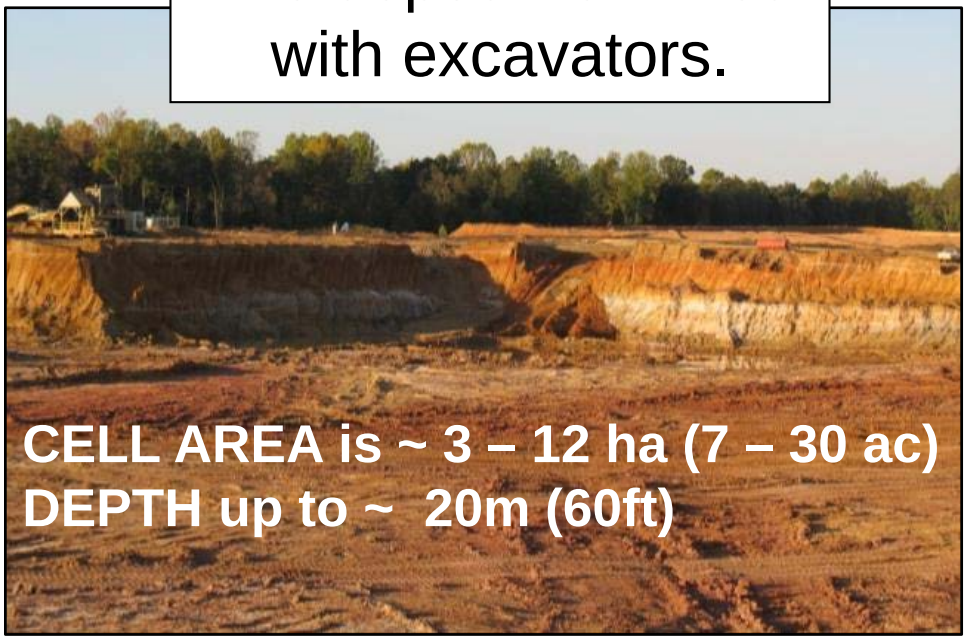
Initial Evaluation of Ripper and Tillage Methods on Reclaimed Heavy Mineral Mine Soils

Zenah Orndorff, Sara Klopf, Lee Daniels,
Ryan Stewart, Raymond Daniel

ILUKA

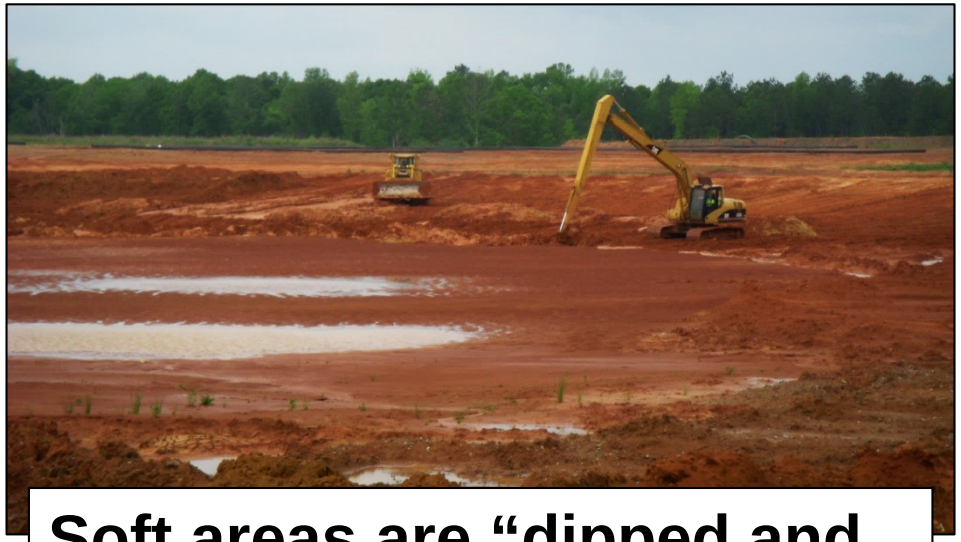
Up to 7,000 ha potentially could be disturbed, much of the area is prime farmland.
To date, the extent of disturbance has been much less, and currently there is no active mining.

The deposit is mined with excavators.



Mined material is loaded into mobile mine unit, slurried, and pumped to concentrator.

After processing, slimes and tails are pumped back to the reclamation pits in a water slurry (~35 to 50% solids).



Soft areas are “dipped and spread”, and dozers spread the slimes to aid in drying.

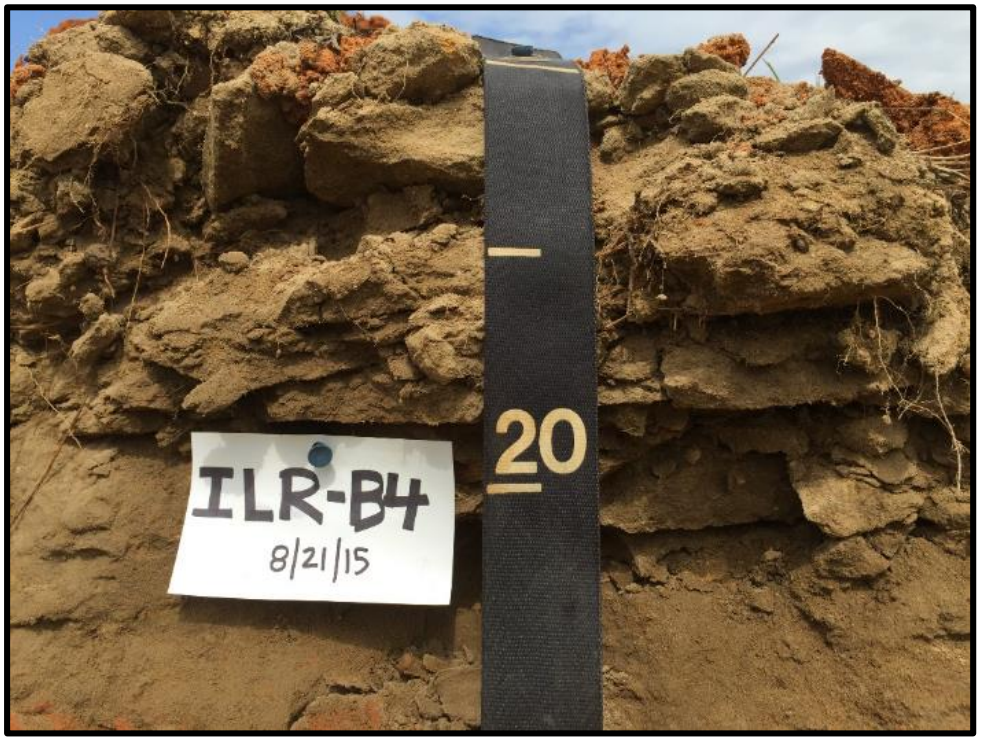
Subsoil:
- deep ripping
- lime and P (per soil test)

Land leveled with steel beam

Topsoil Return,
lime and P (per soil test)

The mining/reclamation process creates various revegetation challenges.

COMPACTION



- Limited rooting
- Limited rainfall infiltration and percolation
- Enhanced runoff

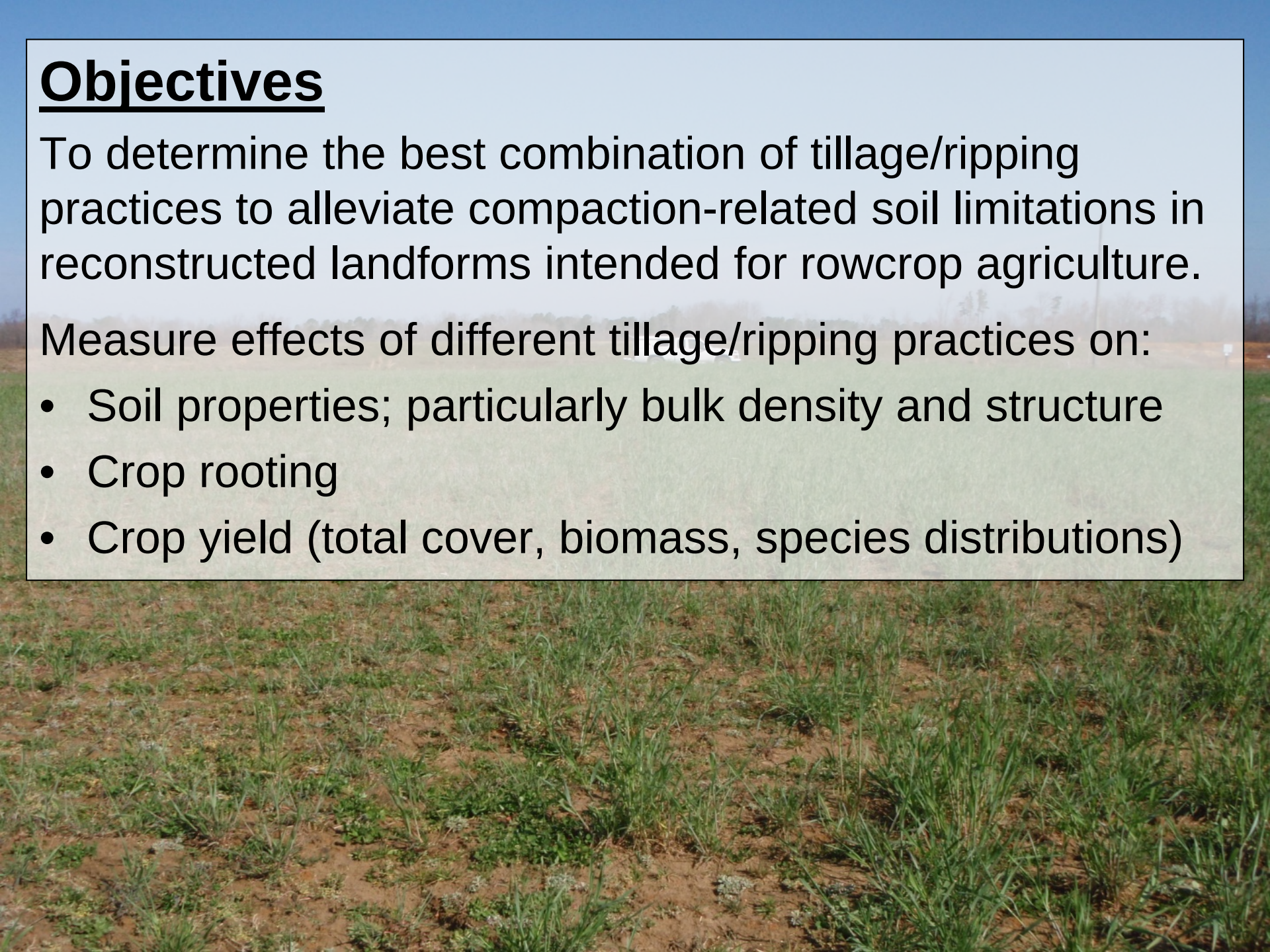
HIGH VARIABILITY

Objectives

To determine the best combination of tillage/ripping practices to alleviate compaction-related soil limitations in reconstructed landforms intended for rowcrop agriculture.

Measure effects of different tillage/ripping practices on:

- Soil properties; particularly bulk density and structure
- Crop rooting
- Crop yield (total cover, biomass, species distributions)



Methods

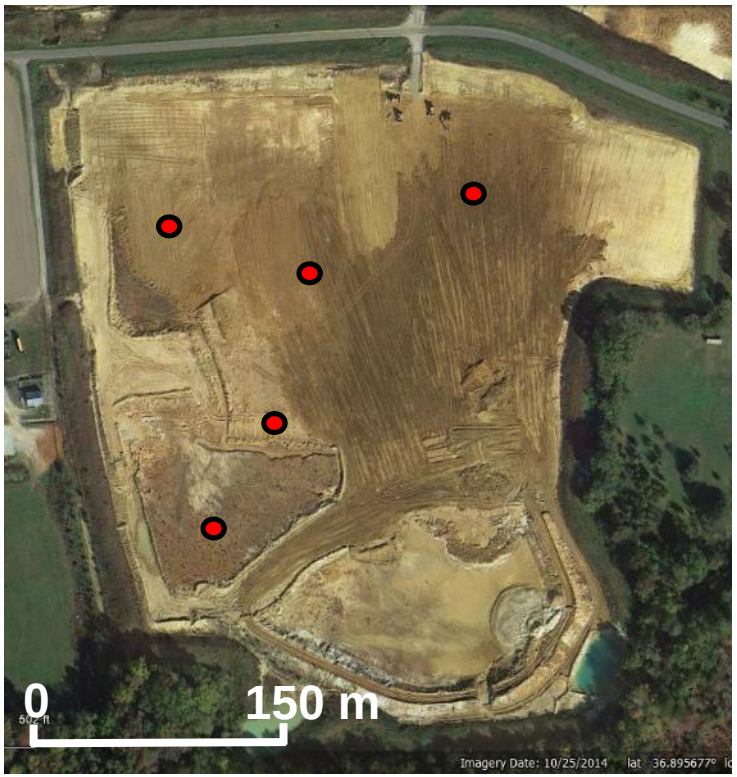
Soil profiles (Mar 2016; pre-installation)

Five soil profiles described to 1.5 m in proposed research area; mainly evaluated for density characteristics.

Bulk density cores collected at ~6 cm and 50 cm.

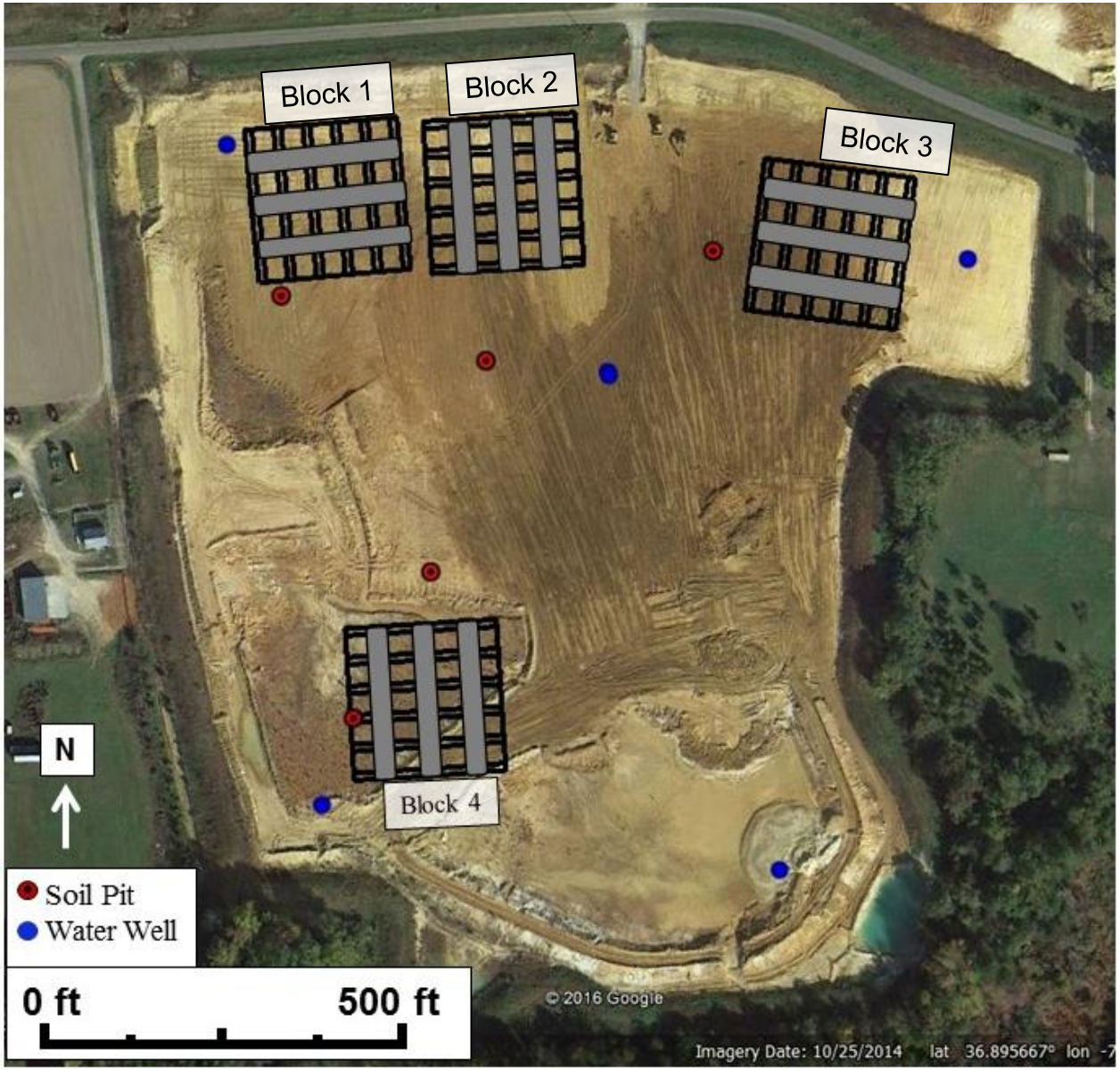
Bulk samples collected from ~0 – 6 cm and 35 – 65 cm for:

- pH (1:1 soil:water slurry)
- Particle Size Anlaysis (PSA)
- Nutrients (Mehlich-1)
- Total-C
- Total-N



Methods

Plot Installation (Aug 2016)



Methods

Plot Installation (Aug 2016)

MAIN TREATMENTS

1. Control; no added tillage

2. Dozer deep-rip - 1 pass ~ 4 ft (1.2 m) shank centers

3. Dozer deep-rip - 2 passes, 50% offset to reduce shank centers to 2 ft (0.6 m)

4. Chisel-plow topsoil to 1 to 2” (0.05 m) below subsoil contact

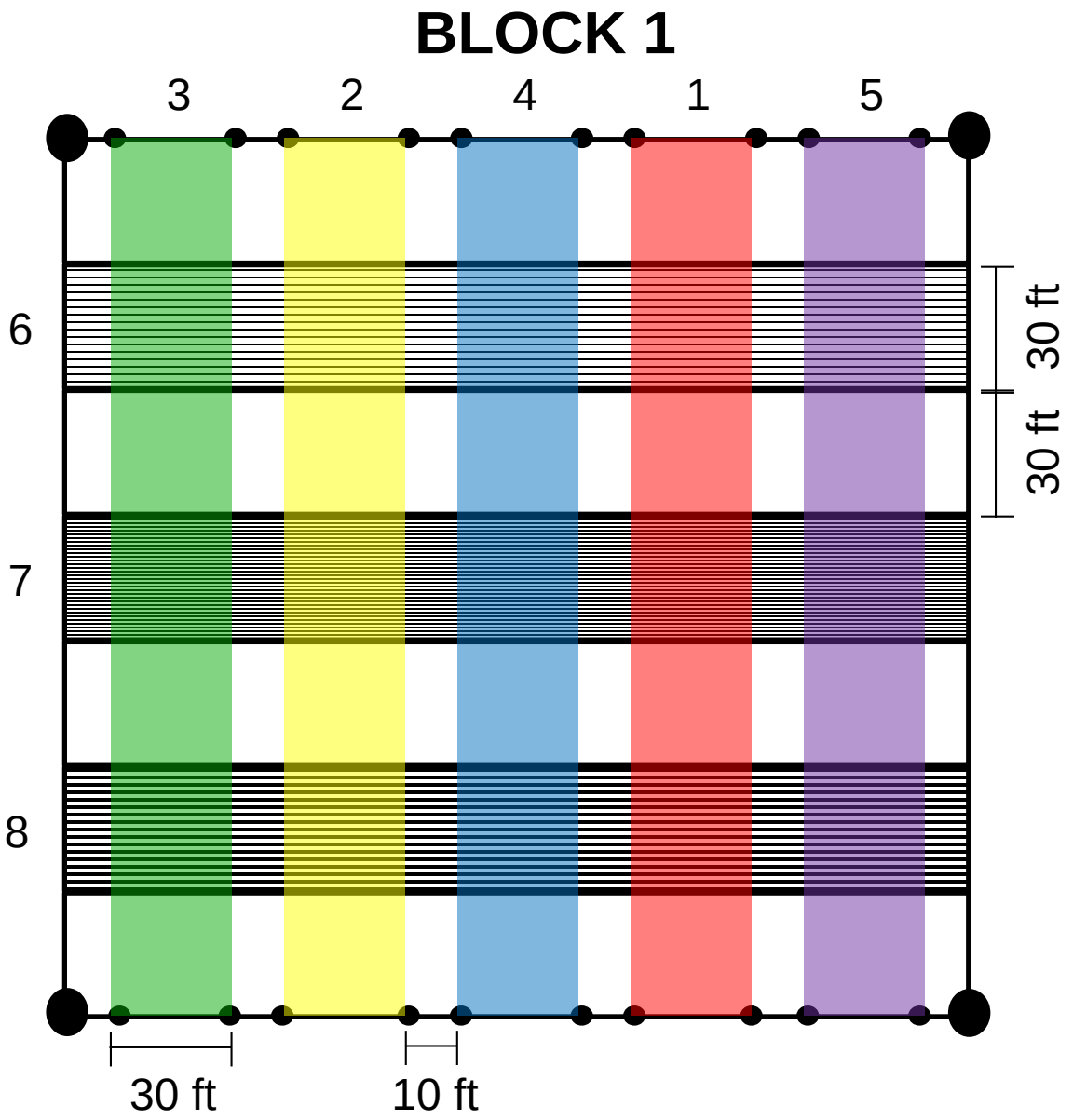
5. No-till ripper

CROSS-RIPPING

6. Dozer (1 pass)

7. Chisel-plow

8. No-till ripper

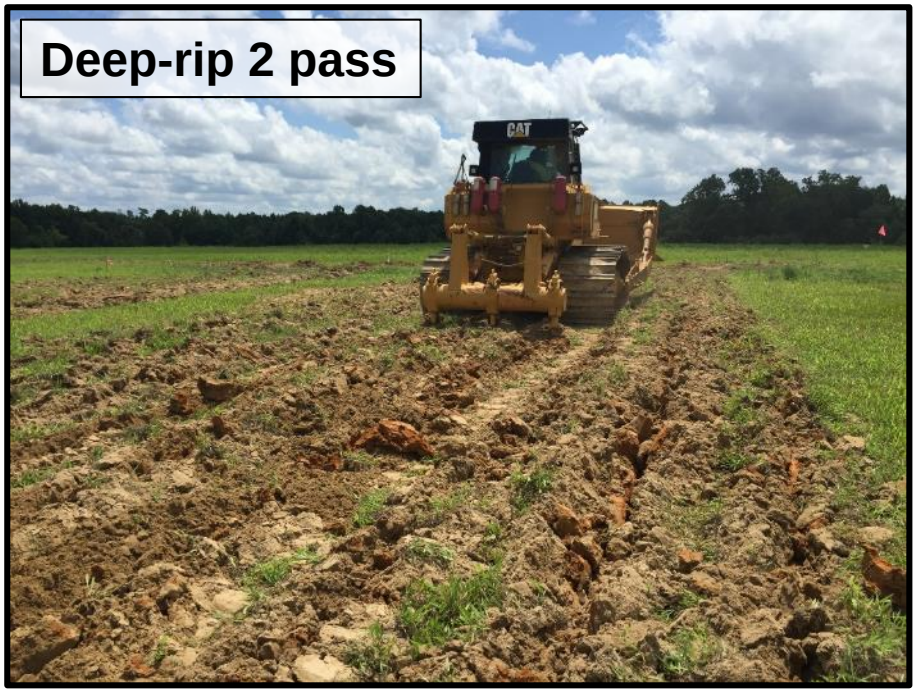



Deep-ripper
CAT
CAT


No-till ripper

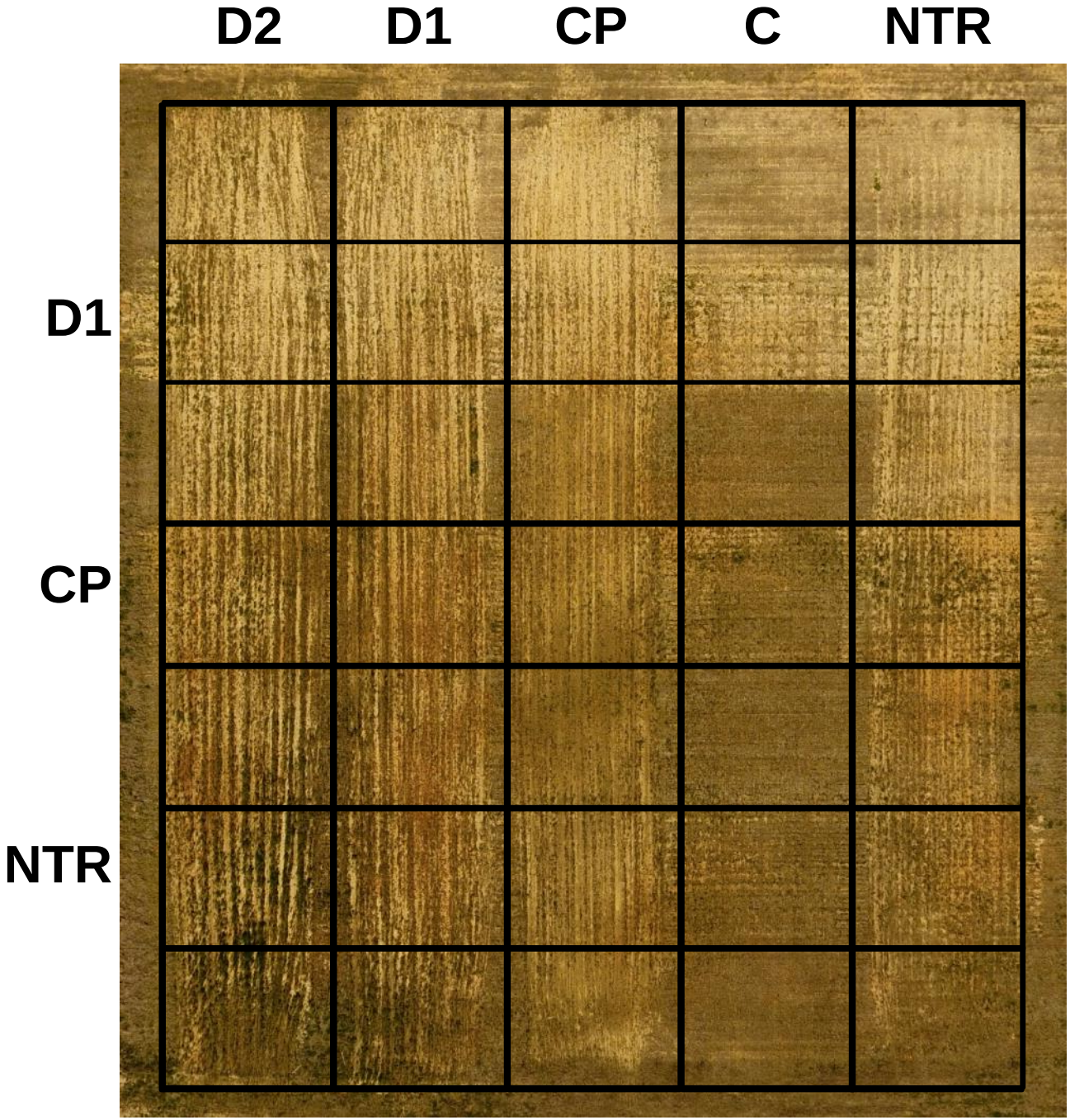

Chisel Plow


Deep-rip 1 pass


Deep-rip 2 pass
CAT


Chisel plow


No-till ripper


D2
D1
CP
C
NTR
D1
CP
NTR

Methods

Plot Installation (Aug 2016)

During plot installation:
Soil samples collected at 0 – 15 cm and 38 – 53 cm from each main treatment (4 samples/treatment/block), immediately sealed in plastic bags, and analyzed for:

- Moisture content
- pH (1:1 soil:water slurry)
- Particle size analysis
- Nutrients (Mehlich-1)

After plot installation:
one overall composite surface sample was collected from each block to determine fertilizer and lime needs.

Methods

Plot Installation (Aug – Sept, 2016):

Date	Applications, Additional Tillage, and Seeding
08/24/2016	All blocks sprayed with a 2% mixture of Roundup and 2-4-D (2 parts Roundup to 1 part 2-4-D)
08/31/2016	Block 4 spread with 1 ton/ac (2.2 Mg/ha) lime
09/06/2016	Tillage plots (chisel plow, single rip, and double rip) received 2 passes with disc. No discing was completed on the no-till rip or control plots.
09/07/2016	Blocks 1 – 3 received 300 lbs/ac (336 kg/ha) of 15-30-15 fertilizer
09/07/2016	Block 4 received 550 lbs/ac (616 kg/ha) of 15-30-15 fertilizer
09/07/2016	All blocks: 30 lbs/ac (33.6 kg/ha) rye broadcast for nurse crop
09/08/2016	Cultivator run once over tillage plots (chisel plow, dozer single rip, and dozer double rip)
09/08/2016	All blocks seeded with final pasture mix: 20 lbs/ac (22.4 kg/ha) fescue 20 lbs/ac (22.4 kg/ha) orchardgrass 5 lbs/ac (5.6 kg/ha) alfalfa 8 lbs/ac (9.0 kg/ha) clover (med. red, ladino)

Methods

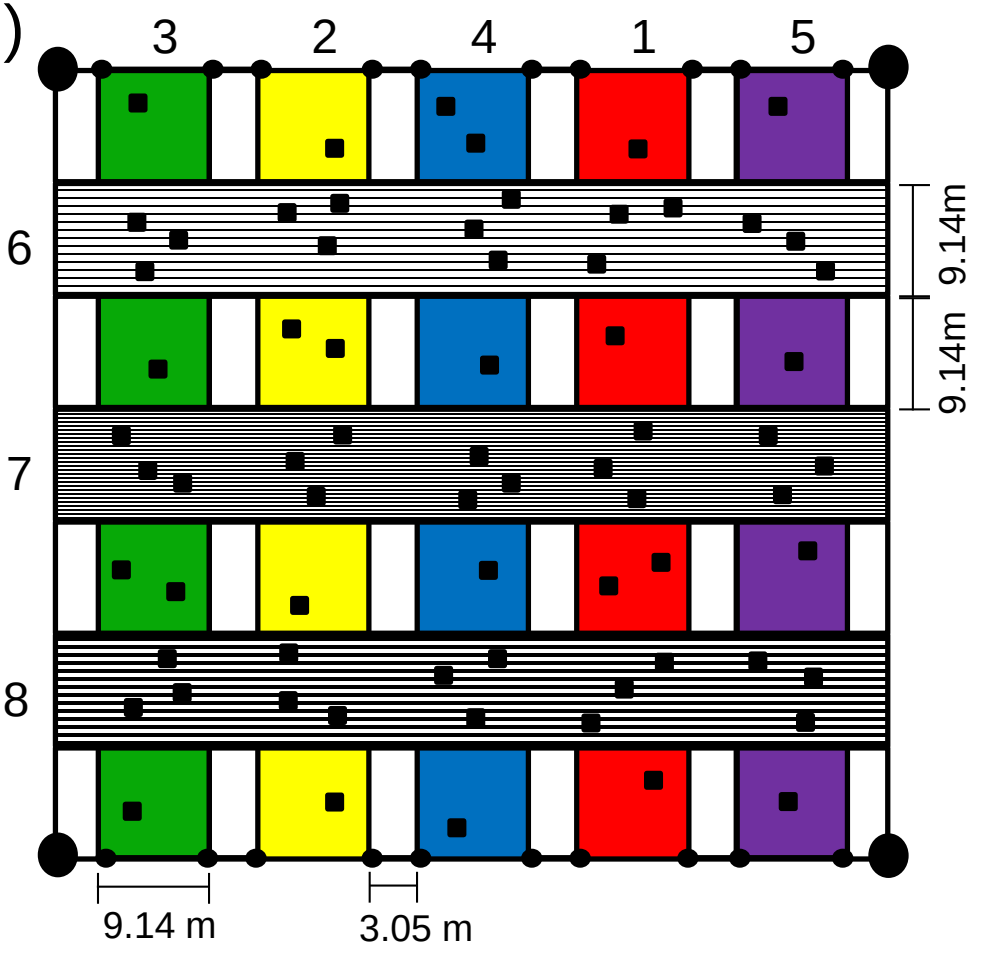
Vegetation assessment (Nov ‘16, Apr ‘17, Sept ‘17)

Main treatments: 5 1-m^2 quadrats assessed
(4 blocks = 20 total/main treatment)

Main treatment x cross-treatment: 3 1-m^2 quadrats
(4 blocks = 12 total/combination)

- Total % vegetative cover
- Dominant species
- Photos taken to visually document vegetation establishment

Sampling scheme illustrated here is as an example, it does not show actual sample points.



Methods

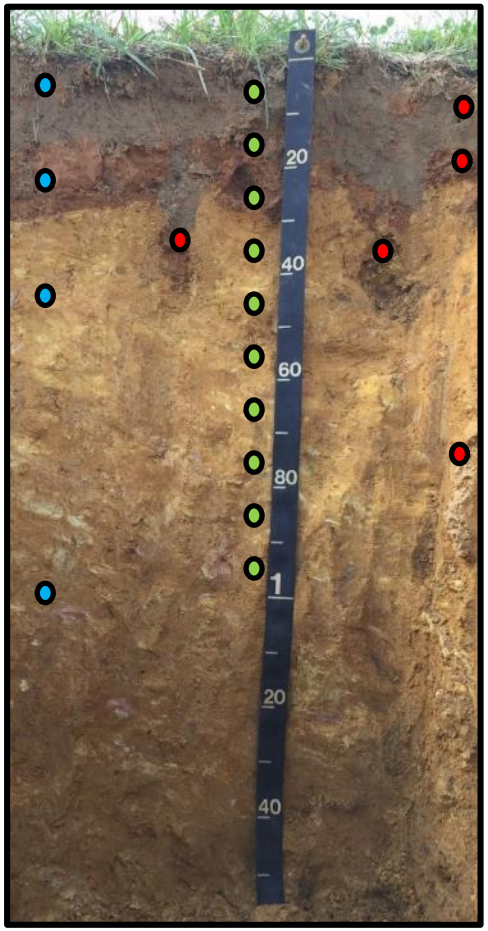
Soil profiles (Nov 2017)

Twenty soil profiles described to ~1.5 m

D2 (no crossrip)
C (no crossrip)
CP (no crossrip)
D2 x D1
D2 x CP

For each block, one soil pit was completed for each of these 5 selected treatments.

- Bulk samples collected from each horizon:
  - pH (1:1 soil:water)
  - Particle size analysis
  - Nutrients (Mehlich-1)
  - Total-C
  - Total-N
- Incremental samples collected every 10 cm (up to 100 cm)



- Bulk density cores collected in triplicate from:
  - Ap
  - directly below Ap
  - 75 cm
- Bulk density core (single) collected from every ripper trace.

Soil profiles (Mar 2016)

0 – 12 cm: LS, loose topsoil; platey and granular structure in upper portion grading to weak sbk-massive; roots (t); very friable (moist), friable-firm (dry); prominent pores in platey structure near surface.

12 – 28 cm: SCL-SC, moderately tight clayey material; massive; very few roots (t); firm (moist), very-extremely hard (dry).

28 – 90+cm: S, loose sandy tailings; single grain; no roots.

Pit filled with water at ~1m.

Soil profiles (Mar 2016)

0 – 32 cm: LS, loose topsoil (much thicker than other profiles); platey and granular structure in upper portion grading to weak sbk-massive; roots (t); very friable (moist), friable-firm (dry); prominent pores in platey structure near surface; very thin surface crusting.

32 – 60 cm: C, dense clay; massive; no roots; very firm (moist), extremely hard (dry).

60 – 100+ cm: SC-SCL, sandier and slightly less dense than above; massive; no roots.

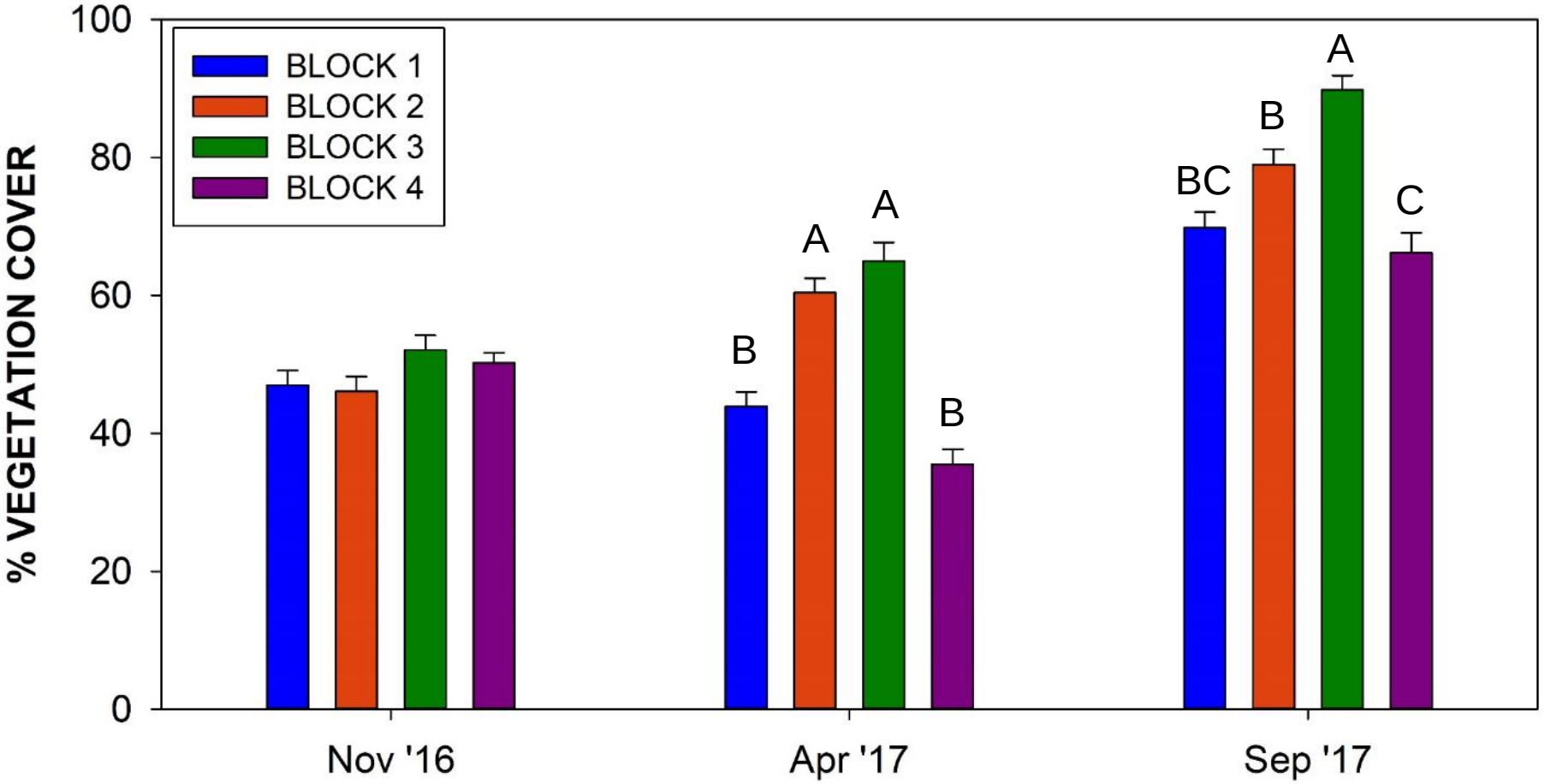
PRE-INSTALLATION SOILS DATA (from soil pits and plot installation)

	Surface Soil	Subsoil
Texture	loamy sand, sandy loam	sand to clayey
Moisture	3.5 – 11.9% (avg 6.5%)	2.3 – 29.2% (avg 10.5%)
pH	5.3 – 7.0 (avg 5.9)	4.4 – 7.0 (avg 5.3)
Roots	Common; grow throughout	Few to none; grow along cracks
Bulk density	1.52 – 1.65	1.53 – 1.62
Total-N	0.02 – 0.04%	0.01 – 0.02%
Total-C	0.12 – 0.39%	0.05 – 0.12%

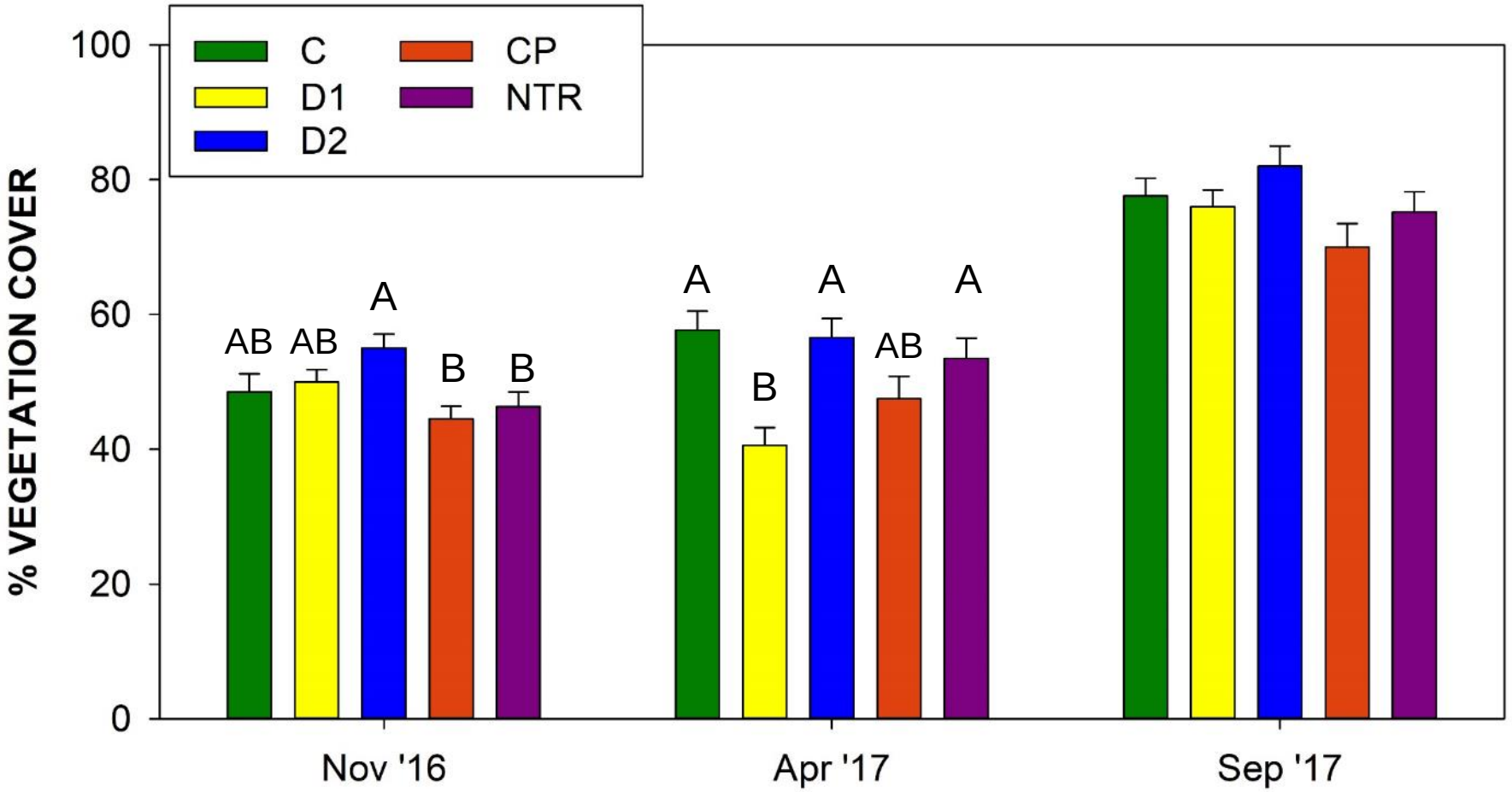
Mehlich 1 extractable nutrients from surface soils

Block	pH	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B
		---------- mg/kg ----------								
1	5.9	8	19	159	42	0.5	5.7	1.4	13.4	0.08
2	6.2	13	21	201	51	0.4	5.6	0.4	22.3	0.07
3	5.9	12	22	212	49	0.3	5.5	0.3	19.7	0.14
4	5.6	5	28	209	39	0.4	3.9	0.3	15.4	0.14

VEGETATION COVER BY BLOCK OVER THREE SAMPLING DATES

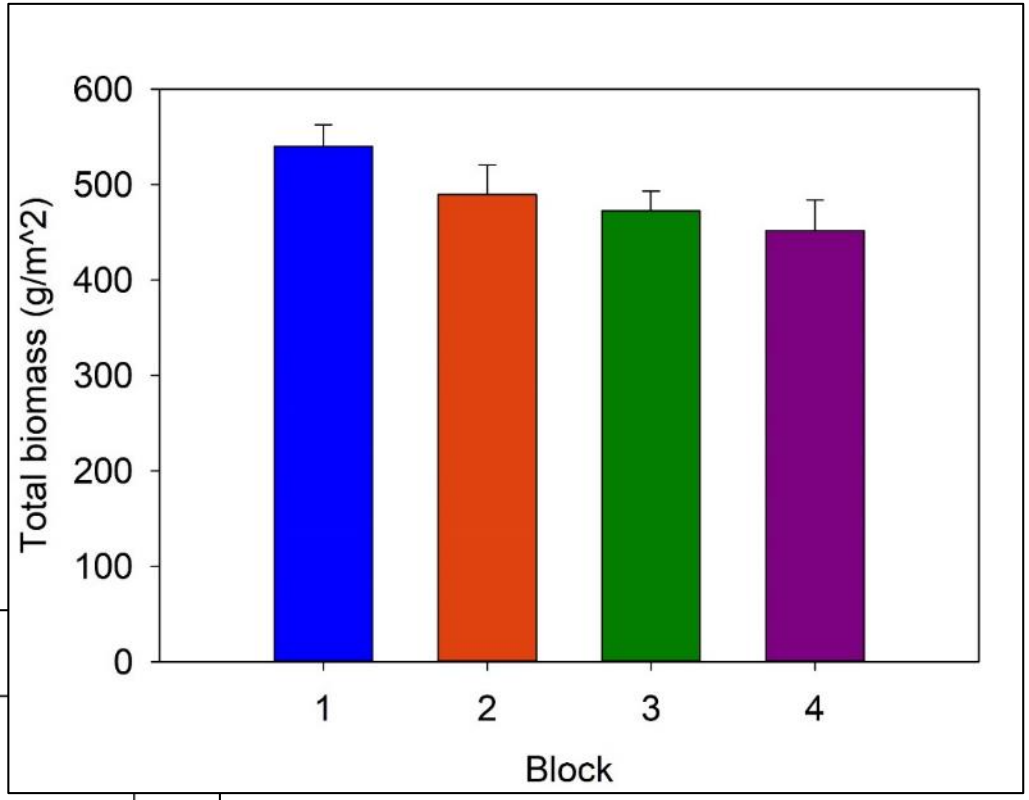


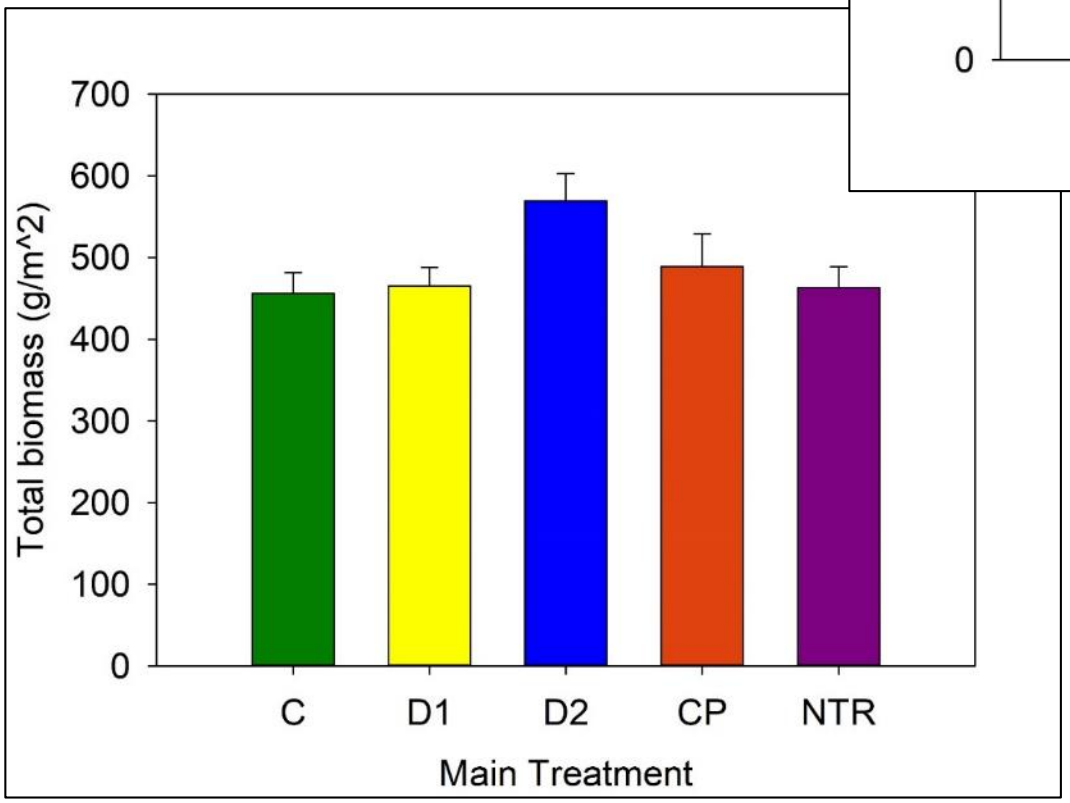
VEGETATION COVER BY MAIN TREATMENT OVER THREE SAMPLING DATES

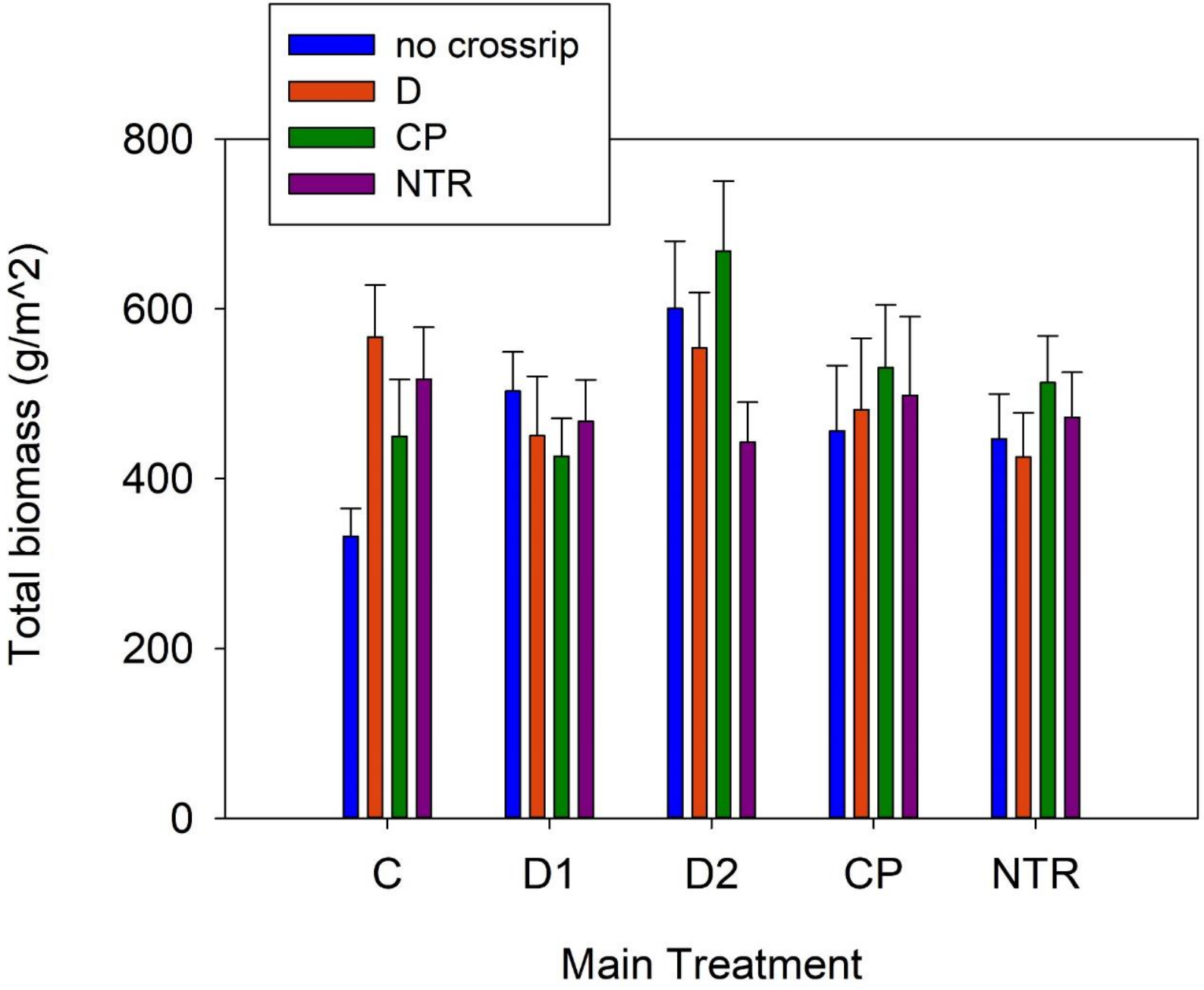


TOTAL BIOMASS

No significant differences by block or treatment



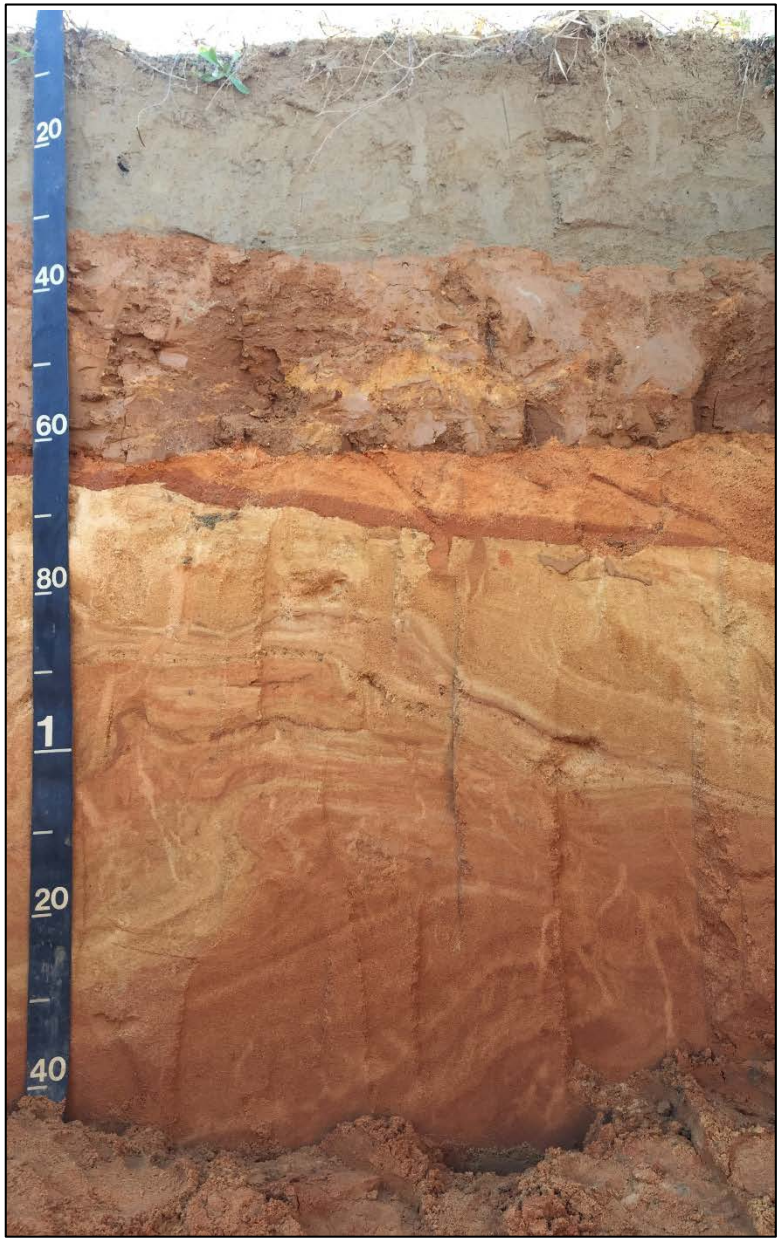


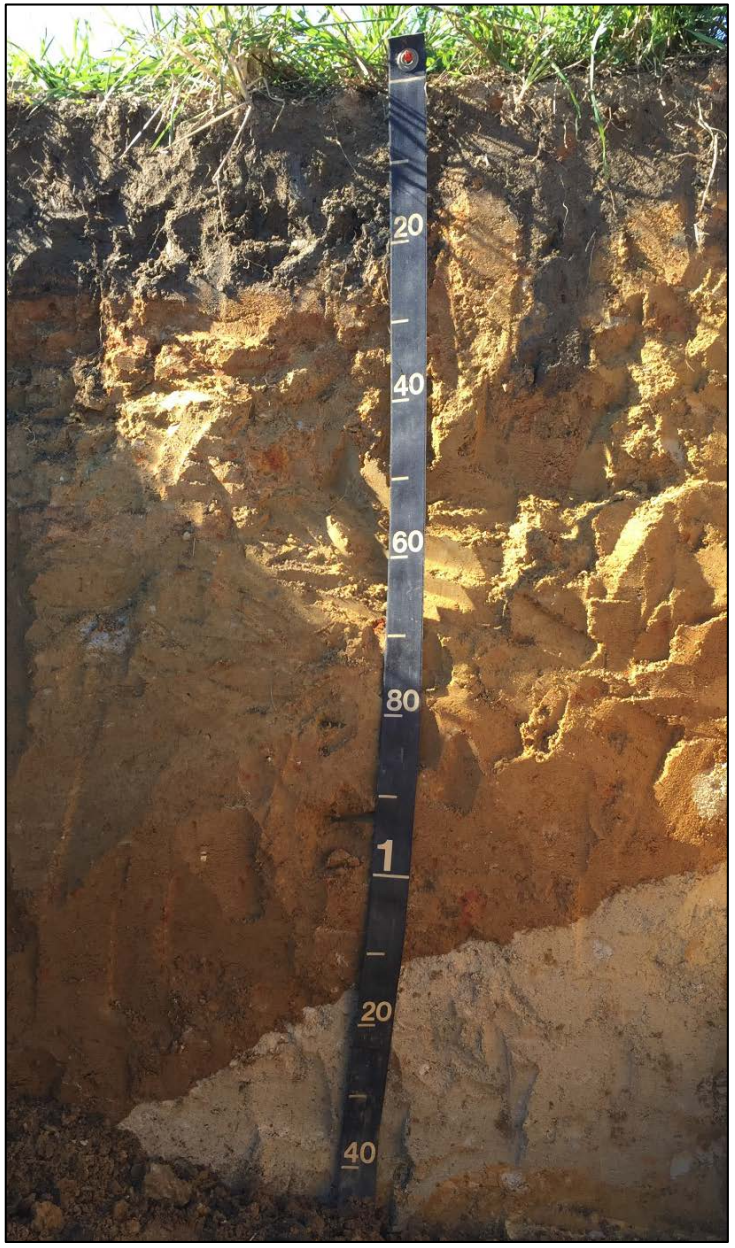

no crossrip
D
CP
NTR
800
600
400
200
0
Total biomass (g/m^2)
C
D1
D2
CP
NTR
Main Treatment


Dozer 1x
Dozer 2x


Dozer 1x
Dozer 1x
crossrip

These mine soils are highly variable

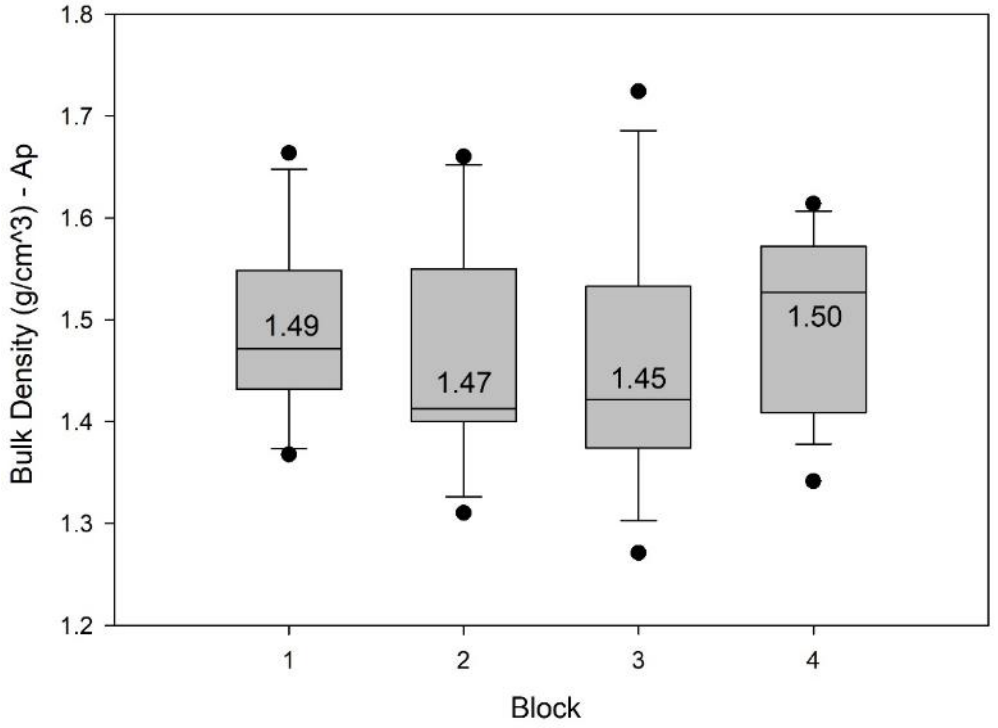


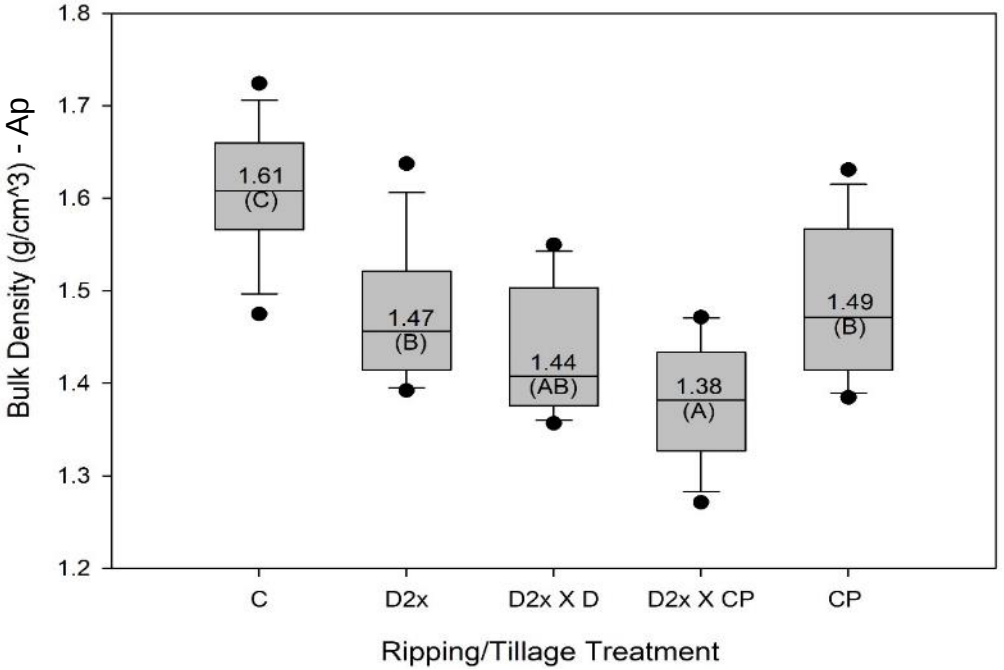


SOIL
BULK DENSITY

SURFACE Db
15 months after plot installation

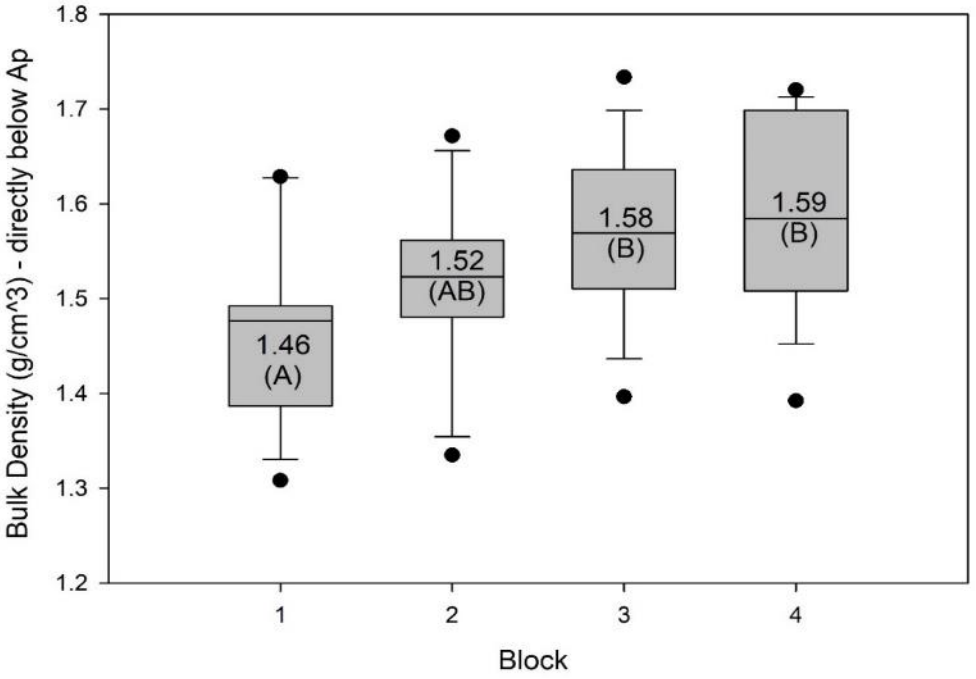
(Note: Surface Db pre-installation 1.52 – 1.65 g/cm^3)

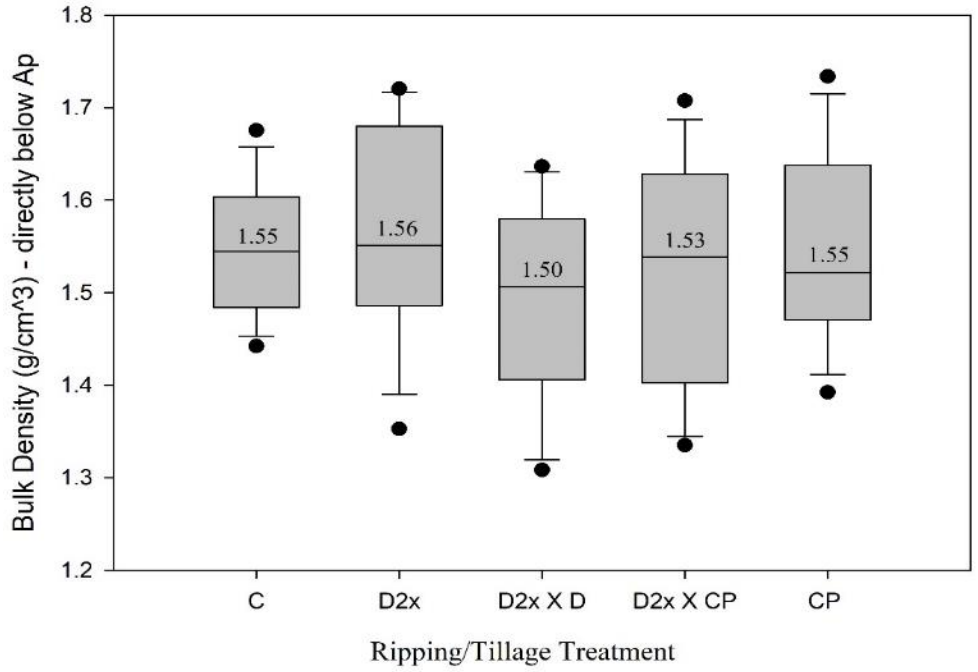




SOIL
BULK DENSITY

Db directly below Ap
15 months after plot installation

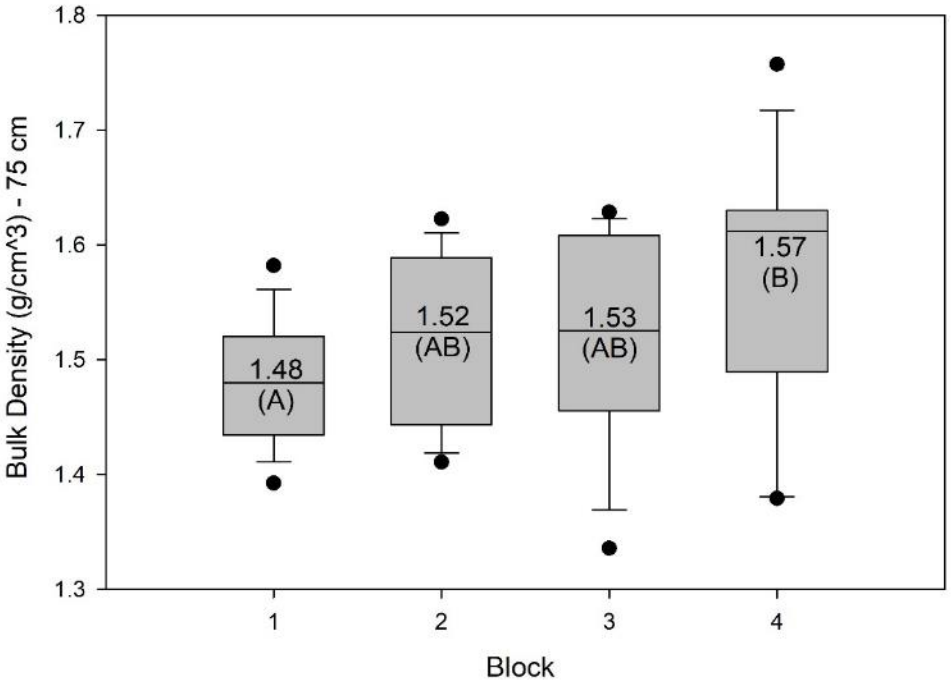


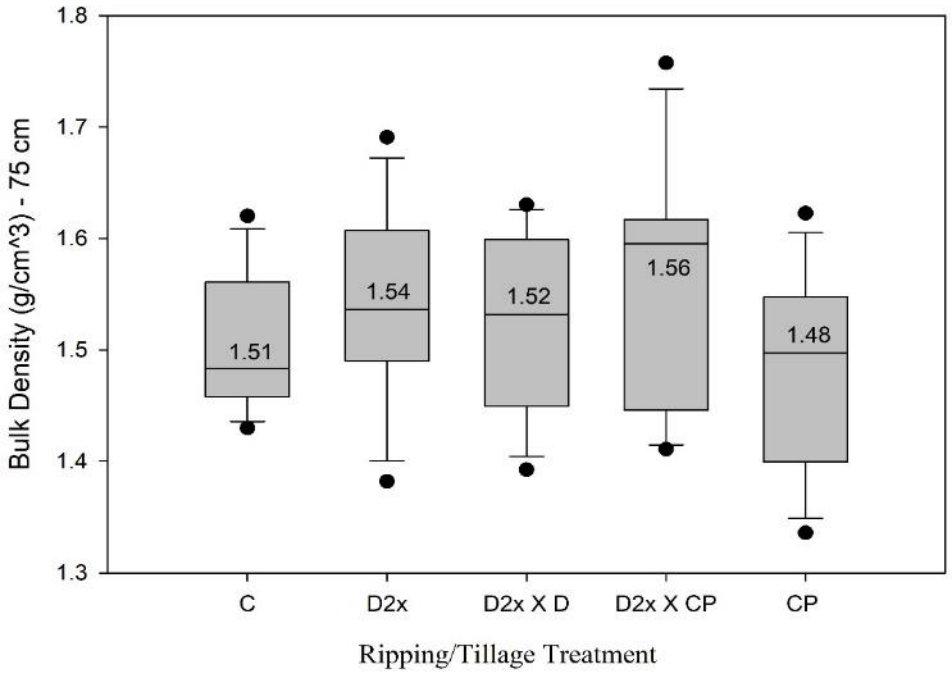


SOIL
BULK DENSITY

SUBSOIL Db
15 months after plot installation

(Note: Subsoil Db pre-installation 1.53 – 1.62 g/cm³)





Ripper traces observed in all but one of the D1 and D2 treatments.

Increased rooting was noted in only 1 ripper trace.

Bulk density was variable among the ripper traces, and was not consistently different from surrounding soil.

Subsoil Rooting

- Most prevalent in profiles that received the D2 main treatment.
- Rooting depth affected by soil texture and associated properties – i.e. clayey soils more prone to development of cracks which allow deeper rooting, clay increases water and nutrient holding, etc…
- High lateral variability makes it difficult to isolate treatment effects on vegetation response.

Conclusions

- Deep ripping produced a rougher initial soil surface that led to *visibly better* initial establishment and growth of both the cover crop and perennial pasture species. Cross-ripping further enhanced this.
- The extreme spatial variability of the surface soil conditions led to high variance in vegetative parameters which minimized statistical differences.
- Deep ripping lowered surface bulk density and produced vertical cracks in the subsoil which enhanced rooting in and around those cracking patterns.
- Further evaluation of the data may reveal relationships among ripping treatments, soil types, and vegetation response.

Acknowledgements

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