Variable Rate Irrigation
UNIVERSITY OF NEBRASKA-LINCOLN
Biological Systems Engineering

Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

Water, Energy and Agriculture Initiative
WEAI

Variable Rate Irrigation for Mining Undepleted Soil Water

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ICID World Irrigation Forum, November 8, 2016, Chiang Mai, Thailand

Potential Benefits of VRI

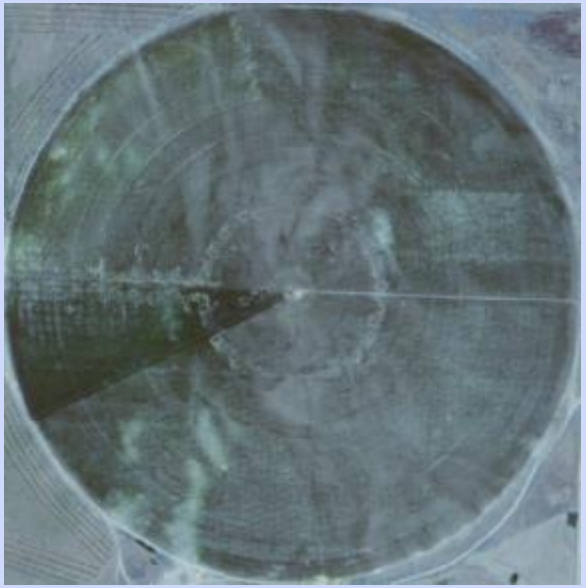
- Avoid putting chemical/liquid manure on waterways (create an "avoidance area")
- Reduce pumping
  - Reduce energy costs
  - Reduce nitrate leaching
- Prevent pivot from getting stuck
- Reduce yield losses due to over-irrigation
- Reduce water application rates on steep slopes (reduce runoff/erosion)
- Reduce over-application with corner arms
- More yield with a given water allocation

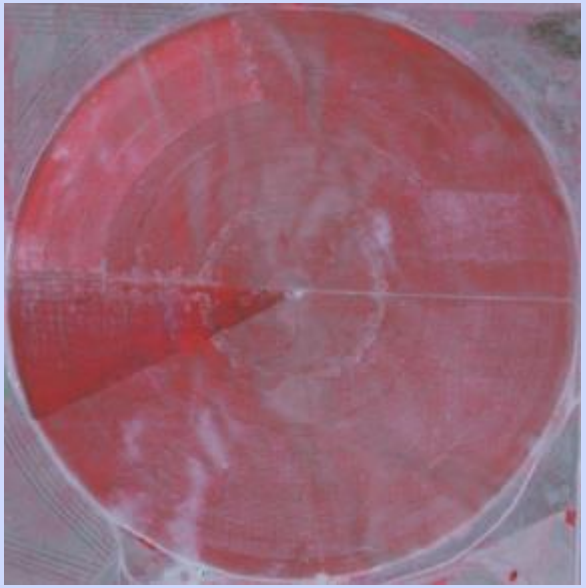
Tool Box

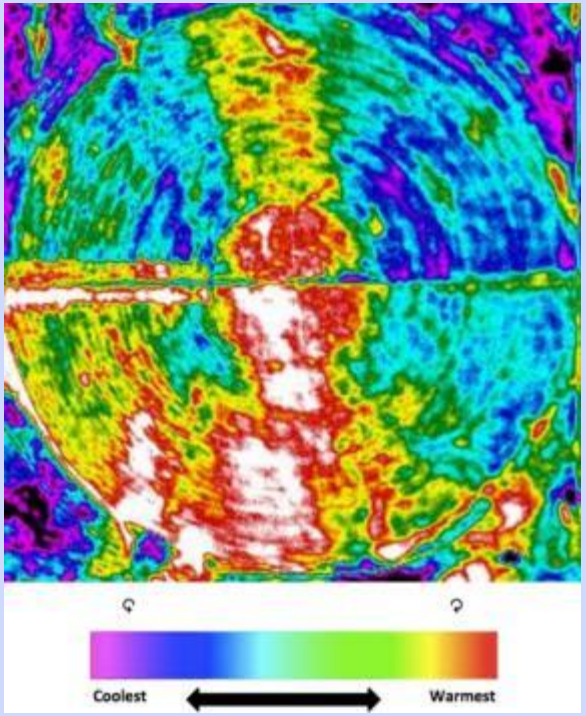
- visual observation + GPS
- yield maps
- topo maps / digital elevation models
- apparent electrical conductivity (EC_a)
- aerial imagery
- soil sampling and analysis

- **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**

ARDC WWC Movie.avi

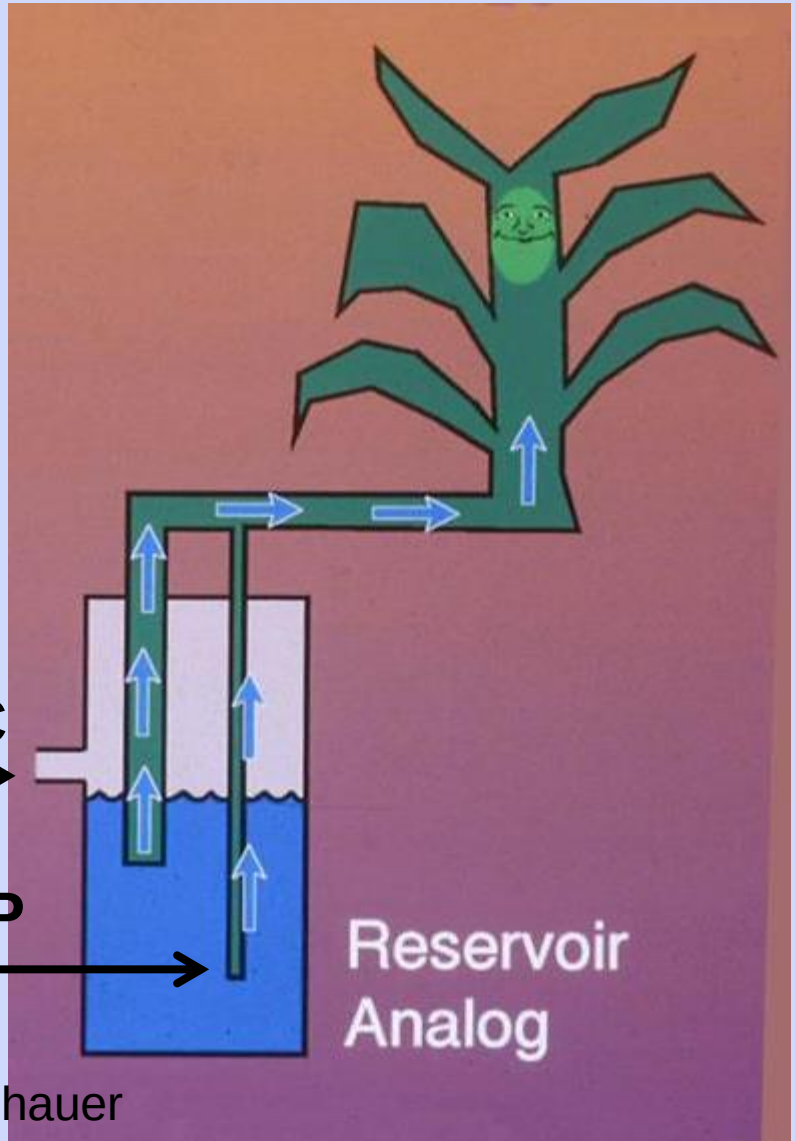
In collaboration with
Trenton Franz

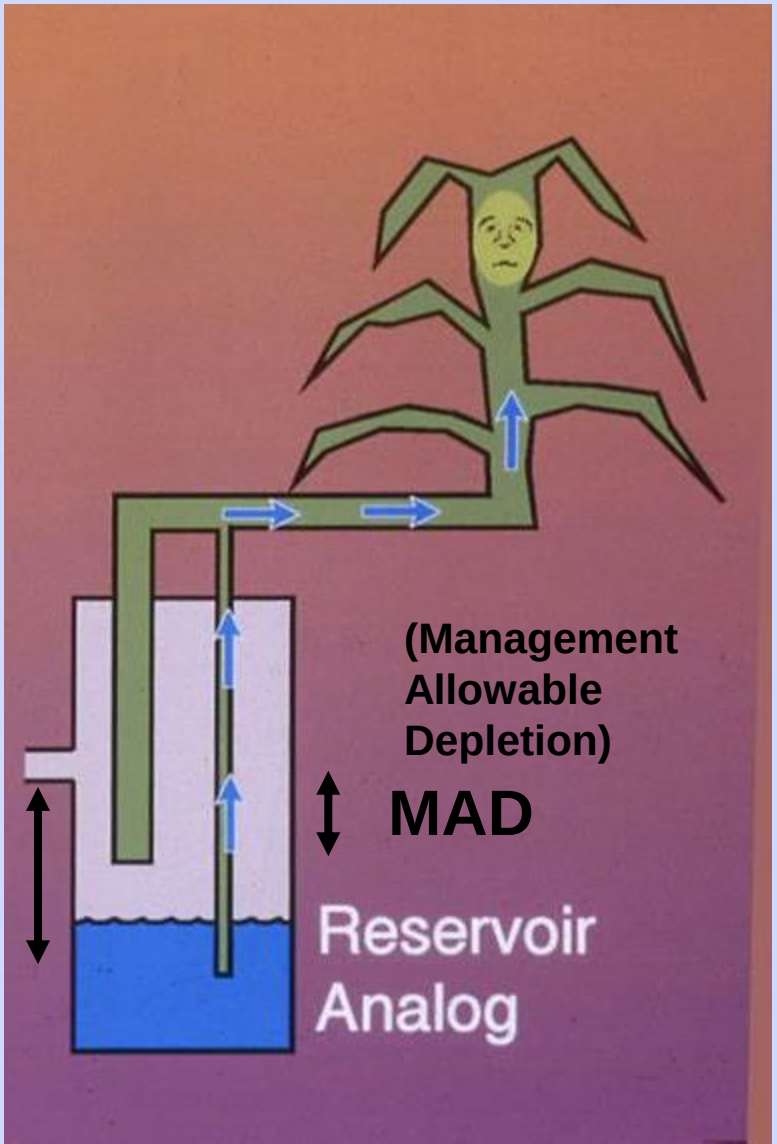
Side-by-side with CRP rover.
Also towing a Dualem 21S for EM.

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



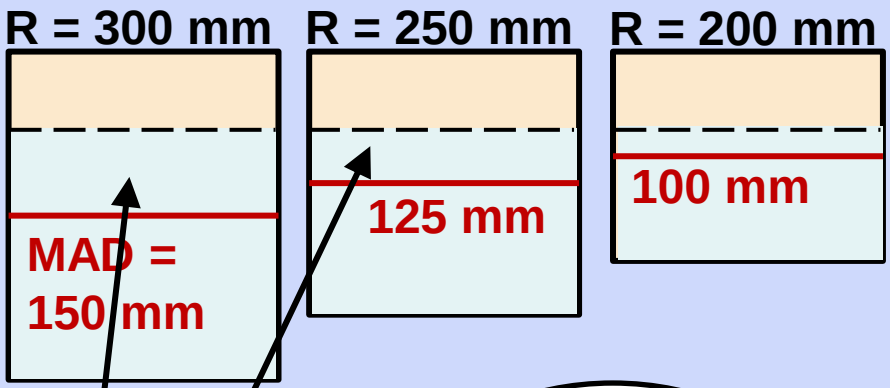


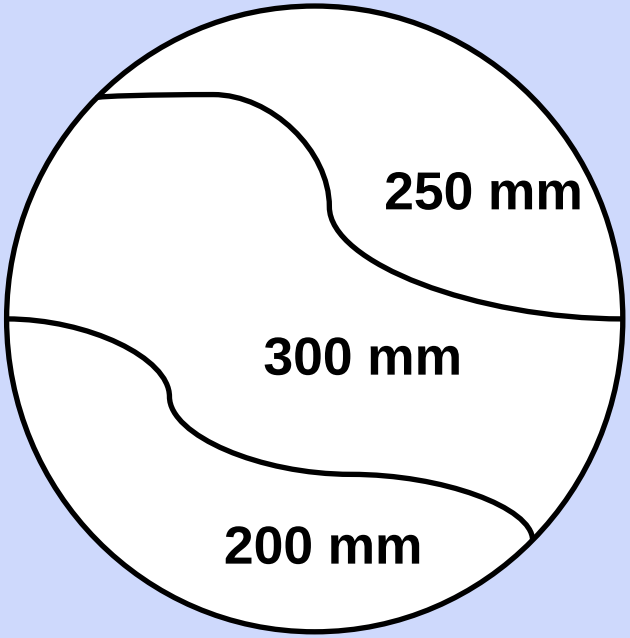
Eisenhauer

Prescription Map Based on MAD

- Spatial Map of R
- MAD = 0.5 * R

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





Hypothetical field with variable R

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

Barker et al. (2016)

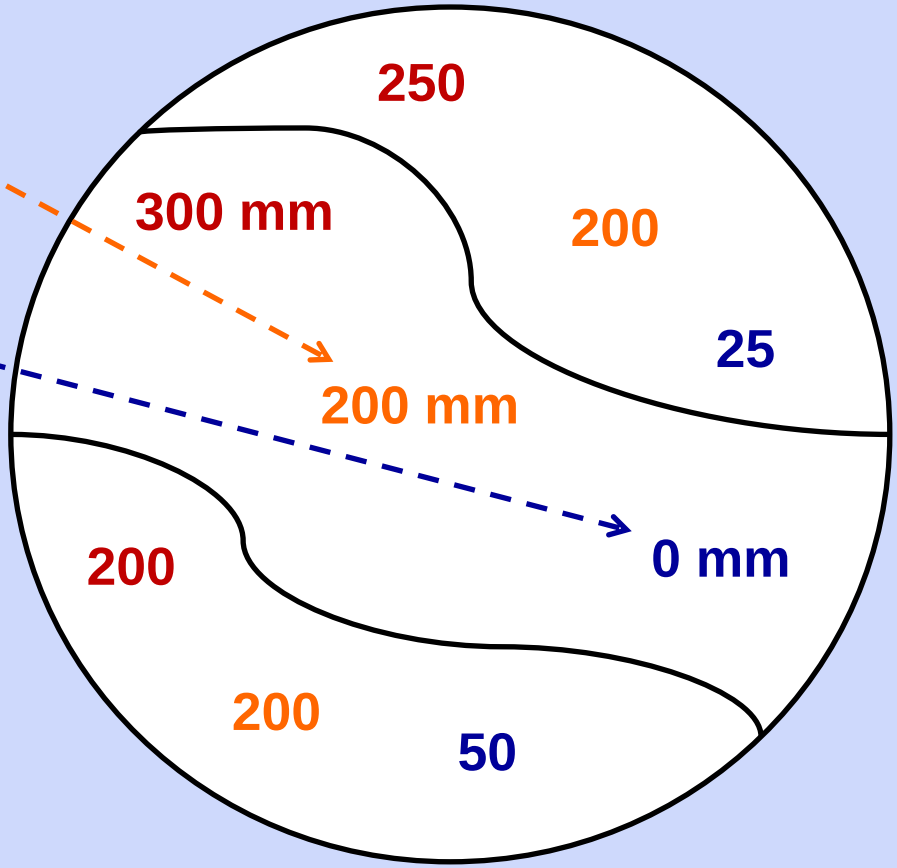
Prescription Map Based on MAD

- **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

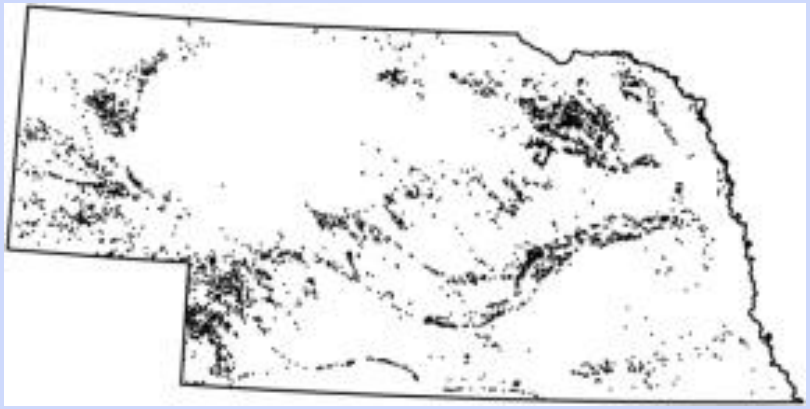


Barker et al. (2016)

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

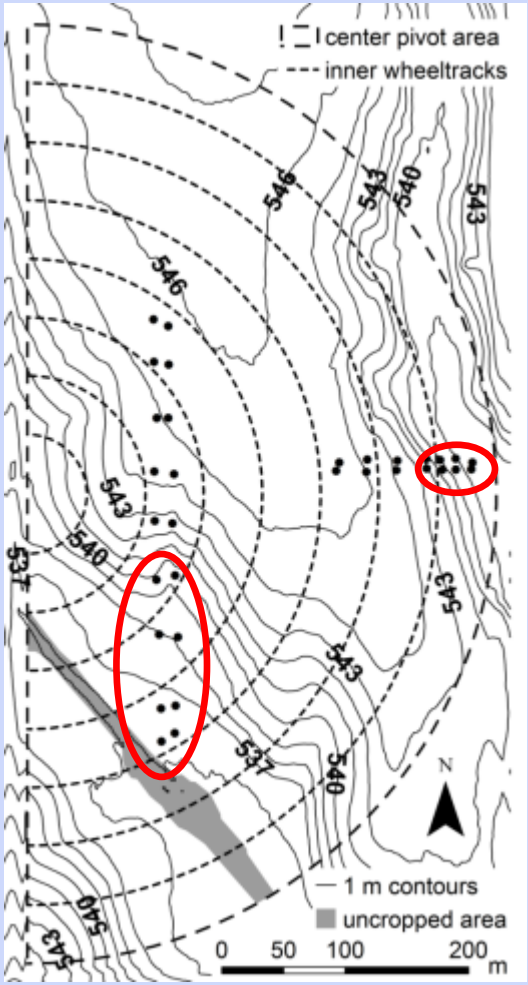


13% of fields:
pumping reduction > 25 mm

Lo et al. (2016)

Field Testing

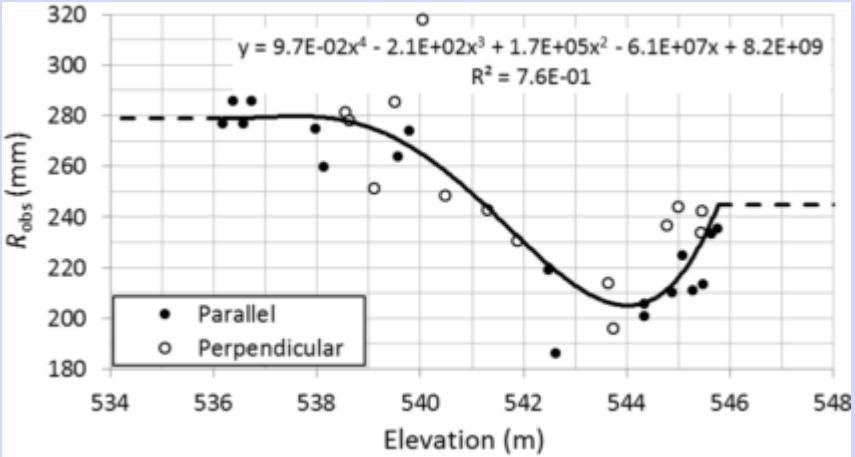
- **Neutron probe measured high FC at the bottom of the hill**
- **Field-observed FC may be higher than lab-determined FC due to:**
  - **Layering**
  - **Compacted layers**
  - **Water table**

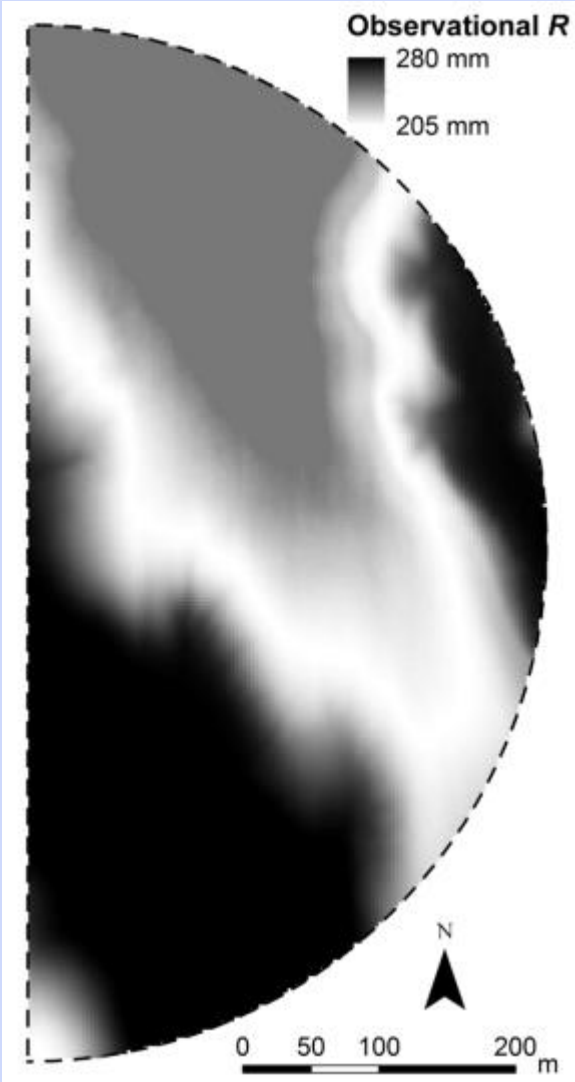


Lo et al. (2016)

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)



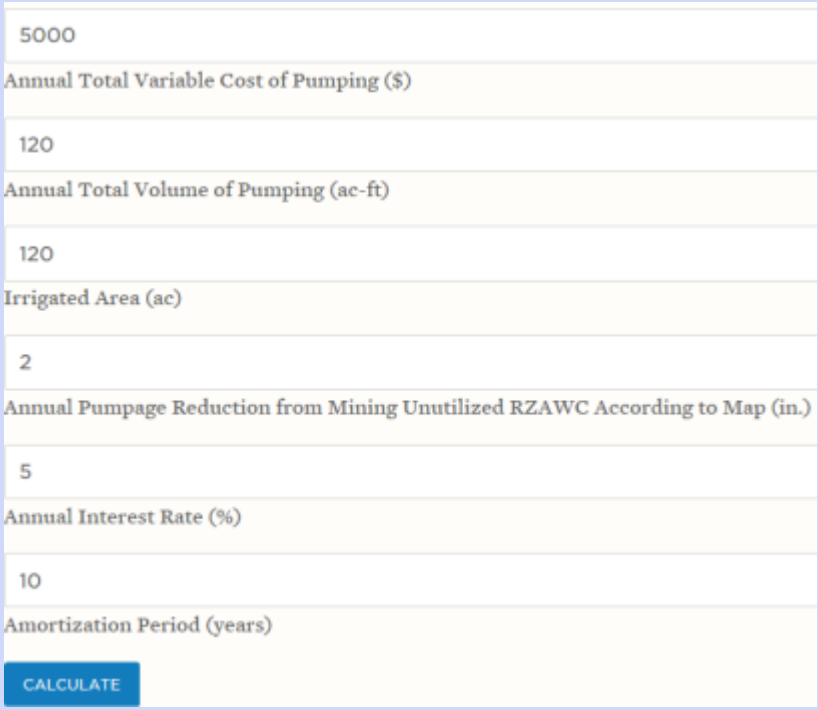


Lo et al. (2016)

Online Map Tool for VRI

- **Nebraska website for field-specific pumping reduction and economics**

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



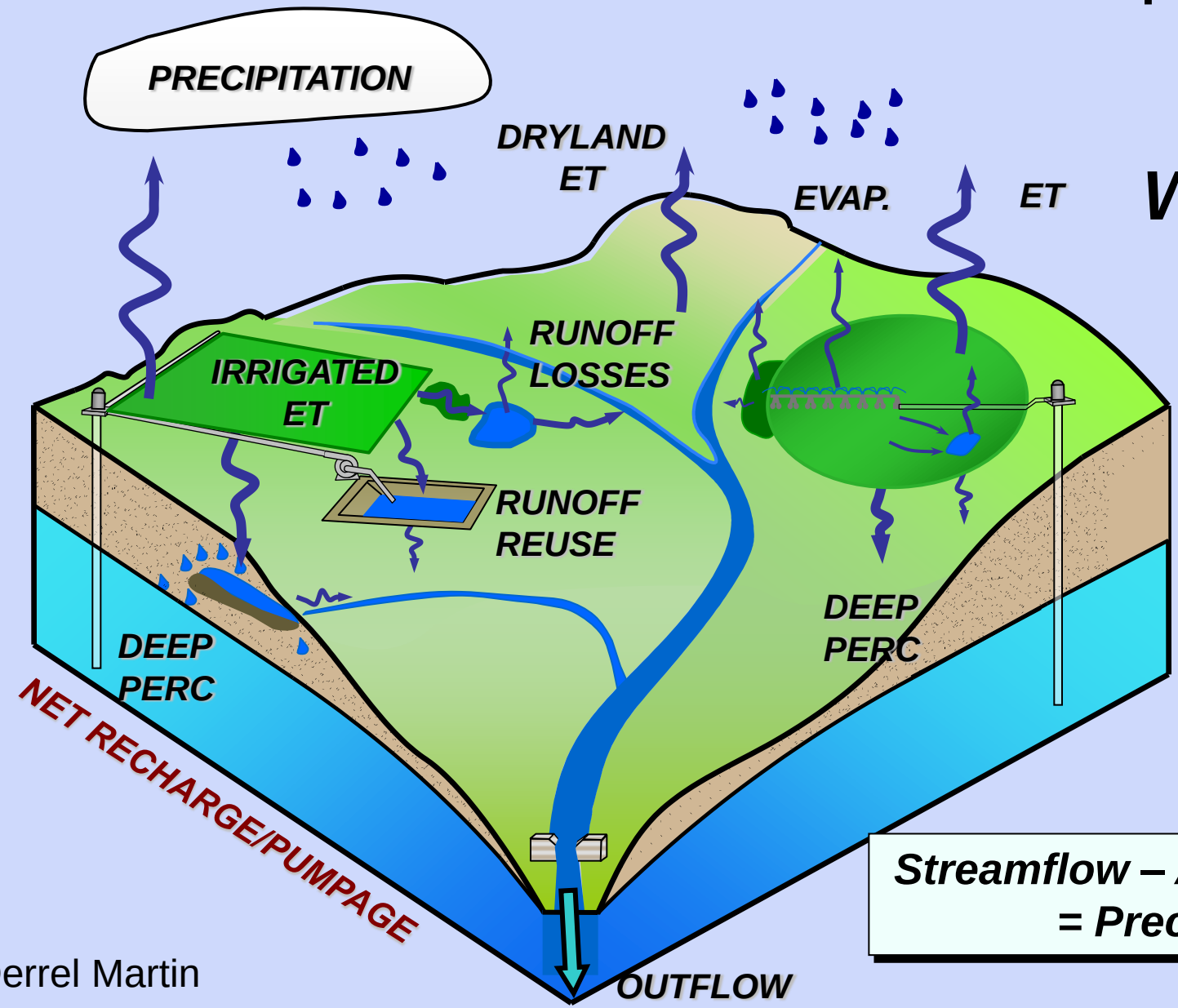
International online VRI savings calculator:

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**

Nebraska CornBoard
Soybeans Nebraska Soybean Board
Nebraska Public Power District
IANR

Acknowledgements:

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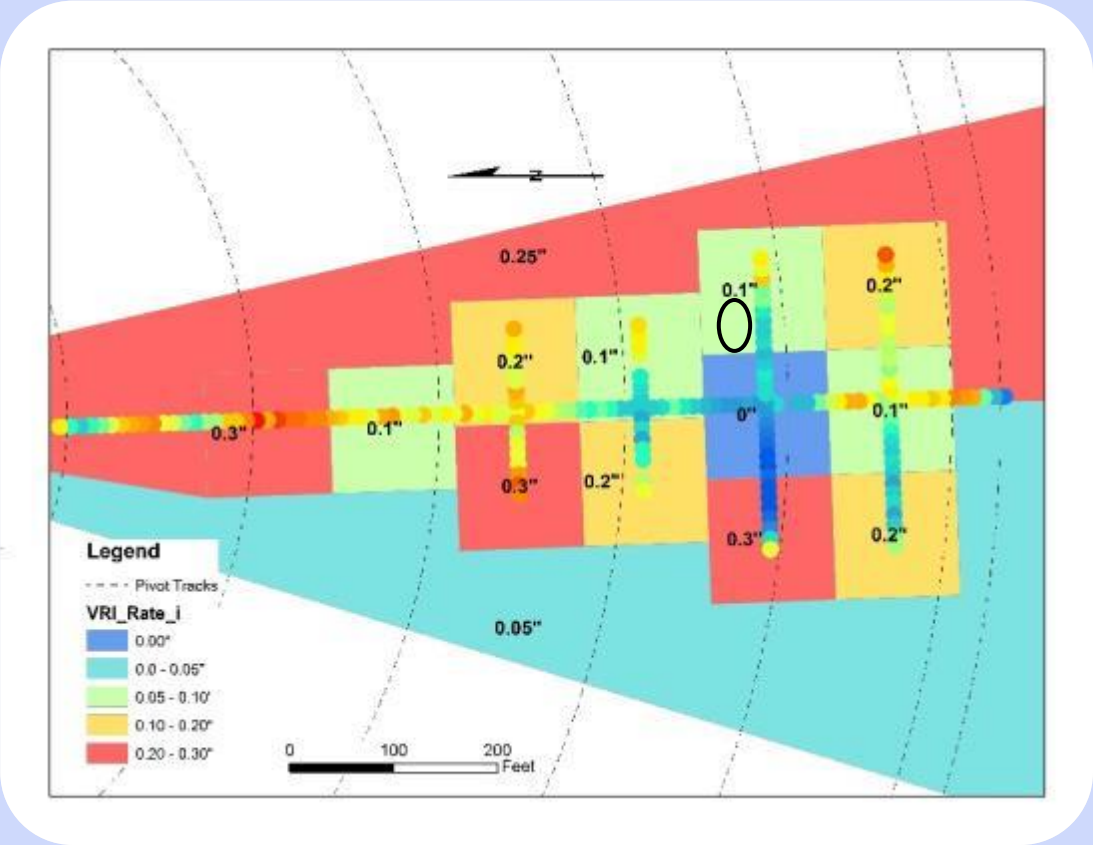
Keith Miller, Tyler Smith, Alan Boldt, Phil Christenson, John Christenson

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**


EXTENSION

EC783
(Revised February 2016)

Principles and Operational Characteristics of Watermark Granular Matrix Sensor to Measure Soil Water Status and Its Practical Applications for Irrigation Management in Various Soil Textures

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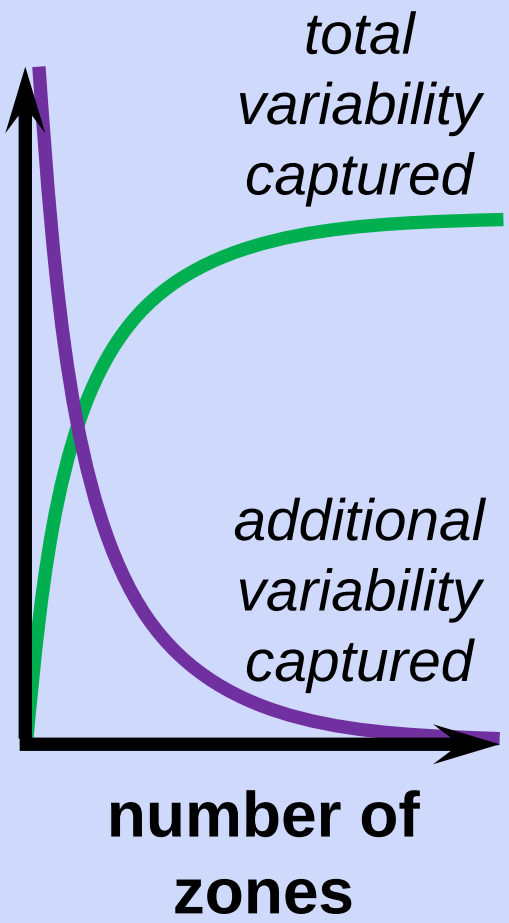
Number of Zones



- **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:**

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

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

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

T. Lo thesis (2015)