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

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

CELL AREA is ~ 3 – 12 ha (7 – 30 ac)
DEPTH up to ~ 20m (60ft)

~ 40% Fe-Coated Kaolinite (slimes)
~ 60 % Quartz Tailings

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

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

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

Topsoil Return,
lime and P (per soil test)
The mining/reclamation process creates various revegetation challenges.

**COMPACATION**

- 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 Analysis (PSA)
- Nutrients (Mehlich-1)
- Total-C
- Total-N
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
Chisel Plow

No-till ripper

Deep-ripper

Chisel Plow
<table>
<thead>
<tr>
<th>D2</th>
<th>D1</th>
<th>CP</th>
<th>C</th>
<th>NTR</th>
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</table>
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.
### Plot Installation (Aug – Sept, 2016):

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

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

Main treatments: 5 1-m² quadrats assessed (4 blocks = 20 total/main treatment)

Main treatment x cross-treatment: 3 1-m² 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 density cores collected in triplicate from:
  - Ap
  - directly below Ap
  - 75 cm

- Bulk density core (single) collected from every ripper trace.

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)
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)

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

### Mehlich 1 extractable nutrients from surface soils

<table>
<thead>
<tr>
<th>Block</th>
<th>pH</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Zn</th>
<th>Mn</th>
<th>Cu</th>
<th>Fe</th>
<th>B</th>
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</tr>
<tr>
<td>1</td>
<td>5.9</td>
<td>8</td>
<td>19</td>
<td>159</td>
<td>42</td>
<td>0.5</td>
<td>5.7</td>
<td>1.4</td>
<td>13.4</td>
<td>0.08</td>
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<tr>
<td>2</td>
<td>6.2</td>
<td>13</td>
<td>21</td>
<td>201</td>
<td>51</td>
<td>0.4</td>
<td>5.6</td>
<td>0.4</td>
<td>22.3</td>
<td>0.07</td>
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<tr>
<td>3</td>
<td>5.9</td>
<td>12</td>
<td>22</td>
<td>212</td>
<td>49</td>
<td>0.3</td>
<td>5.5</td>
<td>0.3</td>
<td>19.7</td>
<td>0.14</td>
</tr>
<tr>
<td>4</td>
<td>5.6</td>
<td>5</td>
<td>28</td>
<td>209</td>
<td>39</td>
<td>0.4</td>
<td>3.9</td>
<td>0.3</td>
<td>15.4</td>
<td>0.14</td>
</tr>
</tbody>
</table>
VEGETATION COVER BY BLOCK OVER THREE SAMPLING DATES
VEGETATION COVER BY MAIN TREATMENT OVER THREE SAMPLING DATES

% VEGETATION COVER

Nov '16 | Apr '17 | Sep '17
---|---|---
C | CP | D1 | NTR | D2
AB | AB | A | A | A
B | B | A | A | A
TOTAL BIOMASS

No significant differences by block or treatment
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/cm³)
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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