Irrigation Management Tech, VRI, & VRF

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Irrigation Management Tech

Imagery

Soil Moisture

Soil Variability

Crop Growth and Development

System Details and Performance

Weather

Topography
Water Balance Models

- Saturation
- Field Capacity
- Depletion
- MAD = Trigger Point
- Latest Start Date
- Wilting Point
- Irrigation
- Water Freely Drains
- Management Zone
- Crop Water Stress Zone
- Water Not Available to the Crop

Effective Rainfall

Effective Rainfall (ER) - Portion of total rainfall that assists in meeting the consumptive use requirements of growing crops (Avinash et al., 1990)

\[
ER = \text{Total Rain} - (\text{Run Off} + \text{Deep Perc} + \text{Interception})
\]

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Runoff

Effective Rainfall (ER)
- Portion of total rainfall that assists in meeting the consumptive use requirements of growing crops (Avinash et al., 1990)

\[ ER = Total \ Rain - (Runoff + Deep \ Perc + \text{Interception}) \]

![Figure 1. Runoff curves for straight row crop conditions with moderate slopes and relatively dry soil.](image1)

![Figure 2. Runoff curves for row crops grown on the contour, or straight rows having little slope, and relatively dry soil.](image2)

Source: Cahoon et al. (1992) – NebGuide G92-1099-A

Deep Percolation

Effective Rainfall (ER)
- Portion of total rainfall that assists in meeting the consumptive use requirements of growing crops (Avinash et al., 1990)

\[ ER = Total \ Rain - (Runoff + Deep \ Perc + \text{Interception}) \]

Hard to quantify relative to rain event. Two estimation methods.

Method 1: Instant drainage
- \[ DP = Total \ Rain - (Runoff + \text{Interception}) - Storage \ Deficit \]
  - where: \( Storage \ Deficit = (\theta_{FC} - \theta_v) \cdot R_d \)

Method 2: Daily Drainage (Wilcox Method, Miller and Aarstad, 1972)
- Example Garden City, KS: \( DP = 42.7 \left( \frac{TSW}{729} \right)^{18.06} \)
  - where, TSW is total soil water (mm) in 1.8 m profile
Canopy Interception

Effective Rainfall (ER)
- Portion of total rainfall that assists in meeting the consumptive use requirements of growing crops (Avinash et al., 1990)

\[ ER = \text{Total Rain} - (\text{Run Off} + \text{Deep Perc} + \text{Interception}) \]

Soybean \( \text{Inter} = 0.0001 \times \text{LAI}^{1.030} \)
Avg. Inter. = 1.8 mm (Lamm and Manges, 2000)

Gross and Net Irrigation

Gross Irrigation
- Total irrigation pumped

Net Irrigation
- \[ Net = Gross \times E_a \]
\( E_a \) is percent of water delivered to field that is stored in root zone.
Crop Water Use

Evapotranspiration (aka Crop Water Use)
- Water transferring from liquid to vapor state by crop transpiration and evaporation from soil and plant surfaces (i.e., canopy interception).

Crop Coefficients

Evapotranspiration ($ET_a$)
- Crop $ET_a$ is commonly estimated using the two-step approach, which includes calculating a reference ET and multiplying by a crop coefficient ($K_c$)

$$ET_a = K_c \cdot ET_{ref}$$

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</table>

Source: High Plains Regional Climate Center (HPRCC)
Crop Coefficients for Corn North Platte, NE

\[ y = -2E \cdot 06x^3 + 0.3175x^2 - 13626x + 2E+08 \]
\[ R^2 = 0.862 \]

Multiple Sources for Reference ET

- Public Data (e.g., High Plains Regional Climate Center)
- Personal Weather Station (e.g., FarmersEdge, DTN, Arable, John Deere, etc.)
- On-Site Atmometer (ETgage)
- **Distance from location?**
- **Caution:** Make sure to match up reference surface with \( K_c \) values (i.e., alfalfa vs grass)
Active Crop Root Zone

Soil depth where crops are extracting water and nutrients

Source: Irmak and Rudnick (2014)

1. Significant extraction from top three feet
2. Could monitor fourth foot for deep percolation
3. Fourth foot may be important for more arid locations or smaller water supplies

Irrigation Scheduling Models

Don’t Worry! There are publicly available irrigation scheduling models.
Alternative Scheduling Tools

Soil Water Sensors

Infrared Thermometry

Dendrometry

Remote Sensing

Soil Water vs. Dendrometer

2018 TAPS Farm #16

Irrigations

Fertilizations

Maximum Daily Shrinkage (MDG)

Irrigation or Fertilization (Inches)
ET Model vs. Soil Water Sensors

2018

- Pioneer 1197 Corn following Soy
- N rate: 220 lbs/acre
- Seeding Rate: 34,000 per acre

**Equation:**
\[ y = -1.4092x^2 + 21.476x + 195.67 \]
\[ R^2 = 0.91 \]

Scheduled using ET Data
Scheduled using Soil Water Sensors

How to Advise on Soil Water Sensor Use

**Timeline:**
May 9 – Sept. 22, 2017

**ET:** 24.5 inches
**Rain:** 13.8 inches

**Graph:**
- **ET, Rain, and/or Irrigation (inches):**
- **Evapotranspiration**
- **Rainfall**

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ET vs. (Irrigation + Rainfall)

Farm 1: 3.5 inches
Farm 10: 6.8 inches
Farm 15: 10.75 inches

Soil Water Status

Farm 1: 3.5 inches
Farm 10: 6.8 inches
Farm 15: 10.75 inches
Useful Information for Irrigation Management

- Historical Records (Yield data, compaction issues, etc.)
- Soil Properties (NRCS soil surveys, ECa mapping)
- Topography (DEM-digital elevation maps via survey, LiDar, etc.)
- Field Conditions (Residue level, pest pressure, nutrient availability, etc.)
- Visual Observations (Drainage ways, streams, roads, etc.)
- Soil Water Status (Soil water sensors)
- Weather Conditions/Evaporative Demand (Climatic variables via weather station)
- Crop Water Stress (Thermal sensors)
- Crop Growth and Condition (Canopy reflectance, visual imagery, and crop models)
- Remote Access to Irrigation System and Technology (Telemetry)
- System Performance (Pressure transducers, telemetry, flow meter, etc.)

Will Irrigation Tech Pay for Itself?

How to Assess Economic Value?

- Reduction in pumping and wear/tear on system
- Increase in grain yield
- Reduction in labor and travel costs to check systems
- Peace of mind (i.e., confidence in decision)
- Staying in compliance
- Among others!
Reduction in Pumping

So how much would it take to cover technology cost through reduction in pumping?

Table 3. Gallons of diesel fuel required to pump an acre-inch at a performance rating of 100%.

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Energy Source | Units | Multiplier
---|-------|-------
Diesel   | gallons | 1.00  
Electricity | kilowatt-hours | 14.12  
Propane | gallons | 1.814  
Gasoline | gallons | 1.443  
Natural Gas | 1000 cubic feet | 0.2056

Source: Martin et al. (2017)

Table 4. Multiplier when pumping plant performance rating is less than 100%.

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Reduction in Irrigation Withdrawal (in)

Pumping Lift (ft)

Diesel Cost: $3.00/gal
Field Size: 120 acres
Efficiency: 75% of NPPPC Sensor Cost: $1,500
Increase in Grain Yield

So how much would it take to cover technology cost through increase in grain yield?

![Graph showing increase in grain yield with varying crop prices and sensor costs.]

Field Size: 120 acres

Sensor Cost => $1,500 — $2,500 — $3,500

Things to Consider When Selecting Tech

1. Convenience
2. Cost
3. Remote Access
4. Accuracy
5. Support
6. Soil Type & Condition
7. Number Needed
8. Crop Type and Rooting Depth
9. Integration with Other Sensors
Variable Rate Irrigation

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University of Nebraska-Lincoln
West Central Research and Extension Center
Brule Water Laboratory near Brule, NE
41° 1' 43.20"N and 101° 58' 17.53"W

Topographic Map

Elevation (m)
- Soft Edge
- 1061 - 1064
- 1073 - 1075
- 1058 - 1061
- 1070 - 1073
- 1055 - 1058
- 1067 - 1070
- 1052 - 1055
- 1064 - 1067
- 1050 - 1052

Slope (%)
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12

Types of VRI

Sector/Speed Control
Fixed Zone Control
Irregular Zone Control

Depending on system and controller VRI can be managed in sectors, bank of sprinklers, or individual sprinklers.
**Speed Control**

- Changes end tower speed at specified angular positions
- Modifies application depth in sectors of the circular pass
- Alters application duration but not application intensity
- Does not affect sprinklers, system curve, or pump performance curve

**Sector/Speed Control**

- Application intensity at a given radius from pivot point

**Sprinkler Control**

- Individual or groups of sprinklers (i.e., banks of sprinklers)
- Changes in application depth accommodated by
  - Speed of pivot
  - Pulsing of sprinklers
- Management zone must be greater than sprinkler throw diameter (consider sprinkler overlap!). More zones = more work!
Fixed Zone VRI System near Big Springs, NE

Smallest Zone
1º Change
Span Control

Span 1 - 6: On

Primary Valve

Secondary Valves

Controller

Span 7-8: Off

Sprinkler Control VRI near Grant, NE

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Following installation of a VRI system a producer has to determine where, when, and how much to irrigate.

- **Zone delineation (i.e., Where)**
  - How small or large should a zone be?
  - How many zones are necessary?
  - Are the zones fixed (static) or do they change (dynamic)?

- **Irrigation prescription (i.e., When & How Much)**
  - Should irrigation timing be on a fixed or variable schedule?
  - Should application depth change for a zone over time?
  - Do I need to monitor each zone?

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### Approaches to Managing VRI

- **One fixed delineation of sectors/zones**
- **One prescription map** specifying the fixed depth or fixed depth percentage in each sector/zone for every pass
- Least complex as compared with other approaches
- Sufficient for avoidance and other simple applications
- Variations in weather and crop condition within and between seasons might hinder effectiveness of applications
Static Zone and Dynamic Prescription

- One fixed delineation of sectors/zones
- Prescription maps can change throughout a season
- Timely water status information for each sector/zone is necessary
- Simple versions (e.g., based on multiple sets of soil water sensors) may be ready for adoption
- Can respond to variations in weather, crop, and soil conditions throughout the season

Dynamic Zone and Dynamic Prescription

- Delineation of sectors/zones and the prescription maps can change throughout a season
- Requires frequent availability of spatial data for entire field
- Emerging with the development of ground-based mobile sensor systems, dense sensor networks, and aerial imaging services (e.g., remote sensing)
How Many Zones???

Four to five management zones (MZ) was sufficient to explain within field variability of available water content (AWC) and total within-zone variance decreased as the number of zones increased from 1 to 10 (Haghverdi et al., 2015)

Source: Haghverdi et al. (2015)

Zone Delineation near Brule, NE

Zone-specific VRI treatments:
• low
• medium
• high
Size of zones?

Should consider size of equipment and data collection (and resolution).

- Sprinkler wetted radius?
- Communication of irrigation commands
  - i.e., node connectivity
- Resolution and accuracy of data
  - Imagery, ECa, WebSoil Survey, etc.

Variable Rate Fertigation

- Attempts to spatially vary irrigation intensity, irrigation duration, and/or nutrient concentration to intentionally apply different fertilizer rates across a field

- Two Options:
  - Variable Rate Injection
  - Constant Rate Injection
Variable Rate Fertigation

- One approach to VRF maintains constant fertilizer concentration while water flow rate changes
- Fertilizer rate would be proportional to water amount
- Relative deviations from average concentration were -5.1 to 3.0% (CV of 3.1%) per 6-minute round

![Graph showing fertilizer:water volumetric ratio vs. measured water flow rate (gpm)](Lo et al. (2019))

Constant Rate Injection

- Chemical injection rate ($i$) remains constant, while irrigation intensity and/or duration are adjusted.
- Prescription tool was developed in Python to convert a map of chemical dosages into a VRI map to achieve variable fertilizer.

![Graph showing adjusted actual N rate vs. target N rate (lb/ac)](Lo et al. (2019))
How to manage VRF?

Methods:
• Imagery
• Active optical sensors
• Spatial soil and leaf tissue sampling
• Prescription broke apart through season
  • UNL Algorithm distributed over the season
• Several others!

Active Optical Sensors
Ex. Model for managing VRF?

- Using integrated datasets for decision making can provide insights into enhanced agronomic questions.
- For TAPS, Farmers Edge utilized their “N-Manager” Product that incorporates soil data by zones, crop production plans, in-field weather data, and imagery to derive Nitrogen needs by zone and crop growth stages.

**TAPS July 1, 2019**

**Prescribed N Rate**
- Zone 1: 60 lbs/ac
- Zone 2: 50 lbs/ac

**Approach:**
- Apply less and re-run model later.

Source: Scott Speck

- “N-Manager” is a modelled based Nitrogen management tool that utilizes multiple datasets to run scenarios each day based on soil data, crop growth stage, and current, historical, and forecasted weather data.
- As zones are updated with weather information, recommendations can be exported or used to make Nitrogen decisions.
- Other datasets are used to analyze crop potential such as daily satellite imagery, or crop growth stages. NDVI values derived from different zones can be used to identify deficiency areas for field testing or for confirmation of model.

- Fig 3. Farmers Edge “Scouting Map” viewed on UNL TAPS plots.
Thank you! Questions?

The mention of trade names or commercial products in and during this presentation does not constitute an endorsement or recommendation for use by the University of Nebraska-Lincoln or the author.