Why is Untangling Water and N Stresses so Difficult

Life is complicated!
Water or Nitrogen Use Efficiency

What assumptions do we make about efficiency?
Reality on NUE

Chaoqun Lu, Jien Zhang, Peiyu Cao, and Jerry L. Hatfield, 2019 J GeoPhysical Res.
Reality on WUE

Reality is that yield has been increasing but water use has not changed as much as yield.
Limitations on productivity

- Inadequate water or nitrogen supply to the plant
- Yield is negatively correlated to April and May rainfall and positively correlated to July and August rainfall
- Yield response to N is more complex
What do we want to know?

- How much is the stress impacting productivity?
- What can be done to correct the problem and is it worth the cost?
What we know!
Nitrogen Response Across Fields

- Strip Yields
- Nitrogen (kg/ha)
- Yield (Mg/ha)

Year: 2000
- Carroll 1
- Carroll 2
- Sac
- Shelby
- Story 1
- Story 2

Year: 2001
- Story 3

Year: 2002
- Calhoun W
- Calhoun E
- Carroll
- Dallas N
- Dallas S

Graph showing yield vs. nitrogen for different fields across the years 2000-2002.
Yield Correlation with RS data

SAVI 3rd flight

SAVI 4th flight
R3 SPAD means, Aug. 01, 2002

**SPAD values**
- 41.4 - 52.8
- 52.8 - 56.4
- 56.4 - 59.2
- 59.2 - 62.2
- 62.2 - 68.8

**Nitrogen treatments**
- L = 70 #N
- M = 110 #N
- H = 150 #N
Field Scale Variation
Spatial Patterns within Fields

Dallas South

EM-38 Yield Reflectance
Water vs Nitrogen

- Dissect the growing season into phenological stages for the Midwest
- Spring conditions
- Excess water that limits plant root development and causes crusting, limiting oxygen. Result is yellow plants due to excess water not lack of N.
Water vs Nitrogen

- Reproductive stages
- Soil water is often the limitation rather than N because of rainfall patterns and soil water holding capacity.
Detection of Stress

- **Nitrogen**
  - Indices related to leaf or canopy chlorophyll content
    - MCARI
    - CI

- **Water**
  - Indices related to canopy temperature
    - CWSI
MCARI

MCARI over corn

Tassels impact the reflectance patterns
Leaf Chlorophyll

![Graph showing chlorophyll index over day of year](image-url)
GPP vs CI (Corn)

Irrigated and Rainfed Maize

\[ y = -6.59 \times 10^{-10}x^2 + 2.84 \times 10^{-04}x - 2.37 \]

\[ R^2 = 0.91 \]

Giteson et al
Soil Water Use Patterns
Soils within the field have different water use patterns depending upon soil water holding capacity and precipitation patterns.
WUE was limited by soil water availability, not nitrogen.
Feedbacks between Water & N

- Inefficient water and nitrogen use
- Increased N leads to increased growth
- Increased growth leads to increased water use
- In water limited soils this creates a water deficit condition
Cycles interact over time and space with different rates.

Key Processes:
- Photosynthesis
- Respiration
- Org Matter decomposition
- Plant decomposition
- Precipitation
- Evaporation
- Infiltration
- Runoff
- Percolation
- N Fixation
- Mineralization
- Denitrification
- Plant decomposition

Solar Radiation:

Carbon Cycle

Water Cycle

Nitrogen Cycle

Soil Surface

Solar Radiation influences the cycles through various processes, including photosynthesis, precipitation, and mineralization, among others.
Challenges

- Understand the growth, water use, and nitrogen dynamics are closely related
- If we are going to improve NUE, need to realize that water use and availability may be the major limitation
- Need to start using the G x E x M framework to evaluate management practices to optimize genetic performance for the variable environment (soils and weather)