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Attaining Higher Corn Yields:
Tools and Approaches

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Northcentral Director, IPNI

Attaining higher corn yields

- High yielding farmers typically experiment with different management practices to determine what works best on their farm
  - Hybrid test areas
  - Comparison of “current” vs. “improved” management systems
  - Fertility trials
- Getting significantly higher yields takes:
  - Attention to detail
  - Patience
  - Determination
  - Time

Outline

- Current trends in corn grain yield
- Tools
  - Hybrid Maize crop model
  - On-farm research resources
- Thoughts on things to try
  - Fertility trials
  - Comparing management systems

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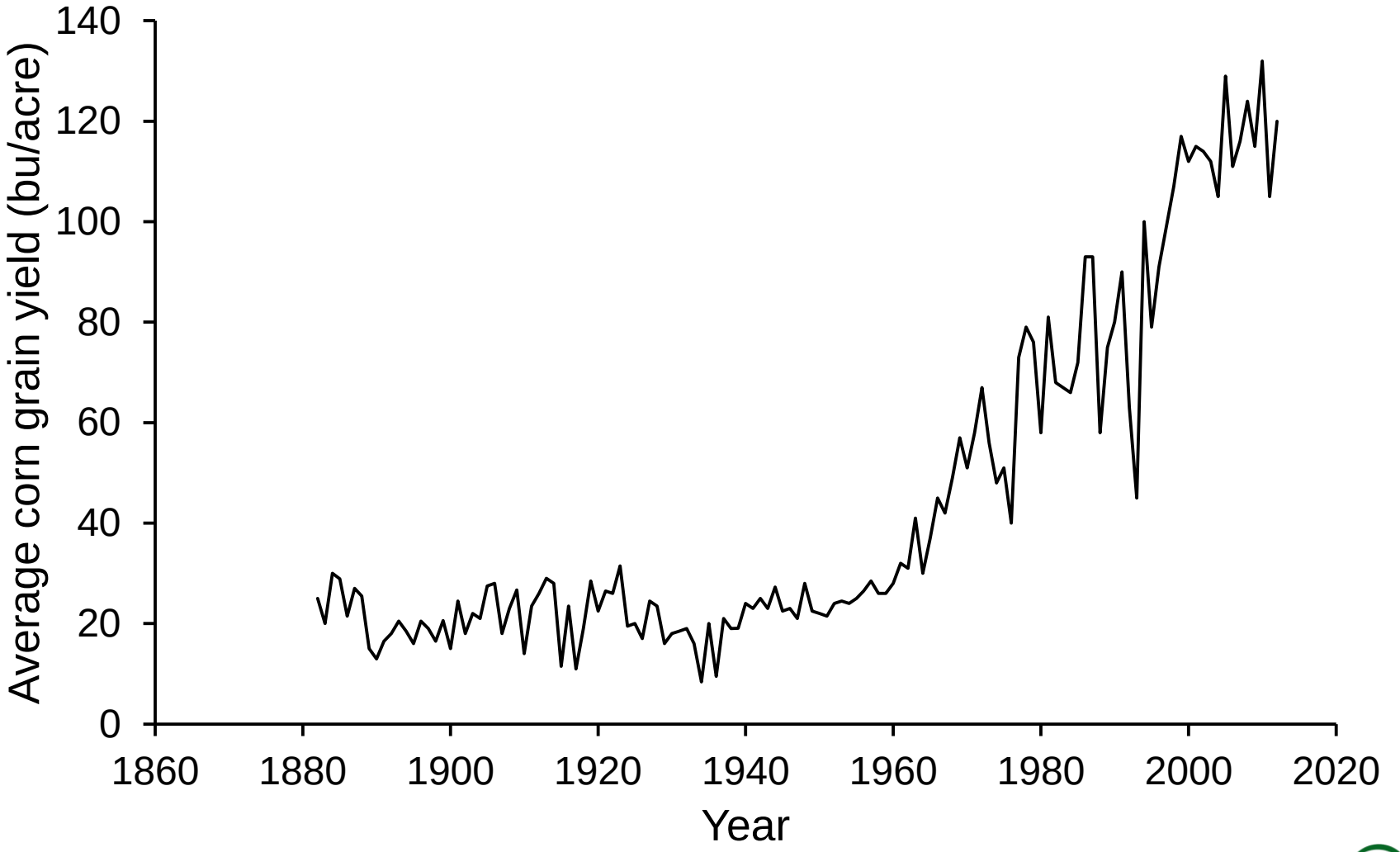
Current trends in corn yields

North Dakota crop statistics:

Average corn grain yield



USDA-NASS. 2012. Quick Stats. Available online at quickstats.nass.usda.gov

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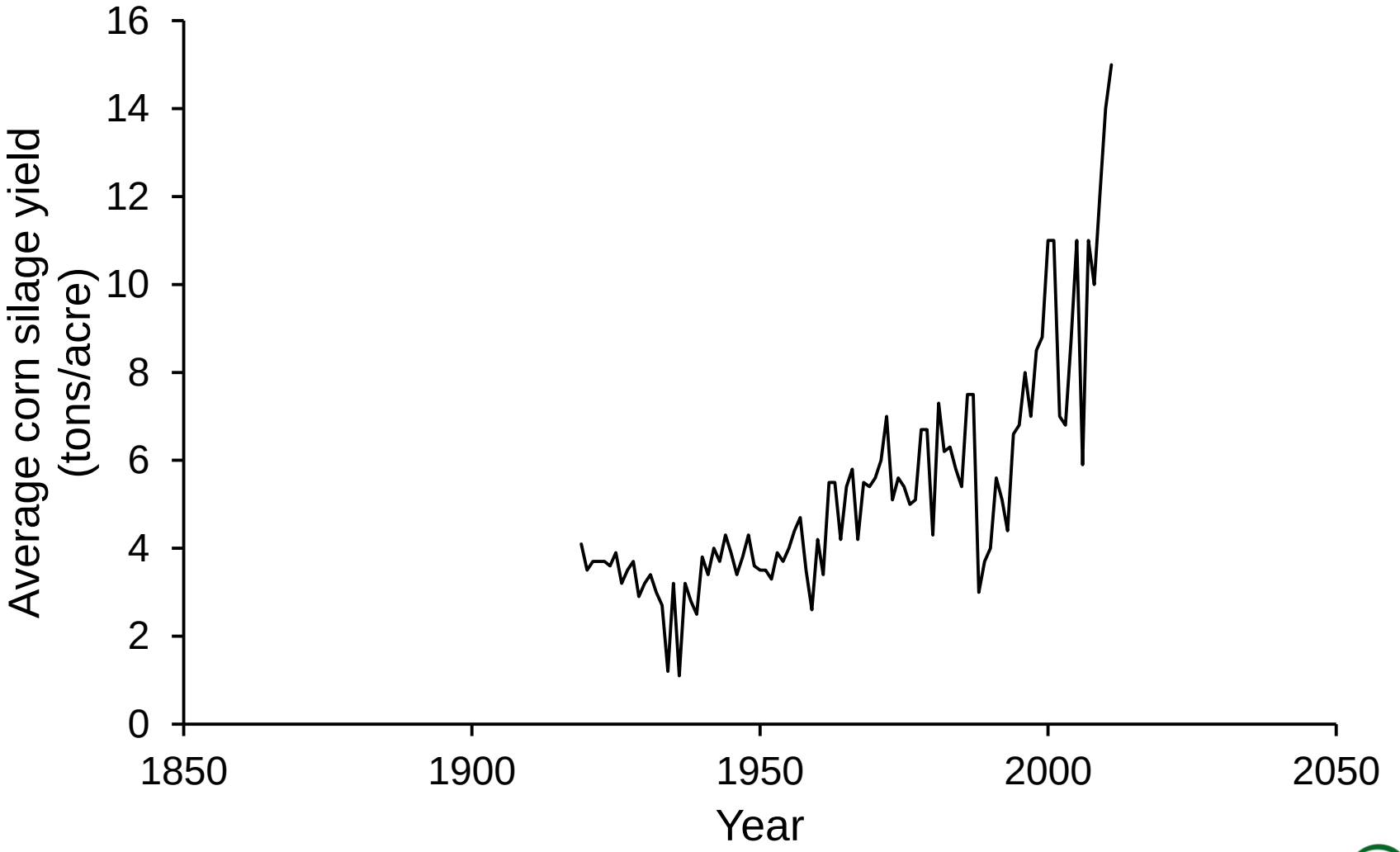
North Dakota crop statistics:

Average corn silage yield



USDA-NASS. 2012. Quick Stats. Available online at quickstats.nass.usda.gov

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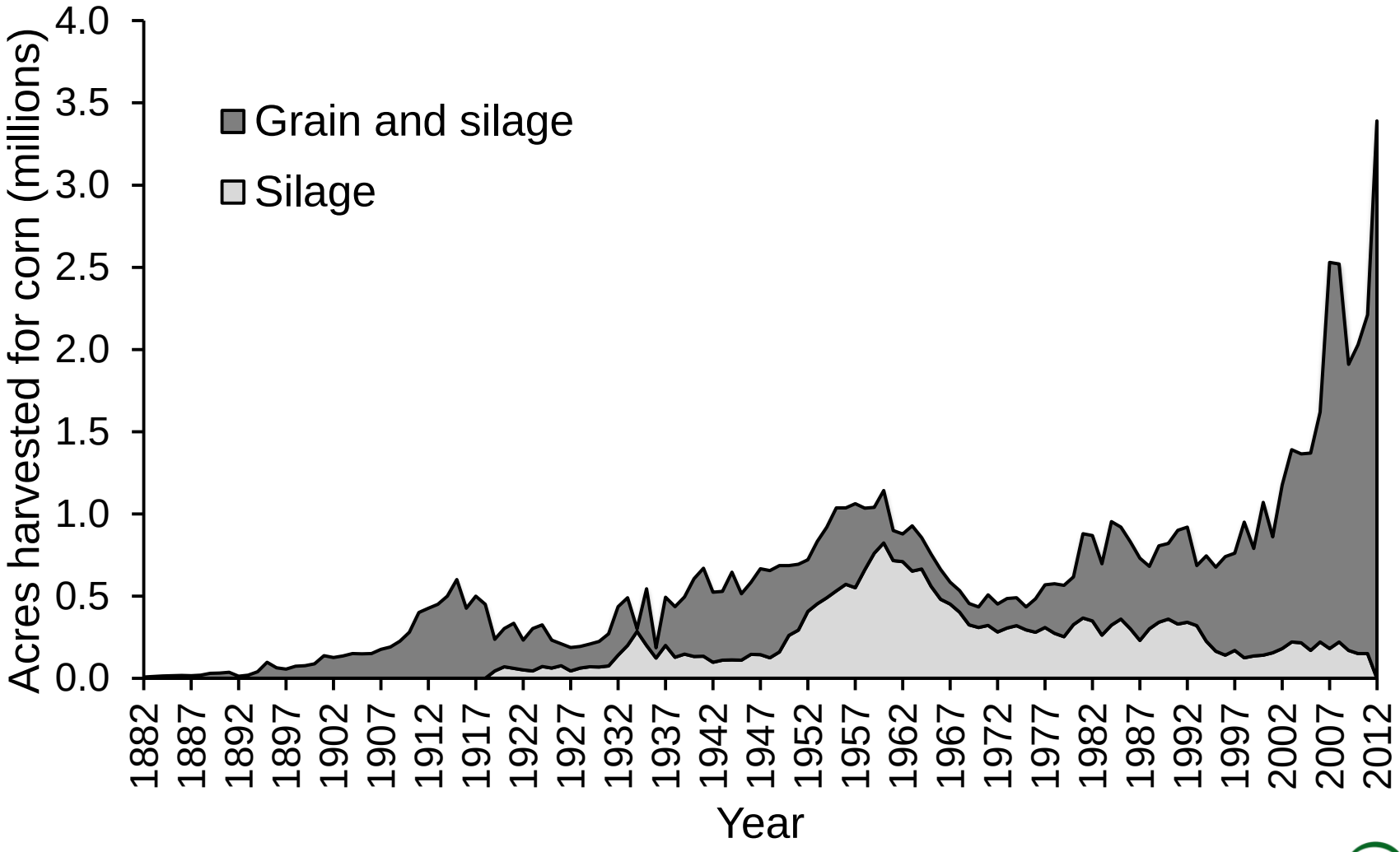
North Dakota crop statistics:

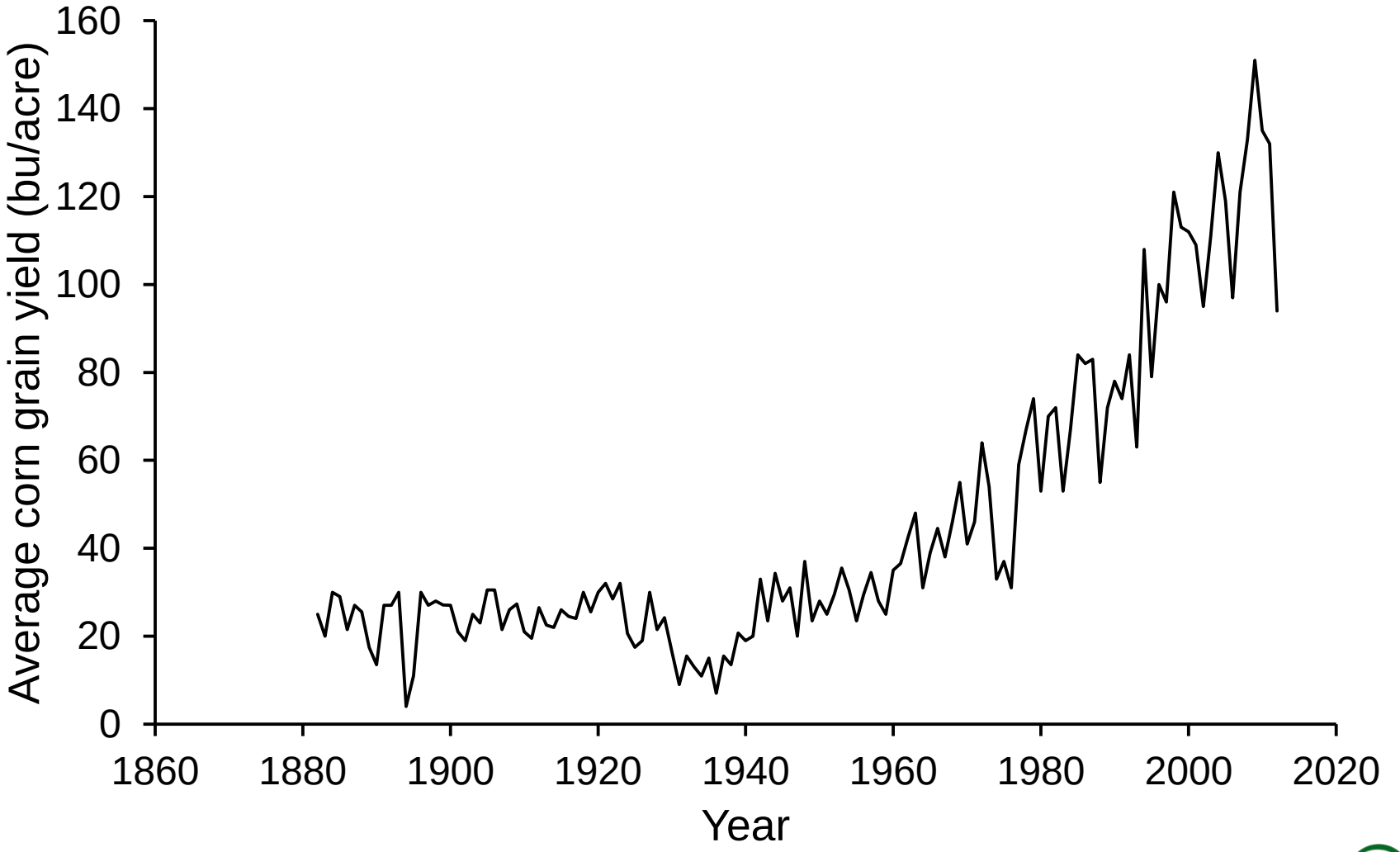
Corn acres harvested



USDA-NASS. 2012. Quick Stats. Available online at quickstats.nass.usda.gov

South Dakota crop statistics:

Average corn grain yield



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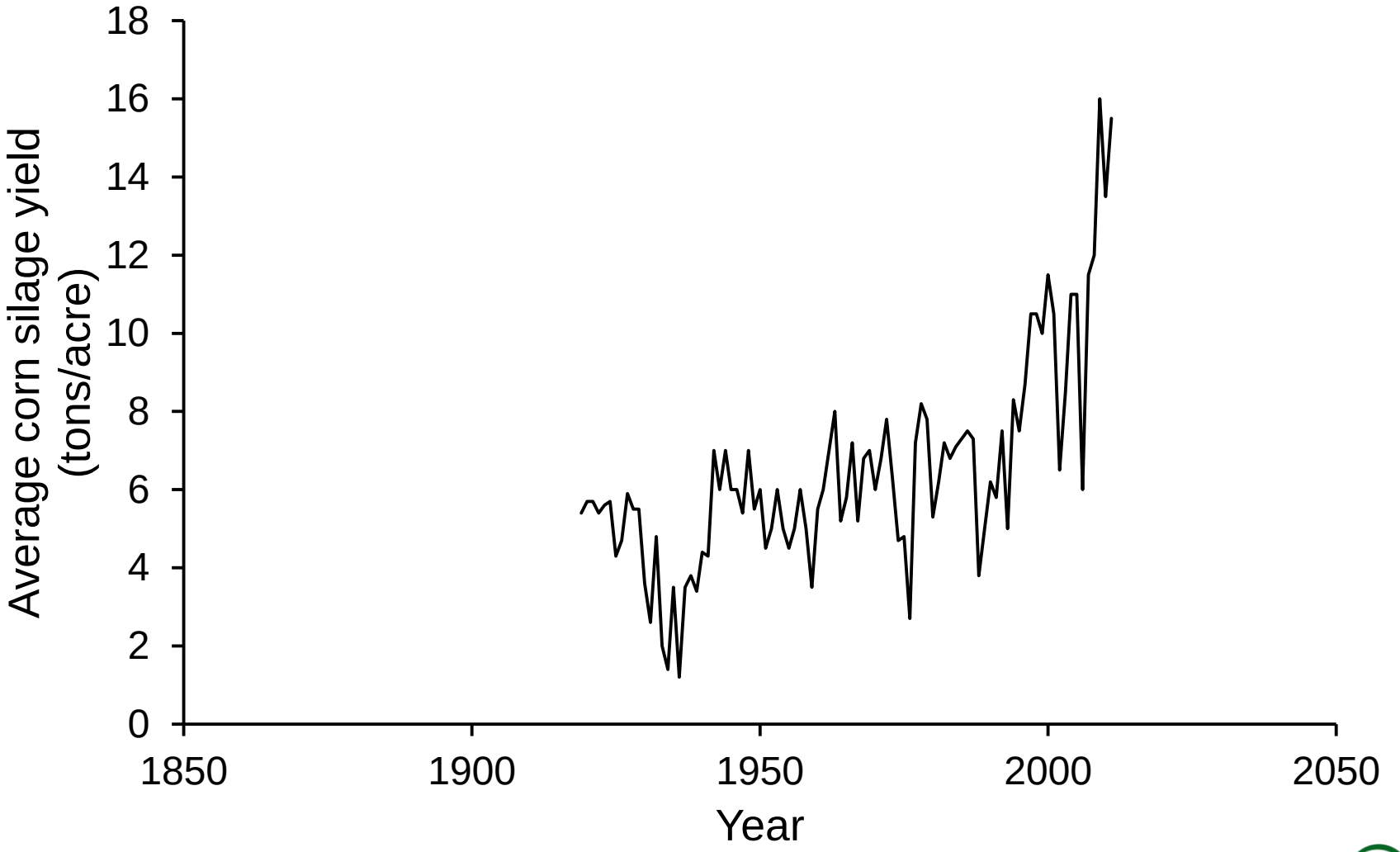
South Dakota crop statistics:

Average corn silage yield



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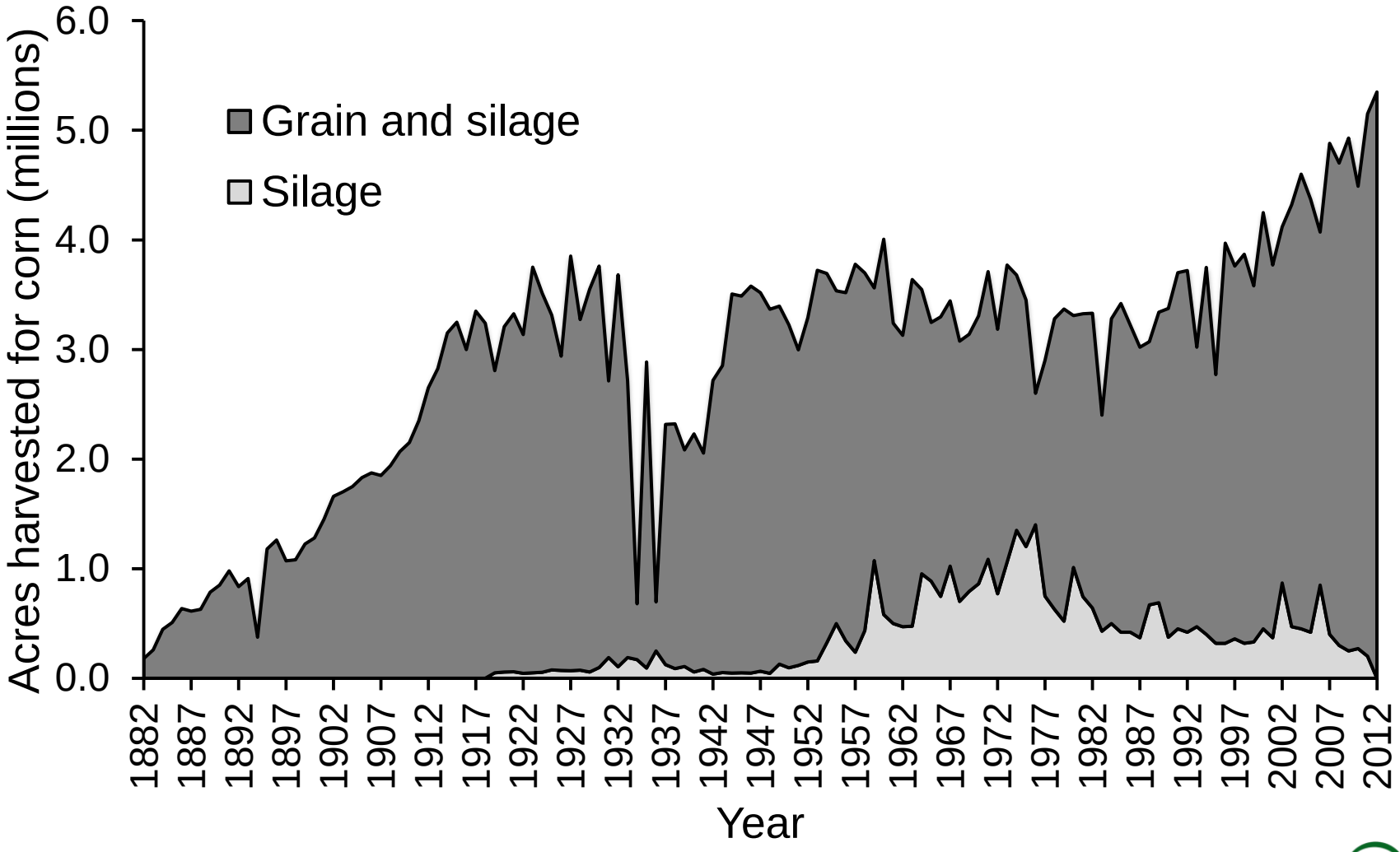
South Dakota crop statistics:

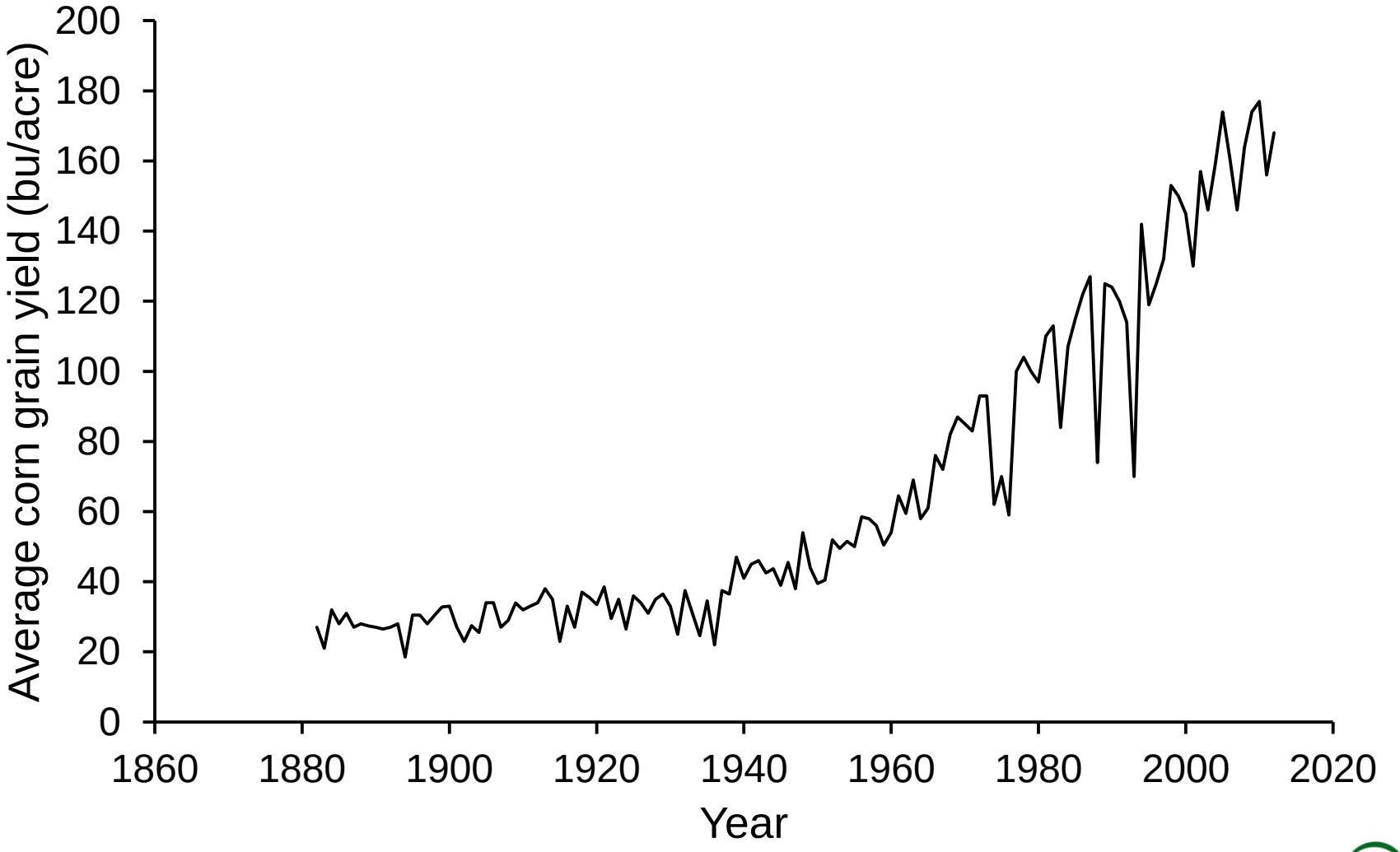
Corn acres harvested



USDA-NASS. 2012. Quick Stats. Available online at quickstats.nass.usda.gov

Minnesota crop statistics:

Average corn grain yield



USDA-NASS. 2012. Quick Stats. Available online at quickstats.nass.usda.gov

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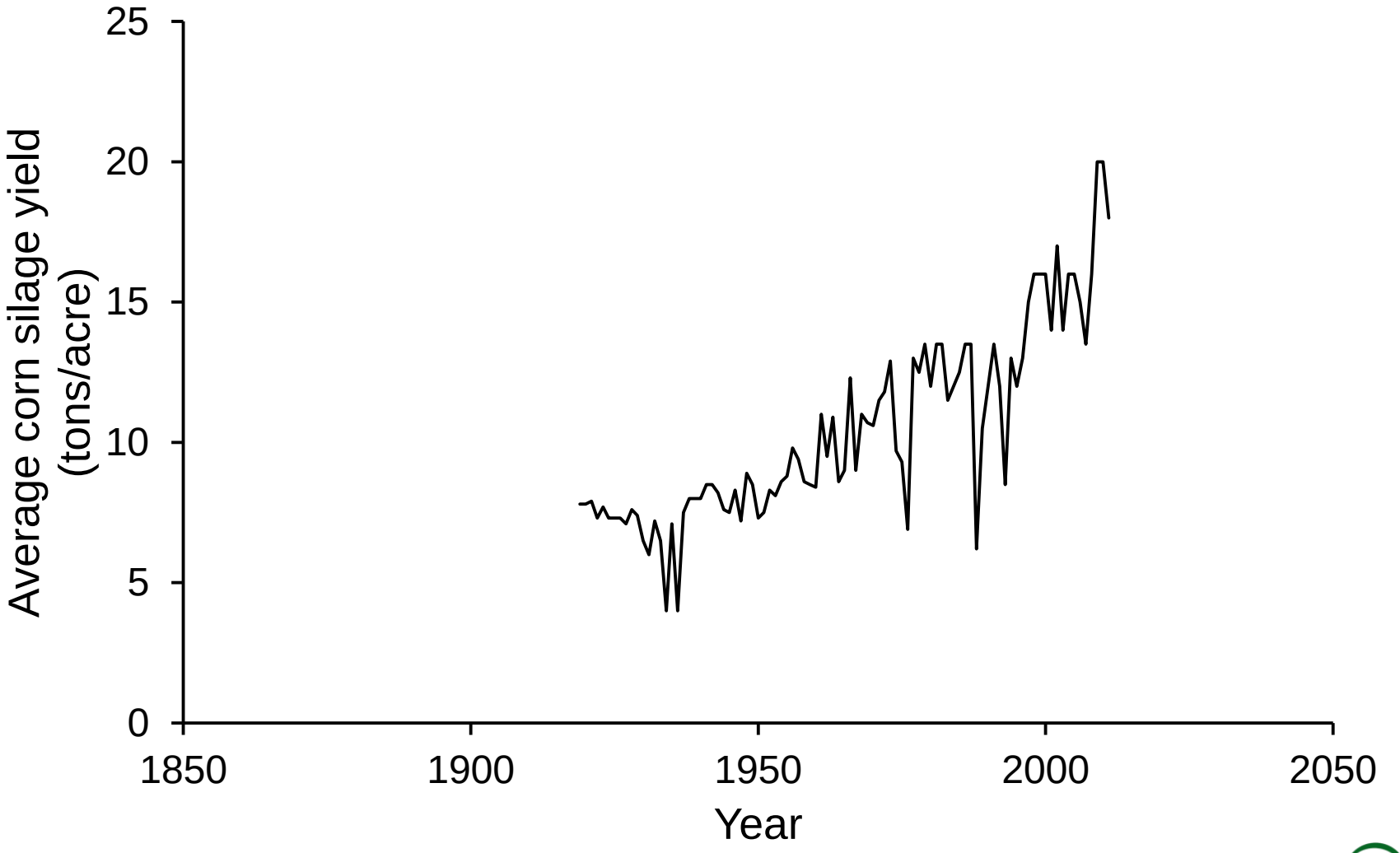
Minnesota crop statistics:

Average corn silage yield



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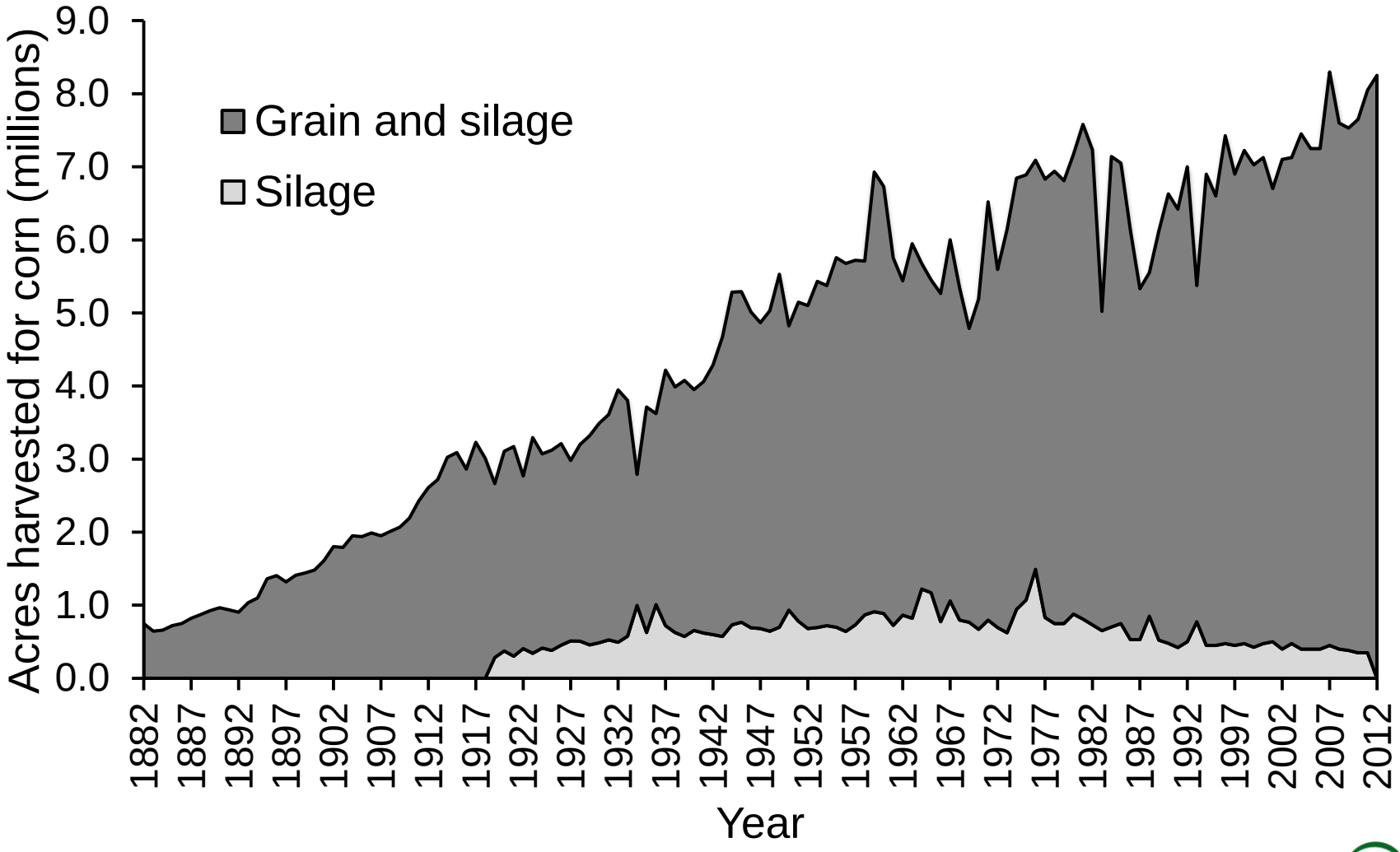
Minnesota crop statistics:

Corn acres harvested



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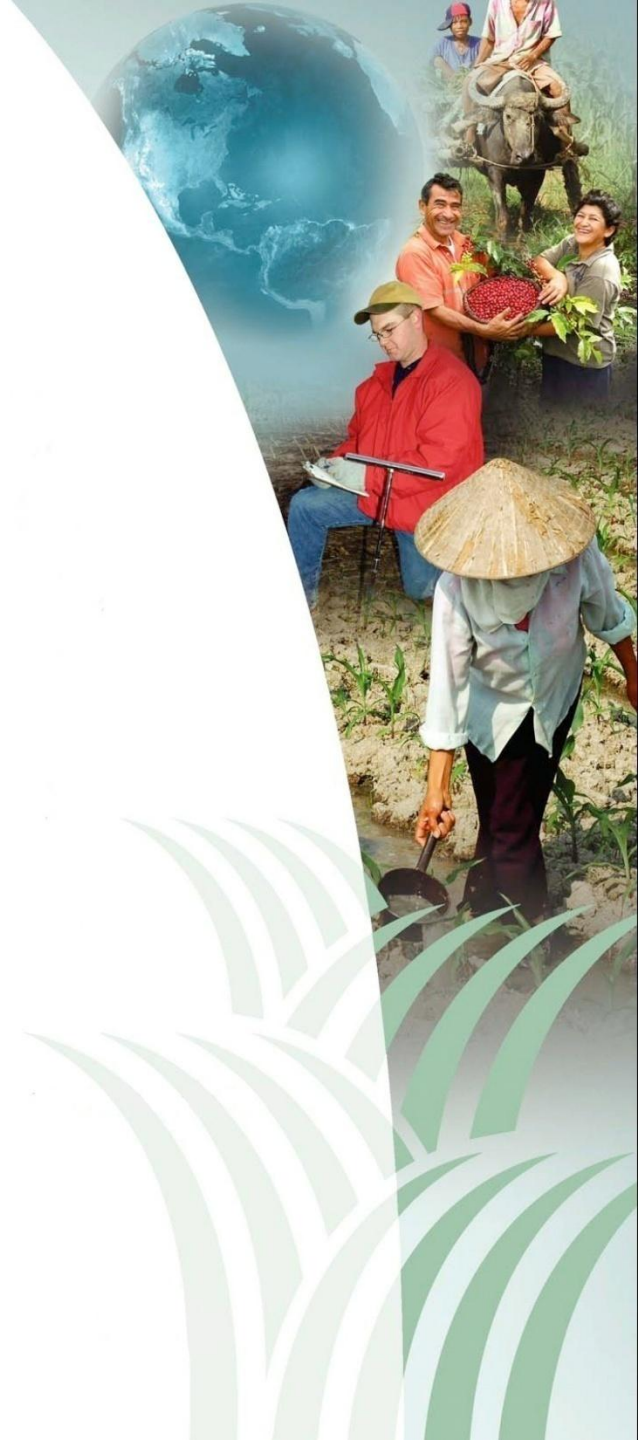
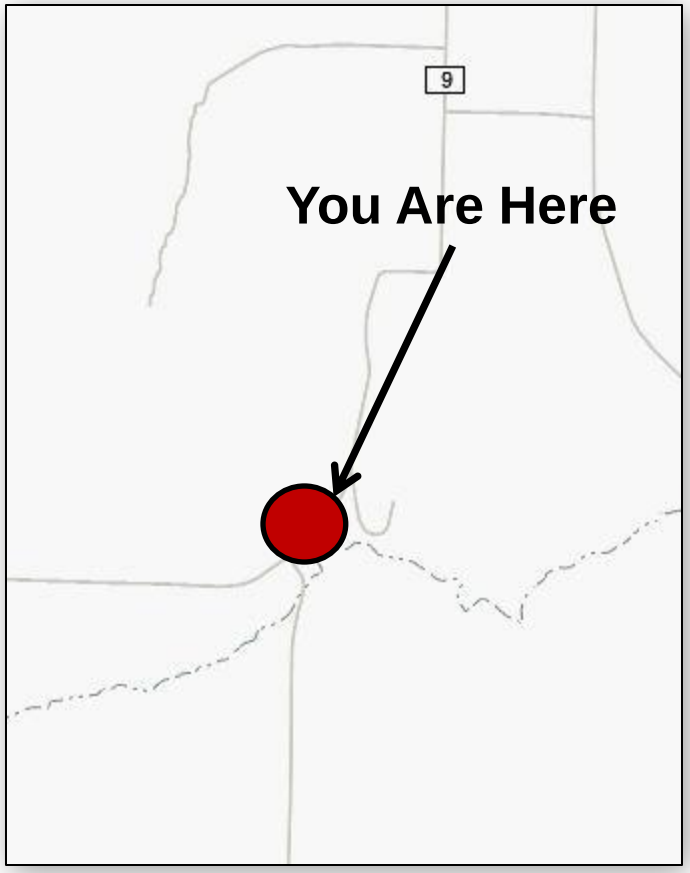


Tools:
Hybrid Maize crop model

Simulating potential yield

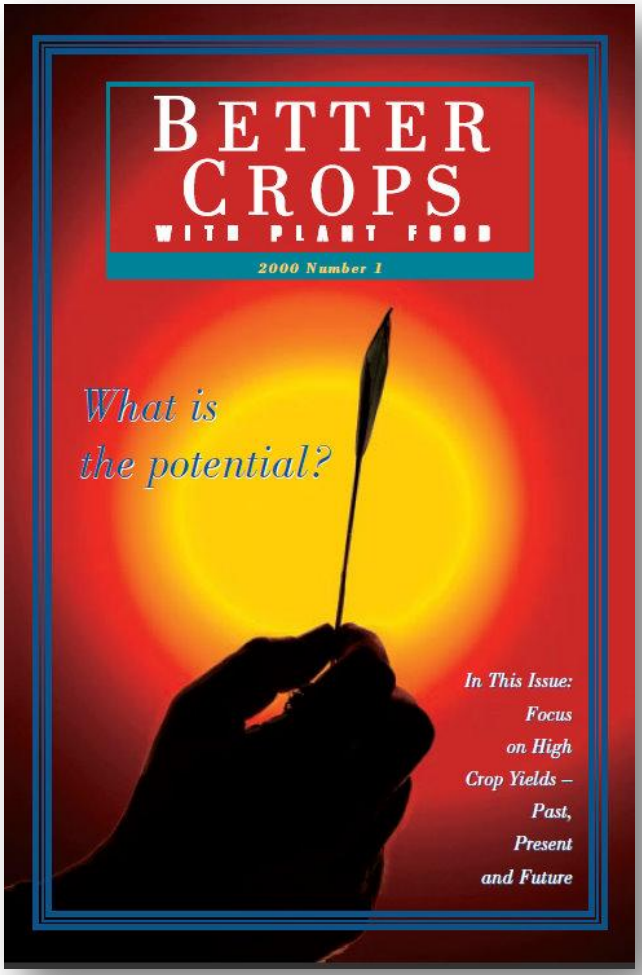
Addressing questions from farmers

- In the future, my operation will need corn yields to increase by ***X*** bu/acre to remain profitable.
- Is this realistic?
- How close am I to what is truly possible (what is the gap)?
- What things are affecting my ability to reach higher yields? Are they things I can control?



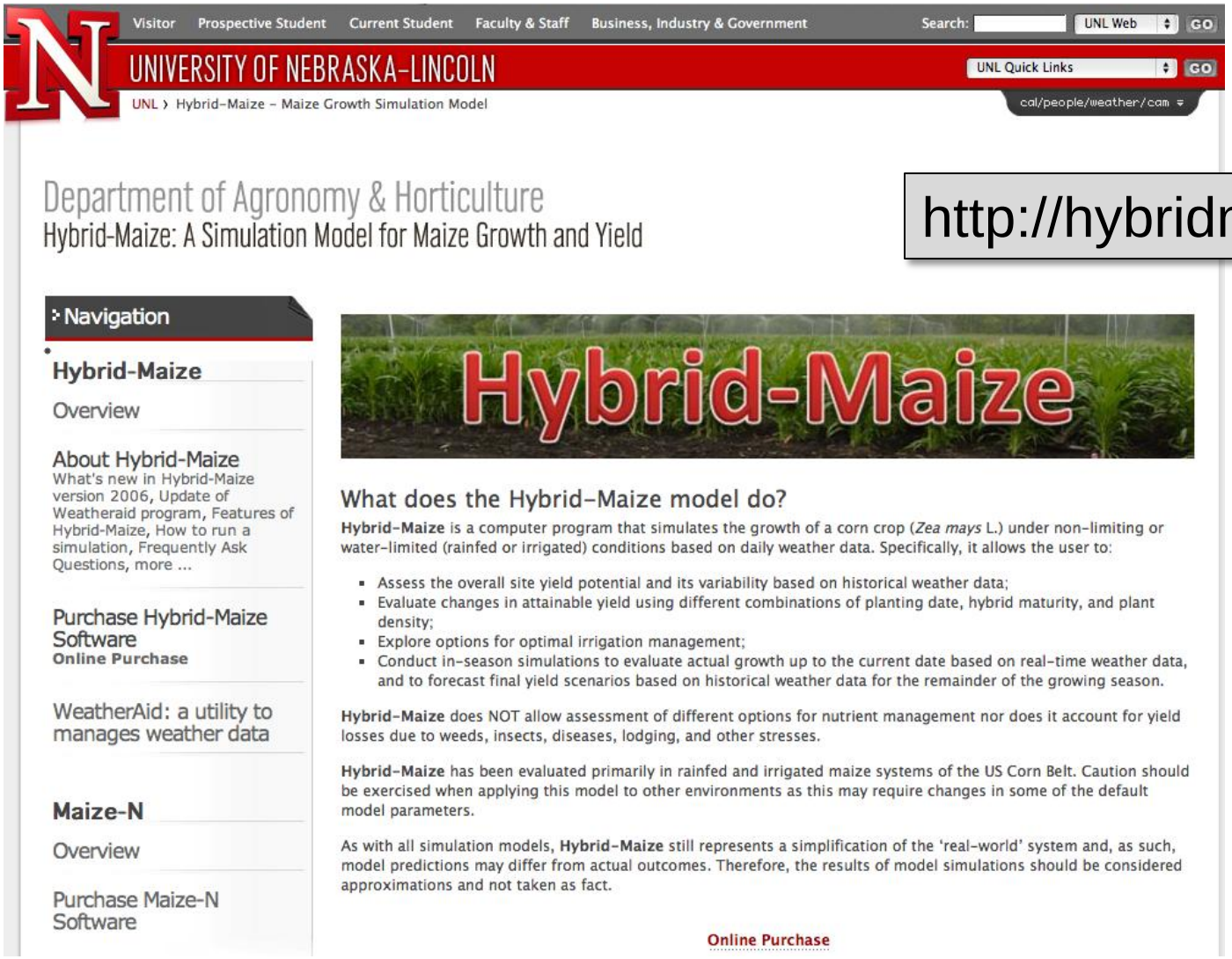
Yield goal vs. potential yield

- Farmers want to know how close their yields are to what is possible
- Potential yield:
  - "…the maximum yield that could be reached by a crop in given environments" (Evans and Fischer. 1999. Crop Sci. 39:1544)
  - Estimated through crop growth models
- Yield goal:
  - Average of historical yields + _____%
  - "What has been done plus a little more"
  - Estimates for the coming season are used to determine "maintenance rates"

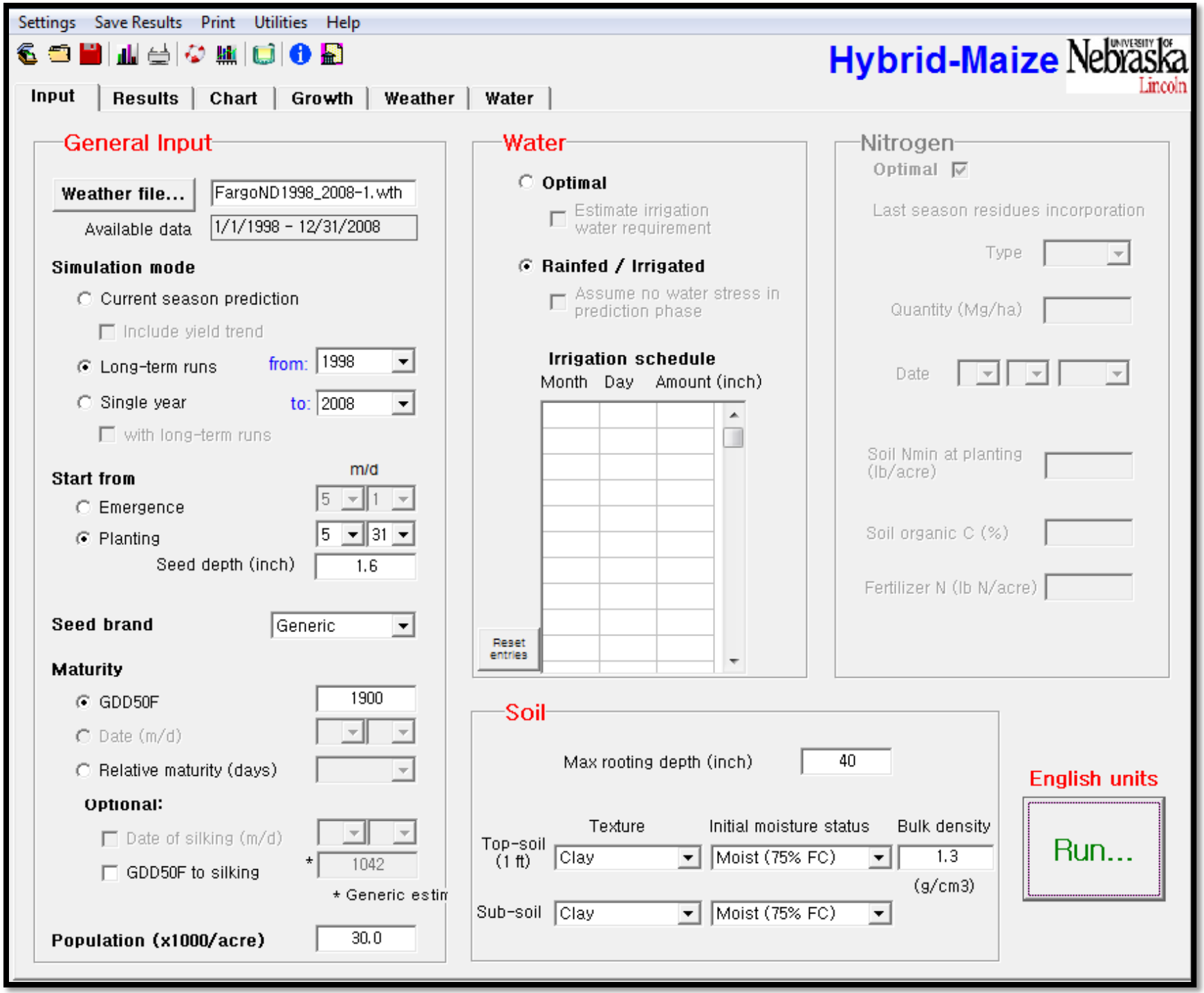


Estimating potential yield

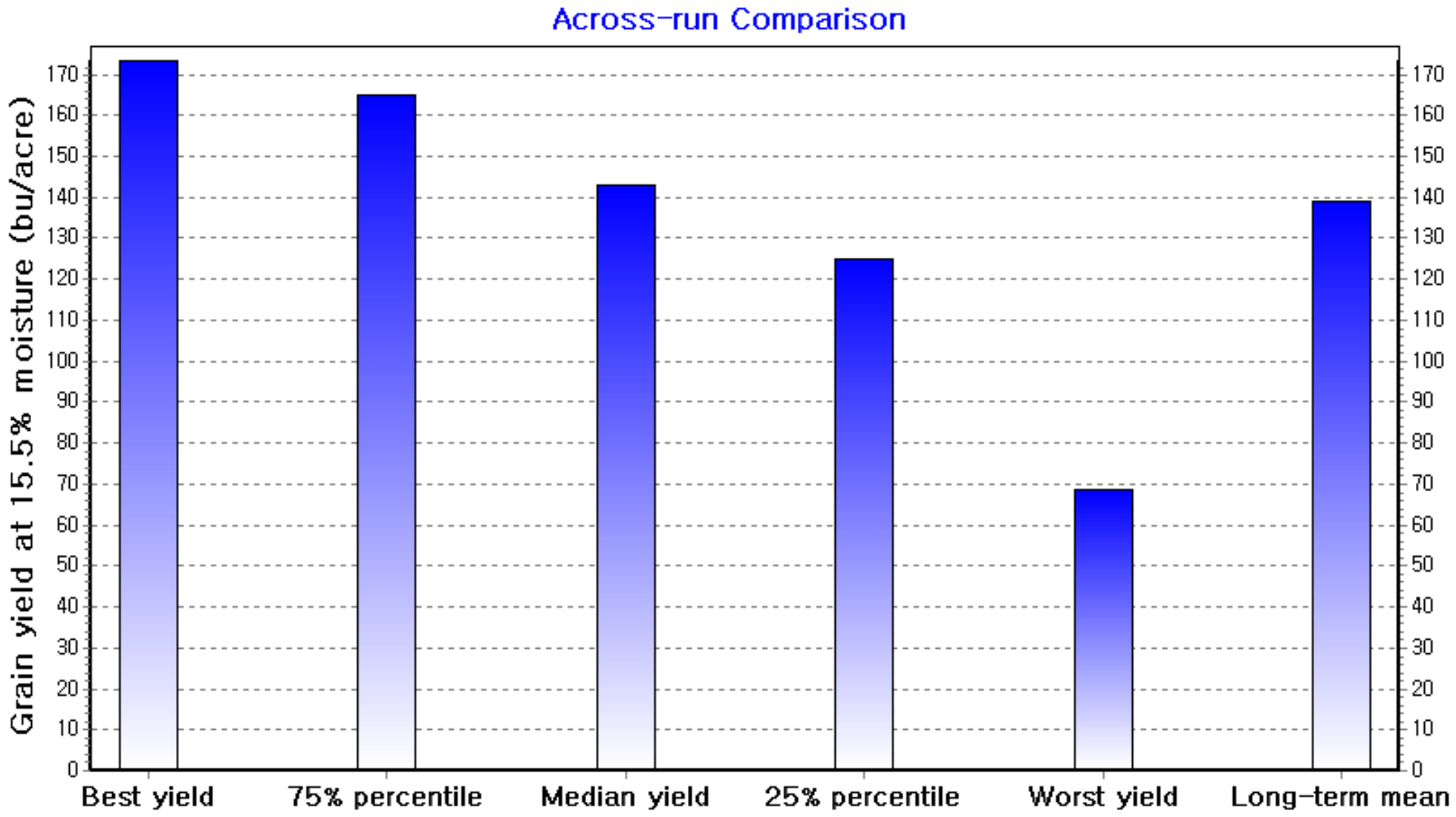
Hybrid-Maize plant growth simulation software



http://hybridmaize.unl.edu


Settings
Save Results
Print
Utilities
Help
Hybrid-Maize
University of Nebraska Lincoln
Input
Results
Chart
Growth
Weather
Water
General Input
Weather file...
FargoND1998_2008-1.wth
Available data
1/1/1998 - 12/31/2008
Simulation mode
Current season prediction
Include yield trend
Long-term runs
from:
1998
Single year
to:
2008
with long-term runs
Start from
m/d
Emergence
5
1
Planting
5
31
Seed depth (inch)
1.6
Seed brand
Generic
Maturity
GDD50F
1900
Date (m/d)
Relative maturity (days)
Optional:
Date of silking (m/d)
GDD50F to silking
1042
* Generic estim
Population (x1000/acre)
30.0
Water
Optimal
Estimate irrigation water requirement
Rainfed / Irrigated
Assume no water stress in prediction phase
Irrigation schedule
Month
Day
Amount (inch)
Reset entries
Nitrogen
Optimal
Last season residues incorporation
Type
Quantity (Mg/ha)
Date
Soil Nmin at planting (lb/acre)
Soil organic C (%)
Fertilizer N (lb N/acre)
Soil
Max rooting depth (inch)
40
Texture
Initial moisture status
Bulk density
Top-soil (1 ft)
Clay
Moist (75% FC)
1.3
(g/cm3)
Sub-soil
Clay
Moist (75% FC)
English units
Run...

Example output from a 10-yr simulation



Primary output generated by *Hybrid-Maize*

- Maize yields can be simulated for 1 year or many years
- Forecasted yields can be generated for a current season, using year-to-date weather data combined with long-term weather data
  - Requires a minimum of 10 years of historical weather data
    - Summarized by day
    - No missing data

Run	Gr. Y
1998	143.0
1999	162.0
2000	164.8
2001	169.9
2002	159.5
2003	68.7
2004	124.2
2005	173.3
2006	125.0
2007	129.7
2008	110.8

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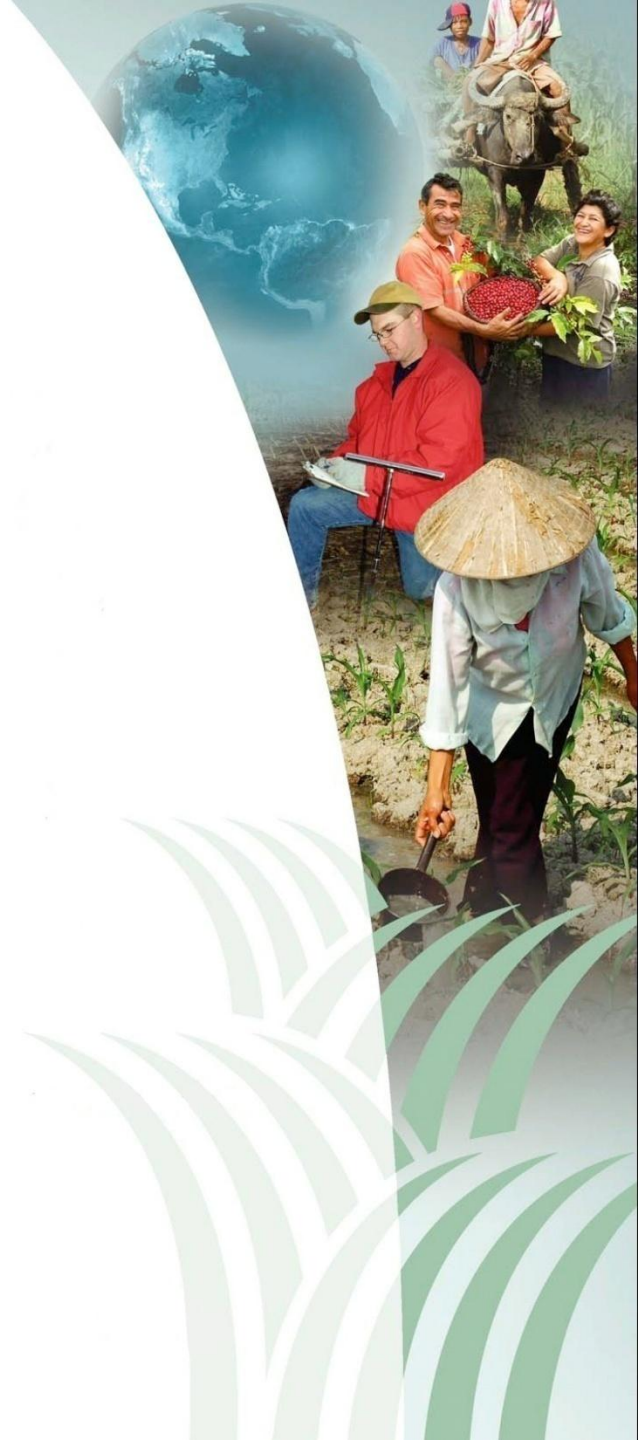
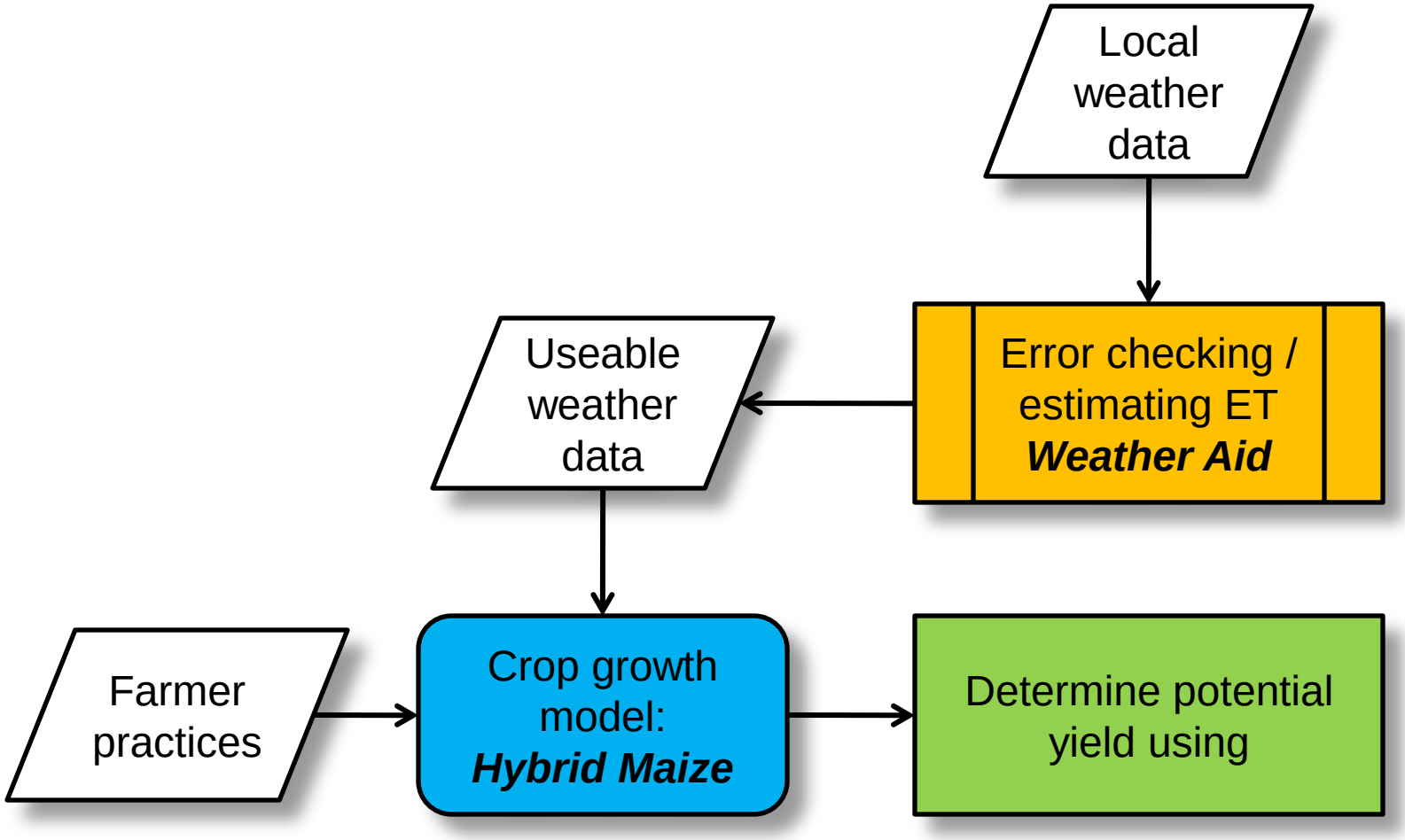


Tools:
Hybrid Maize crop model

Getting weather data

Process for determining potential yield



Required weather data

- Daily data for the following:
  - Minimum air temperature
  - Maximum air temperature
  - Total precipitation
  - Average wind speed
  - Average relative humidity
- Weather data resources:
  - NASA (usually complete through 2008 - free)
    http://power.larc.nasa.gov/cgi-bin/cgiwrap/solar/agro.cgi?email=agroclim@larc.nasa.gov
  - Midwestern Regional Climate Center
    http://mrcc.isws.illinois.edu
  - High Plains Regional Climate Center
    Automated Weather Data Network (AWDN: $10/year/station)
    http://www.hprcc.unl.edu/data/

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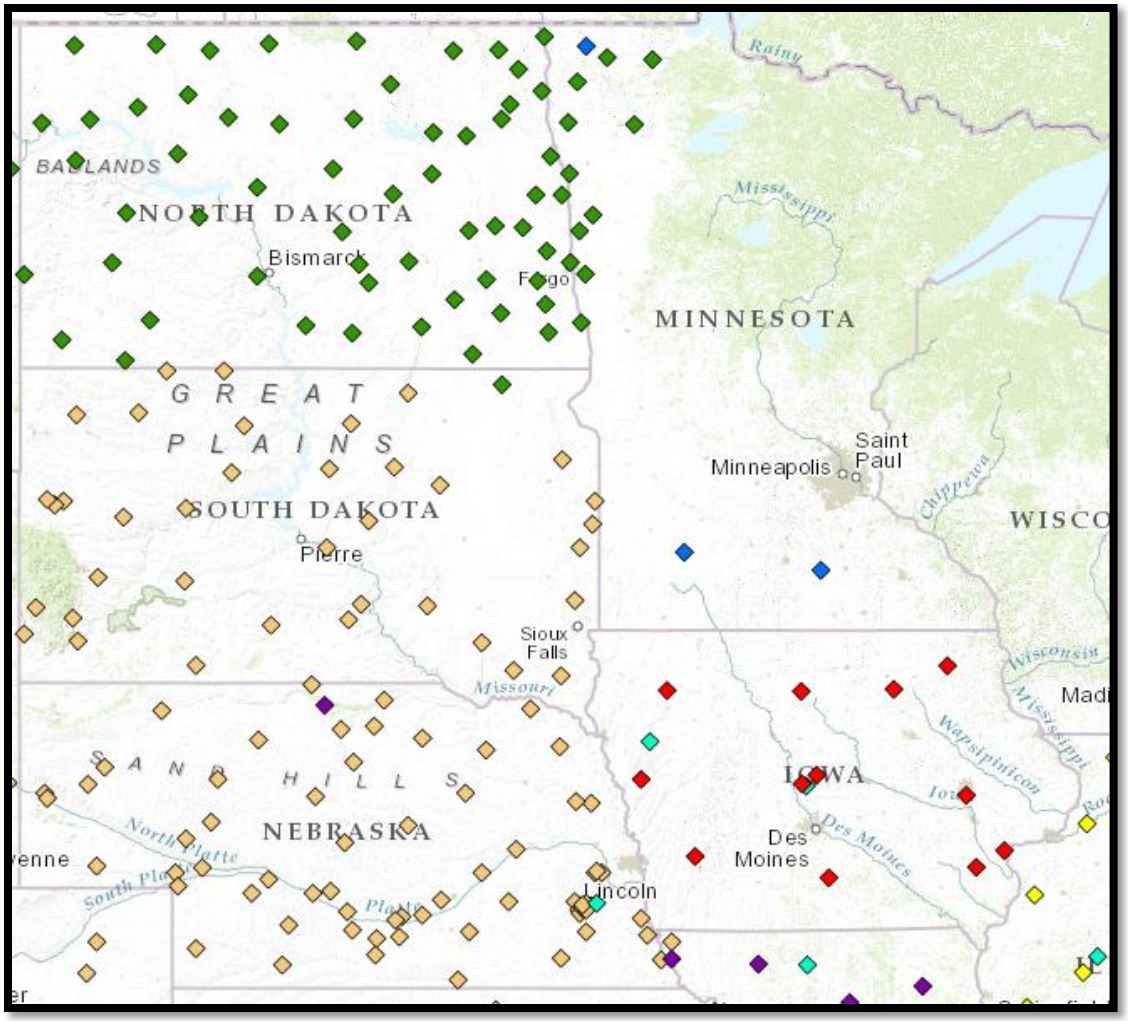
Mesonets:
Mesoscale networks

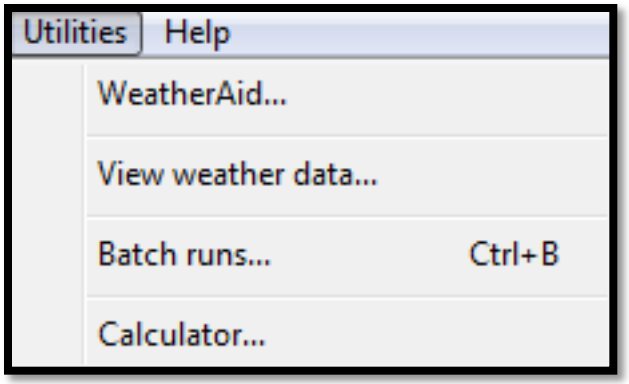
- Automated, environmental monitoring stations
- Most capture data needed by Hybrid Maize



http://www.hprcc.unl.edu/data/

Weather Aid tool in Hybrid Maize

- Readily retrieves data from NASA
- Checks for errors and allows you to correct them
- Estimates evapotranspiration
- Formats weather data into the format needed by Hybrid Maize



NASA Climatology Resource for Agroclimatology
Daily Averaged Data (Evaluation Version)

Please Note: Data sets preceding January 1, 2008 are derived from different sources of data than those on or after January 1, 2008. It is not recommended to use time series data to assess trends across that date.

Enter BOTH latitude and longitude either in decimal degrees or degrees and minutes separated by a "_".

Example: Latitude 33.5 Longitude -80.75 OR Latitude 33_30 Longitude -80_45

Latitude? South: -90 to 0 North: 0 to 90

Longitude? West: -180 to 0 East: 0 to 180

Start Date: Jan 1 2012 *SEE AVAILABLE DATES*

End Date: Dec 31 2012 *BESIDE EACH PARAMETER*

Choose between two output formats (1 OR 2):

1) Download solar and meteorological parameters in ICASA ASCII column format? Yes

2) Download single or multiple solar radiation and meteorological parameters in ASCII column format:

Note: Precipitation usually lags in availability. See available dates when choosing the parameters in the list to the right.

- Top-of-atmosphere Insolation (Jul 1983-near present)
- Insolation on Horizontal Surface (Jul 1983-near present)
- Downward Longwave Radiative Flux (Jul 1983-near present)
- Average Air Temperature at 2 m (Jan 1983-near present)
- Minimum Air Temperature at 2 m (Jan 1983-near present)
- Maximum Air Temperature at 2 m (Jan 1983-near present)
- Relative Humidity at 2 m (Jan 1983-near present)
- Dew Point at 2 m (Jan 1983-near present)
- Precipitation (Jan 1997-Aug 2009)

Submit Reset *This form is "Reset" if the input is out of range.*

WeatherAid

File Control Help

Open input file... FargoND1998_2008-1.wth

WeatherAid Explorer

Step 1: Specify input data

Data template: Hybrid-Maize

Rows before data start: 4

Reference ET estimated by FAO Penman-Monteith method.! SRAD daily Insolation Incident On A Horizontal Surface (MJ/m^2/day
46.95 (Lat.)

Year	DOY	Solar MJ/m2	T-max oC	T-min oC	RelHum %	Precip mm	ET mm
1998	1	5.10	-1.4	-7.2	94	0.1	0.1
1998	2	4.10	-2.6	-16.8	97	4.9	0.1
1998	3	5.50	-19.5	-26.2	68	0.2	0.2
1998	4	5.80	-14.6	-23.1	72	0.0	0.2
1998	5	4.20	-8.3	-15.2	78	0.0	0.2
1998	6	7.20	-11.4	-14.2	78	0.0	0.2

Column	1	2	3	4	5	6	7	8	9	10	11	12
Variable	Year	DOY	Solar	T-max	T-min	RelHun	Precip	ET	Ignore	Ignore	Ignore	Ignore
Unit			MJ/m2	oC	oC	%	mm	mm				

Spacer

Reset

Step 2: Select task

1, Convert to Hybrid-Maize format

Convert and rearrange for Hybrid-Maize use

Hybrid-Maize requires daily weather data of:

- Solar radiation
- Maximum temperature (T-max)
- Minimum temperature (T-min)
- Relative humidity of the air
- Precipitation
- Reference evaportranspiration (ET)

Step 3: Process

Output

Reference ET estimated by FAO Penman-Monteith method.! SRAD
46.95 (Lat.)

Year	DOY	Solar MJ/m2	T-max oC	T-min oC	RelHum %	Precip mm
1998	1	5.10	-1.4	-7.2	94	0.1
1998	2	4.10	-2.6	-16.8	97	4.9
1998	3	5.50	-19.5	-26.2	68	0.2
1998	4	5.80	-14.6	-23.1	72	0.0
1998	5	4.20	-8.3	-15.2	78	0.0
1998	6	7.20	-11.4	-14.2	78	0.0
1998	7	6.20	-7.0	-13.6	85	0.0
1998	8	3.80	-6.5	-8.6	84	0.0
1998	9	5.40	-9.8	-24.5	87	0.0

Load in Excel

Save

Load back to input panel

Update HM weather file

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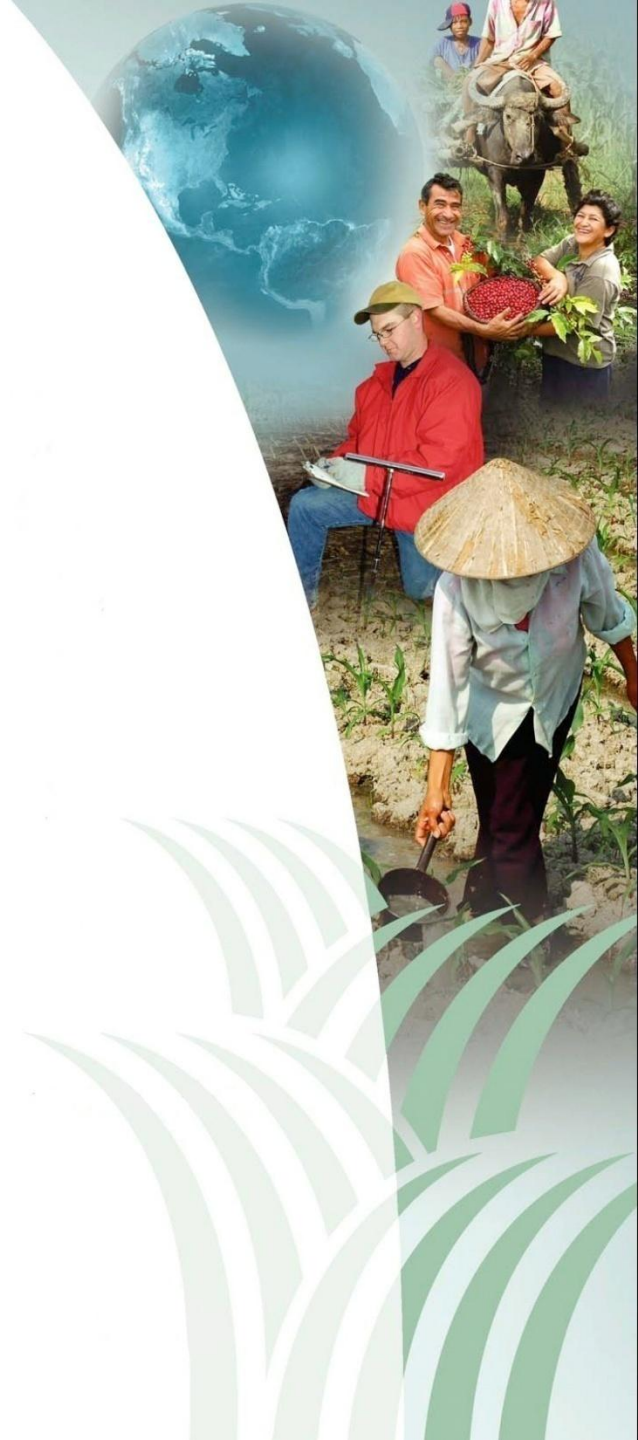

Tools:
Hybrid Maize crop model

Interpreting the yield gap

Defining the gap to target

"…achieving consistent cereal yields that exceed 70% of the yield potential barrier depends on sophisticated management of soil and water resources and applied inputs. A precision agriculture approach is required to insure that the requisite resources for crop growth are available and crop protection needs are met without deficiency or excess at each point in time during the growing season."

-- Prof. Ken Cassman

Later presentations quoted 80-85% as the target to attain consistently

Cassman, K.G. 1999. Proc. Natl. Acad. Sci. 96:5952-5959.

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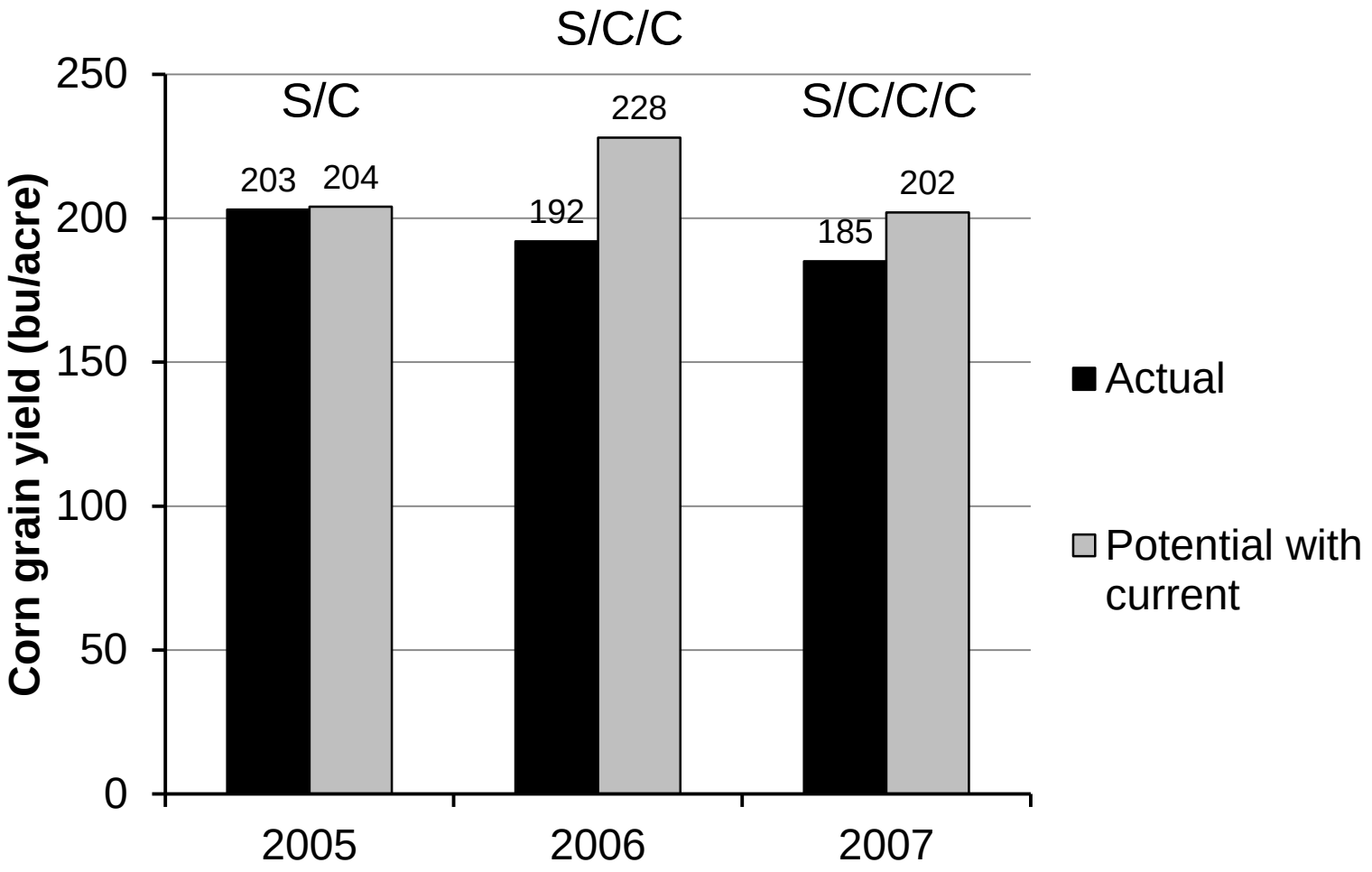
Calculating the gap

$$\textit{relative yield}\ (Y_R) = \left(\frac{\textit{actual yield}}{\textit{potential yield}} \right) \text{ X } 100\%$$

Interpretation categories for relative yield:

Relative yield (Y_R)	Interpretation
$Y_R < 80$	Yield gap is too large
$80 \leq Y_R < 100$	Yield gap is within the target range
$100 \leq Y_R$	No yield gap exists

Comparing average actual yield to the potential yield under current practices



Management practices that can be examined by *Hybrid-Maize*

- Site data
  - Soil texture of:
    - Upper 12 in. of soil profile
    - Subsoil
  - Bulk density of upper 12 in. of soil profile
- Management practices
  - Planting or emergence date
    - And planting depth, if only the planting date is known
  - Seed brand
  - Total growing degree days of hybrid
  - Final population
  - Initial moisture status of upper 12 in. of soil
  - Initial moisture status of subsoil

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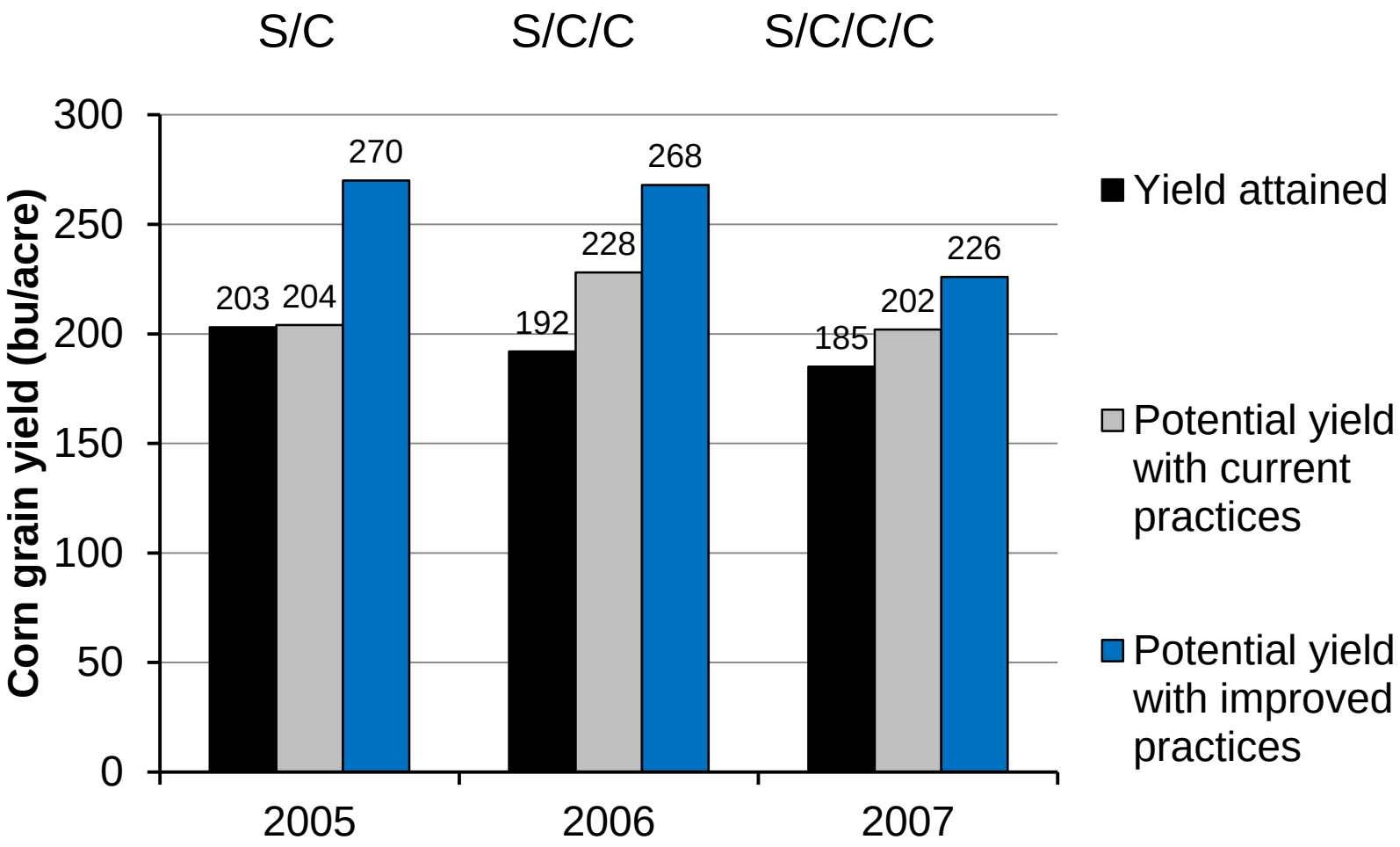
Yield gap for improved practices



Summary

- Farmers are asking, “What yields could I be getting?”
- To answer this question, *Hybrid Maize* can be used to estimate potential yield
  - Actual yields can be compared to potential yields under the management practices used in a given season
  - *Hybrid Maize* can be used to run different scenarios to see what changes in management practices might improve yields
- Field testing is then needed to determine the actual effects of changing management practices

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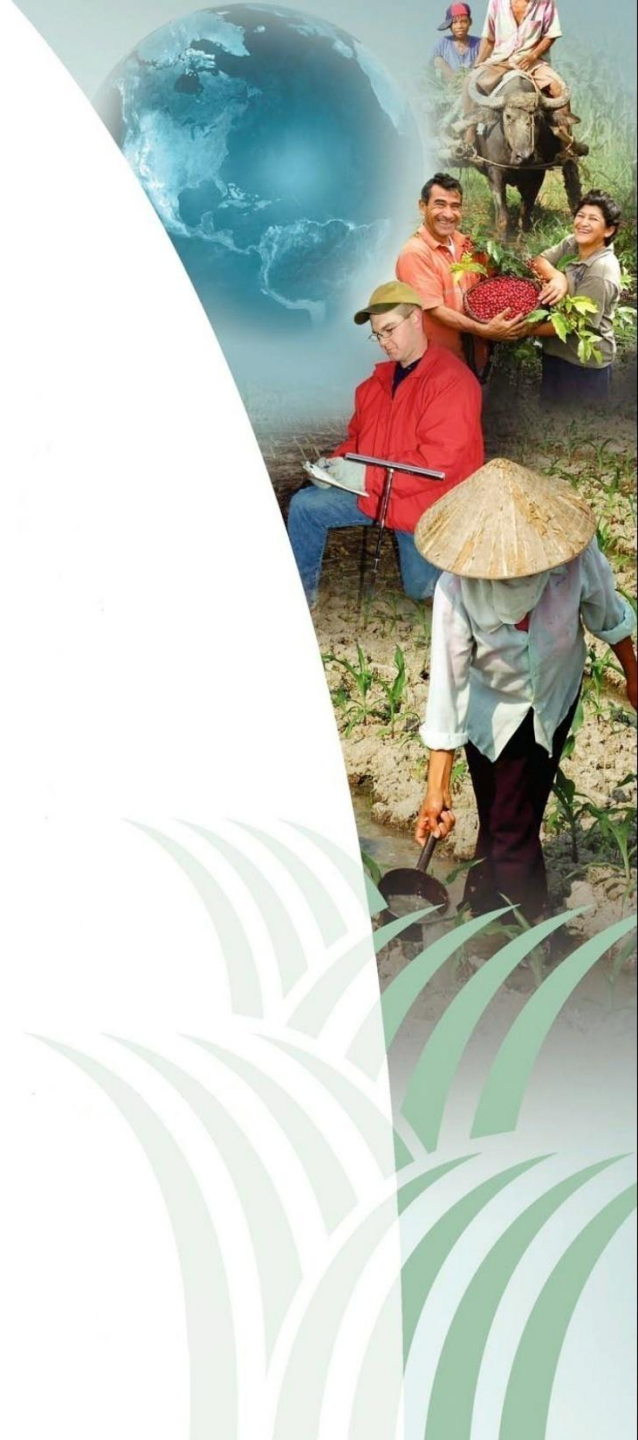
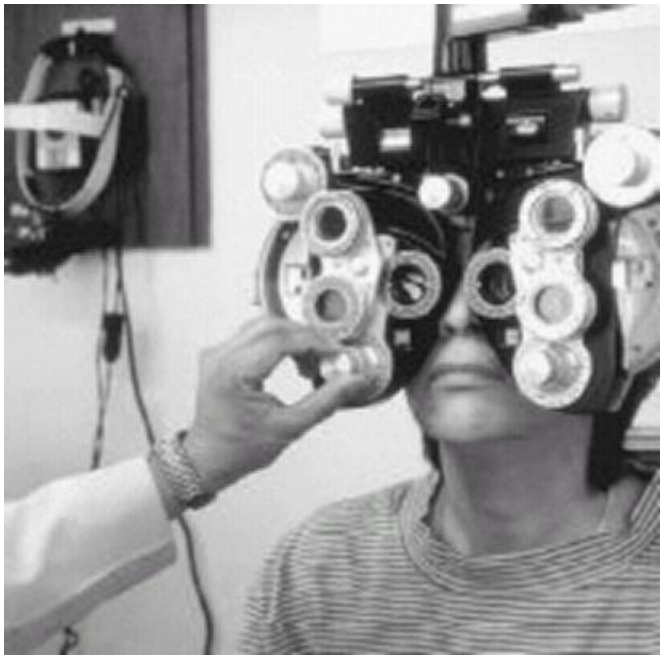


Resources for on-farm research:

Management comparisons

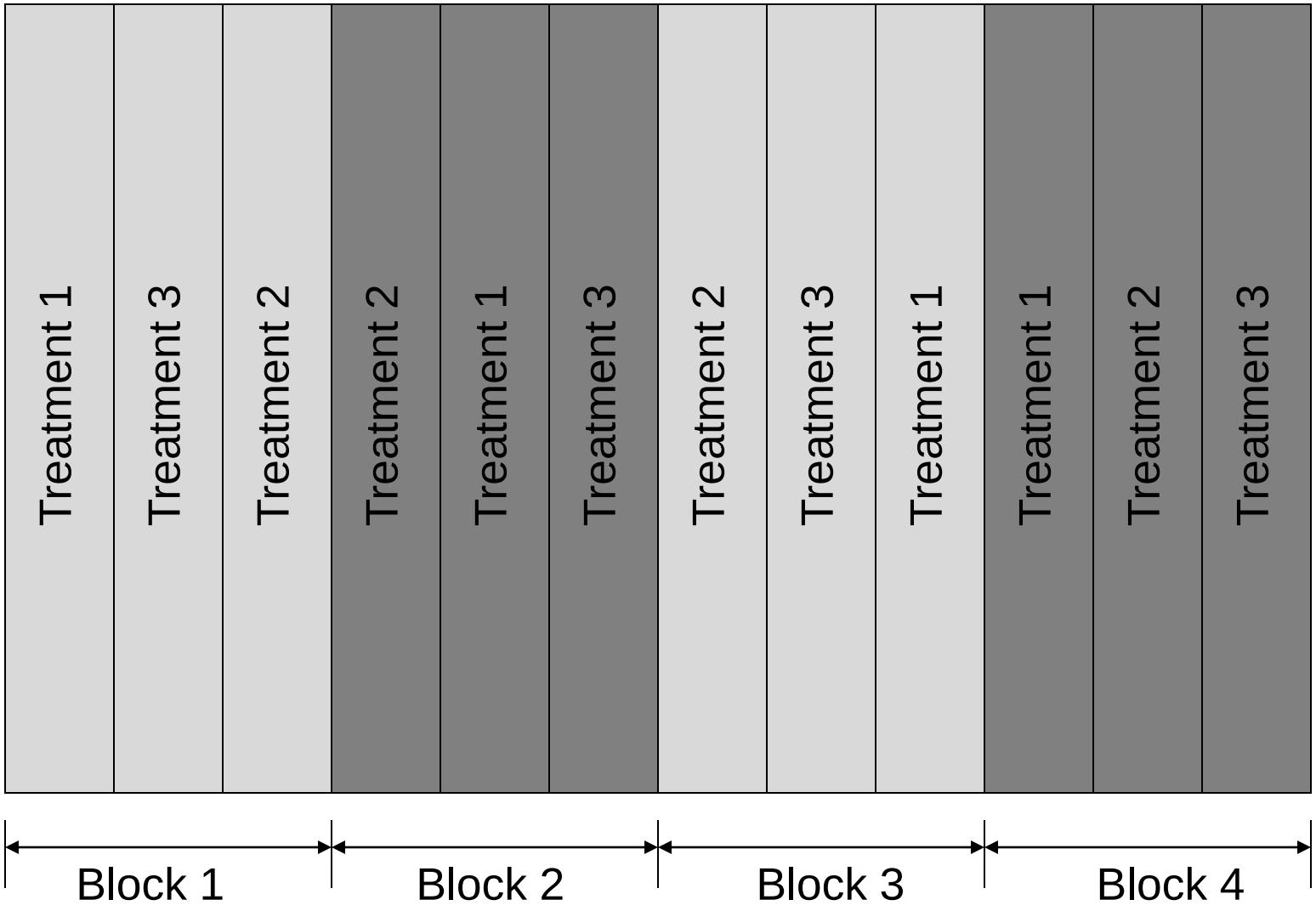
The goals of management comparisons

- Be able to determine if there were differences among treatments
  - Analysis of variance
- Be able to tell which treatments stood out as being better or worse
  - Compare the averages of the treatments
    (mean comparisons)



"Is that better or worse?"

Blocking and randomization



ANalysis Of VAriance (ANOVA)

- Concept:
  - The variability between treatments in the experiment should be greater than the background variability at the site
  - This analysis does not tell you which treatments were different from each other
  - The Least Significant Difference (LSD) is a second analysis that does tell you which particular treatments were different from one another

What is the least significant difference?

- The minimum difference that needs to exist between treatments for them to be considered statistically different

Treatment	Average (mean)	
Improved management	200 bu/A	a
Current management	175 bu/A	b
LSD	20 bu/A	

Online tool for ANOVA and LSD

http://pnwsteep.wsu.edu/agstatsweb/index.html

http://pnwsteep.wsu.edu/agstatsweb/index.html

○ Completely Randomized Design (CRD) ◉ Randomized Complete Block Design (RCBD)

Level of Significance

○ 1% ◉ 5% ○ 10% ○ 20%

	Replication/Block 1	Replication/Block 2	Replication/Block 3	Replication/Block 4	Treatment Mean
Treatment 1	67	50	23	45	46
Treatment 2	90	80	45	68	71
Replication/Block Mea	79	65	34	57	59

Analyze | Save File | New Analysis | Logout

Source	Degree of Freedom	Sum Square	Mean Square	Observed F	P value	
Total	7	3,314	473			
Treatments	1	1,201	1,201	176	0.09%	Significant
Blocks	3	2,093	698	102	0.16%	Significant
Error	3	21	7			
Required F	10					
Correction Factor	27,378					
Standard Deviation	3					
Coeff. of Variation	4%					

LSD	6	
Treatment Name	Mean	
Treatment 1	46	A
Treatment 2	71	B

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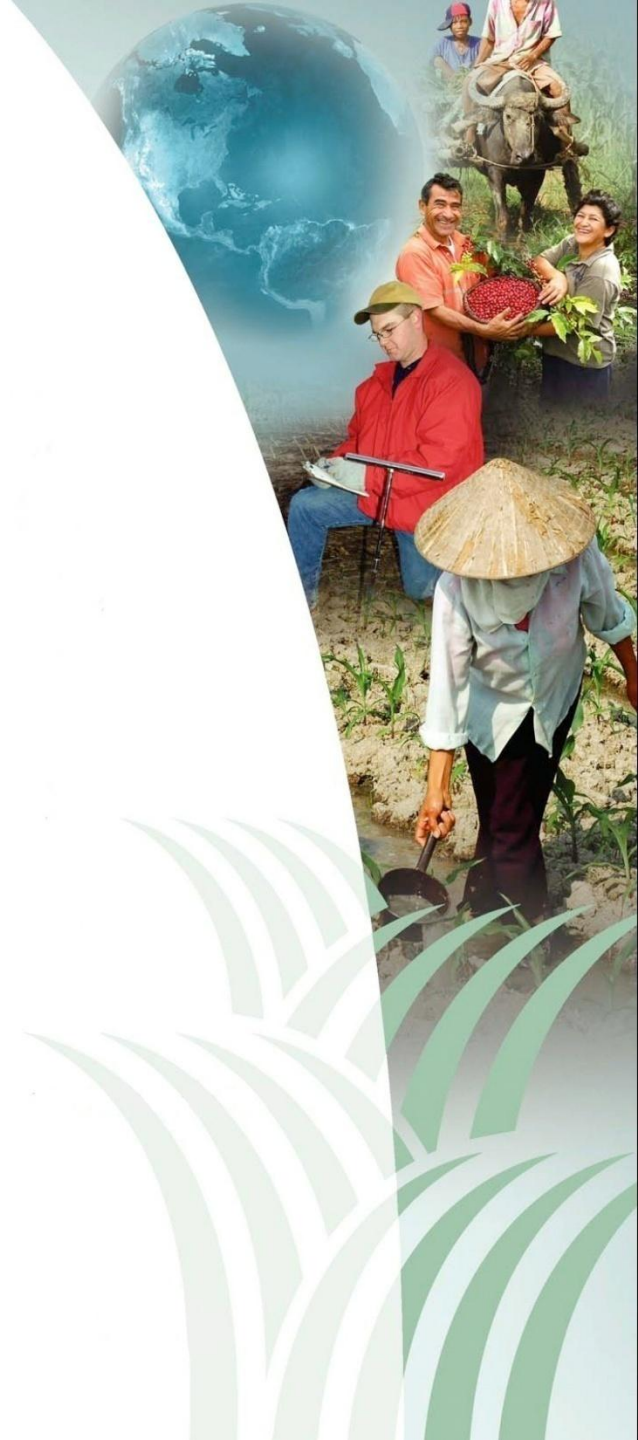


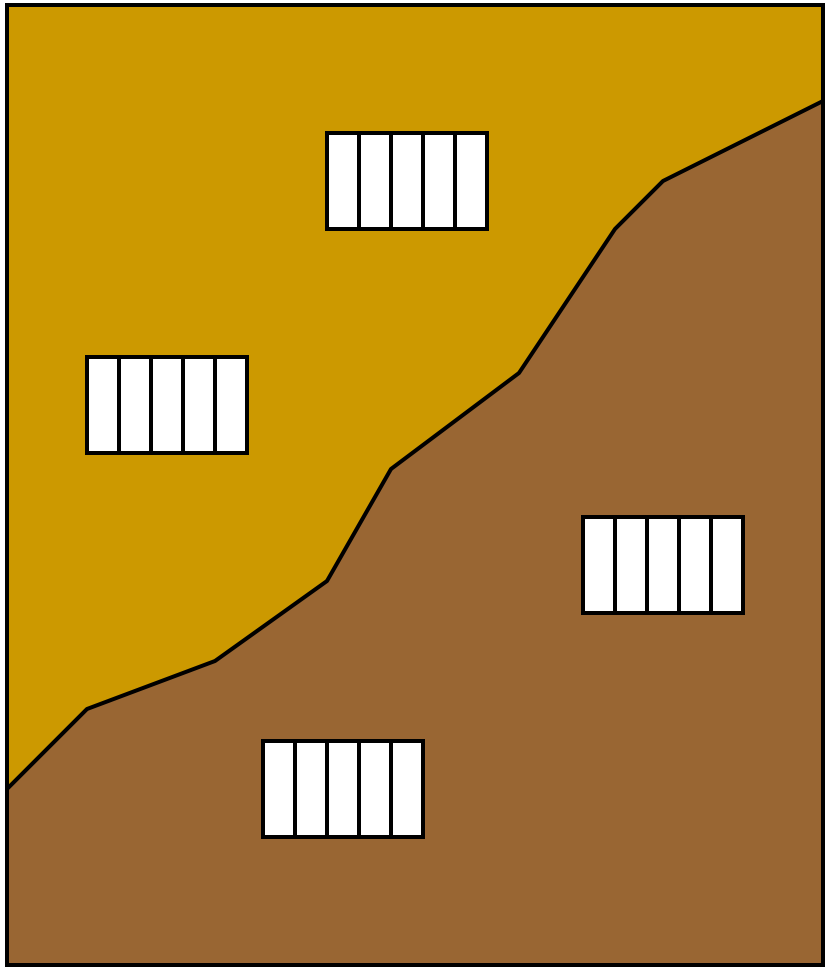
Resources for on-farm research:

Rate studies

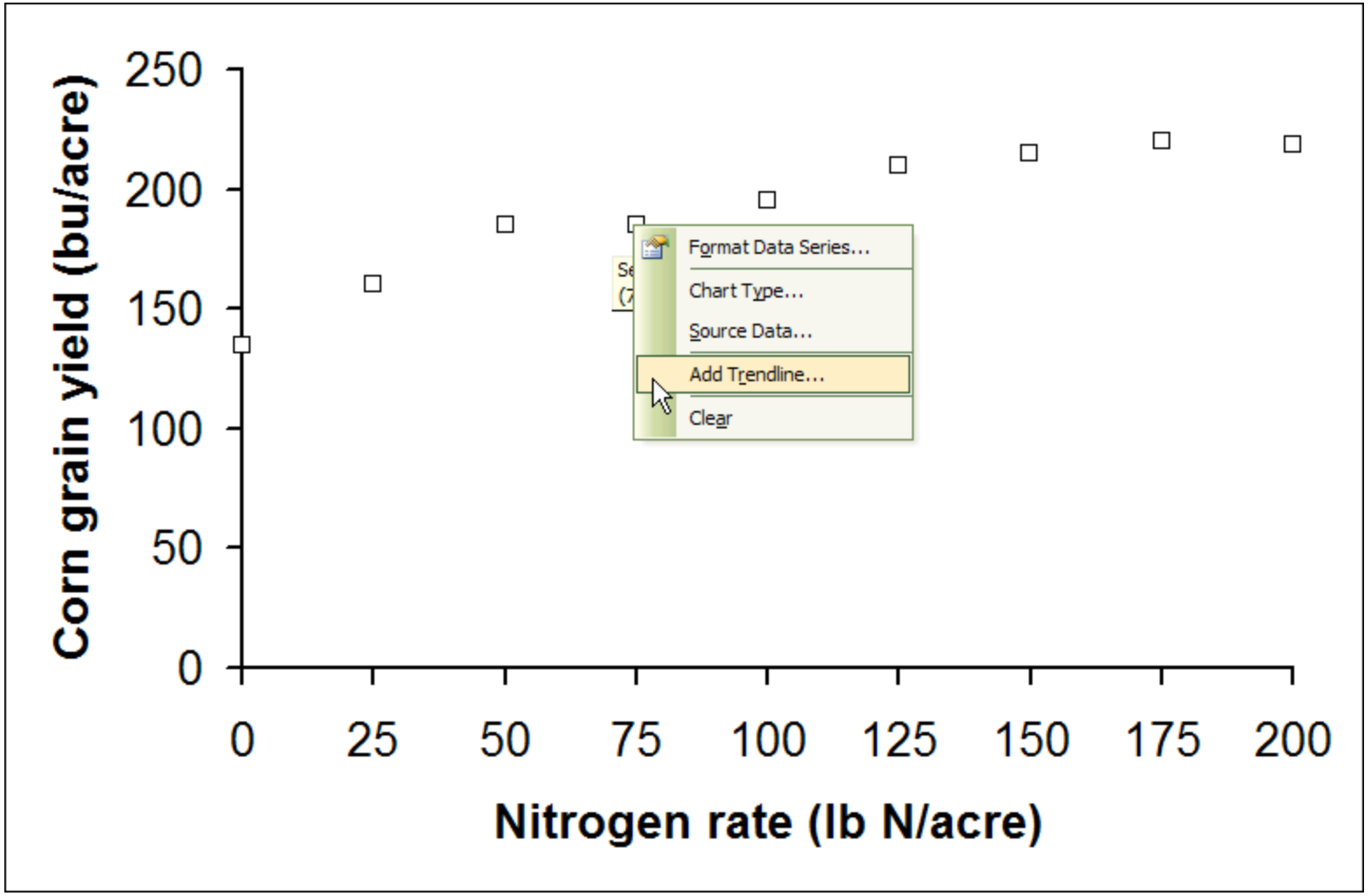
Rate studies

Layout

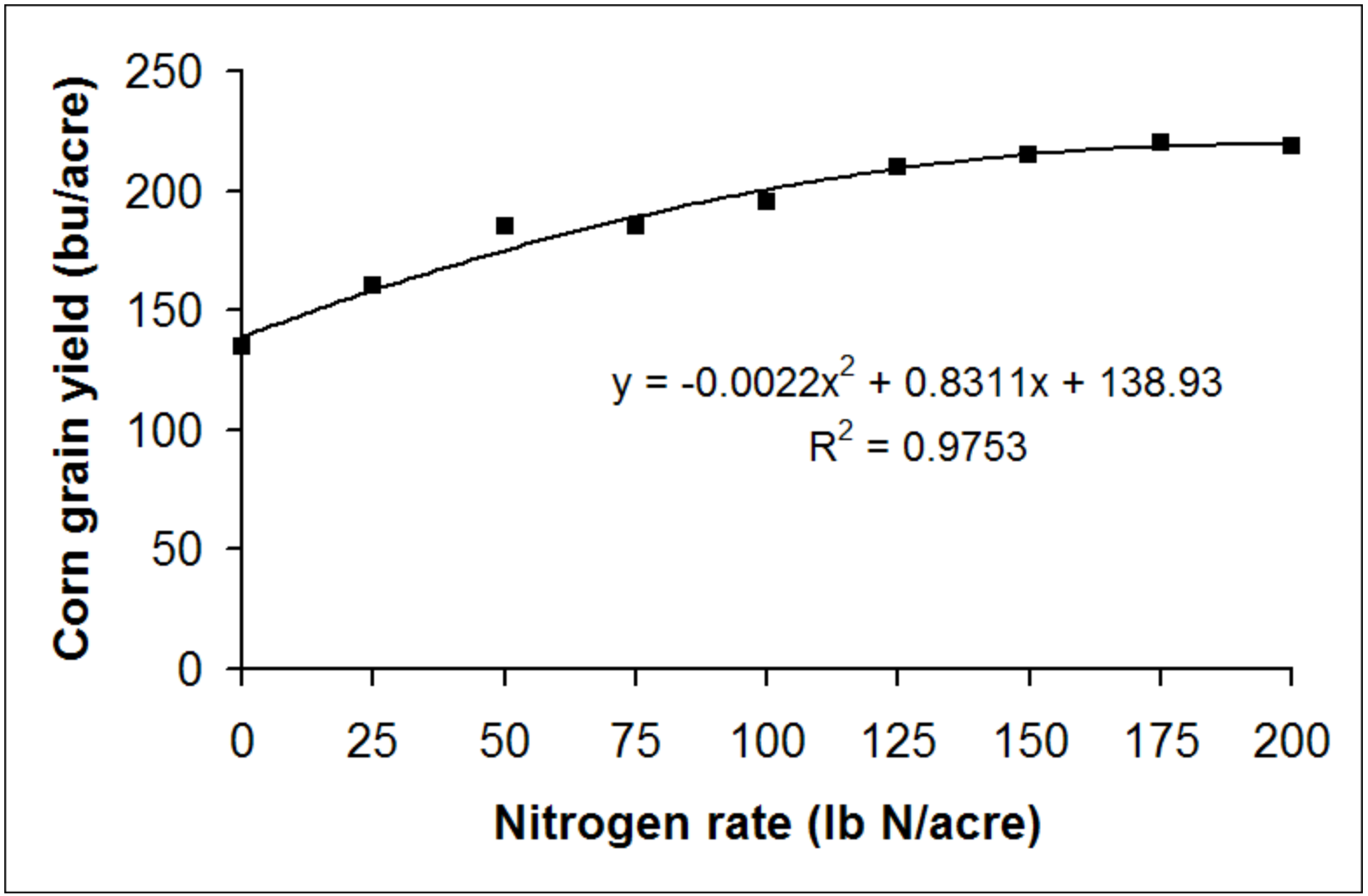
- Use at least 4 rates, 5 to 6 are preferable
- Keep a constant increment between rates (0, 50, 100, 150, 200, 250)
- Try to keep strips at least 250 ft. long
- Keep all plots the same length
- Randomize order of rates
- Replicate at least 2 times



Excel “out of the box”



Excel “out of the box”



Calculating:

Rate for maximum yield

$$y = -0.0022x^2 + 0.8311x + 138.93$$

1) Number in front of the x: 0.8311

2) Number in front of the x^2: change the sign (- to +) and multiply by 2

$$2*0.0022$$

3) Divide 1) by 2): 189 lb/acre

Calculating:

Economically optimum rate

Calculate ratio of nutrient price ($/lb of actual) to crop price:

$$\frac{\$0.65/lb}{\$6.50/bu} = 0.1$$

$$y = -0.0022\,x^2 + 0.8311x + 138.93$$

1) Number in front of the x: subtract from the price ratio $0.1 - 0.8311$

2) Number in front of the x^2: change the sign (- to +) and multiply by 2 $2*0.0022$

3) Divide 1) by 2): 166 lb/acre

Crop Nutrient Response Tool

- http://nane.ipni.net/articles/NANE0001-EN

Crop Nutrient Response Tool (CNRT) v4.2

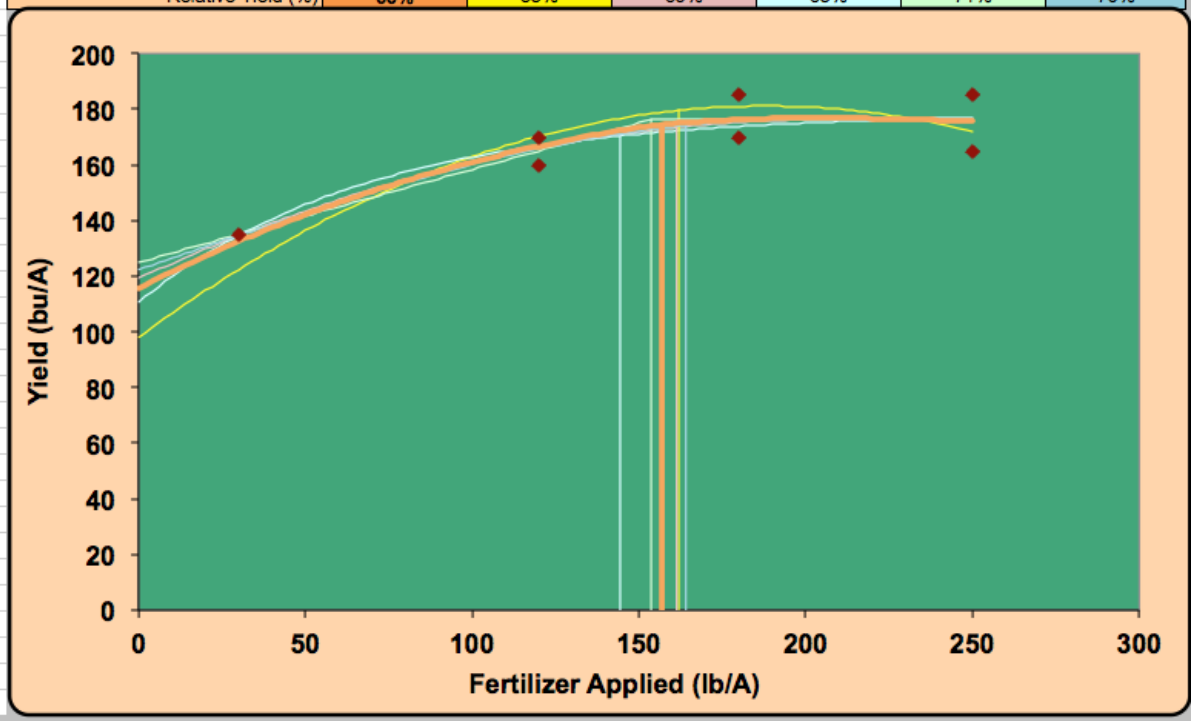
Step 1: Enter rate and yield data.
Step 2: Click the Fit button.
Step 3: Adjust crop and fertilizer prices.
Step 4: Click to append information to summary.

Site Details	
Site	
Year	
Town	
County	
State or province	
Latitude	
Longitude	
Altitude	
Soil texture class	
Preceding crop	
Expected Yield (bu/A)	
Timing and placement	
Tillage	
Site degree-days	
Crop species	
Cultivar	
PSNT (ppm)	
Manure N (lb/A)	
Planting date	
Harvest date	
Crop ($/bu)	4.50
Fertilizer ($/lb)	0.55
Price ratio (f/c)	0.122
Crop N content (lb/bu)	0.70
N harvest index	0.67
Fertilizer source	

Append site information to summary

Fertilizer rate, lb/A	Crop Yield, bu/A
30	135
120	160
180	185
250	185
120	170
180	170
250	165

Fit		R^2-weighted Mean	Quadratic (Q)	Quadratic-Plateau (QP)	Mitscherlich (M)	Linear-Plateau (LP)	Spherical (SP)
	A:		98	119	179	125	122
	B:		0.88	0.55	-68	0.33	54
	C:		-0.0024	-0.0013	-0.014	176	196
	R^2:		70%	81%	80%	82%	82%
MERN (lb/A):		157	162	161	144	154	164
Yield @ MERN (bu/A)		174	180	173	170	176	174
Partial Factor Productivity (PFP)		1.11	1.11	1.08	1.18	1.15	1.06
Agronomic Efficiency (AE_N)		0.37	0.50	0.34	0.41	0.33	0.32
Partial N Balance (PNB):		78%	78%	75%	83%	80%	74%
Recovery Efficiency (RE_N)		39%	53%	35%	43%	35%	33%
Delta Yield (bu/A)		59	82	54	60	51	52
Relative Yield (%)		66%	55%	69%	65%	71%	70%



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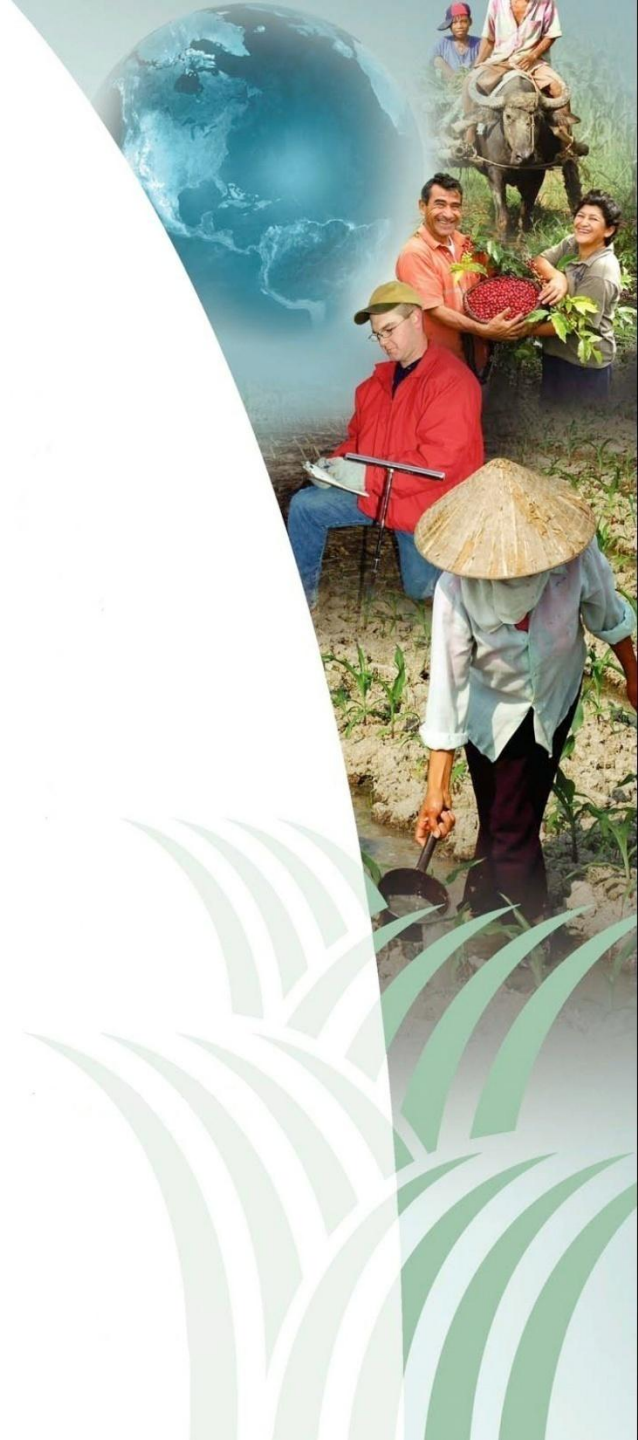
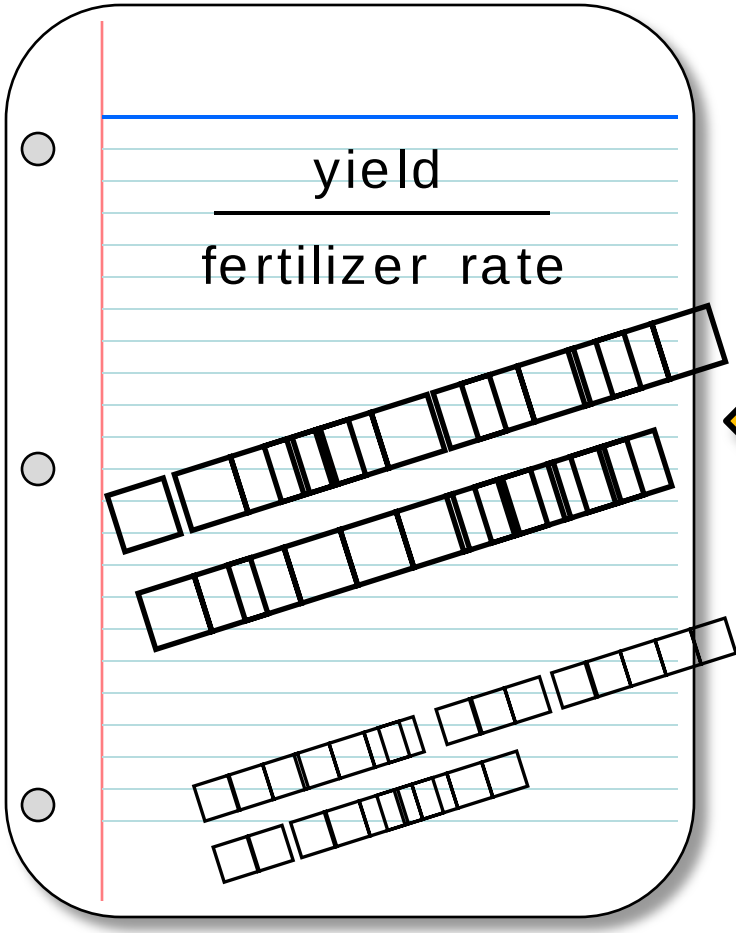


Resources for on-farm research:

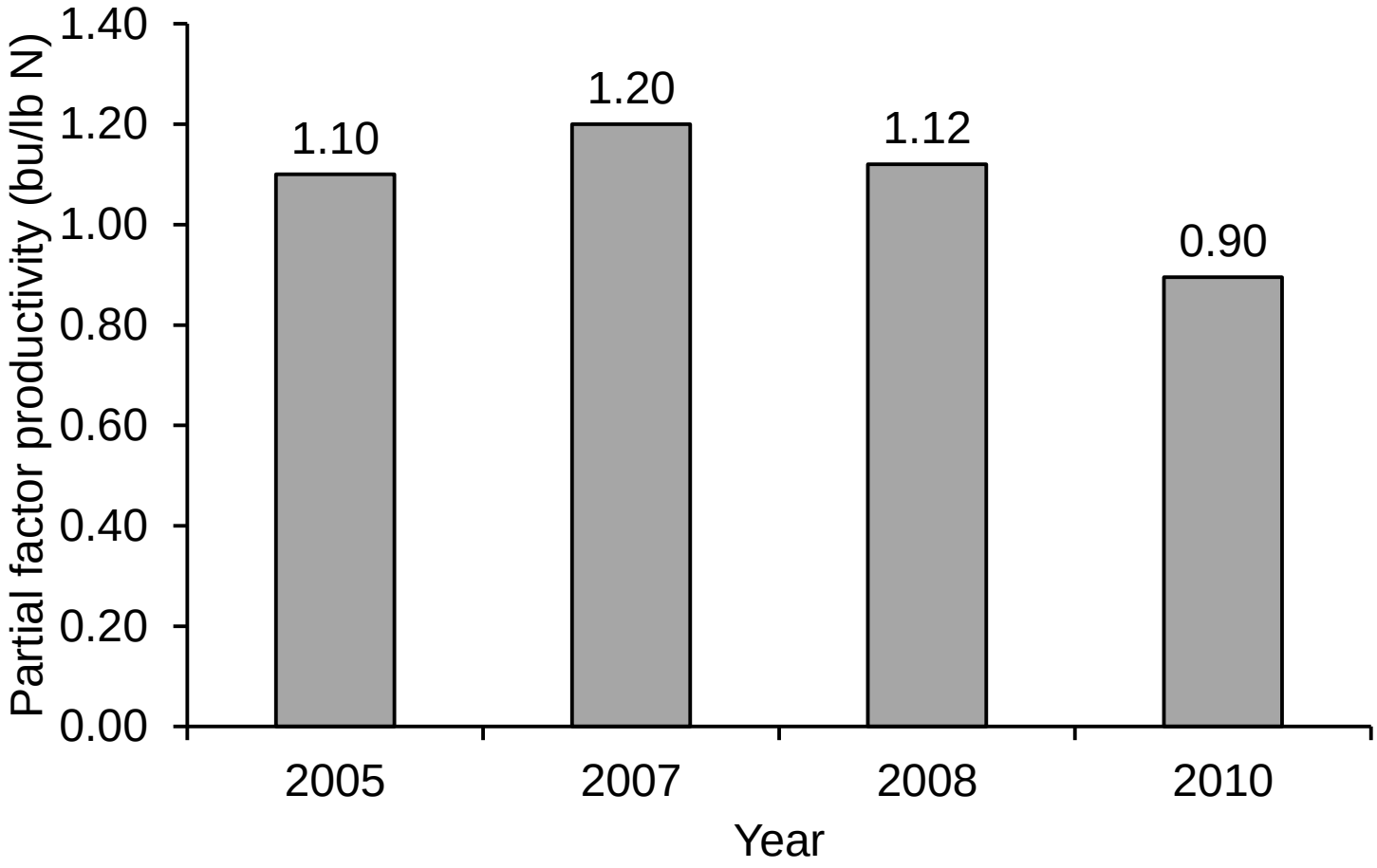
Measuring more than yield

Nutrient use efficiency:
Partial factor productivity



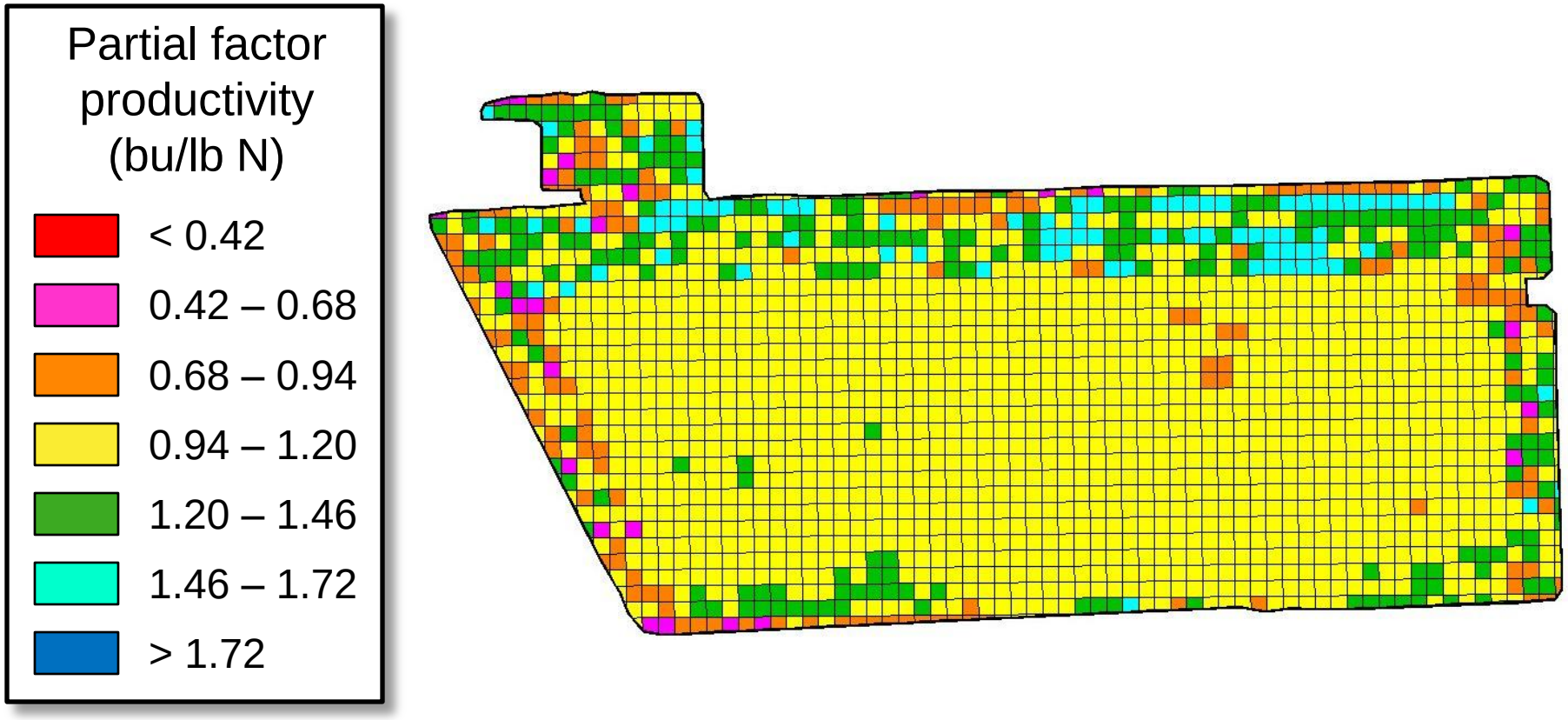
Things we can measure
Grain yield of a fertilized crop
Grain yield of an unfertilized crop
Fertilizer application rate
Nutrient content of the grain

Partial factor productivity of nitrogen for corn grain:
Scale: Field, north central Indiana



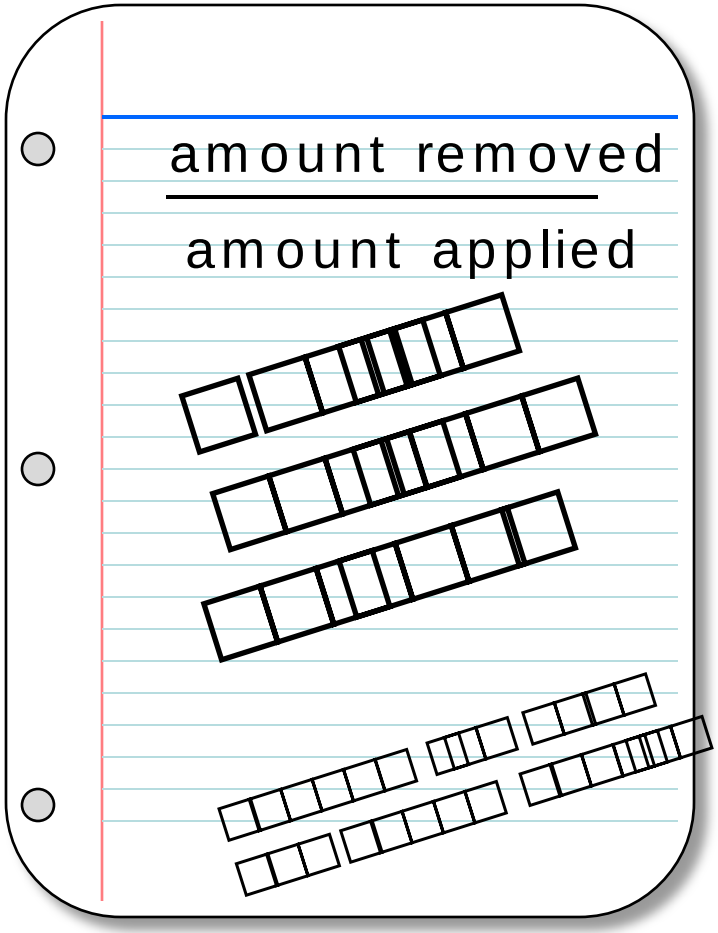
Data: Lance Murrell Consulting and IPNI

Partial Factor Productivity of nitrogen for corn grain:
Scale: Within-field, north central Indiana



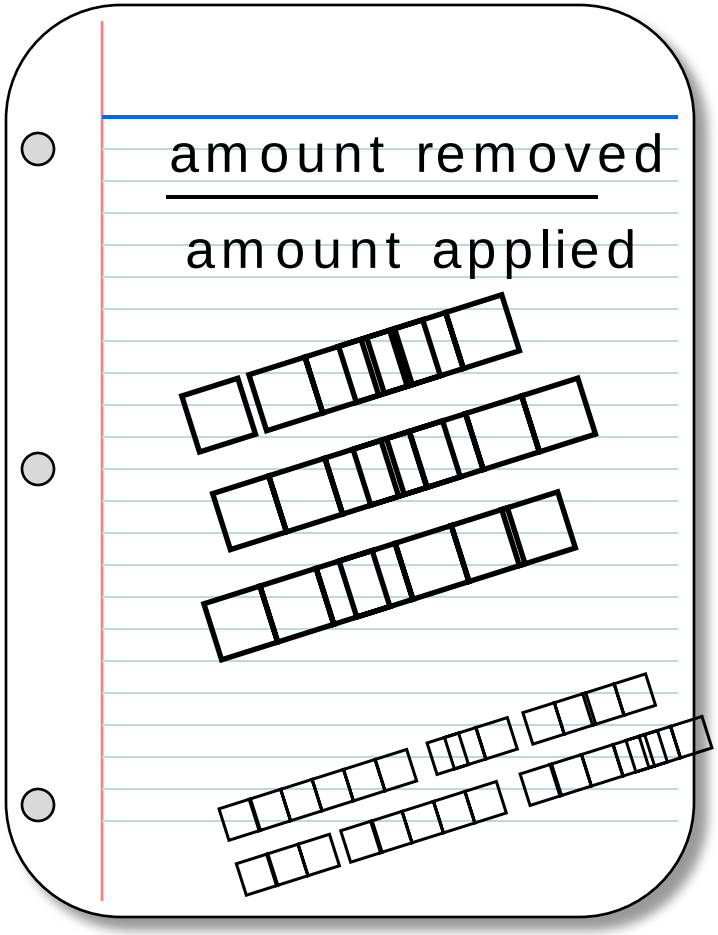
Data: Lance Murrell Consulting and IPNI

Nutrient use efficiency:
Partial nutrient balance



Things we can measure
Grain yield of a fertilized crop
Grain yield of an unfertilized crop
Fertilizer application rate
Nutrient content of the grain

Nutrient use efficiency as measured by: *Partial nutrient balance*



Guidelines

- Partial nutrient balance values:
  - approx. 1.0
    removal = application
    (some sense of sustainability)
  - less than 1.0
    removal is less than application
    (soil nutrient levels are increasing)
  - greater than 1.0
    removal is more than application
    (soil nutrient levels are decreasing)

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