APPLICATION OF VARIABLE RATE IRRIGATION TECHNOLOGY TO IMPROVE WATER CONSERVATION AND CROP PRODUCTIVITY

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2015

- Introduction
- Thesis Objectives and Results
- Soil Moisture & Temperature Probe

New technologies and advanced decision support systems

- Water conservation
- Water use efficiency
- Crop productivity
- Energy consumption

2013 06 27

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Why VRI?

Most fields are not uniform because of natural variations in soil chemical and physical properties and topography

- Yield reduction
- Water wastage
- Adverse environmental effects

http://www.precisionirrigation.co.nz/

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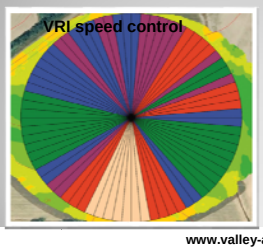
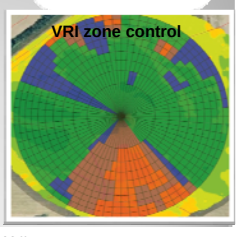
VRI

Variable Rate Irrigation





www.valley-au.com

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Overall objective

Improve water use efficiency and crop productivity

Specific objectives

- **Performance evaluation of VRI technology**
- **Defining site-specific management zones**
- **Modelling of crop yields under various MZ**
- **Evaluation of crop productivity, water, and energy saving benefits of VRI technology**

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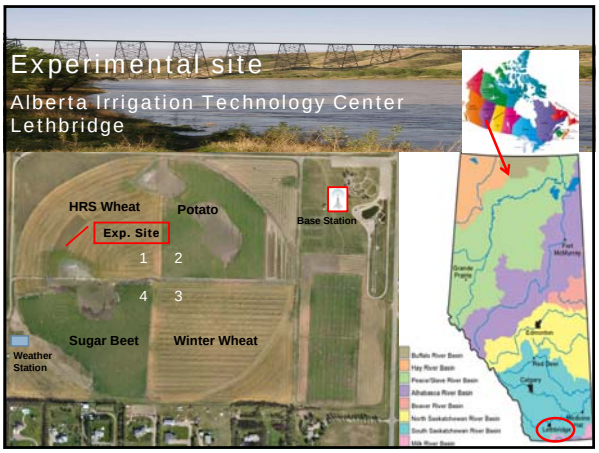

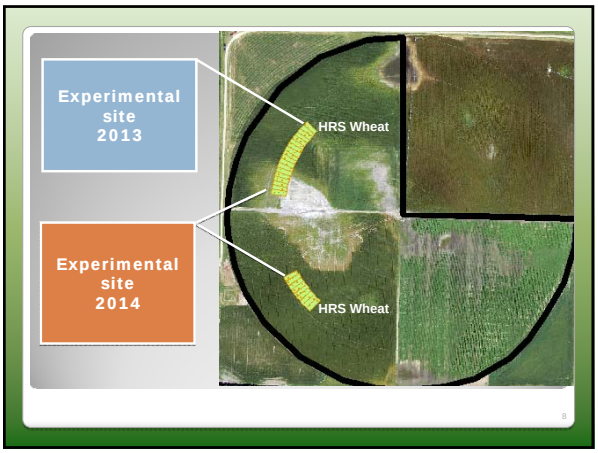

Objective one

Performance evaluation and demonstration of VRI technology

- Application depth
- CU: Coefficient of uniformity

ANSI/ASAE S436.1 DEC01

Test Procedure for Determining the Uniformity of Water Distribution of Center Pivot and Lateral Move Irrigation Machines Equipped with Spray or Sprinkler Nozzles

$$CU = 100 \times \left[1 - \frac{\sum_{i=1}^{n} |d_i - \bar{d}|}{\sum_{i=1}^{n} d_i} \right]$$

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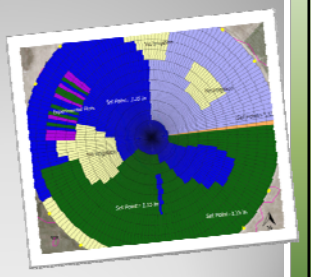
Irrigation treatments and prescription map

Irrigation depths for 2013

1. NI= 100 % = 25 mm
2. HI= (100+25) % = 32 mm
3. LI= (100-25) % = 19 mm



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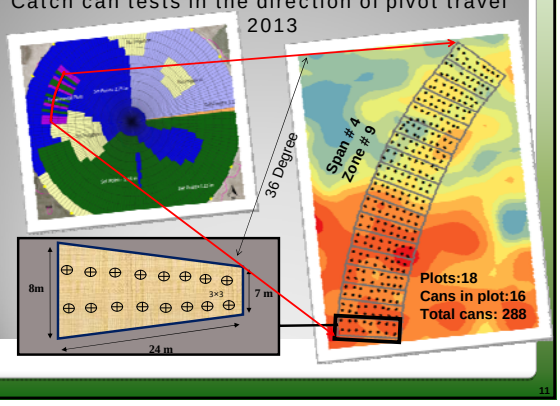
Catch can tests in the direction of pivot travel 2013



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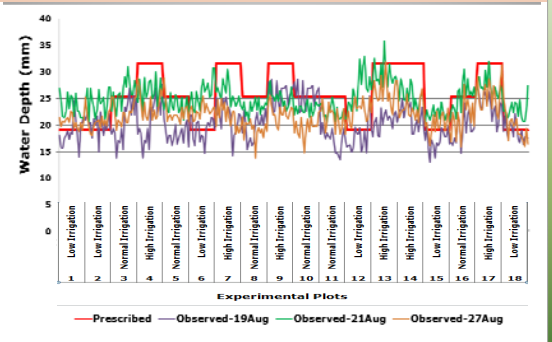
Expected and observed depths in Catch cans



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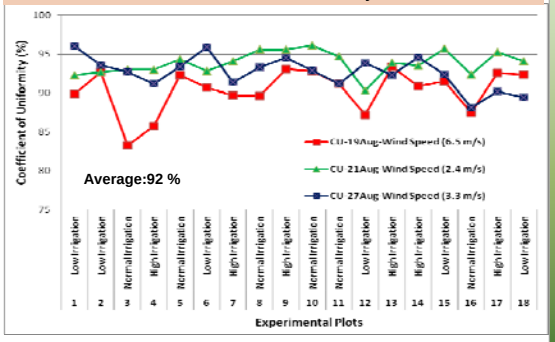
Coefficient of Uniformity 2013



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Performance evaluation of VRI system

Irrigation events	19Aug	21Aug	27Aug
CU (%)	90	94	93
Wind Speed (m/s)	6.5	2.4	3.3
System performance	Good (85-90)	Very Good (90-95)	Very Good (90-95)

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Performance evaluation of VRI system

Application depths

Treatments	Applied Depth (mm)	Average Observed Depth (mm)	RMSE (mm)	Ave - RMSE (mm)
Low Irrigation	19	21	3	5
Normal Irrigation	25	22	4	
High Irrigation	32	25	8	

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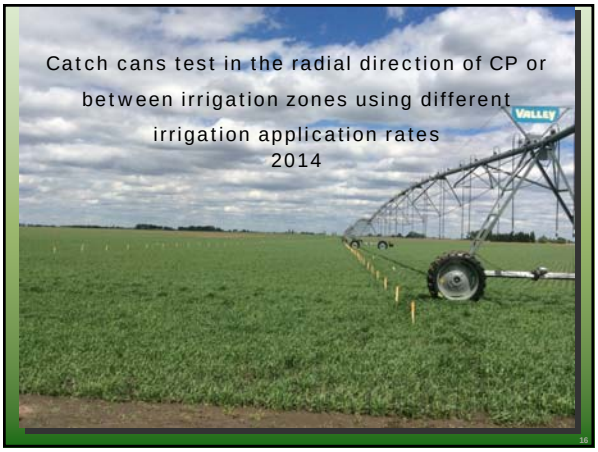
Catch cans test in the radial direction of CP or between irrigation zones using different irrigation application rates 2014



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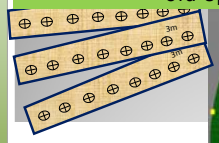
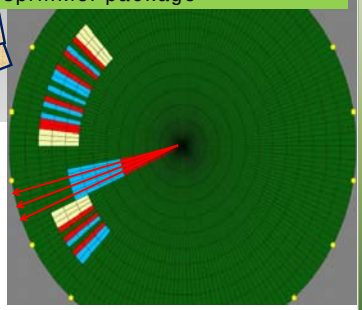
Experimental set up in the radial direction with old sprinkler package





Spans # 2-5
Cans in each line:75
Total cans: 225
Irrigation rates:
40%, 70%, 100%
8mm, 14mm, 20mm

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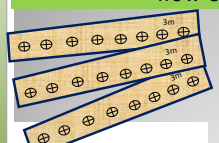
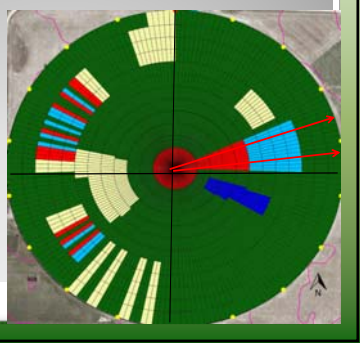
Experimental set up in the radial direction with new sprinkler package





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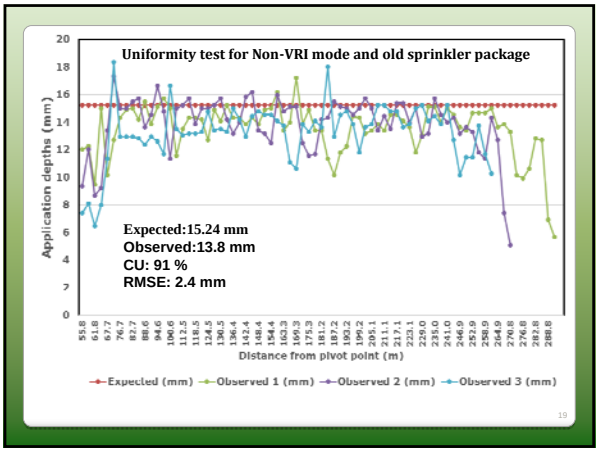
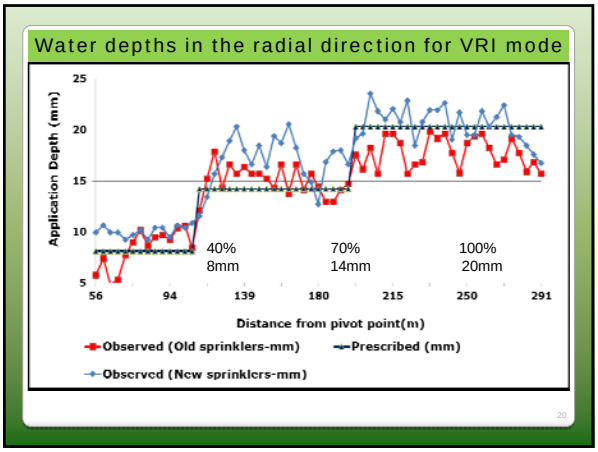




System performance for VRI and Non-VRI mode

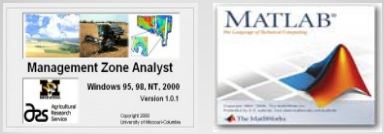
System Mode	VRI		Non-VRI	
CU (%)	old sprinklers	new sprinklers	old sprinklers	new sprinklers
	84.7	91.77	91	93.5
Wind Speed (m/s)	3.2	2.6	2.4	2.3
RMSE	2.1	2.29	2.4	1.8
System performance	Good (85-90)	Very Good (90-95)	Very Good (90-95)	Very Good (90-95)

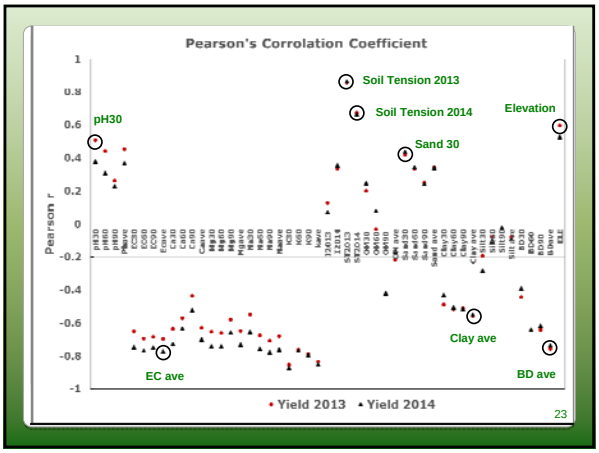
Objective two:
Defining site-specific management zones

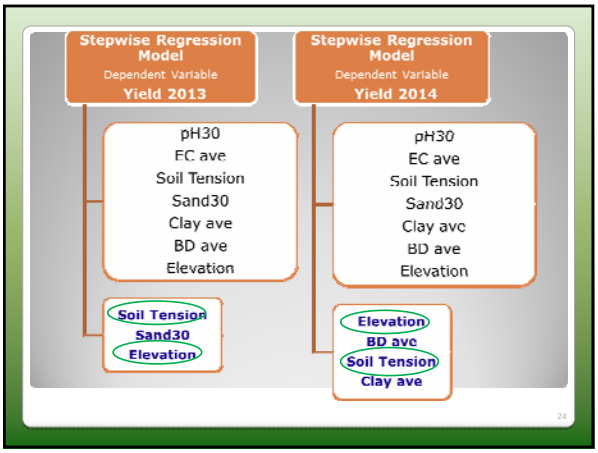
The fuzzy c-means clustering algorithm

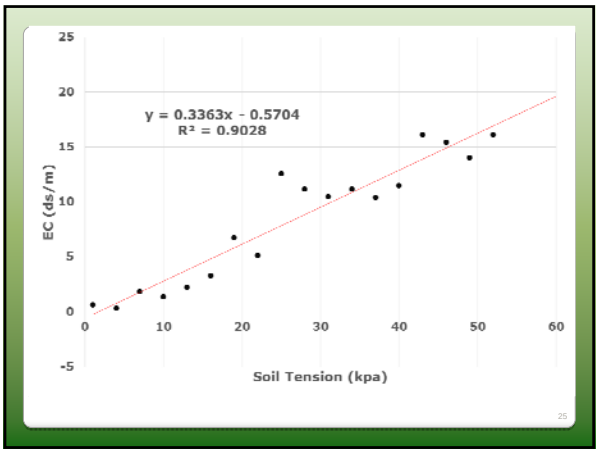
A clustering algorithm organises items into groups based on a similarity criteria

Management Zone Analyst (MZA)

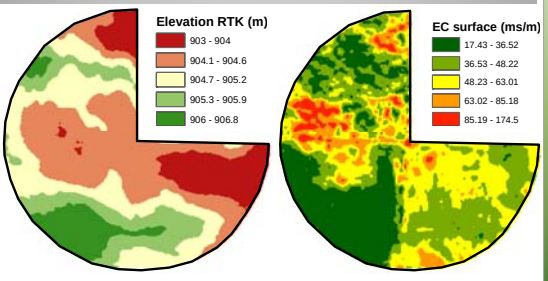








Elevation and Electrical Conductivity



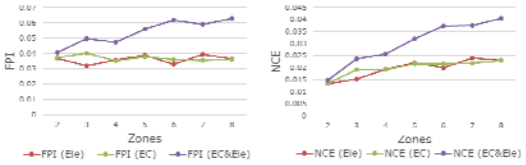
Management Zone Analyst (MZA)

The fuzzy c-means clustering algorithm

A clustering algorithm organises items into groups based on a similarity criteria

FPI and NCE

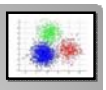
are couple of cluster indices that indicates the degree of separation and disorganization



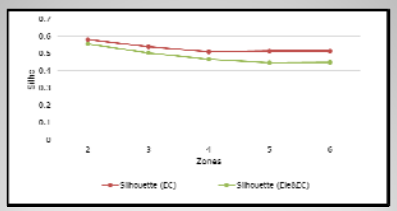
FPI: The fuzziness performance index

NCE: The normalized classification entropy

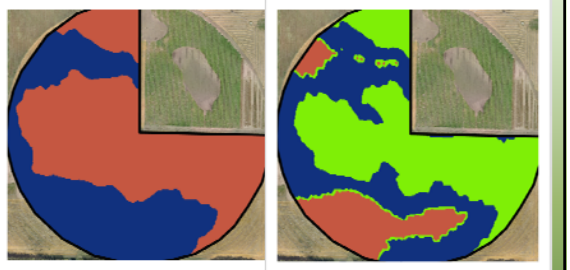
MATLAB



The k-means clustering algorithm



Silhouette displays a measure of clusters separation



2 Clusters with RTK Elevation

Zone 1

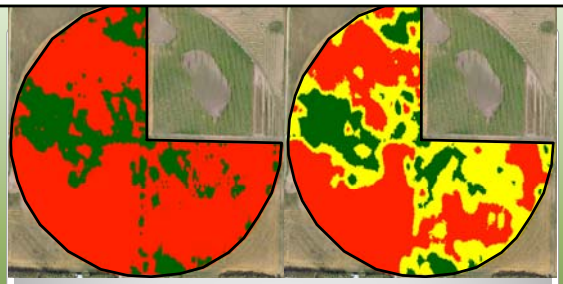
Zone 2

3 Clusters with RTK Elevation

Zone 1

Zone 2

Zone 3



2 Clusters with EC surface

Zone 1

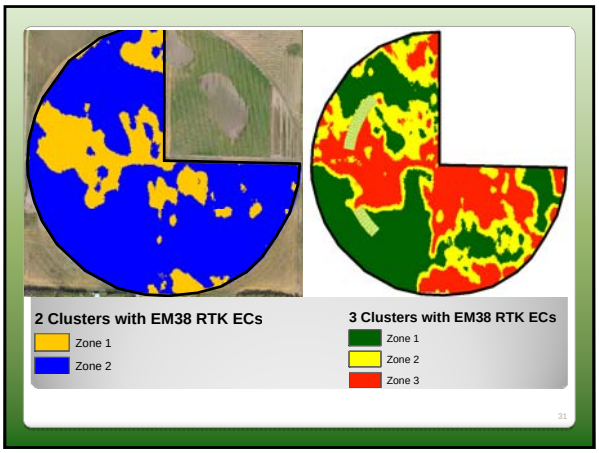
Zone 2

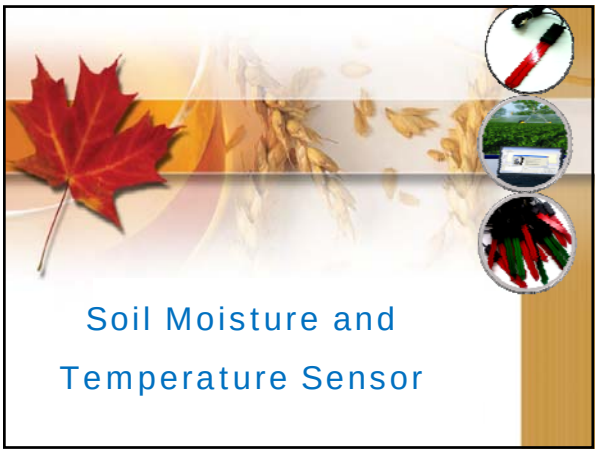
3 Clusters with EC surface

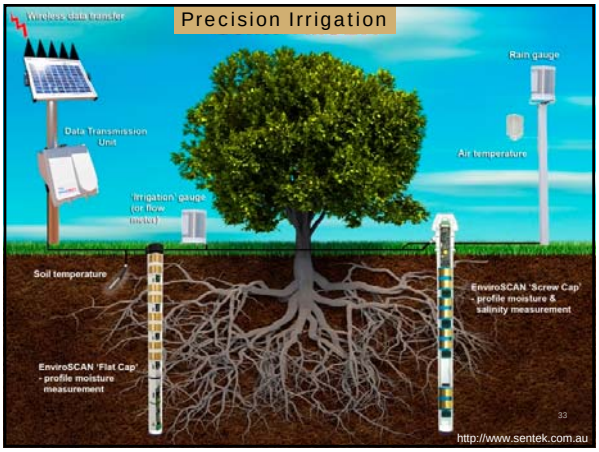
Zone 1

Zone 2

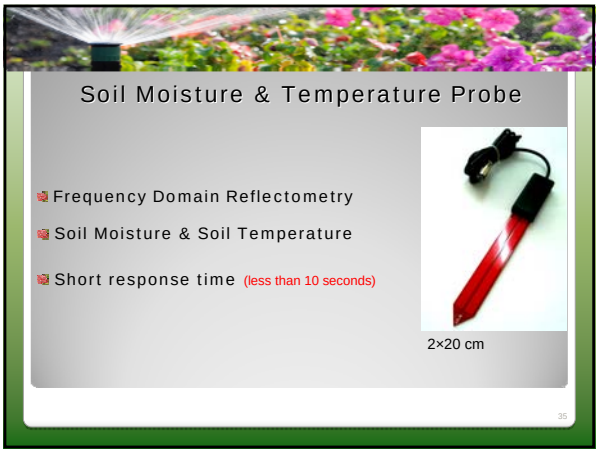
Zone 3


2 Clusters with EM38 RTK ECs
Zone 1
Zone 2
3 Clusters with EM38 RTK ECs
Zone 1
Zone 2
Zone 3

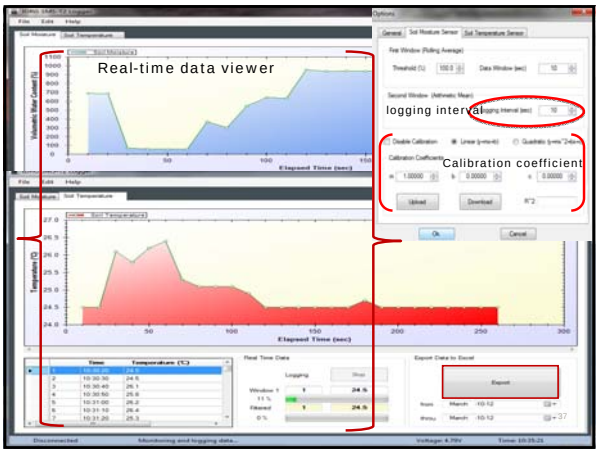

Soil Moisture and
Temperature Sensor


Precision Irrigation
Wireless data transfer
Data Transmission Unit
'Irrigation' gauge (or flow meter)
Rain gauge
Air temperature
Soil temperature
EnviroSCAN 'Screw Cap' - profile moisture & salinity measurement
EnviroSCAN 'Flat Cap' - profile moisture measurement
http://www.sentek.com.au


SMS-T
This device has three main parts
• Soil Moisture & Temperature Probe
• Logger / Reader
• Software


Soil Moisture & Temperature Probe
Frequency Domain Reflectometry
Soil Moisture & Soil Temperature
Short response time (less than 10 seconds)
2×20 cm


Logger / Reader
Four different modes
Saving over 20000 T&M data
Low power requirement (9V battery)
3*8.5*17 cm

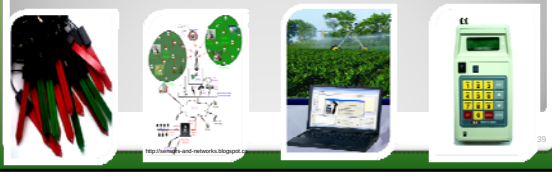


Accuracy

Features	SMS-T
Reading range	0 – Saturation -20 to +50
Stated accuracy	1% Calibrated
Best soil type	All
Affected by salinity	No

Capability

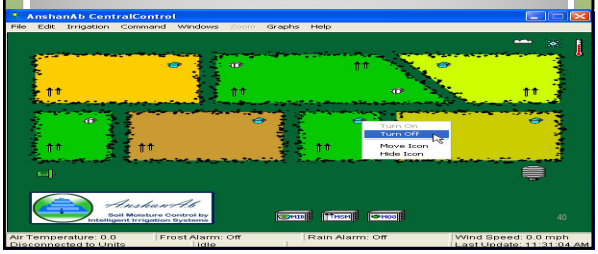
- Wired and Wireless option
- Standard Out-put
- Suitable for PI
- Application (Farmer/Research)



Price

There are two packages available:

Device	Price	Price
Sensor	50-100 $	50-100 $
Reader/Logger	R&L 600-800	R 300-500
Software	Free	Free



Economical Optimization of Variable Rate Irrigation (VRI)

BY
HSIN-HUI HUANG, PhD Candidate
Supervised by: Dr. Viacheslav I. Adamchuk
Bioresource Engineering Department, McGill University, Canada

McGill

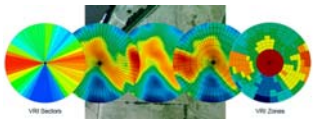
Every drop of water matters!

- Variable rate irrigation (VRI) – control what is necessary
- Information and machinery technologies
- 99% on center-pivot system
- Computerized controlled system
- Water deficit and water logging
- Average 10 – 15 % water reduction
- Challenge? $ $ $ $

Project objectives

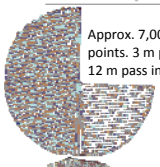
1. Whole field vs. VRI?
2. Economical optimization?

Whole field

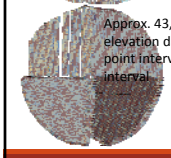


VRI

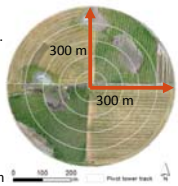
Example field



Approx. 7,000 ECa data points. 3 m point interval. 12 m pass interval

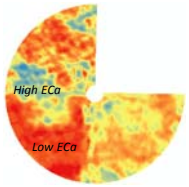


Approx. 43,000 RTK elevation data points. 2 m point interval. 6 m pass interval

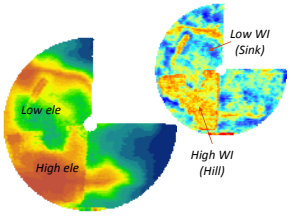


Alberta Irrigation Technology Center (AITC) at Lethbridge, Alberta, Canada.

Characterizing field conditions



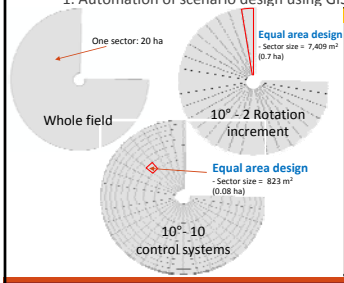
Sensor-based apparent electrical conductivity (ECa)
– Water holding capacity –
– Min. water requirement for max. yield –



RTK elevation (ele) -> Wetness Index (WI)
– Landscape positioning (sink or hill) –
– waterlogging potential –

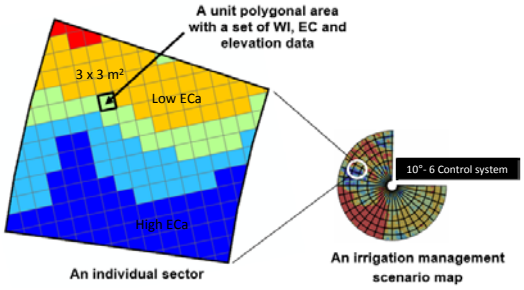
46 Irrigation management scenarios

1. Automation of scenario design using GIS technology (ArcGIS)



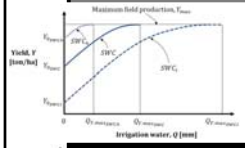
Rotation increments	2°	4°	10°
#. Control Systems	Sector Area (m²)		
Whole field	20,0000		
2	1,495	2,963	7,409
4	498	988	2,470
6	300	593	1,482
8	214	423	1,058
10	166	330	823
12	136	269	674
14	115	228	570
16	100	198	494
18	88	174	436
20	79	156	390
22	71	141	353
24	65	129	322
26	60	119	296
28	55	110	274
30	52	102	255

Sector variability – ECa & WI



Water -> Yield -> Gross income

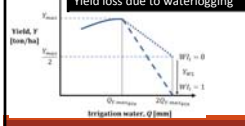
Yield increases to up max. amount



Assumption & given values

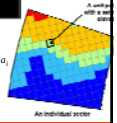
Parameter	Given Value
EC_a	10~50 (mSm-1)
$Q_{Y,max}$	100~400 (mm)
Y_0	0~5 (ton/ha)
Y_{max}	5 (ton/ha)
p_Y	180 (Wheat)
c_E	0.292 ($/ha-mm) or 3 [$/A-I]
n_{irr}	1
c_W	0.486 ($/ha-mm) or 5 [$/A-I]

Yield loss due to waterlogging



Gross income =?

$$GI_{A,\max} = \sum_{i=1}^{n}\left[(p_Y \cdot Y_i) - (c_W + c_E)\cdot Q_{opt} \cdot n_{irr}\right] \cdot a_i$$



More control systems = higher gross income

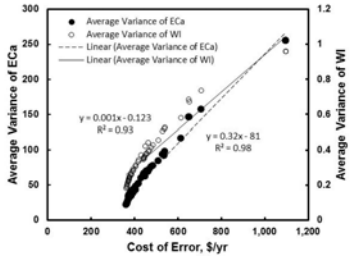
Parameters	Potential Gross Income, GI, ($/yr)			Cost of Error Max. GI - GI$_i$			Variability of the field ECa			Variability of the field WI			VRI System Cost Total	VRI System Cost Over 25yrs
Control Zone Added	2°	4°	10°	2°	4°	10°	2°	4°	10°	2°	4°	10°	VRI,$	Annual,$/yr
0 (uniform rate)	13,618			1,095			255			1.0			0	0
2	14,063	14,064	14,006	650	649	707	147	147	157	0.7	0.7	0.7	5,000	200
4	14,185	14,174	14,100	528	539	613	94	98	117	0.5	0.5	0.6	9,000	360
6	14,265	14,251	14,177	448	462	536	62	69	92	0.4	0.4	0.5	13,000	520
8	14,294	14,284	14,204	419	429	509	52	60	85	0.3	0.4	0.5	17,000	680
10	14,309	14,297	14,229	404	416	484	43	52	78	0.3	0.3	0.4	21,000	840
12	14,320	14,309	14,237	393	404	476	39	48	76	0.3	0.3	0.4	25,000	1000
14	14,329	14,319	14,245	384	394	468	35	44	73	0.3	0.3	0.4	29,000	1160
16	14,335	14,324	14,252	378	389	461	32	42	71	0.2	0.3	0.4	33,000	1320
18	14,341	14,330	14,259	372	383	454	30	40	70	0.2	0.3	0.4	37,000	1480
20	14,344	14,333	14,261	369	380	452	27	38	68	0.2	0.3	0.4	41,000	1640
22	14,347	14,337	14,269	366	376	444	25	36	67	0.2	0.2	0.4	45,000	1800
24	14,348	14,338	14,270	365	375	443	25	36	66	0.2	0.2	0.4	49,000	1960
26	14,349	14,339	14,269	364	374	444	24	35	66	0.2	0.2	0.4	53,000	2120
28	14,351	14,341	14,271	362	372	442	23	34	65	0.2	0.2	0.4	57,000	2280
30	14,352	14,343	14,273	361	370	440	22	33	65	0.2	0.2	0.4	61,000	2440

Highest gross income

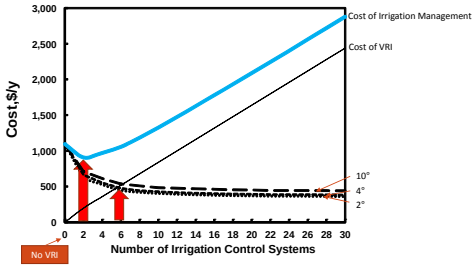
Highest cost of error

Highest field variability

High field variance = lower gross return



Economical management = Knowing gain vs cost!



Conclusions

- More control systems or smaller sector size brings more gross incomes
- Reduce sector variability increases gross income
- Model, assumption, and site-specific parameters affect results
- Sensitivity analysis
- Economic assessment prior to implantation

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QUESTION?