Evaluating Soil Properties, Yield, Protein, and Response to Variable Nitrogen Application 2012-2013 Crop Seasons

Crop Opportunity

Western Applied Research Corporation

March 13, 2019

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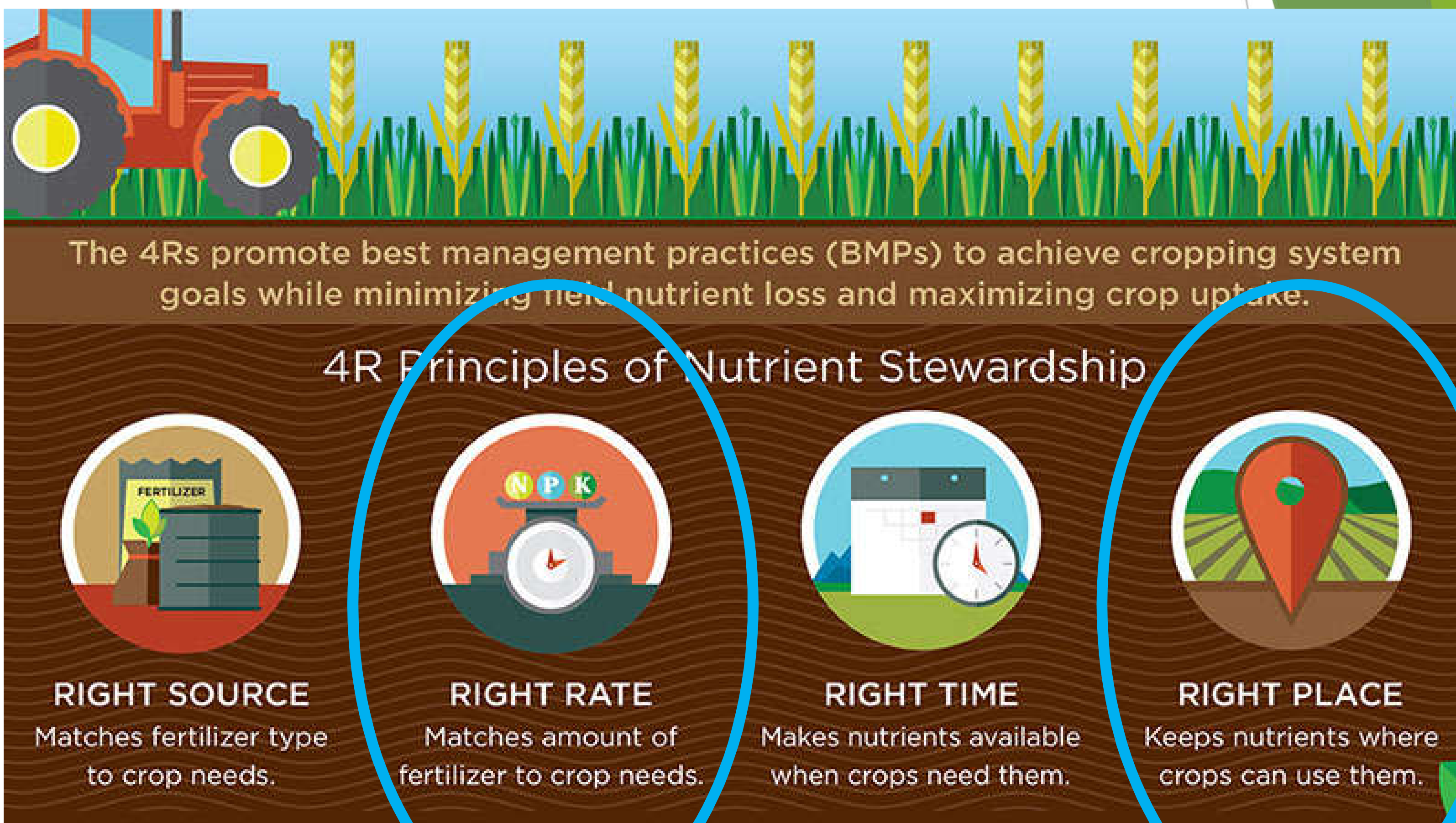
Background

- Data presented is part of MSc work collected in 2012 and 2013 at the University of Saskatchewan Dept of Soil Science

Farm Management Decisions and Discussions

- What is the best fertility program this year?
- Changes from year to year?
- What is the farm wide variability in soil nutrient status?
- What about within field variability?
- How do I maximize yield, and minimize fertility costs?
- What are logistical constraints to applying fertilizer?
- Why is such variability present and what is effect on yields?

4R Nutrient Stewardship



What is the Right Fertilizer Rate?

- International Plant Nutrition Institute
- Right rate:
  - Matches applied fertility to crop demand
- Overapplication
  - Potential detrimental losses to environment beyond the field
  - $ loss from the farm
- Underapplication
  - Unrealized yield potential
  - Mining soil reserves
  - Reduced amount of crop residues returned to soil

https://www.ipni.net/ppiweb/bcrops.nsf/$webindex/49FF68D11908EB2085257394001B2356/$file/07-4p14.pdf

Identify and Apply Precision Fertility

- Precision Agriculture
  - GPS guidance
  - Sectional control
- Variable Rate (VR) N Fertilizer Application
  - Concept: Match N rates to varying production potentials in a field
  - Does it work?

Context

- In theory VR N should:
  - Improve yield and N-use efficiency
  - However, improvements at the farm level have been difficult to document
- Reflects knowledge gaps of:
  - Temporal and spatial variation in soil properties controlling yield
  - Environmental controls
  - How this affects response to applied N
    - (Cassman et al., 2002)

Context

In practice:

- Many farmers apply the same fertilizer rate across a whole field regardless of variability in yield potential

Why?

- Efficient means are needed to create a variable application map
- Cost to ID, sample and predict crop response in separate zones
- Uncertainty surrounding benefits to be achieved

Challenge:

- ID efficient reliable mechanisms to make VR map
- Predict accurate fertilizer rates within the VR map

Context

- Current methods to create VR maps include:
  - Soil electrical conductivity (EC) maps
  - Satellite imagery
  - Elevation maps
  - Yield maps
  - Soil surveys
- All reveal variability in many different aspects
  - How do they relate to crop response?

Research Questions

- What is the effect of soil properties on crop yield and protein in a typical landscape in southern SK?

- Will protein concentration of crops help delineate effective fertilizer management zones?

Research Question

- Yield
  - Can establish how much N it takes to produce a target yield
- Protein
  - Reflects balance of N to other yield limitations

Precision Agriculture, 1, 327–338 (1999)

Method for Precision Nitrogen Management in Spring Wheat: I Fundamental Relationships

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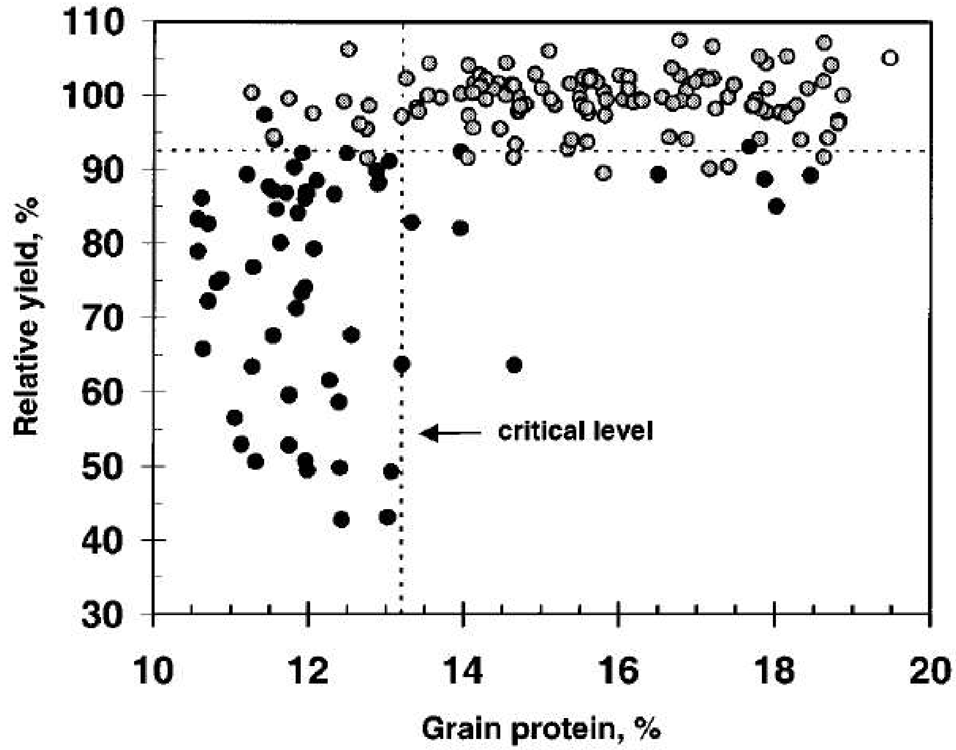

Figure 2. Relative yield vs. grain protein for spring wheat. Havre, 1996–1998. 'Dark circles' indicate yield significantly (0.05 level) below maximum. 'Light circles' indicate yield was not reduced by N deficiency or excess. Critical level defined by Cate–Nelson analysis.

Precision Agriculture, 2, 25–38, 2000

Method for Precision Nitrogen Management in Spring Wheat: II. Implementation

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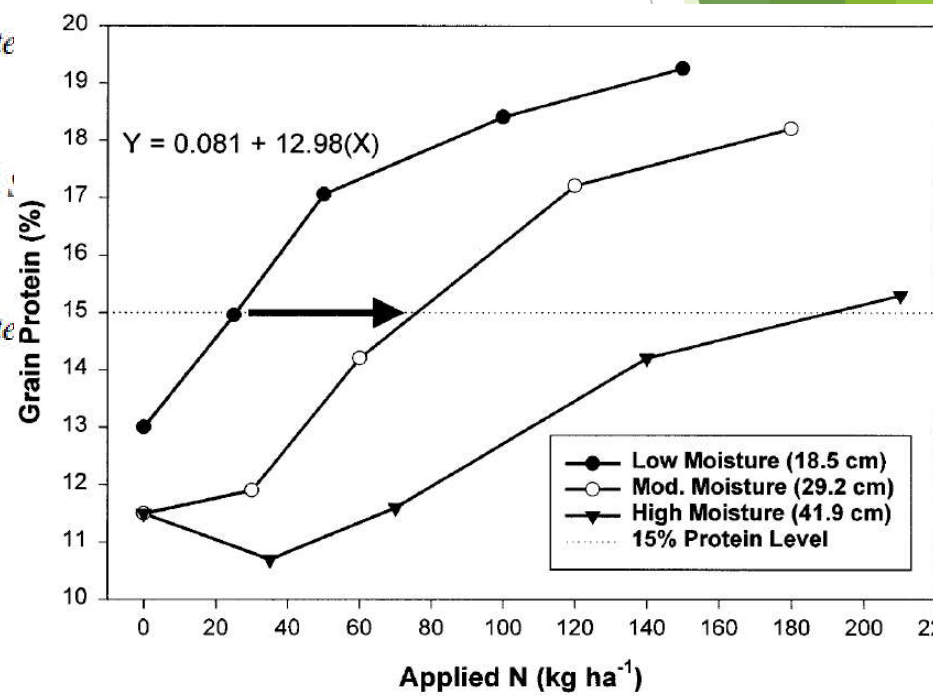


Figure 1. Relationship between grain protein and applied N with respect to low, normal, and high moisture regimes. Each symbol represents the mean across four cultivars of spring wheat. Slope of line for first three plotted points of low moisture regime given by linear regression equation. Arrow denotes 50 kg ha^{-1} increase in applied N to maintain protein concentration of 15% with increase in moisture from low to moderate levels.

Canola and Pea Protein: Yield Relationships

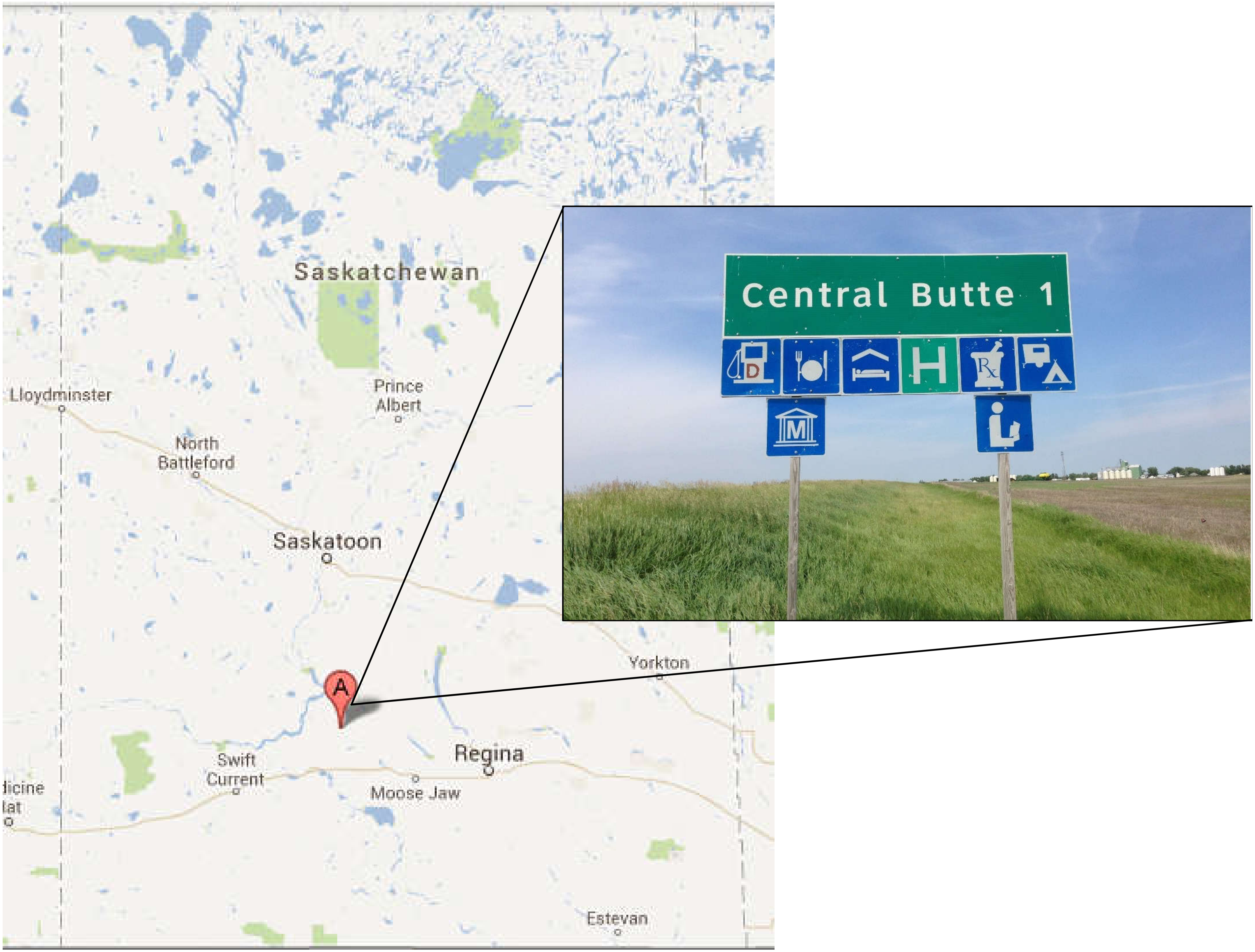
- Yield and protein relationships have not been studied in detail like wheat
- If protein sensing is a valuable tool, much work needs to be done on these relationships

Summer 2012

- Determine relationships between:
  - Crop yield
  - Crop protein
  - Soil landscape properties
    - Salinity
    - Organic matter
    - pH
    - Soil nutrients

Summer 2013

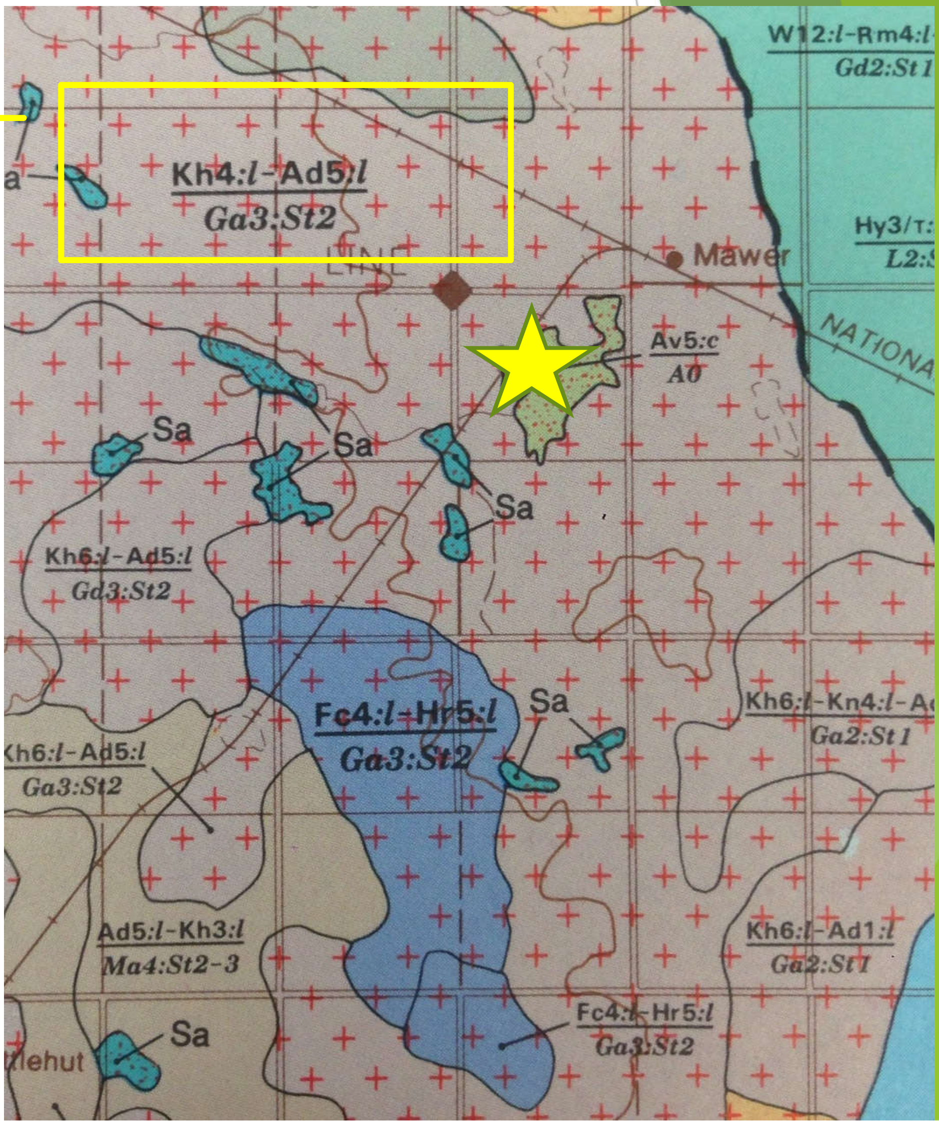
- Use these relationships to:
  - 1) Develop VR Nitrogen prescription
  - 2) Compare performance to constant rate
    - Side by side comparison


Saskatchewan
Lloydminster
Prince Albert
North Battleford
Saskatoon
Yorkton
A
Swift Current
Regina
Moose Jaw
Estevan
Central Butte 1

Soil Association

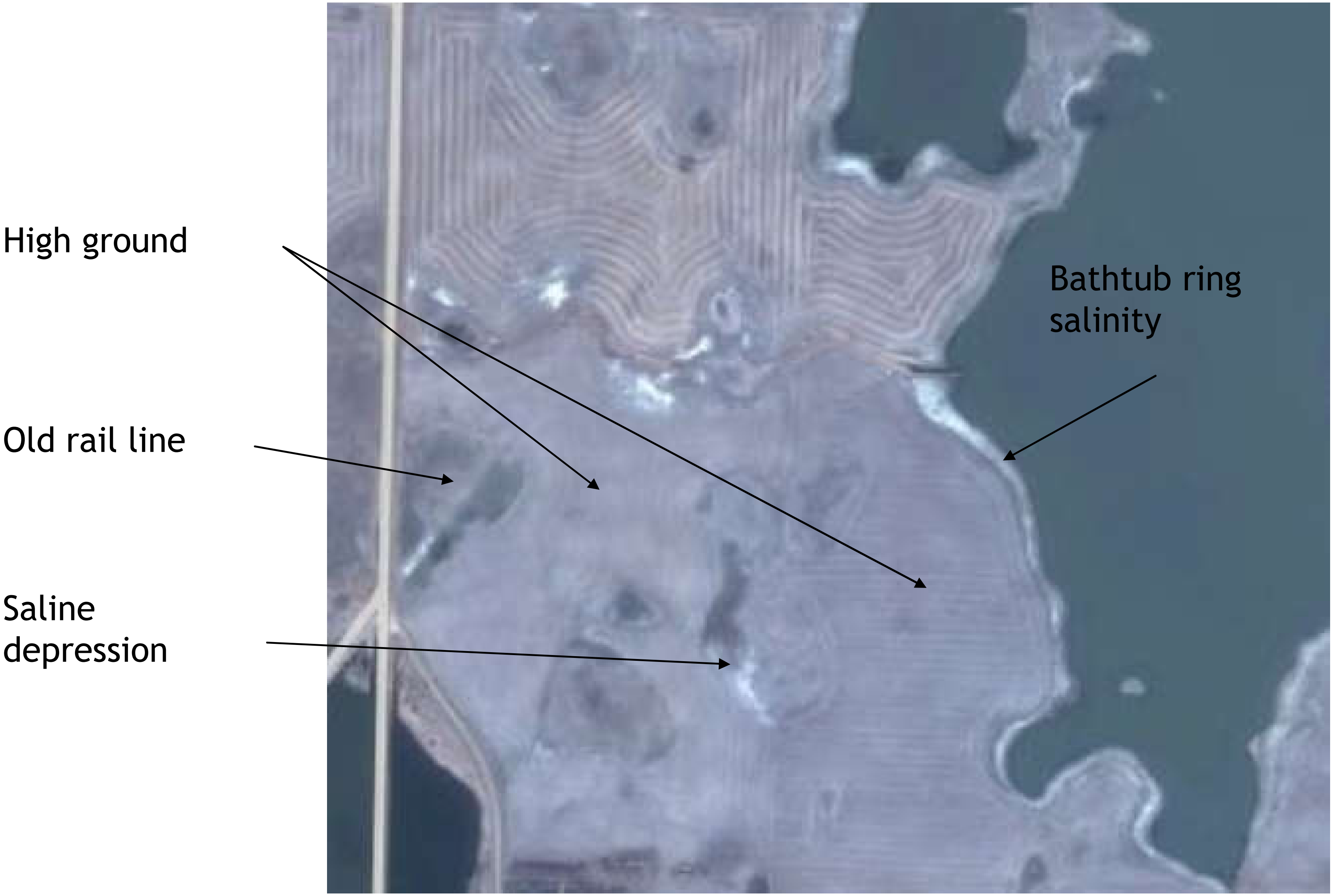
<u>Kh4:l- Ad5:l</u>

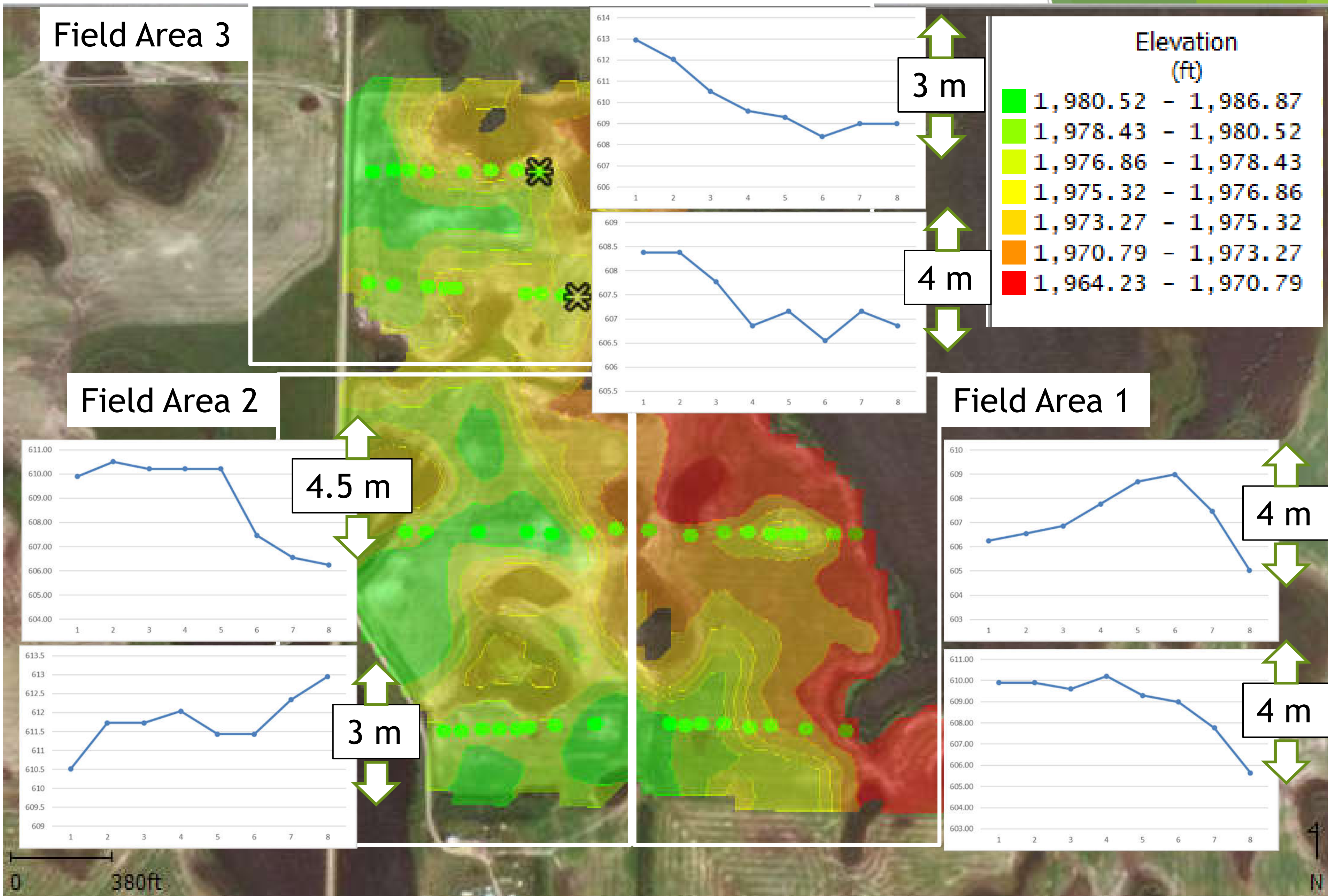
Ga3:St2

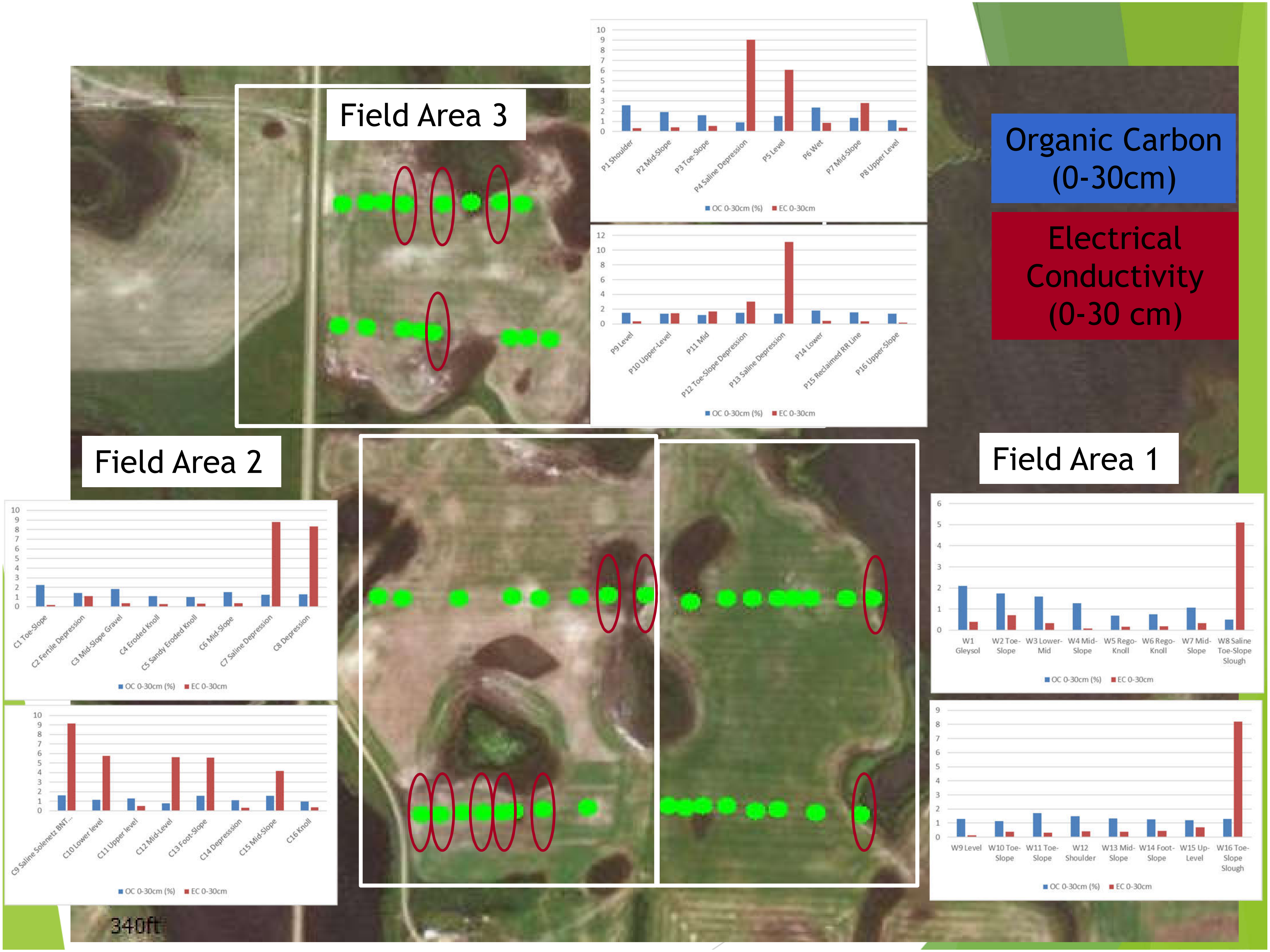


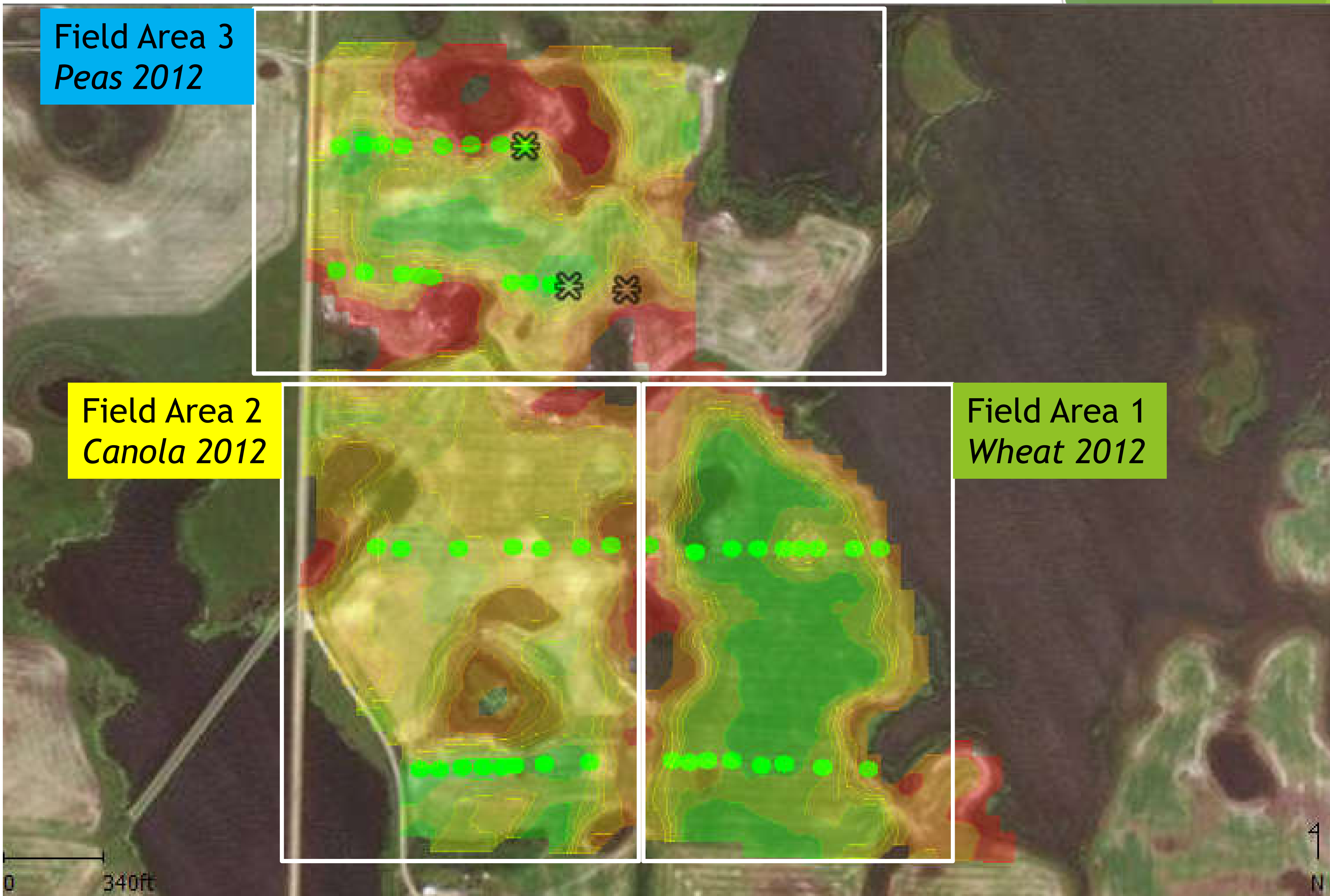
(Ayres et al., 1985)

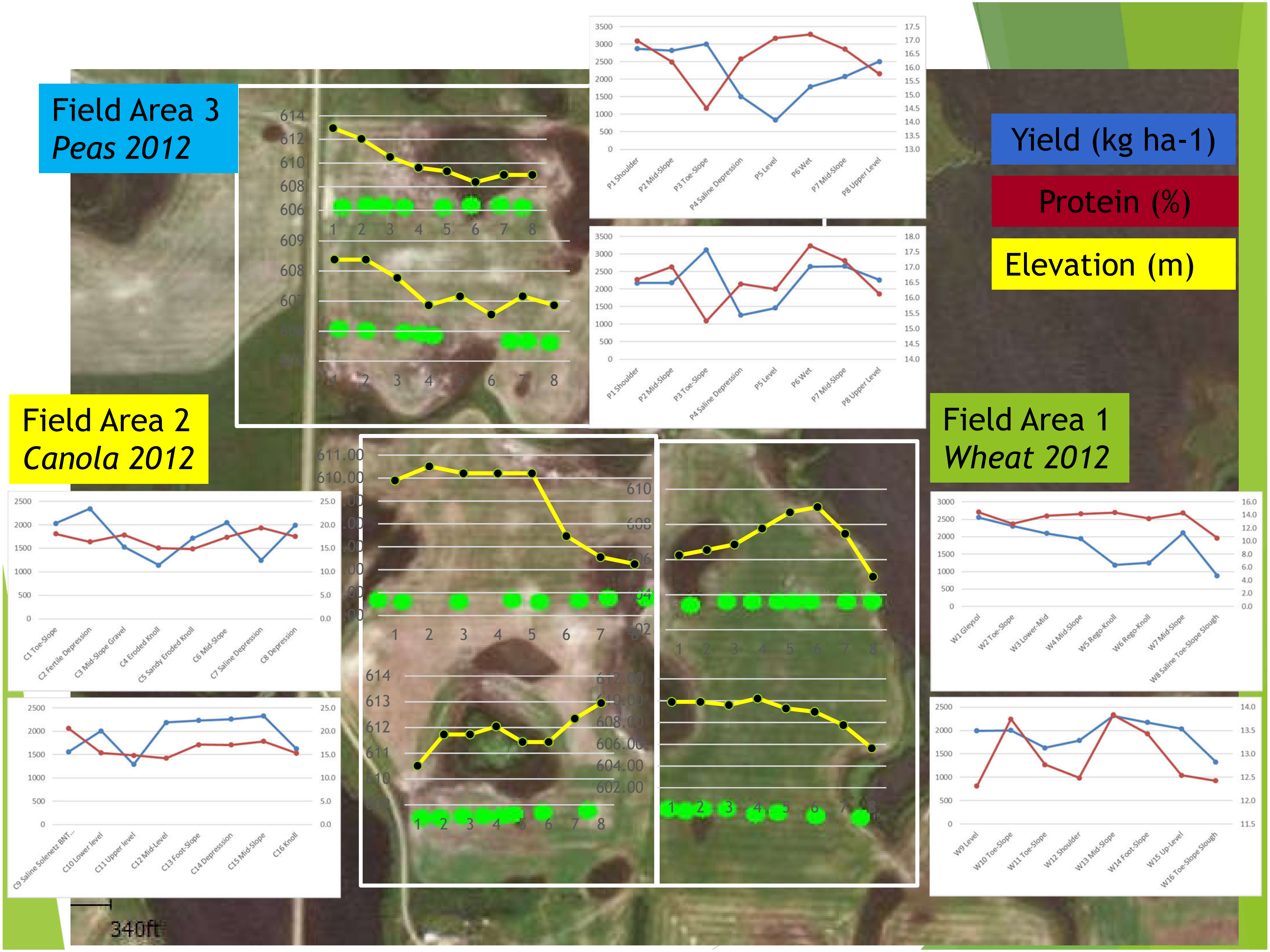
SW 31-20-03 W3


High ground
Old rail line
Saline
depression
Bathtub ring
salinity


Field Area 3
Field Area 2
Field Area 1
3 m
4 m
4.5 m
3 m
4 m
4 m
Elevation
(ft)
1,980.52 - 1,986.87
1,978.43 - 1,980.52
1,976.86 - 1,978.43
1,975.32 - 1,976.86
1,973.27 - 1,975.32
1,970.79 - 1,973.27
1,964.23 - 1,970.79
0
380ft
N

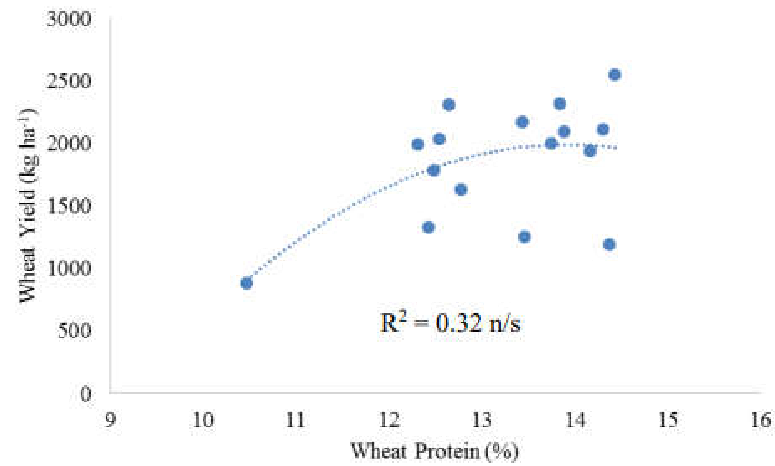

Field Area 3
Field Area 2
Field Area 1
Organic Carbon (0-30cm)
Electrical Conductivity (0-30 cm)
P1 Shoulder
P2 Mid-Slope
P3 Toe-Slope
P4 Saline Depression
P5 Level
P6 Wet
P7 Mid-Slope
P8 Upper Level
P9 Level
P10 Upper-Level
P11 Mid
P12 Toe-Slope Depression
P13 Saline Depression
P14 Lower
P15 Reclaimed RR Line
P16 Upper-Slope
C1 Toe-Slope
C2 Fertile Depression
C3 Mid-Slope Gravel
C4 Eroded Knoll
C5 Sandy Eroded Knoll
C6 Mid-Slope
C7 Saline Depression
C8 Depression
C9 Saline Solenetz BNT...
C10 Lower level
C11 Upper level
C12 Mid-Level
C13 Foot-Slope
C14 Depression
C15 Mid-Slope
C16 Knoll
W1 Gleysol
W2 Toe-Slope
W3 Lower-Mid
W4 Mid-Slope
W5 Rego-Knoll
W6 Rego-Knoll
W7 Mid-Slope
W8 Saline Toe-Slope Slough
W9 Level
W10 Toe-Slope
W11 Toe-Slope
W12 Shoulder
W13 Mid-Slope
W14 Foot-Slope
W15 Up-Level
W16 Toe-Slope Slough
OC 0-30cm (%)
EC 0-30cm
340ft


Field Area 3
Peas 2012
Field Area 2
Canola 2012
Field Area 1
Wheat 2012
0
340ft
N



Field Area 3
Peas 2012
Yield (kg ha-1)
Protein (%)
Elevation (m)
P1 Shoulder
P2 Mid-Slope
P3 Toe-Slope
P4 Saline Depression
P5 Level
P6 Wet
P7 Mid-Slope
P8 Upper Level
Field Area 2
Canola 2012
C1 Toe-Slope
C2 Fertile Depression
C3 Mid-Slope Gravel
C4 Eroded Knoll
C5 Sandy Eroded Knoll
C6 Mid-Slope
C7 Saline Depression
C8 Depression
C10 Lower level
C11 Upper level
C12 Mid-Level
C13 Foot-Slope
C14 Depresssion
C15 Mid-Slope
C16 Knoll
Field Area 1
Wheat 2012
W1 Gleysol
W2 Toe-Slope
W3 Lower-Mid
W4 Mid-Slope
W5 Rego-Knoll
W6 Rego-Knoll
W7 Mid-Slope
W8 Saline Toe-Slope Slough
W9 Level
W10 Toe-Slope
W11 Toe-Slope
W12 Shoulder
W13 Mid-Slope
W14 Foot-Slope
W15 Up-Level
W16 Toe-Slope Slough
340ft

Wheat Protein and Yield



Landscape Position		Protein	Yield (kg/ha)
Gleysol	W1	14.4	2554
Rego-Knoll	W5	14.4	1190
Mid-Slope	W7	14.3	2110
Mid-Slope	W4	14.2	1942
Lower-Mid	W3	13.9	2099
Mid-Slope	W13	13.8	2318
Toe-Slope	W10	13.7	2002
Rego-Knoll	W6	13.5	1254
Foot-Slope	W14	13.4	2177
Toe-Slope	W11	12.8	1631
Toe-Slope	W2	12.6	2307
Shoulder	W12	12.5	2038
Up-Level	W15	12.5	1787
Toe-Slope Slough	W16	12.4	1328
Level	W9	12.3	1994
Saline Toe-Slope Slough	W8	10.5	882

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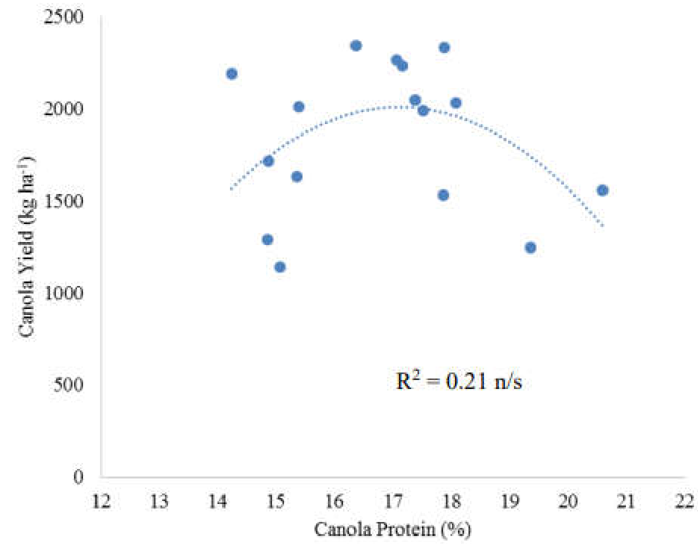
Canola Protein and Yield



Landscape Position		Protein	Yield (kg/ha)
Saline Solenetz BNT Depression	C9	20.6	1559
Saline Depression	C7	19.4	1246
Toe-Slope	C1	18.1	2032
Mid-Slope Gravel	C3	17.9	2331
Mid-Slope	C15	17.9	1532
Depression	C8	17.5	1993
Mid-Slope	C6	17.4	2047
Foot-Slope	C13	17.2	2234
Depresssion	C14	17.1	2263
Fertile Depression	C2	16.4	2342
Lower level	C10	15.4	2010
Knoll	C16	15.4	1630
Eroded Knoll	C4	15.1	1143
Sandy Eroded Knoll	C5	14.9	1715
Upper level	C11	14.9	1289
Mid-Level	C12	14.2	2190

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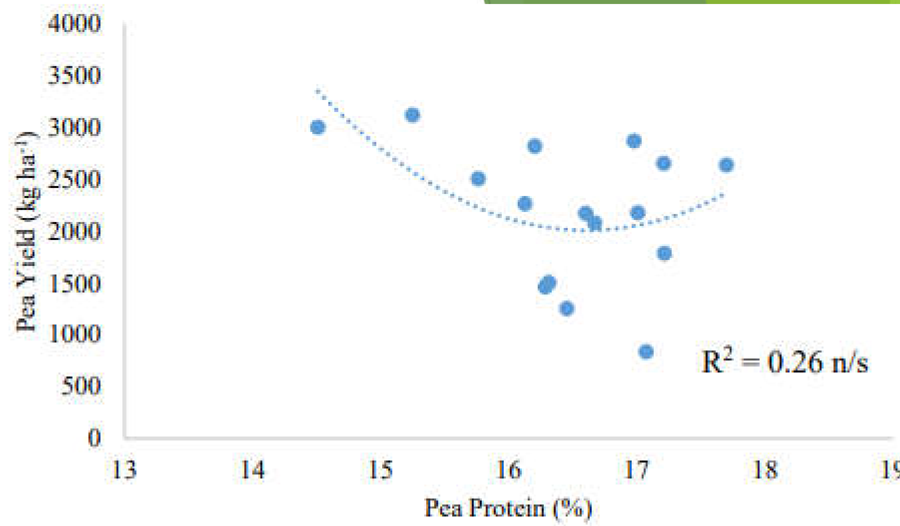
Pea Protein and Yield



Landscape Position		Protein	Yield (kg/ha)
Lower	P14	17.7	2640
Wet	P6	17.2	1784
Reclaimed RR Line	P15	17.2	2654
Level	P5	17.1	839
Shoulder	P1	17	2178
Upper-Level	P10	17	2871
Mid-Slope	P7	16.7	2079
Level	P9	16.6	2173
Toe-Slope Depression	P12	16.5	1256
Saline Depression	P4	16.3	1507
Saline Depression	P13	16.3	1465
Mid-Slope	P2	16.2	2820
Upper-Slope	P16	16.1	2264
Upper Level	P8	15.8	2506
Mid	P11	15.2	3122
Toe-Slope	P3	14.5	3004

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Wheat VR N Strategy based on Canola & Pea Protein: Yield Relationship

Constant Rate 50 kg N ha^{-1}

Table 3.3. Variable rate N strategies for wheat grown in 2013 on canola (Fig. 3.4; Field Area 2) and pea stubble (Fig. 3.7; Field Area 3).

Protein: Yield Combination		N Rate Rationale for Each Protein: Yield Combination	
HP	HY	High protein indicates N not limiting; therefore will reduce N rate to 40 kg ha^{-1}	-20%
HP	MY		
HP	LY		
MP	HY	Medium protein indicates more N required; therefore will increase N rate to 60 kg ha^{-1}	+20%
MP	MY		
MP	LY	Medium protein and low yield indicates more N required; therefore raise N to super rate of 70 kg ha^{-1}	+40%
LP	LY	Low protein and low yield indicates some other factor limiting yield, therefore reduce N rate to 0 kg ha^{-1}	

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Canola VR N Strategy based on Wheat Protein: Yield Relationship

Constant Rate 60 kg N ha^{-1}

Table 3.4. Variable rate N rate strategies for canola grown in 2013 on wheat stubble (Fig. 3.8; Field Area 1).

Protein: Yield Combination		N Rate Rationale for Each Protein: Yield Combination	
HP	MY	High protein indicates N not limiting yield, therefore reduce N rate to 48 kg ha^{-1}	-20%
HP	LY	High protein indicates N not limiting yield, therefore reduce N rate to 42 kg ha^{-1}	-30%
MP MP	HY MY	Medium protein indicates more N required, therefore increase N to 72 kg ha^{-1}	+20%
MP	LY	Medium protein and low yield & gravel soil indicates soil property limiting yield: reduce N rate to 48 kg ha^{-1}	-20%
LP LP LP	HY MY LY	Low protein and medium to high yields indicates more yield could be achieved, increase N rate to 84 kg ha^{-1}	+40%

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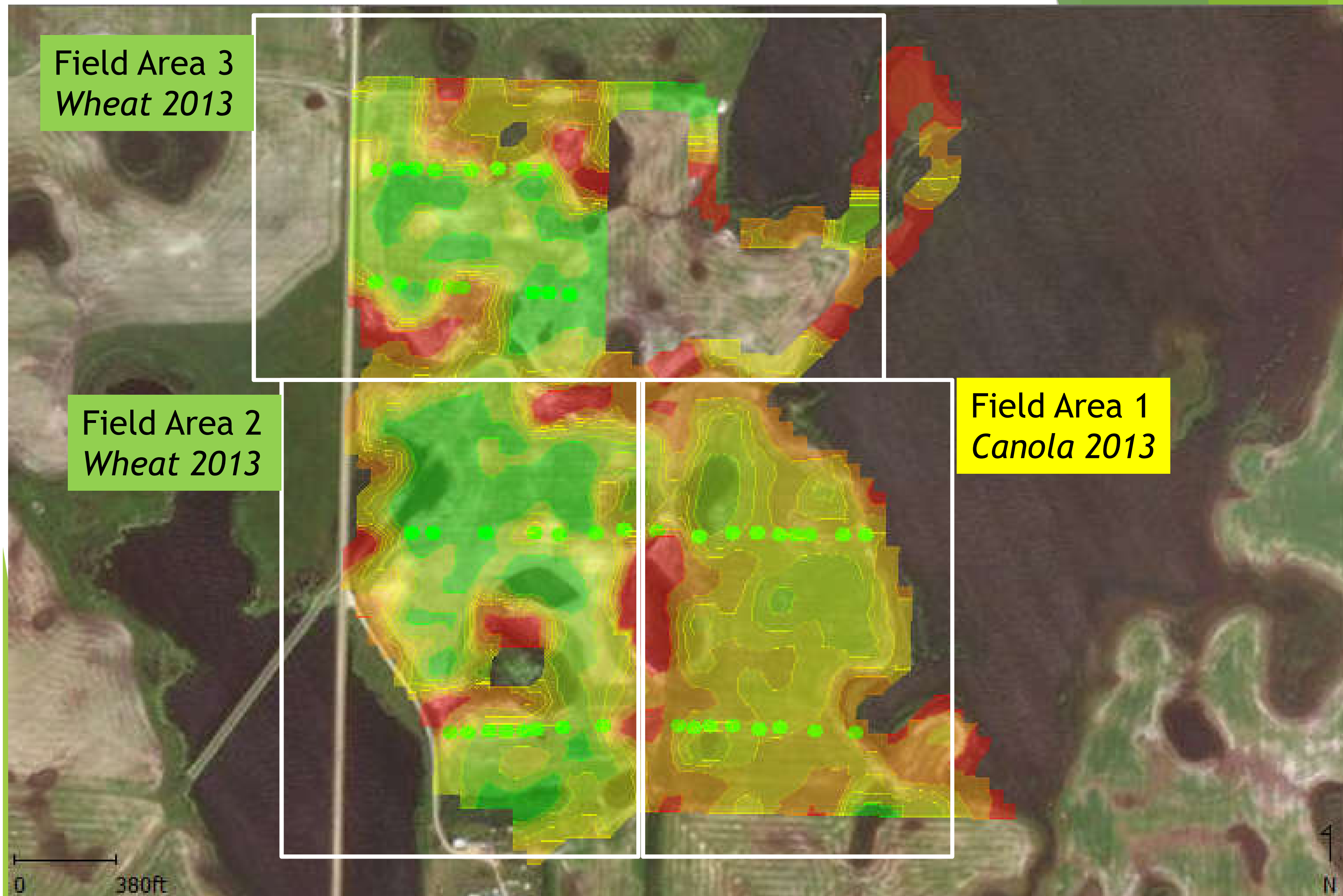
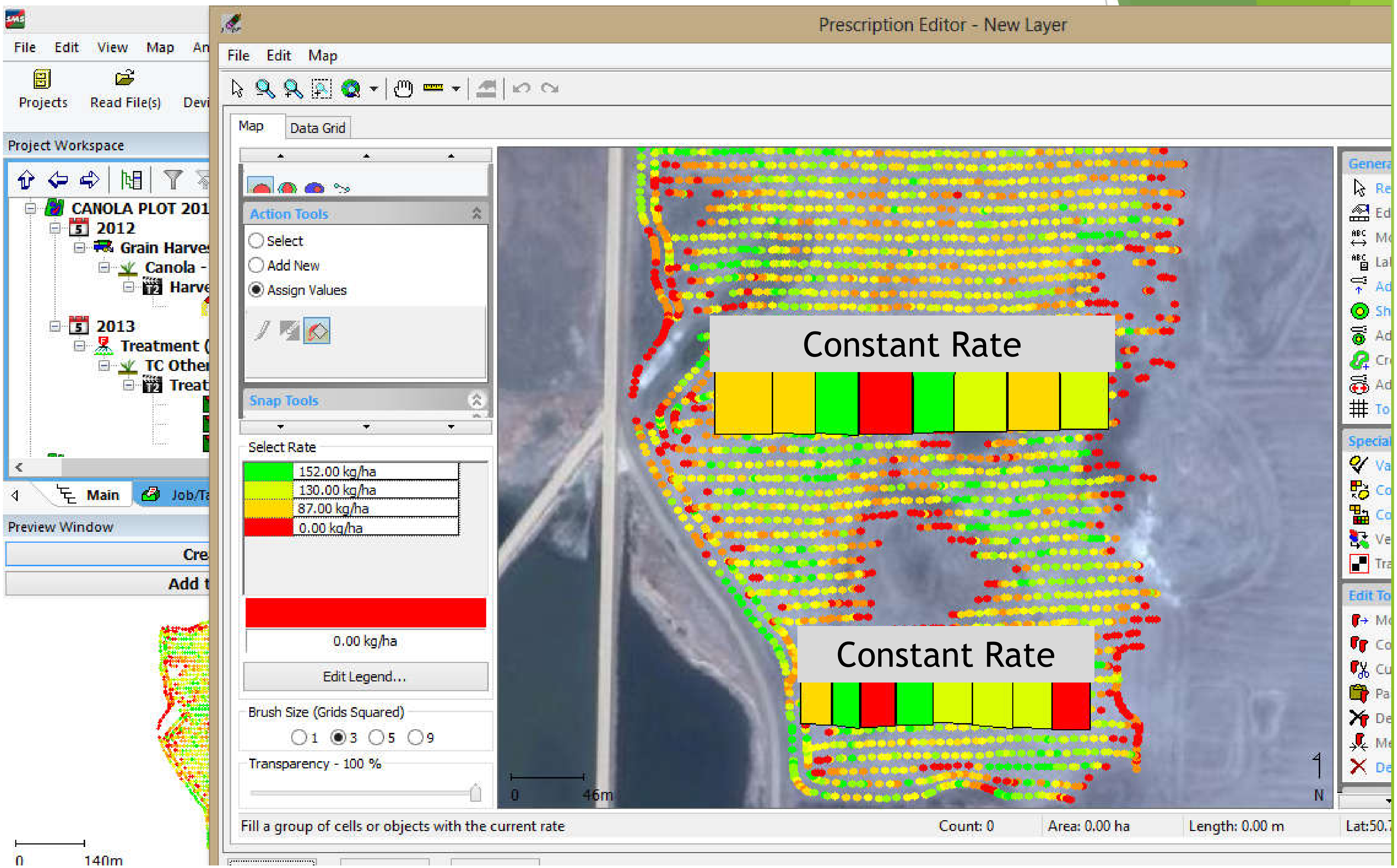
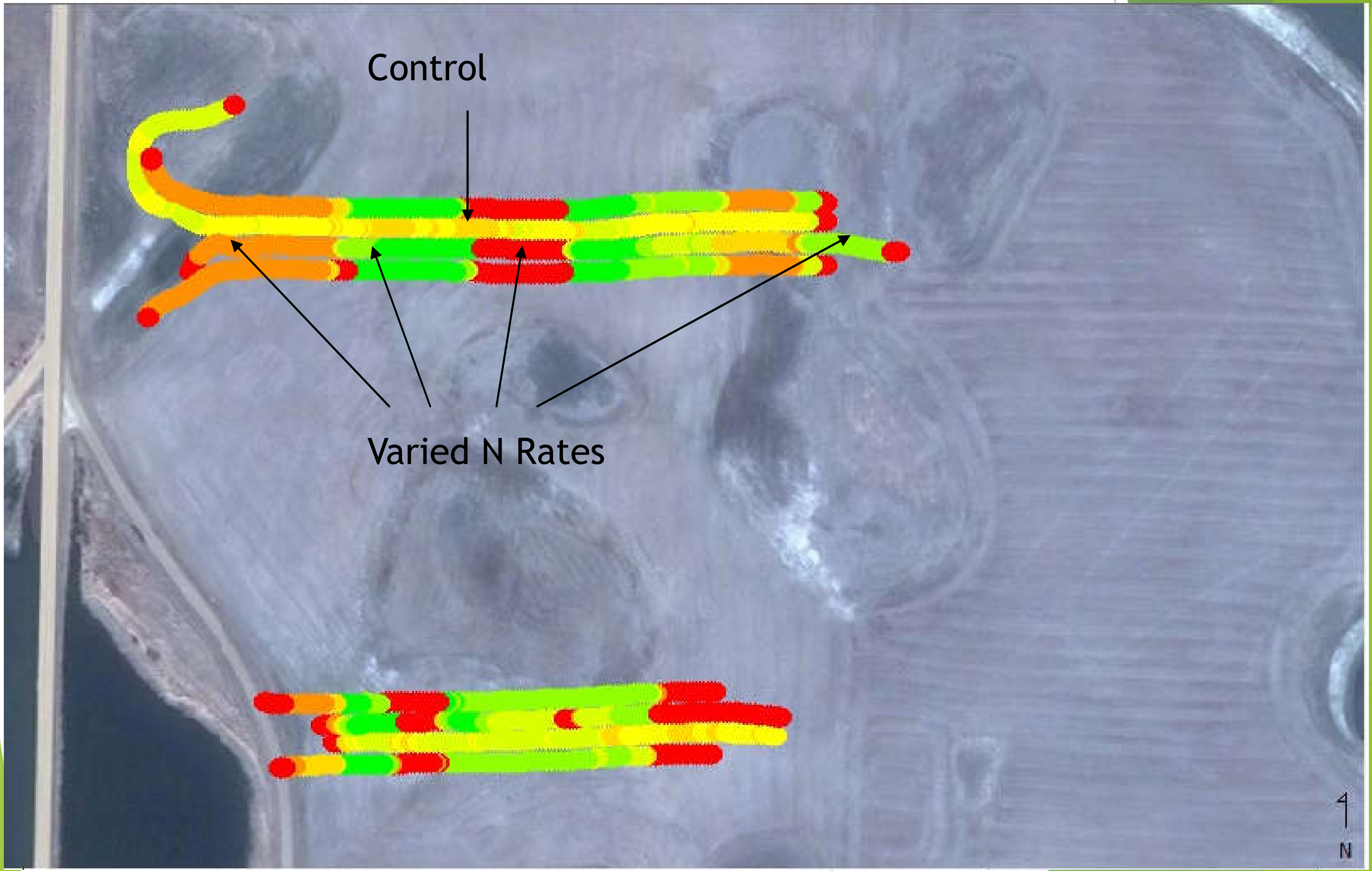
Field Operations 2013


Field Area 3
Wheat 2013
Field Area 2
Wheat 2013
Field Area 1
Canola 2013
0
380ft
N

VR Prescription Editor

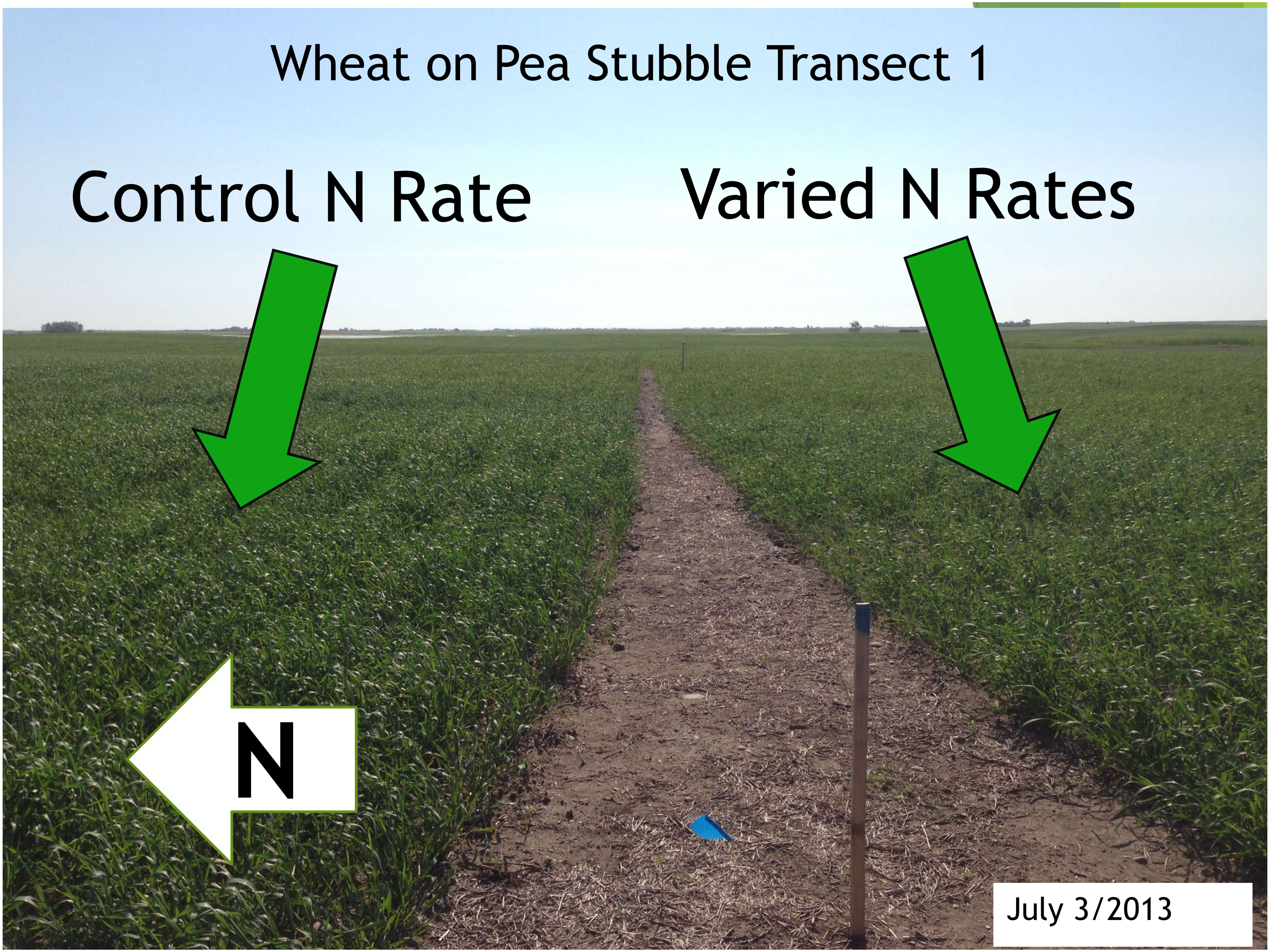


Wheat on Canola Stubble



Precipitation

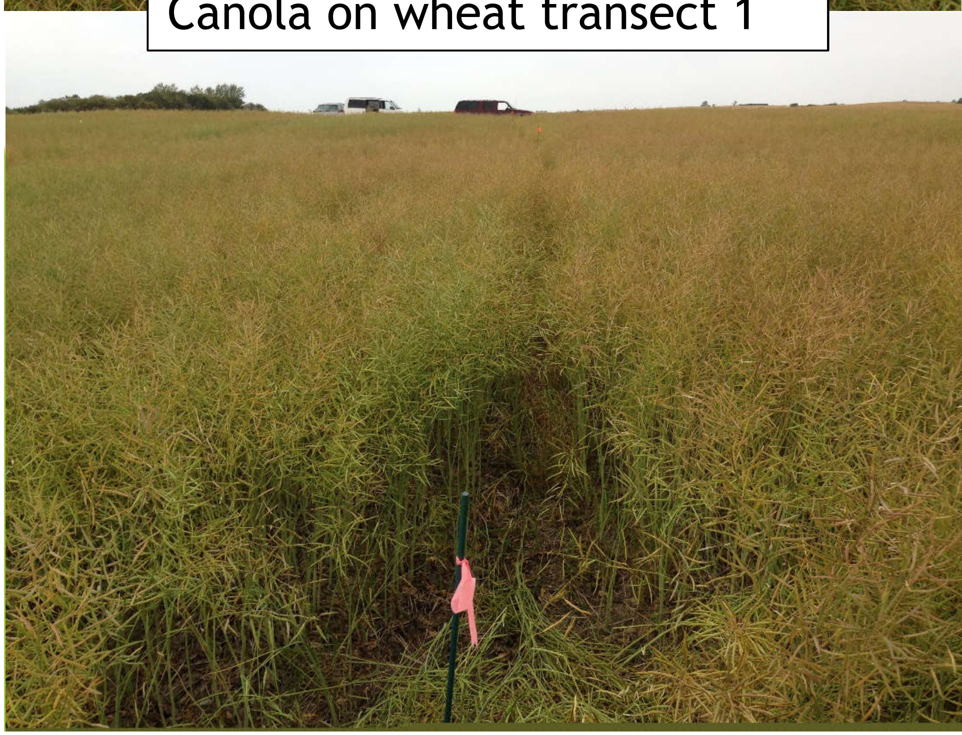
Month	2011	2012	2013
	Rainfall (mm)		
April	3	26	6
May	38	116	29
June	11	109	82
July	52	37	54
Aug	53	26	60
Sept	6	4	42
Oct	27	0	0
Total (mm)	**190**	**318**	**273**
Total (inches)	**7.6**	**12.7**	**10.9**


Wheat on Pea Stubble Transect 1
Control N Rate
Varied N Rates
N
July 3/2013

Harvest 2013 Data

Canola on wheat transect 1

Wheat on peas transect 1

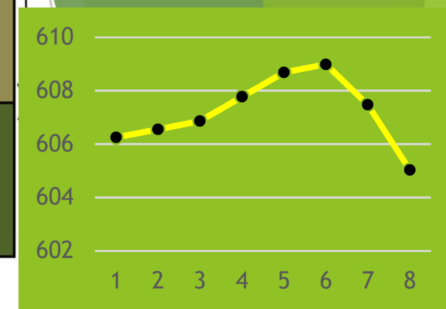


Transect 1

Control	**60 kg N/ha (130kg 46-0-0/ha)**							
Variable Rate	**48 (104)**	**72 (157)**	**48 (104)**	**48 (104)**	**42 (91)**	**42 (91)**	**48 (104)**	**84 (182)**
Transect Point 2012 Wheat Protein: Yield	CW1 **HP HY**	CW2 **MP HY**	CW3 **HP MY**	CW4 **HP MY**	CW5 **HP LY**	CW6 **HP LY**	CW7 **HP MY**	CW8 **LP LY**

38m | 27m | 27m | 16m | 17m | 37m | 27m

189 m



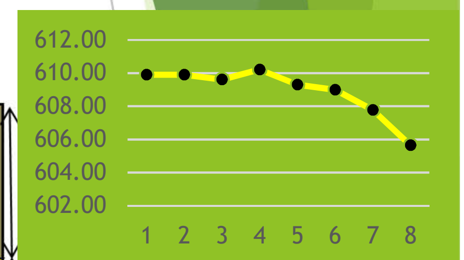
Transect 2

Control	**60 kg N/ha (130kg 46-0-0/ha)**							
Variable Rate	**72 (157)**	**48 (104)**	**72 (157)**	**72 (157)**	**48 (104)**	**72 (157)**	**72 (157)**	**48 (104)**
Transect Point 2012 Wheat Protein: Yield	CW9 **MP MY**	CW10 **HP MY**	CW11 **MP MY**	CW12 **MP MY**	CW13 **HP MY**	CW14 **MP MY**	CW15 **MP MY**	CW16 **MP LY**

18m | 18m | 26m | 30m | 23m | 40m | 45m

200 m

9m (30ft)



Field Area 1

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Canola Yield All Treatments

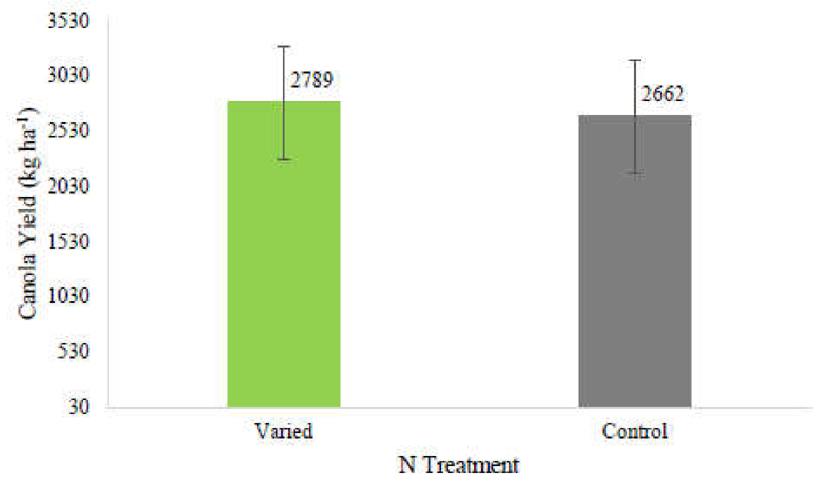
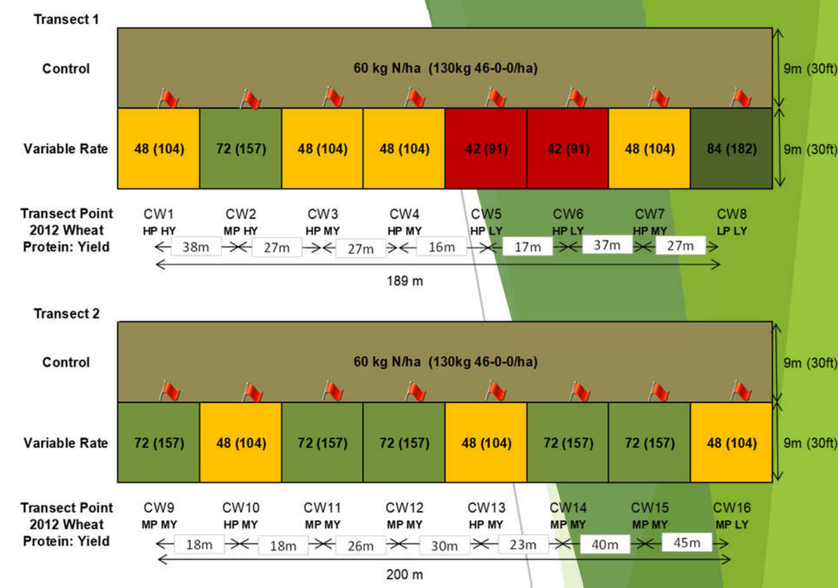
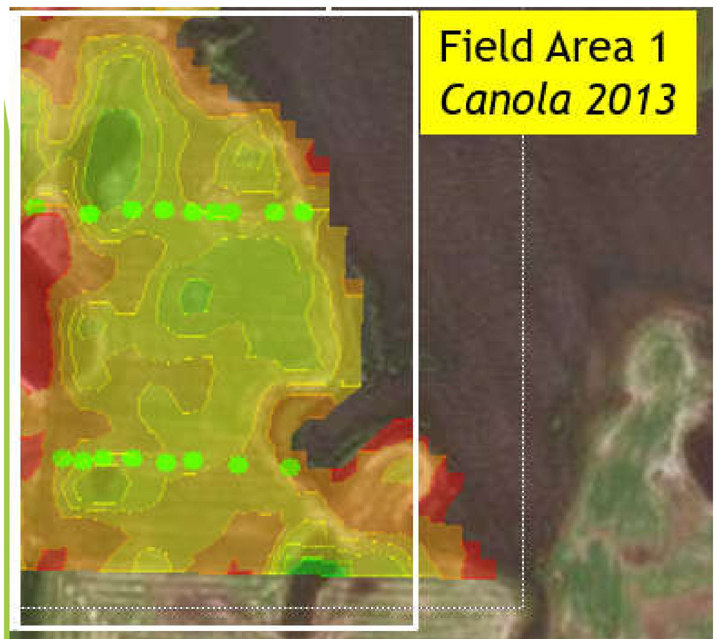


Fig. 4.10. Mean canola yield grown in 2013 on wheat stubble (kg ha^{-1}) on Field Area 1. Bars indicate standard deviation of the mean (n=16).





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Canola Protein All Treatments

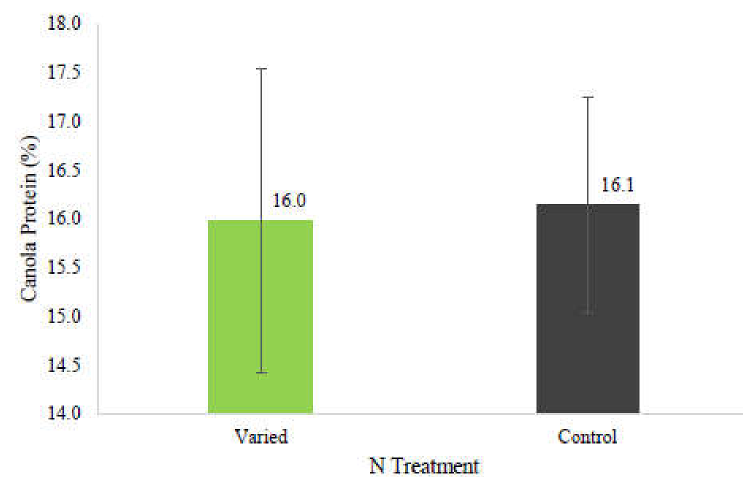


Fig. 4.13. 2013 canola protein (%) by N treatment on wheat stubble on Field Area 1. Bars indicate standard deviation of the mean (n=16).

Canola Yield by N Treatment

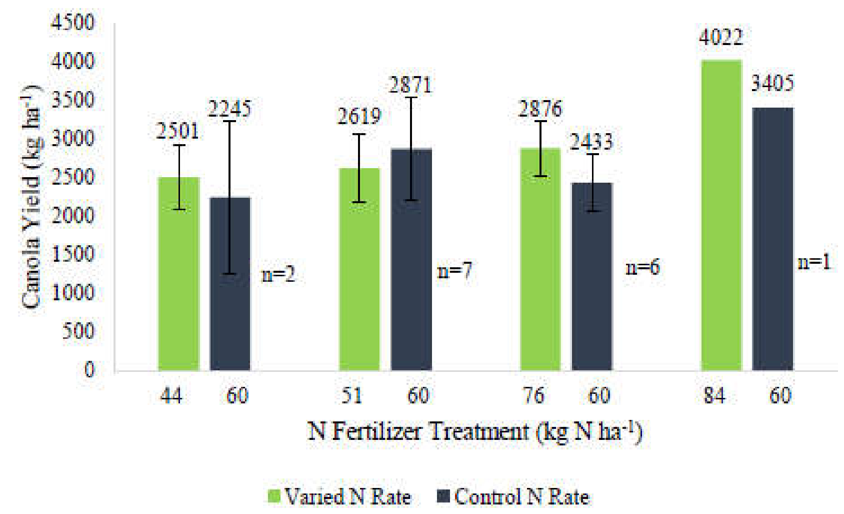
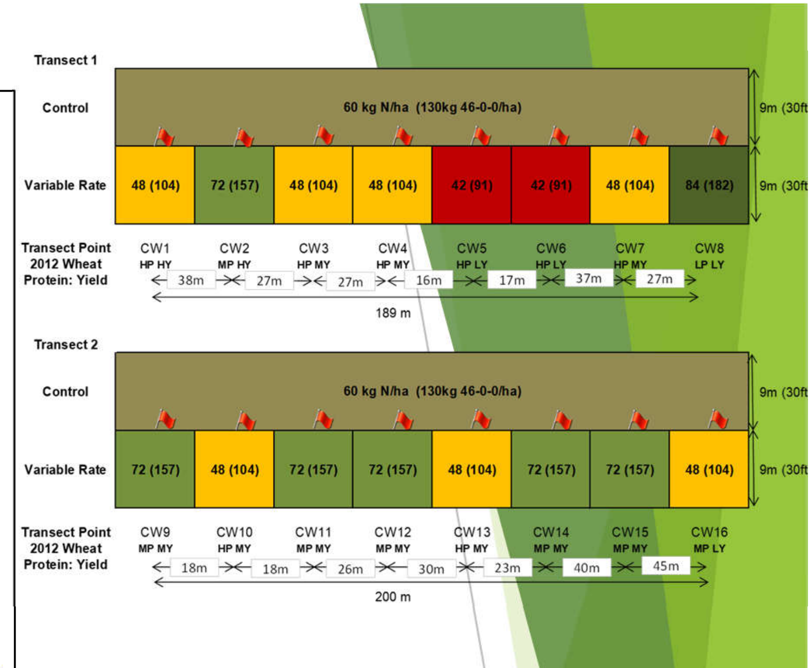
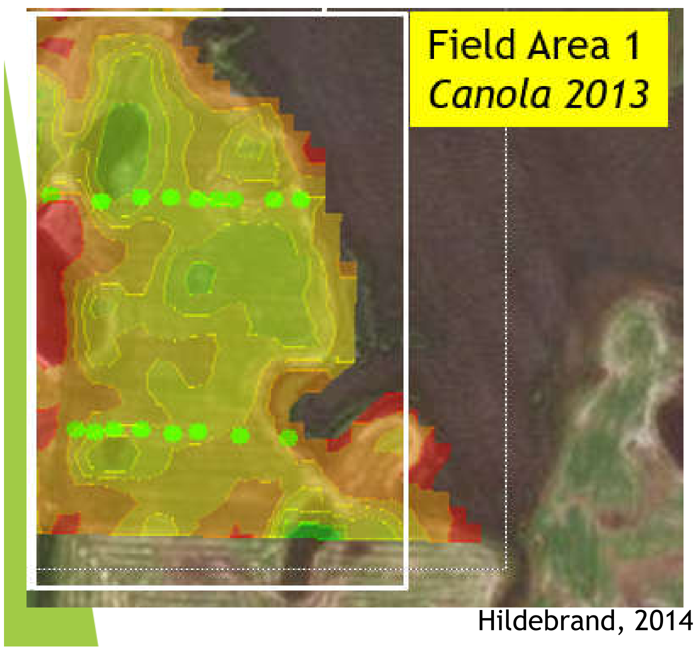


Fig. 4.12. 2013 canola yield (kg ha^{-1}) by N on wheat stubble in Field Area 1. Bars indicate standard deviation of the mean.



Canola Protein by N Treatment



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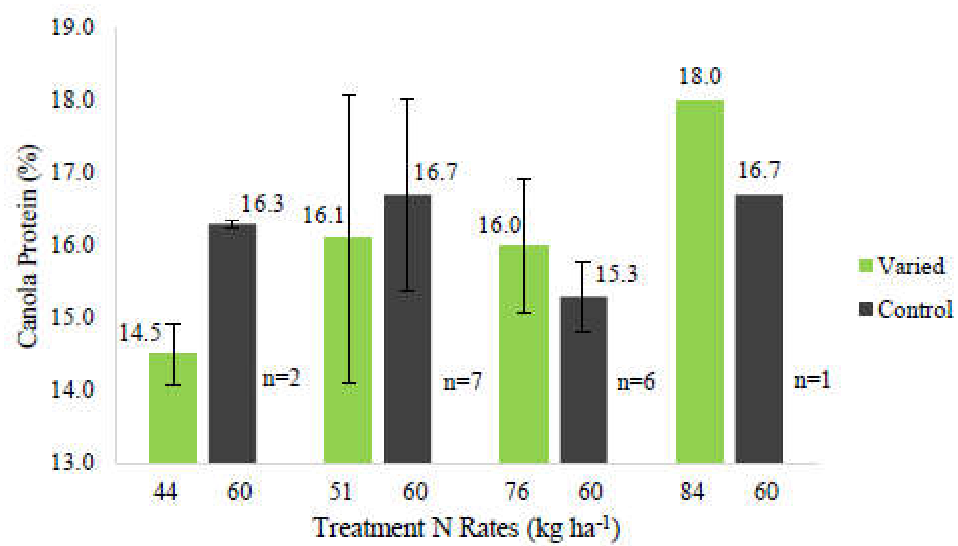
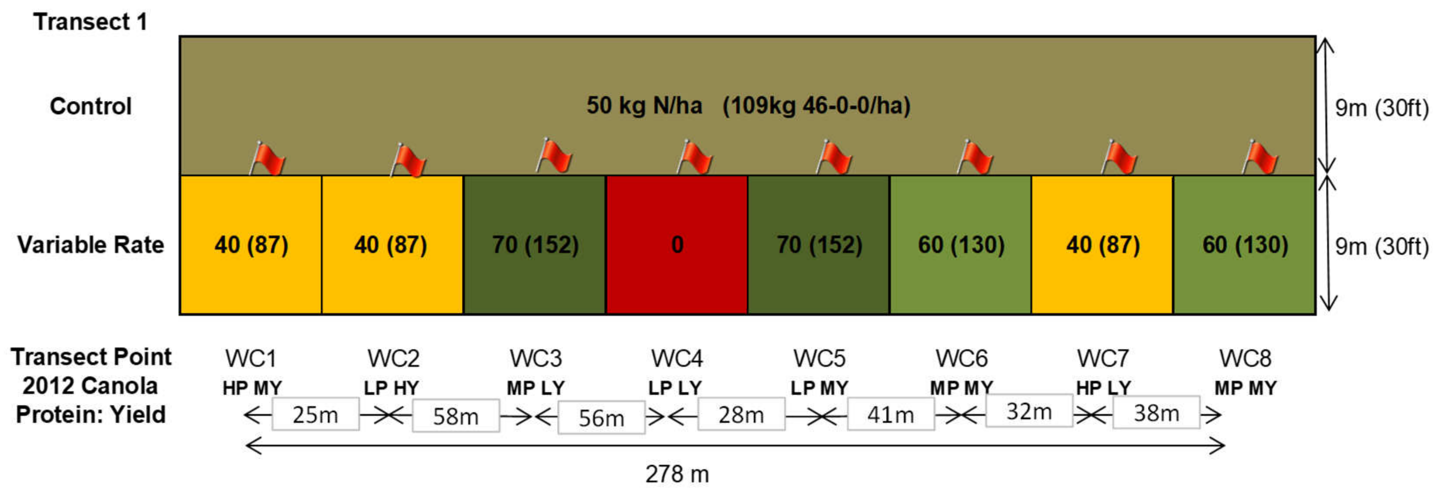
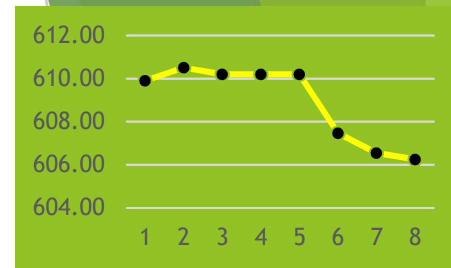
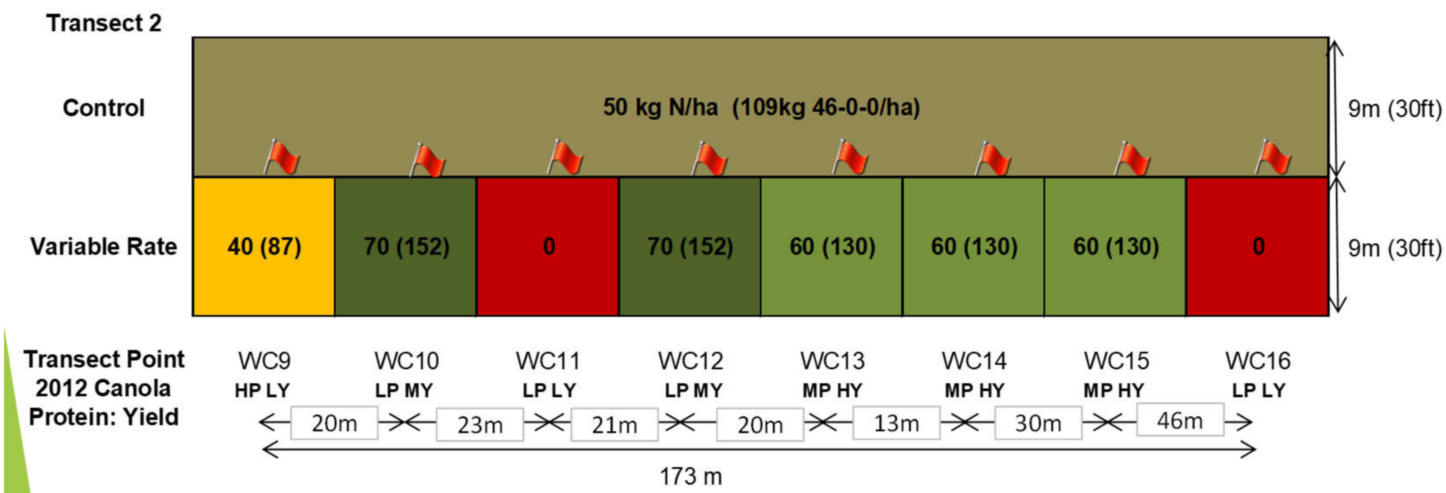
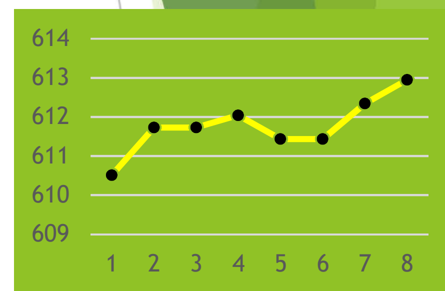


Fig. 4.15. Canola protein by N treatment grown in 2013 on wheat stubble on Field Area 1. Bars indicate standard deviation of the mean.









Field Area 2

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Wheat on Canola Stubble Yield All Treatments

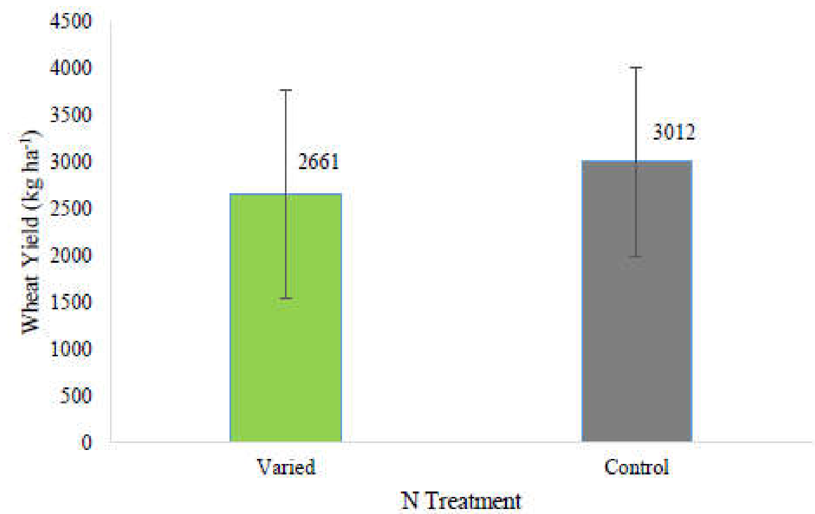
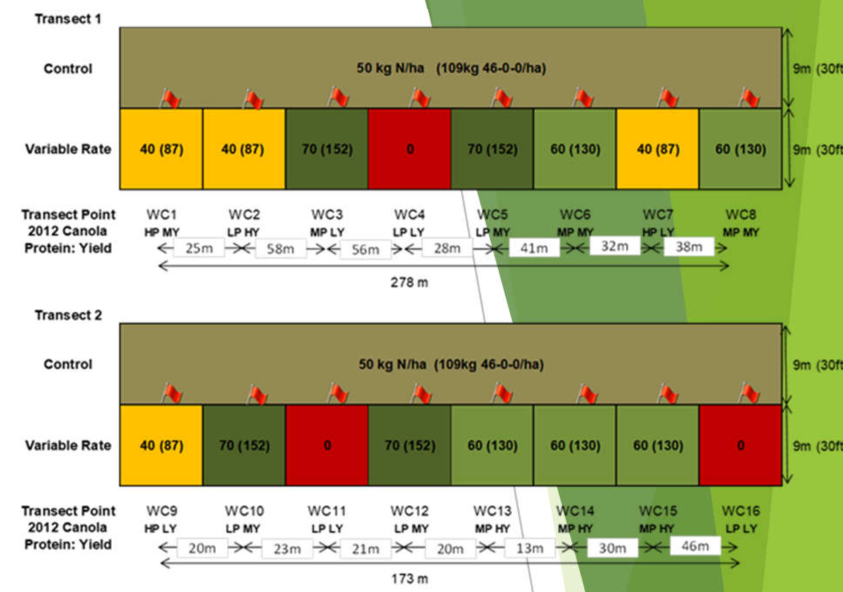
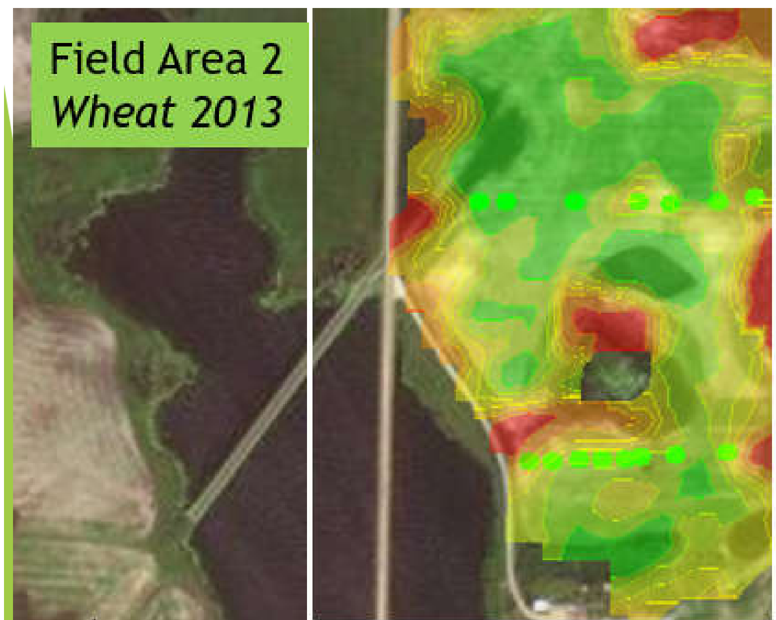


Fig. 4.16. Mean wheat yield grown in 2013 on canola stubble (kg ha^{-1}) on Field Area 2. Bars indicate standard deviation of the mean (n=16).



Wheat on Canola Stubble Protein All Treatments



Hildebrand, 2014

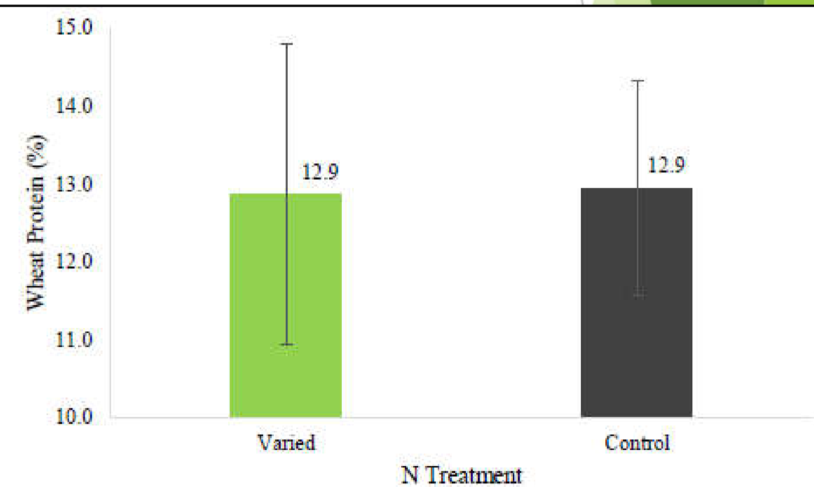


Fig. 4.19. Mean protein content of wheat grown in 2013 on canola stubble on Field Area 2. Bars indicate standard deviation of the mean (n=16).

Wheat on Canola Stubble Yield By N Treatment

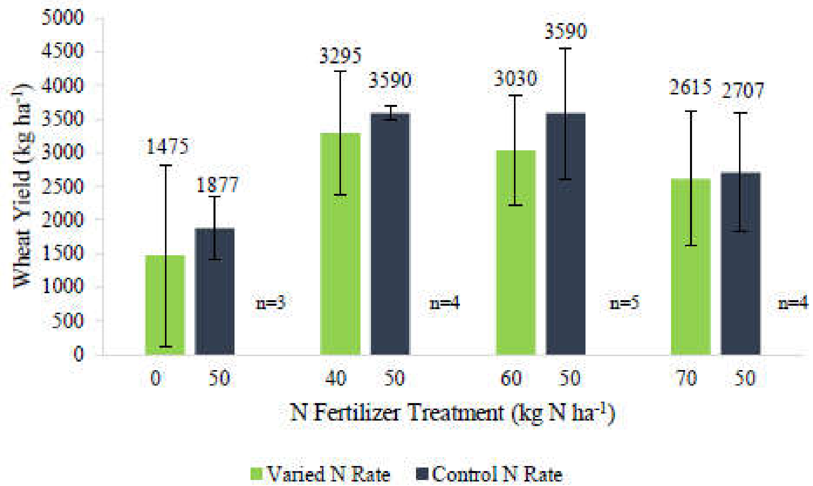
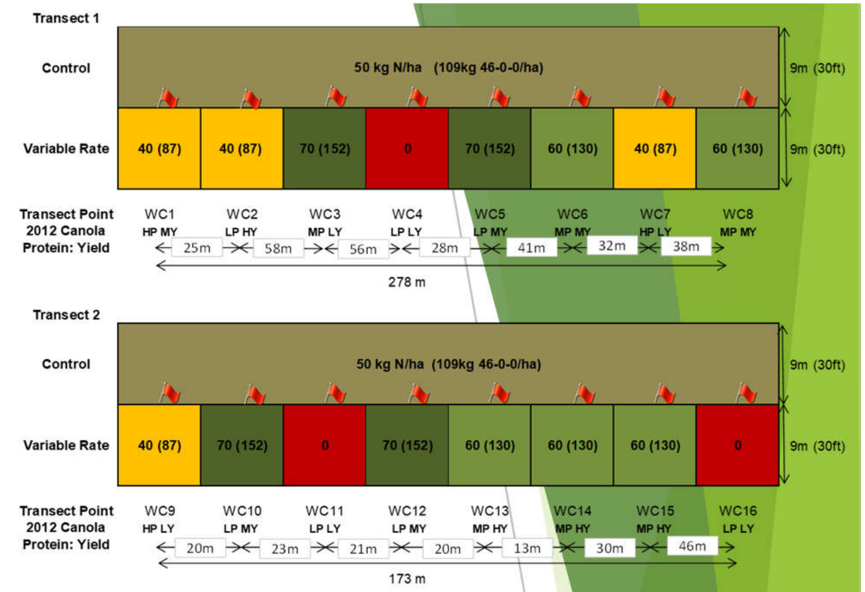
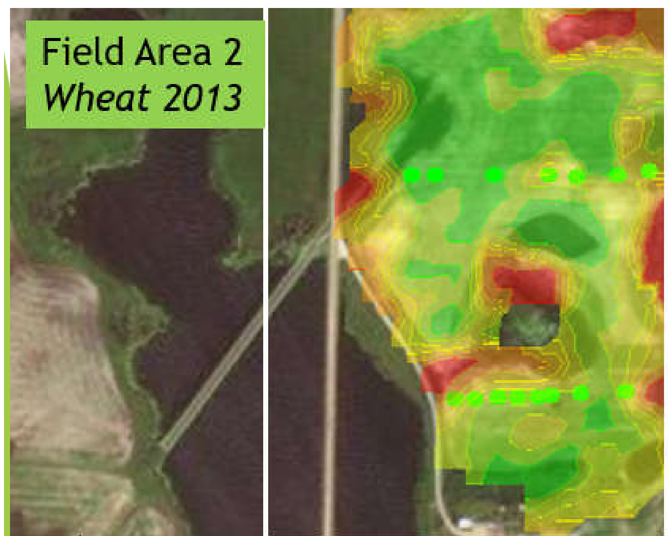


Fig. 4.18. 2013 wheat yield (kg ha^{-1}) by N treatment grown in 2013 on canola stubble in Field Area 2. Bars indicate standard deviation of the mean.



Wheat on Canola Stubble Protein By N Treatment



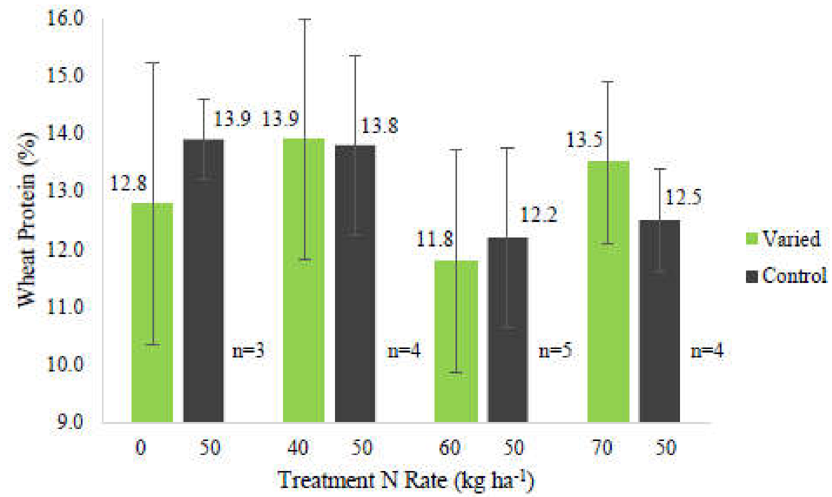


Fig. 4.21. Wheat protein by N rate on canola stubble in Field Area 2 in 2013. Bars indicate standard deviation of the mean.

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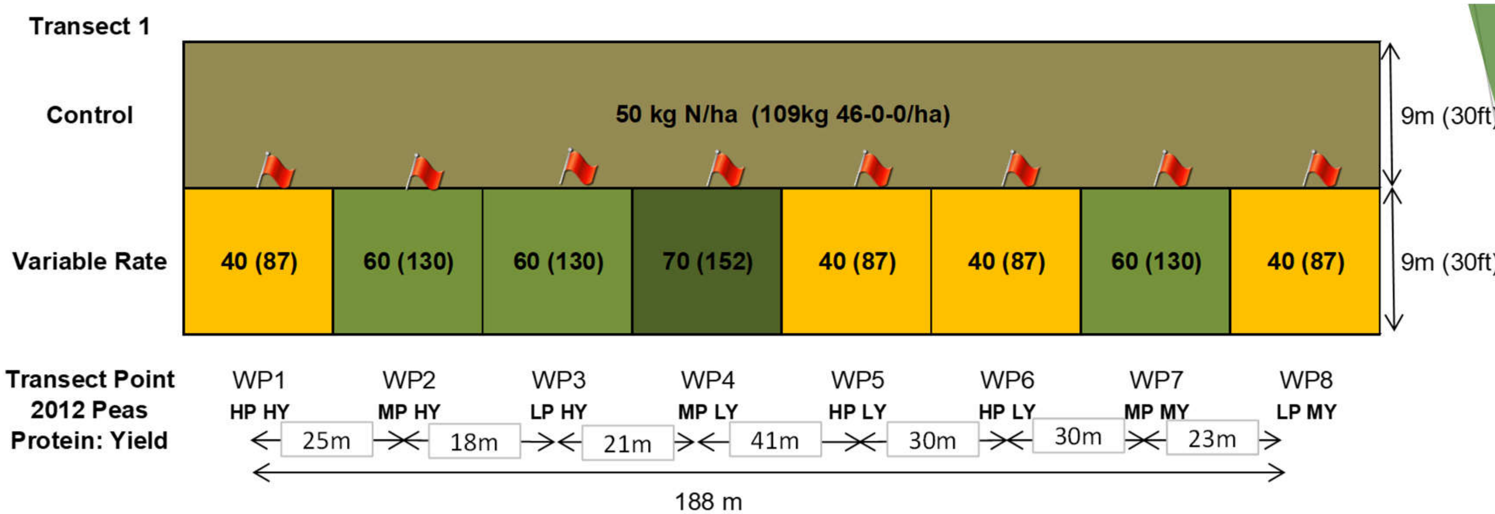

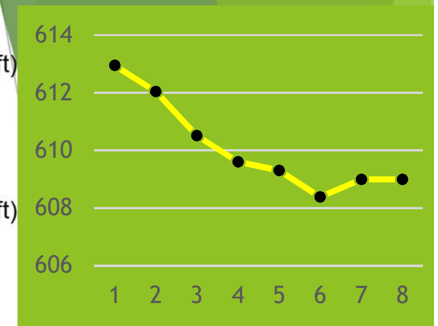

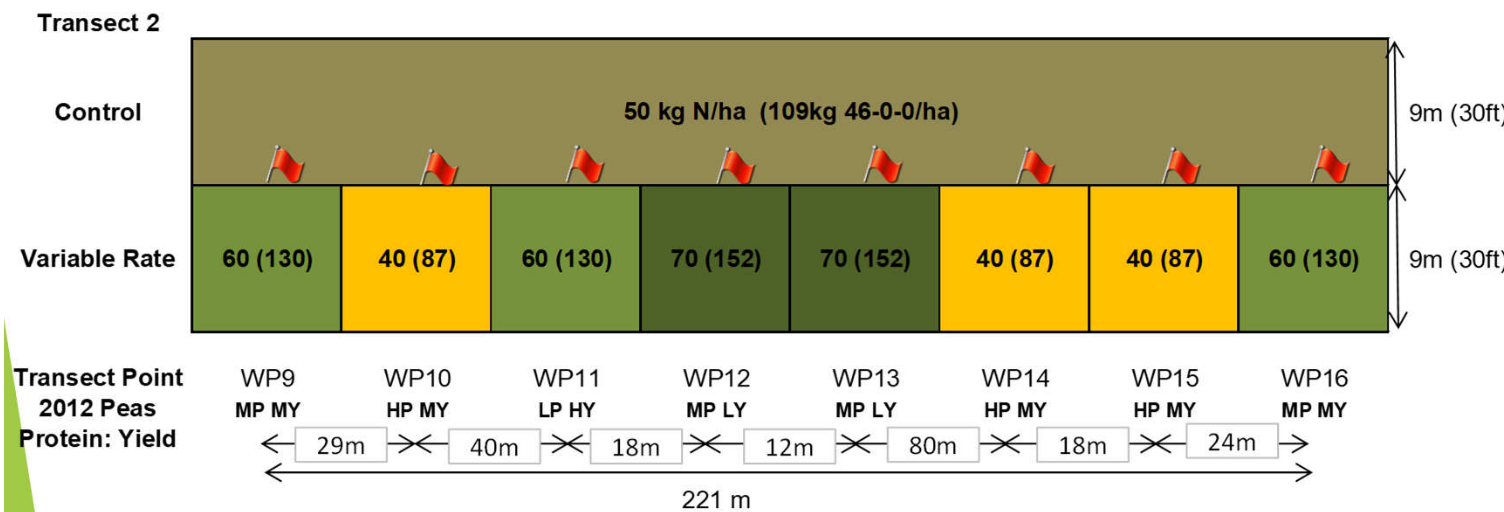

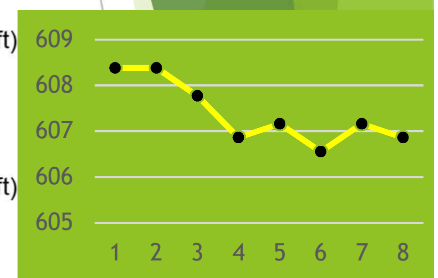

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Wheat on Pea Stubble Yield All Treatments

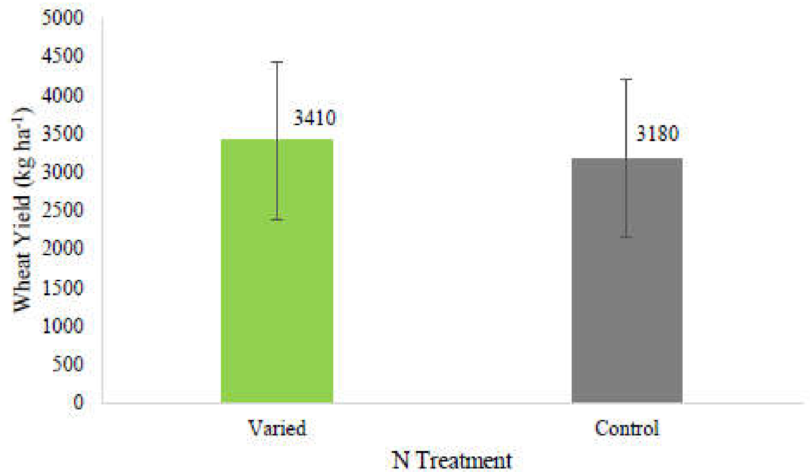
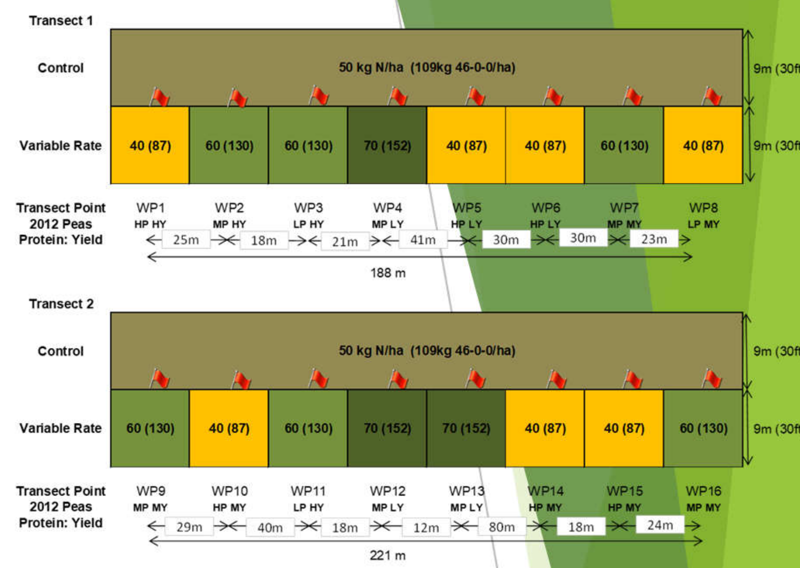


Fig. 4.22. Mean wheat yield grown in 2013 on pea stubble (kg ha^{-1}) on Field Area 3. Bars indicate standard deviation of the mean (n=16).



Wheat on Pea Stubble Protein All Treatments

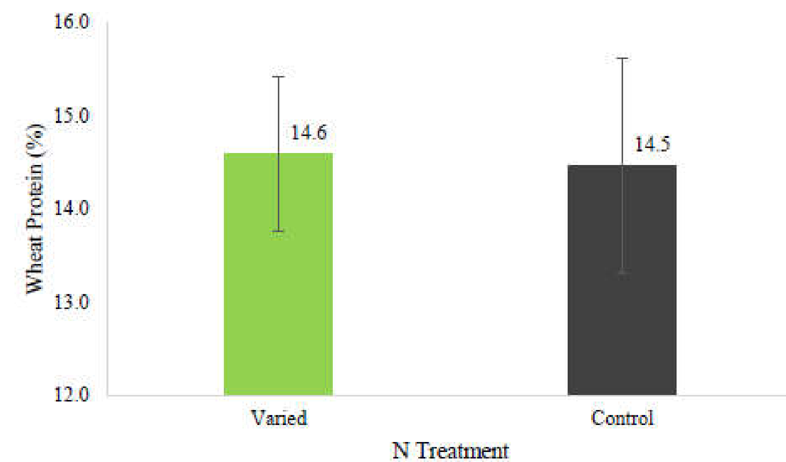


Fig. 4.25. Mean wheat protein grown in 2013 on canola stubble on Field Area 3. Bars indicate standard deviation of the mean.

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Wheat on Pea Stubble Yield By N

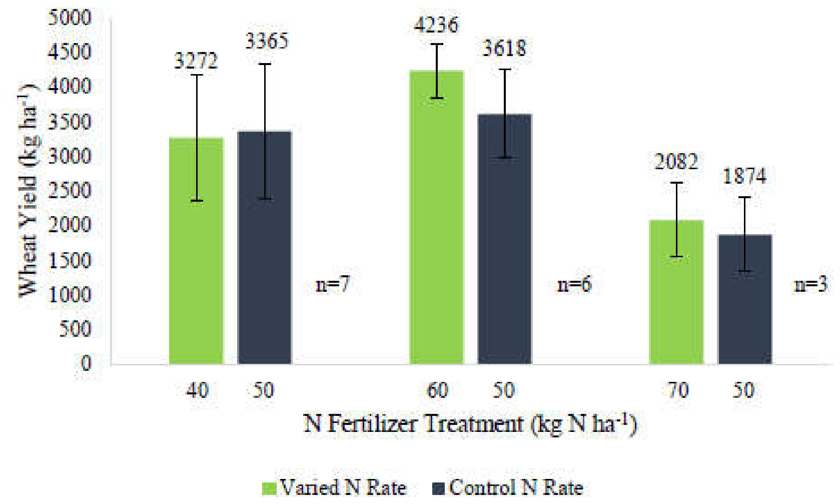
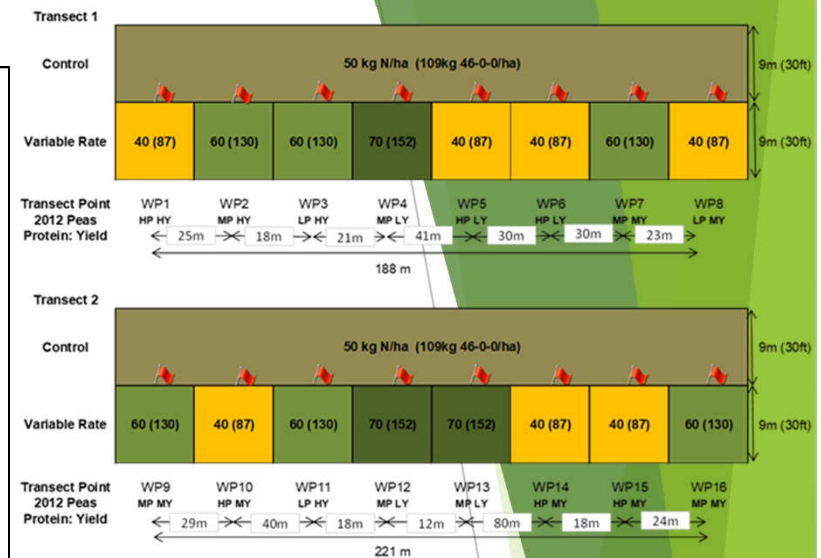


Fig. 4.24. 2013 wheat yield (kg ha^{-1}) by N treatment on pea stubble. Bars indicate standard deviation of the mean.



Wheat on Pea Stubble Protein By N Treatment

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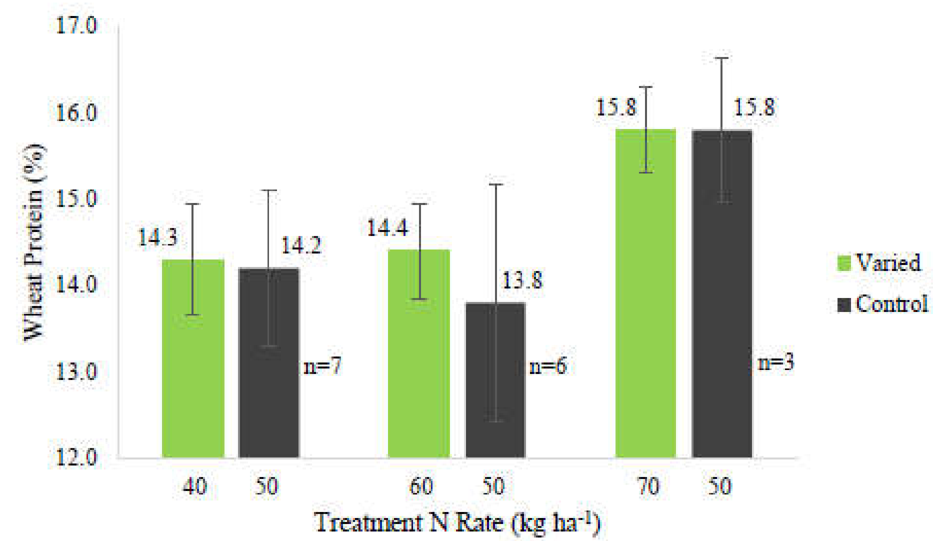

Fig. 4.27. 2013 wheat protein by N treatment on pea stubble in Field Area 3. Bars indicate standard deviation of the mean.

Relationship of Canola Yield and Protein to Soil Properties

Canola: Soil Relationships	2012		2013		2013	
	Base Year		Variable N		Constant N	
	Yield	Protein	Yield	Protein	Yield	Protein
Organic carbon (%) (0-30 cm)	ns	**r=0.65***	ns	ns	**r=0.57 ***	ns
EC (dS m^{-1}) (0-30 cm)	ns	ns	**r=0.51***	ns	ns	ns
2013 Soil Moisture Spring (30-60 cm)	ns	ns	ns	ns	ns	**r=-0.50***

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* indicates significant correlation at $p < 0.05$

Relationship of Wheat Yield and Protein to Soil Properties

Wheat: Soil Relationships	2012		2013							
	Base Year		Wheat on Canola Stubble				Wheat on Pea Stubble			
			Variable		Constant		Variable		Constant	
	Yield	Protein	Yield	Protein	Yield	Protein	Yield	Protein	Yield	Protein
Organic Carbon (%) (0-30 cm)	**0.74***	ns	**0.51***	ns	ns	ns	ns	ns	ns	ns
EC (dS m^{-1}) (0-30cm)	ns	**0.51***	ns	ns	ns	ns	**-0.52***	ns	**-0.51***	ns
2013 Soil Moisture Spring (30-60 cm)	ns	ns	ns	ns	ns	**-0.60***	ns	ns	ns	ns

* indicates significant correlation at $p < 0.05$

Hildebrand, 2014

Did protein help create N zones?

- Increasing N rates:
  - Generally a positive yield and protein response where previous crop was low or medium protein
  - Low and medium protein good indicator that more N was required
- Decreasing N rates:
  - Generally a negative yield and protein response where previous crop was high protein
  - High protein a less reliable indicator that N could be reduced

Table 5.1. Mean impact of VR N strategy on yield and protein vs constant N rate.

VR Strategy		Canola on Wheat	Wheat on Canola	Wheat on Peas
Decrease N Rate	Yield (kg ha^{-1})	-99	-336	-67
	Protein (%)	-1.2	-0.5	0.1
Increase N Rate	Yield (kg ha^{-1})	395	-336	471
	Protein (%)	1.0	0.3	0.3

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Conclusions

- Average yield and protein across the landscape in varied N rate and constant N rate were similar
- Since similar total amounts of N fertilizer were used in each, no difference in economic return
  - Same results for each crop
- Prescription approach needs refining?
  - What can be improved?
  - Be careful about reducing N rates in a VR prescription!

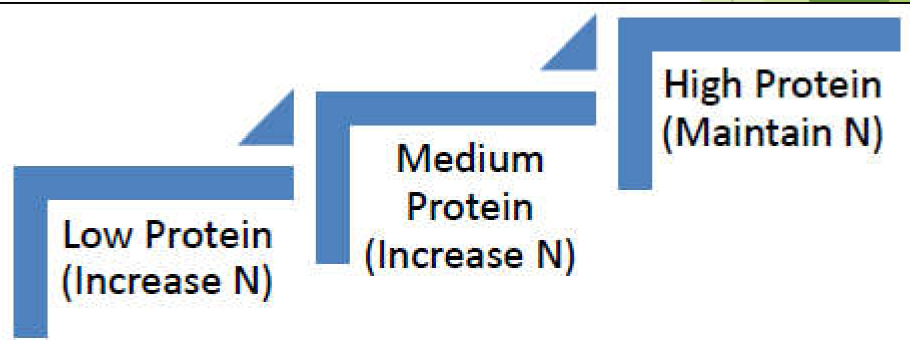

Fig. 5.1. N strategy for subsequent crop based on protein content of current crop.

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Further Thoughts & Considerations

- What is the right rate?
- Depends!

- Available water — Unknown in advance
- Soil Texture
- Soil pH
- Soil EC
- Heat Units
- Relative to other nutrients

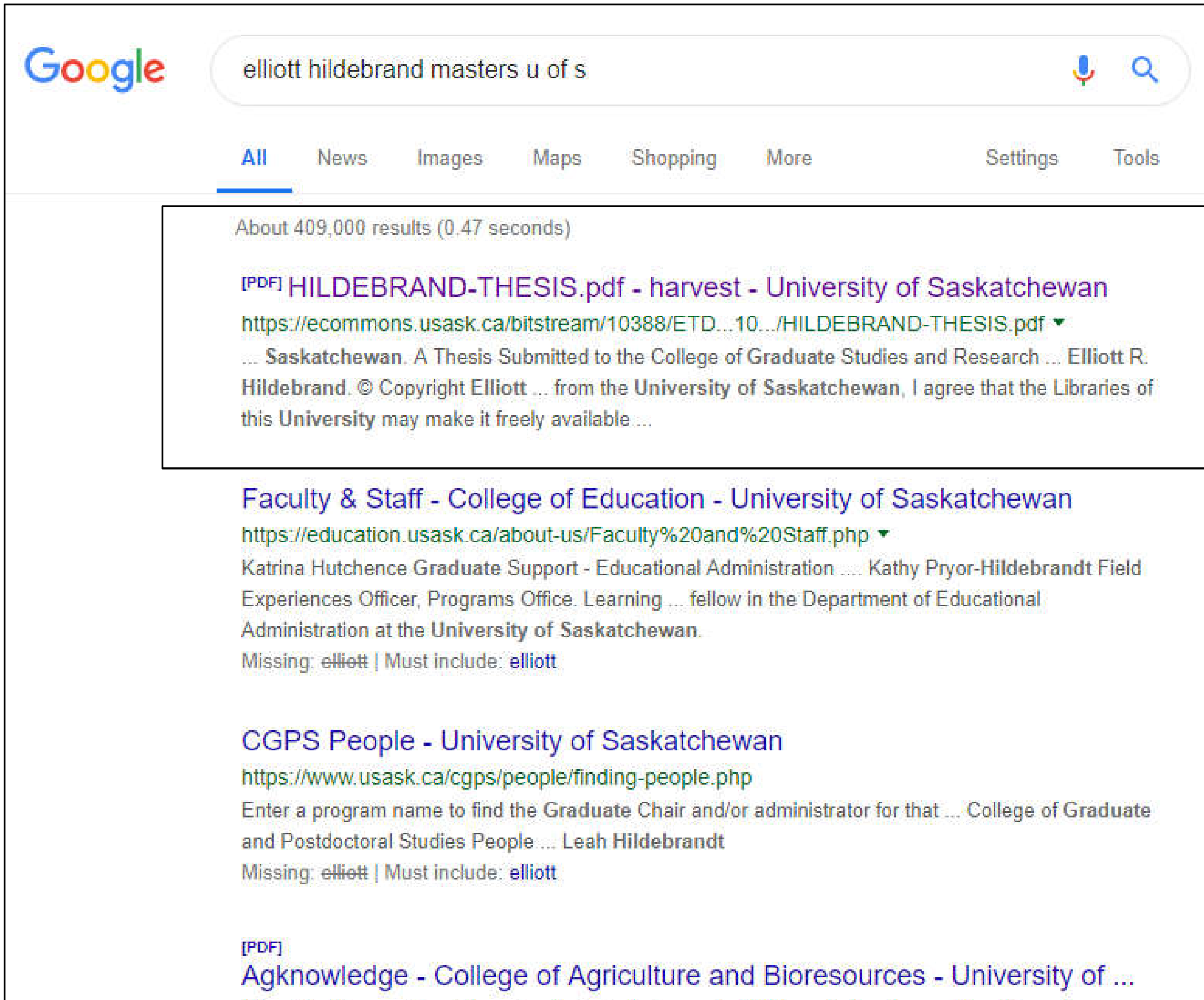
Right Rate

- Size of the field area
- Cost of sampling
- Confidence in sampling
- Cost of prescription

- Value of fertilizer
- Value of crop
- Grower risk tolerance

Be aware of data variability; are differences significant?

More Information



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  - Scott Noble
- Les Henry
  - Valuable insight

Team Schoenau

Thank You!
Questions?

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