Computational Approach to a Major Sustainability Issue: Nitrogen Management for Corn

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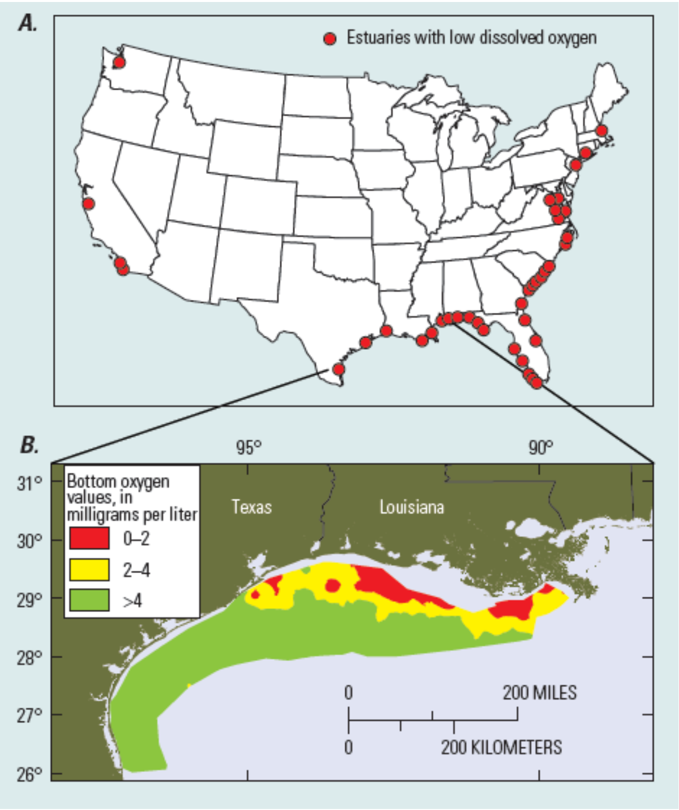
Outline for Today

- Background:
  - Sustainability concerns with agricultural nitrogen
  - Processes affecting N in soil-crop system

- Computational Approach:
  - *Adapt-N* Tool: Background Information
  - *Adapt-N* Tool: Examples and using it effectively

Corn Nitrogen Concerns

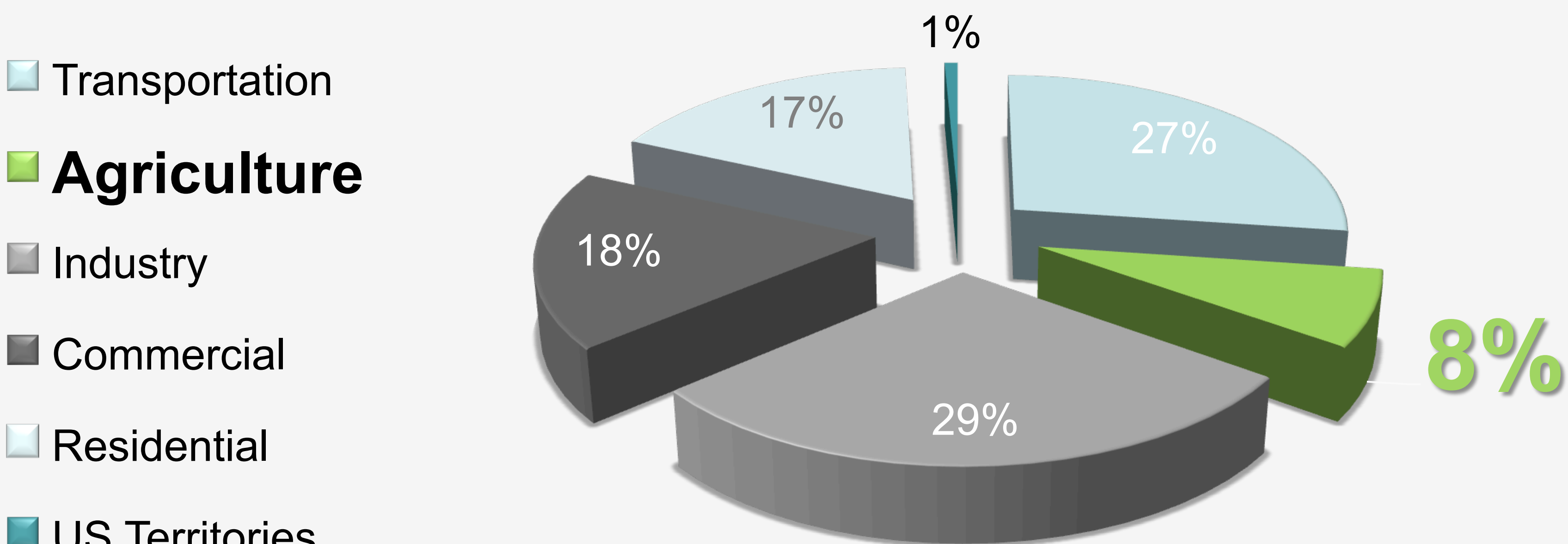
- ~ $5 billion/yr of N fertilizer applied to corn
- Largest energy input in cropping system
- N use efficiency very low (30-40%)
- Greenhouse gases (esp. N_2O)
- Sensitivity to climate change
- High groundwater nitrate levels
- Hypoxia/anoxia in estuaries



From: Dubrovsky et al., 2010

Total Green House Gas Emissions in the US by Economic Sector (2008)

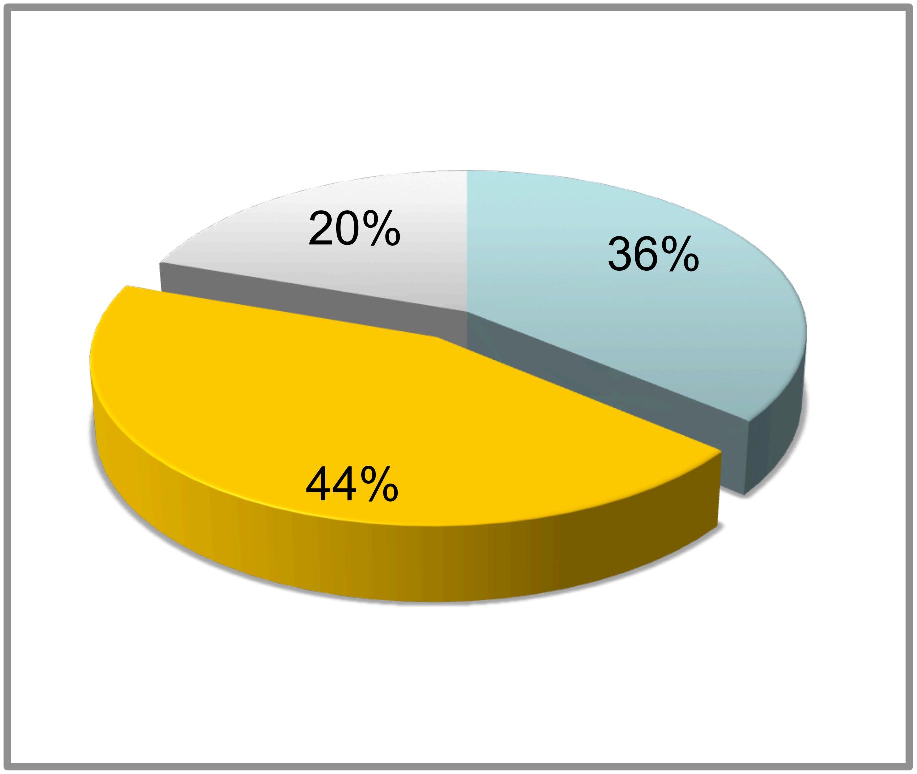
Agriculture accounts for 1.2% of US GDP
→ emits disproportionate levels of GHGs



Source: EPA, 2010

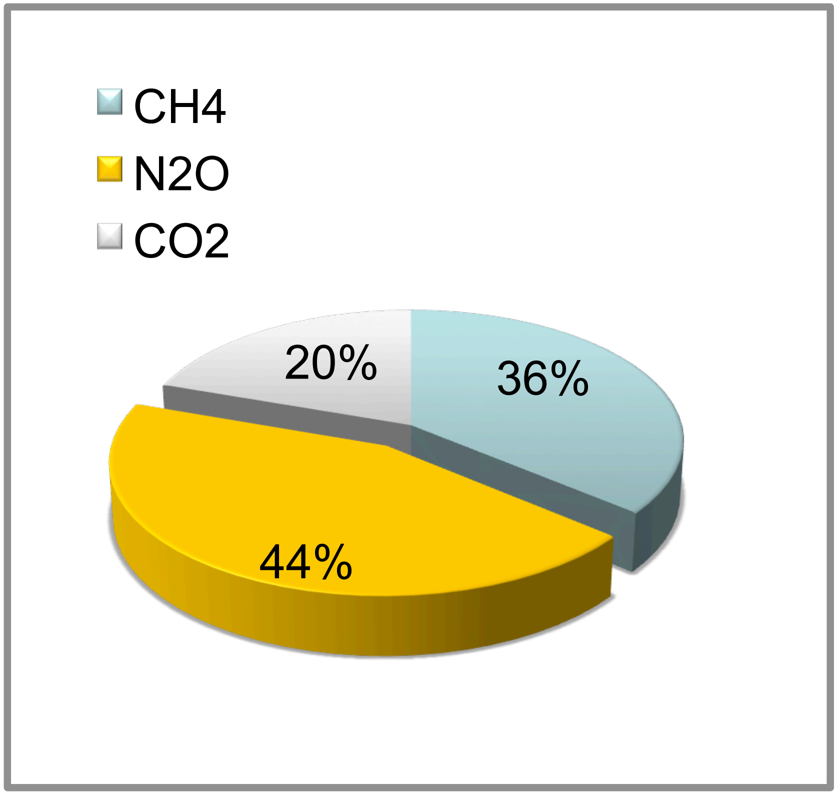
Global Warming Contributions of Agricultural Emissions from Three Greenhouse Gases

Source: EPA, 2010



- Which are the three gases?
- Which of the three greenhouse gases contributes most to global warming potential?
- Which the least?

Agricultural GHG Emissions (2008)



Source: EPA, 2010

N application to agricultural lands in 2008 accounted for:

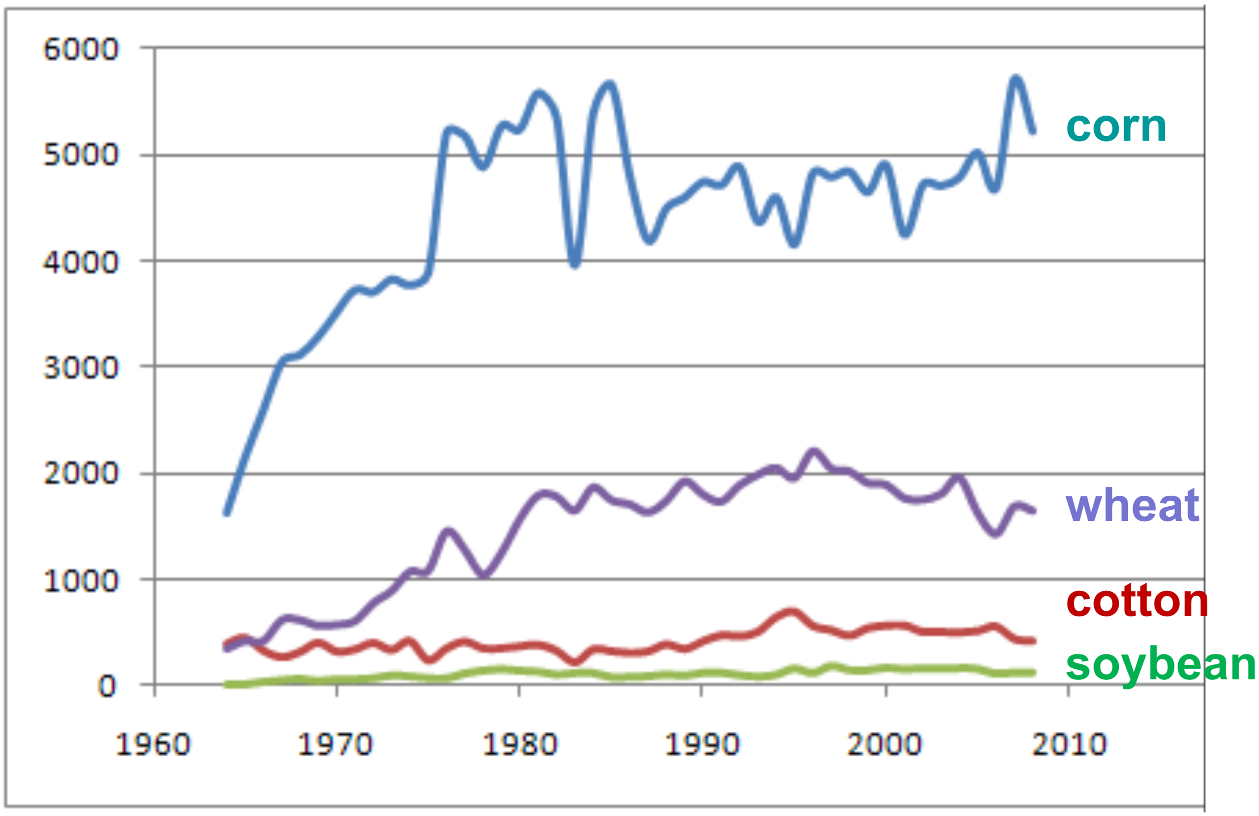
- **92% of Agricultural N_2O losses**
- **Greater global warming potential than all of US Aviation**
- **1.5 time greater global warming potential than Enteric Fermentation**

To Put It Into Perspective with Rounded Numbers….

- Average annual N_2O losses of 7.5 lbs per acre from corn lands is equivalent to
  - combustion of 126 gallons of gasoline
  - 3,700 miles of driving an average passenger car
- Assuming a farm with 500 ac of corn, the annual global warming impact is equivalent to about 1.8 million miles of driving (70 times around earth).

U.S. N Fertilizer Use by Crop

(1,000 tons)



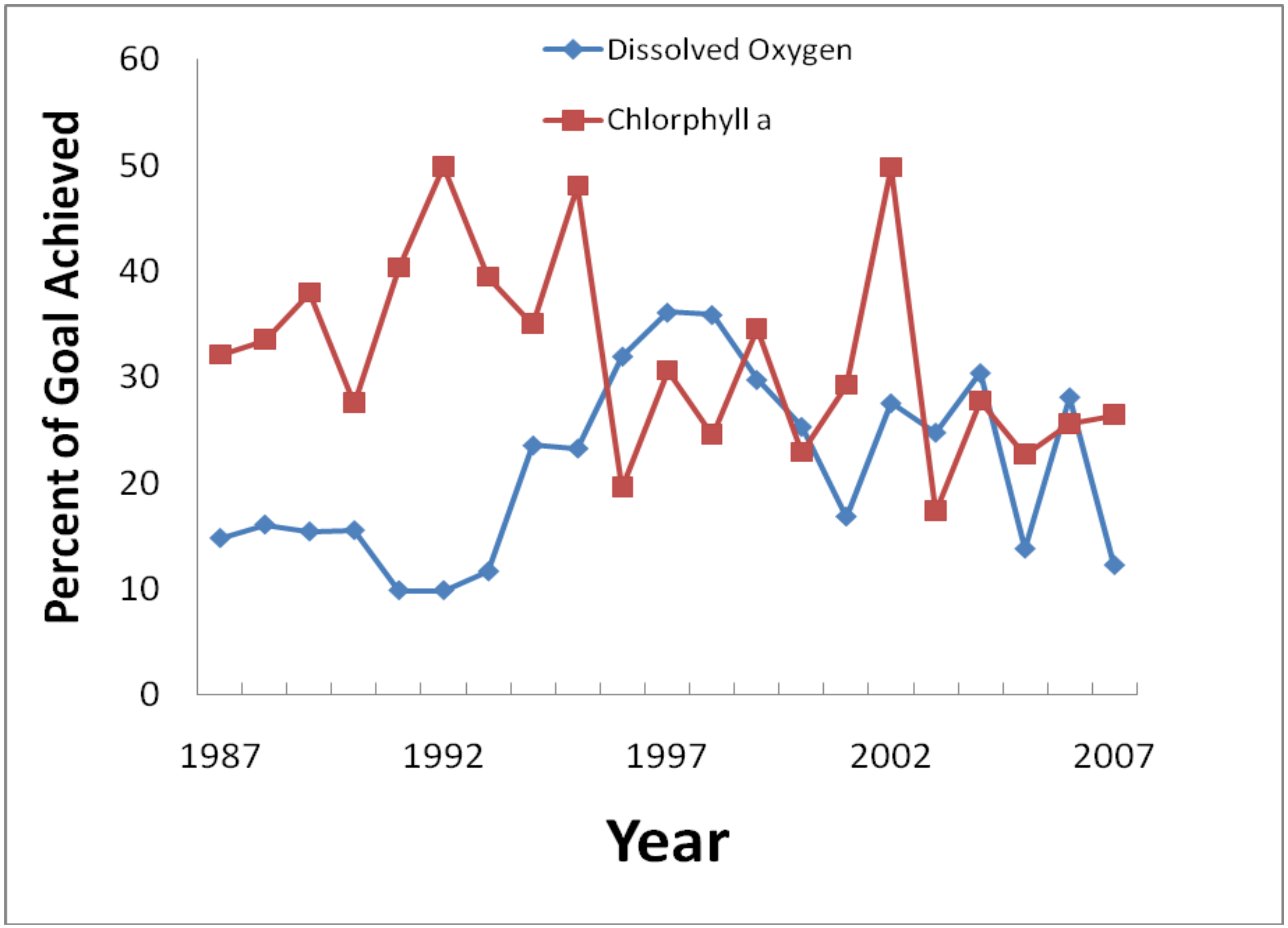
Source: USDA-ERS

Are levels of nutrients in water increasing or decreasing?

From: Dubrovsky et al., 2010, based on NAWQA data

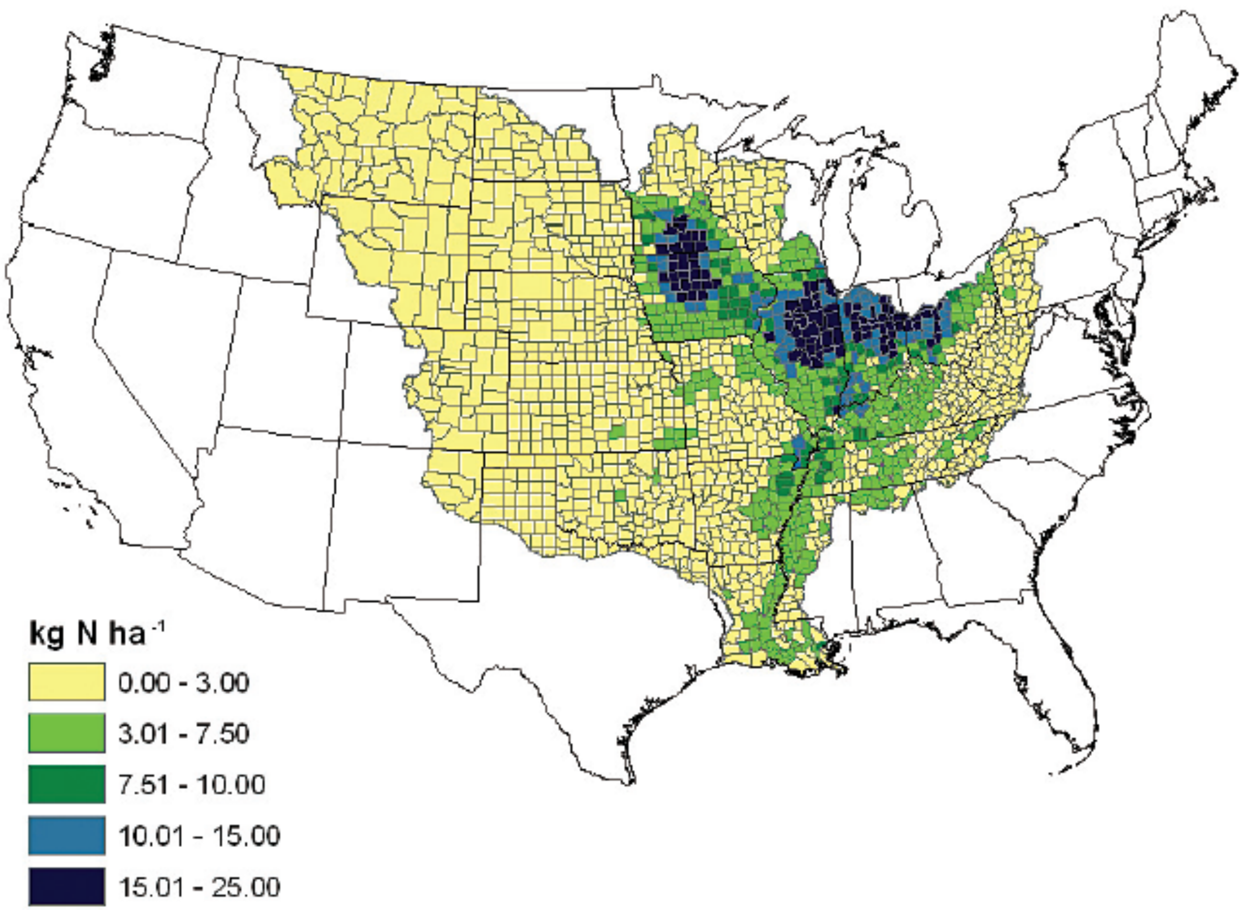
“Despite major Federal, State and local efforts and expenditures to control sources and movement of nutrients within our Nation’s watersheds, national-scale progress was not evident in this assessment, which is based on thousands of measurements and hundreds of studies across the country from the 1990’s and early 2000’s,”

Limited Success with Chesapeake Bay



Chesapeake Bay health assessment (% of goal achieved) for dissolved oxygen and chlorophyll a for the period 1987 to 2007 (data source: USEPA Chesapeake Bay Program)

Riverine N Yield in the MRB



David et al. J. Environ. Qual. 39:1657–1667 (2010)

Prediction of Watershed N Yield

Modeled nitrate N yield (January to June) was best explained by (R^2=0.82):

- river flow x fertilizer N input — 76% of variability explained
- fraction tile drained — 17% explained
- N consumed by humans — 7% explained

But…… drainage reduces nitrous oxide losses!

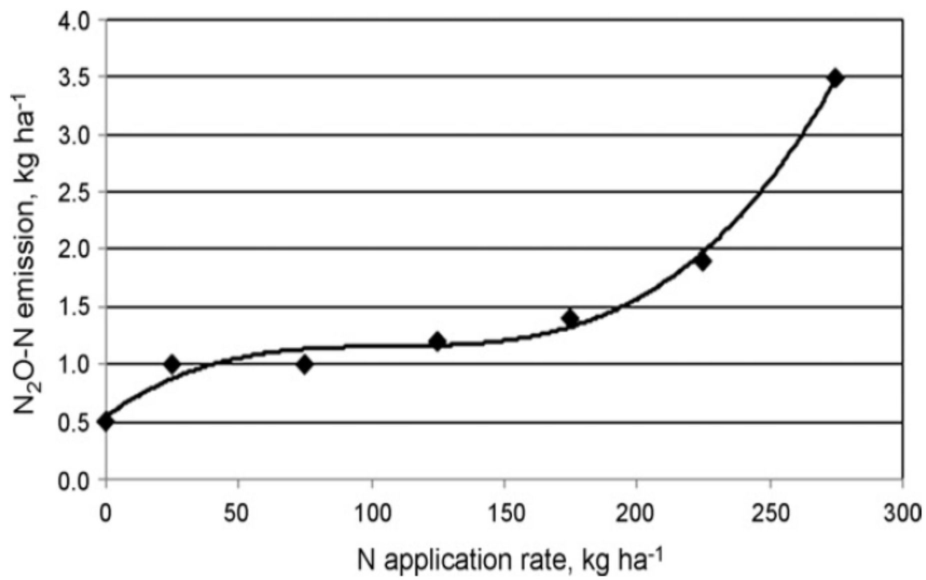
David et al. J. Environ. Qual. 39:1657–1667 (2010)

Control Points for Reducing N Losses

1. Input management (tangible and transparent)
2. Transport mechanism (drainage, irrigation)
3. Remedial actions (filters, buffers, wetlands)

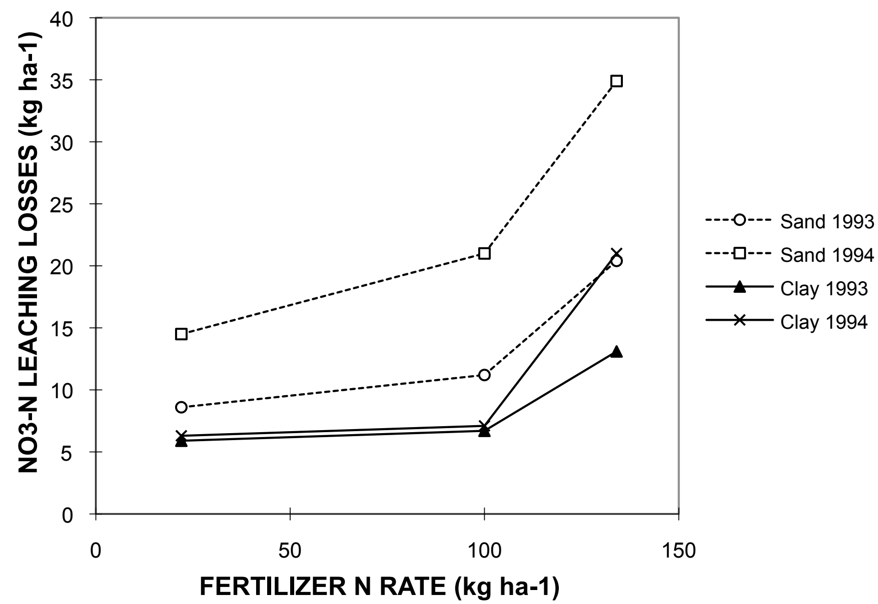
Precise Estimation of Maize N Fertilizer Needs is Important

NITROUS OXIDE



From: Snyder et al., 2009, based on data by Bouwman et al., 2002

NITRATE LEACHING



van Es et al., 2002

****Large losses once crop demand is satisfied****

Many sources of variation in N availability

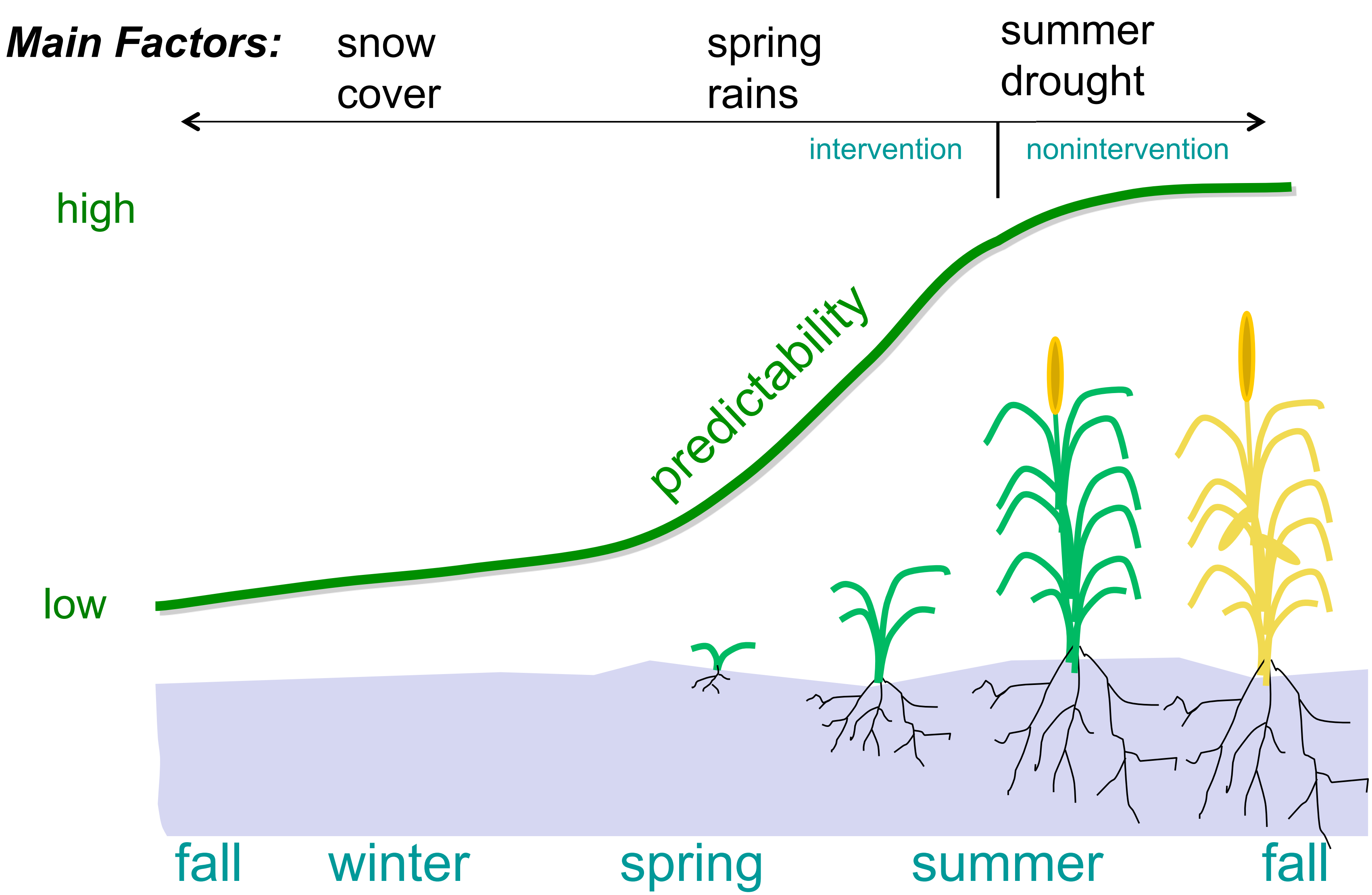
→ generalized recommendations less applicable for corn N needs

Sources of Variability:

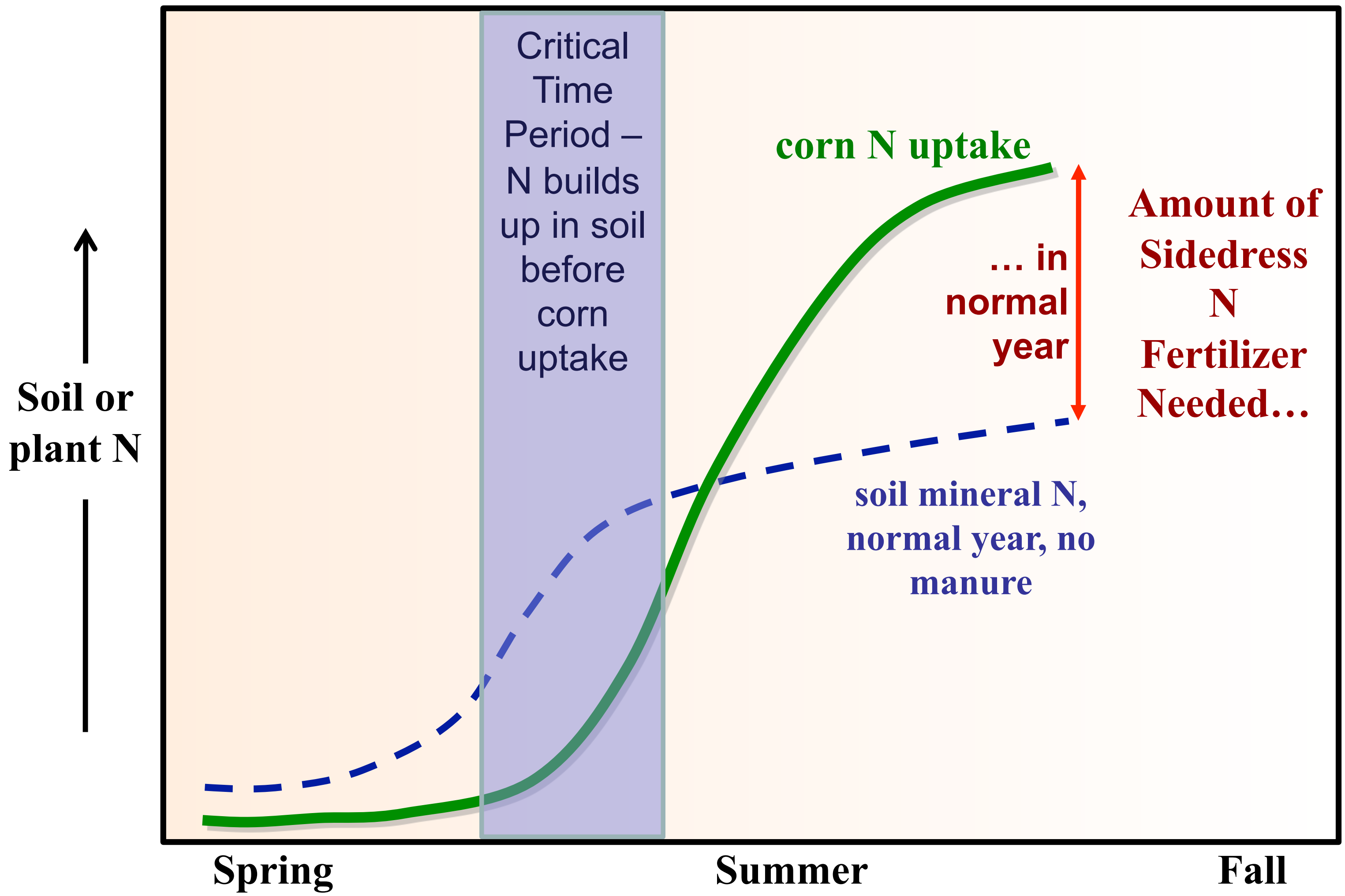
- Organic amendments (manure, compost, etc.)
- Crop rotations
- Soil type differences
- Soil organic matter contents (management-induced soil change)

- Early season weather (warm vs. cool; wet vs. dry)
- Late season weather (warm vs. cool; wet vs. dry)

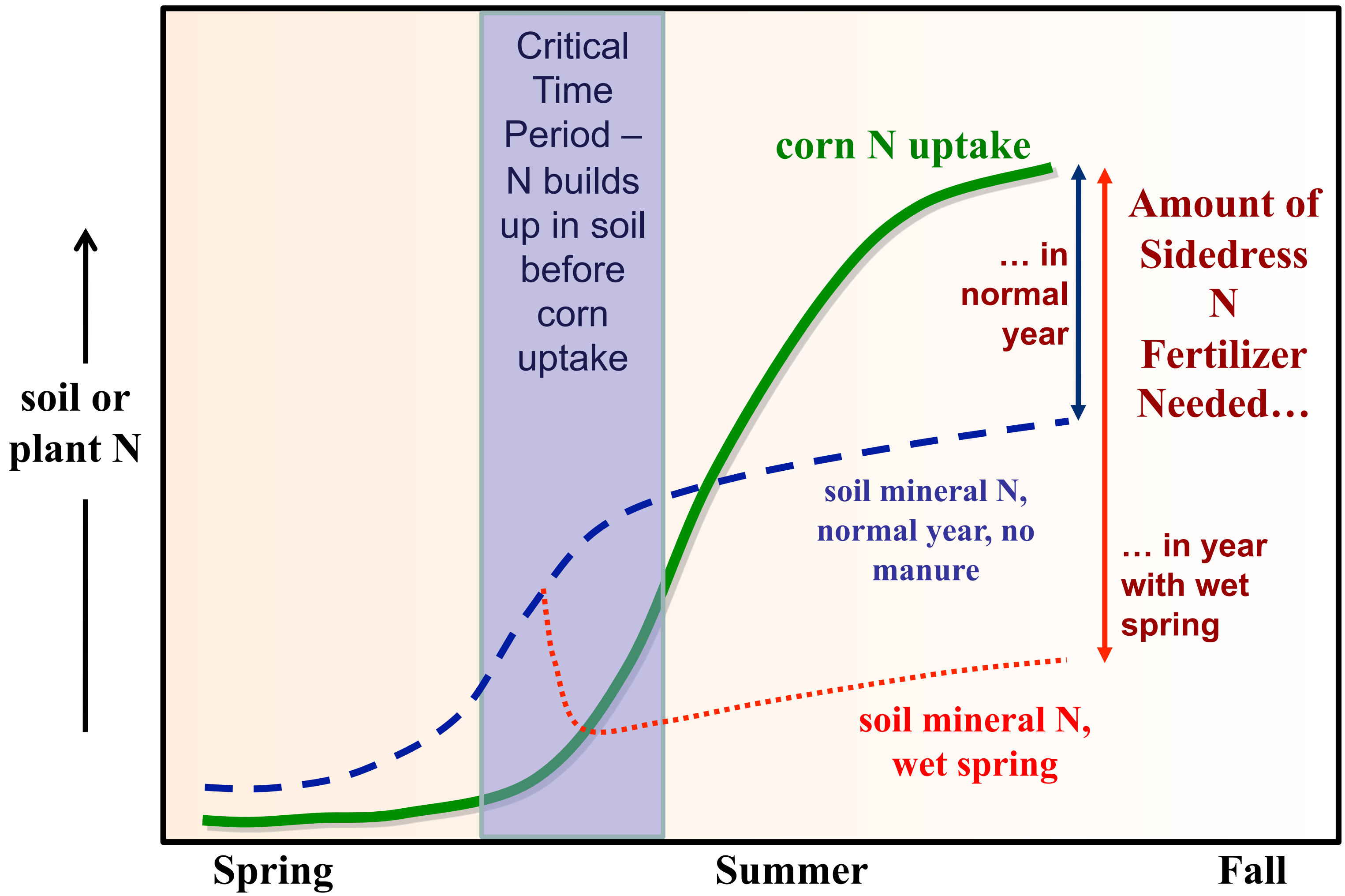
Predicting N Needs for Corn:
Precision for Different Times of Application



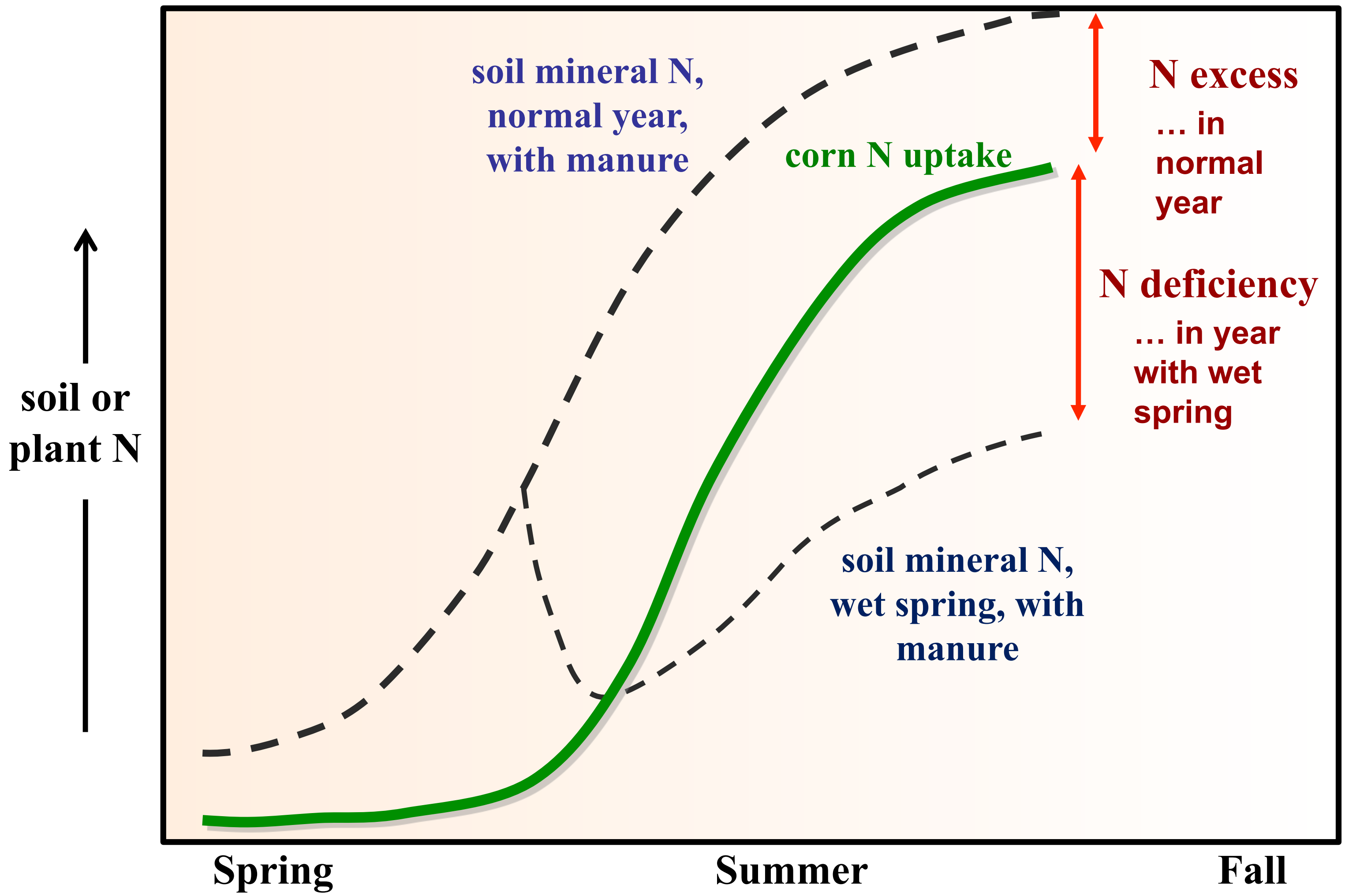
SOM mineralization occurs ahead of corn N uptake……



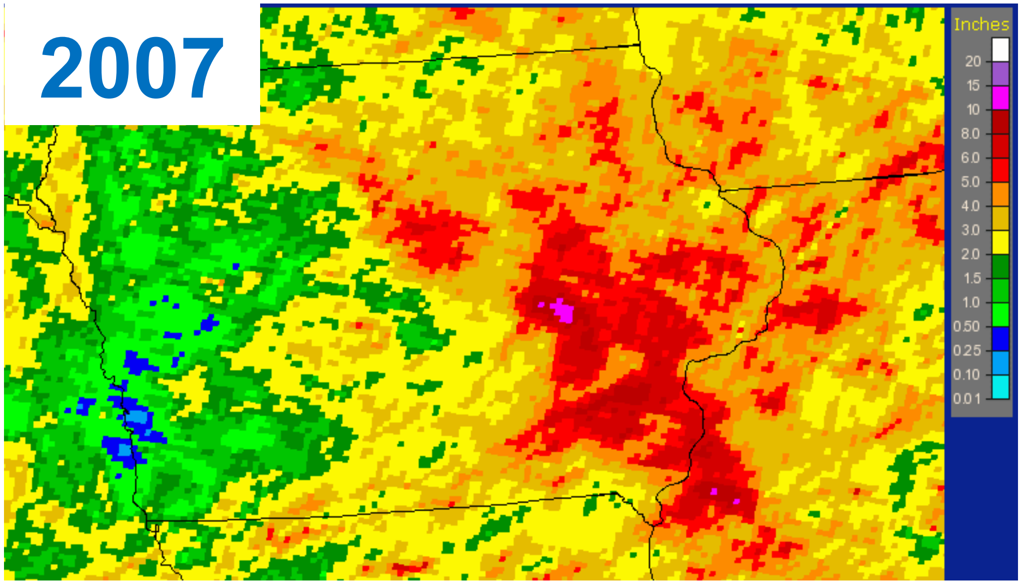
Need for supplemental N fertilizer depends on early season weather …

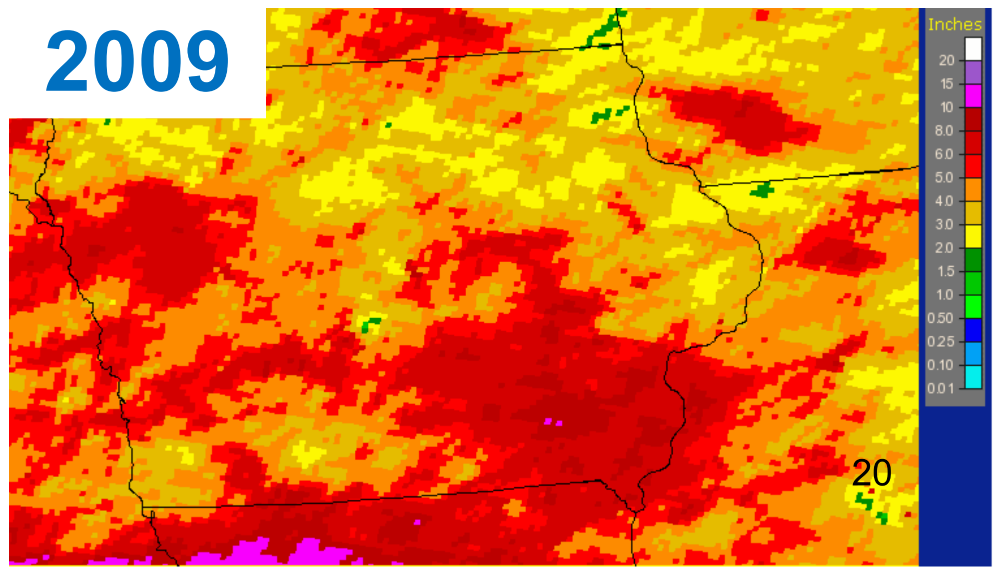


Manure Scenario: Soil N mineralizes from SOM and Manure



Precipitation is highly localized….





June Precipitation Iowa

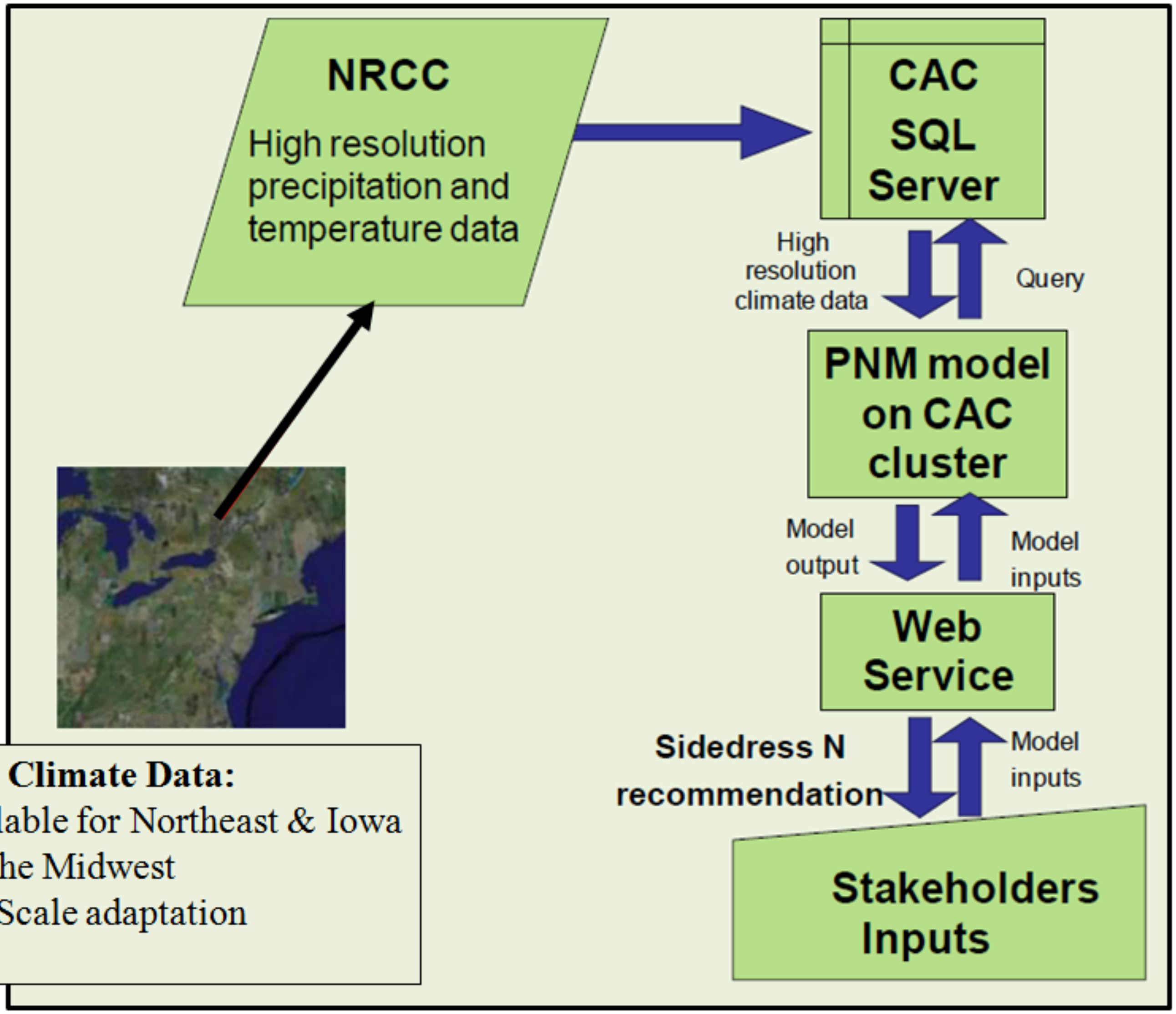
Addressing the Problem with Computational Tools

Why Use Models for N Management?

Photo: Miller-St. Nazianz, Inc.

- Universal process-based approach
  - Incorporates greater system complexity
- Allows for Adaptive Management
  - variable soils (genetic and dynamic)
  - variable management (planting date, organic additions, population, fertility management, etc)
  - variable weather (Hi-Res Climate Data)
- Low cost
- In-season and post-season evaluations possible
  - Sidedress N recommendations
  - End-of-season retrospective evaluations

Adapt-N Infrastructure



High Resolution Climate Data:

- Currently available for Northeast & Iowa
- Expanding to the Midwest
- Enables Field-Scale adaptation

Adapt-N's Cloud Computing Model: Access with Smartphones and Tablets

PNM model:
The core of the *Adapt-N* tool

New model based on the linkage of two simulation models:

- Soil processes model, LEACHN

Hutson, J.L., R.J. Wagenet, and M.E. Niederhofer. 2003. Leaching Estimation And Chemistry Model: a process-based model of water and solute movement, transformations, plant uptake, and chemical reactions in the unsaturated zone. Version 4. Dept of Crop and Soil Sciences. Research Series No. R03-1. Cornell University, Ithaca, NY, USA.

- Crop growth/N uptake model

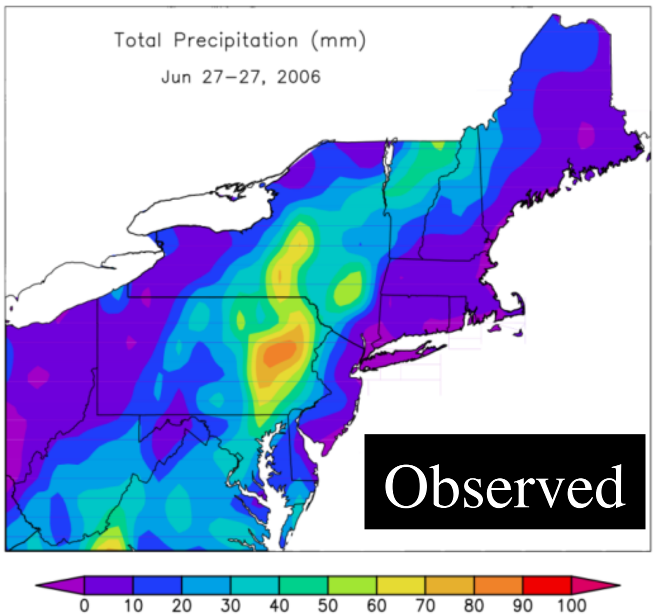
Sinclair, T.R., and R.C. Muchow. 1995. Effect of nitrogen supply on maize yield: I. modeling physiological responses. Agronomy Journal 87:632-641.

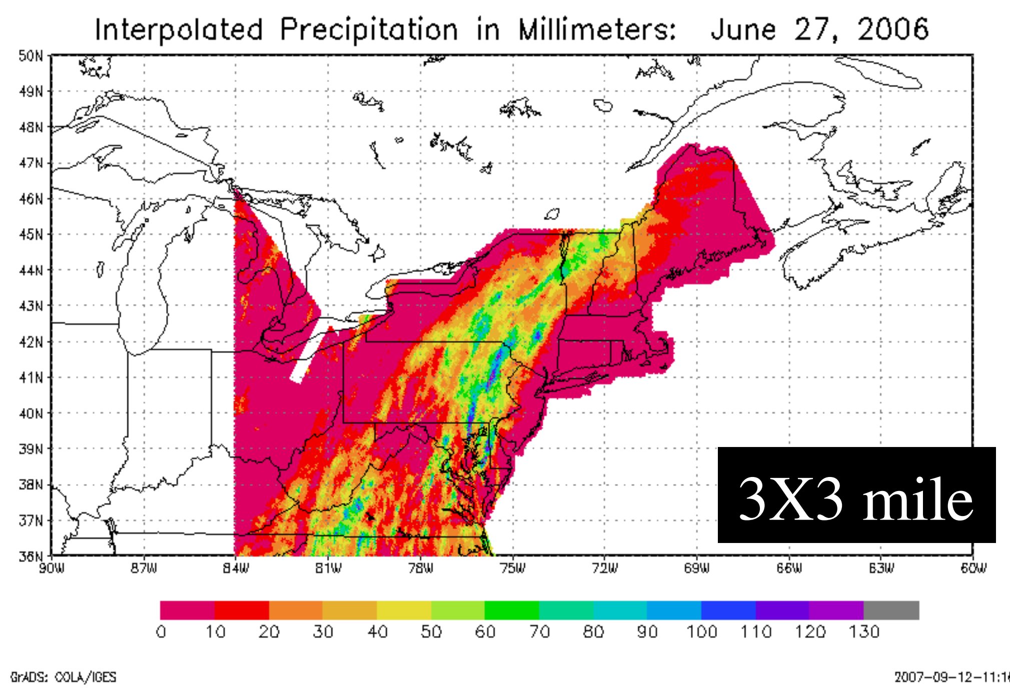
Adapt-N Input:

High Resolution Precipitation Data

Error-Corrected Radar Estimates

Northeast Regional Climate Center





DeGaetano, A.T. & Wilks, D.S. (2008) Radar-guided interpolation of climatological precipitation data. International Journal of Climatology (online)

Adapt-N Interface: User Inputs

Soil, Tillage

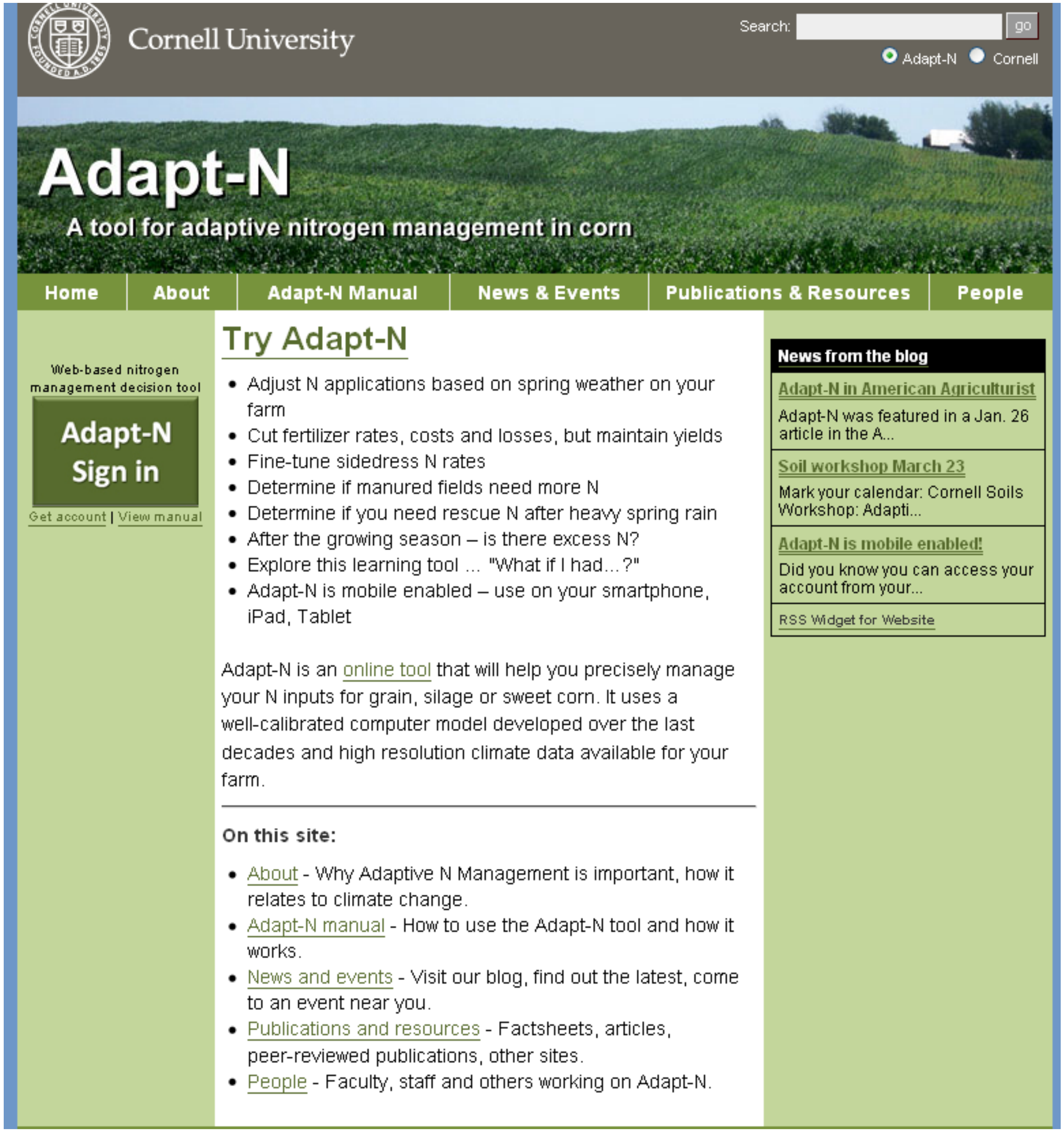
- User ID / Field ID
- Latitude / Longitude
- Soil textural group
- Approximate field slope
- Drainage
- Soil organic matter content
- Rooting depth
- Tillage information

Organic Inputs

- Manure applications:
  Two previous years/current year
- Previous sod crop
- 1st year corn after soybean?

Fertilizer, Crop

- Starter fertilizer
  - type/rate/application date
- Additional fertilizer
- Cultivar maturity class
- Planting date
- Expected harvest population
- Expected Yield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A tool for adaptive nitrogen management in corn
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Web-based nitrogen management decision tool
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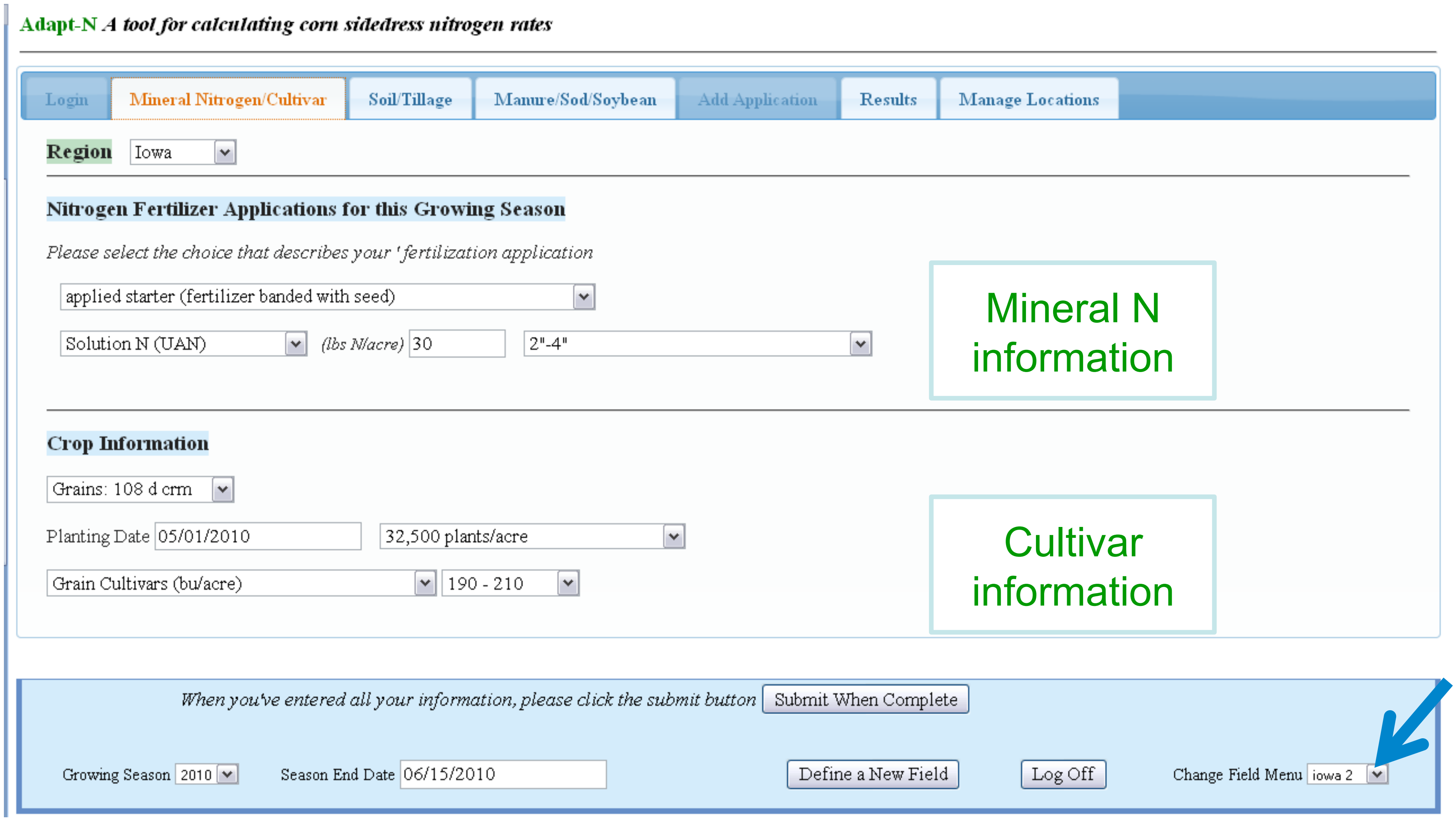
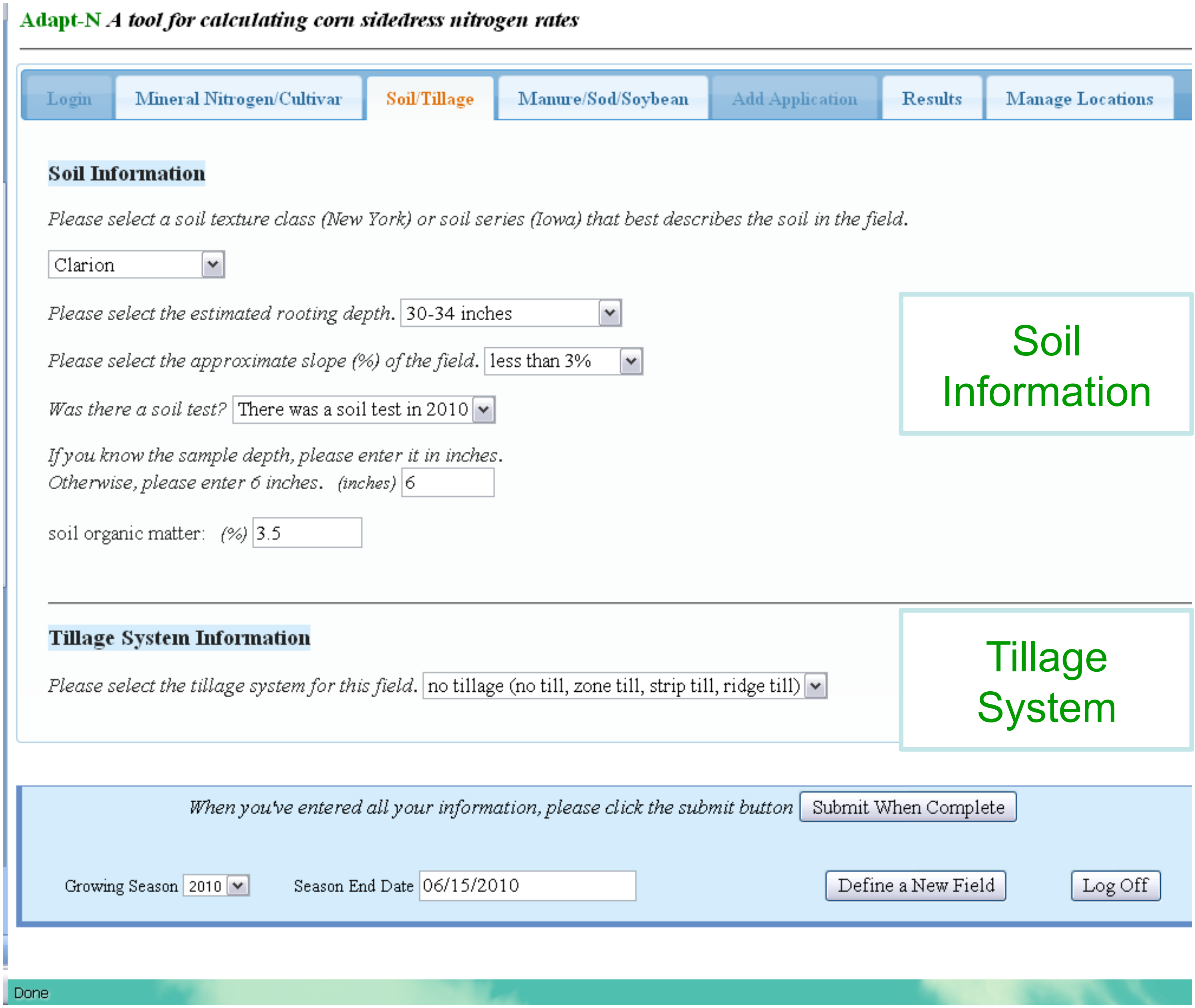
Get account | View manual
Try Adapt-N
• Adjust N applications based on spring weather on your farm
• Cut fertilizer rates, costs and losses, but maintain yields
• Fine-tune sidedress N rates
• Determine if manured fields need more N
• Determine if you need rescue N after heavy spring rain
• After the growing season – is there excess N?
• Explore this learning tool ... "What if I had...?"
• Adapt-N is mobile enabled – use on your smartphone, iPad, Tablet
Adapt-N is an online tool that will help you precisely manage your N inputs for grain, silage or sweet corn. It uses a well-calibrated computer model developed over the last decades and high resolution climate data available for your farm.
On this site:
• About - Why Adaptive N Management is important, how it relates to climate change.
• Adapt-N manual - How to use the Adapt-N tool and how it works.
• News and events - Visit our blog, find out the latest, come to an event near you.
• Publications and resources - Factsheets, articles, peer-reviewed publications, other sites.
• People - Faculty, staff and others working on Adapt-N.
News from the blog
Adapt-N in American Agriculturist
Adapt-N was featured in a Jan. 26 article in the A...
Soil workshop March 23
Mark your calendar: Cornell Soils Workshop: Adapti...
Adapt-N is mobile enabled!
Did you know you can access your account from your...
RSS Widget for Website

Adapt-N Interface Set-up



Soil and Tillage Information



Soil Information

Tillage System

Manure and Rotation Information

up to 3 applications for current and each of two previous years

Adapt-N ***A tool for calculating corn sidedress nitrogen rates***

Login | Mineral Nitrogen/Cultivar | Soil/Tillage | Manure/Sod/Soybean | Add Application | Results | Manage Locations

Manure N Applications

Date	Added	Organic N	Ammonia N	Depth	Solids	Delete Button
04/24/2010	5000	10	8	injected/incorporated within 1 day	4	Delete

You may enter up to three applications for 2008, up to three applications for 2009 and one application for 2010

Select Manure Application

Manure Information

N from Sod Rotation

Previous sod crop in the past three years? sod not applied

Previously Sod?

Previous Soybean Crop

First year corn after soybean? no, did not plant soybeans last year

Previously Soybean?

When you've entered all your information, please click the submit button Submit When Complete

Growing Season 2010 Season End Date 06/15/2010 Define a New Field Log Off

Adapt-N Output

Login | Mineral Nitrogen/Cultivar | Soil/Tillage | Manure/Sod/Soybean | Add Application | Results | Manage Locations

Date: 02/20/2011 simulated 06/15/2010	Latitude: 40.88	Longitude: -94.28
Soil/Field Information		
Soil Texture: Iowa Soil Series: clarion	Field Slope: less than 3%	
Soil Management: no tillage (no till, zone till, strip till, ridge till)	Preplant Soil Test: test in 2010	
Crop Information		
Maturity Class: 108_d_crm	Planting Date: 05/01/2010	Planting Density 32,500 plants/acre
GDD to maturity: 2680		
Expected Yield: 200 bu/acre		
Nitrogen Inputs:		
Organic Sources		
Sod: sod not applied		
Manure	Manure Input	Manure Management
04/24/2010	5000.0 gals/acre manure added 10.0 lbs Organic N/1000 gals 8.0 lbs Ammonium N/1000 gals manure	injected/incorporated within 1 day
Mineral Fertilizer	Date	Depth of Incorporation
starter: solution N (UAN), 30 lbs N/acre	05/01/2010	3 inches
additional: not used	not used	not used

Sidedress Nitrogen Recommendation: 55 lbs N/Acre

Done

Summary of User Inputs

Sidedress Recommendation

Adapt-N Output: Simulation Results

Sidedress Nitrogen Recommendation: **55 lbs N/Acre**

This recommendation is based on an "Expected Yield" entry that is assumed to be the economically optimal yield for your field. As such, it is relatively insensitive to profit within a range of +/- 15 lbs per acre around the recommended rate at current fertilizer and grain prices.

Additional Information

- Results in a printable format
- Sidedress Recommendation Calculations
- Crop Available Water in Root Zone *inches*
- Growing Season Daily Average Temperature
- Post Planting Growing Degree Days
- Growing Season Rainfall
- Cumulative Rainfall for Growing Season
- Cumulative Nitrogen Losses from the Root Zone
- Cumulative Nitrogen Uptake by the Crop
- Cumulative Nitrogen (N) Mineralization (all organic N sources)
- Crop available N in the top 12 inches of the Root Zone
- Post Planting Leaf Number

Simulations Results, beyond sidedress recommendation, can be explored and printed

When you've entered all your information, please click the submit button Submit When Complete

Growing Season 2010 Season End Date 06/15/2010 Define a New Field Log Off Change Field Menu iowa 2

Done

Supporting Data

Sidedress N rate estimated by AdaptN

$CropN_{Harvest}$ - $CropN_{Current}$ - $SoilN_{Current}$ - $SoilN_{postsidedress}$ – $SoybeanN_{Credit}$

Sidedress N rate: 55 lbs N/Acre

$CropN_{Harvest}$: 193 *(lbs N/acre)*

$CropN_{Current}$: 21 *(lbs N/acre)*

$SoilN_{Current}$: 80 *(lbs N/acre)*

$SoilN_{postsidedress}$: 38 *(lbs N/acre)*

$SoybeanN_{Credit}$: 0 *(lbs N/acre)*

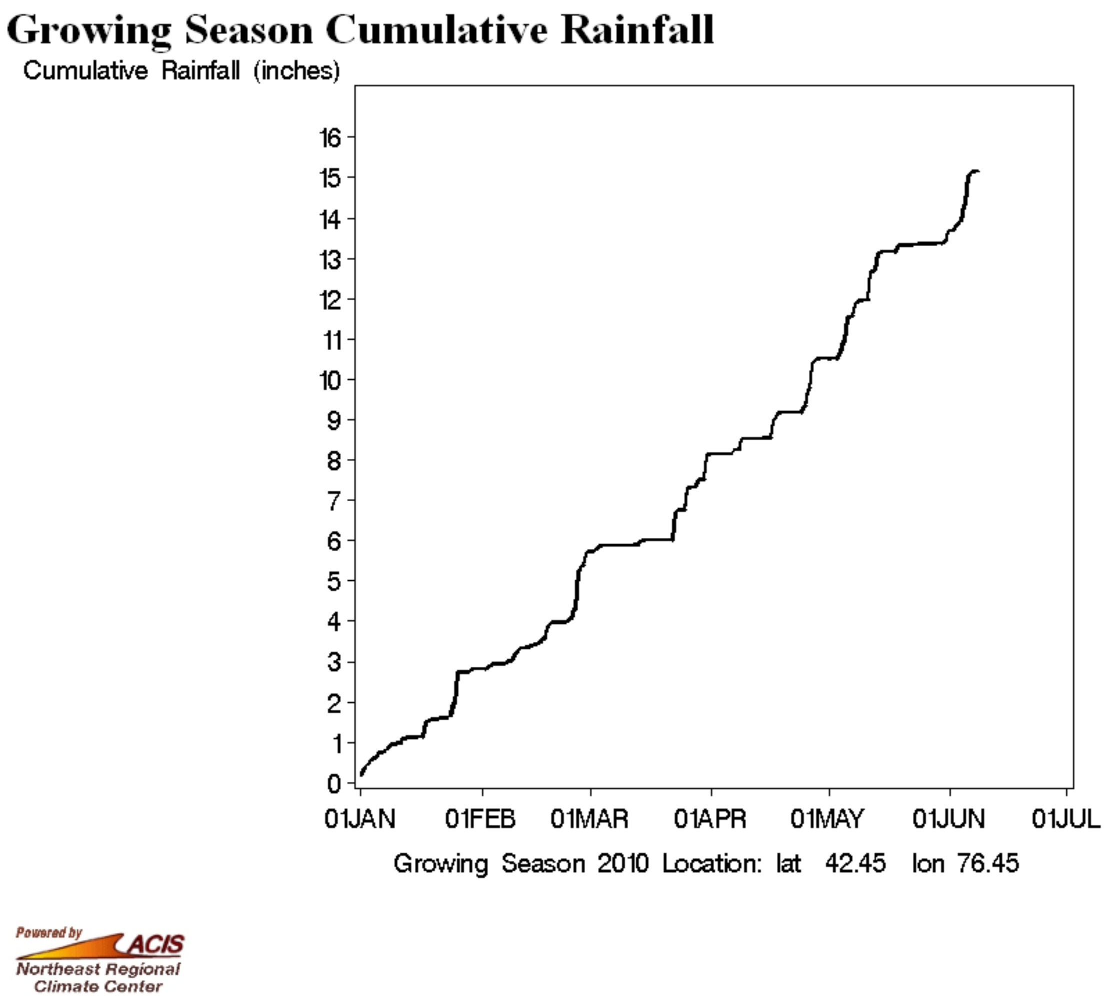
Root Zone Crop Available Water

Note that these estimates are for non-irrigated corn production.

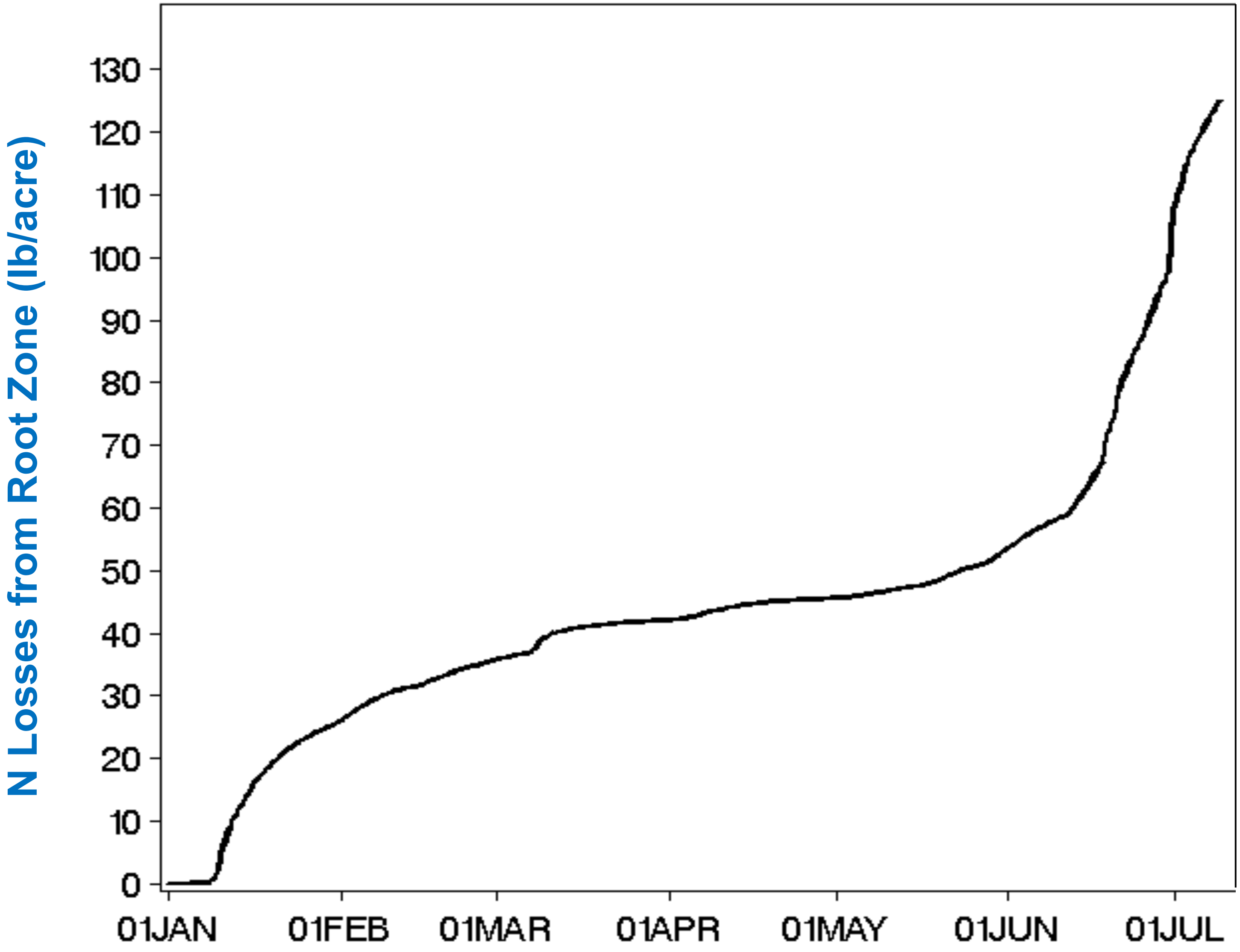
Current root zone crop available water: 6 *inches*

Crop available water at field capacity: 6 *inches*

Cumulative Rainfall



Cumulative N Losses From the Root Zone



Adapt-N Applications

Adapt-N can be used for a wide range of N management practices for corn (grain, silage, sweet):

- Sidedress N rate recommendation
- Rescue N application rate
- Manured fields – Is additional N necessary, and how much?
- Pre-plant applications or applications at planting: Are additional in-season N applications necessary?
- Hindcasting after growing season (excess?; when deficient; what-if?)

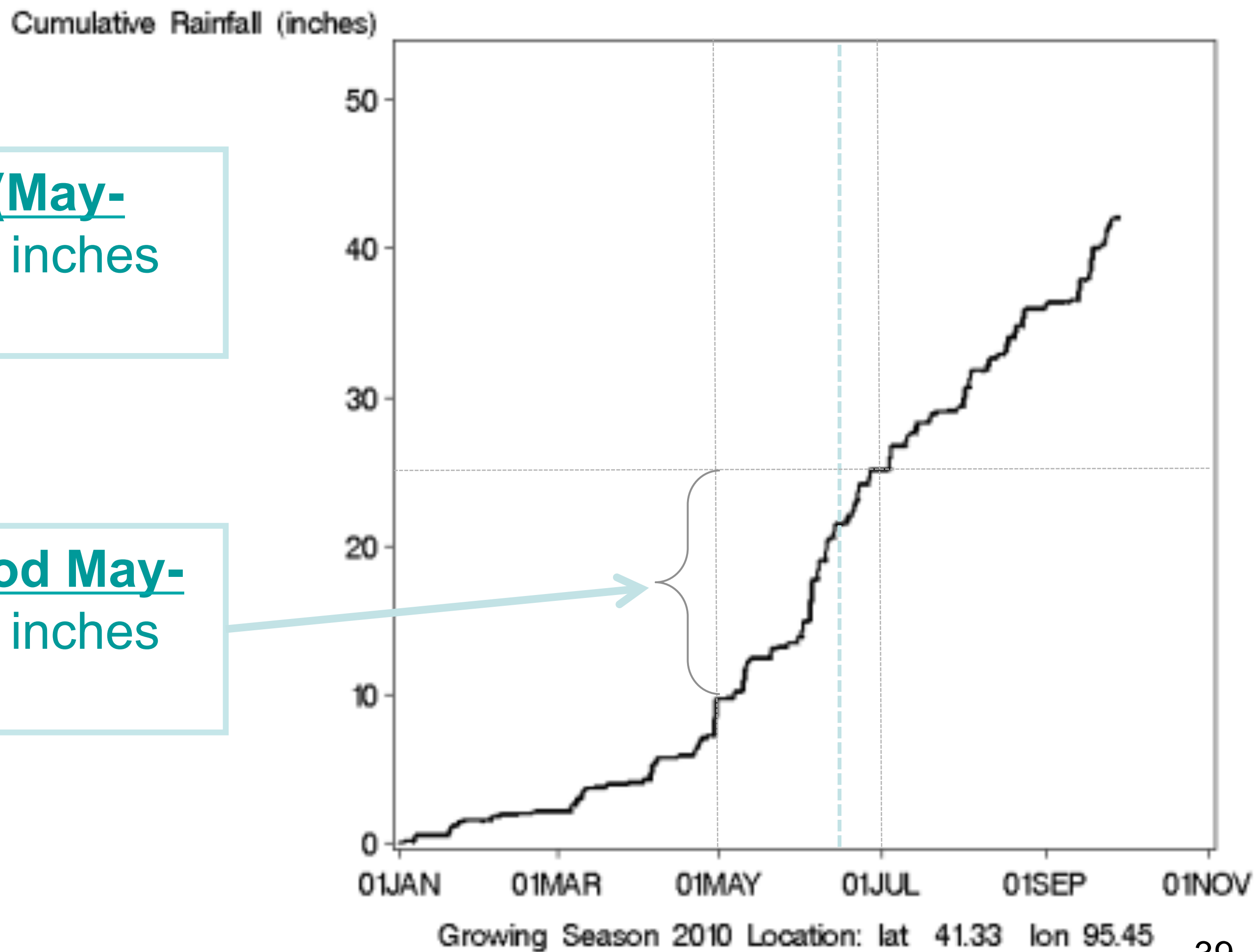
End of Season Evaluations with Adapt-N

Western Iowa 2010

Growing Season Cumulative Rainfall

Growing Season (May-Sept) 2010 32 inches
Normal 19 inches

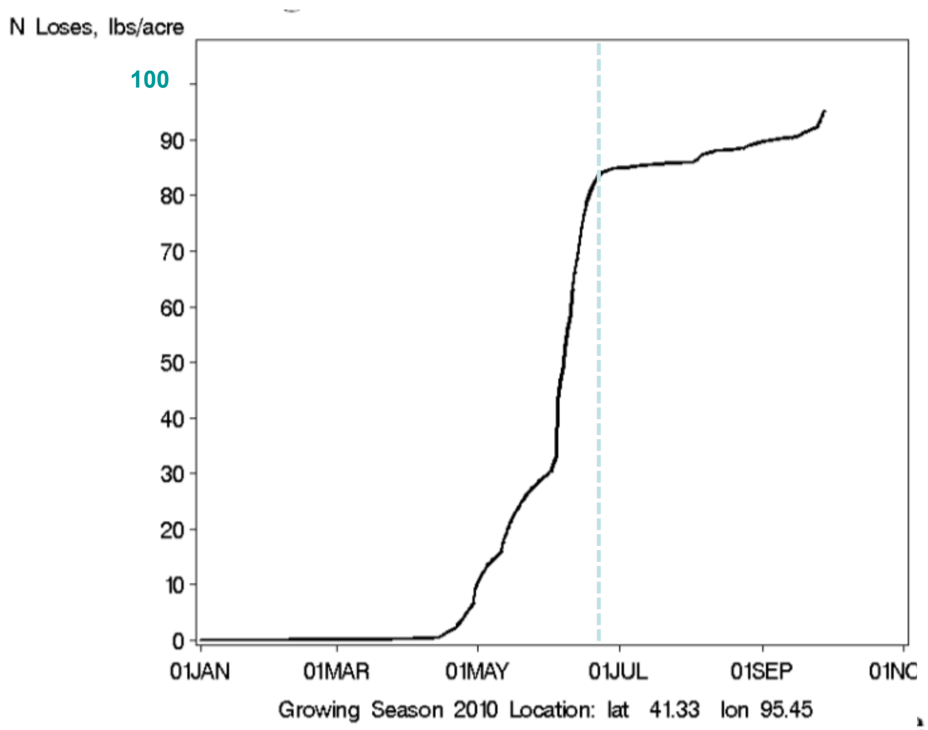
Critical Time Period May-June 2010 19 inches
Normal 8 inches

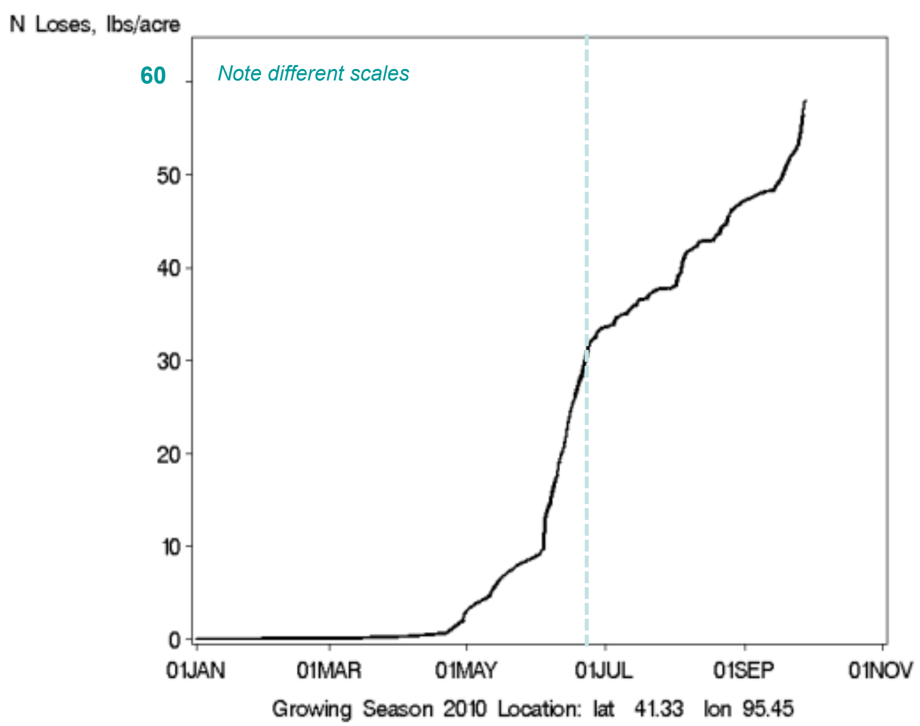


Western Iowa 2010

Cumulative N losses

4/15:	**pre-plant anhydrous 150 lbs/ac**	**4/23:**	**starter MAP 30 lbs/ac**
4/23:	**starter MAP 30 lbs/ac**	**6/14:**	**sidedress UAN 150 lbs/ac**

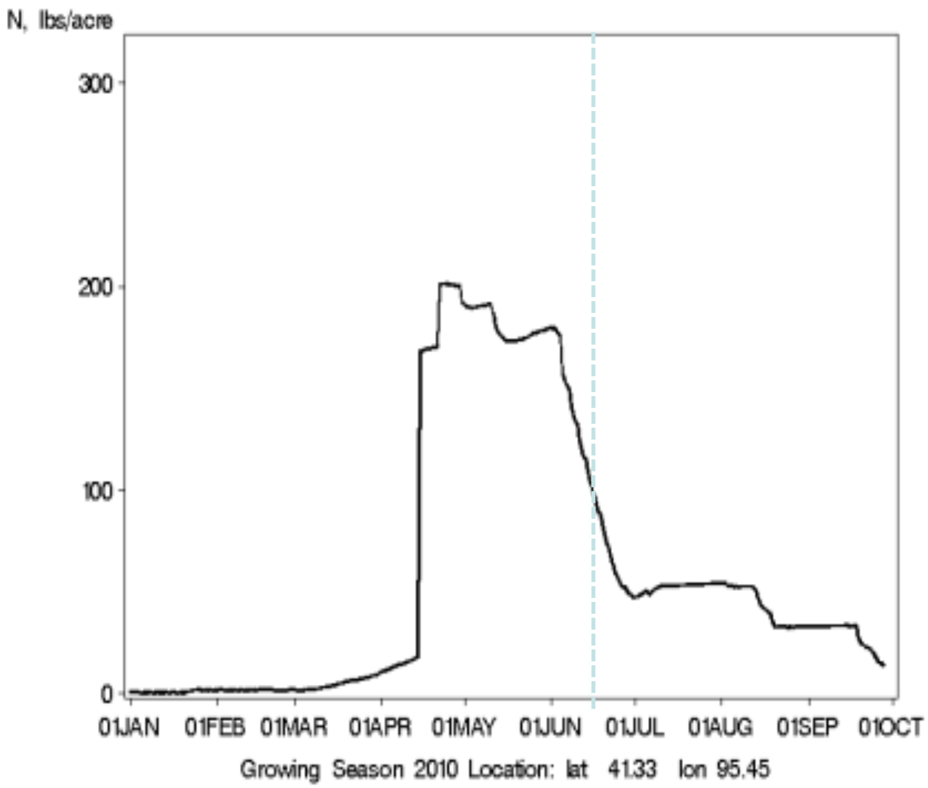




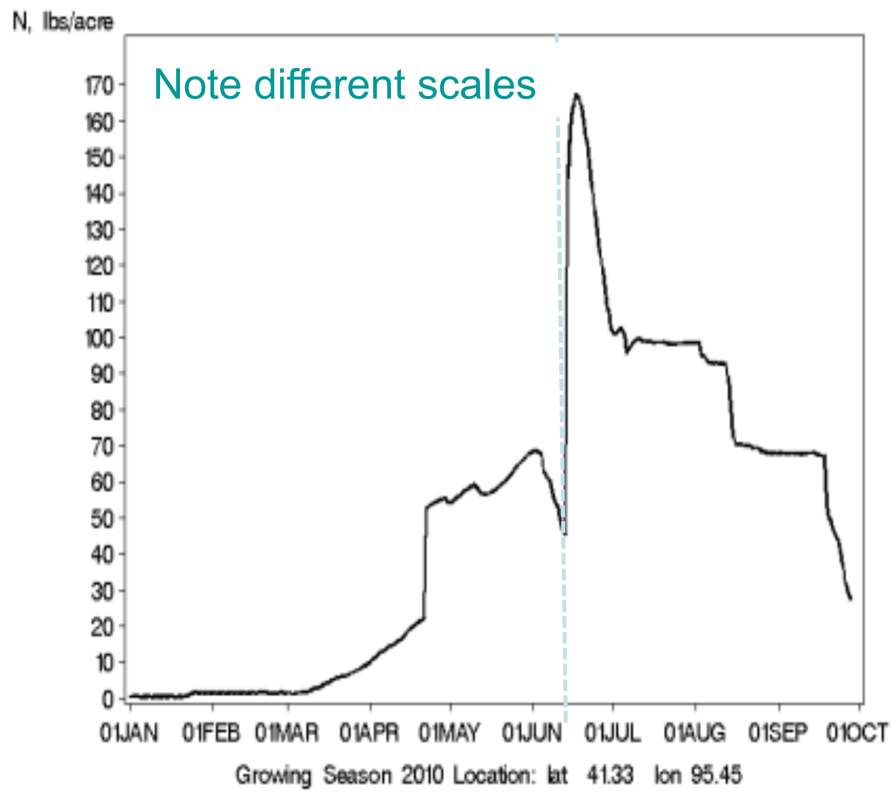
Western Iowa 2010

Soil Nitrate in 0-12 in

4/15: pre-plant anhydrous 150 lbs/ac
4/23: starter MAP 30 lbs/ac

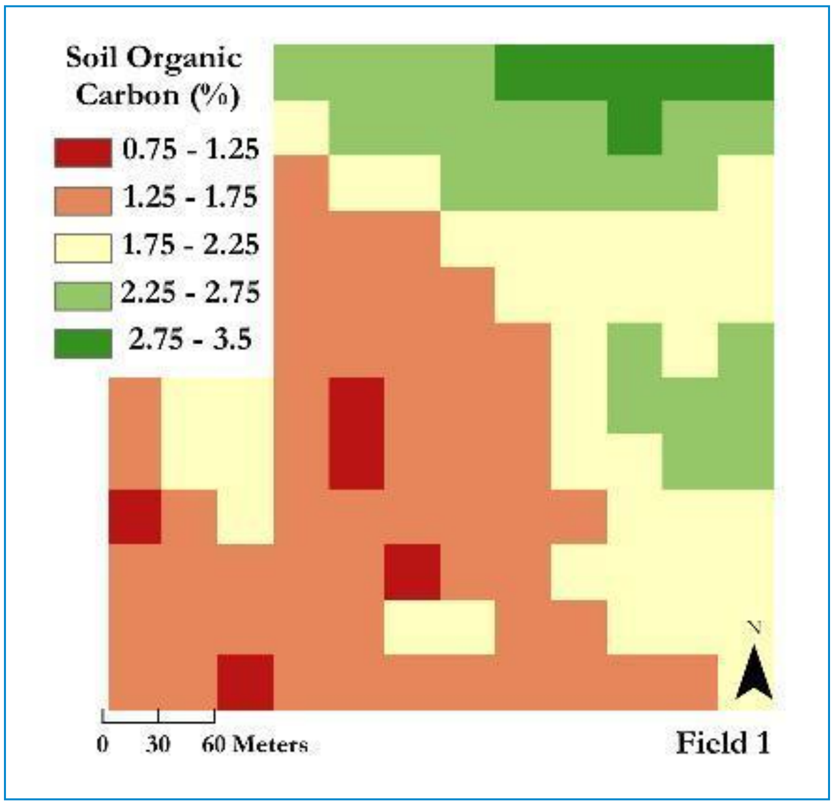


4/23: starter MAP 30 lbs/ac
6/14: sidedress UAN 150 lbs/ac



Using *Adapt-N* for Site-Specific Adaptive Management

NRCS Soil survey

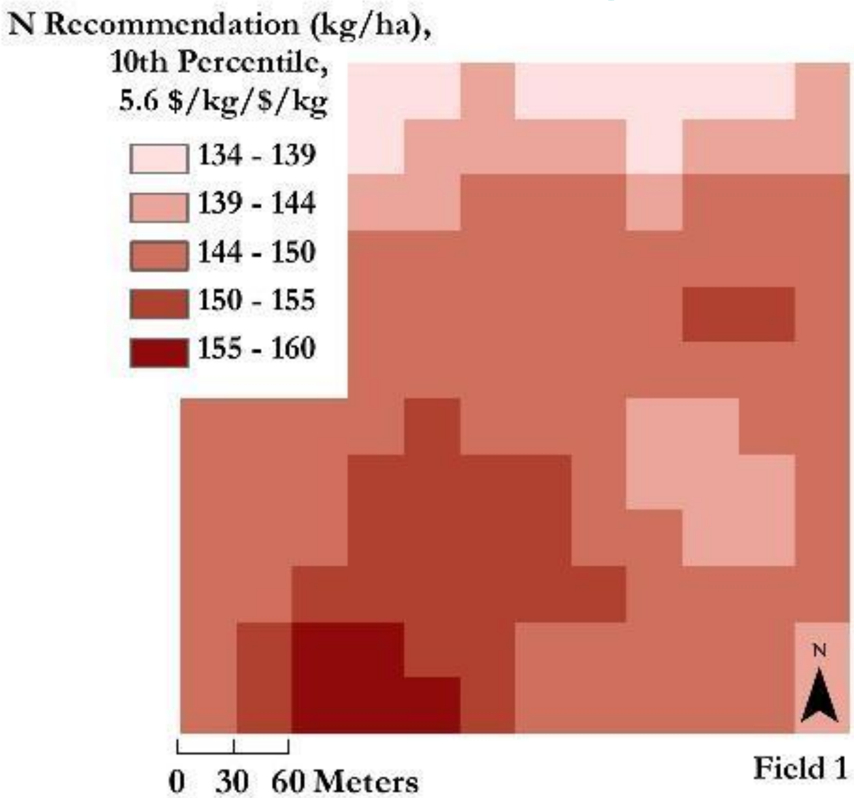


Organic Carbon Content (%) estimated with VIS-NIR Spectroscopy (Veris Technologies)

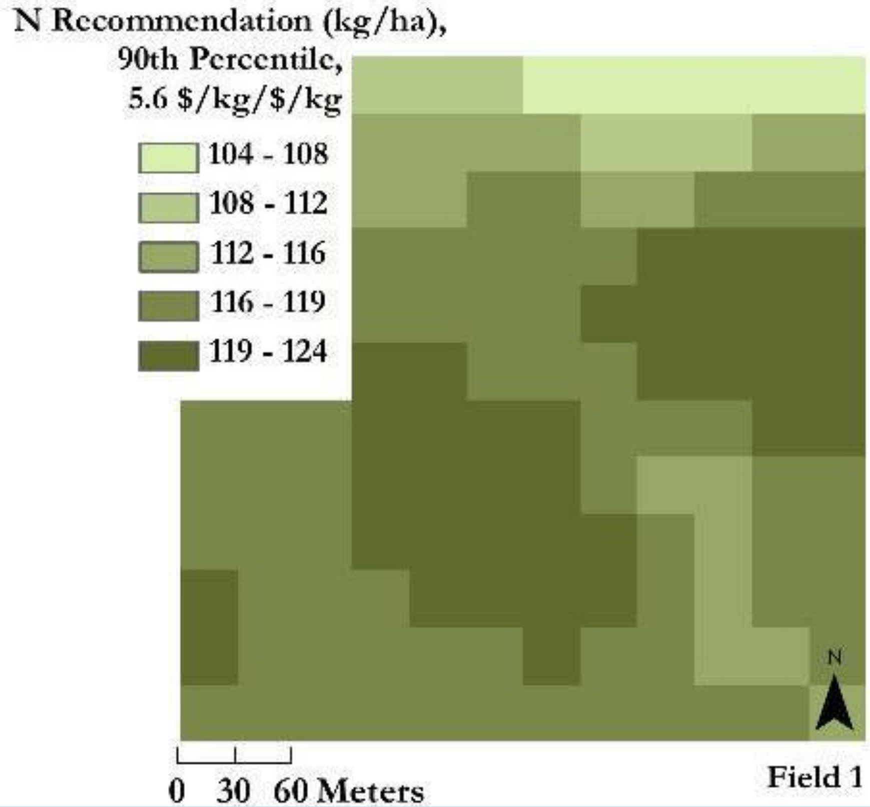
N Sidedress Recommendation (kg/ha)

0.1 Fertilizer to Grain Price Ratio

wet spring



dry spring



Graham, C.J., H.M. van Es, J. Melkonian, and D.A. Laird. 2010. Improved nitrogen and energy use efficiency using NIR estimated soil organic carbon and N simulation modeling. In: D.A. Clay and J. Shanahan. GIS Applications in Agriculture – Nutrient Management for Improved Energy Efficiency. pp 301-325, Taylor and Francis, LLC.

Conclusions

- The need for more precise nitrogen input management is becoming increasingly compelling
- Computational tools can facilitate adaptive N management by incorporating localized information and complex system dynamics, including weather effects
- The Adapt-N tool allows for adaptation to climate change, reduced energy use and environmental losses, and increased profitability

Notes on Adapt-N

- Web site http://adapt-N.eas.cornell.edu
- (soon: ADAPT-N.org)
- To register, email Jeff Melkonian – jjm11@cornell.edu. Provide preferred UserID and password
- Operational for Northeast US and Iowa
- Planned expansion to other humid regions in US, with initial focus on corn belt states