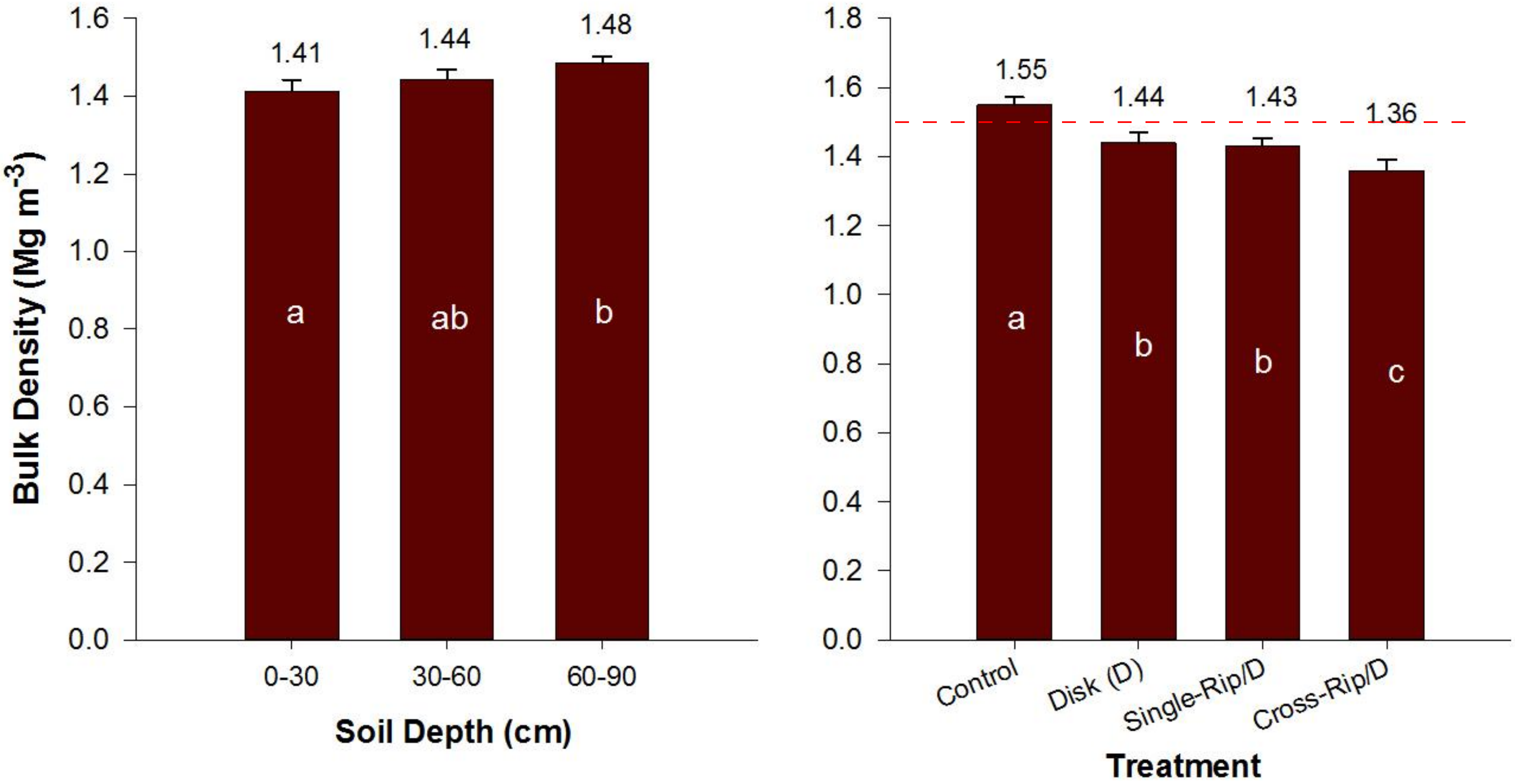
Single-Ripping/D

Disking (D)

Cross-Ripping/D

Bulk Density

(Daddow and Warrington, 1987)



p = 0.0833

p < 0.0001

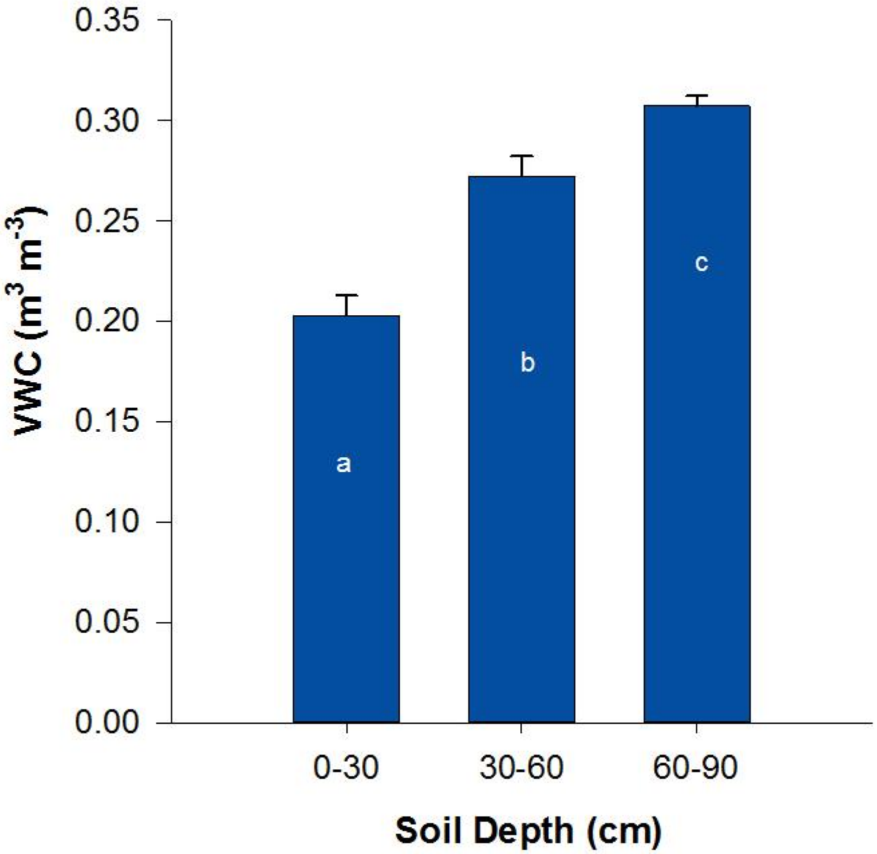
Total Porosity (%)			
Control	**Disk (D)**	**Single-Rip/D**	**Cross-Rip/D**
43_a	45_{ab}	46_b	49_c

p = 0.0031

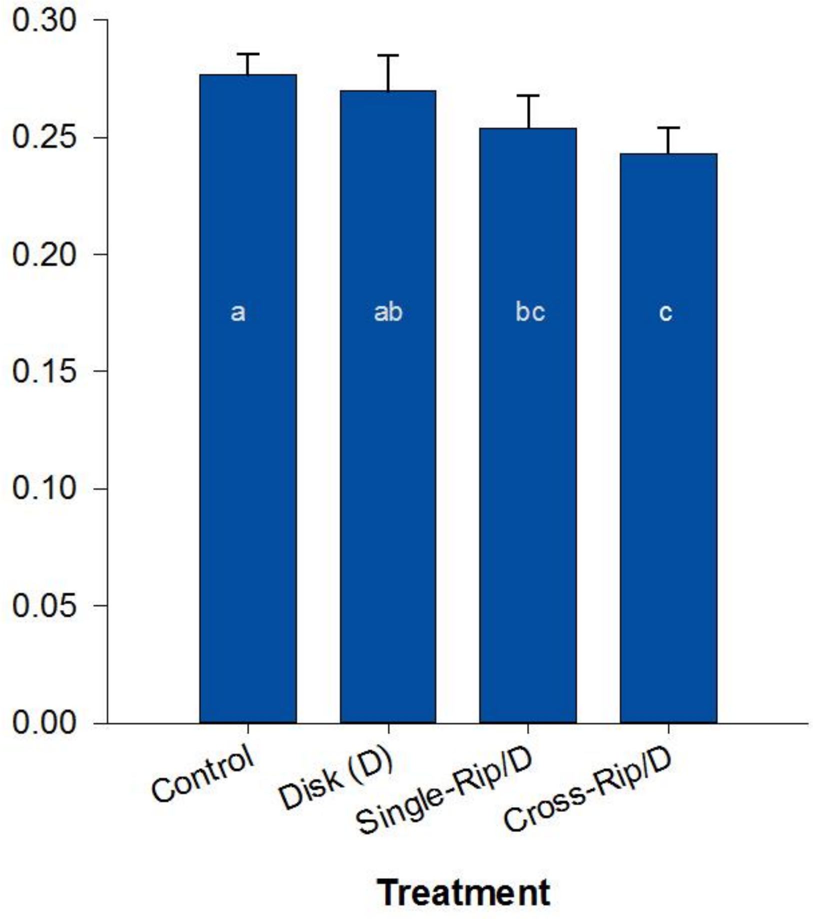
Saturated Hydraulic Conductivity (mm hr^{-1})			
0.0049_a	0.0064_a	0.0059_a	0.0065_a

p = 0.5569

Volumetric Water Concentration

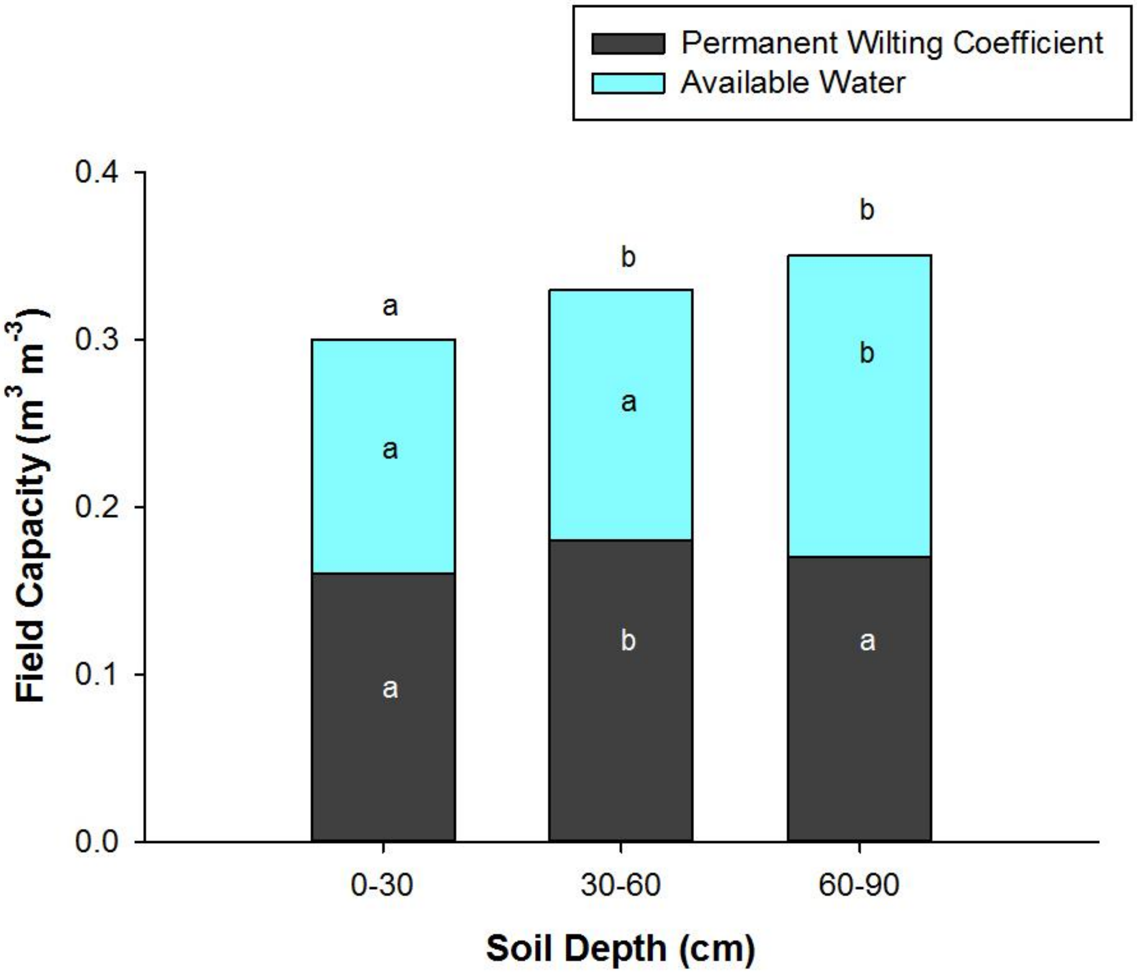


$p < 0.0001$



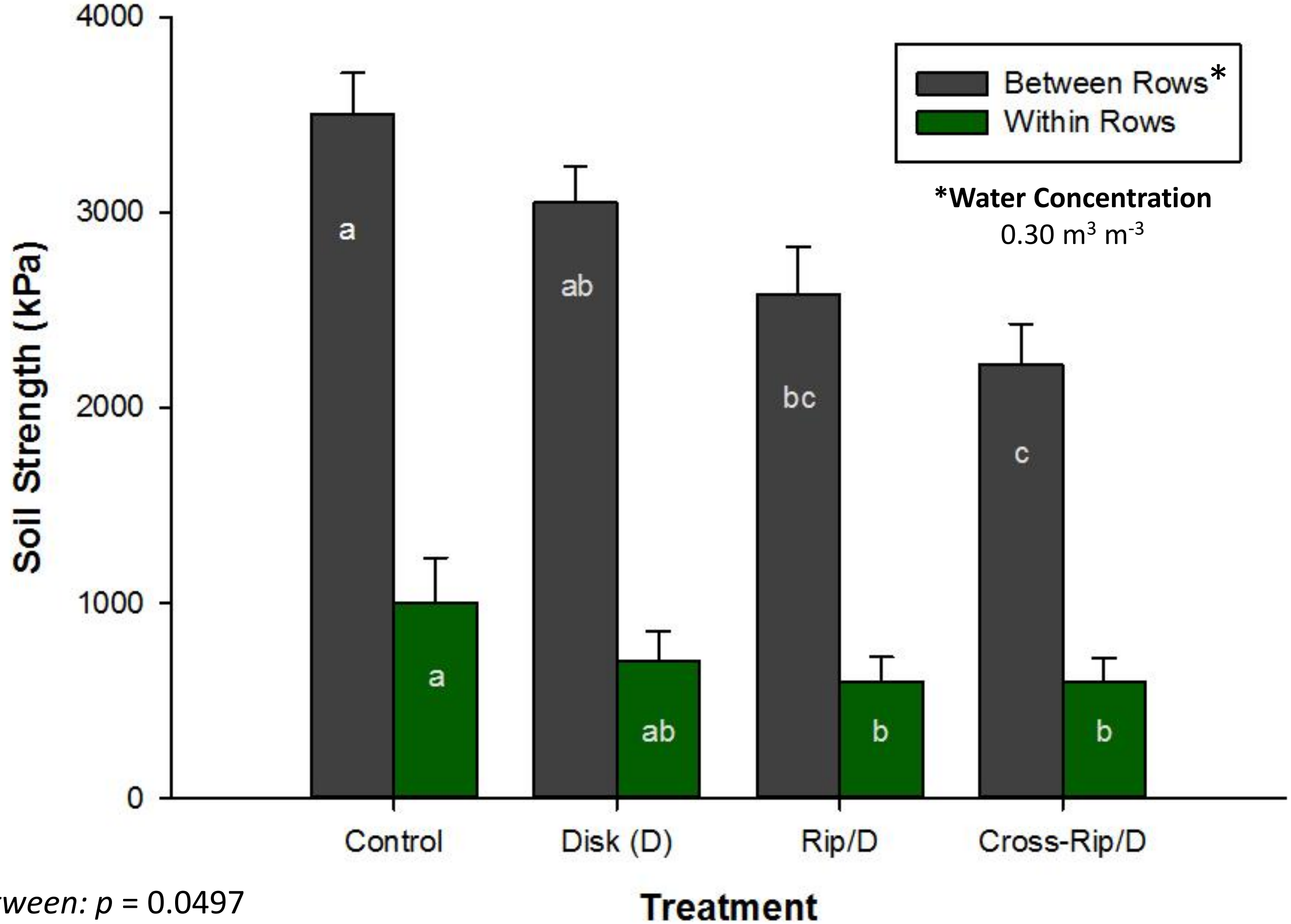
$p = 0.0789$

Soil Water Relations



$p < 0.10$

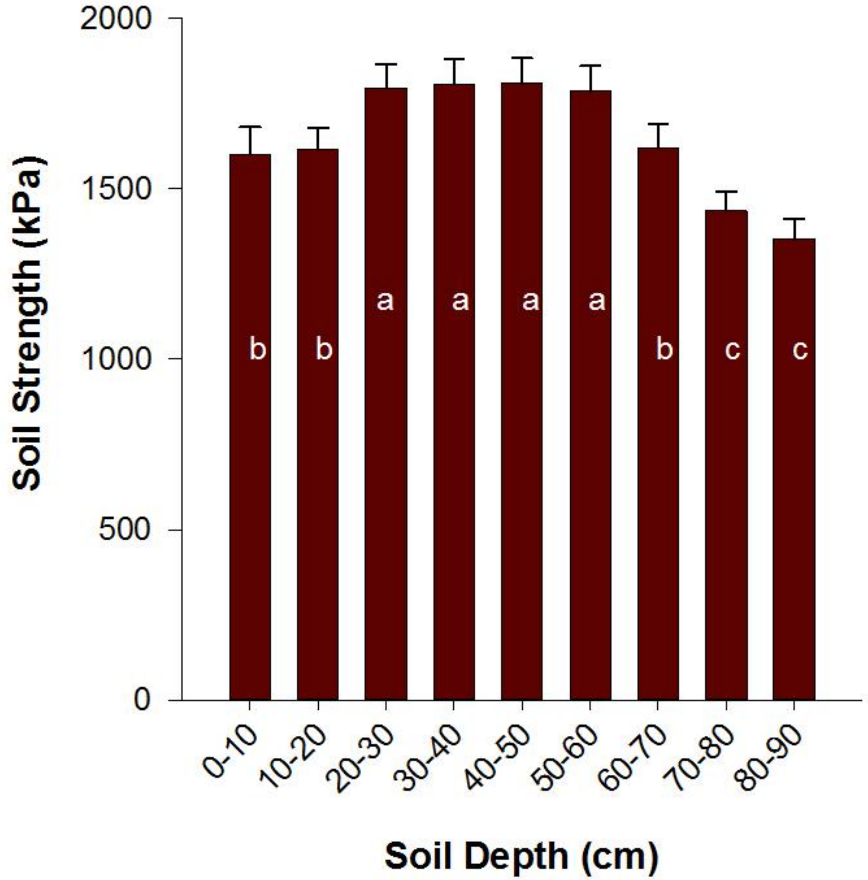
Soil Strength (Surface)



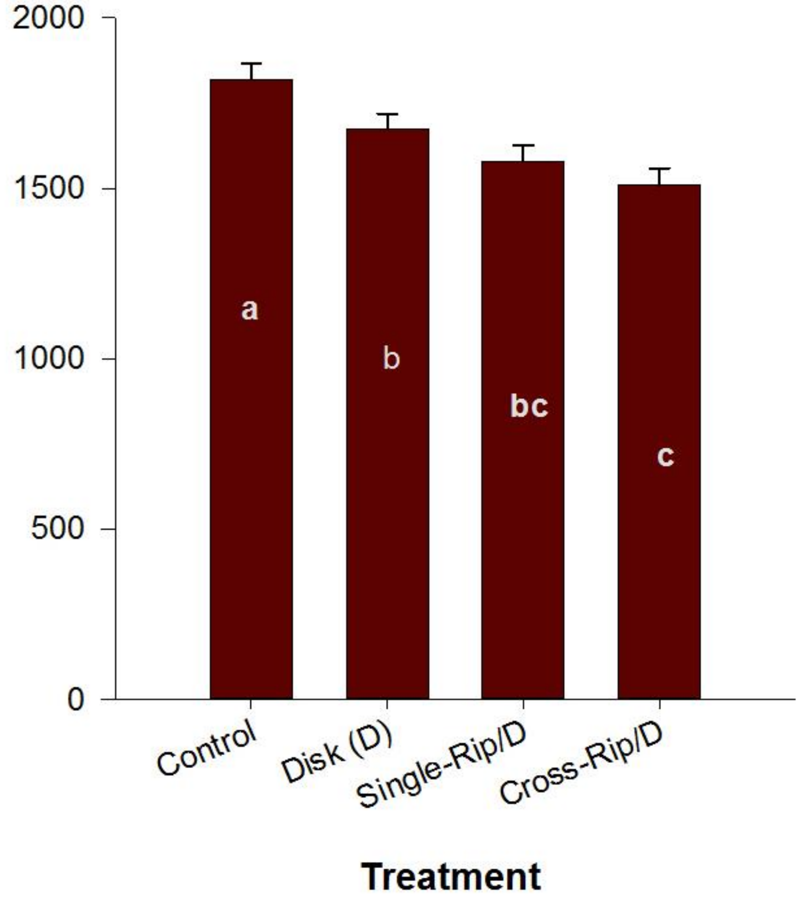
***Water Concentration**
0.30 $m^3 m^{-3}$

Between: p = 0.0497
Within: p = 0.0840

Soil Strength (Pits)



$p < 0.0001$



$p < 0.0001$

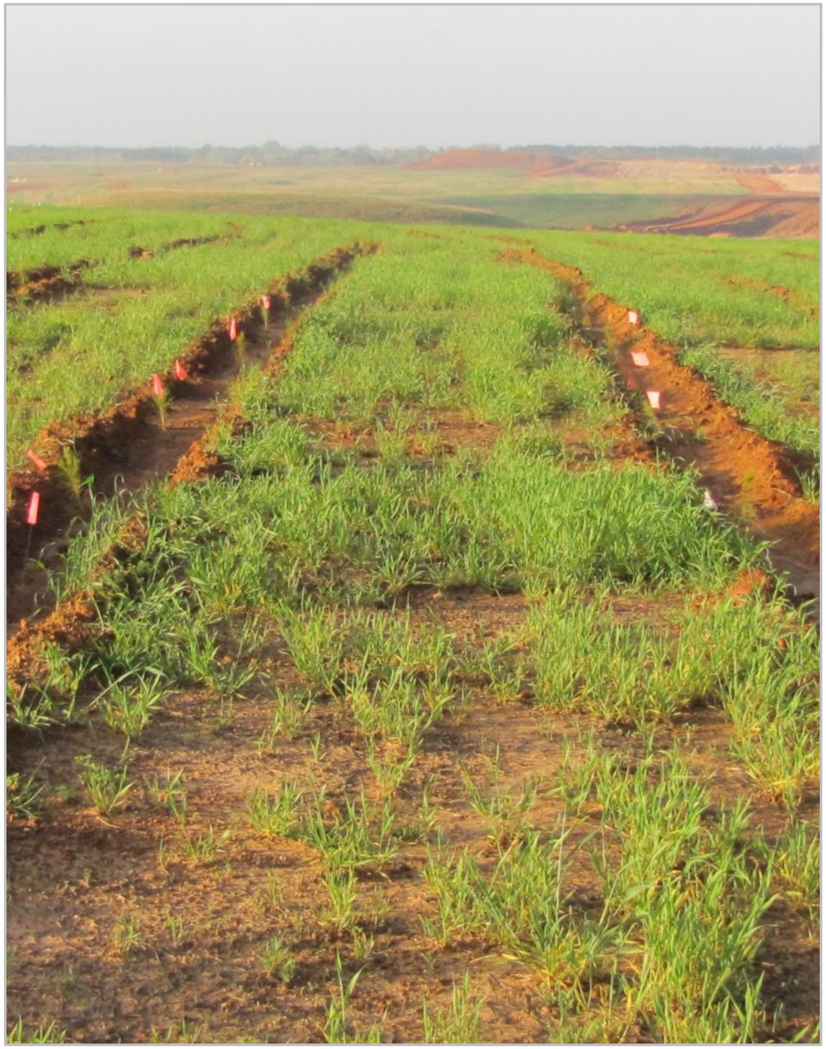
Results

Vegetative Response to Tillage

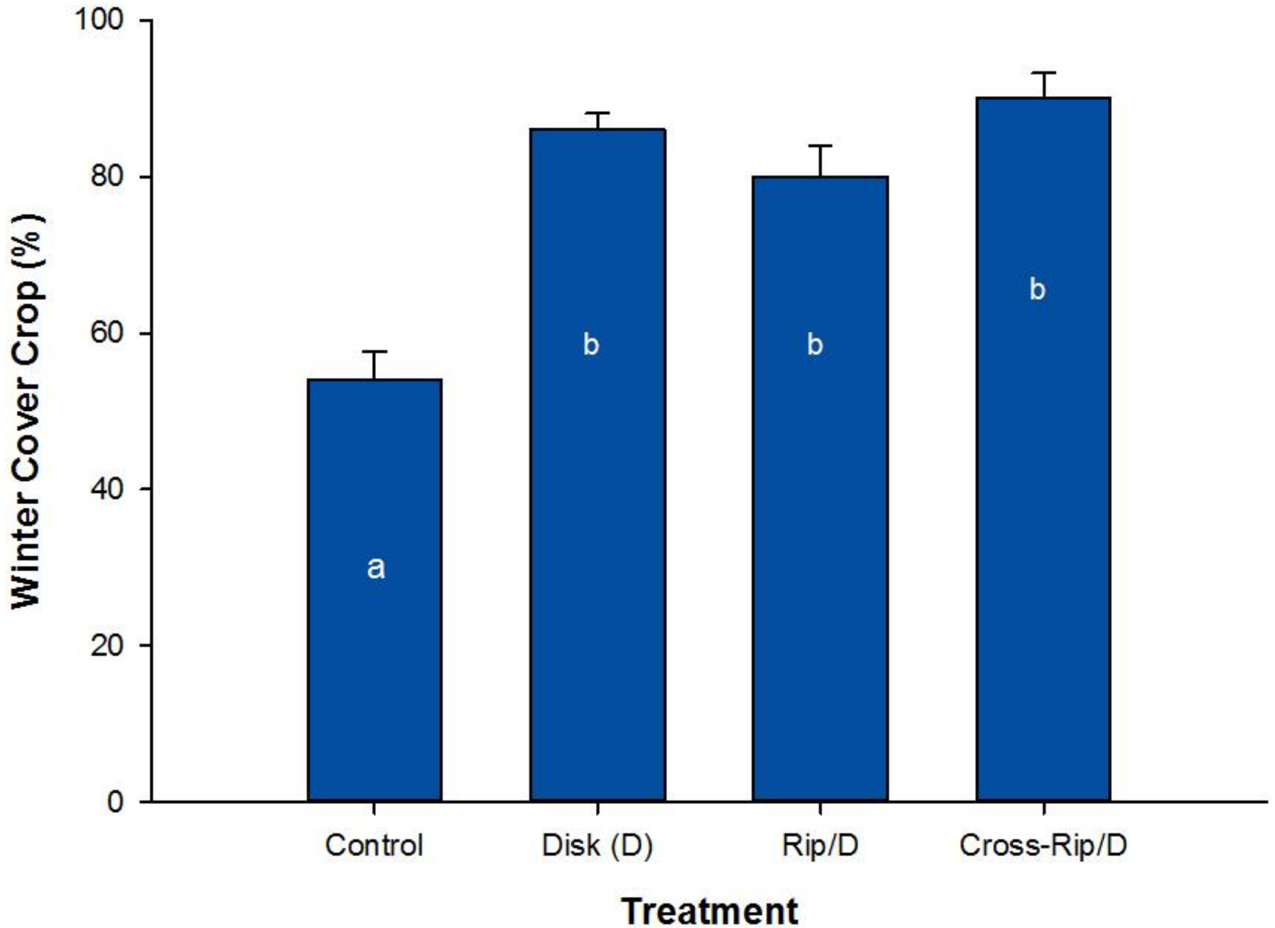

Cross-ripped + disked
Control

Cross-ripped

Control

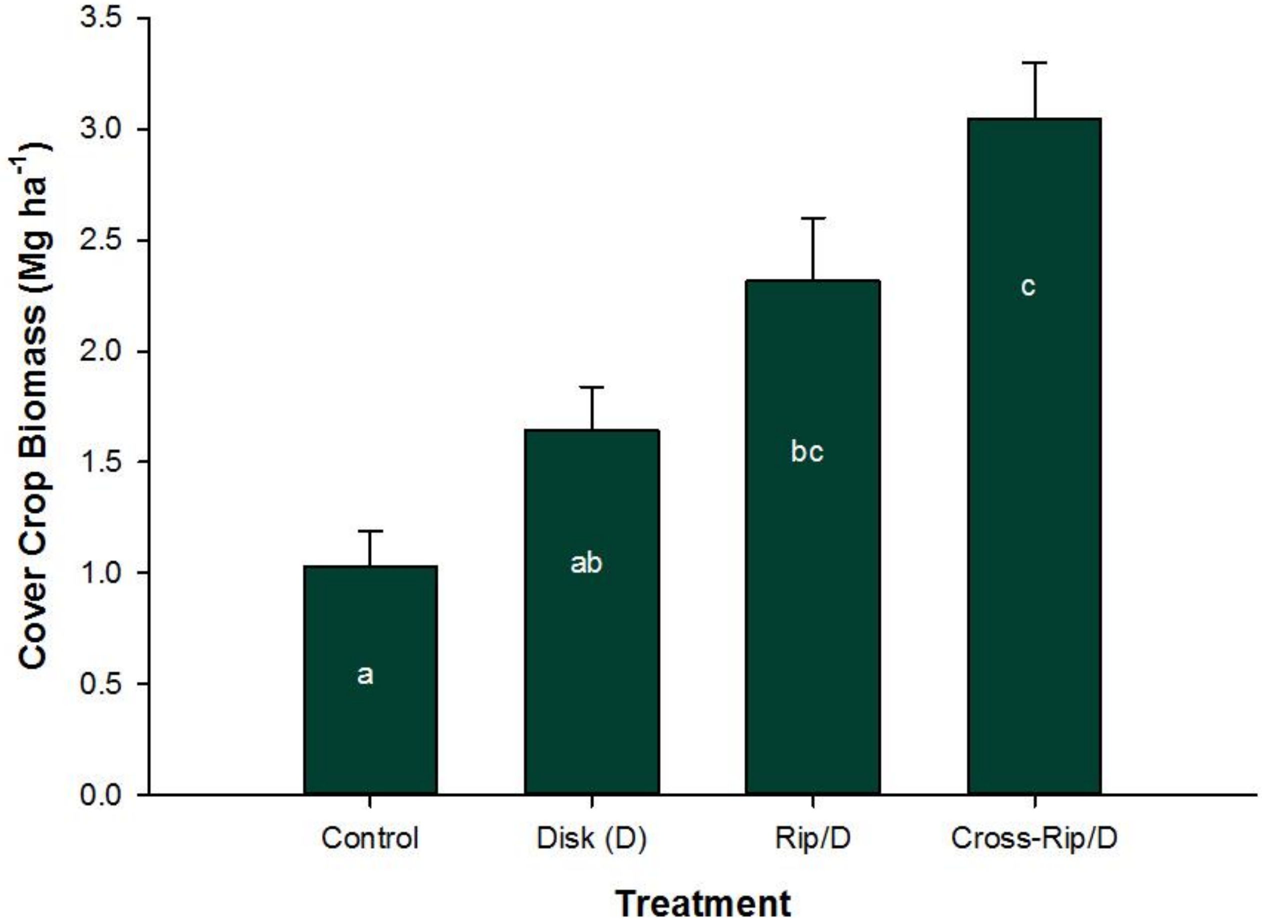


Percent Cover (wheat + clover)



$p = 0.0003$

Aboveground Herbaceous Biomass



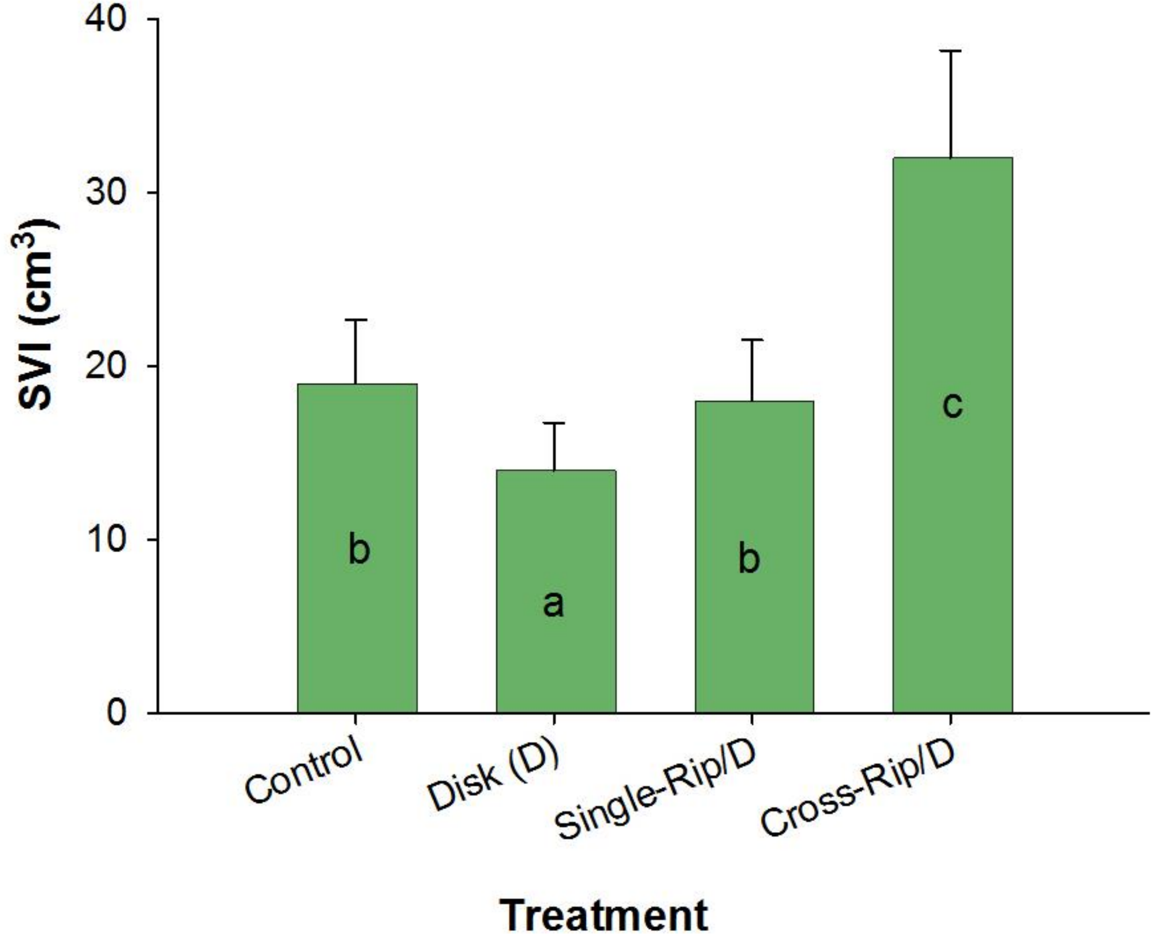
$p = 0.0102$

First Year Survival

Treatment	Survival (%)
Control	85**a**
Disk (D)	91**b**
Single-Rip/D	95**bc**
Cross-Rip/D	97**c**

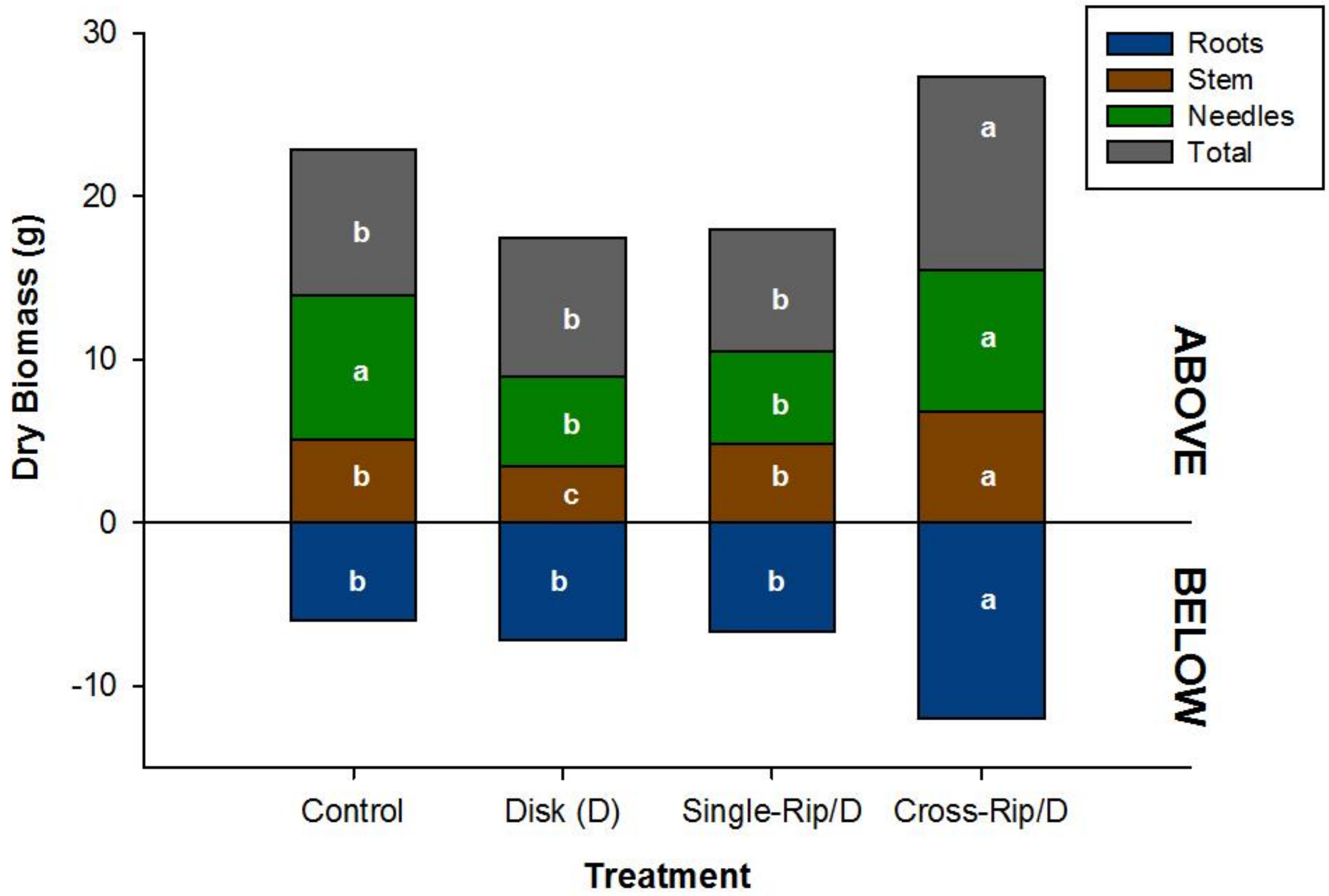
$p < 0.0001$

Growth: Seedling Volume Index



p < 0.0001

Tree Seedling Biomass



$p < 0.10$

Conclusions

- Soil physical properties and vegetative growth improve with increasing levels of tillage
- Cross-ripping + disking may improve long-term tree and site productivity

Acknowledgements

- **Project Sponsors**
  - Luminant Environmental Research Program and Steering Committee
  - McIntire-Stennis Cooperative Forestry Research Program
  - Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University
- **Research Committee**
  - H. Williams, J. Stovall, K. Farrish, L. Young
- **Field/Lab Assistants**
- **American Society of Mining and Reclamation**

Literature Cited

Barth, A.K. and L.R. Hossner. 2000. The relationship between compaction and saturated hydraulic conductivity of post-mine soils in East Texas. *In* Proceedings of National Meeting of the Am. Soc. of Min. Reclam. Tampa, FL. p. 171.

Burger, J.A., and D.M. Evans. 2010. Ripping compacted mine soils improved tree growth 18 years after planting. *In* Proceedings of National Meeting of the Am. Soc. of Min. Reclam. Pittsburgh, PA. p. 15.

Daddow, R.L. and G.E. Warrington. 1983. Growth-Limiting Soil Bulk Densities as Influenced by Soil Texture. Watershed Systems Development Group. USDA Forest Service. p. 17.

Powers, R.F., Alves, T.M., and T.H. Spear. 1999. Soil compaction: can it be mitigated? Reporting a work in progress. Redding, CA: Forest Vegetation Management Conference. p. 47-56.

Priest, J., J. Stovall, D. Coble, B. Oswald, and H. Williams. 2015. Loblolly pine growth patterns on reclaimed mineland: Allometry, biomass, and volume. Forests. 6: 1-35.

Yao, L. and L.P. Wilding. 1994. Micromorphological study of compacted mine soil in east Texas. Developments in Soil Sci. 22: 707-718.

Questions?