Determination of optimum N-rates for Corn: Models versus Reality

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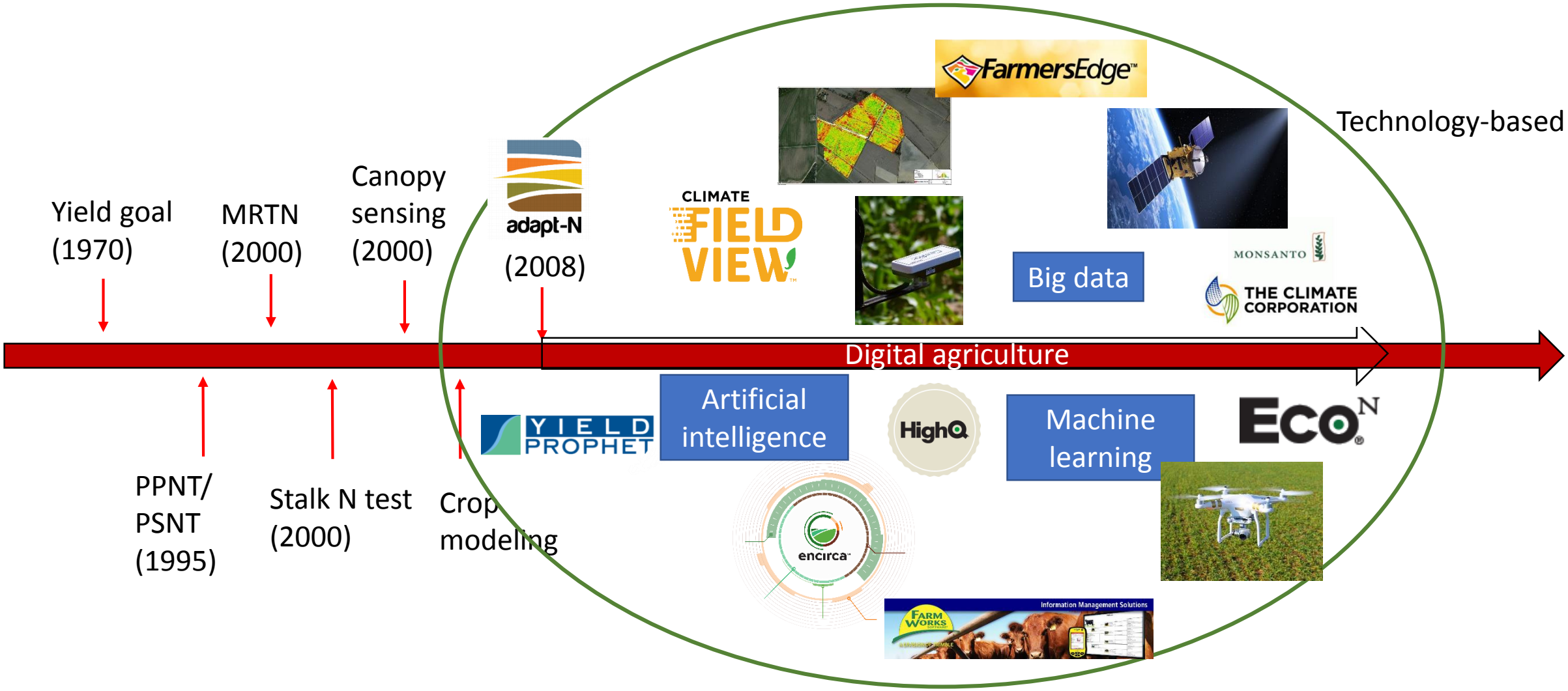
Outline

- N-fertilization approaches and simulation models

- Three examples:
  - **F**orecast and **A**ssessment of **C**ropping sys**T**em**S** (FACTS)
  - EONR prediction (complex model)
  - EONR prediction (simple model)

- Way forward for more accurate EONR predictions

N recommendation tools



Iowa farmers:

Table 4. Methods used to determine nitrogen fertilizer rates, farmers who planted corn and/or soybean in 2011

	Percent Checked
Crop nutrient requirements based upon yield goals	71
Follow recommendations from fertilizer dealer/supplier	62
Apply fertilizer based upon prior experience	58
Use validated field tests from my own farm to establish optimal rates	29
Follow recommendations from crop consultant	24
Follow Iowa State University nutrient management recommendations	22
Corn N Rate Calculator (MRTN)	11

Arbuckle and Rosman, 2014
http://lib.dr.iastate.edu/extension_communities_pubs/24

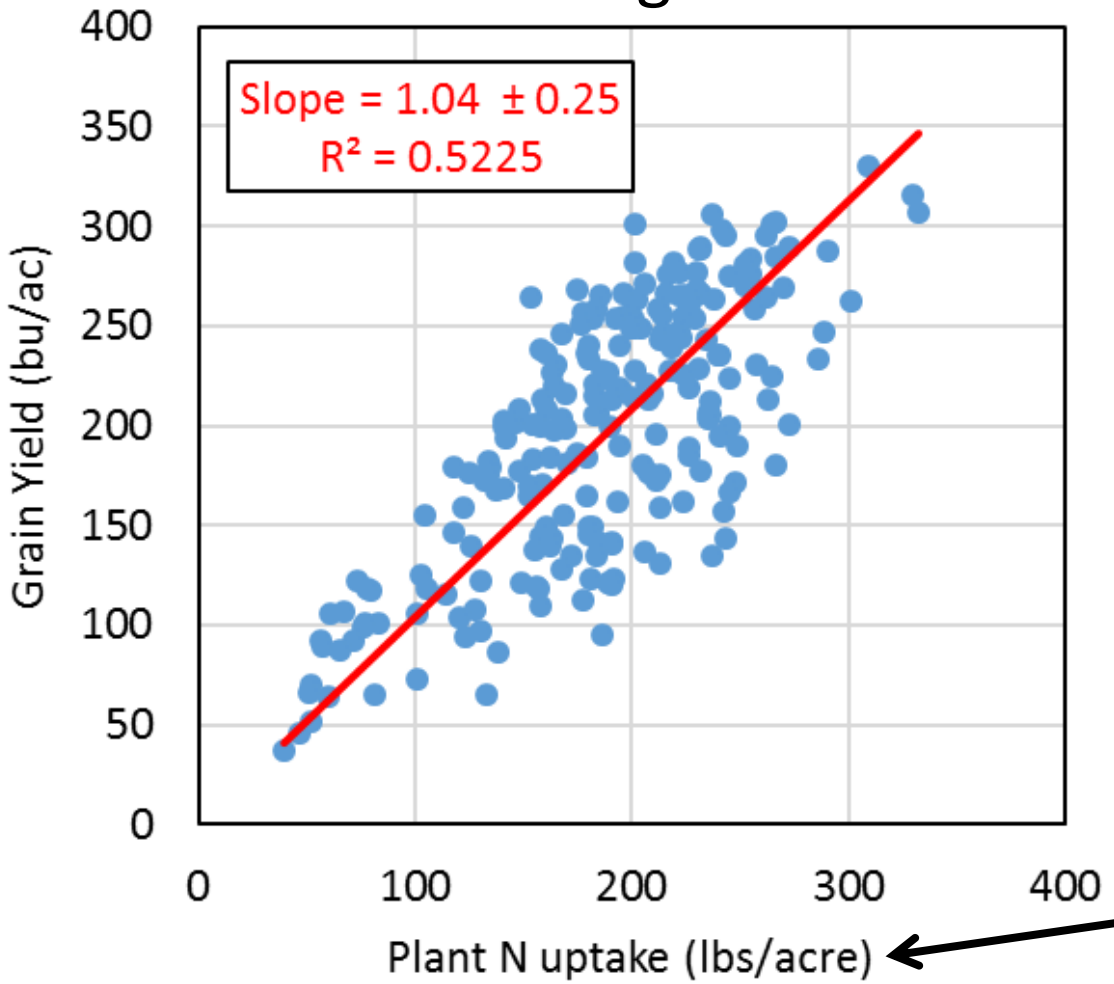
Iowa farmers

Table 5. Number of nitrogen rate determination methods used, farmers who planted corn and/or soybean in 2011

	Percent
One	15
Two	22
Three	27
Four	18
Five	9
Six	2
Seven	1
None of the options provided	6
Average number of methods used	2.8

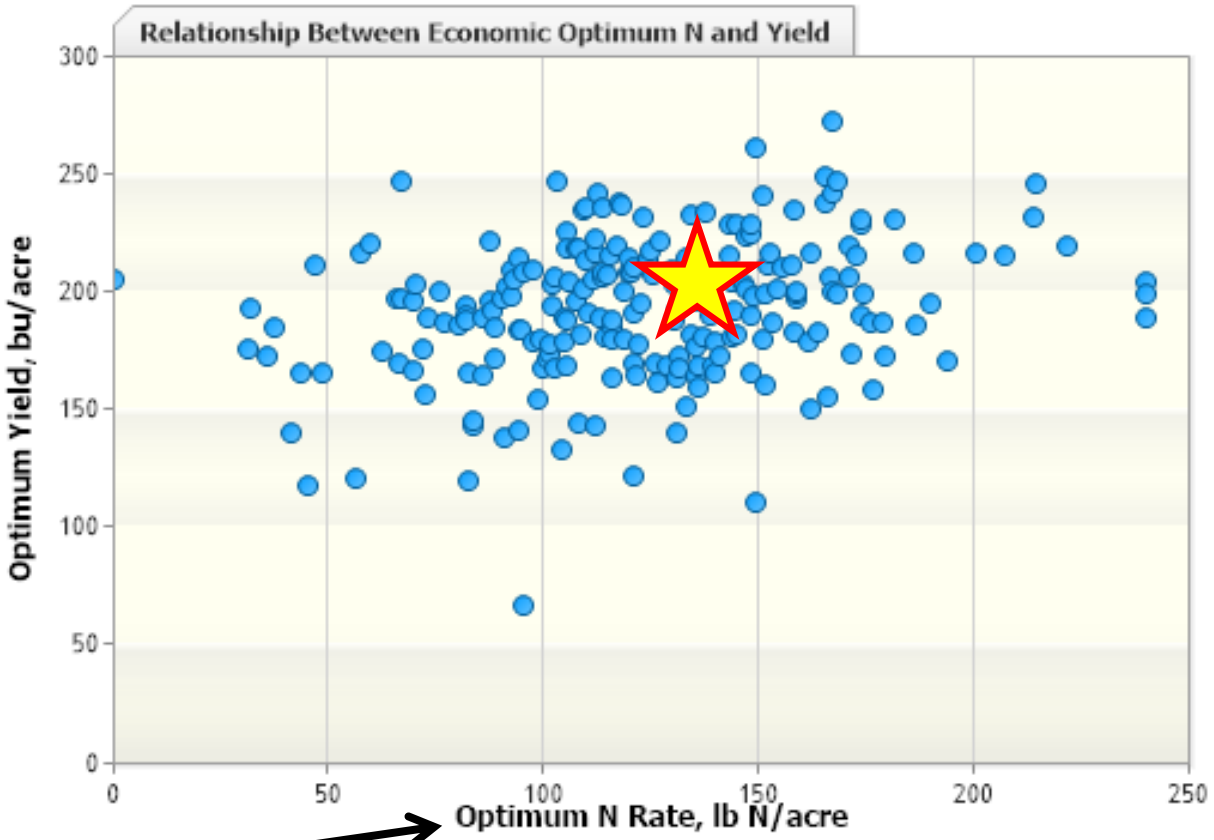
Arbuckle and Rosman, 2014
http://lib.dr.iastate.edu/extension_communities_pubs/24

Yield goal

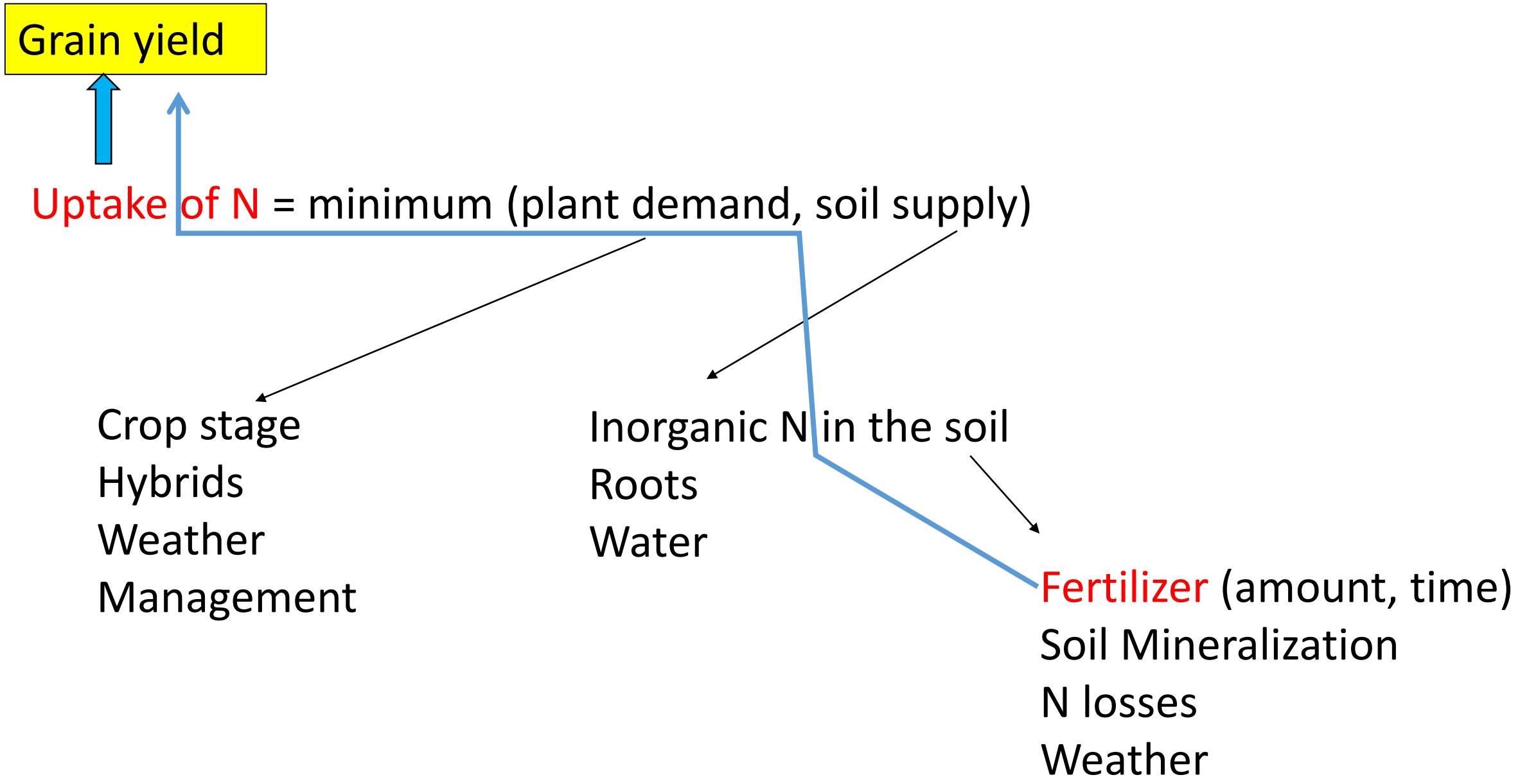


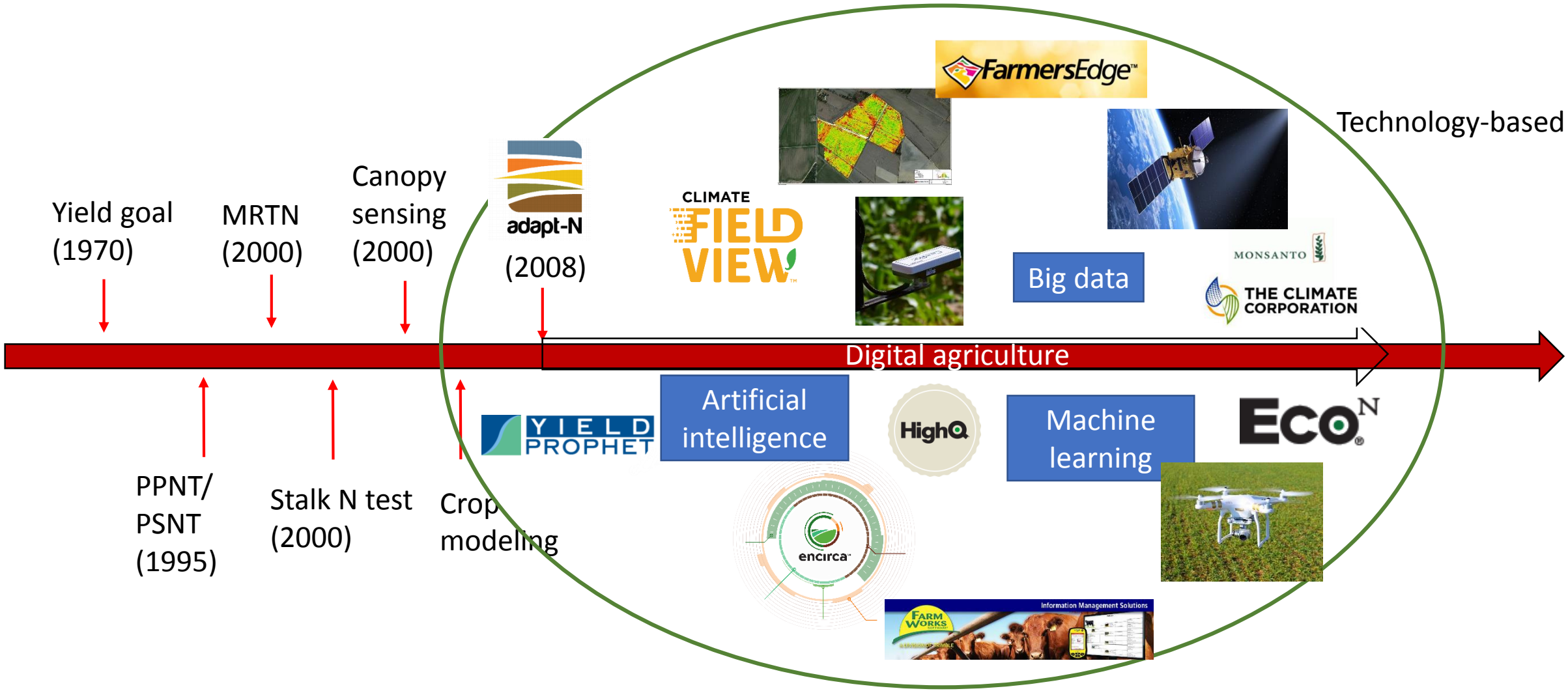
(n=325 data from Iowa)
FACTS database for CS rotation

MRTN

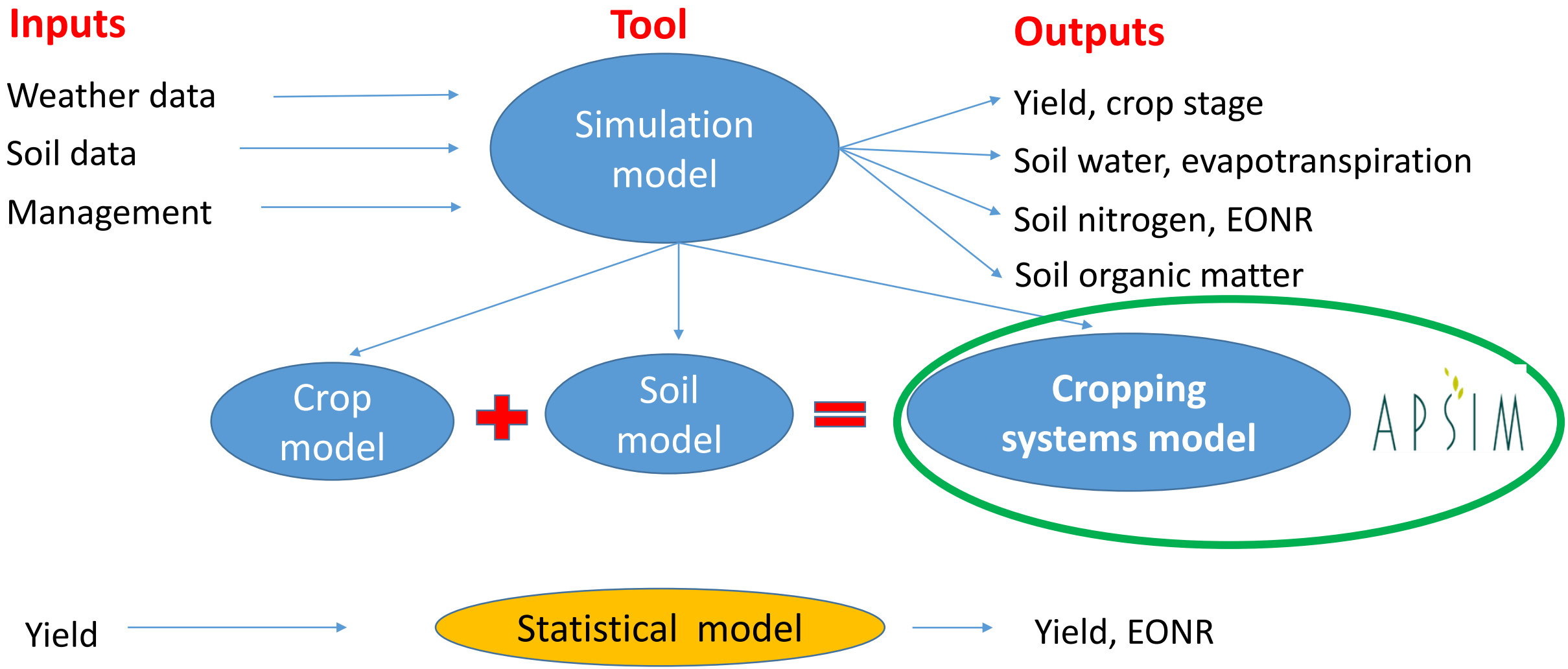


230 site-years, Iowa,
MRTN database for CS rotation


Grain yield
Uptake of N = minimum (plant demand, soil supply)
Crop stage
Hybrids
Weather
Management
Inorganic N in the soil
Roots
Water
Fertilizer (amount, time)
Soil Mineralization
N losses
Weather


Yield goal (1970)
MRTN (2000)
Canopy sensing (2000)
(2008)
Technology-based
Digital agriculture
PPNT/ PSNT (1995)
Stalk N test (2000)
Crop modeling
adapt-N
CLIMATE FIELD VIEW
FarmersEdge
MONSANTO
THE CLIMATE CORPORATION
Big data
YIELD PROPHET
Artificial intelligence
HighQ
Machine learning
ECO N
encirca
FARM WORKS
Information Management Solutions

Different types of simulation models



Three questions about models

1. Are you using models ? – in general, not just agronomic models

   Yes !

2. When was the first crop/soil model developed?

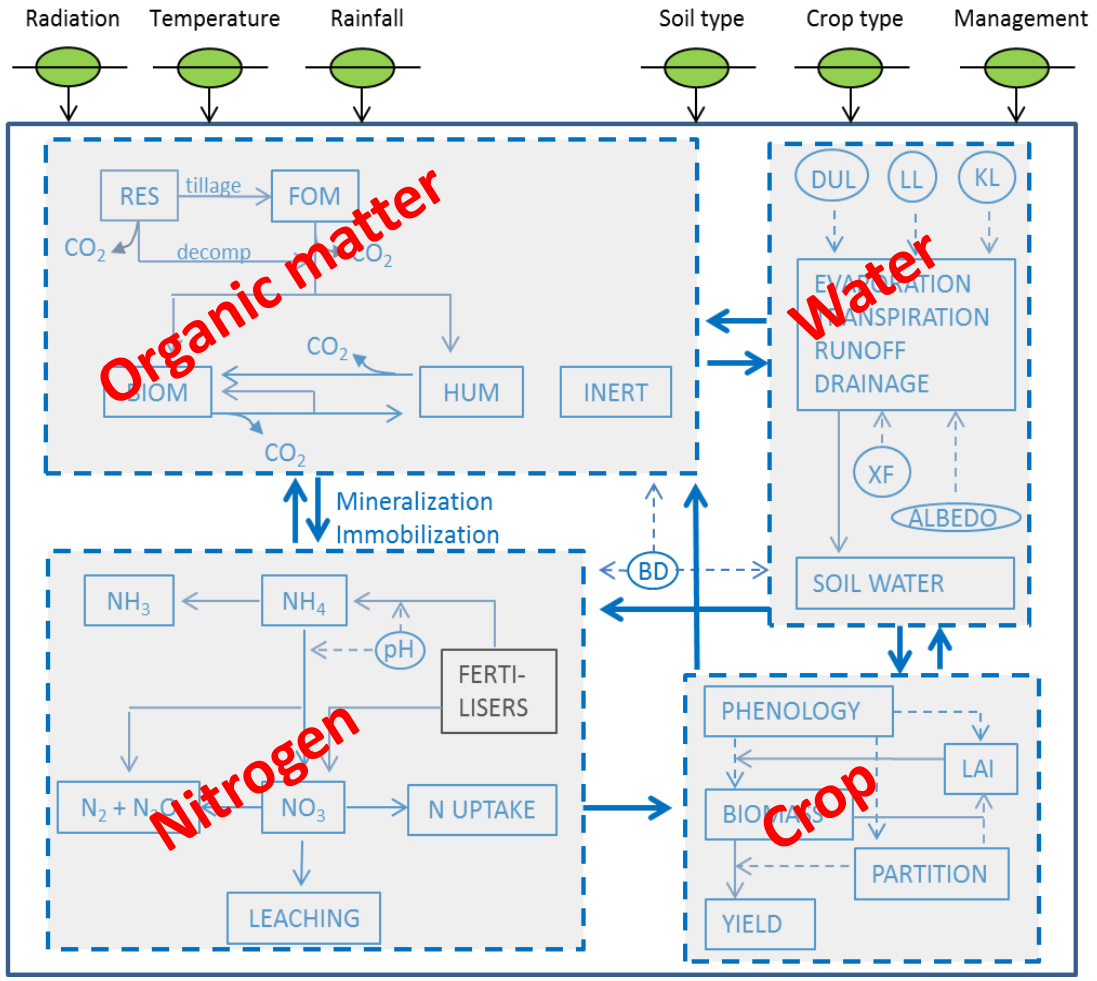
   50 years ago

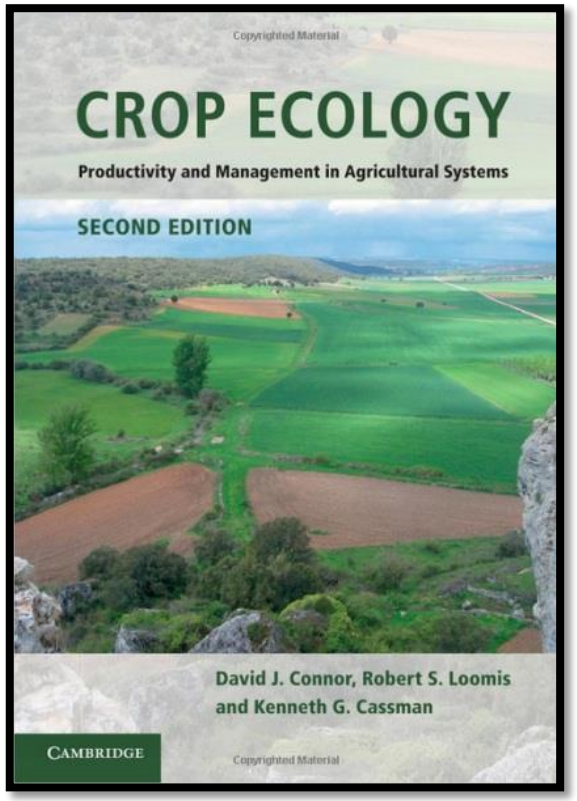
3. How many corn (and soil) models are available today?

   ~ 25 corn models, ~ 20 soil models

And one more – which is the best model?

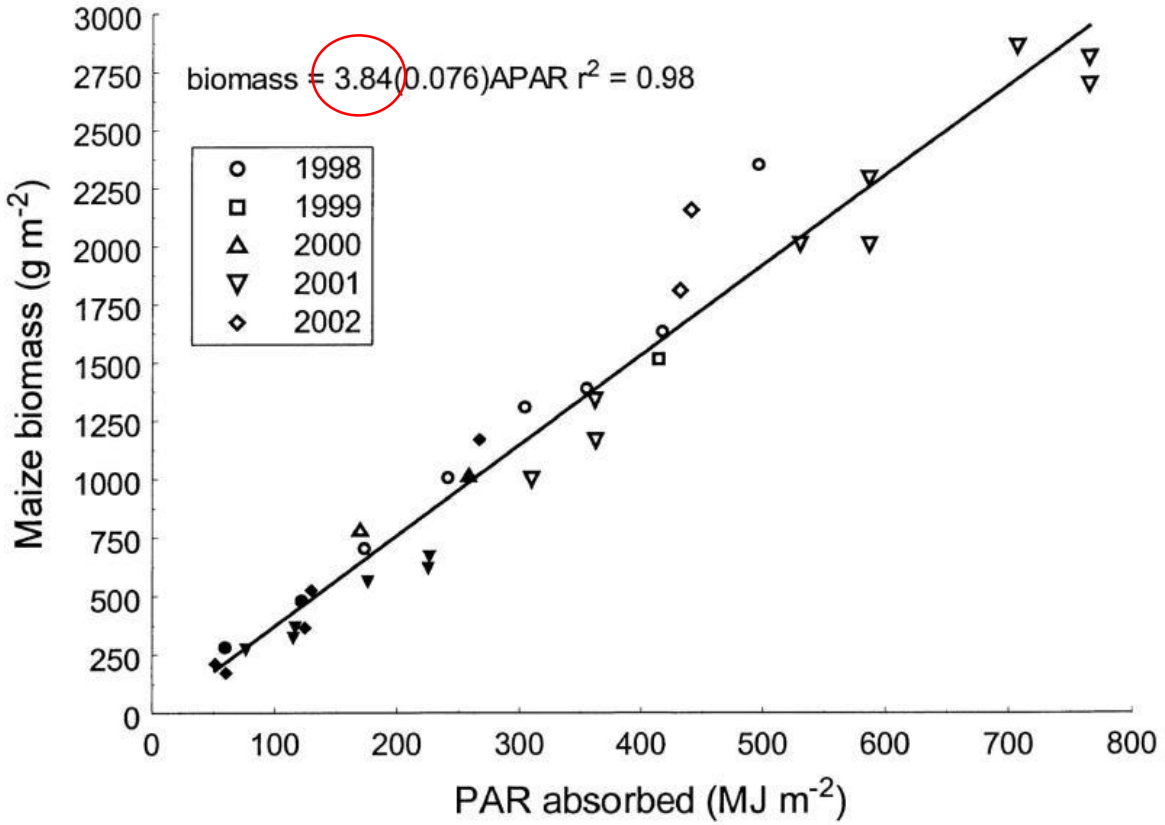
Behind the simulation models – the case of the APSIM model



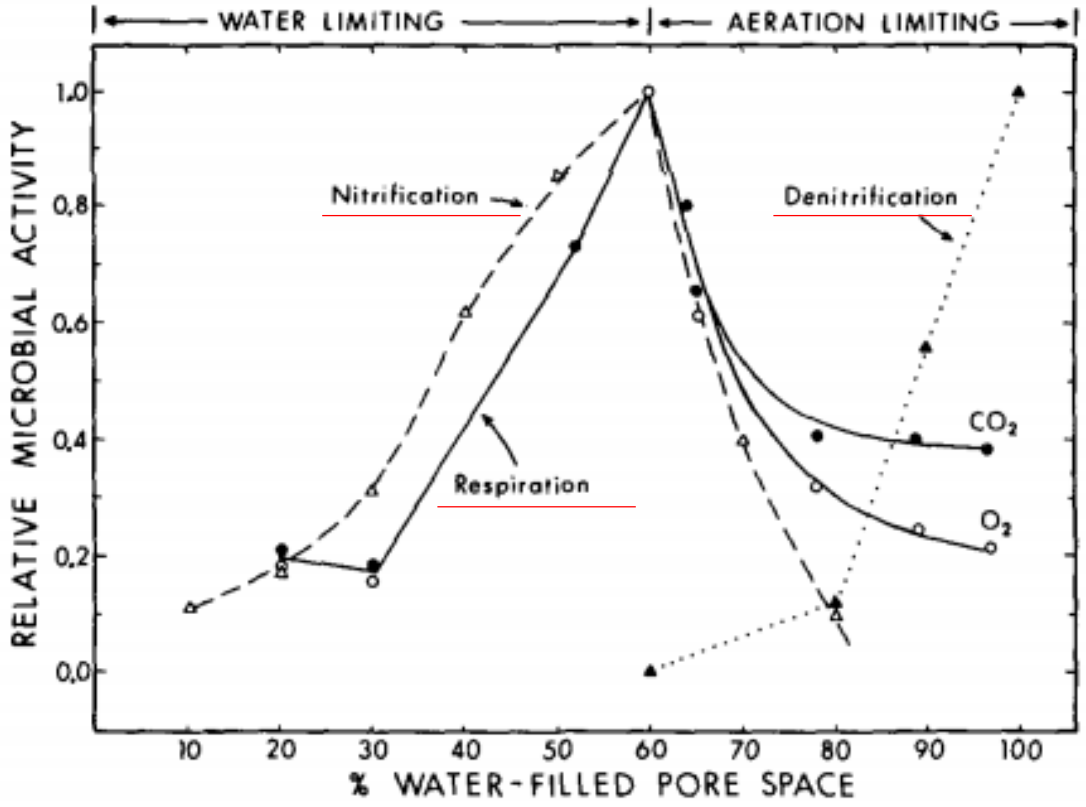


how much dry matter is produced per day
→ how much N and water is needed

how much N become available per layer for uptake

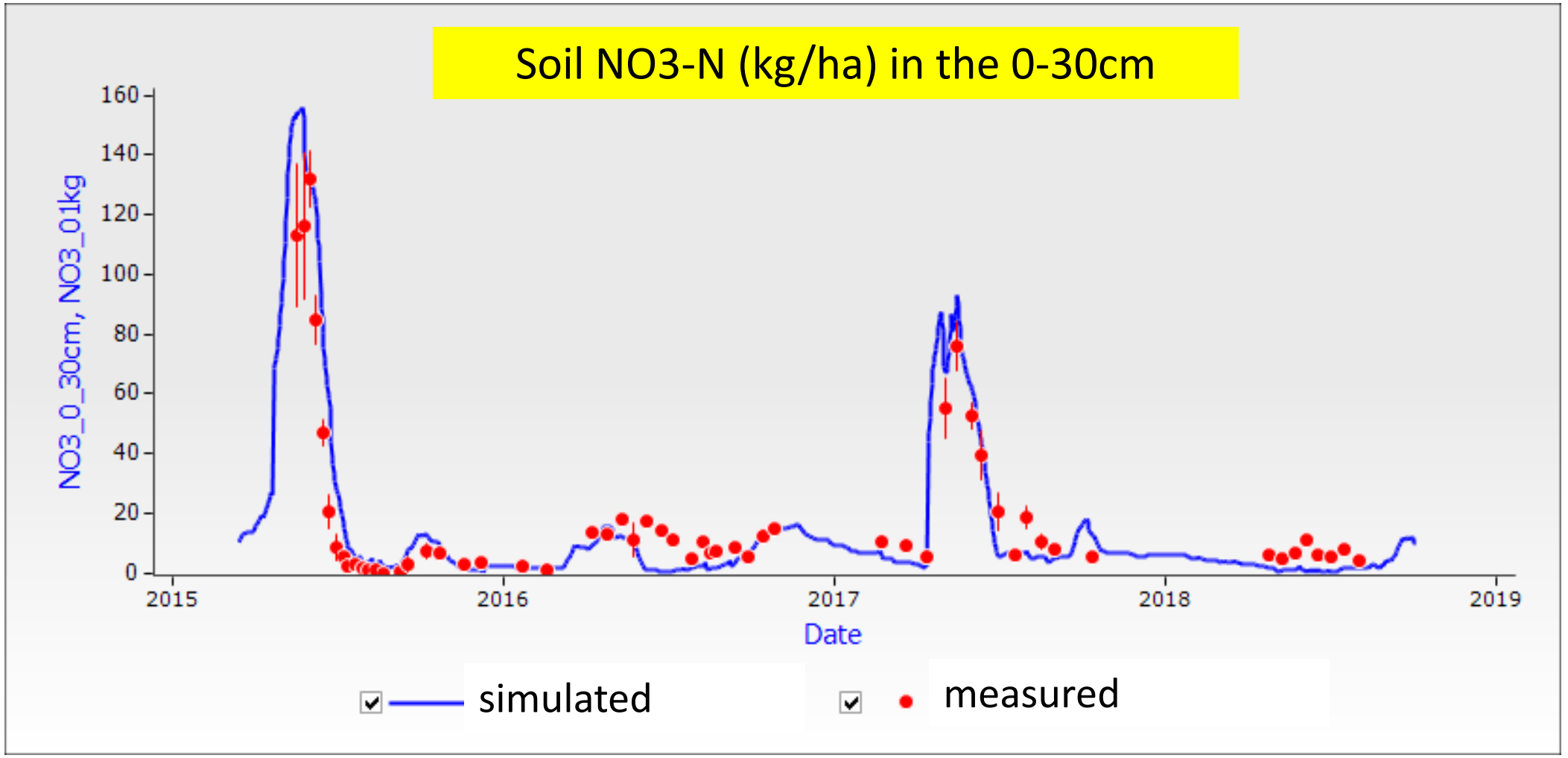


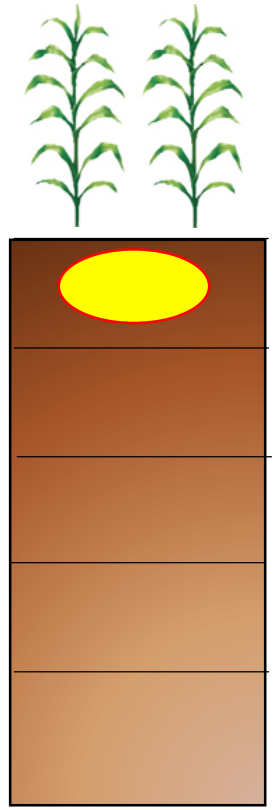
Lindquist et al., 2005 (Agron J)



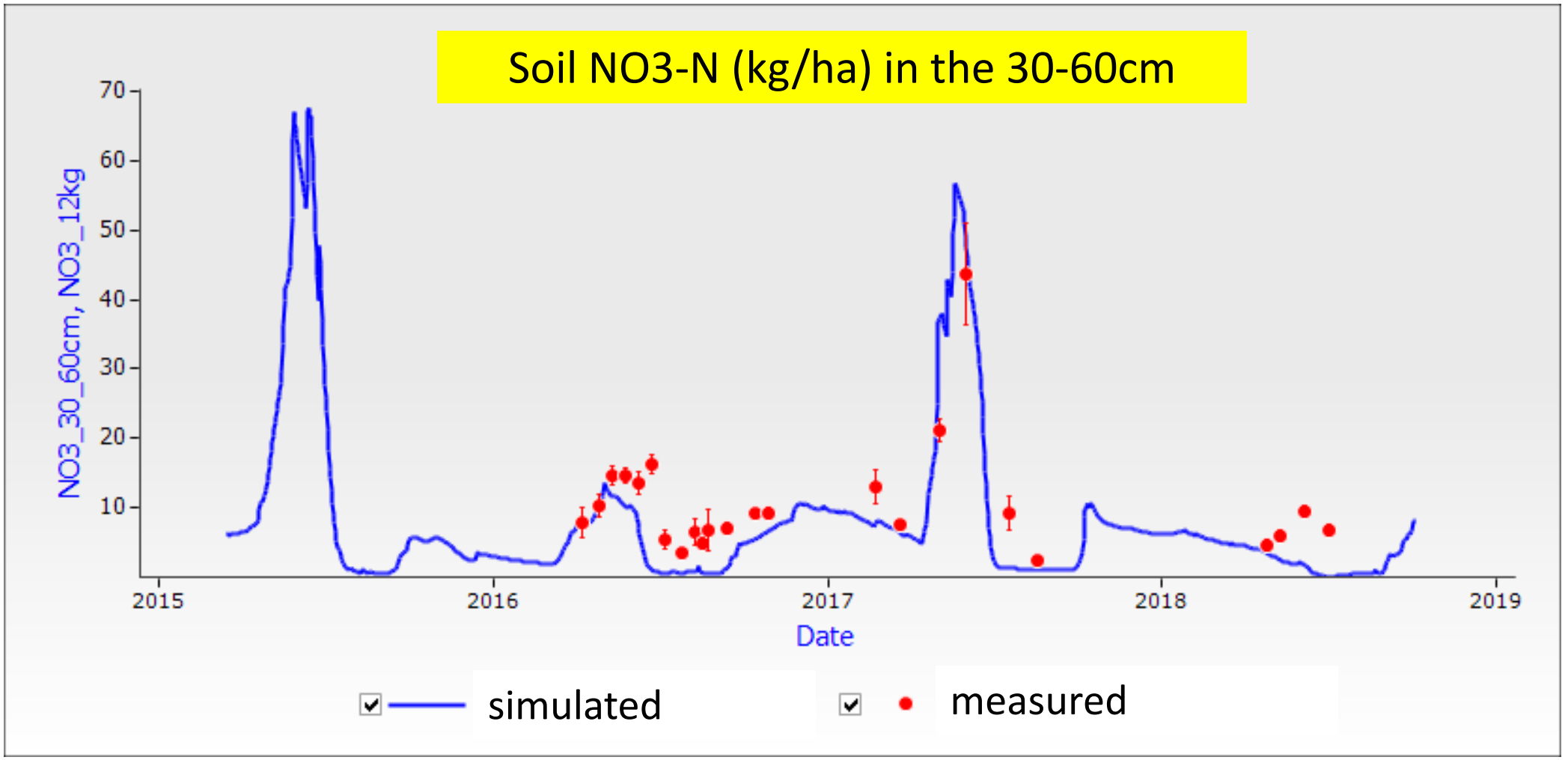
Linn and Doran, 1984 (SSSA)

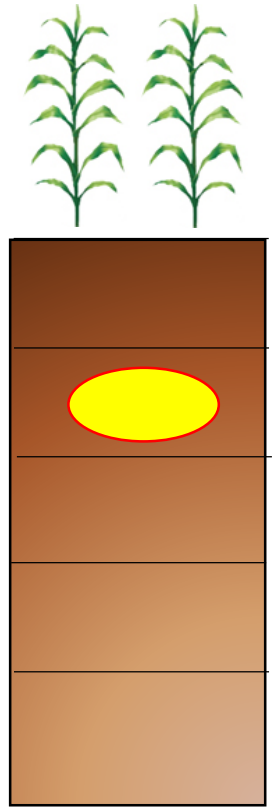
Testing the APSIM model – Corn-soybean rotation in Ames, IA



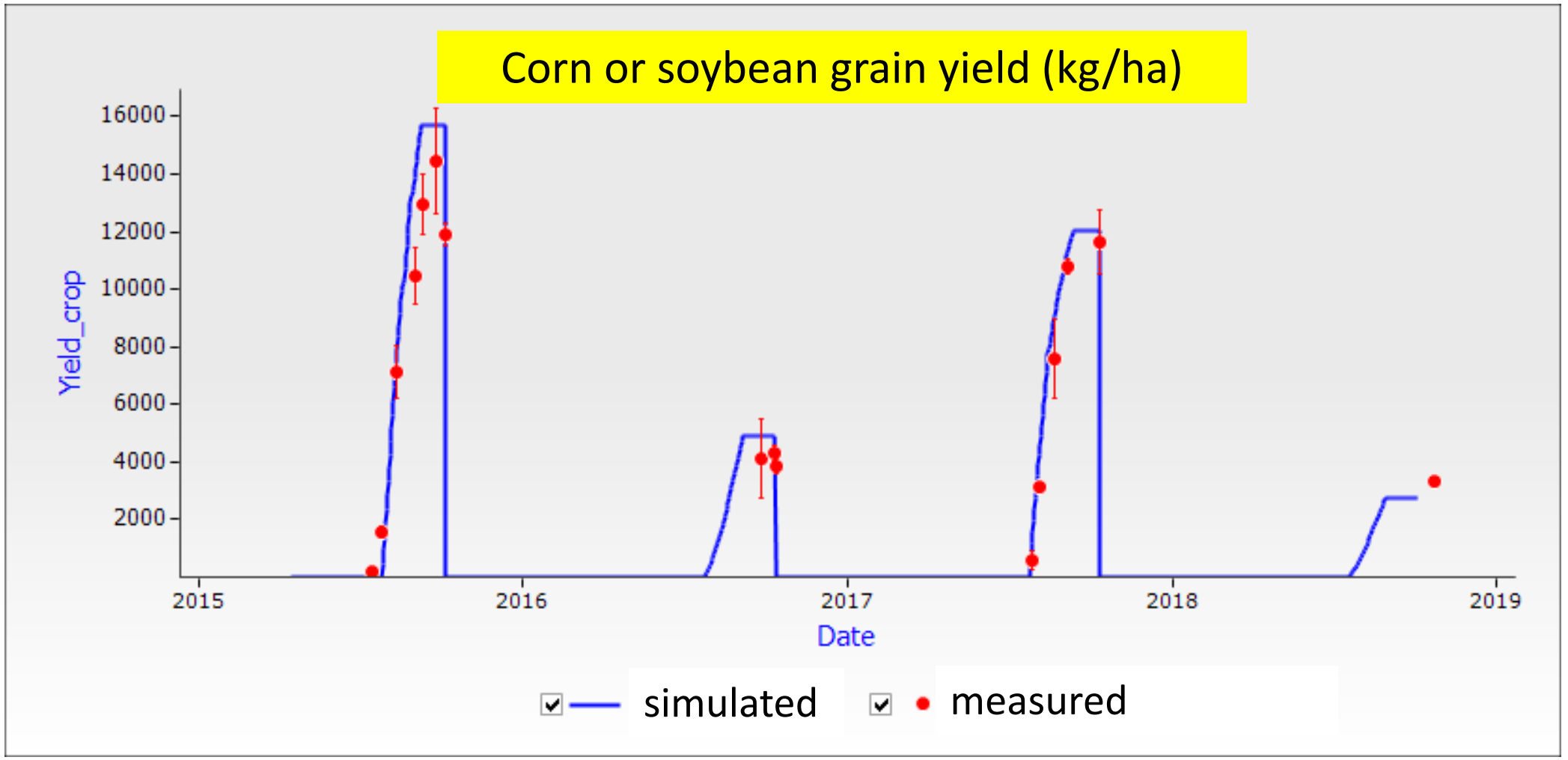


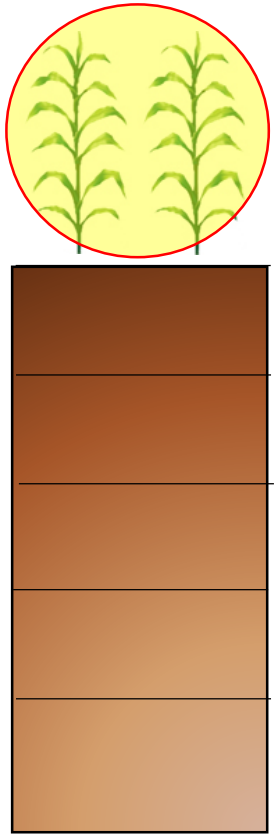
Testing the APSIM model – Corn-soybean rotation in Ames, IA





Testing the APSIM model





- N-fertilization approaches and simulation models

- Three examples:
  - **F**orecast and **A**ssessment of **C**ropping sys**T**em**S** (FACTS)
  - EONR prediction (complex model)
  - EONR prediction (simple model)

- Way forward for more accurate EONR predictions

The FACTS project at Iowa State University

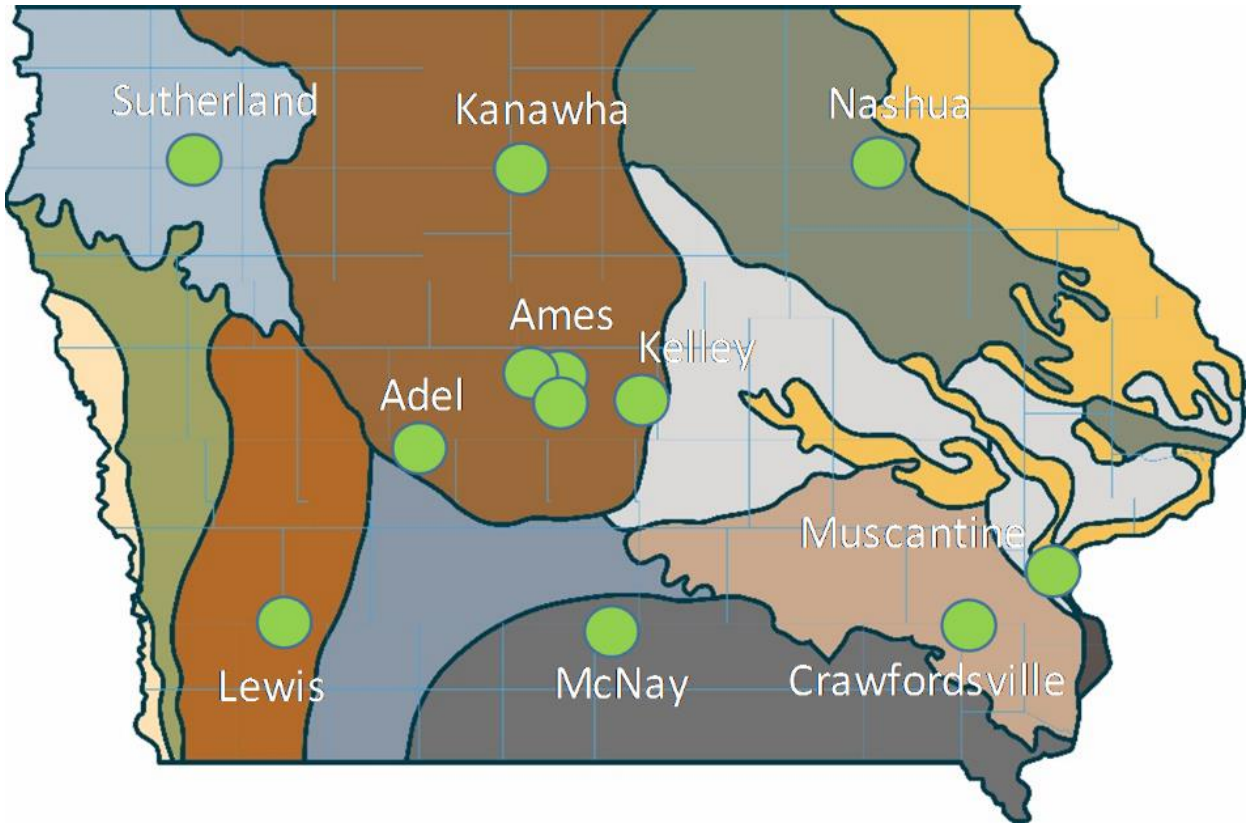
FACTS = public available web tool that provides real-time measurements and simulations for 10 ISU sites in IA: https://crops.extension.iastate.edu/facts/

WHY:

- Quantitative answers to farmers questions [during the season]
- Explain what happened and scenario analysis [after the season]

- Smoother transition to digital Ag space [ground-truth measurements]
- Improve science behind models

Experimental sites

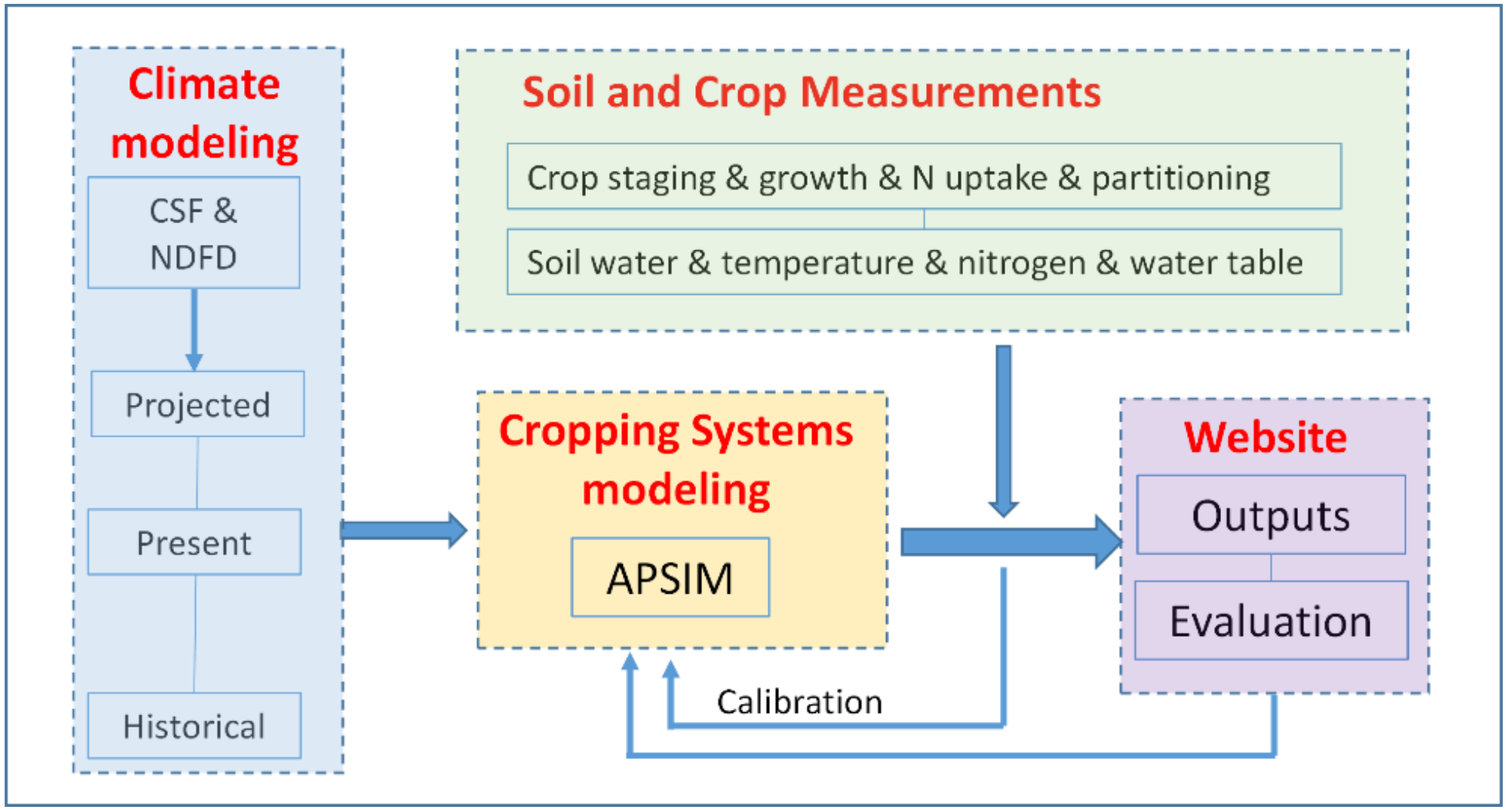


Measurements

- ✓ Soil moisture-temperature
- ✓ Depth to groundwater table
- ✓ Soil nitrate
- ✓ Plant growth, staging
- ✓ Yield and yield components
- ✓ Root depth, mass, length
- ✓ Tile Drainage and N leaching
- ✓ More

Years: 2015, 2016, 2017, 2018 …

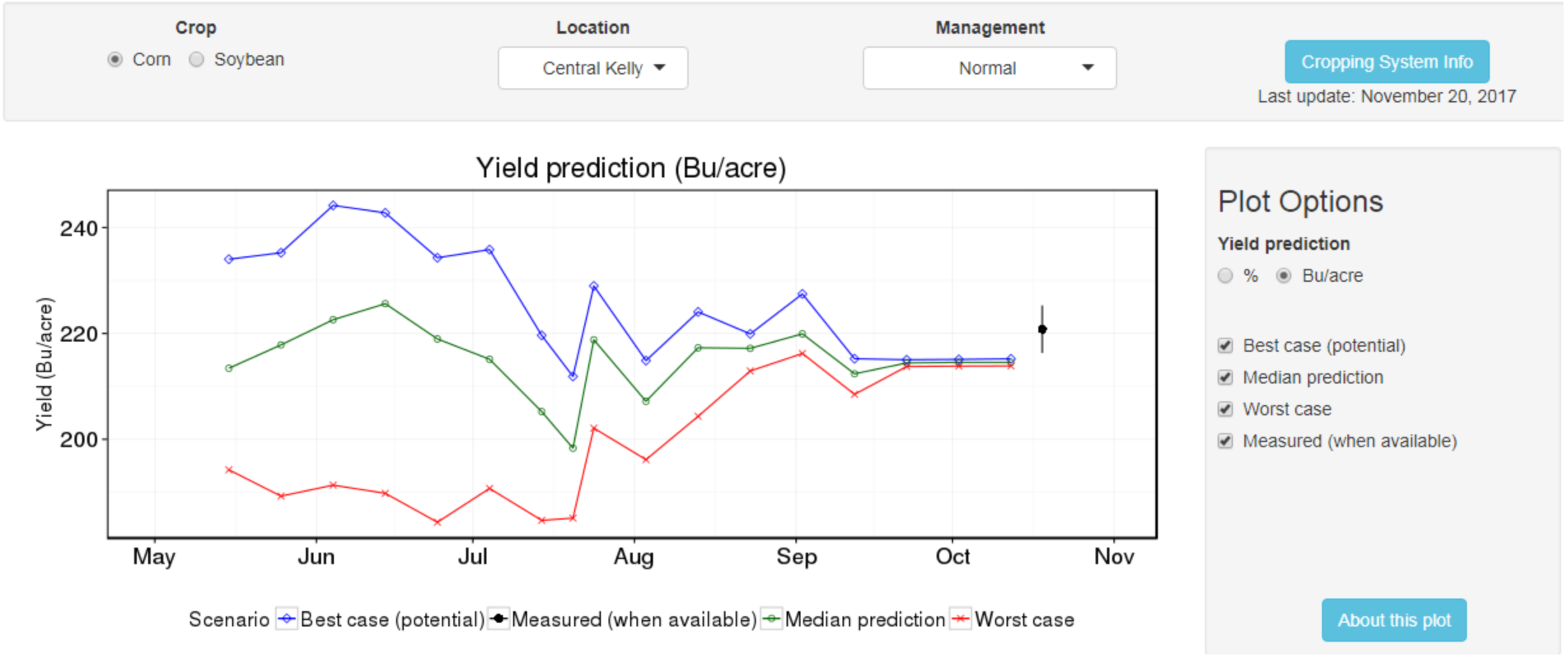
HOW:



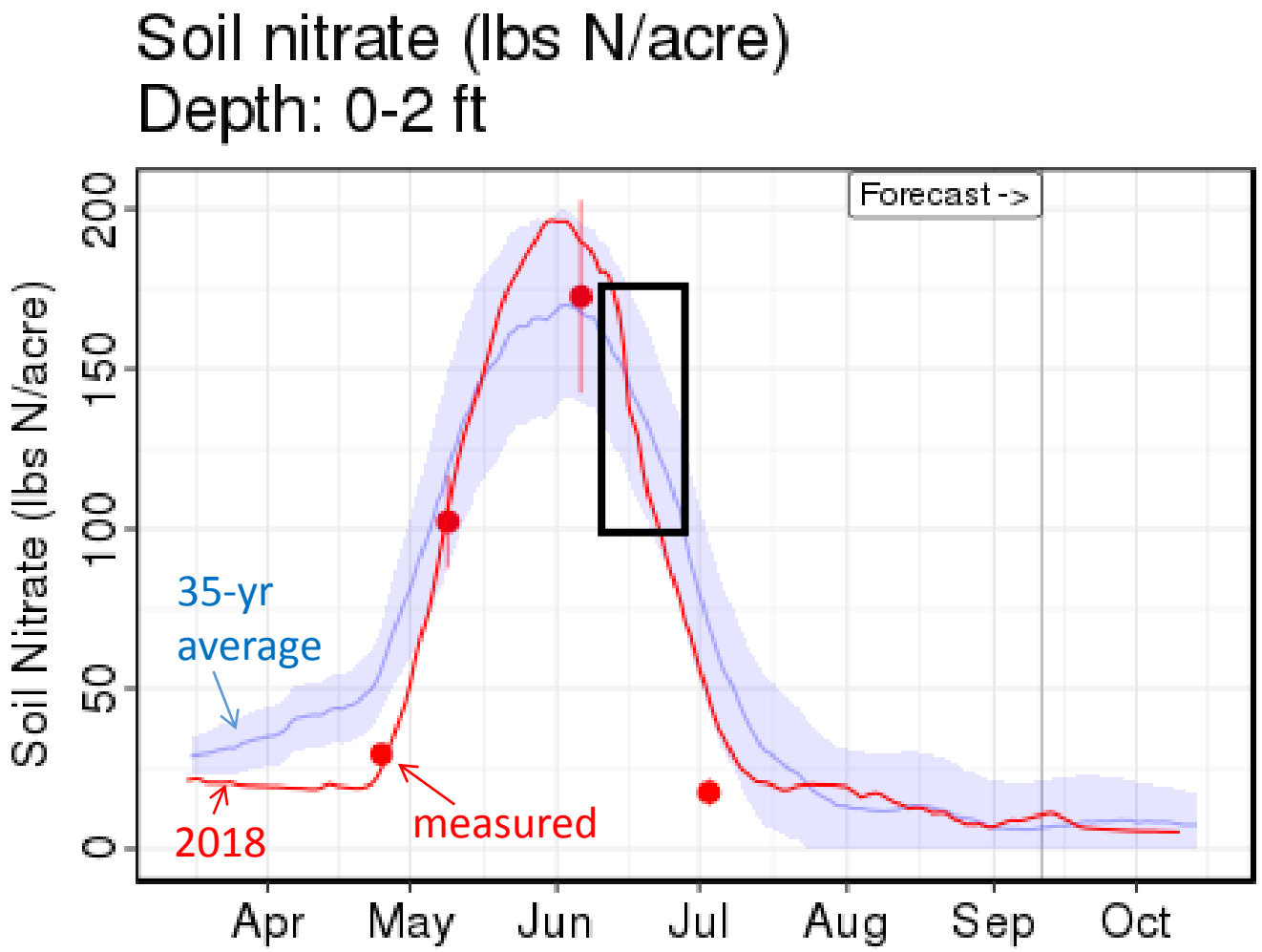
WHAT:

- ✓ Crop staging
- ✓ Crop yield
- ✓ Soil N
- ✓ Plant N
- ✓ Soil water
- ✓ Plant water
- ✓ Root depth
- ✓ Benchmarks
- ✓ Weather

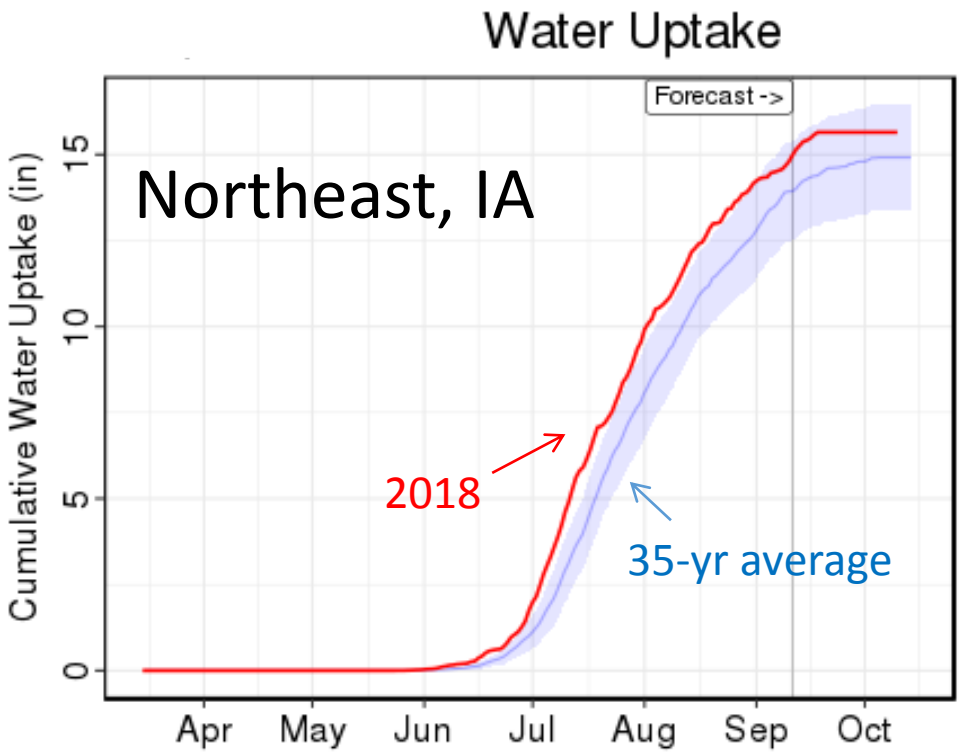
The FACTS part I: yield forecast

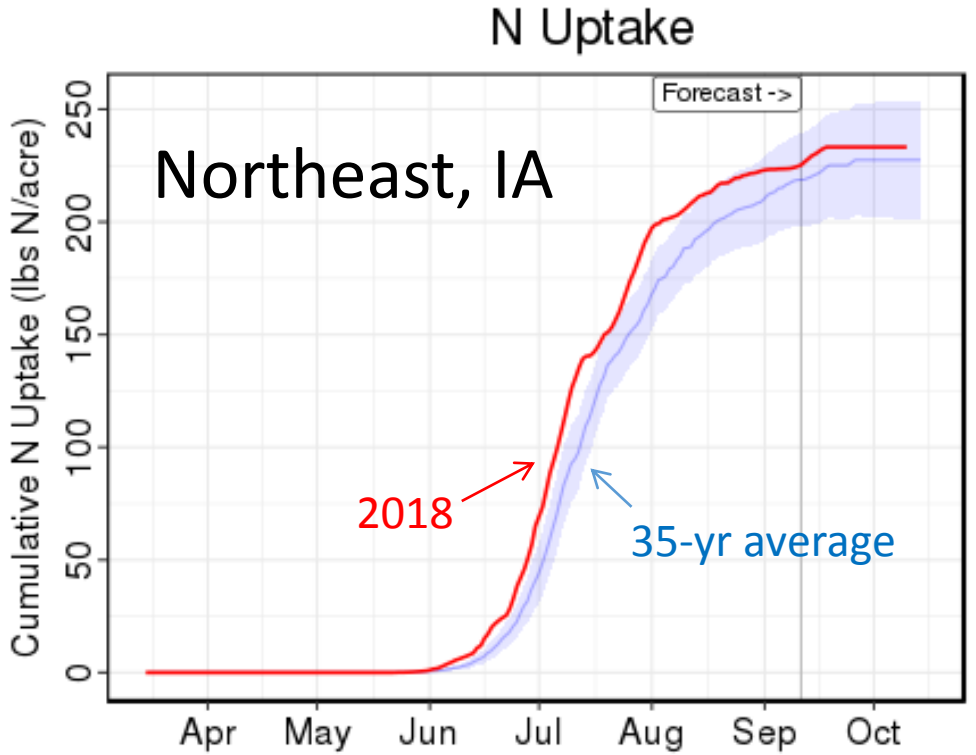


Boone, Iowa
Corn fertilized on Apr 23
N-rate = 150 lbs/ac, UAN
Year = 2018



Faster GDD accumulation → faster plant growth → faster root growth → faster water and nitrogen uptake … but fewer growing days

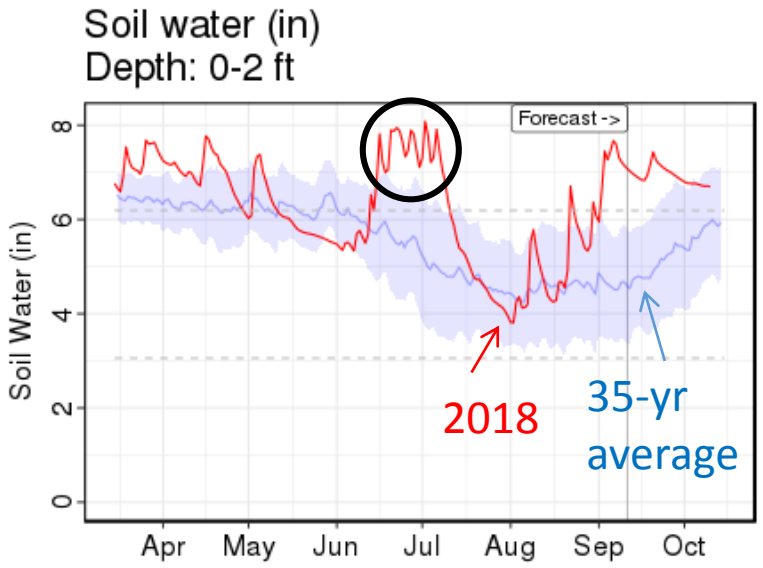




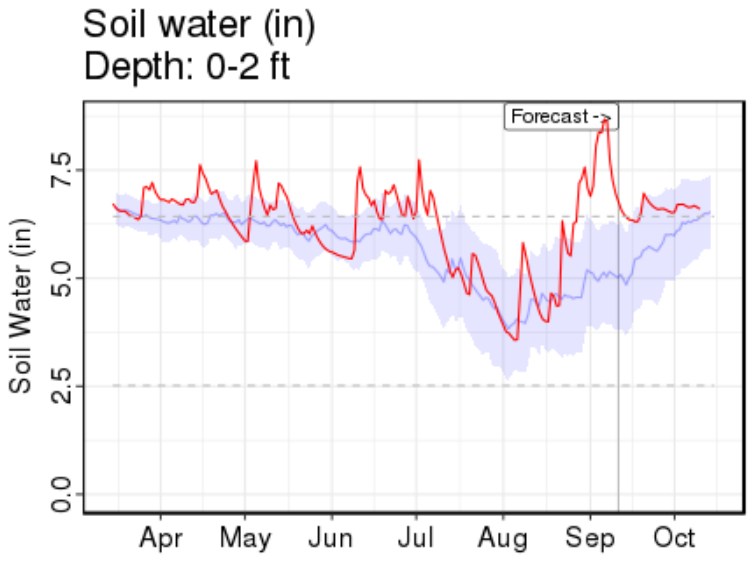
Simulated data: FACTS project

Top 2 feet soil moisture

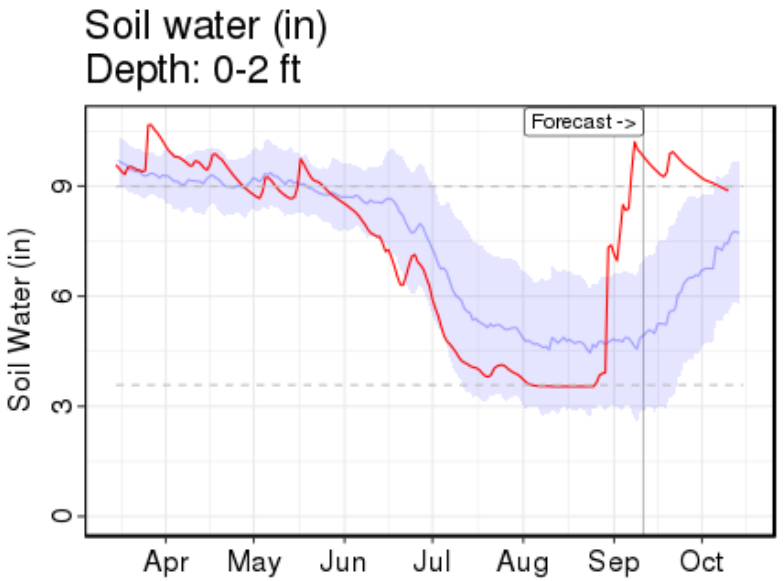
Central, IA
Very wet



Northeast, IA
Normal → wet



Southeast, IA
Dry → wet



Simulated data: FACTS project

Take-home messages from study 1

- Value out of the model in understanding/predicting the complex system
- June-July the months with the most web-visits
  - The addition of the 35-yr patterns was viewed very positively (benchmarking water and nitrogen status)
- Model prediction accuracy is good and getting better year by year.
- In 80% of the cases, yield prediction at planting time was close to measured

- N-fertilization approaches and simulation models

- Three examples:
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- Way forward for more accurate EONR predictions

John Sawyer

Laila Puntel

ORIGINAL RESEARCH ARTICLE

Front. Plant Sci., 11 November 2016 | https://doi.org/10.3389/fpls.2016.01630

Modeling Long-Term Corn Yield Response to Nitrogen Rate and Crop Rotation

Laila A. Puntel[1*], John E. Sawyer[1], Daniel W. Barker[1], Ranae Dietzel[1], Hanna Poffenbarger[1], Michael J. Castellano[1], Kenneth J. Moore[1], Peter Thorburn[2] and Sotirios V. Archontoulis[1*]

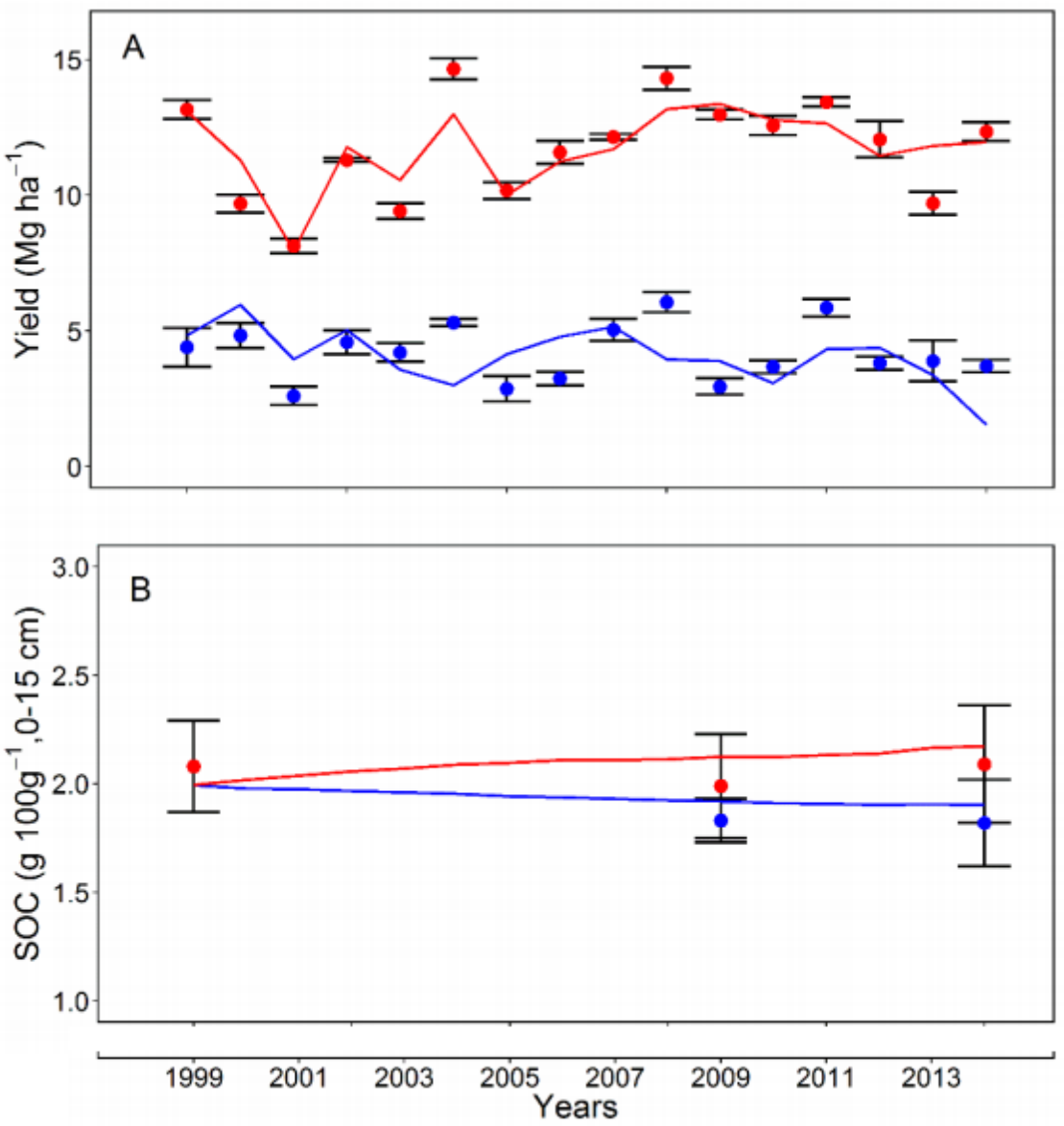
A Systems Modeling Approach to Forecast Corn Economic Optimum Nitrogen Rate

Laila A. Puntel[1*], John E. Sawyer[1], Daniel W. Barker[1], Peter J. Thorburn[2], Michael J. Castellano[1], Kenneth J. Moore[1], Andrew VanLoocke[1], Emily A. Heaton[2] and Sotirios V. Archontoulis[1*]

Model testing

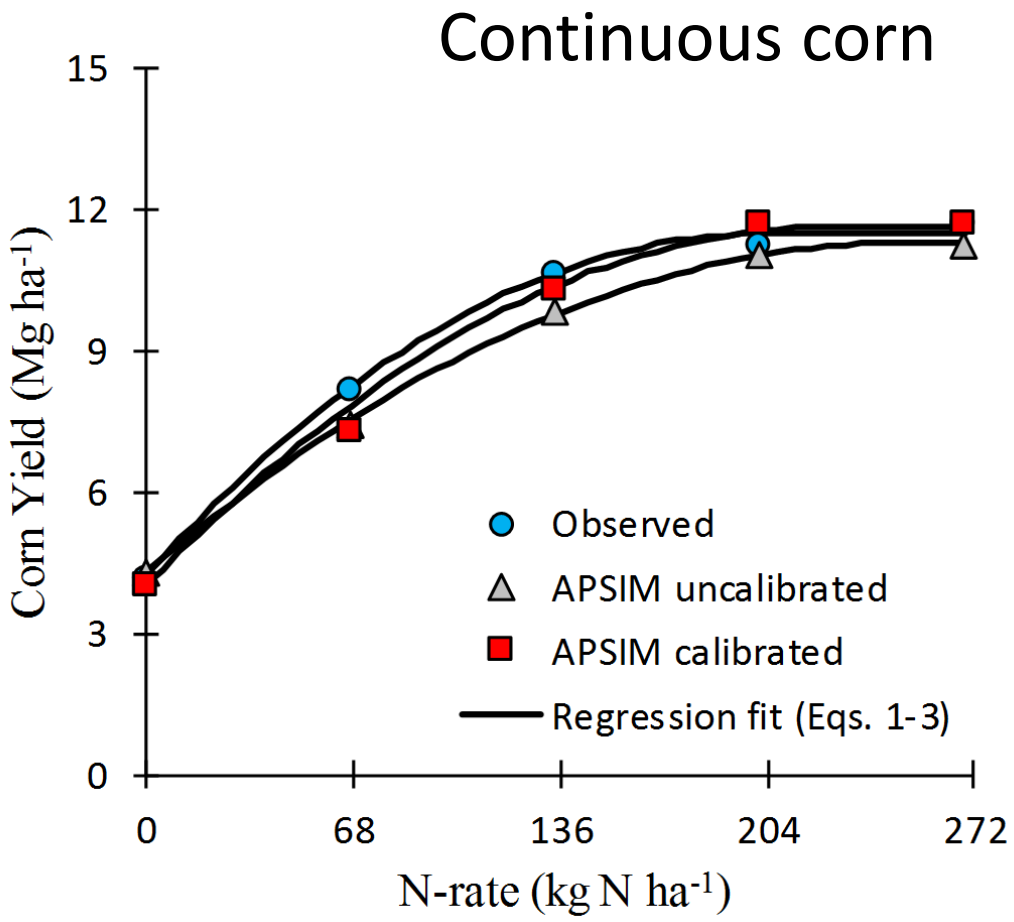
- 32 N-trials
- Two crop rotations
- Five N rates
- 1 site (Ames, IA), 14 years

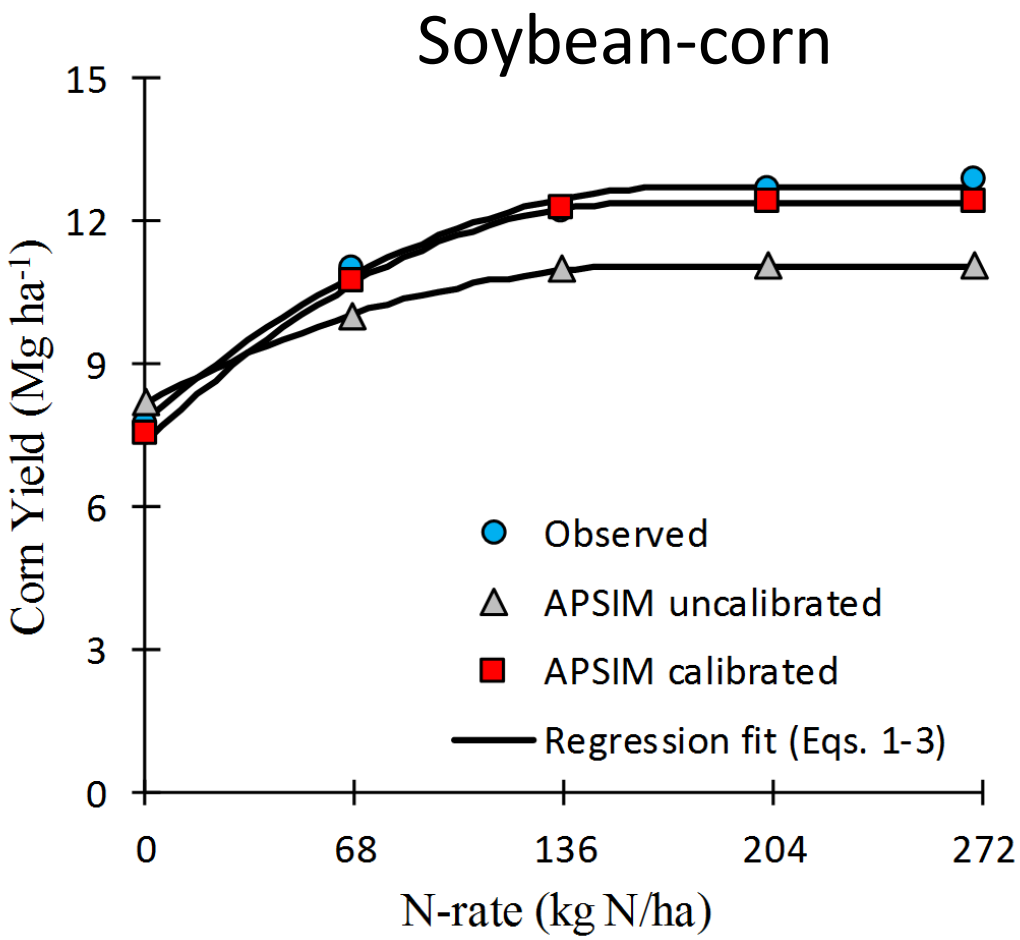
- Points = measurements
- Lines = simulations



Puntel et al., 2016.
Frontiers in Plant Science

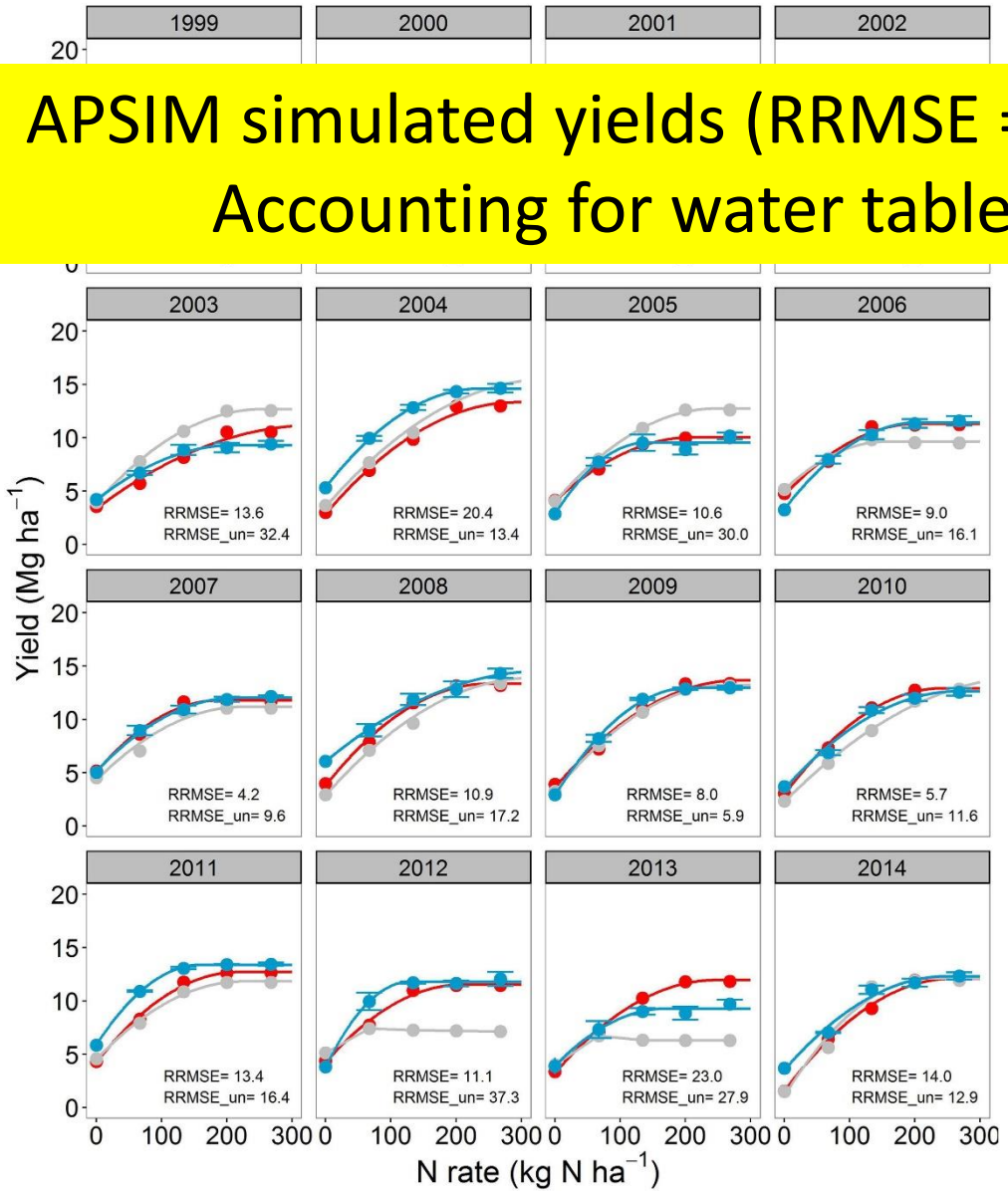
Long-term average EONR predictions very accurate

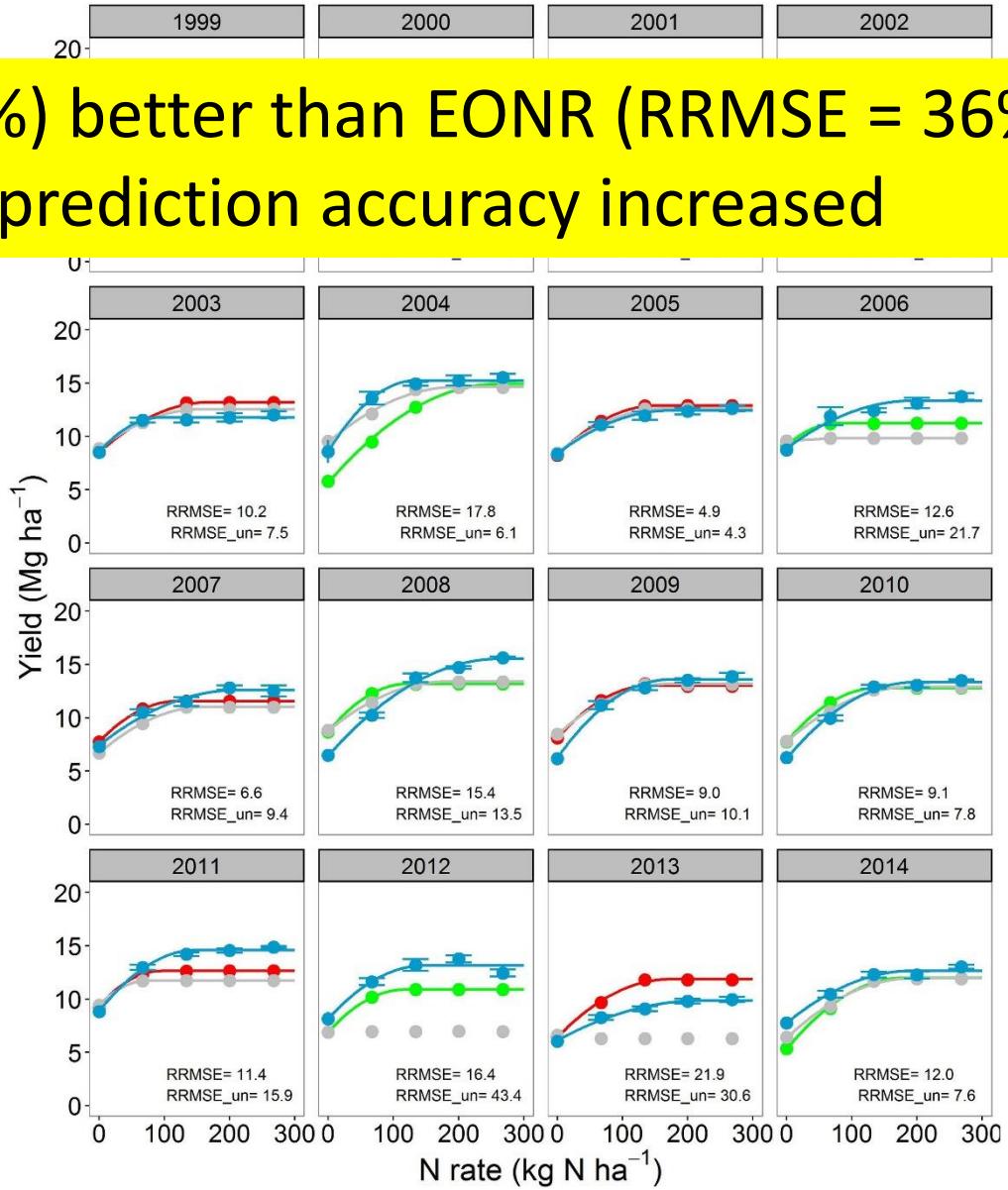




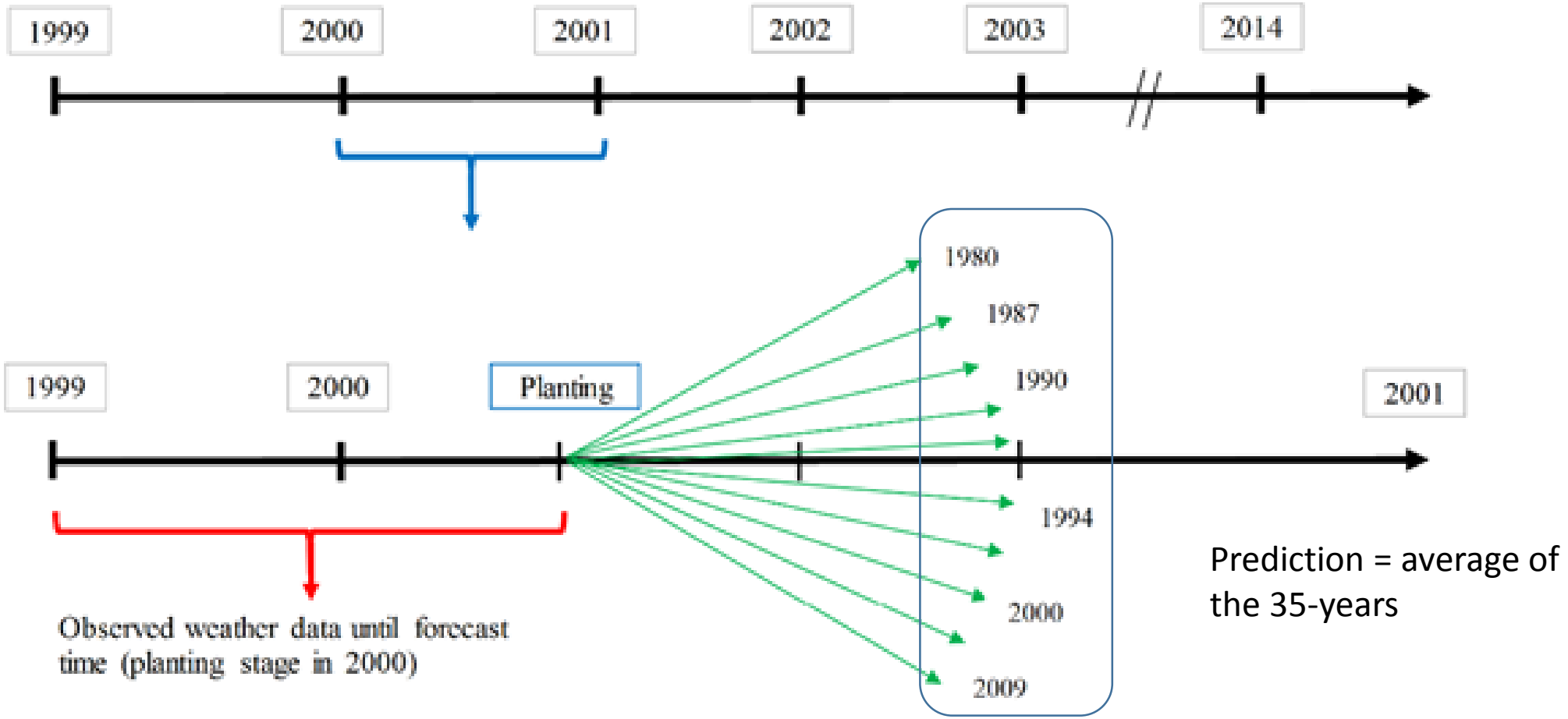
Puntel et al., 2016.
Frontiers in Plant Science

APSIM simulated yields (RRMSE = 12%) better than EONR (RRMSE = 36%)
Accounting for water table the prediction accuracy increased

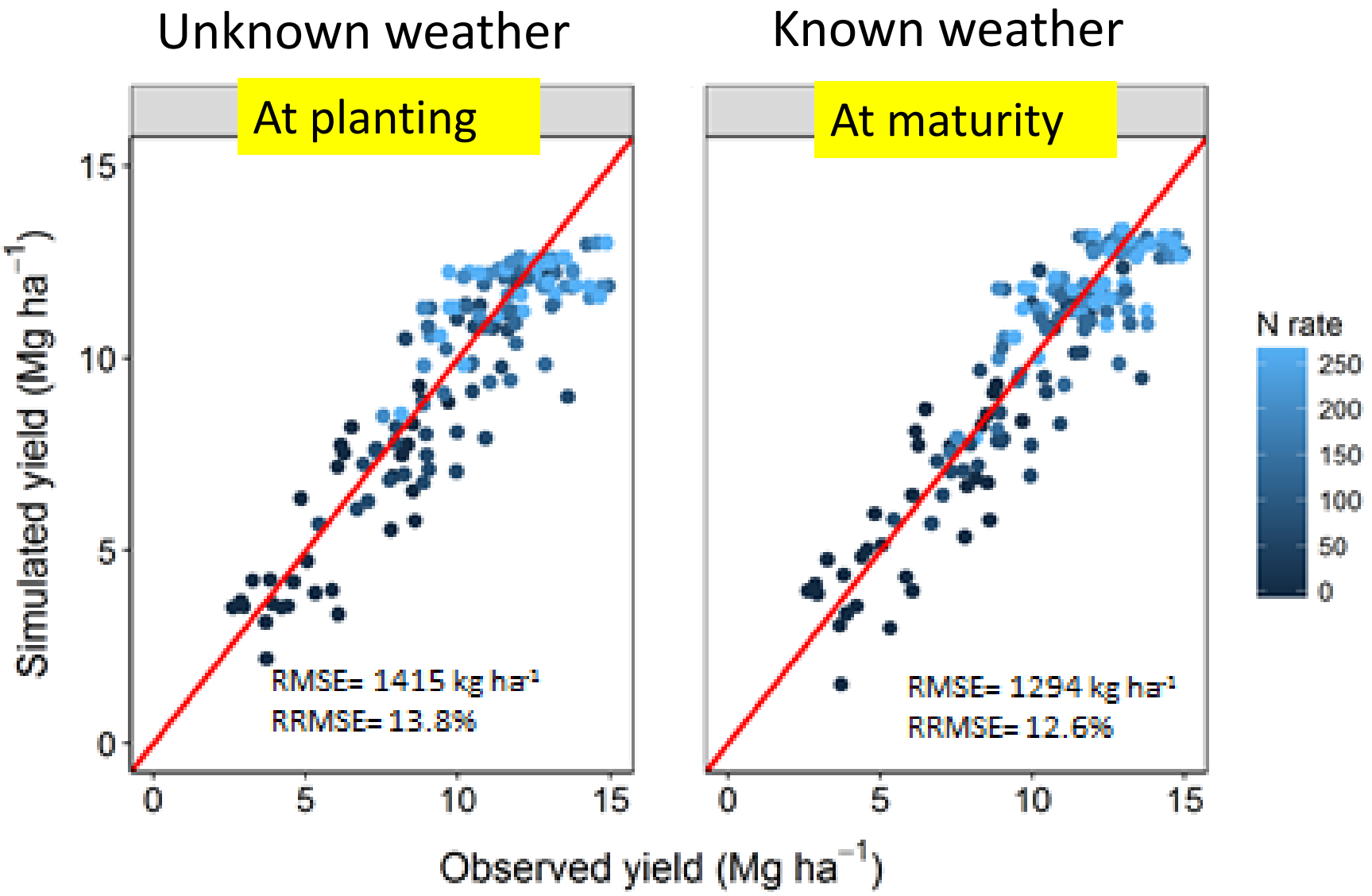




How accurately can APSIM predict yield and EONR at **planting time**?



Prediction = average of the 35-years



Puntel et al., 2018.
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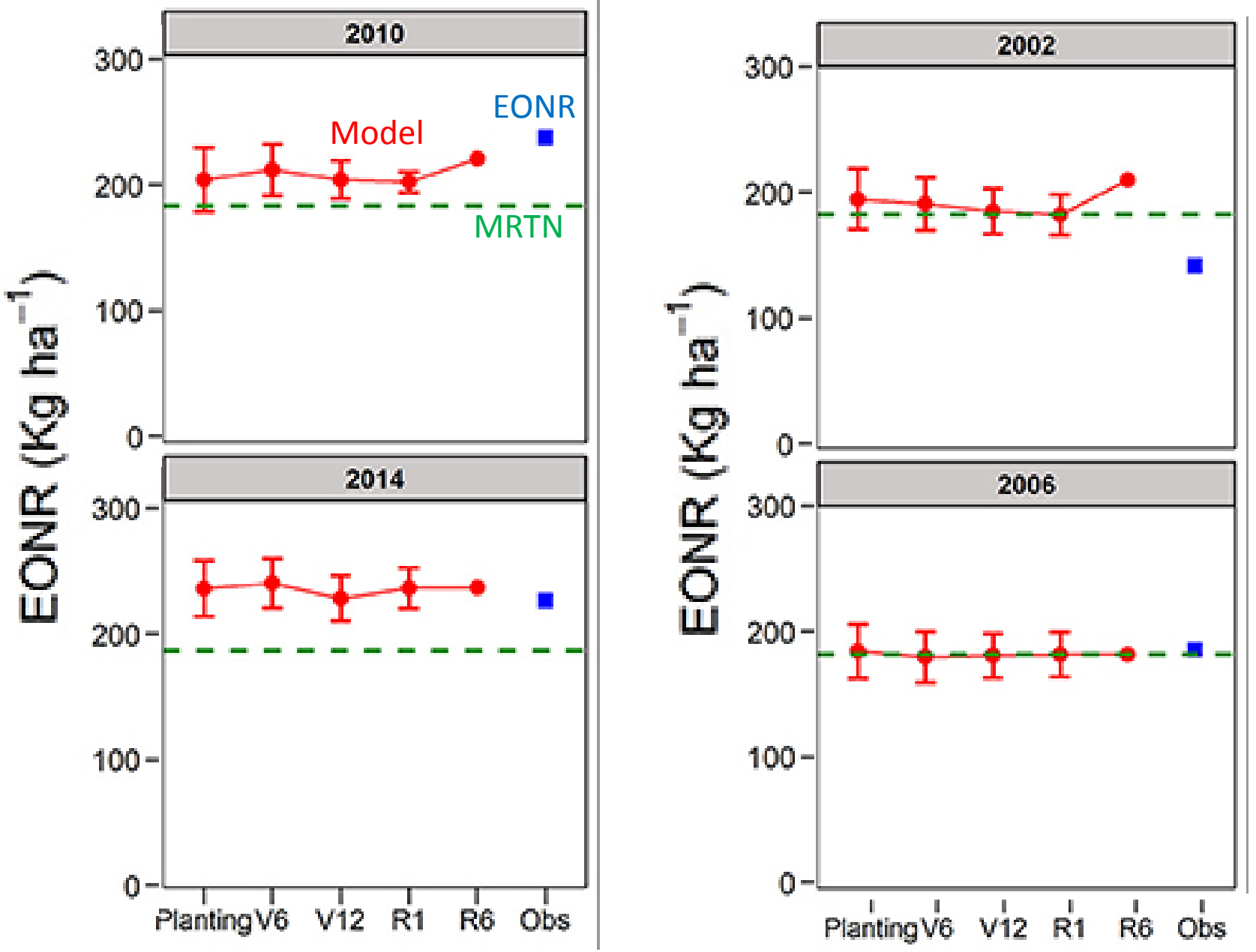
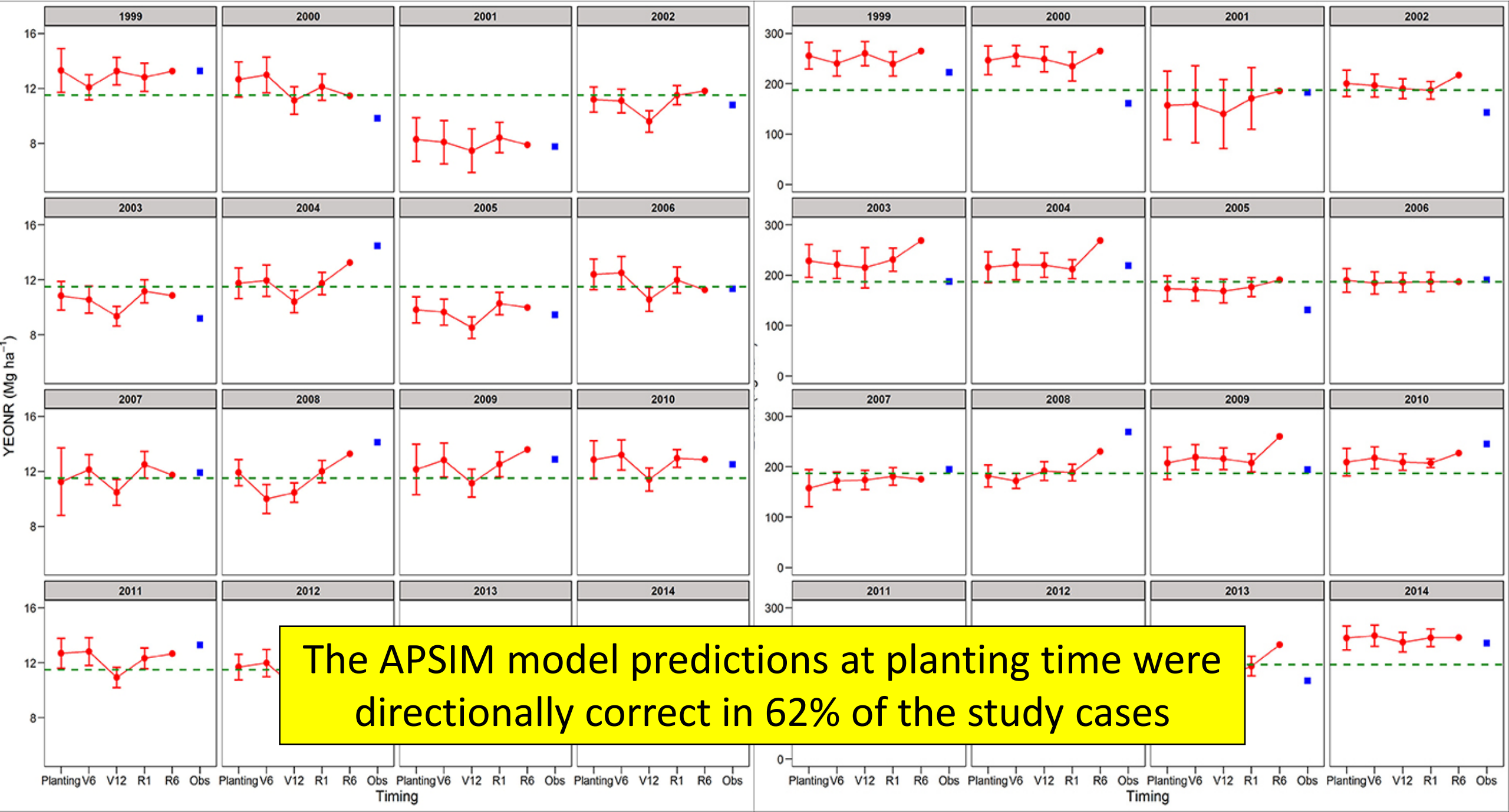
EONR forecast at different times

Continuous corn Iowa



Puntel et al., 2018.
Frontiers in Plant Science



The APSIM model predictions at planting time were directionally correct in 62% of the study cases

Puntel et al., 2018. Frontiers in Plant Science

Take-home messages from study 2

APSIM can be used as an EONR forecasting system:

- Direction
- EONR prediction at planting had about the same accuracy at the prediction at the end of the season

Benefits: science based approach that integrates G, M, and E

Drawbacks: computationally intensive and data input requirements

Next: testing in more sites

Puntel et al., 2018
Frontiers in Plant Science

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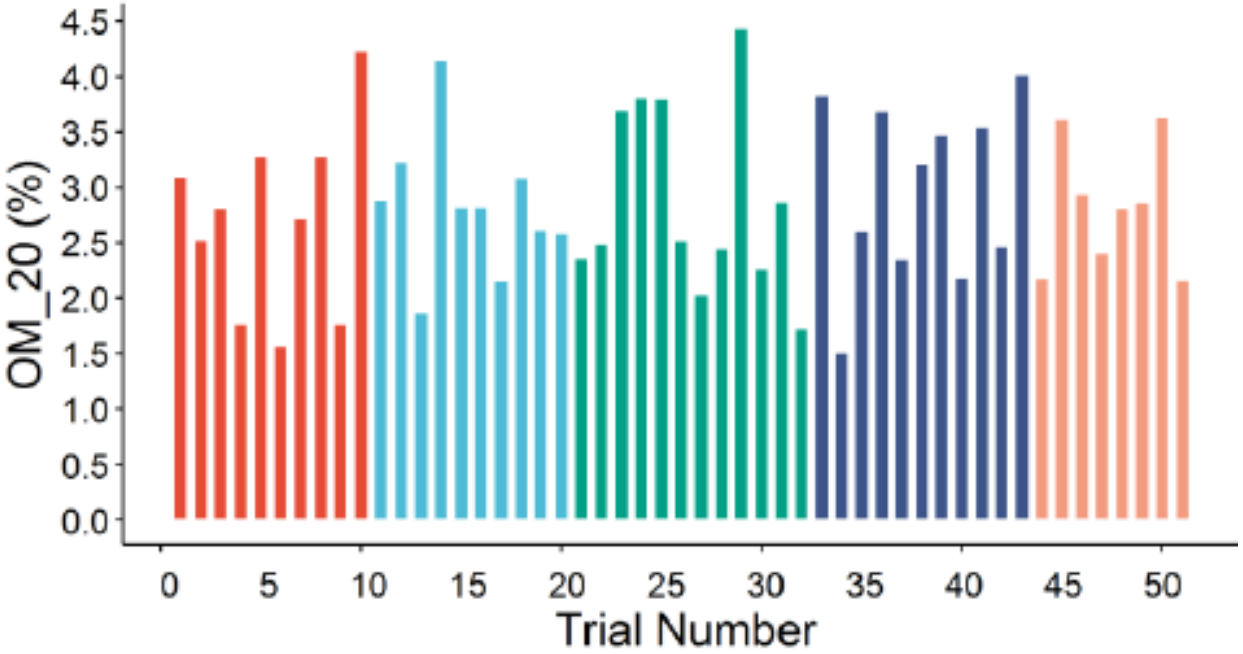
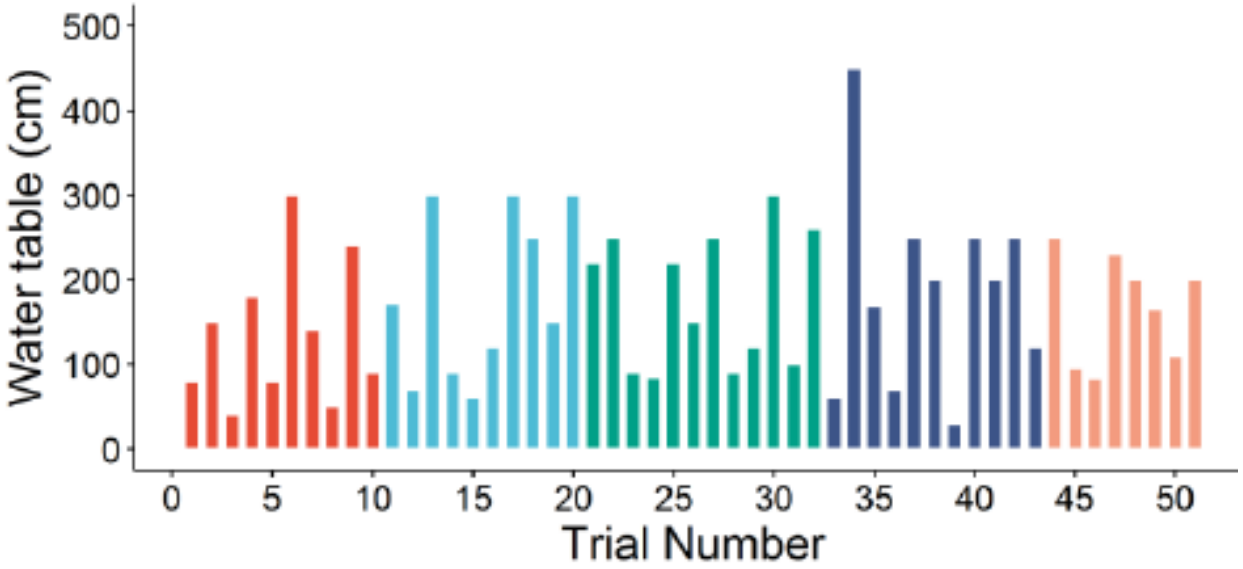
52 N-trials in Argentina
Several measurements per N-trial

Corn production (rainfed):
Argentina 40 million tons
USA 370 million tons



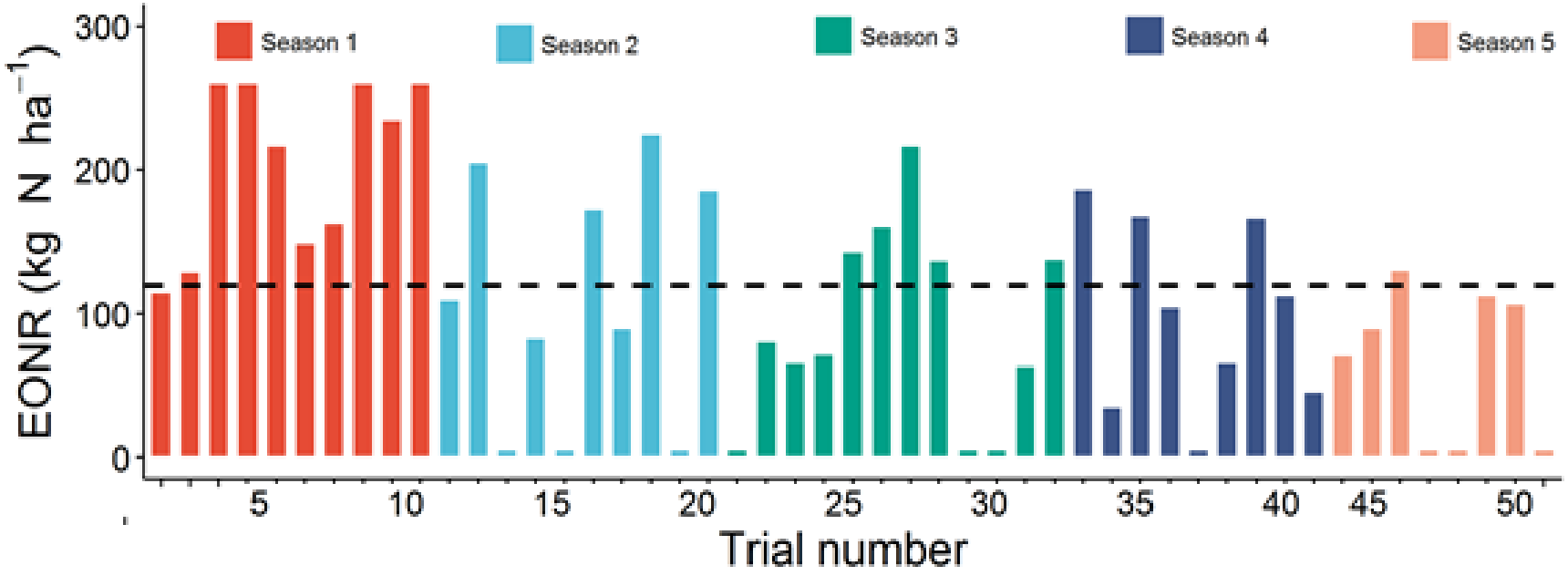


Puntel et al. *In review.*
European J. Agronomy

Research questions

1. Which factors do matter the most in the EONR prediction?
   - **Dynamic** factors (e.g. soil nitrate) or **static** (e.g. texture)?

2. Can simple statistical models predict yield and EONR?



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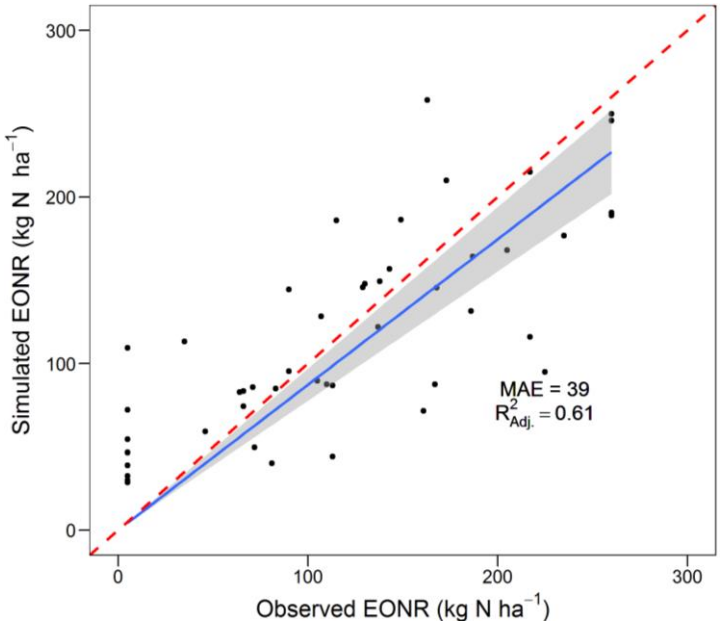
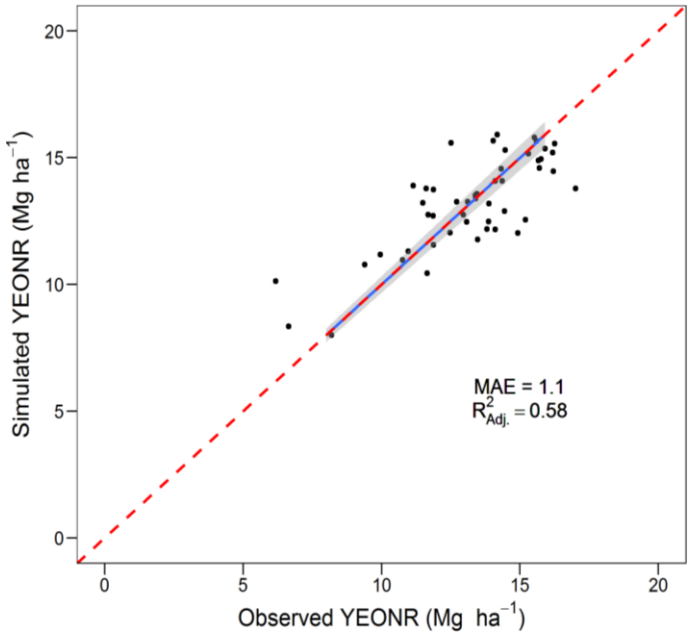
EONR

Static factors R^2_{adj} = 0.2
Dynamic factors R^2_{adj} = 0.50
Static + dynamic R^2_{adj} = 0.61



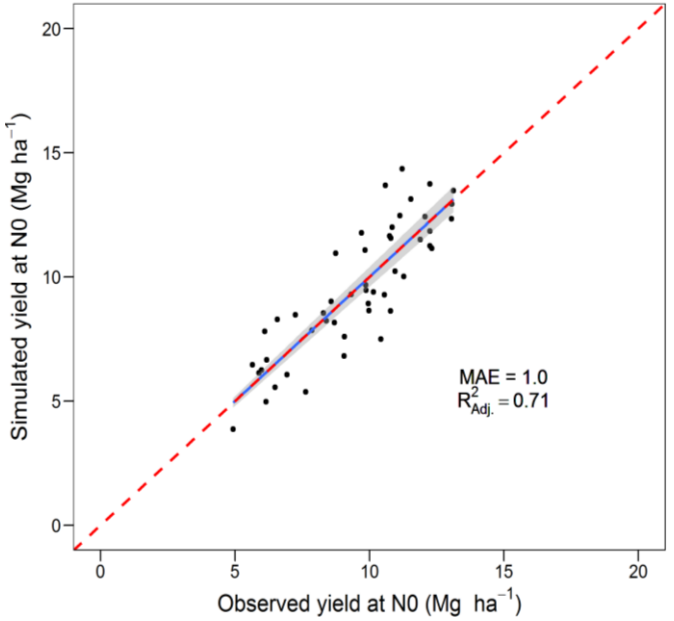
Yield at EONR

Static factors R^2_{adj} = 0.46
Dynamic factors R^2_{adj} = 0.38
Static + dynamic R^2_{adj} = 0.58



Yield at zero N

Static factors R^2_{adj} = 0.34
Dynamic factors R^2_{adj} = 0.54
Static + dynamic R^2_{adj} = 0.71



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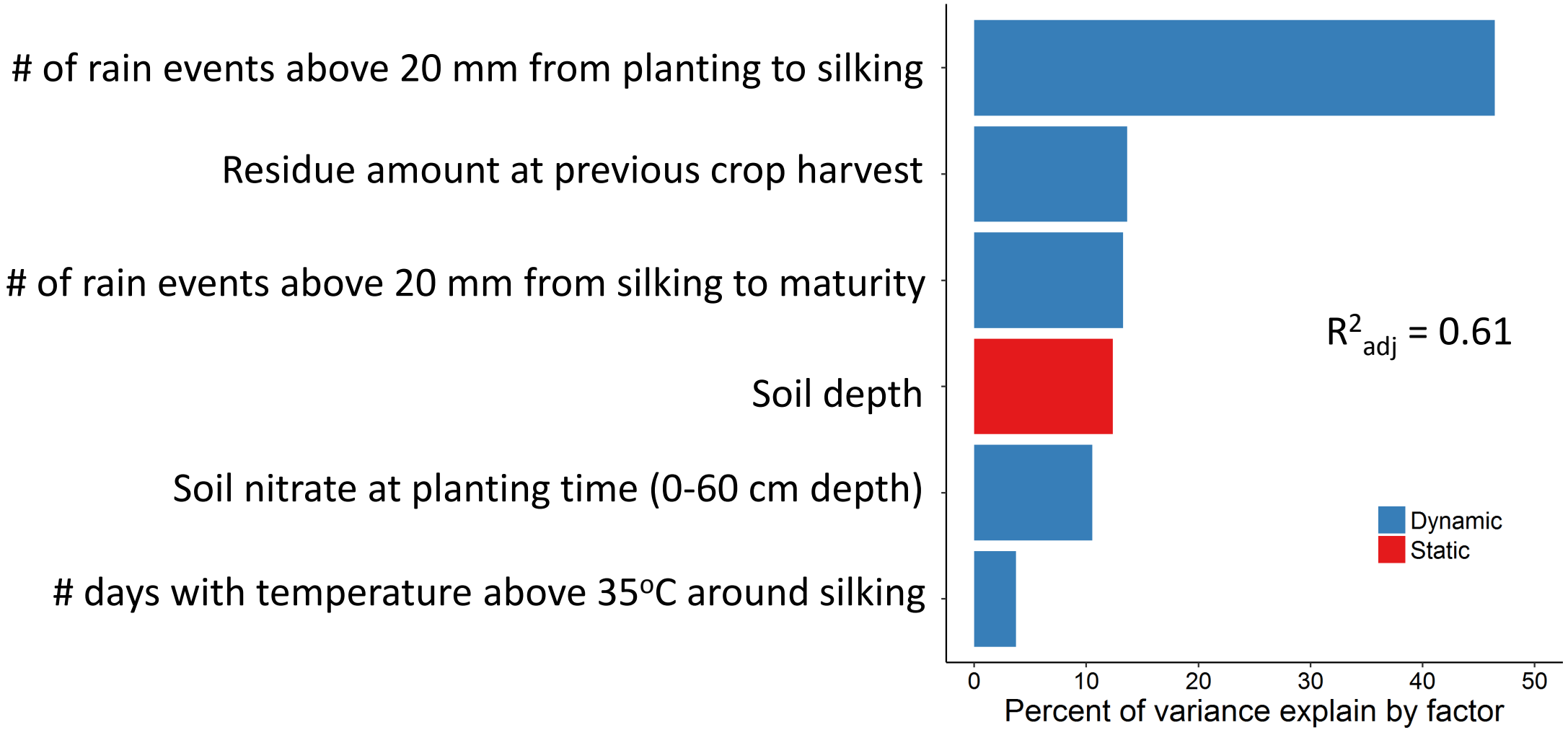
Which factors do matter the most in the EONR prediction?



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EONR (kg N/ha) = intercept + a_1 * soil depth + a_2 * residue amount + a_3 * soil nitrate + a_4 * rain events1 + a_5 * rain events2 + a_6 * temperature

Information only from previous crop harvest to this year's crop planting.
The new EONR forecasting tool:

EONR (kg N/ha) = intercept + b_1 * soil depth + b_2 * residue amount + b_3 * soil nitrate + b_4 * soil water at planting + b_5 * landscape curvature + b_6 * rain events (harvest to planting)

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Take-home messages from study 3

The new statistical model(s) can explain about 60% of the EONR variability

Fills the space between simple (MRTN) and complex (APSIM) models

High potential in view of increasing data availability

Dynamic factors the most important in EONR prediction

- # rain events > 20 mm (about 1’’)
- Yield of previous crop not important!

- N-fertilization approaches and simulation models

- Three examples:
  - **F**orecast and **A**ssessment of **C**ropping sys**T**em**S** (FACTS)
  - EONR prediction (complex model)
  - EONR prediction (simple model)

- Way forward for more accurate EONR predictions

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REVIEWS & INTERPRETATIONS

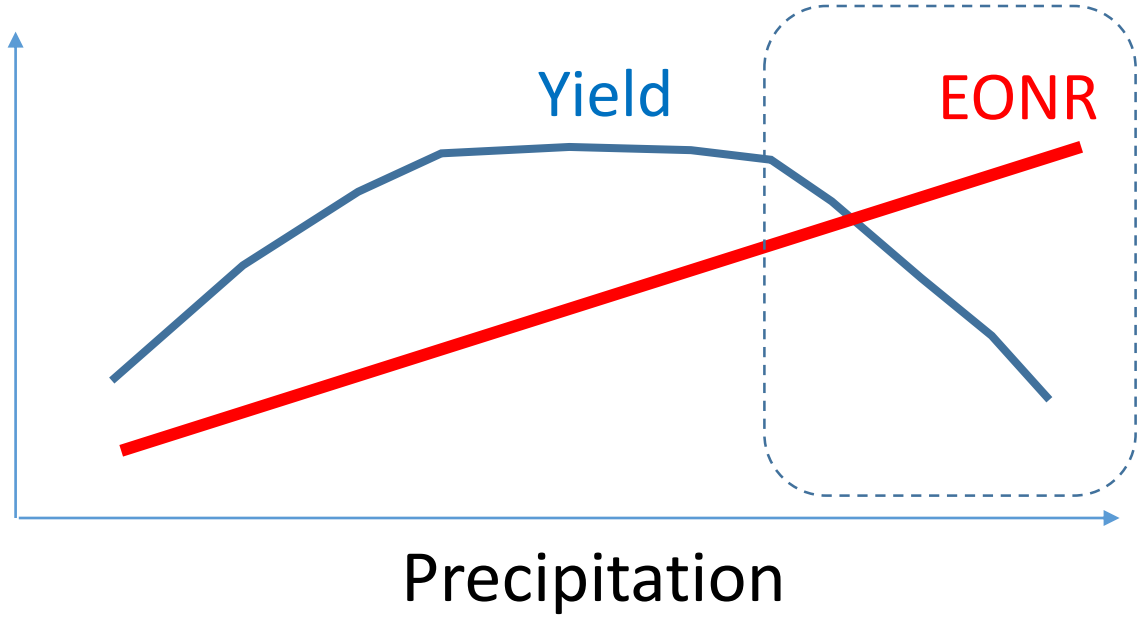
Strengths and Limitations of Nitrogen Rate Recommendations for Corn and Opportunities for Improvement

Thomas F. Morris,* T. Scott Murrell, Douglas B. Beegle, James J. Camberato, Richard B. Ferguson, John Grove, Quirine Ketterings, Peter M. Kyveryga, Carrie A.M. Laboski, Joshua M. McGrath, John J. Meisinger, Jeff Melkonian, Bianca N. Moebius-Clune, Emerson D. Nafziger, Deanna Osmond, John E. Sawyer, Peter C. Scharf, Walter Smith, John T. Spargo, Harold M. van Es, and Haishun Yang

We need more data … but also different data, not just yields and N-trials.

A better understanding of the soil-plant processes will lead to a better prediction of the EONR

No1 issue to be solved is the excessive moisture impacts on soil and plant N

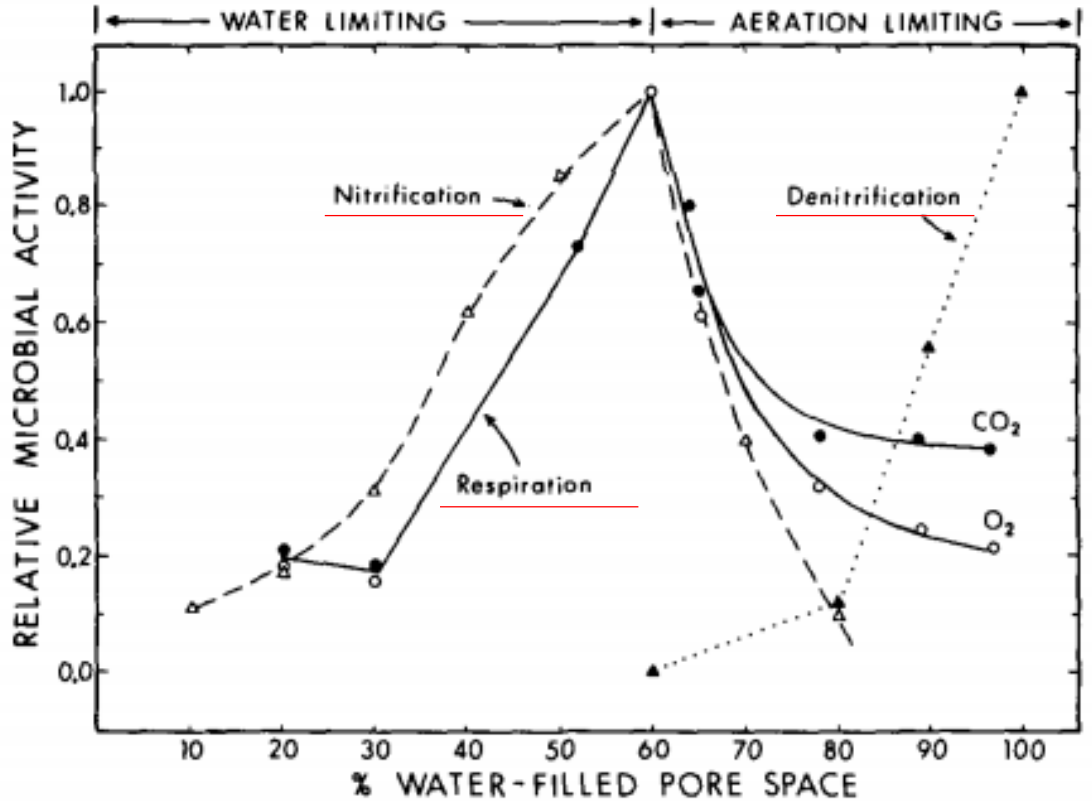


Highest economic and environmental cost

Over the last 10 years we have ran thousands of N-trials across the Corn Belt

How many studies did we do on soil N mineralization, nitrification and denitrification response to moisture?

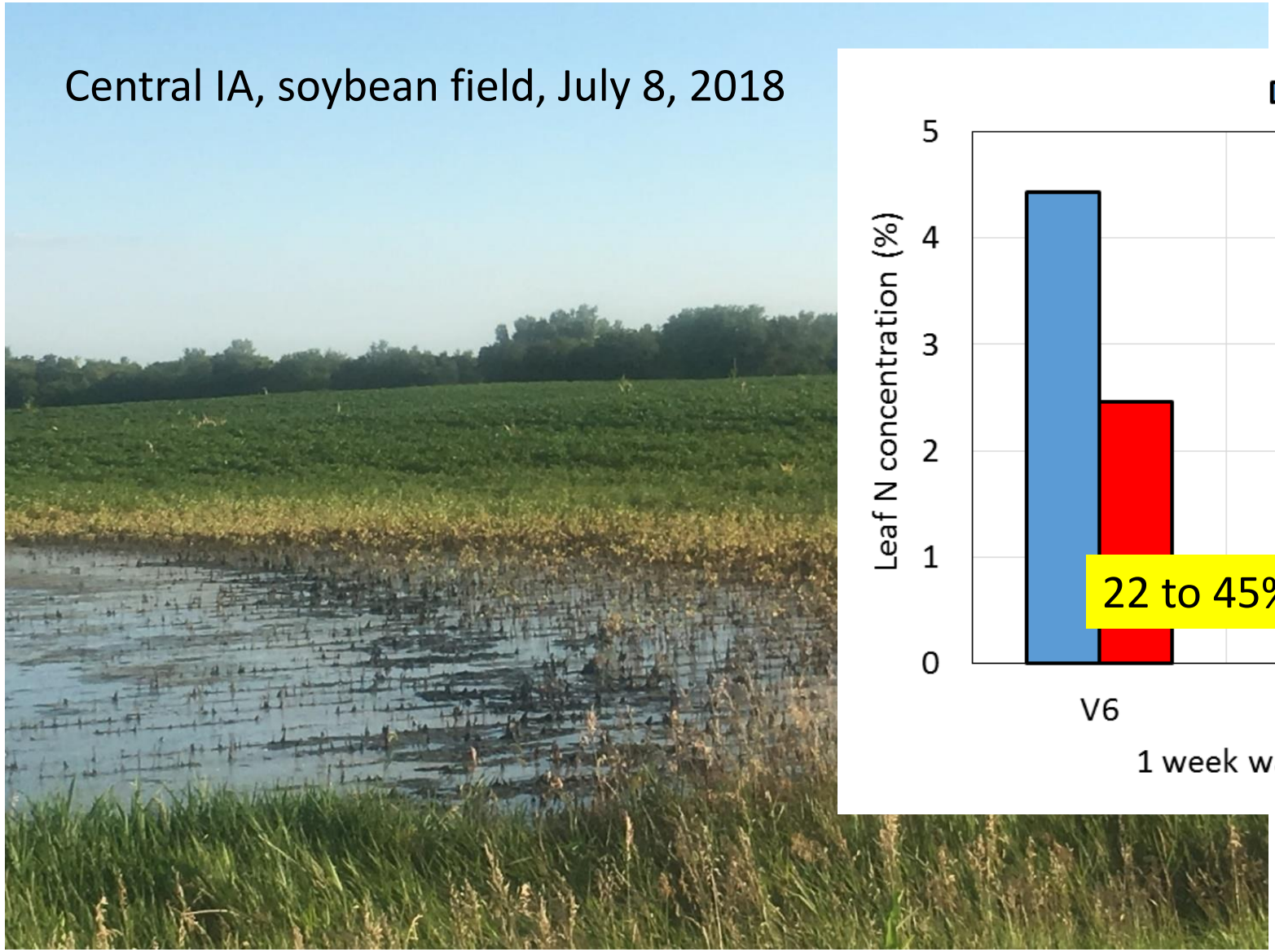
How does this relationship change with soil types or soil depth?

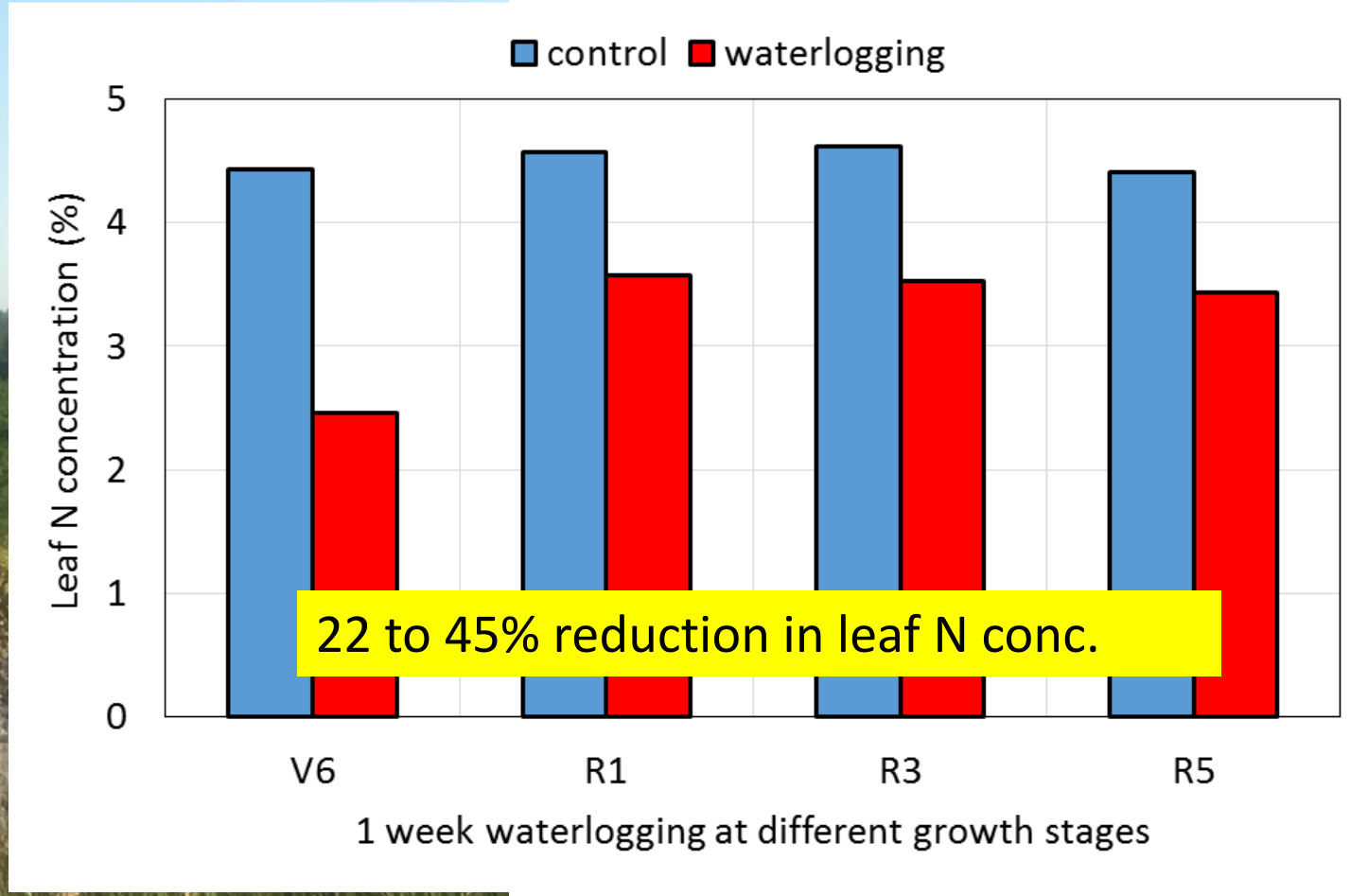


Linn and Doran, 1984 (SSSA)

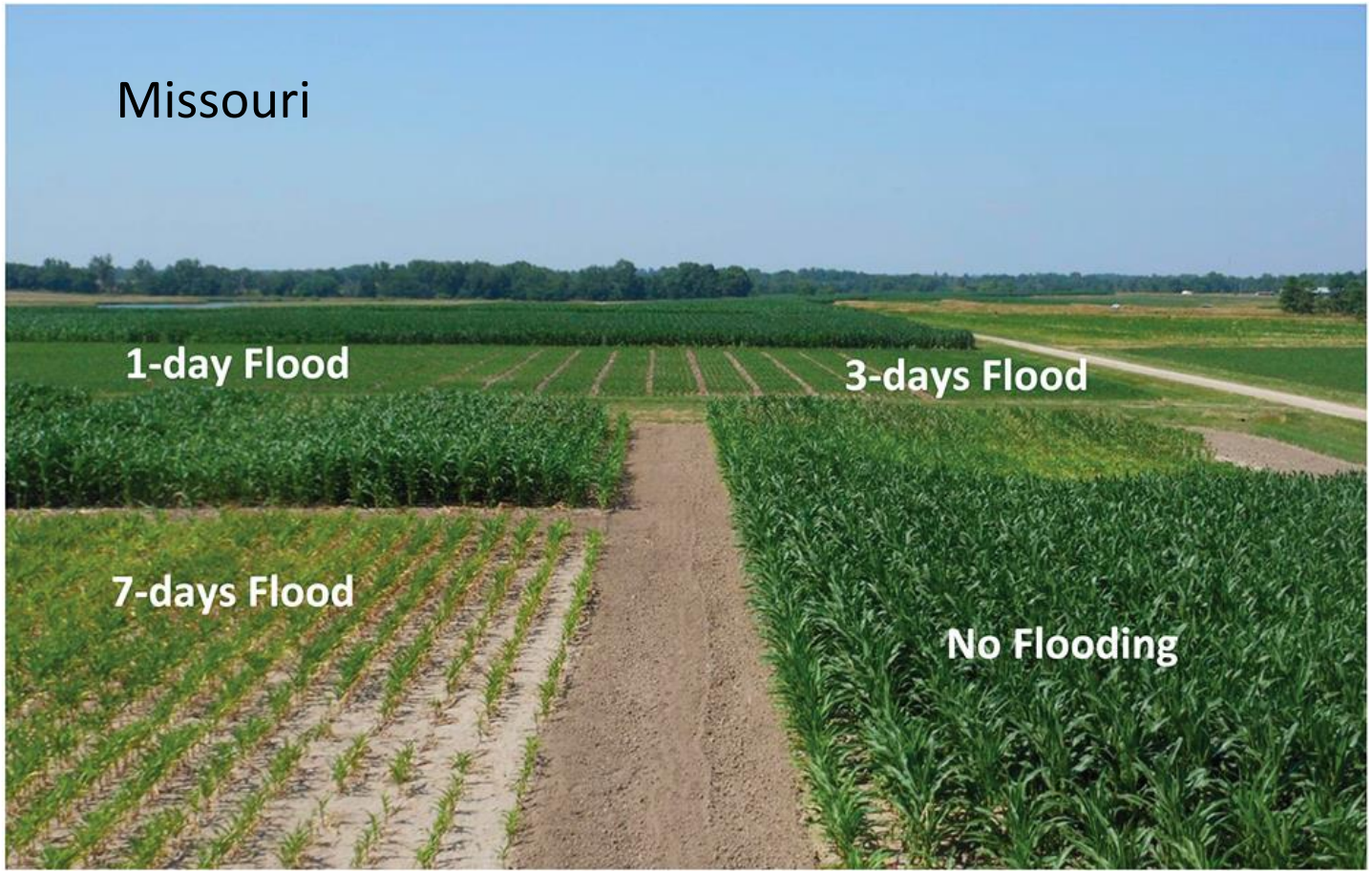
After a heavy rain even in June everyone's mind goes to soil N leaching

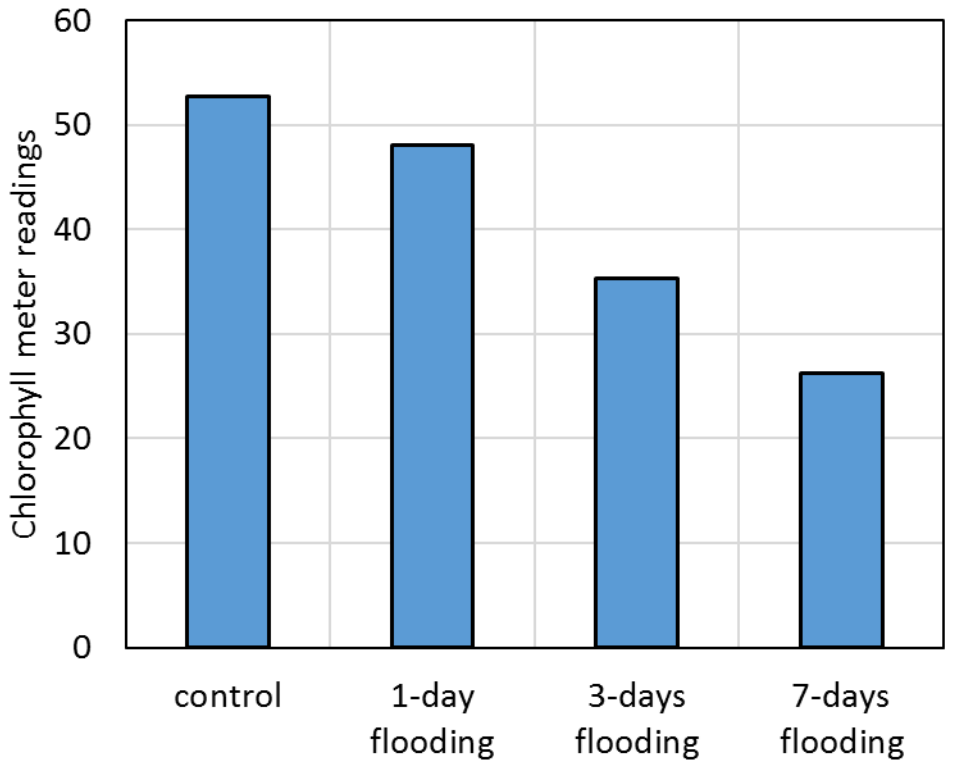
Are we losing N from the plant?





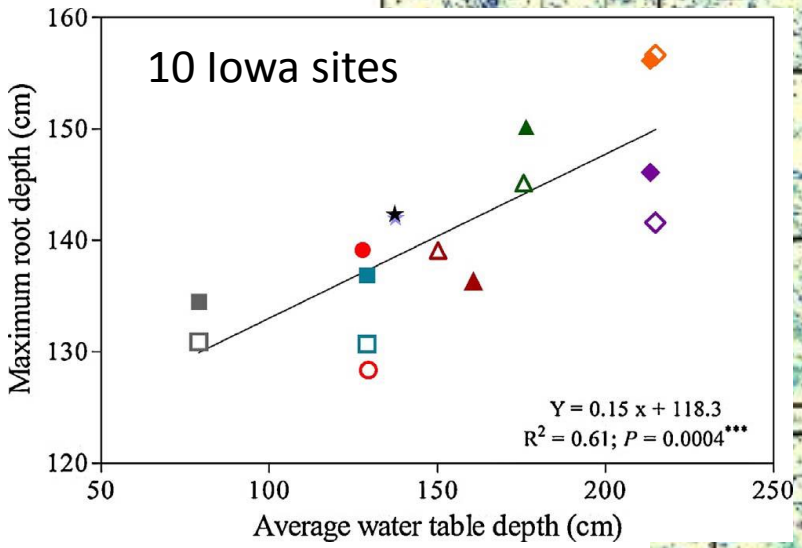
Board, 2008, Journal of Plant Nutrition



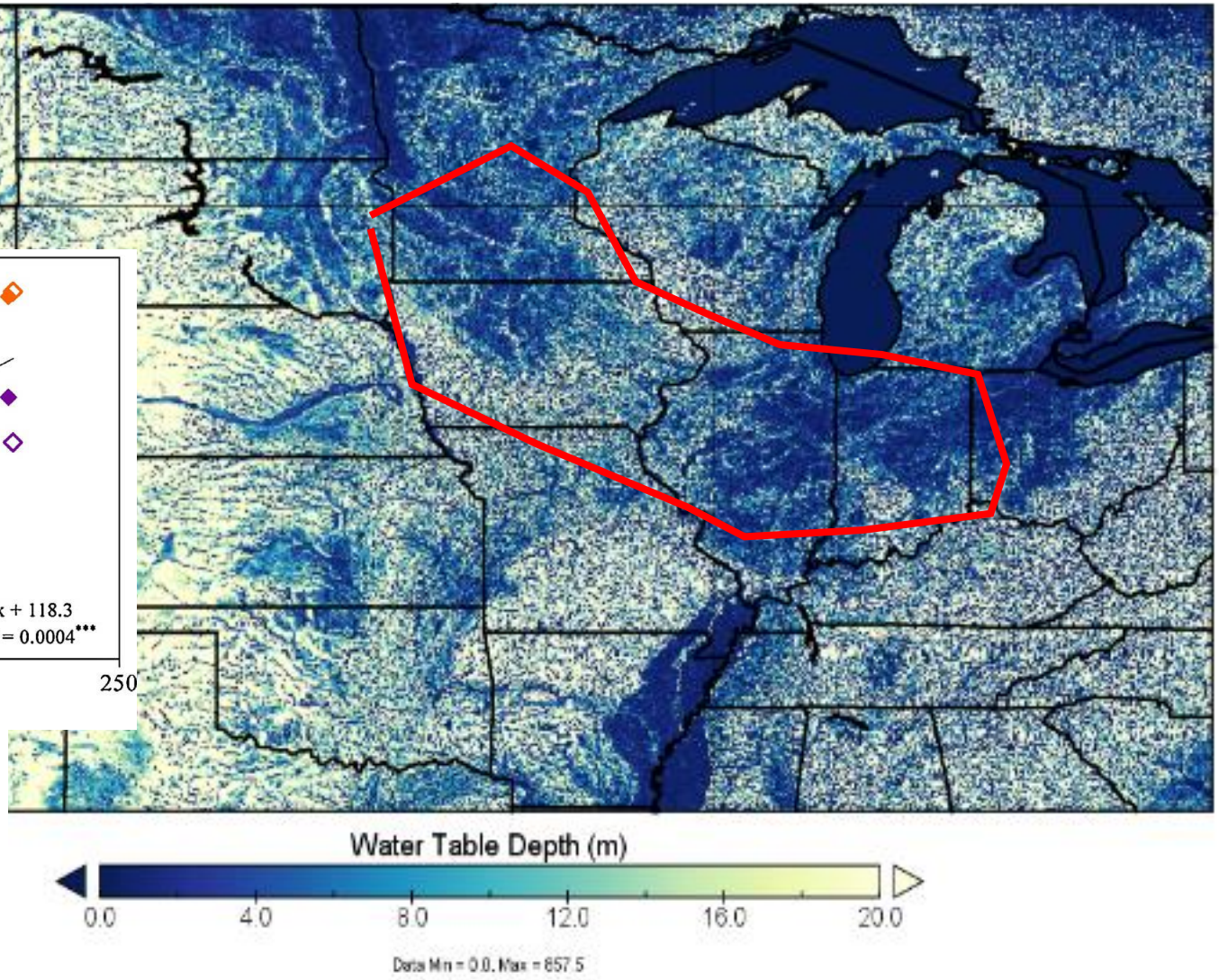


Kaur et al., 2017
Agronomy J

The entire Corn Belt is at a top of a shallow water table



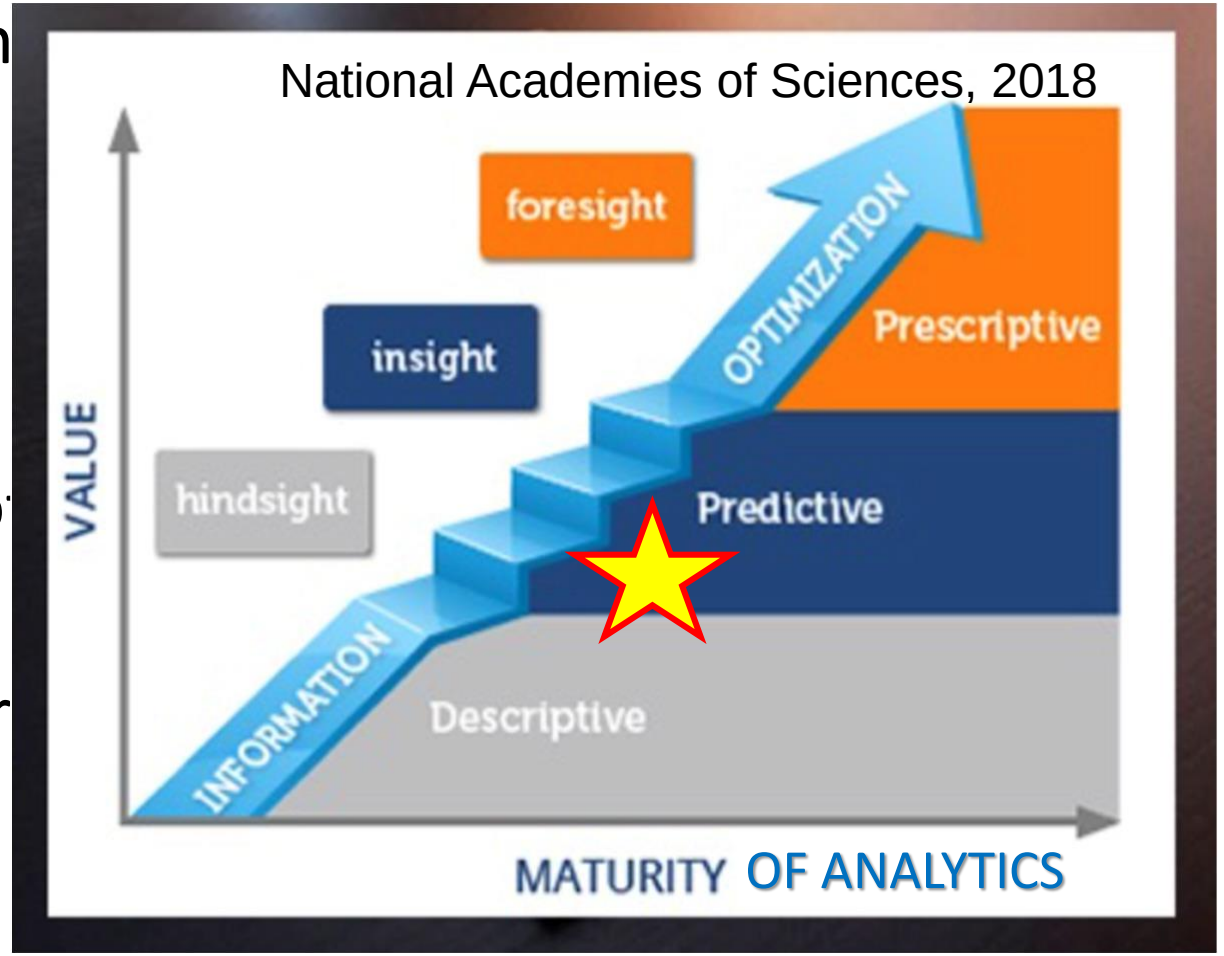
Ordonez et al., 2018
Field Crops Research



Fan et al. 2013, Science
(re-analyzed data)

Conclusions

- We mostly need N-tools (models) in
  have the most significant economic
- If a model is perfect then it is not a
- Do not expect high R^2 values (lots o
- Combine strengths not just compar
- N-trails **AND** other data to fill gaps



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