Variable Rate Irrigation for Mining Undepleted Soil Water

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Potential Benefits of VRI

- Avoid putting chemical/liquid manure on waterways (create an “avoidance area”)
- Reduce pumping
  - Reduce energy costs
  - Reduce nitrate leaching
- Prevent pivot from getting stuck
- Reduce yield losses due to over-irrigation
- Reduce water application rates on steep slopes (reduce runoff/erosion)
- Reduce over-application with corner arms
- More yield with a given water allocation
Each of these tools detects a cause or symptom of spatial differences in optimal irrigation amount.

Tools can be used in combination.
Remote Sensing Imagery

Visible/RGB
- soil color
- plant greenness

(False-Color) Near Infrared
- leaf abundance

Thermal Infrared
- crop stress (not just water stress)

Ongoing research: using imagery to create prescription maps
Cosmic Ray Probes

• Stationary & mobile CRPs
• Spatial volumetric water content in top ~30 cm
• About 300 m diameter footprint
• Then create prescription maps

In collaboration with Trenton Franz

Side-by-side with CRP rover. Also towing a Dualem 21S for EM.
Hypothesis

• Focusing on soil properties…

• With conventional irrigation, soil water in some soils remains undepleted

• VRI could be used to mine this undepleted water
A Quick Review: FC & WP

FC (Field Capacity)

WP (Wilting Point)

R (Root Zone Available Water Capacity)

MAD (Management Allowable Depletion)
Prescription Map Based on MAD

- Spatial Map of $R$
- $MAD = 0.5 \times R$

VRI can be used to mine the differences in $MAD$ across the field.

These two zones have more available water than the other zone, even though depletion is equal.

Barker et al. (2016)
Prescription Map Based on MAD

- **MAD**
- **SWD = Soil Water Deficit**
- **Irrigation**
  Mine ½ of the extra water in high MAD soils

\[ I_{IMZ} = \frac{1}{2} (MAD_{max} - MAD_{IMZ}) \]

Use this map twice

Barker et al. (2016)
GIS Analysis of VRI Potential in Nebraska

- 49,224 center pivots analyzed
- USDA gSSURGO for soil properties
- Pumping reduction from mining undepleted soil water

2% of fields: pumping reduction > 51 mm
13% of fields: pumping reduction > 25 mm

Lo et al. (2016)
Field Testing

- Neutron probe measured high FC at the bottom of the hill
- Field-observed FC may be higher than lab-determined FC due to:
  - Layering
  - Compacted layers
  - Water table

Lo et al. (2016)
Field Testing

• For this field, R correlated to elevation
  – R did not correlate with EC

• gSSURGO provides a conservative estimate
  – 22 mm pumping reduction (field measured R)
  – 9 mm pumping reduction (gSSURGO)

Lo et al. (2016)
Online Map Tool for VRI

- Nebraska website for field-specific pumping reduction and economics

Lo et al. (2016)
http://heeren.unl.edu/map

International online VRI savings calculator:
https://www.precisionirrigation.co.nz/save
By Precision Irrigation
Disclaimer: Reduced pumping ≠ reduced consumptive use

Watershed Water Balance

Streamflow – Aquifer Decline = Precip – ET

Derrel Martin
Final Observations

- Prescription maps can account for soil properties to mine undepleted soil water
- This method can reduce pumping costs and nitrate leaching
- Increasing yield is likely to be the best way to economically justify zone control VRI
- Future research should develop a VRI DSS that integrates remote sensing with soil properties
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Keith Miller, Tyler Smith, Alan Boldt, Phil Christenson, John Christenson

Additional VRI Resources:
http://heeren.unl.edu/
Importance of a System Evaluation

- Pivot orientation off by about 4° at orientation of test
- Important for avoidance areas, may not be as important for practical applications of VRI

Barker et al. (2016)
VRI System Checklist

• For speed control and sprinkler control (one-time):
  • Pivot point GPS coordinates
    • Affects the calculated position of the pivot

• For sprinkler control only (at least once per season):
  • Communication of nodes
    • Check VRI panel records
  • Operation of solenoid valves
    • Use pulse mode for testing and walk along pivot

• Response of variable frequency drive (if installed)
Irrigation Scheduling for VRI

- Soil moisture sensors
  - One or more per management zone in representative location(s)?

- Soil water balance
  - Need to know soil properties for each zone

- Irrigation trigger for each static zone
  - Watermarks: refer to extension publication on relating centibars to depletion fraction in different soil types
  - More research is needed in general
Number of Zones

- Developing more zones might not be better than developing fewer zones
- More zones require more management
- Research on four fields showed that compared to ten zones:
  - For speed control, four zones captured 83-95% as much variability in $EC_a$
  - For sprinkler control, four zones captured 85-94% as much variability in $EC_a$
VRI Investment/Affordability

- Compare present value of VRI benefits with VRI total cost
- If VRI for 124 ac costs $20,000 (USD) and is paid for entirely by one benefit:

<table>
<thead>
<tr>
<th>Category of VRI benefit</th>
<th>Example price</th>
<th>Annual field-average change at breakeven</th>
</tr>
</thead>
<tbody>
<tr>
<td>irrigation cost reduction</td>
<td>$3/ac-ft of gross irrigation</td>
<td>-78” of gross irrigation</td>
</tr>
<tr>
<td></td>
<td>$117/ac-ft of gross irrigation</td>
<td>-2” of gross irrigation</td>
</tr>
<tr>
<td>agrochemical cost reduction</td>
<td>47¢/lb of N</td>
<td>-44 lb/ac of N</td>
</tr>
<tr>
<td></td>
<td>66¢/lb of N</td>
<td>-32 lb/ac of N</td>
</tr>
<tr>
<td>yield benefit increase</td>
<td>$5.30/bu of corn at 15.5% moisture</td>
<td>+4 bu/ac of corn at 15.5% moisture</td>
</tr>
</tbody>
</table>

Based on economics at the farm gate, increasing yield is the most likely way to pay for a zone control VRI system

(interest rate of 5% and amortization period of 10 years)