Saskatchewan Canola Development Commission Final Report.

1. Executive Summary:

A three year Precision Farming study was conducted in Indian Head, SK. to look at the effects of nitrogen fertility, management zones, crop plant population, weeds and diseases on canola yields using a field scale approach. The results from the study demonstrates that yield variability was greatest due to different environmental conditions encountered each year, management zones, diseases and weed pressures. This study highlights the importance of variable rate fertilization programs and crop monitoring to maximize field profitability.

2. Acknowledgments:

IHARF would like to acknowledge the in-kind sponsorship of New Holland North America and Markusson Country for supplying the necessary farm equipment needed for this research project, as well as Simplot Canada for their in-kind support for liquid fertilizer, SCDC for their financial support for the disease survey and the rest of the IHARF Precision Farm sponsors listed on our web site : http://paridss.usask.ca/precisionfarm. Furthermore, IHARF would like to acknowledge Dr. Prakash Basnyat, Dr. Brian McConkey and Dr. Guy Lafond for their unprecedented expertise in the data analysis for this project and Chris Omoth for his technical support.

Background: The overall objective of the Precision Farming Project initiated by Indian Head Agricultural Research Foundation (IHARF) in 1999 is to determine cost effective ways of assigning management units to a field and to adjust production practices according to these management units. The project is comparing a variety of methods of assigning management units against detailed soil samples taken on a one-acre grid. Presently, the high cost of assigning management units using extensive soil sampling makes this approach uneconomical. Some of the alternative approaches under study involves measurements with an EM38 (soil salinity meter), digital elevation map, yield map, remote sensing using the non differentiated vegetative index (NDVI), aerial black and white and infra-red photographs, general soil survey and ground based hyperspectral measurements.

Objective:

The objective of this project was to collect information on the spatial variability of crop plant populations, weeds and plant diseases during the 2000, 2001 and 2002 growing season in order to determine the effect of these biotic factors on the final grain yield of canola as part of a variable rate nitrogen program on the IHARF Precision Farm.

3. Details of Experimental procedures

Introduction:

Canola yields are affected by year to year variations in growing season conditions but also by many biotic factors on a field scale basis. The best way to determine the effects of the biotic factors on canola final yield is to look at them on a field scale basis. In 1998, IHARF started a Precision Farming Project on 308 acres of land. In 1998 the farm was divided in 8 – 38.5 acre fields. A crop rotation of spring wheat- canola-spring wheat – field pea was implemented. Furthermore, 308 markers were geo-referenced and inserted in the ground for data collection purposes in the spring of 1998. In 2000, a variable rate fertility program for nitrogen was implemented for the wheat and canola fields based on a checker board grid pattern that allowed replication of several N rates in each of the management zones predetermined using satellite images.
Weeds, plant counts and disease rating were done at every marker and recorded on paper. Using a Geographical Information systems (GIS) it was then possible to create layers of information for each data set collected at every marker. In the fall, each fields were harvested with a TR99 combine equipped with a yield monitor and GPS antenna in order to create yield maps.
By overlaying all the data layers into a GIS , it was possible to extract the information necessary to determine which of the biotic factors had the greatest effect on final grain yield in canola.

Materials and Methods

A- Seeding:

Seeding was done with a 33 foot Flexicoil 5000 series air drill, equipped with double shoot stealth openers on 12 inch spacing. The seed and granular fertilizer (P and K) rates were controlled using a Flexicoil 2340 series air cart. The Liquid nitrogen was metered and delivered by a Pattison liquid wagon retrofitted with a Flexicoil 67 Sprayer XL rate controller .

In 2000, the Flexicoil TASK controller was used to read the prescription maps and transfer the rate information to the rate controller mounted on the liquid wagon.
In 2001 and 2002, a Compac IPAQ handheld computer , loaded with the Farm Works Software (Farm Site Mate) was used to read the liquid nitrogen prescription maps.

As applied maps were created on-the -go at seeding as the computer system would send information to the rate controller and record the feedback simultaneously. As Applied Maps were created for 2000 and 2002. In 2001 the computer system used could not record as applied information thus only the nitrogen rates of the prescription maps were used in the analysis.

B- Spraying:

Each canola field was sprayed for weeds after the weed survey was done using a 90 foot boom Flexicoil 67 XL High Clearance Sprayer. A detailed list of dates of application, rates and chemicals can be found in Appendix A.

C- Harvest:

The canola crop was swathed each year prior to harvest with a 25 foot swather. Each swath was harvested using a New Holland TR99 combine equipped with an Agleader PF3000 yield monitor and GPS system. In 2000 record yields were achieved due to favorable growing conditions. However in 2001 and 2002 the dry growing conditions lowered the yields considerably. Furthermore, in 2002, the yield data was not good as extreme wind conditions blew the canola swaths thereby affecting yield results.

D- Management Zone delineation:

In 2000, a Normalized Vegetation Index map (NDVI) was created for the entire Precision Farm using the Red (0.63 nm - 0.69 nm) and Near-Infrared (0.76 nm - 0.9 nm) bands of Landsat-7 TM images acquired from the previous two years. NDVI is an indirect measure of crop biomass and is strongly correlated to final grain yield (Basnyat et al (2003). We were able to define three (3) distinct management zones based on NDVI: Low , Medium and High Biomass (Appendix B, Figure 9).
The management zones were delineated using an unsupervised classification or clustering method to identify naturally occurring clusters in NDVI using IDRISI32 image analysis software. As a starting point, five classes were delineated and checked for the significant difference in mean NDVI using least significant difference (LSD) at p=0.05. If there were two or more zones whose mean NDVI were not significantly different, clustering was redone with one less zone. If all zones had significantly different NDVI, the clustering was redone with one more zone. We assumed that the optimal number of zones was equal to the maximum number of statistically significant individual zones based on zonal mean NDVI. Zones were delineated separately for each Landsat TM Imaging and averaged together to obtain a complete management zone map for the entire farm. (for more details refer to Basnyat et al. 2003)

For pictures of seeding implement, management zones, prescriptions, as applied and yield maps refer to Appendix B.

E- Data collection:

a) Plant counts:

Plant counts were done 2 weeks after crop emergence. Four (4) counts were done at each geo-referenced marker using the one meter row method, recorded and expressed as plants per meter square.

b) Weeds count:

Weeds count were done 3 to 4 weeks after seeding and just prior to the in-crop herbicide application around each marker. Four counts using a 0.25 cm^2 quadrat, were recorded and converted to a per meter squared (m^2) value. Each weed specie was identified and recorded separately. For the analysis purpose of this report only a total weed density, broadleaf weed and grassy weed density were used. Broadleaf weed densities included the annual weeds stinkweed, lambs quarter, flixweed, kochia, and the perennial weeds Dandelion and Canada Thistle. Grassy weeds included annuals such as volunteer wheat, green foxtail, wild oat and barn yard grass.

c) Disease rating:

Canola plants were rated for disease severity (foliar, stem, and pods, on a whole plant basis) at 4 locations around each geo-referenced marker using the Horsfall-Barratt disease rating (0-11) scale in 2001 and 2002. Alternaria pod spot (*Alternaria* spp.) was also rated for disease severity at 4 locations around each marker using the Horsfall-Barratt rating scale. Blackleg (*Leptosphaeruia maculans*) and sclerotinia (*Sclerotinia sclerotiorum*) lesions that occurred on any part of the canola stem were assessed separately from basal stem cankers. The number of plants with stem or basal lesions of both blackleg and sclerotinia were noted between 2 x 24 ft. (length of distance between swaths). The prevalence of staghead (*Albugo candida*) and aster yellows (mycoplasma) were also noted. Canola plants were rated after the crop had been swathed.

d) Elevation data collection:

In the fall of 2000, elevation data for the entire Precision Farm was collected using a Trimble Real Time Kinematic (RTK) system. Elevation data points were measured on a 3 meter by 3 meter grid at a sub-centimeter accuracy.
The RTK system consisted of a base station positioned in the field over a known geodetic point, and a roving station mounted on a vehicle. As the vehicle traveled in the field, elevation data points were recorded and stored on the on-board computer.

F- Data analysis:

a) Data preparation:

For all three years, elevation, yield, weeds, plant counts and disease ratings data were kriged on a per field basis using GS+ software. The kriging method allowed the creation of a smooth interpolated surface for each parameter measured. The liquid nitrogen "As Applied" maps for 2000 and 2002 were used "as is" to have an accurate nitrogen applied value per fields.
Each map layer were imported into ArcView GIS program for overlay and data analysis purposes.

The kriged elevation data was transformed into a digital elevation map in ArcView. Using the "slope calculation" module of Spatial Analyst, a "Slope" map layer was created and used in the analyses.

b) Data extraction:

In 2000 and 2001, a 1 acre grid was used to extract and calculate an average value for each parameters in each cell of the grid. As a result, there were 40 averages per field per data layer available for statistical analysis.
In 2002 a 0.25 acre grid was used to extract and calculate an average value for each parameter.

c) Data analysis:

Data extracted from each grid cell was pooled for each year and a correlation matrix was developed for all the parameters measured to identify which parameter had a strong association with final grain yield of canola each year.
Furthermore, mean values for each variable were extracted per management zones and statistically compared using an analysis of variance (ANOVA)with the SAS program. Stepwise multiple regression analyses was also used each year to determine the contribution of each parameter to canola yield.

4. Results

Year 2000:

Table1: 2000 Correlation Matrix

	Norm.Yield	N fert	Plants/m²	Slope	Weeds/m²	Grasses/m²	Broadleaf/m²
Norm. Yield	1						
N fert	0.67*	1					
Plants/m²	-0.21	-0.14	1				
slope	-0.34*	-0.47*	0.16	1			
weeds/m²	0.34*	0.21	0.12	-0.29	1		
Grasses/m²	0.25	0.22	0.4*	-0.46*	0.84*	1	
Broadleaf/m²	0.22	0.02	-0.43*	0.25	-0.05	-0.28	1

(* Significant at the 5% level)

In 2000 the canola yields were very good. An average of 55 bushels per acre was obtained for the two fields at the Precision Farm. In order to pool yield data for two different fields for correlation purposes, yield data was normalized by using this formula: **((yield data point - mean)/standard deviation).** The resulting yield values ranged between -4 to +4.

A positive correlation of 0.67 (Table 1) between normalized yield and nitrogen fertility suggested that the nitrogen fertility treatments had a positive effect on yields where yields increased as nitrogen fertility increased (Figure 1).

However, a negative correlation between canola plant stand (plants/m2) and yield existed due to the significant difference in plant population between the fields and nitrogen rates (Table 2). Furthermore, plant numbers per meter squared were not significantly affected by management zones but mostly by the effects of field. (Table 3).

Figure 1: Effects of Nitrogen treatments on Canola yield.

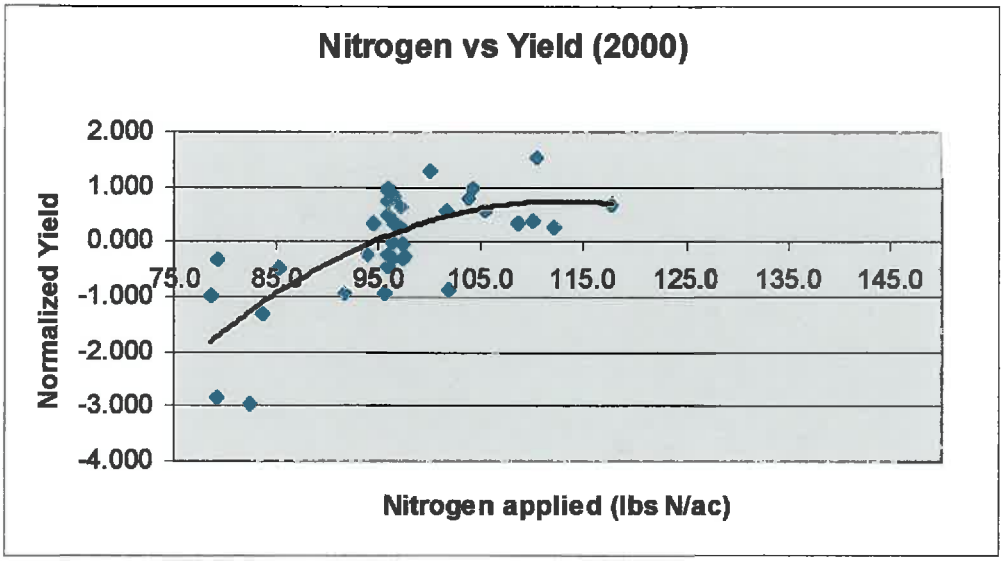


Table 2. The effects of nitrogen rates and field on the number of plants per meter square in canola in 2000.

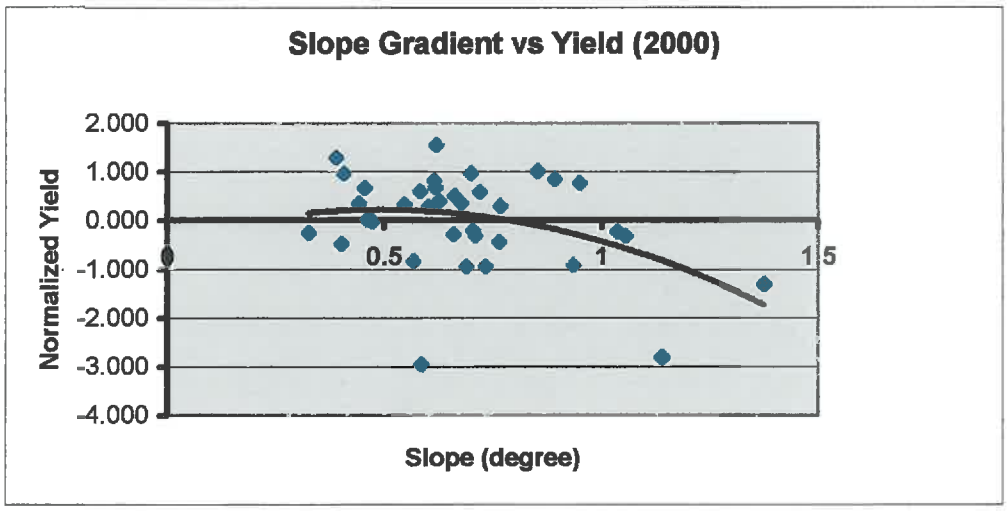
N Rate (kg/ha)	Field #		Mean
	2	7	
84	78	122	100
109	79	114	96
132	73	97	85
Mean	78	109	
N rate *; Field *; s.e.=8.5 cv=8.9%			

Table 3. The effects of field and Management Zones on the number of plants per meter square in Canola in 2000.

Mgt Zone	Field #		Mean
	2	7	
1 (low)	79	118	107
2 (medium)	77	104	88
3 (high)	-	103	103
Mean	78	109	
Mgt Zone ns; Field *; s.e.=8.5 cv=8.9%			

Slope gradient had a negative impact on yields. As slope gradient increased, yields decreased which explained the negative correlation of -0.24 found between slope and normalized yield (Figure 2). Similar results were found by Pennock et al (2001) in Hepburn, SK in a hummocky landscape where higher yields were highest in concave, lower lying areas of the field and lower yields in the mid-slope to shoulder areas.

Figure 2: Effect of Slope gradient on Canola yield.



Furthermore, management zones significantly affected yields and the higher observed yields were closely associated to high NDVI areas or high biomass areas and lower yields associated with low NDVI values or low biomass zones (Table 4). These results proved that the technique used for zone delineation from Landsat-7 imagery were accurate.

Table 4. The effects of Field and Management Zones on the grain yield (kg/ha) of Canola in 2000.

Mgt Zone	Field #		Mean
	2	7	
1 (low)	1966	2445	2302
2 (medium)	2245	2597	2389
3 (high)	-	2695	2695
Mean	2192	2563	
Mgt Zone **; Field **; s.e.=189; cv=7.9%			

As weed counts were done before the in-crop weed control program, correlation between weed counts and normalized yield explained the effectiveness of the herbicides used to control specific weed pressure in the field. A positive correlation of 0.32 was found between total weed density count and yield which would confirmed that weed pressure was under control during the season and the weeds had little effect on crop final yield. This finding is further confirmed when correlating broadleaf weeds and grassy weeds to yield with correlation values of 0.25 and 0.22 respectively.

Overall, in 2000 yield were mostly affected by the differences in field conditions (43%), nitrogen rates (14 %) and weeds (0.1 %) as shown by the stepwise multiple regression analysis summarized in Table 5.

Table 5. Summary of Stepwise regression to determine the factors that have the greatest effects on yield of canola based on field scaled measurements in 2000.

Variable	Partial R-square	Model R-square	Pr>F
Field	0.43	0.43	<.0001
N Rate	0.14	0.57	0.003
Broadleaf weed #s per m^2	0.06	0.63	0.037
Total weed #s per m^2	0.04	0.67	0.05

Year 2001:

Year 2001 was the driest year of the three year study at Indian Head, SK (Table 6). Canola yields were greatly affected by the lack of moisture but yielded on average 30 bushels per acre for the two fields at the Precision Farm.

Table 6: Monthly Precipitation accumulation (mm) in Indian Head, SK for the 2000, 2001 and 2002 growing seasons.

	2000	2001	2002	Long term mean
May	68.2	1.6	17.6	44
June	105.2	29.4	115.4	88
July	45.6	41	48.6	49
August	63.4	13.2	98	44
Total	282	204	279	225

Nitrogen fertility treatments did not work as effectively due to the lack of moisture during the growing season as represented graphically in figure 3. Furthermore, the poor correlation between yield and nitrogen fertility would support that (Table 7).

Figure 3: Effects of Nitrogen treatments on Canola Yield

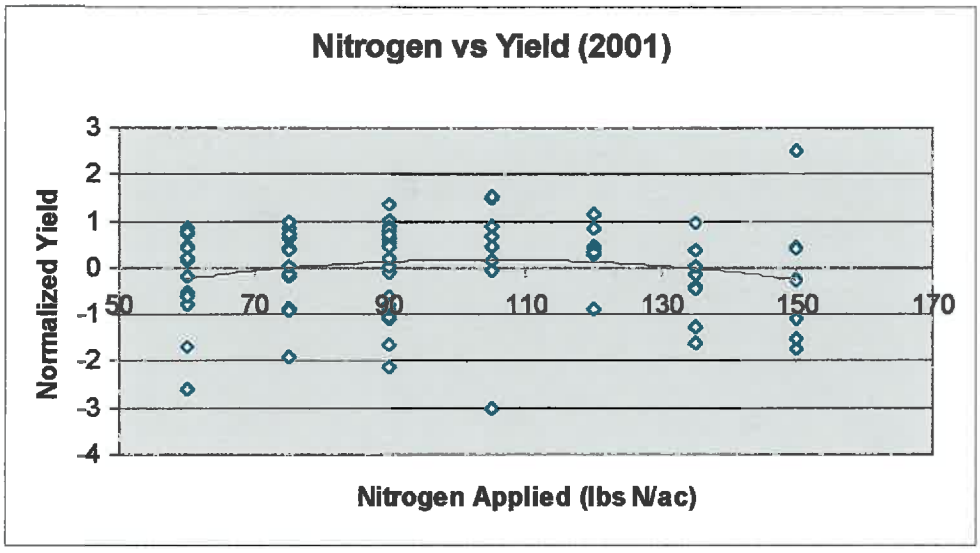


Table 7: 2001 Correlation Matrix

	Yield	N Fert	Plnts/m2	HB Rating	POD Rating	Sclerotinia Stem rating	Sclerotinia Basal rating	BlackLeg Stem rating	Blackleg Basal rating	Slope	Weeds/m2
Yield	1										
N Fert	0.005	1									
Plnts/m2	0.12	-0.14	1								
HB Rating	0.23*	0.02	0.31*	1							
POD Rating	0.27*	-0.08	0.22	-0.22	1						
SS rating	0.32*	-0.03	-0.07	0.24*	-0.12	1					
SB rating	0.29*	-0.04	0.14	0.57*	-0.13	0.17	1				
BL Rating	-0.32*	0.03	0.24*	0.1	-0.1	-0.16	0.02	1			
BL Rating	-0.08	-0	0.17	0.18	-0.28*	-0.007	0.03	0.48*	1		
Slope	-0.37*	0.15	-0.37*	-0.18	-0.47*	-0.18	-0.18	0.032	-0.09	1	
Weeds/m2	0.26*	-0.09	-0.08	0.37*	-0.22	0.39*	0.41*	-0.1	0.21	-0.22	1

(* significant at the 5% level)

With the use of a different on-board computers we achieved a more consistent plant stand for both fields. However actual plant population was much lower than target plant population of 40 to 55 plants per meter square. However, a small positive correlation between plant density and yield was found. Furthermore, the effects of field and management zones on plant population were not significant (Table 8), and plant population was not affected by nitrogen treatments nor field effects.(Table 9).

Table 8. The effects of field and management zones on the number of plants per meter square in canola in 2001.

Mgt Zone	Field #		Mean
	3	8	
1 (low)	32	31	31
2 (medium)	33	34	33
3 (high)	32	33	33
Mean	32	31	
All factors not significant; cv=12.7%			

Table 9. The effects of nitrogen rates and field on the number of plants per meter square in canola in 2001.

N Rate (kg/ha)	Field #		Mean
	3	8	
60	33	33	33
75	33	32	33
90	32	32	32
105	29	31	30
120	35	29	32
135	34	27	31
150	32	30	31
Mean	32	31	
All factors not significant; cv=12.7%			

Despite the dry conditions, yield varied significantly between management zones and field (Table 10) where higher yield were found in the high biomass zone and lowest yield in the low biomass zone. These findings are very similar to the year 2000 which confirmed that the management zones previously delineated were similar between both years.

Table 10. The effects of field and management zones on the grain yield (kg/ha) of canola in 2001.

Mgt Zone	Field #		Mean
	3	8	
1 (low)	1747	1577	1621
2 (medium)	2076	1725	1998
3 (high)	2127	2004	2127
Mean	1986	1599	
Mgt Zone **; Field **; s.e.=201; cv=11.2%			

Weed control was also effective during the 2001 growing season as a positive correlation between total weed density and normalized yield of 0.29 existed. However, due to the drought conditions total weed density was greatly reduced as compared to the 2000 growing season.

Disease ratings were done before harvest when the canola plants were swathed. Horsfall-barratt and Pod ratings showed a positive correlation with yield. However when the raw data was looked at closely, the ratings were very low for both fields. Therefore , disease pressure did not affect canola yield dramatically.

However, when correlating disease rating and slope a negative correlation appeared which would lead to the conclusion that the flatter the surface area, the greater the disease pressure. In a glaciolacustrine type of landscape where the experiment had been set-up, runoff water accumulated on lower lying flatter areas which could increase the incidence of diseases.

A positive correlation between Plant stand and diseases was noticeable which suggested that disease pressure was higher in areas of higher plant density. These findings are similar to those reported by Krupinsky et al (2002) where higher plant stand, high nitrogen levels and high soil moisture levels promoted the growth of canola diseases .

Overall, in 2001management zones had the greatest effect on final yield (43%), followed by weed density (13%), Sclerotinia basal lesions (4%), landscape curvature, field and BlackLeg lesions (3%). All the parameters measured could explain 67% of the yield variability as per the stepwise multiple regression analysis results listed in Table 11.

Table 11. Summary of Stepwise regression to determine the factors that have the greatest effects on yield of canola based on field scaled measurements in 2001.

Variable	Partial R-square	Model R-square	Pr>F
Mgt Zone	0.43	0.43	<.0001
Total Weed Density (# m^{-2})	0.13	0.56	<.0001
Sclerotinia Basal Stem Lesions	0.04	0.60	0.007
Curvature of field	0.02	0.62	0.046
Field on Precision Farm	0.02	0.64	0.034
Blackleg Lesions on Stem	0.02	0.64	0.047
Blackleg Basal Lesions	0.01	0.67	0.13

Year 2002.

The year 2002 was also very dry (Table 6). Beneficial precipitation arrived late in June which affected canola growth. Low available soil moisture and poor seedling emergence had a greater effect on final yield of canola than weeds and disease pressure. Furthermore, swaths suffered extreme wind damage which resulted in dramatic grain loss. Yield maps showed an average of 18 bushels per acre for both fields of canola. For this reason, correlation between yield and other parameters were not looked at for 2002. Only weeds, disease ratings and plant density data were correlated with nitrogen fertility and slope gradient and analysis of variance between means was performed.

Canola plant population was consistent throughout both fields. Plant counts were not affected by management zones and field (Table 12) or by nitrogen rates (Table 13).

Table 12. The effects of field and management zones on the number of plants per meter square in canola in 2002.

Mgt Zone	Field #		Mean
	4	5	
1 (low)	47	56	48
2 (medium)	48	58	56
Mean	48	58	
Mgt Zone ns; Field ns; cv=8.8%			

Table 13. The effects of nitrogen rates and Field on the number of plants per meter square in canola in 2002.

N Rate (kg/ha)	Field #		Mean
	4	5	
0	47	60	
40	49	58	
60	48	58	
90	48	55	
120	47	55	
Mean	48	48	
N rate ns; Field ns; cv=8.8%			

Even though yield losses due to harvest conditions were important, there was a significant yield difference between each management zone as noticed in the past two years (Table 14). This observation concluded that our management zone delineation method developed from Landsat 7 imagery was accurate for a gently undulating, glacio-lacustrine type of landscape.

Table 14. The effects of field and management zones on the grain yield (kg/ha) of canola in 2002.

Mgt Zone	Field #		Mean
	4	5	
1 (low)	854	1124	863
2 (medium)	696	1160	1088
Mean	829	1159	
Mgt Zone **; Field **; cv=13.3%			

Furthermore, nitrogen treatments had a significant negative impact on yields (Table 15) as yields decreased from the lowest to the highest nitrogen rates.

Table 15. The effects of field and Nitrogen rate on the grain yield (kg/ha) of canola in 2002.

N Rate (kg/ha)	Field #		Mean
	4	5	
0	822	1229	1044
40	860	1238	1076
60	867	1187	1027
90	796	1034	887
120	777	1033	872
Mean	829	1159	
N rate **; Field **; cv=13.3%			

Correlation between total weed density and nitrogen fertility were very close to zero which would indicate that nitrogen fertility had no effects on weed density (Table 16). Similar results were found in 2001. However the positive correlation of 0.21 found between weeds and nitrogen fertility in 2000 can be explained by the difference in available moisture in early June of that year.

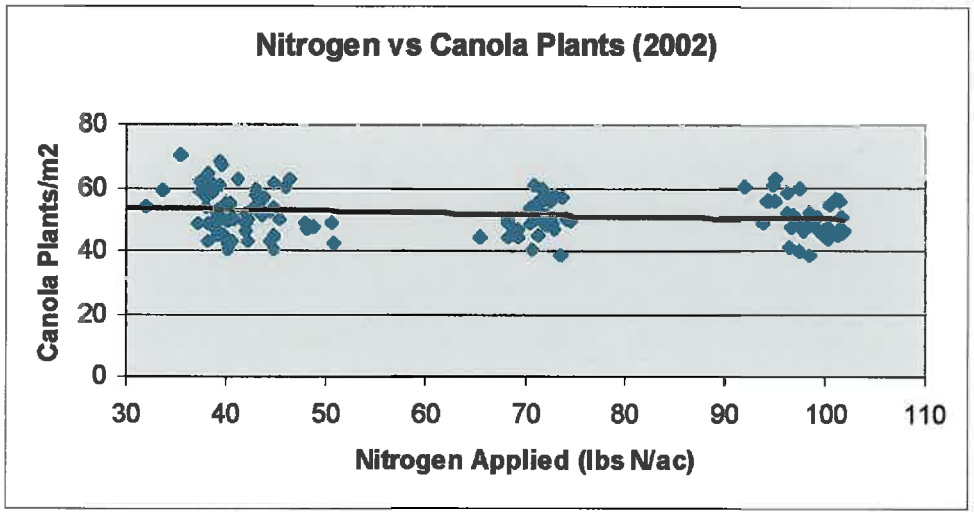
Table 16: 2002 correlation Matrix.

	N fert	Weeds	Plants/m2	HB Rating	Pod Rating	Sclerotinia Stem rating	Sclerotinia Basal rating	BlackLeg Stem rating	Blackleg Basal rating	Slope
N fert	1									
Weeds	0.08	1								
Plants/m2	-0.23*	-0.27*	1							
HB Rating	0.06	0.15*	-0.14*	1						
POD Rating	-0.22*	-0.04	0.28*	0.2	1					
Sclerotinia Stem	0.1	0.13	-0.49*	0.03	-0.31*	1				
Sclerotinia Basal	-0.21*	-0.19*	0.42*	-0.29*	-0.23*	-0.05	1			
BlackLeg Stem	0.01	0.15*	-0.51*	0.27*	-0.05	0.28*	-0.33*	1		
Blackleg Basal	0.15*	0.77*	-0.44*	0.21*	-0.06	0.17*	-0.42*	0.34*	1	
Slope	0.24*	0.02	-0.25*	0.06	-0.07	0.36*	-0.21*	0.06	0.07	1

(* = Correlation significant at the 5% level)

Nitrogen fertility and canola plant density were negatively correlated (-0.23) which would indicate that as nitrogen fertility increased plant density would decrease. This phenomena could be attributed to toxic high residual soil nitrate levels present in the spring due to the 2001 fertilization program that would be detrimental to seedling emergence (Krupinsky et al. (2002)) (Figure 4).

Figure 4: Effects of Nitrogen Treatments on Canola Plant Stand.



Nitrogen treatments had no effects on whole plant Horsfall-Baratt ratings but was negatively correlated to Pod ratings (-0.26). However this interaction was not observed in 2001.

Slope gradient had no effect on weed population, HB and Pod rating as correlation values were near zero. These results emphasize the negative effects of drought conditions on weeds and disease pressure.

Overall in 2002, yields were mostly affected by the difference in field conditions (55%), followed by nitrogen rates (5%), Sclerotinia Basal lesions (4%), Management zones (3%) and other parameters listed in Table 17. From the stepwise multiple regression analysis results acquired, a total of 7% of yield variability could be explained by the parameters (Table 17) which is an improvement from the past 2 years.

Table 17. Summary of Stepwise regression to determine the factors that have the greatest effects on yield of canola based on field scaled measurements in 2002.

Variable	Partial R-square	Model R-square	Pr>F
Field on Precision Farm	0.55	0.55	<.0001
N rate	0.05	0.60	<.0001
Sclerotinia Basal Stem Lesions	0.04	0.64	<.0001
Mgt Zone	0.03	0.67	<.0001
Spotting on Pods	0.01	0.68	0.01
Grassy weeds (# m^{-2})	0.01	0.69	0.049
Blackleg Basal Legions	0.01	0.70	0.03
Curvature of field	0.01	0.71	0.07

Combined year 2001 and 2002.

By pooling the data form 2001 and 2002 we were able to determine the factors that affected yield the most by using a stepwise multiple regression analysis (Table 18). Our results show that 87 % of the yield variability in both years could be explained by 11 variables. The most significant contributing variables to yield variations were year to year differences (69%), followed by Management Zones (10%) and Sclerotinia basal lesions (3%). Surprisingly, N rates only contributed very little to overall yield variability which could be explained by the semi-drought conditions experienced in those years.

Table 18. Summary of Stepwise regression to determine the factors that have the greatest effects on yield of canola based on field scaled measurements over the growing seasons 2001 and 2002.

Variable	Partial R-square	Model R-square	Pr>F
Year	0.69	0.69	<.0001
Mgt Zone	0.10	0.79	<.0001
Sclerotinia Basal stem lesions	0.03	0.82	<.0001
Plants per meter square	0.01	0.83	<.0001
Field on Precision Farm	0.01	0.84	<.0001
Blackleg on Stem	0.01	0.85	.001
Spotting on Pods	0.01	0.85	.001
Grassy weeds (# m^{-2})	0.01	0.86	.001
Curvature of field	0.038	0.86	.001
Broadleaf weeds (# m^{-2})	0.002	0.86	.056
N rate	0.002	0.87	.09

5. Conclusion:

The use of field scale research plots enabled us to quantify the contribution of certain variables to canola final yield. The greatest contributor to yield variability in the past three years was environmental/climate conditions. Differences in yearly precipitation affected the canola yield the most.. The second most important variable was the effects of the management zones. This latest finding emphasized the importance of variable rate fertilization programs based on management zones as yield variability is directly affected by nitrogen rates and management zones potential productivity. The third and fourth variables that played an important role in yield variability were diseases and weeds. This enabled us to conclude that careful crop monitoring for disease and weeds should be done in order to reduce the negative effects these two variables have on canola crops.
The study confirmed that the method developed for assigning management units to a field was accurate, robust and consistent from year to year. This method provides an important tool for producers to learn more about the uniformity of their fields and also to help them be more strategic in how they approach the management of their fields because of the identified zones. It could assist them in their soil sampling.

6. References:

Basnyat, P; Lafond, G.P.; McConkey, B.; Pelcat, Y.; Moulin, A.; 2003
Optimal Time for Remote Sensing Crops by Satellite in the Canadian Prairies; Canadian Journal of Plant Science (accepted)".

Krupinsky, J.M.; Bailey, K.L.; McMullen, M.P., Gossen, B.D. and Turkington, T.K. 2002.Managing Plant Disease Risk in diversified Cropping Systems.Agronomy Journal. 94:198-209

Pennock, D.;Walley, F.; Solohub, M.; Si,B.; Hnatowich, G. 2001.Topographically Controlled Yield response of Canola to nitrogen Fertilizer. Soil Science Society America Journal; 65:1838-1845.

7. Statement of Expenses.

Statement of Expenses:

Description	Amount
Field Technicians	2500
Summer Student	1500
Travel and Meals	1000
Total	5000

Appendix A:

Field operations history for 2000, 2001 and 2002 growing season.

2000 Precision Farm

Report on Production Practices for 2000.

All fields had Pre-Seeding Burn-Off of 0.5 L/ac Round-up Original applied with 5.0 gal/ac of water.

Field 4:
Seeded to : Peas
Variety: Swing
Date seeded: May 3rd, 2000

Seeding rates: 161 lbs/ac and 218 lbs/ac
Seeded area per treatment: 10 acres
Number of treatments per field: 4 (refer to drawing of treatments for treatments placement)

Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac for the whole field
Soil Inoculant: Lefatech soil Inoculant @ 3.8 lbs/ac

Spraying Date: June 7th, 2000
Chemicals used:
Odyssey @ 0.017 Kg/ac
Merge @ 0.5 L / 100 L sol.
Water @ 6.5 US Gal /ac

Plant Counts: May 30th, 2000
Harvested :August 23rd , 2000
Protein Sample: August 22nd, 2000

Field 5:
Seeded to : Peas
Variety: Swing
Date seeded: May 5th , 2000

Seeding rates: 161 lbs/ac and 218 lbs/ac
Seeded area per treatment: 10 acres
Number of treatments per field: 4 (refer to treatment map)

Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac for the whole field
Soil Inoculant: Lefatech soil Inoculant @ 3.8 lbs/ac

Spraying Date: June 7th, 2000
Chemicals used:
Odyssey @ 0.017 Kg/ac
Merge @ 0.5 L / 100 L sol.
Water @ 6.5 US Gal /ac

Plant Counts: May 30th, 2000
Harvested: August 18th , 2000
Protein sample: August 16th, 2000

Field 7:
Seeded to : Canola
Variety: Liberty Link Invigor 2573 Canola
Date seeded: May 9th , 2000
Seeding rate: 5.0 lbs/ac
Seeded area per treatment: 10 acres

P - Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac

N - Fertilizer used : 28-0-0
Treatments per field: 2 - duplicated once (refer to treatment map)
Treatment type: 1 Uniform rate and 1 Variable Rate (N rates calculated using Farm Phase II software)
Application Rates:
Uniform Treatment : 26.6 Imp Gal / Ac or 94 lbs N / ac
Variable Rate : Zone 1 : 32.5 Imp gal /ac or 116 lbs of actual N/ac
Zone 2 : 27.2 imp gal/ac or 97 Lbs of actual N/ac
Zone 3 : 21.3 Imp gal/ac or 76 lbs of actual N/ac
Spraying Date: June 7th, 2000
Chemicals used:
Liberty @ 1.35 L /ac
Select @ 0.026 L /ac
Amigo @ 0.5 L / 100 L of Solution
Water @ 5.0 US gal/ac

Plant Counts: May 30th, 2000
Harvested: September 12th,2000
Protein Sample: August 29th, 2000

Field 2:
Seeded to : Canola
Variety: Liberty Link Invigor 2573 Canola
Date seeded: May 17th , 2000
Seeding rate: 5.0 lbs/ac
Seeded area per treatment: 10 acres

P - Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac for the whole field

S - Fertilizer used : 20.5-0-0-24
Application rate: Side banded @ 62.5 lbs of product / ac or 15 lbs of actual S /ac for the whole field

N - Fertilizer used : 28-0-0
Treatments per field: 2 - duplicated once (refer to treatment map)
Treatment type: 1 Uniform rate and 1 Variable Rate (N rates calculated using Farm Phase II software)
Application Rates:
Uniform Treatment : 26.9 Imp Gal / ac or 96 lbs N / ac
Variable Rate : Zone 1 : 33.4 Imp gal/ac or 119.2 lbs actual N/ac
Zone 2 : 31.7 Imp gal/ac or 113.2 lbs of actual N/ac
Zone 3 : 26.9 Imp gal/ac or 96 lbs of actual N/ac
Zone 4 : 20 Imp gal/ac or 71.4 lbs of actual N/ac
Zone delineation: Done using Remote sensing satellite images of NDVI Index of 1998 and 1999

Spraying Date: June 7th, 2000
Chemicals used:
Liberty @ 1.35 L /ac
Select @ 0.026 L /ac
Amigo @ 0.5 L / 100 L of Solution
Water @ 5.0 US gal/ac

Plant counts: June 5th,2000.
Harvested: September 12th,2000
Protein Samples: September 11th, 2000

Field 1:
Seeded to : Wheat
Variety: AC Barry
Date seeded: May 17th , 2000
Seeding rate: 120 lbs/ac
Seeded area per treatment: 10 acres

P - Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac for the whole field

N - Fertilizer used : 28-0-0 Liquid
Treatments per field: 4 (refer to treatment map)
Treatment type: 3 Uniform rate and 1 Variable Rate (N rates calculated using Farm Phase II software)
Application Rates:
Uniform Treatments :
High rate: 33.3 Imp gal / ac or 118 lbs of actual N/ac
Medium rate: 29.1 Imp gal/ ac or 103.8 lbs of actual N/ac
Low rate 13.2 Imp gal/ac or 47.1 lbs of actual N/ac
Variable Rate :
Rates varied from 15 Imp gal/ac to 37 Imp gal/ac or 53.5 lbs of N/ac to 132.1 lbs N/ac
Variable rate application map based on Nitrogen removal from grain Protein and yield from 1999.

Spraying Date: June 30th, 2000
Chemicals used:
Puma Super @ 0.31 l/ac
Curtail M @ 0.8 l/ac

Plant Count: June 5th, 2000
Harvested: September 14th, 2000
Protein Sample: September 14th, 2000

Field 3:
Seeded to : Wheat
Variety: AC Barry
Date seeded: May 20th , 2000
Seeding rate: 120 lbs/ac
Seeded area per treatment: 10 acres

P - Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac for the whole field

N - Fertilizer used : 28-0-0 Liquid
Treatments per field: 4 (refer to treatment map)
Treatment type: 3 Uniform rate and 1 Variable Rate (N rates calculated using Farm Phase II software)
Application Rates:

Uniform Treatments :
High rate: 20.7 Imp gal / ac or 73.9 lbs of actual N/ac
Medium rate: 17.4 Imp gal/ ac or 62.1 lbs of actual N/ac
Low rate 9 Imp gal/ac or 32.1 lbs of actual N/ac
Variable Rate :
Rates varied from 0 Imp gal/ac to 34 Imp gal/ac or 0 lbs of N/ac to 121.4 lbs N/ac
Variable rate application map based on Nitrogen removal from grain Protein and yield from 1999.

Spraying Date: June 30th, 2000
Chemicals used:
Puma Super @ 0.31 l/ac
Curtail M @ 0.8 l/ac

Plant Count: June 5th, 2000
Harvested September 15th, 2000
Protein Sample: September 14th, 2000

Field 6:
Seeded to : Wheat
Variety: AC Barry
Date seeded: May 20th , 2000
Seeding rate: 120 lbs/ac
Seeded area per treatment: 10 acres

P - Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac for the whole field

N - Fertilizer used : 28-0-0 Liquid
Treatments per field: 4 (refer to treatment map)
Treatment type: 3 Uniform rate and 1 Variable Rate (N rates calculated using Farm Phase II software)
Application Rates:
Uniform Treatments :
High rate: 26 Imp gal / ac or 92.8 lbs of actual N/ac
Medium rate: 22.7 Imp gal/ ac or 81 lbs of actual N/ac
Low rate: 14.3 Imp gal/ac or 51 lbs of actual N/ac
Variable Rate :
Rates varied from 0 Imp gal/ac to 30 Imp gal/ac or 0 lbs of N/ac to 107.1 lbs N/ac
Variable rate application map based on Nitrogen removal from grain Protein and yield from 1999.

Spraying Date: June 30th, 2000
Chemicals used:
Puma Super @ 0.31 l/ac
Curtail M @ 0.8 l/ac
Spraying date: July 25th, 2000
Folicur @
Water @ 4.5 US gal/ac

Plant Count: June 5th, 2000
Harvested: September 14th, 2000
Protein Sample: September 14th, 2000

Field 8:
Seeded to : Wheat
Variety: AC Barry
Date seeded: May 20th , 2000
Seeding rate: 120 lbs/ac

Seeded area per treatment: 10 acres

P - Fertilizer used : 12-51-0
Application rate : Side banded @ 59 lbs of Product / ac or 30 lbs actual P / ac for the whole field

N - Fertilizer used : 28-0-0 Liquid
Treatments per field: 4 (refer to treatment map)
Treatment type: 3 Uniform rate and 1 Variable Rate (N rates calculated using Farm Phase II software)
Application Rates:

Uniform Treatments :

High rate: 26.6 Imp gal / ac or 94 lbs of actual N/ac
Medium rate: 23.2 Imp gal/ ac or 82.8 lbs of actual N/ac
Low rate: 14.8 Imp gal/ac or 52.8 lbs of actual N/ac

Variable Rate :

Rates varied from 12 Imp gal/ac to 27 Imp gal/ac or 42.8 lbs of N/ac to 96.4 lbs N/ac

Variable rate application map based on Nitrogen removal from grain Protein and yield from 1999.

Spraying Date: June 30th, 2000
Chemicals used:

Puma Super @ 0.31 l/ac
Curtail M @ 0.8 l/ac

Spraying date: July 25th, 2000

Folicur @
Water @ 4.5 US gal/ac

Plant Count: June 5th, 2000
Harvested September 15th, 2000
Protein Sample: September 14th, 2000

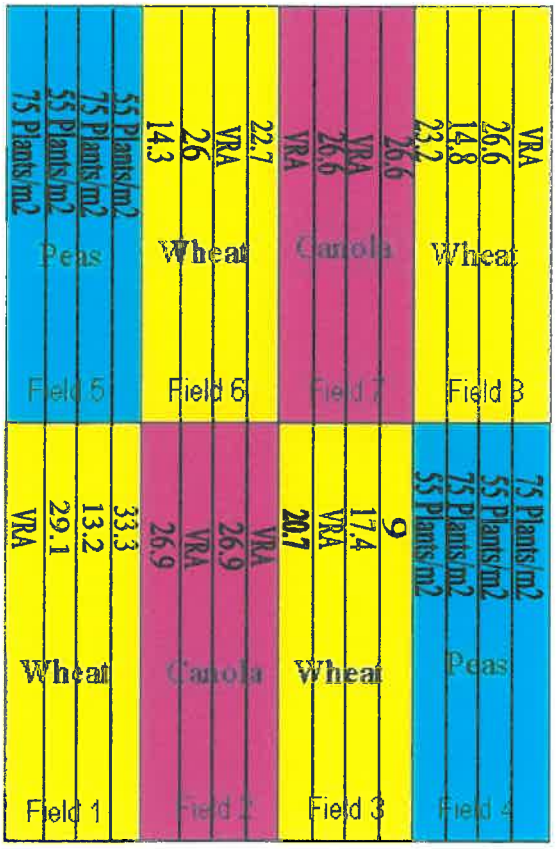
Weeds count:

Field 4,5,7: May 31st, 2000.
Field 1,2,3,6 and 8: June 5th, 20000

Fall Weed Control:

Fields 1,4,6: September 30, 2000 - 1l Round-up in 5 Gal Water.
Fields 2,3,5,7,8: October 10,2000 - 0.45 L/ac 2-4 D Ester 500 in 4.2 gal water.

Crop Planning for 2000



Note:
1-In The Wheat and Canola fields : the numbers indicate Imp gal/ac of 28-0-0 applied uniformaly in a strip. A treatment strip is equal to 5 air seeder width or 165 feet.
2- VRA (variable rate application) indicates the part of the prescription map that was used to apply 28-0-0

2001 Precision Farm
Report on Production Practices for 2001.

Field 1:
Seeded to Peas
Variety: Swing
Date seeded: May 4th, 2001
Seeding rate: 112 lbs/ac and 163 lbs/ac
Seeded area per treatment: 20 acres

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 39 lbs of product/ac or 20 lbs actual P/ac for the whole field
Seed innoculant: LiphaTech @ 5 lbs/ac

Spraying Date: May 8th, 2001
Chemicals used:
Roundup Transorb @ 0.5 l/ac
Water 5 Imp gal/ac

Spraying Date: June 4th, 2001
Chemicals used:
Odyssey @ 0.0173 kg/ac
Merge @ 0.5 l/100l sol.
Water @ 10 Imp gal/ac.

Harvested: August 14th, 2001

Field 6:
Seeded to: Peas
Variety: Swing
Date seeded: May 5th, 2001
Seeding rate: 112 lbs/ac and 163 lbs/ac
Seeded area per treatment: 20 acres

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 39 lbs of product / ac or 20 lbs actual P / ac for the whole field
Seed innoculant: LiphaTech @ 5 lbs/ac

Spraying Date: May 8th, 2001
Chemicals used:
Roundup Transorb @ 0.5 l/ac
Water 5 Imp gal/ac

Spraying Date: June 4th, 2001
Chemicals used:

Odyssey @ 0.0173 kg/ac
Merge @ 0.5 l/100l sol.
Water @ 10 Imp gal/ac.

Harvested: August 15th, 2001

Field 3:
Seeded to Canola
Variety: Liberty Link Invigor 2663
Date seeded: May 14th, 2001
Seeding rate: 5.0 lbs/ac

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 57.7 lbs of product/ac for the whole field

S - Fertilizer used: 20.5-0-0-24
Application rate: Side-banded @ 104.2 lbs of product/ac for the whole field

N - Fertilizer used: 28-0-0
7 different N rates were replicated within the field:
Rate 1 (rt1): 60 lbs N/ac
Rate 2 (rt2): 75 lbs N/ac
Rate 3 (rt3): 90 lbs N/ac
Rate 4 (rt4): 105 lbs N/ac
Rate 5 (rt5): 120 lbs N/ac
Rate 6 (rt6): 135 lbs N/ac
Rate 7 (rt7): 150 lbs N/ac

Spraying Date: June 9th, 2001
Chemicals used:

Decis @ 0.05 l/ac
Water @ 10.8 Imp gal/ac

Spraying Date: June 21st, 2001
Chemicals used:

Liberty @ 1.35 L /ac
Select @ 0.026 L /ac
Amigo @ 0.5 L / 100 L of Solution
Water @ 10 Imp gal/ac

Swathed: August 18th, 2001
Harvested: August 31st, 2001

Field 8:
Seeded to Canola
Variety: Liberty Link Invigor 2663
Date seeded: May 14th, 2001
Seeding rate: 5.0 lbs/ac

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 57.7 lbs of product/ac for the whole field

S - Fertilizer used: 20.5-0-0-24
Application rate: Side-banded @ 104.2 lbs of product/ac for the whole field

N - Fertilizer used: 28-0-0
7 different N rates were replicated within the field:
Rate 1 (rt1): 60 lbs N/ac
Rate 2 (rt2): 75 lbs N/ac
Rate 3 (rt3): 90 lbs N/ac
Rate 4 (rt4): 105 lbs N/ac
Rate 5 (rt5): 120 lbs N/ac
Rate 6 (rt6): 135 lbs N/ac
Rate 7 (rt7): 150 lbs N/ac

Spraying Date: June 9th, 2001
Chemicals used:
Decis @ 0.05 l/ac
Water @ 10.8 Imp gal/ac

Spraying Date: June 21st, 2001
Chemicals used:
Liberty @ 1.35 L /ac
Select @ 0.026 L /ac
Amigo @ 0.5 L / 100 L of Solution
Water @ 10 Imp gal/ac

Swathed: August 18th, 2001
Harvested: August 31st, 2001

Field 2:
Seeded to: Wheat
Variety: AC Barrie
Date seeded: May 16th, 2001
Seeding rate: 120 lbs/ac

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 57.7 lbs of product / ac for the whole field

S- Fertilizer used: 20.5-0-0-24
Application rate: Side-banded @ 41.7 lbs of product/ac for the whole field

N - Fertilizer used: 28-0-0 Liquid
7 different N rates were replicated within the field:
Rate 1 (rt1): 55 lbs N/ac
Rate 2 (rt2): 75 lbs N/ac
Rate 3 (rt3): 90 lbs N/ac
Rate 4 (rt4): 105 lbs N/ac
Rate 5 (rt5): 120 lbs N/ac
Rate 6 (rt6): 135 lbs N/ac
Rate 7 (rt7): 150 lbs N/ac

Spraying Date: May 15th, 2001
Chemicals used:
Roundup Transorb @ 0.5 l/ac
Water @ 5 gal/ac

Spraying Date: June 23rd, 2001
Chemicals used:
Curtail M @ 0.8 l/ac
Water @10 gal/ac.

Swathed: August 21st, 2001
Harvested: August 28th, 2001

Field 4:
Seeded to: Wheat
Variety: AC Barrie
Date seeded: May 17th, 2001
Seeding rate: 120 lbs/ac

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 57.7 lbs of product/ac for the whole field

S- Fertilizer used: 20.5-0-0-24
Application rate: Side-banded @ 41.7 lbs of product/ac for the whole field

N - Fertilizer used: 28-0-0 Liquid
7 different N rates were replicated within the field:
Rate 1 (rt1): 55 lbs N/ac
Rate 2 (rt2): 75 lbs N/ac
Rate 3 (rt3): 90 lbs N/ac
Rate 4 (rt4): 105 lbs N/ac
Rate 5 (rt5): 120 lbs N/ac
Rate 6 (rt6): 135 lbs N/ac
Rate 7 (rt7): 150 lbs N/ac

Spraying Date: May 15th, 2001
Chemicals used:
Roundup Transorb @ 0.5 L/ac
Water @ 5 gal/ac

Spraying Date: June 23rd, 2001
Chemicals used:
Curtail M @ 0.8 L/ac
Water @10 gal/ac.

Swathed: August 21st, 2001
Harvested: August 29th, 2001

Field 5:
Seeded to Wheat
Variety: AC Barrie
Date seeded: May 15th, 2001
Seeding rate: 120 lbs/ac

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 57.7 lbs of product / ac for the whole field

S- Fertilizer used: 20.5-0-0-24
Application rate: Side-banded @ 41.7 lbs of product/ac for the whole field

N - Fertilizer used: 28-0-0 Liquid
7 different N rates were replicated within the field:
Rate 1 (rt1): 55 lbs N/ac
Rate 2 (rt2): 75 lbs N/ac
Rate 3 (rt3): 90 lbs N/ac
Rate 4 (rt4): 105 lbs N/ac
Rate 5 (rt5): 120 lbs N/ac
Rate 6 (rt6): 135 lbs N/ac
Rate 7 (rt7): 150 lbs N/ac

Spraying Date: May 15th, 2001
Chemicals used:
Roundup Transorb @ 0.5 L/ac
Water @ 5 gal/ac

Spraying Date: June 23rd, 2001
Chemicals used:
Curtail M @ 0.8 l/ac
Water @ 10 gal/ac.

Swathed: August 21st, 2001
Harvested: August 28th, 2001

Field 7:
Seeded to: Wheat
Variety: AC Barrie
Date seeded: May 16th, 2001
Seeding rate: 120 lbs/ac

P - Fertilizer used: 11-52-0
Application rate: Side-banded @ 57.7 lbs of product / ac for the whole field

S- Fertilizer used: 20.5-0-0-24
Application rate: Side-banded @ 41.7 lbs of product/ac for the whole field

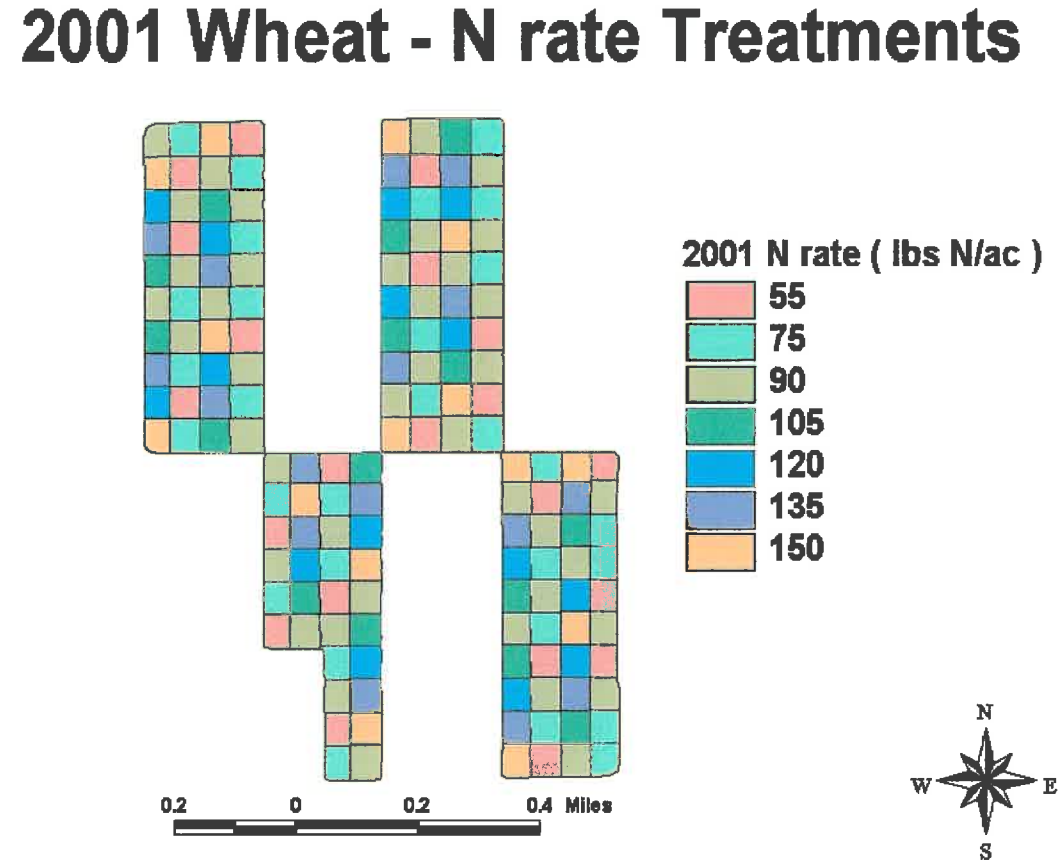
N - Fertilizer used: 28-0-0 Liquid
7 different N rates were replicated within the field:
Rate 1 (rt1): 55 lbs N/ac
Rate 2 (rt2): 75 lbs N/ac
Rate 3 (rt3): 90 lbs N/ac
Rate 4 (rt4): 105 lbs N/ac
Rate 5 (rt5): 120 lbs N/ac
Rate 6 (rt6): 135 lbs N/ac
Rate 7 (rt7): 150 lbs N/ac

Spraying Date: May 15th, 2001
Chemicals used:
Roundup Transorb @ 0.5 l/ac
Water @ 5 gal/ac

Spraying Date: June 23rd, 2001
Chemicals used:
Curtail M @ 0.8 l/ac
Water @ 10 gal/ac.

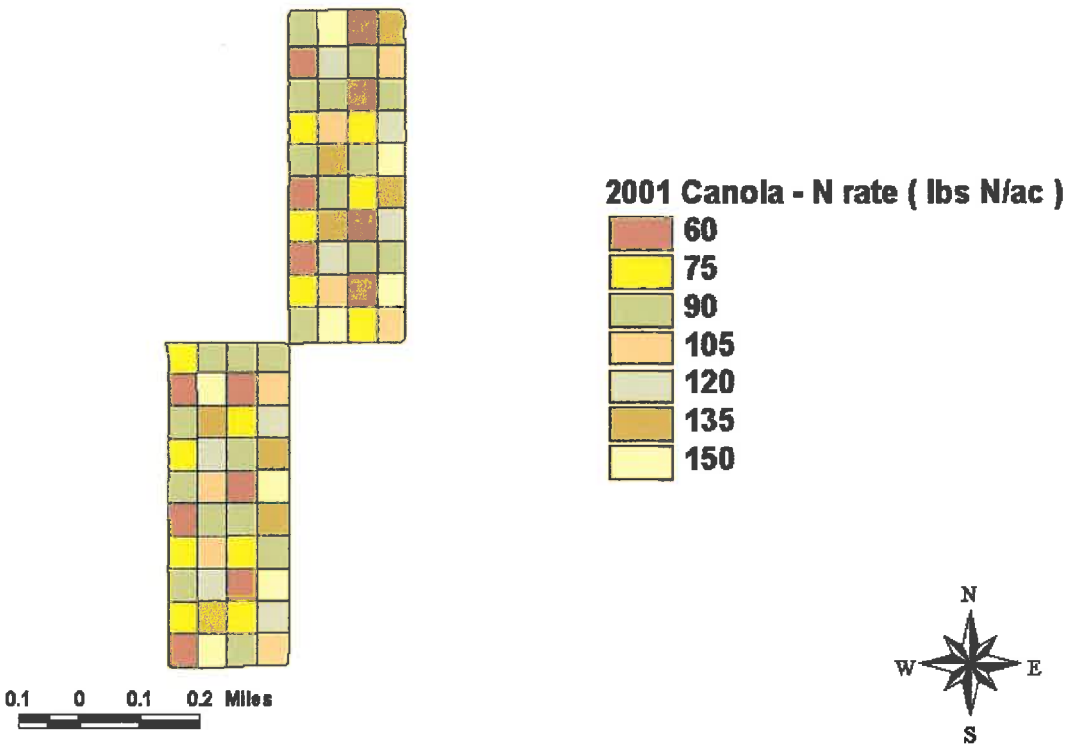
Swathed: August 21st, 2001
Harvested: August 28th, 2001

2001 Nitrogen Prescription Map for the Wheat Fields at the IHARF Precision Farm.



Note: Grid cell is equal to 1 acre (43560 square feet)

2001 Nitrogen Prescription Map for the Canola Fields at the IHARF Precision Farm.



Note: Grid cell is equal to 1 acre (43560 square feet)

2002 Field Operations

Field 2 and 7:
Crop: Peas
Cultivar: Swing
Seeding Rate: L = 167 lbs/ac
H = 228 lbs/ac
Seeding pattern: L-H-L-H (F7)
Seeding pattern: H-L-H-L (F2)
Seeding Date: April 30,2002 (F7)
Seeding Date: May 1st, 2002 (F2)

Innoculant: Lipahtech granular @ 5lbs/ac
Fertilizer:

- 11-52-0 @ 48.1 lbs prod/ac (30 lbs P/ac)

Rolled: May 2, 2002
Sprayed June 7, 2002

- Odyssey + 10 Imp gal/ac H20

Field 4 - 5:
Crop: canola
Cultivar: In Vigor 2663 + Helix
Seeding Rate: 5 lbs/ac

Seeding Date: May 7, 2002 for F4
May 9, 2002 for F5

Fertilizer:

- 11-52-0 @ 48.1 lbs prod/ac (30 lbs P/ac)
- 20.5-0-0-24 @ 62.5 lbs prod./ac (15 lbs S/ac)
- 28-0-0 = VRA (0- 6.1 - 11.7 - 20.1 - 28.8 Imp gal/ac of 28-0-0)

Sprayed June 16, 2002

- Decis + 8.5 US gal h2o

Sprayed June 20, 2002

- Liberty @ 1.1l/ac
- Select
- amigo in 10 Imp gal/ac

Field 1, 3, 6 and 8:
Crop: Wheat
Cultivar: Prodigy
Seeding Rate: 120 lbs/ac

Seeding Date: May 10, 2002 for F6 and F8
May 11, 2002 for F1 and F3

Fertilizer:

- 11-52-0 @ 48.1 lbs prod/ac (30 lbs P/ac)
- 28-0-0 = VRA (0- 6.9 - 15.3 - 23.7 - 32.1 Imp gal/ac of 28-0-0)

Sprayed June 14, 2002 (F1 + F6)

- Puma Super
- Curtail M
- 10 Imp gal/ac of H20

Sprayed June 14, 2002 (F3 + F8) (Where Peas will be grown in 2003)

- Puma Super
- Buctril M
- 10 Imp gal/ac of H20

Appendix B

Photos and Details
of GIS maps.

Figure 1: Seeding Equipment:

Figure 2: Harvesting Equipment:

Figure 3: 2000 Nitrogen Prescription Maps

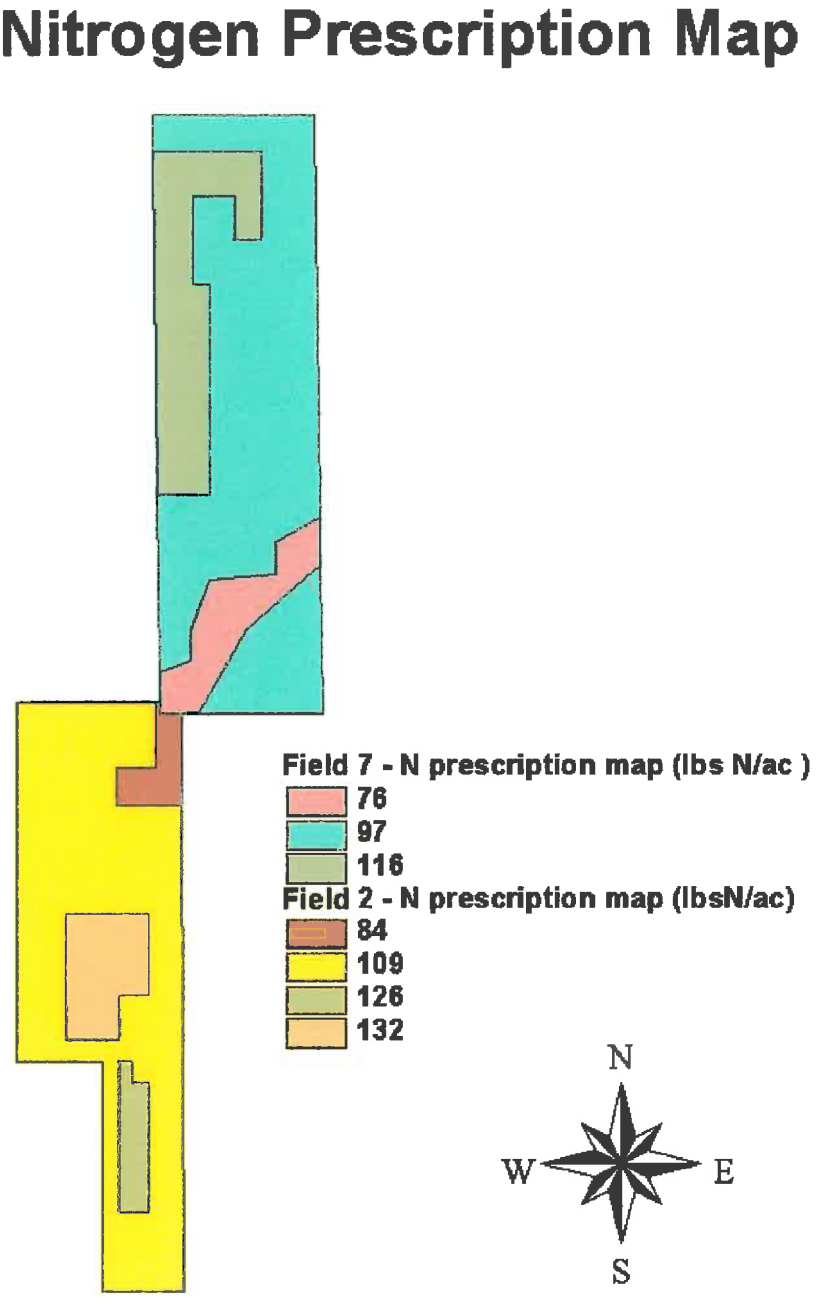


Figure 4: 2001 Nitrogen Prescription Map:

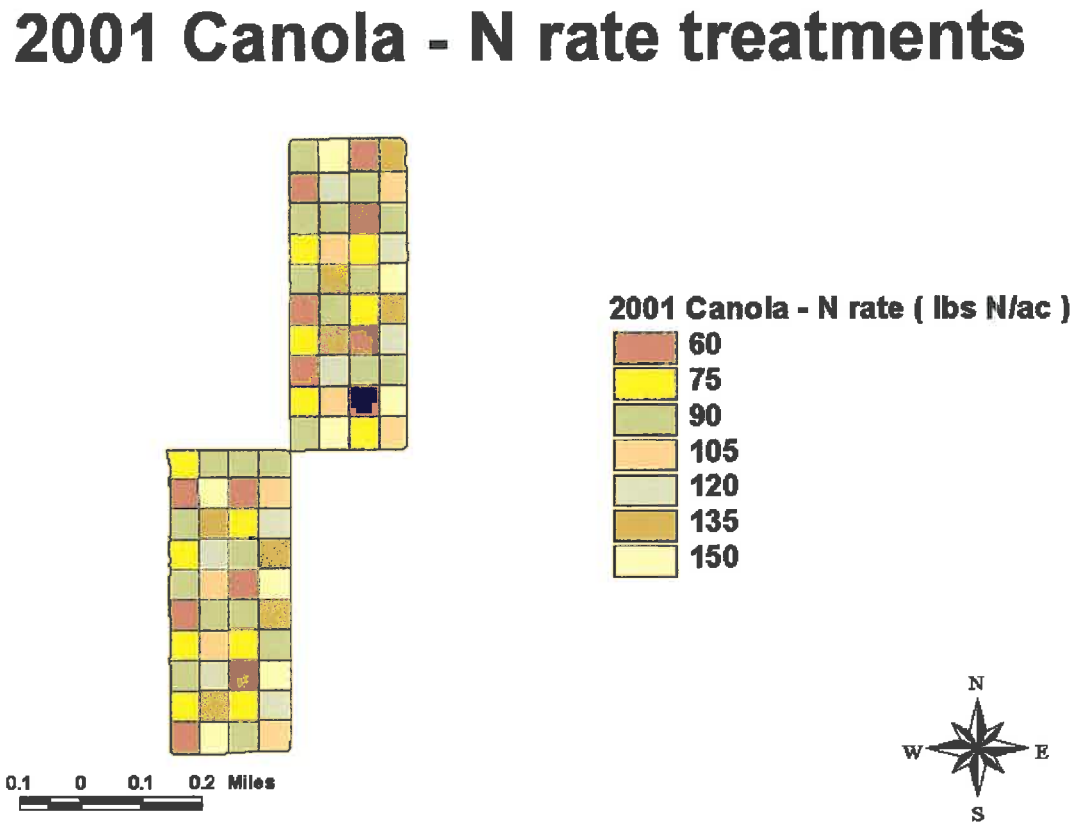


Figure 5: 2002 Nitrogen Prescription Map:

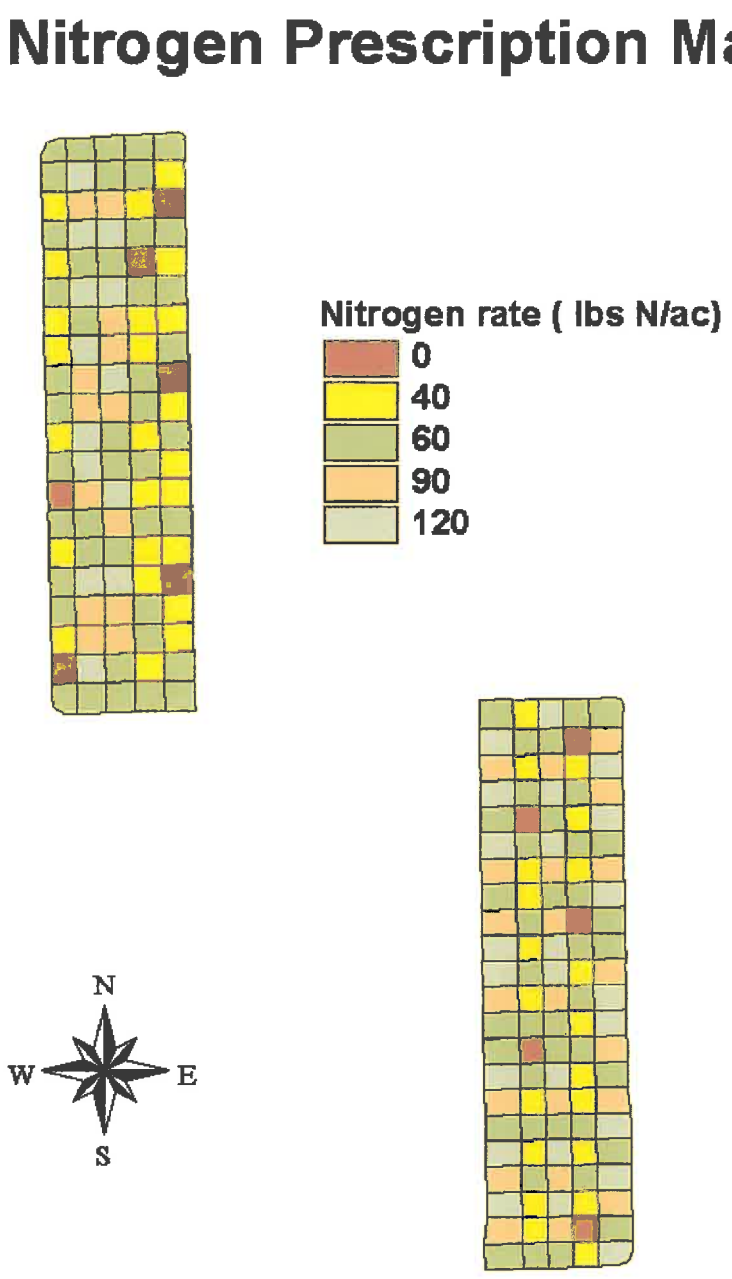


Figure 6: 2000 Yield maps

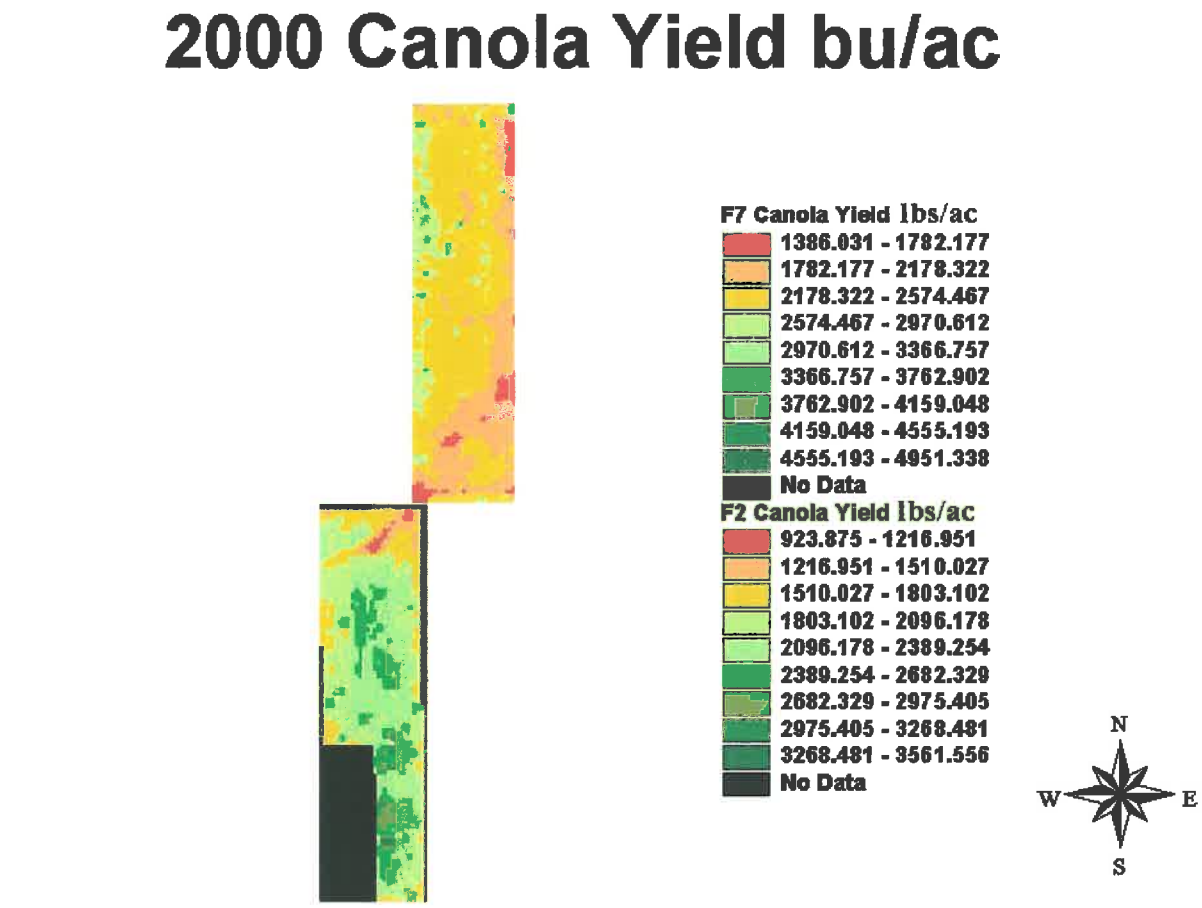


Figure 7: 2001 Yield maps

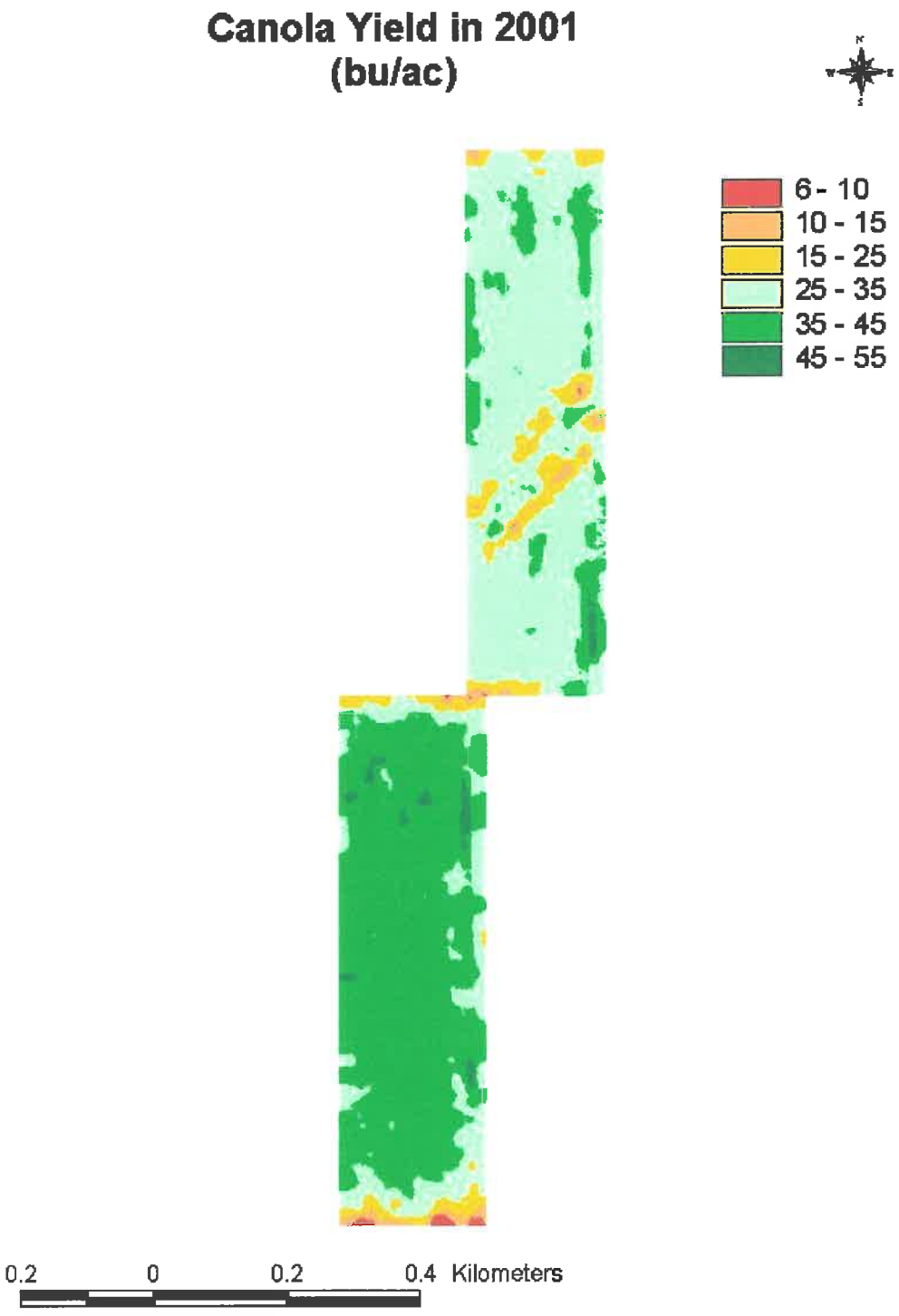


Figure 8: 2002 Yield maps

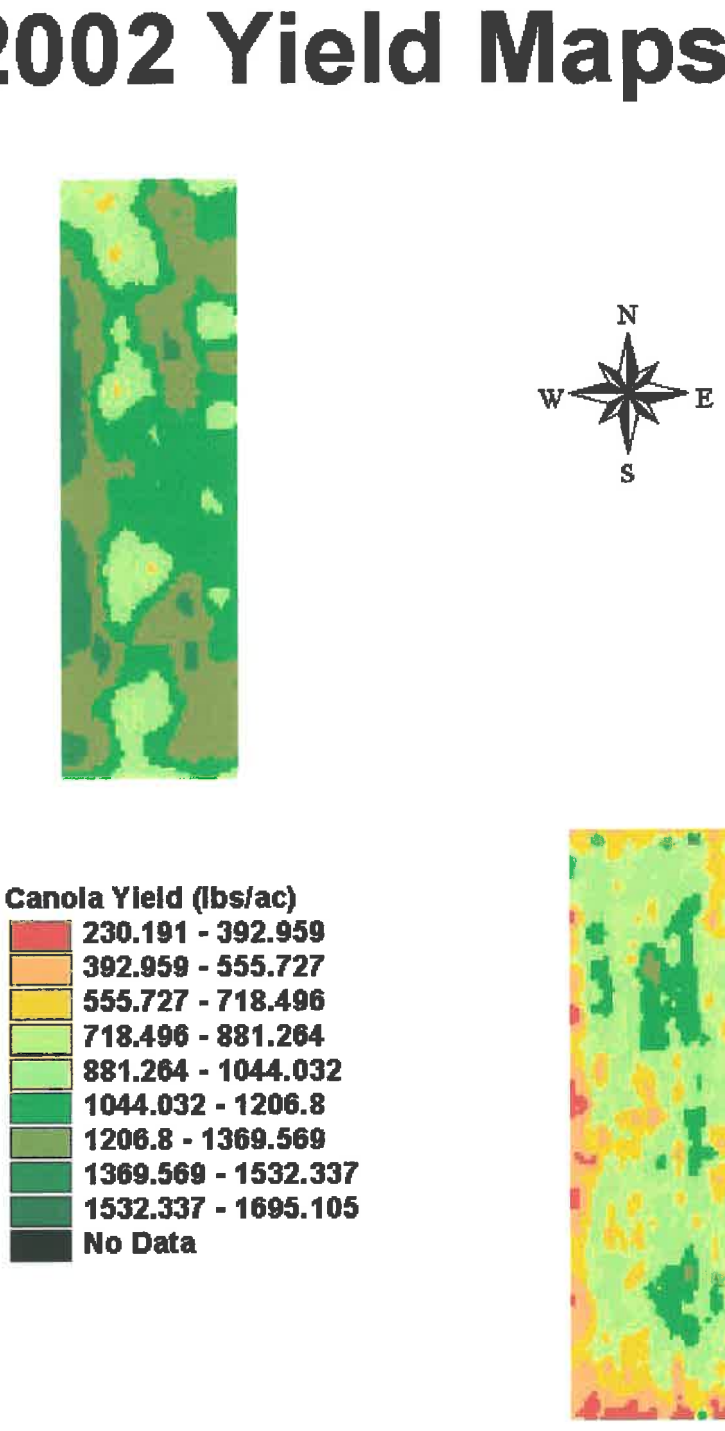


Figure 9: Management Zones for the Precision farm based on NDVI.