Smarter Irrigation for Profit

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Tasmanian Institute of Agriculture
(TIA) - University of Tasmania

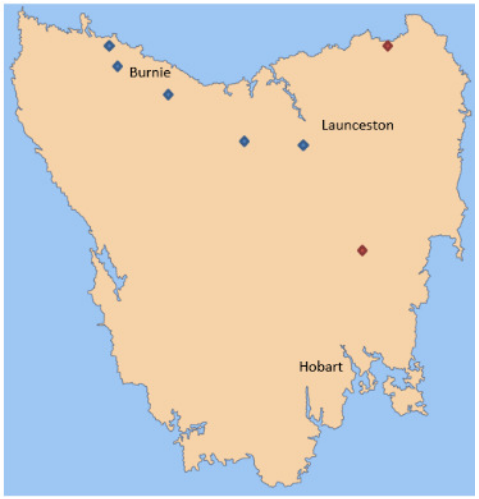
TIA is a joint venture of the University of Tasmania and the Tasmanian Government

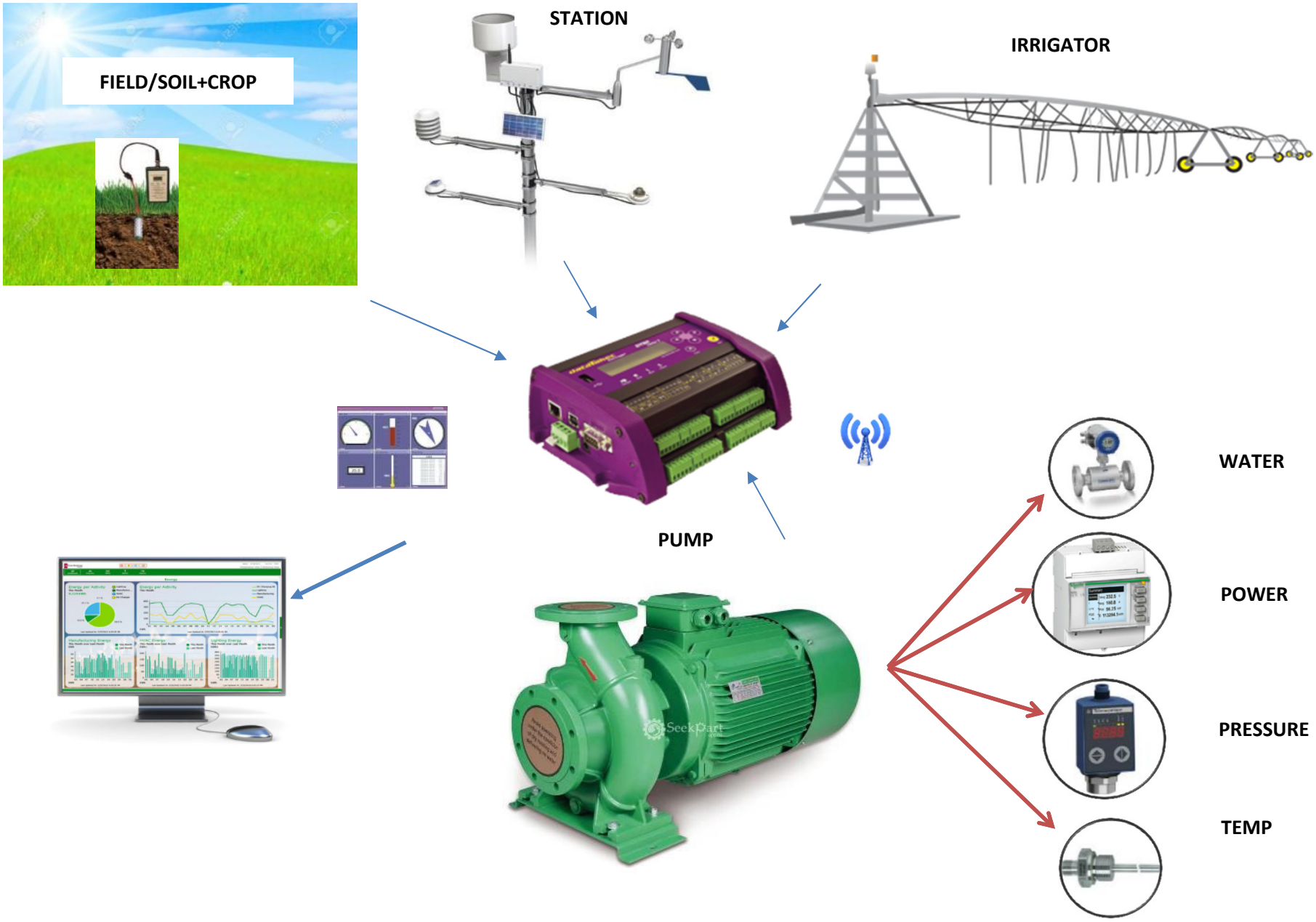
Overview

- Project overview
- Energy case study
- Distribution uniformity
- Irrigation scheduling and pasture growth rates
- Variable rate irrigation
- From precision to decision - automation
- Spatial measurement of soil moisture

Project 2b – Smart Automated irrigation

- Increasing farm profit through efficient use of irrigation input to dairy pastures
  - Five Farmer sites
    - 4 with human interface
    - 1 with Automation (VARIwise)




FIELD/SOIL+CROP
WEATHER STATION
IRRIGATOR
PUMP
WATER
POWER
PRESSURE
TEMP

Measuring energy

Shifting water

- Water is very **HEAVY** material!!
- 1 Litre is a kilogram. 1000 litres is a tonne.
- 1 MegaLitre(ML) is 1000 tonnes= 20 B-double trucks
- Need **Lots** of Energy to lift & move water
- 1 ML on 1 ha is same as 100 mm rainfall
- Every ML per ha is 1000 tonnes per hectare

Energy use in pumping

Pivot Site	kWhr/ML	$/kWhr	$/ML
1	113	0.23	$26.08
2	157	0.23	$36.16
3	220	0.23	$50.65
4	304	0.23	$70.00
5	**787**	**0.23**	**$181.05**

- Benchmarks
  - 4-8 kWh/ML/meter head
  - 150-300 kWh/ML
  - $30-70/ML Daley and Callow 2014

Energy savings

Site 5

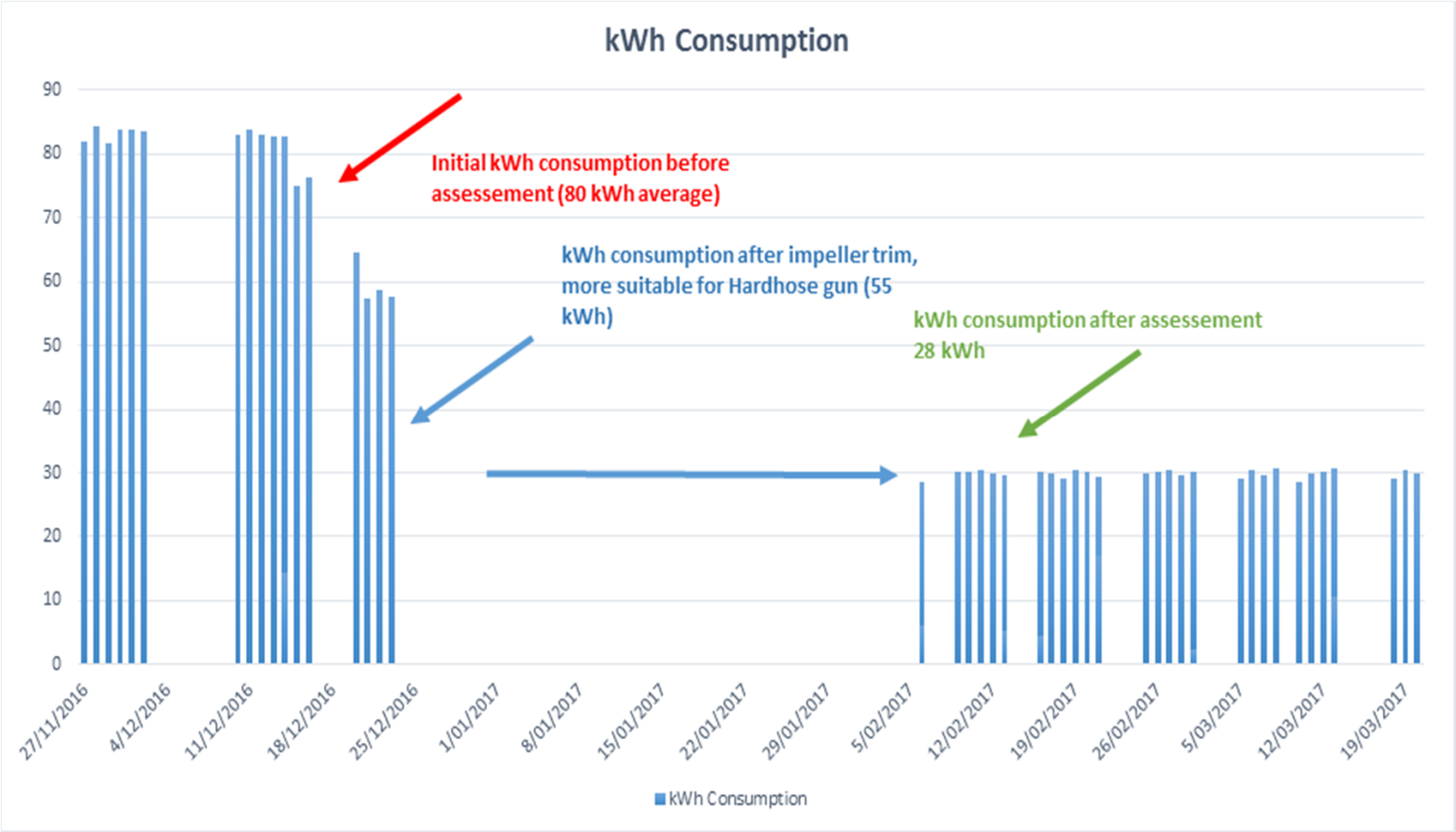
- Measured results before and after pump and motor replaced
- 787 kWh/ML vs 266 kWh/ML
- Savings of $120/ML or $20,000 for the season

Old setup

New pump

New setup

Energy savings



Energy savings

Site 3 – 117 Ha pivot

- Old pump replaced with new pump with the same specifications
- $50 vs $43 /ML
- Savings of $4900 for 6ML/ha of irrigation

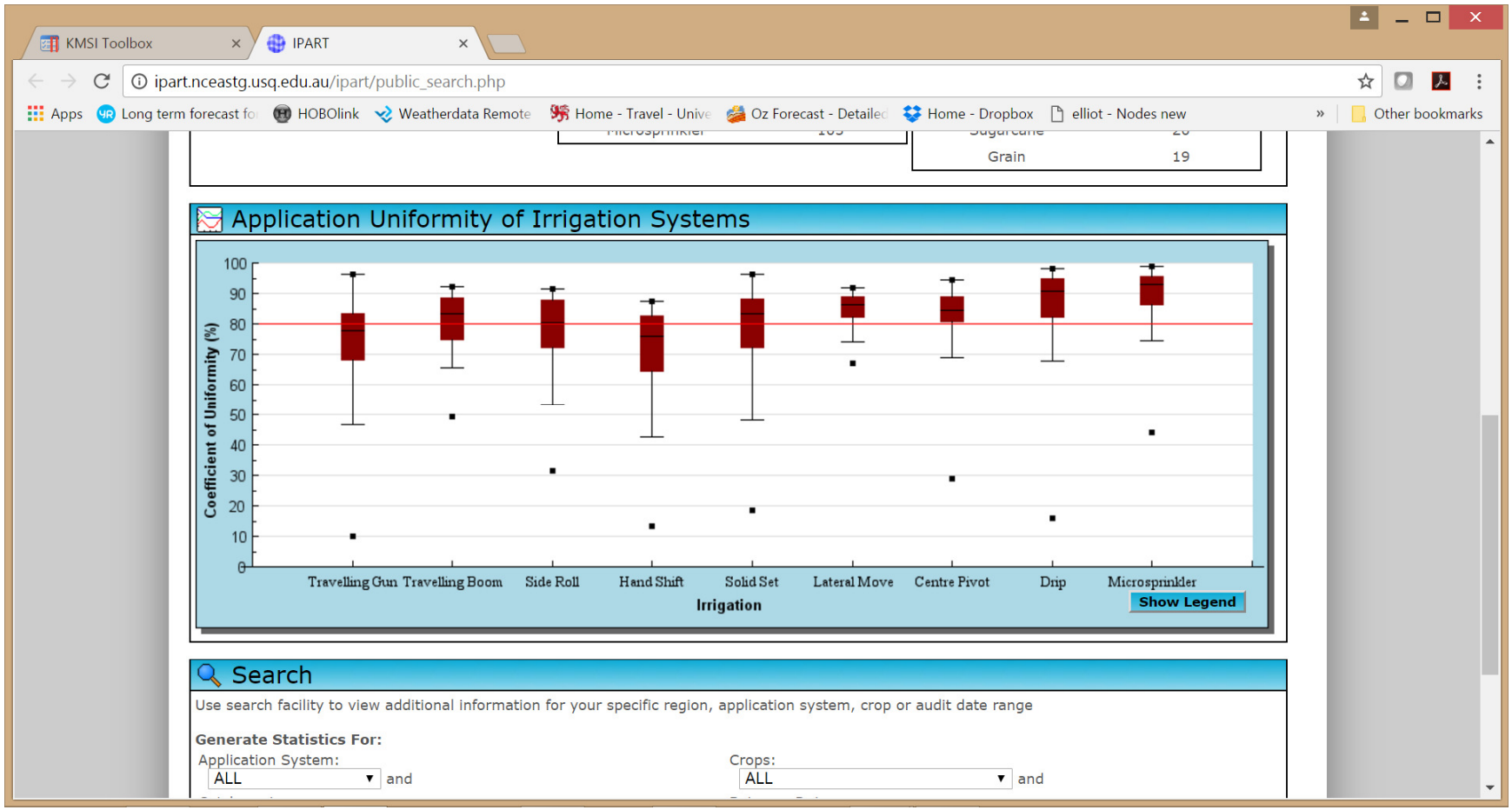
- VRI installed - 34% reduction in water use
- Potential $15000 saved in energy cost for pumping and $8000 saved in reduced water purchases

Summary

- Matching the pump and motor with the irrigation system can provide significant energy cost savings – don't assume it is ok!!

- Maintenance on existing systems can make a difference

Uniformity


KMSI Toolbox
IPART
ipart.nceastg.usq.edu.au/ipart/public_search.php
Apps
Long term forecast fo
HOBOlink
Weatherdata Remote
Home - Travel - Unive
Oz Forecast - Detailed
Home - Dropbox
elliot - Nodes new
Other bookmarks
Grain 19
Application Uniformity of Irrigation Systems
Coefficient of Uniformity (%)
100
90
80
70
60
50
40
30
20
10
0
Travelling Gun
Travelling Boom
Side Roll
Hand Shift
Solid Set
Lateral Move
Centre Pivot
Drip
Microsprinkler
Irrigation
Show Legend
Search
Use search facility to view additional information for your specific region, application system, crop or audit date range
Generate Statistics For:
Application System:
ALL
and
Crops:
ALL
and

Dairy Australia
Your Levy at Work

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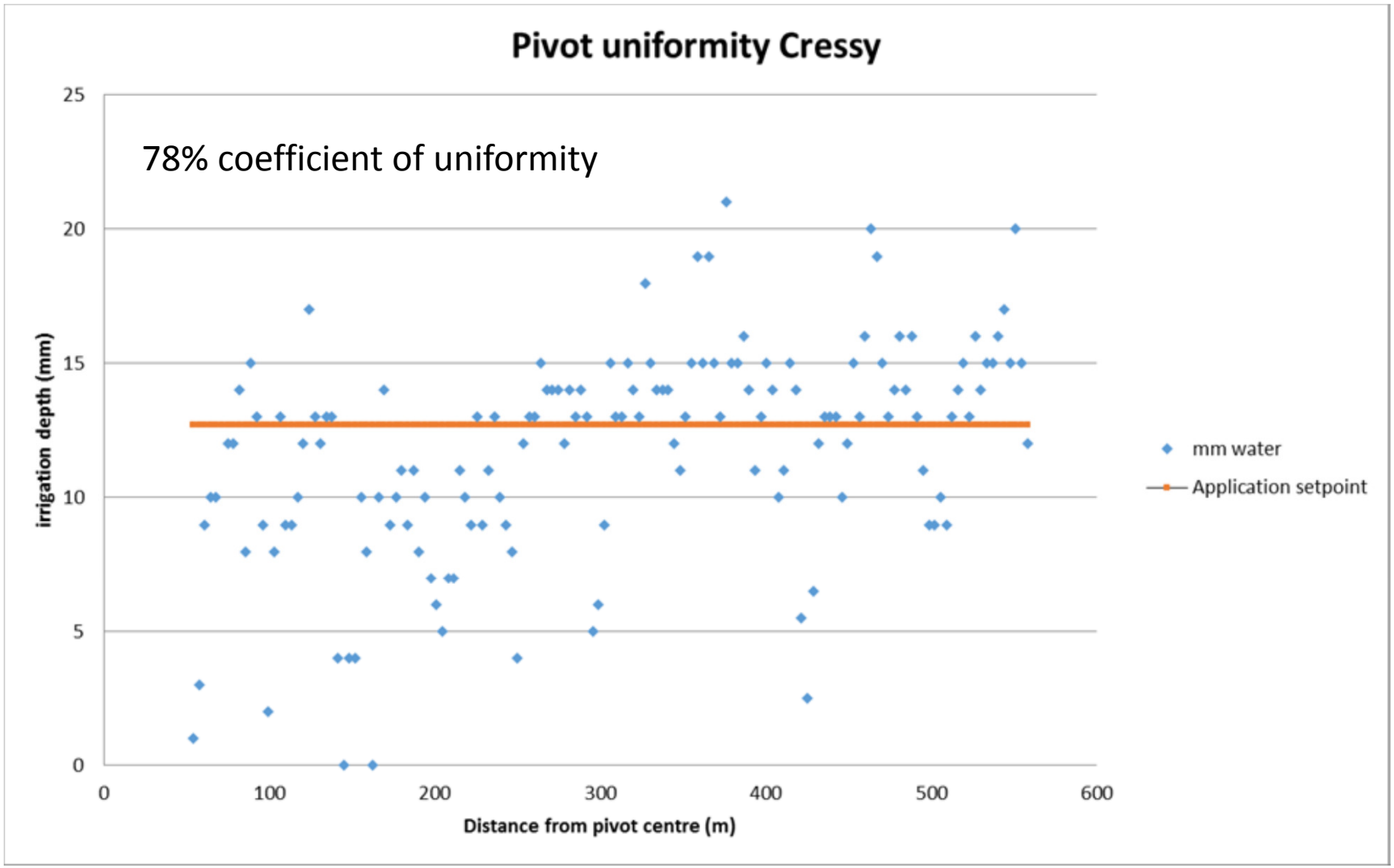
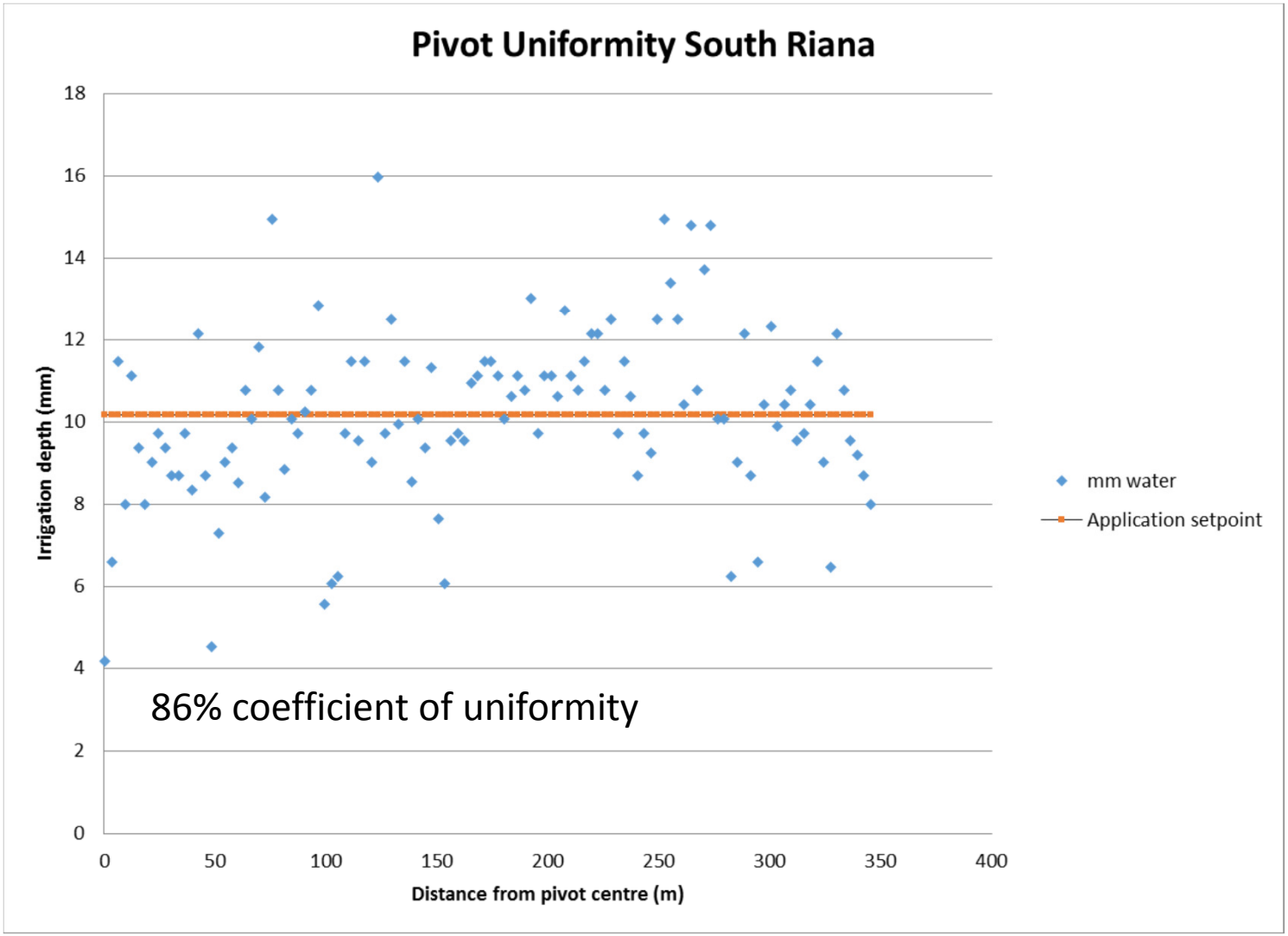
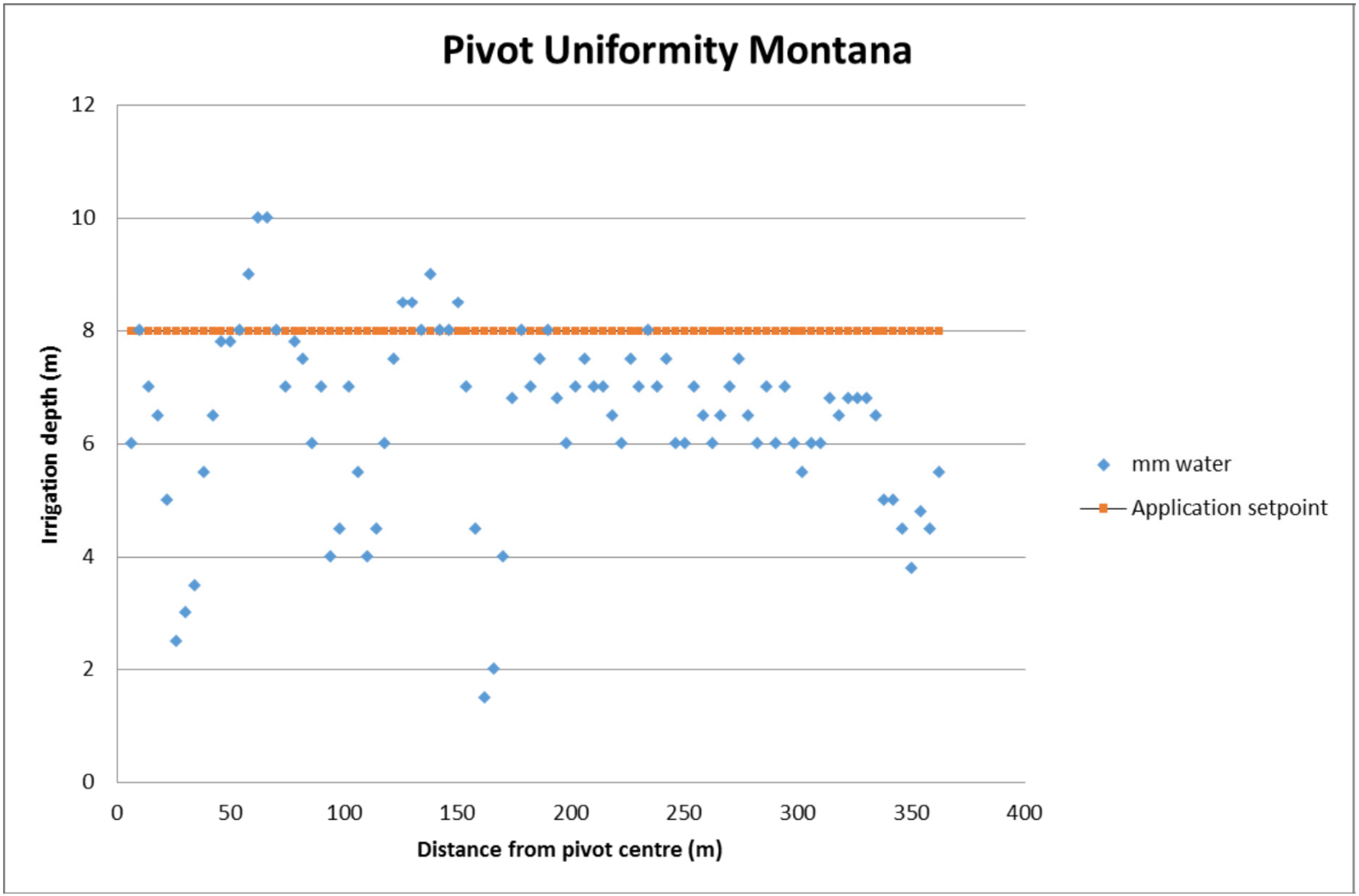
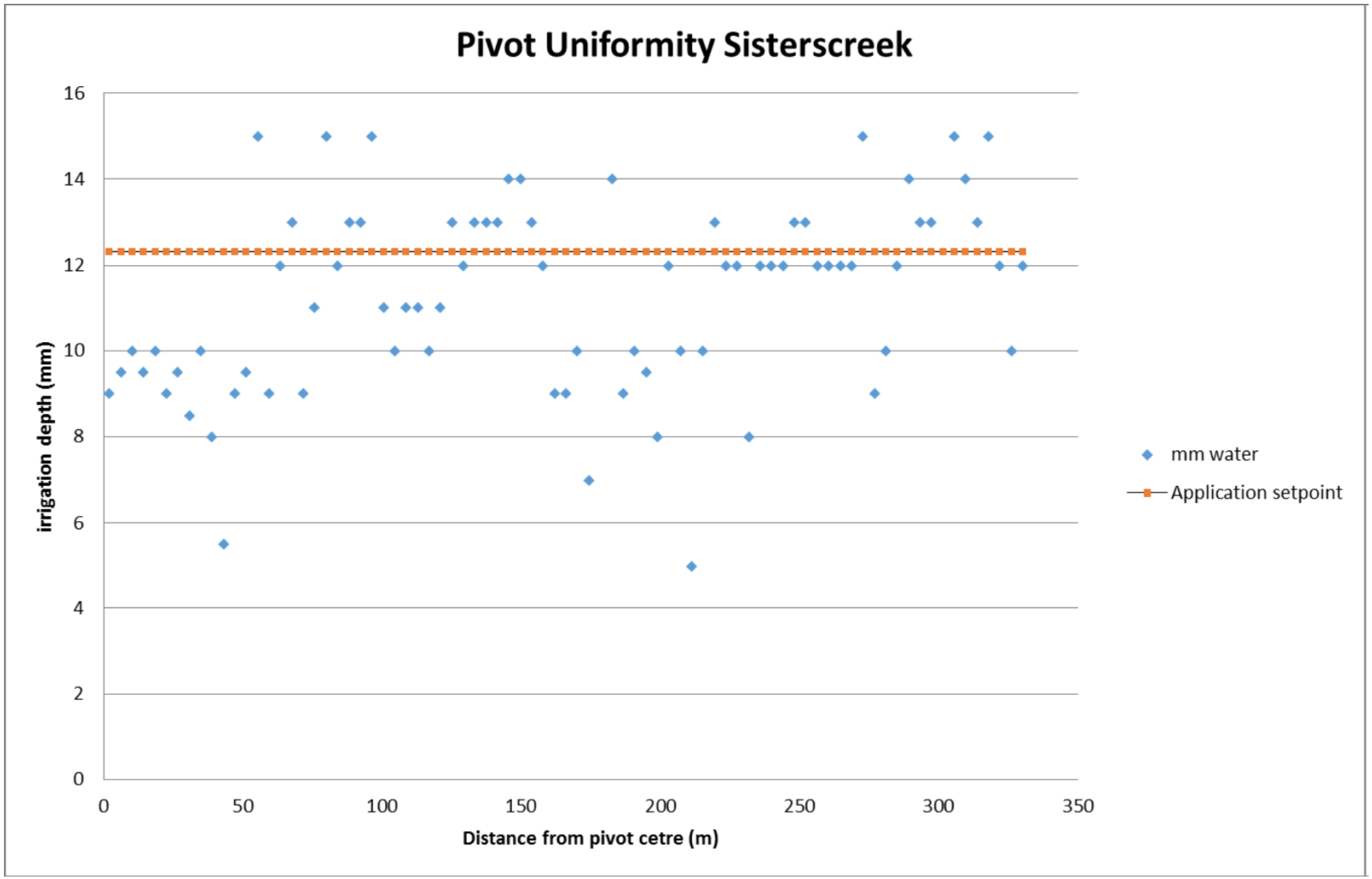
TASMANIAN INSTITUTE OF AGRICULTURE




Pivot Uniformity South Riana
Irrigation depth (mm)
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
400
Distance from pivot centre (m)
mm water
Application setpoint
86% coefficient of uniformity


Pivot Uniformity Montana
Irrigation depth (m)
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
Distance from pivot centre (m)
mm water
Application setpoint


Pivot Uniformity Sisterscreek
irrigation depth (mm)
16
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
Distance from pivot cetre (m)
mm water
Application setpoint

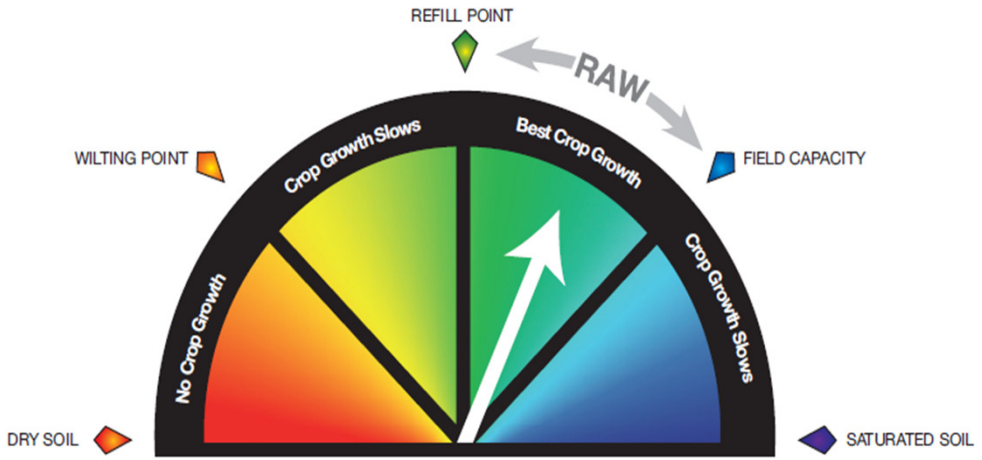
Irrigation scheduling

Irrigation scheduling

- Need to know
  - Readily available water
  - Evapotranspiration
  - System capacity

  - Soil moisture probes are useful to visualise what is in the bucket!!

Readily Available Water (RAW)



- Ranges between 9 and 27mm for pasture with root depth of 30cm

Texture	mm/cm
Sand	0.3
Loamy sand	0.5
Loam	0.9
Clay Loam	0.8
Medium Clay	0.6

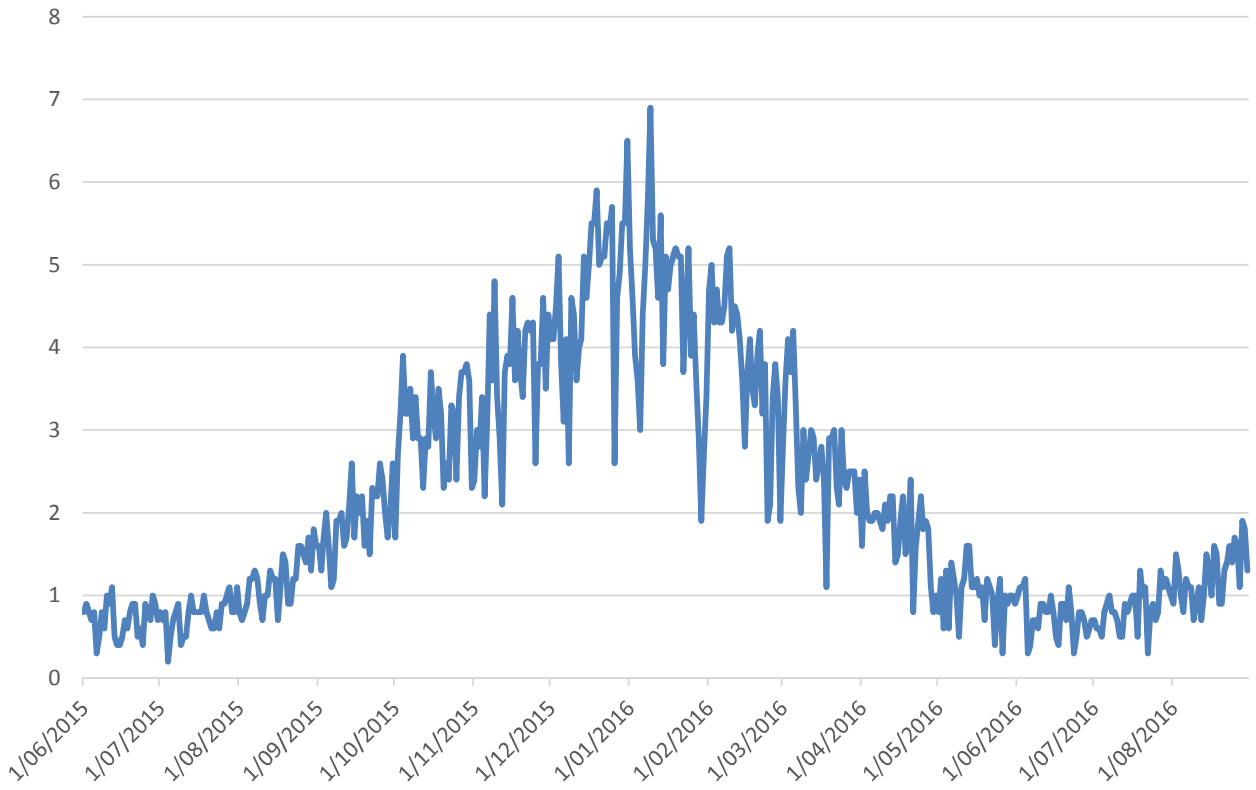
Bill Cotching 2009 Soil health for farming in Tasmania

Image sourced from http://www.agric.wa.gov.au/PC_95247.html?s=1001 (May 2013).

Evapotranspiration

6.0 to 6.5 mm/day maximum in January

ET0 (mm)
Deloraine



System Capacity

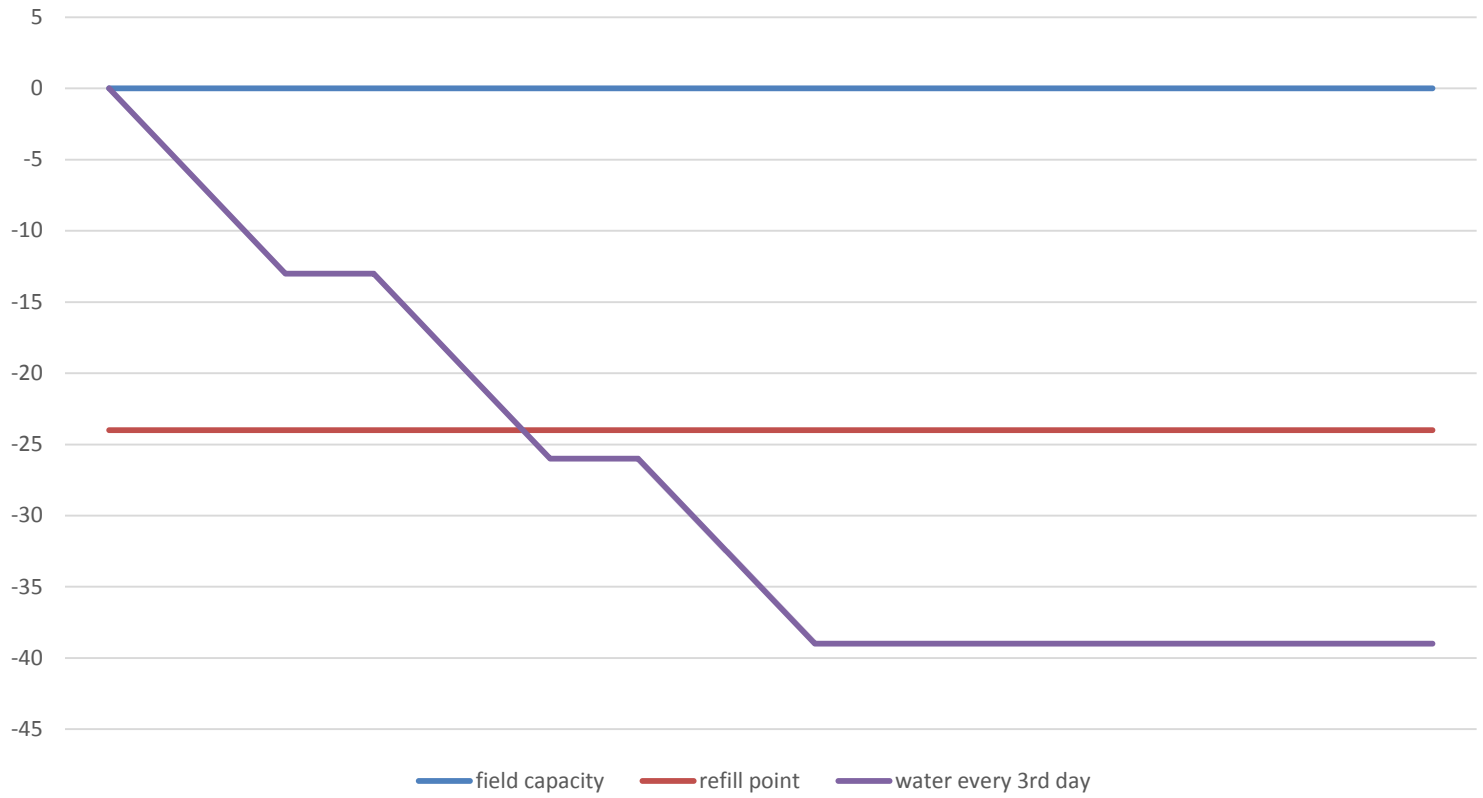
The system capacity is the maximum possible rate at which the machine can apply water to the irrigated field area

Expressed in mm/day

NOT the depth applied per pass (mm)

$$\text{System Capacity} = \frac{\text{Daily pump flow rate (L/day)}}{\text{Field irrigated area (m}^2\text{)}}$$

- RAW 24 mm
- ETo max 6.5mm
- System capacity 6.5 mm
- Watering every third day

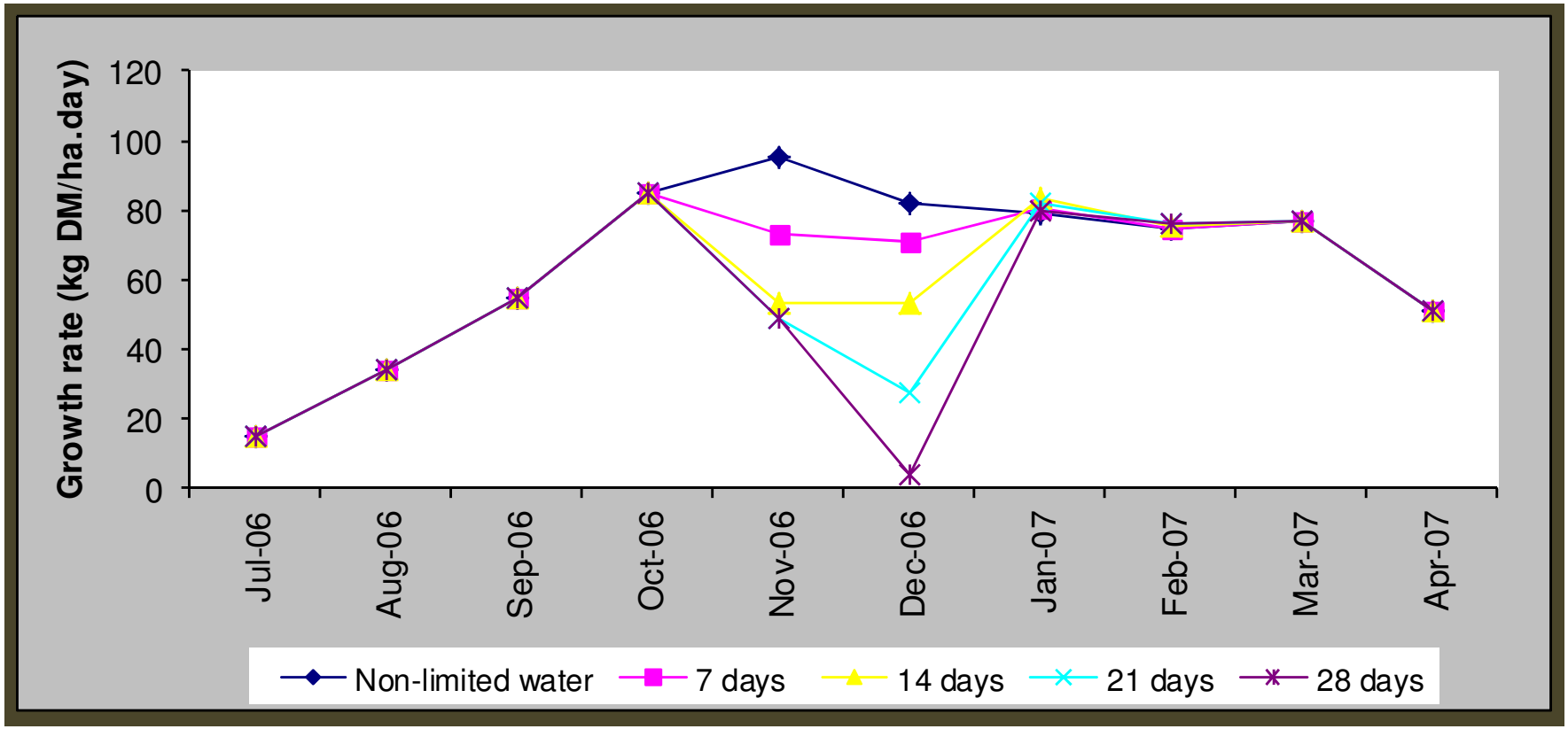


Irrigation scheduling and pasture productivity

Getting start-up time right!

- Modelling the effect of delaying irrigation start
  - Delaying irrigation start-up by 7, 14, 21 and 28 days
  - Effect on pasture growth rates and pasture utilisation
  - Repeated for a number of seasons
  - Determined the relationship between start-up delay and loss in pasture utilisation

Getting start-up time right!

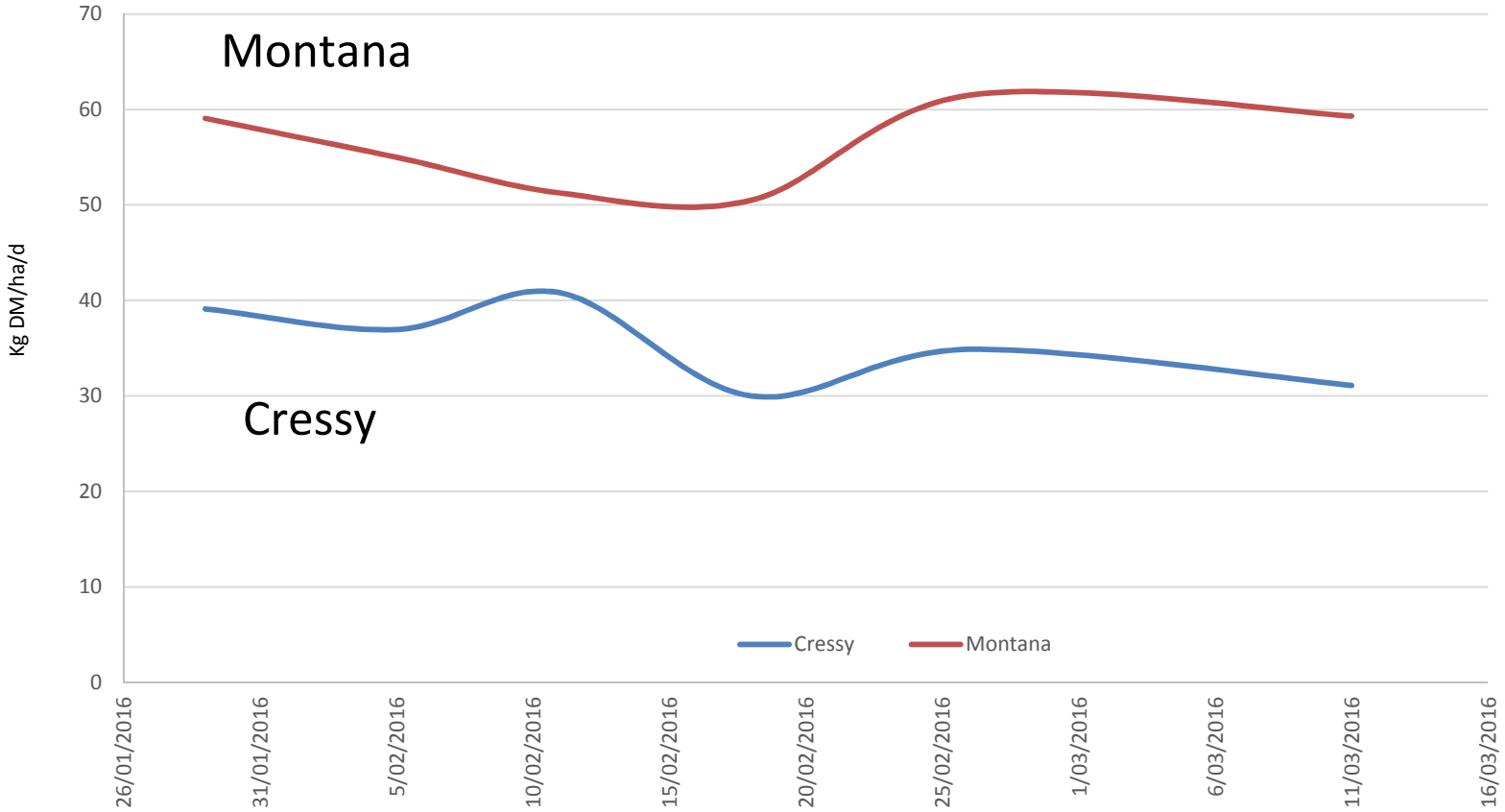


Getting start-up time right!

- Delaying irrigation start-up can lead to a reduction in pasture utilisation equivalent to 105kg DM/ha/d delay.
  - Assuming an irrigated area of 50ha and 100kg reduction.
  - A 5 day delay in start-up results in a reduction of approximately 25t DM utilisation across the irrigated area.
  - 1t DM equals 77kg milk solids at $4.50 = $346
- For a five day delay in irrigation start-up = $8,650

Cressy site

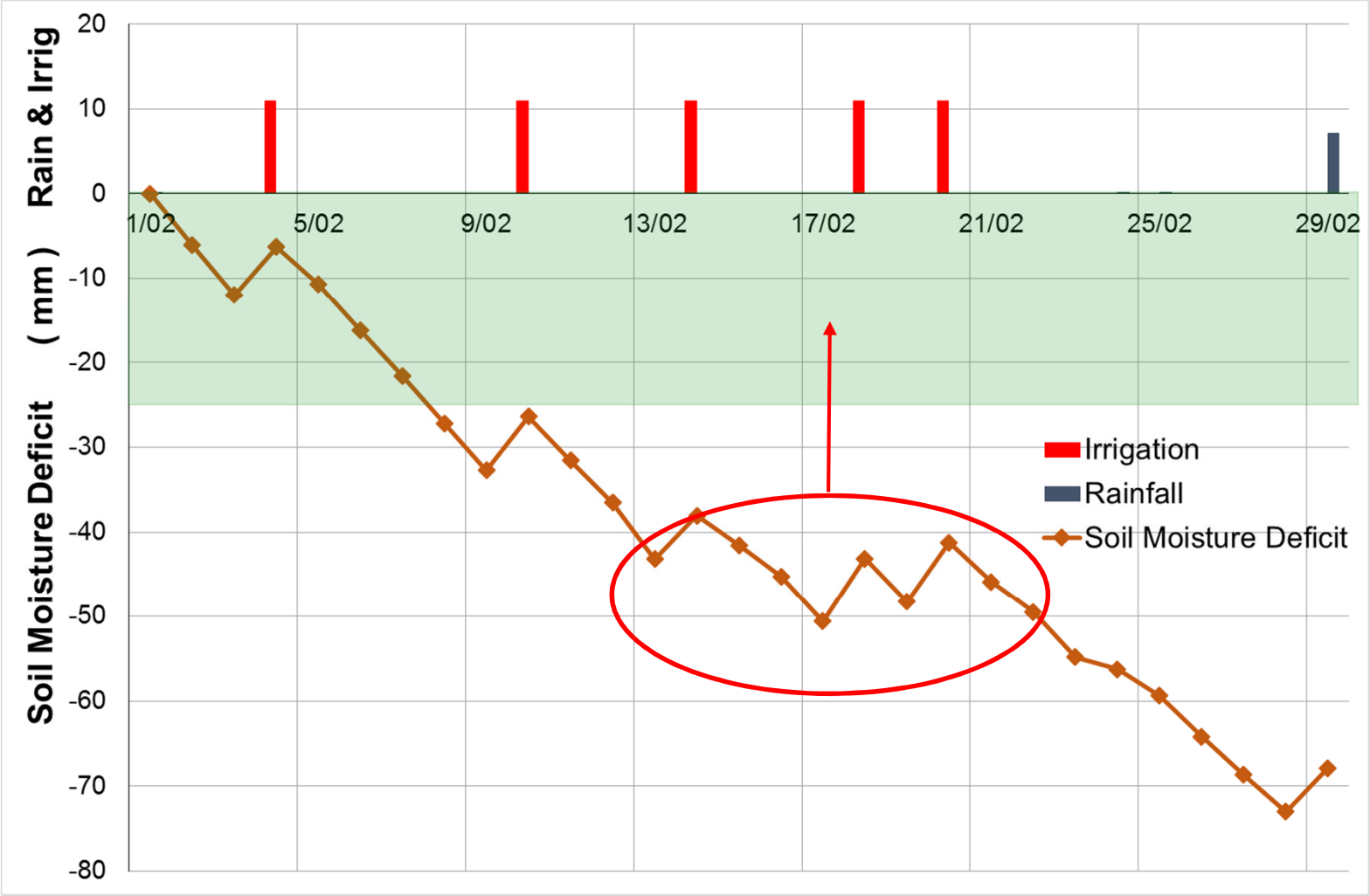
Pasture growth rates 2016
Cressy vs Montana



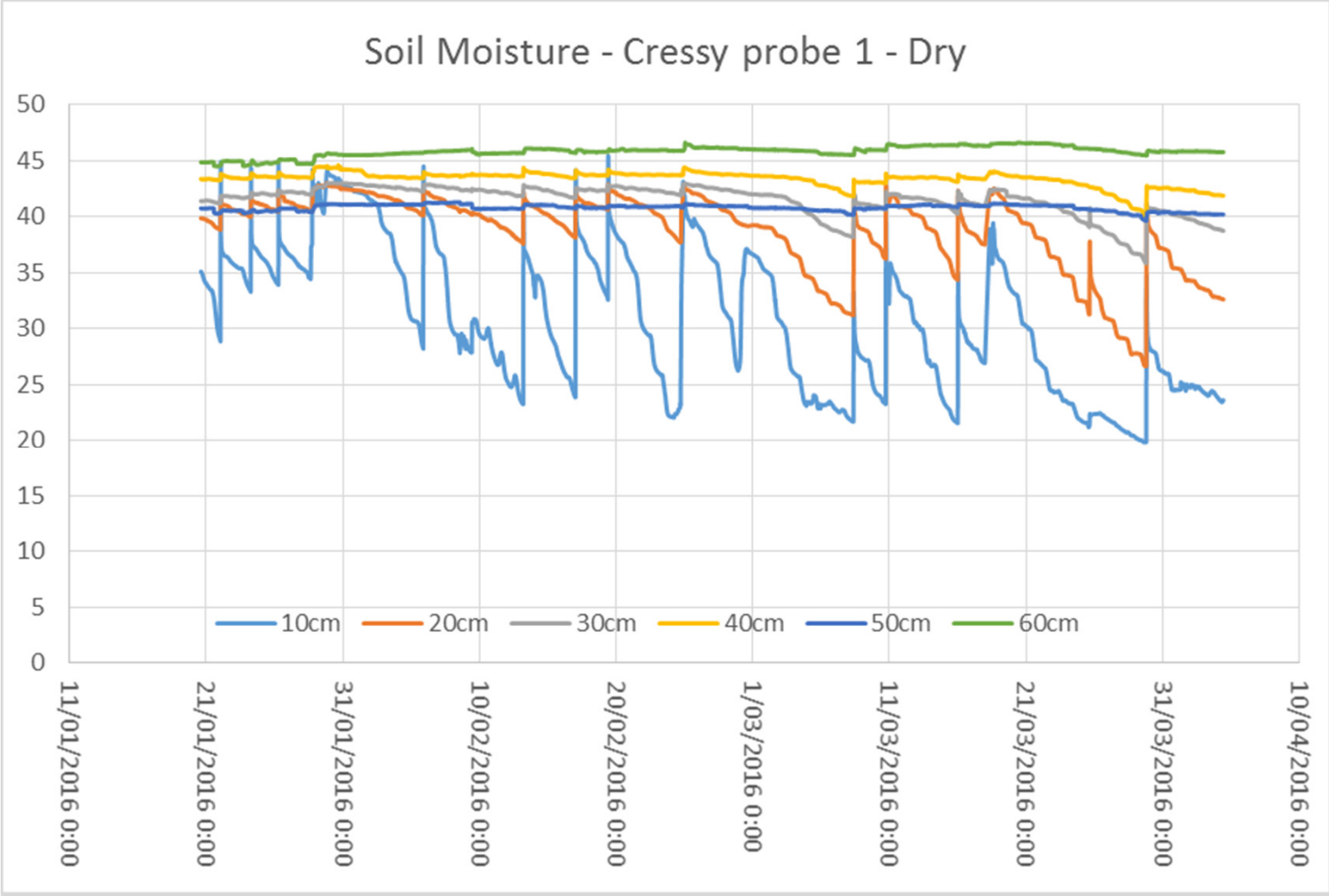
The farmers calculation

- Cressy averaged 30-40kg DM/ha/d
- Opportunity loss of 20kg DM/ha/d
- Opportunity loss of 210t pasture on 117ha pivot replaced with purchased grain
- $200/t extra cost
- $42,000 extra cost over three months

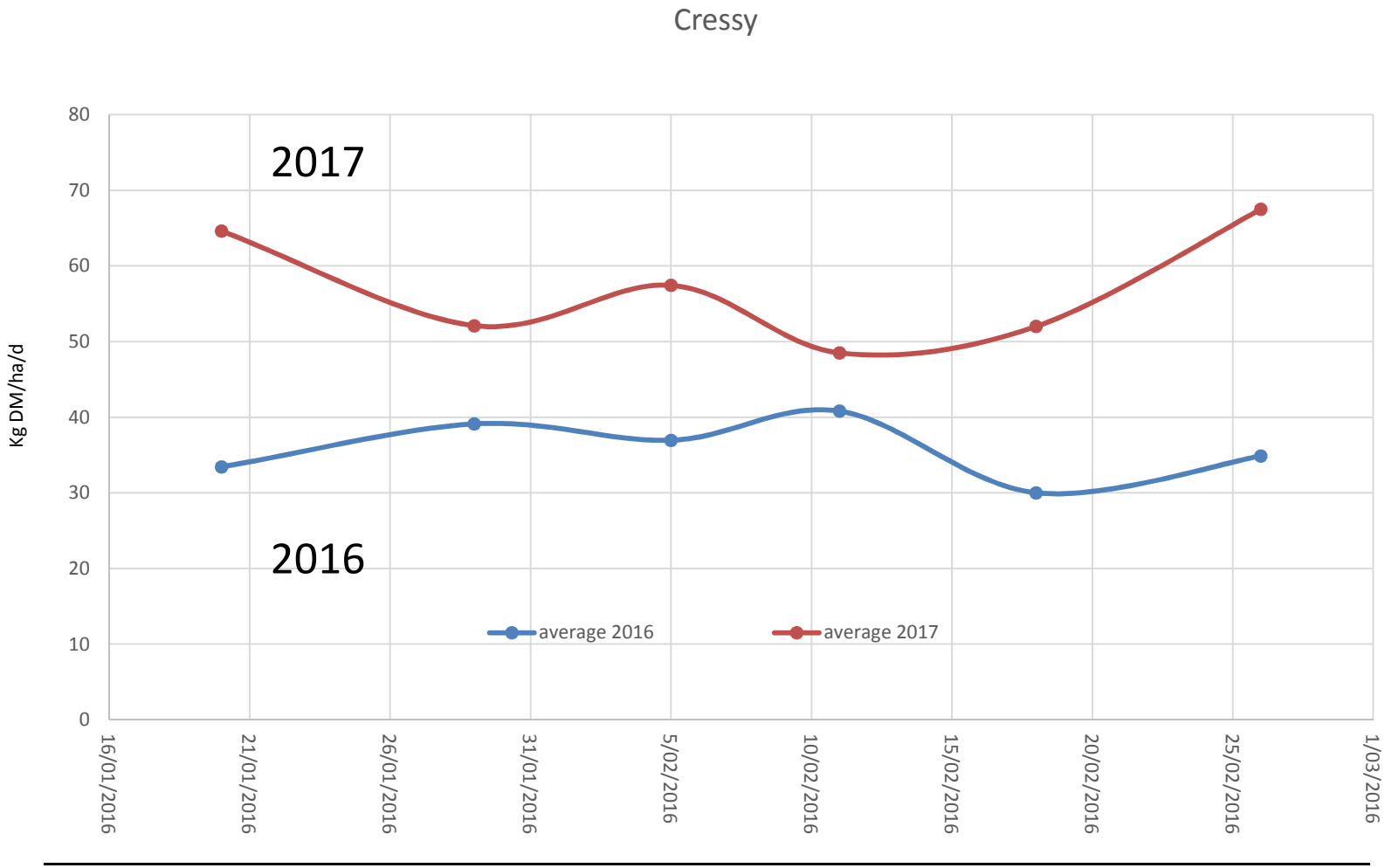
The Green Drought



2016


Soil Moisture - Cressy probe 1 - Dry
50
45
40
35
30
25
20
15
10
5
0
10cm
20cm
30cm
40cm
50cm
60cm
11/01/2016 0:00
21/01/2016 0:00
31/01/2016 0:00
10/02/2016 0:00
20/02/2016 0:00
1/03/2016 0:00
11/03/2016 0:00
21/03/2016 0:00
31/03/2016 0:00
10/04/2016 0:00

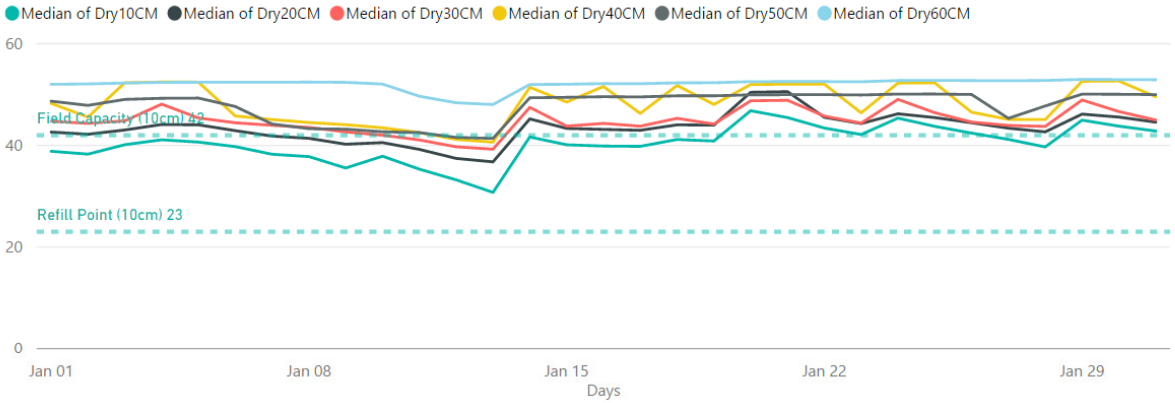
2016 vs 2017


Cressy
Kg DM/ha/d
80
70
60
50
40
30
20
10
0
2017
2016
average 2016
average 2017
16/01/2016
21/01/2016
26/01/2016
31/01/2016
5/02/2016
10/02/2016
15/02/2016
20/02/2016
25/02/2016
1/03/2016

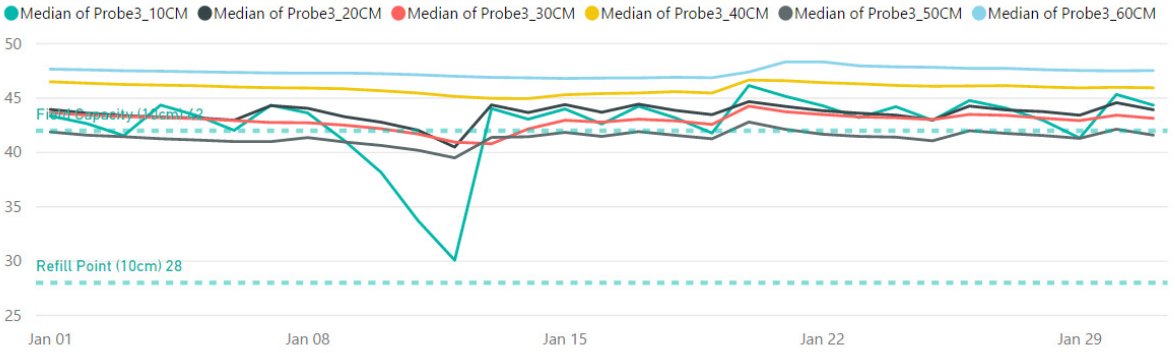
Excessive irrigation?

Montrose Dairy Cressy - Soil Moisture + Rainfall

Dry Probe (Median)

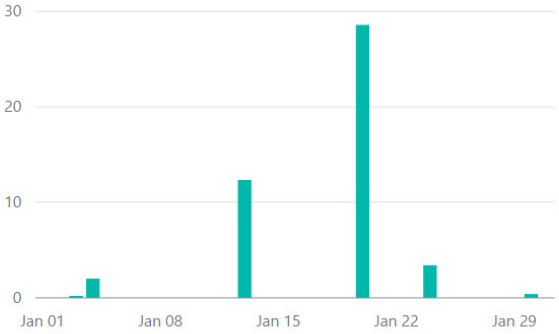


Intermediate Probe (Median)

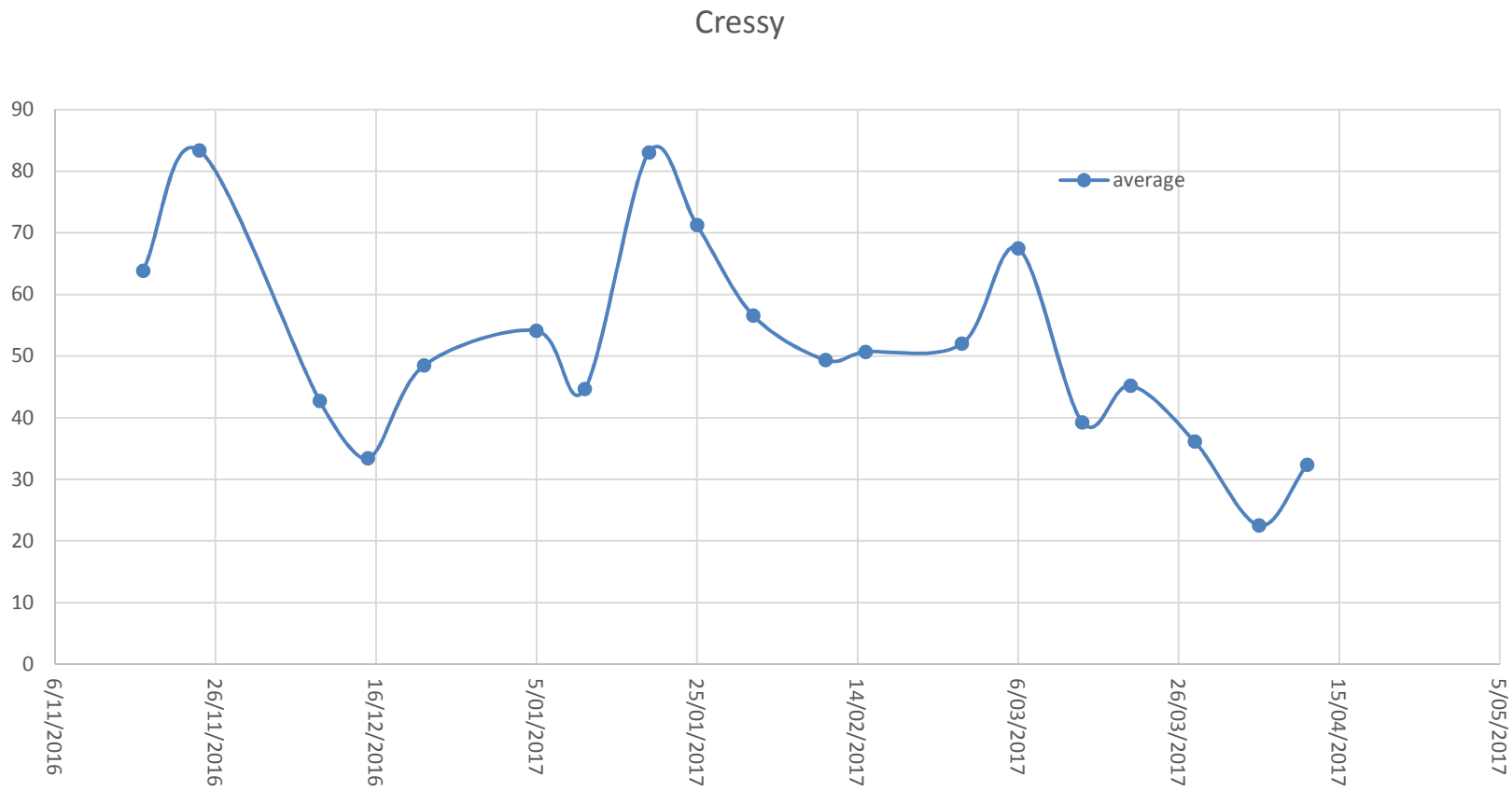


Months

Rainfall by Day



2016/17 Pasture growth rates

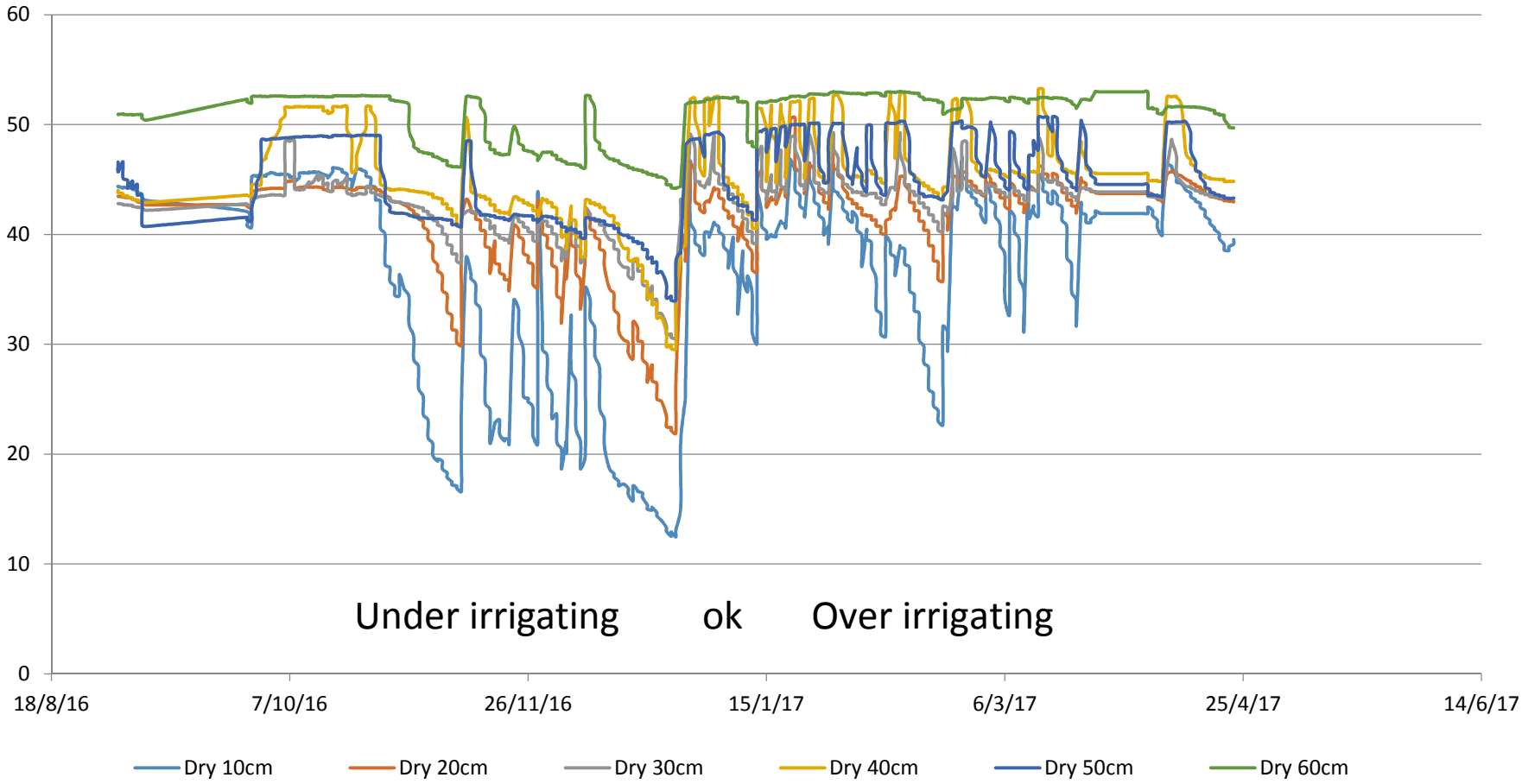


Installing new VRI

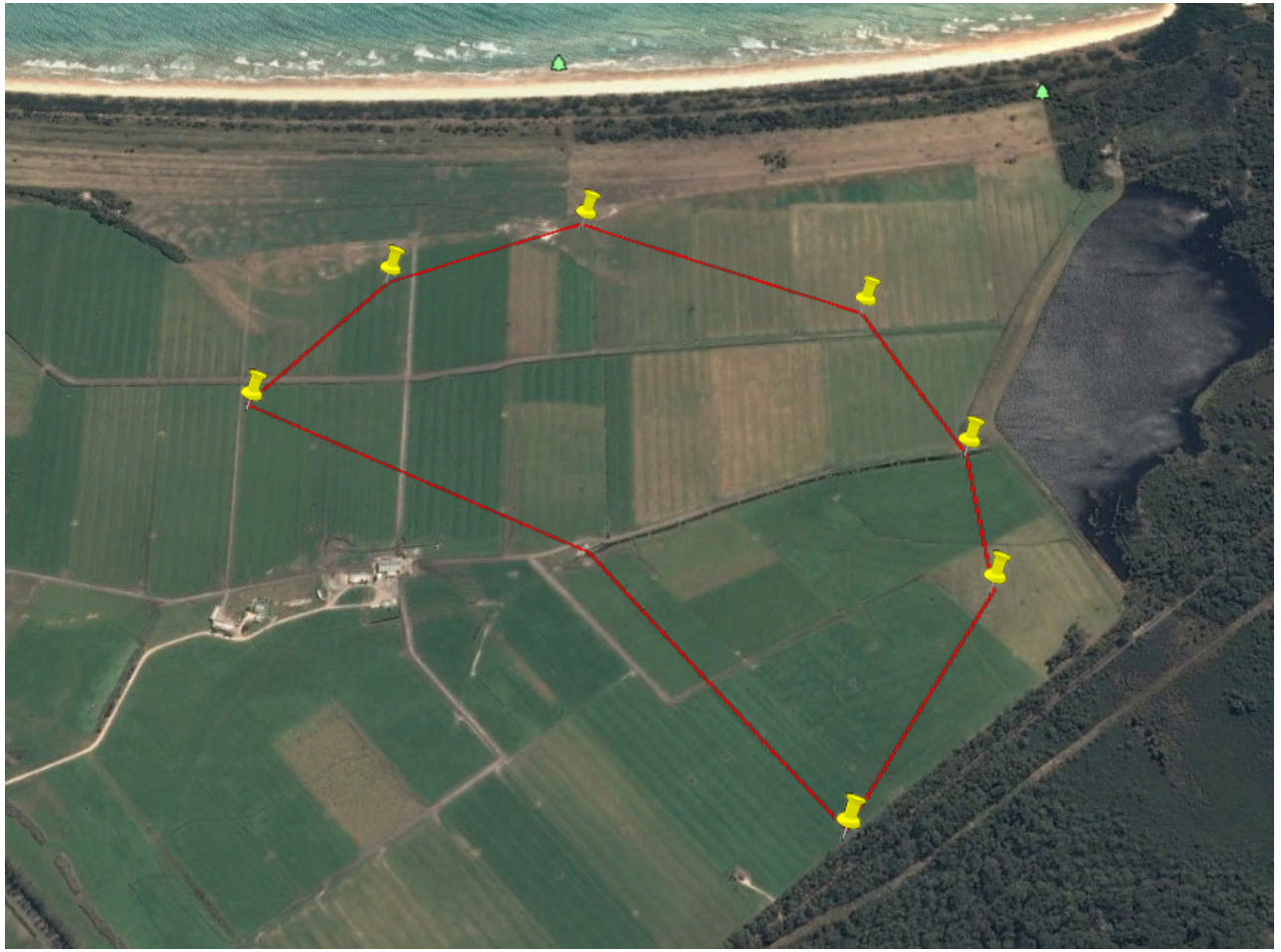
Over irrigating?

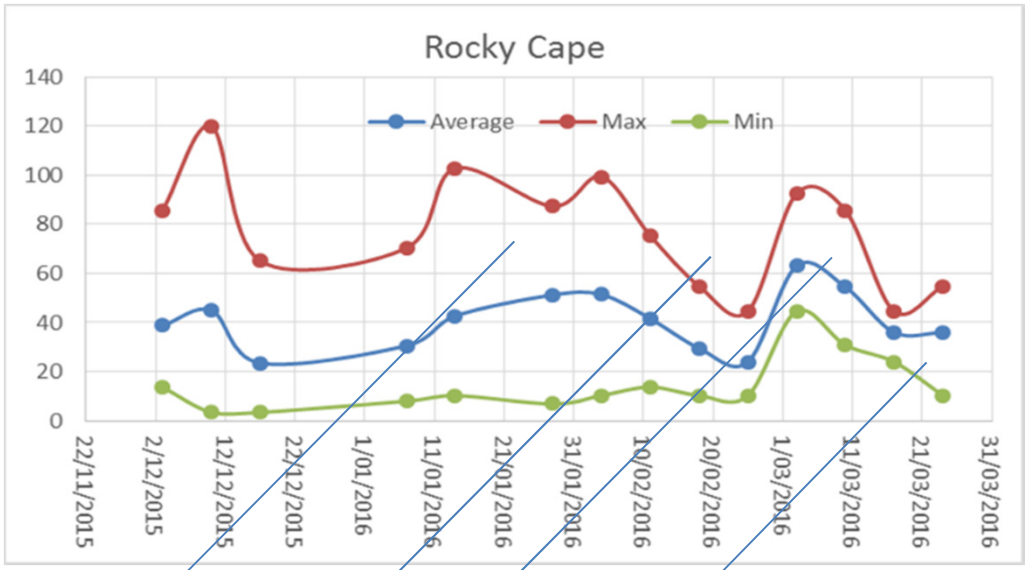
Grazing management?

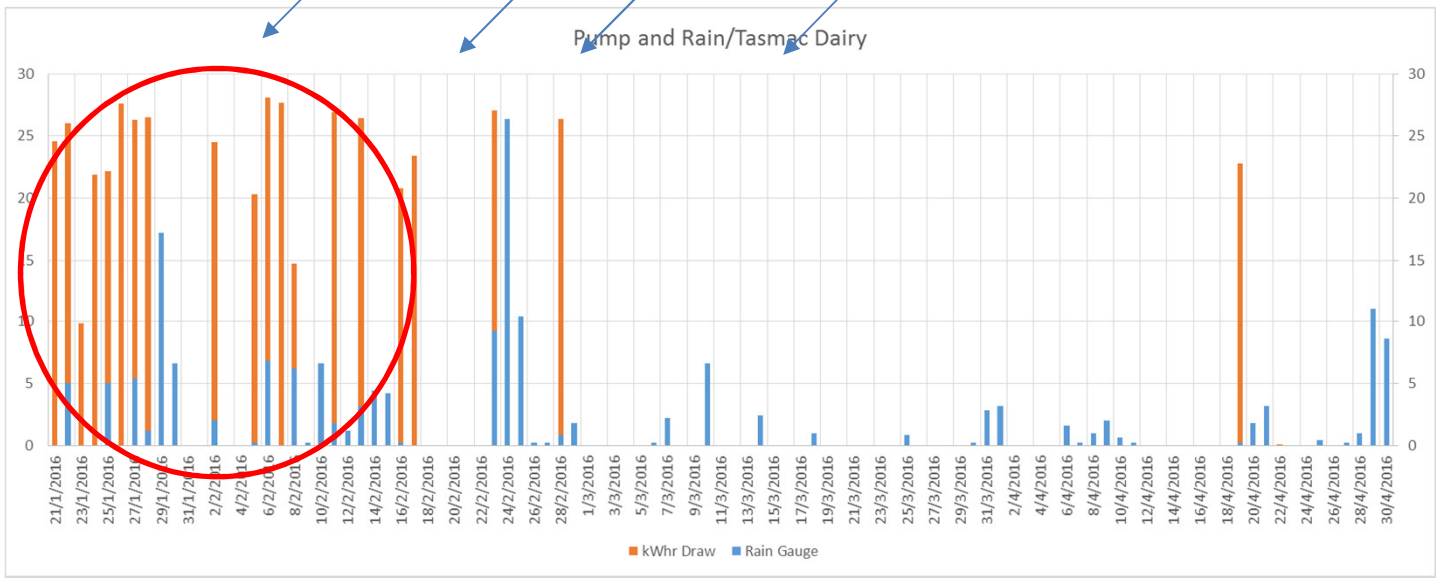
2016/17 Soil moisture



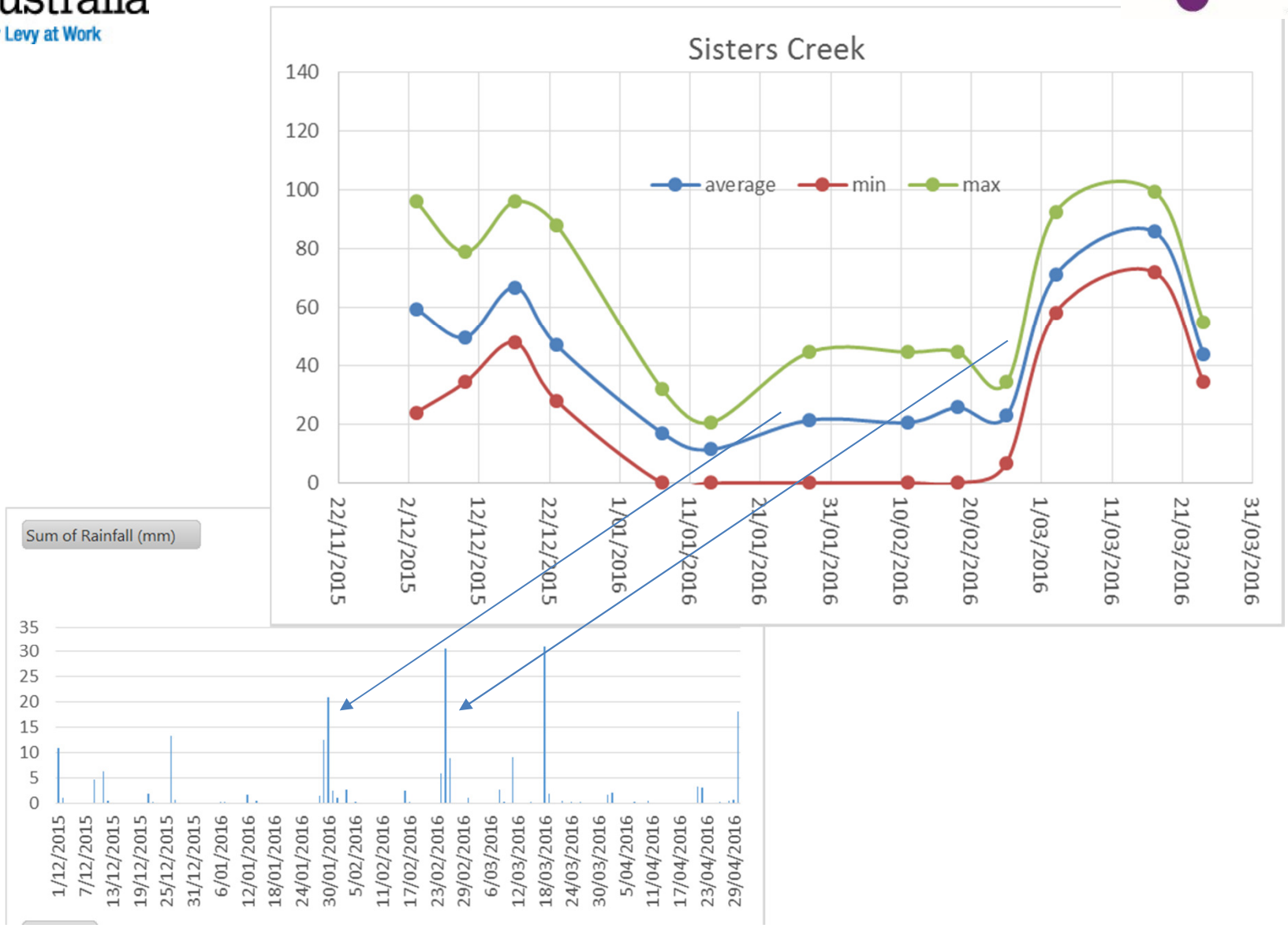
Rocky Cape site



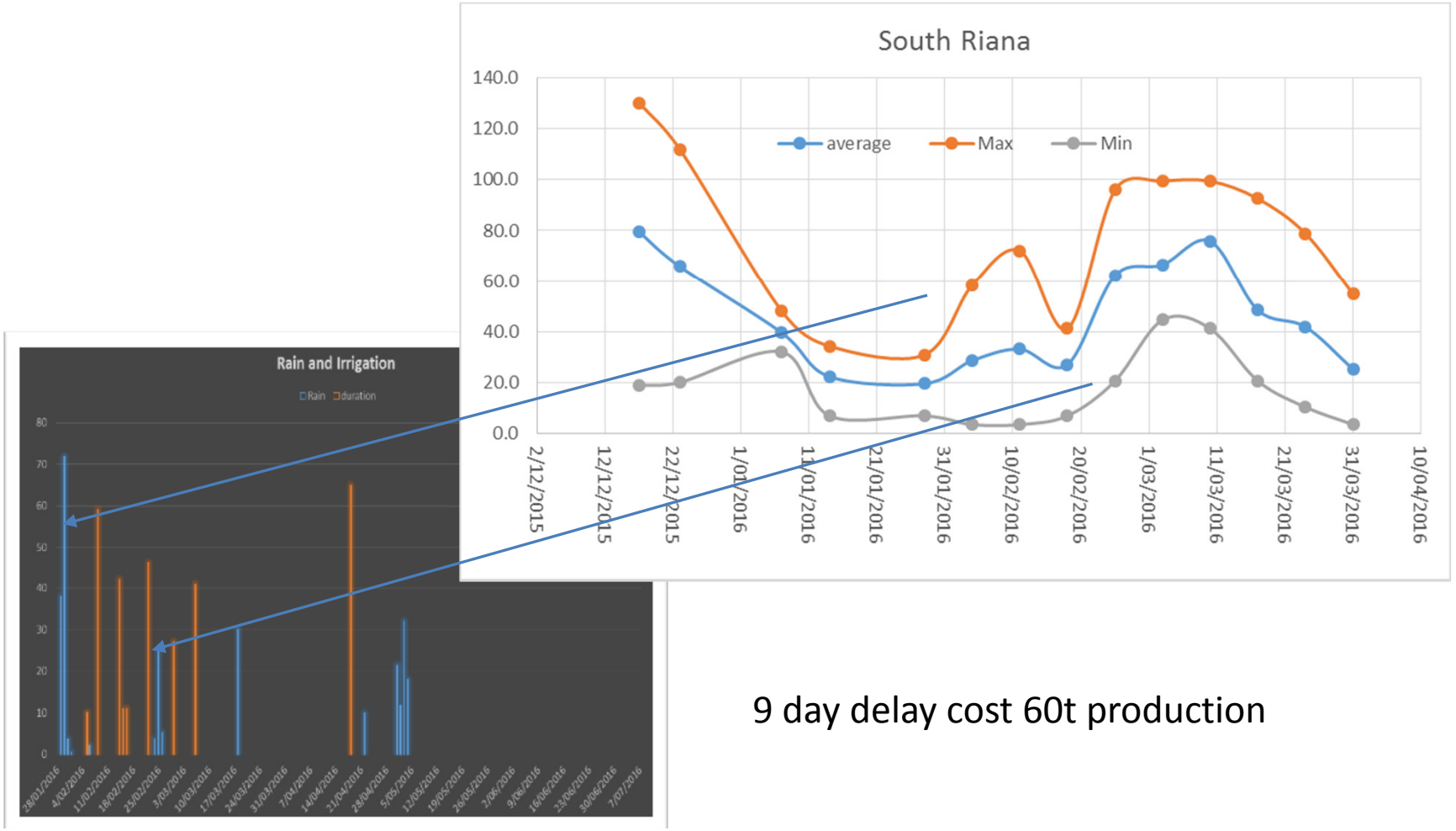

Rocky Cape
Average
Max
Min
140
120
100
80
60
40
20
0
22/11/2015
2/12/2015
12/12/2015
22/12/2015
1/01/2016
11/01/2016
21/01/2016
31/01/2016
10/02/2016
20/02/2016
1/03/2016
11/03/2016
21/03/2016
31/03/2016


Pump and Rain/Tasmac Dairy
kWhr Draw
Rain Gauge

Sisters Creek site


Sisters Creek
140
120
100
80
60
40
20
0
average
min
max
22/11/2015
2/12/2015
12/12/2015
22/12/2015
1/01/2016
11/01/2016
21/01/2016
31/01/2016
10/02/2016
20/02/2016
1/03/2016
11/03/2016
21/03/2016
31/03/2016
Sum of Rainfall (mm)
35
30
25
20
15
10
5
0
1/12/2015
7/12/2015
13/12/2015
19/12/2015
25/12/2015
31/12/2015
6/01/2016
12/01/2016
18/01/2016
24/01/2016
30/01/2016
5/02/2016
11/02/2016
17/02/2016
23/02/2016
29/02/2016
6/03/2016
12/03/2016
18/03/2016
24/03/2016
30/03/2016
5/04/2016
11/04/2016
17/04/2016
23/04/2016
29/04/2016

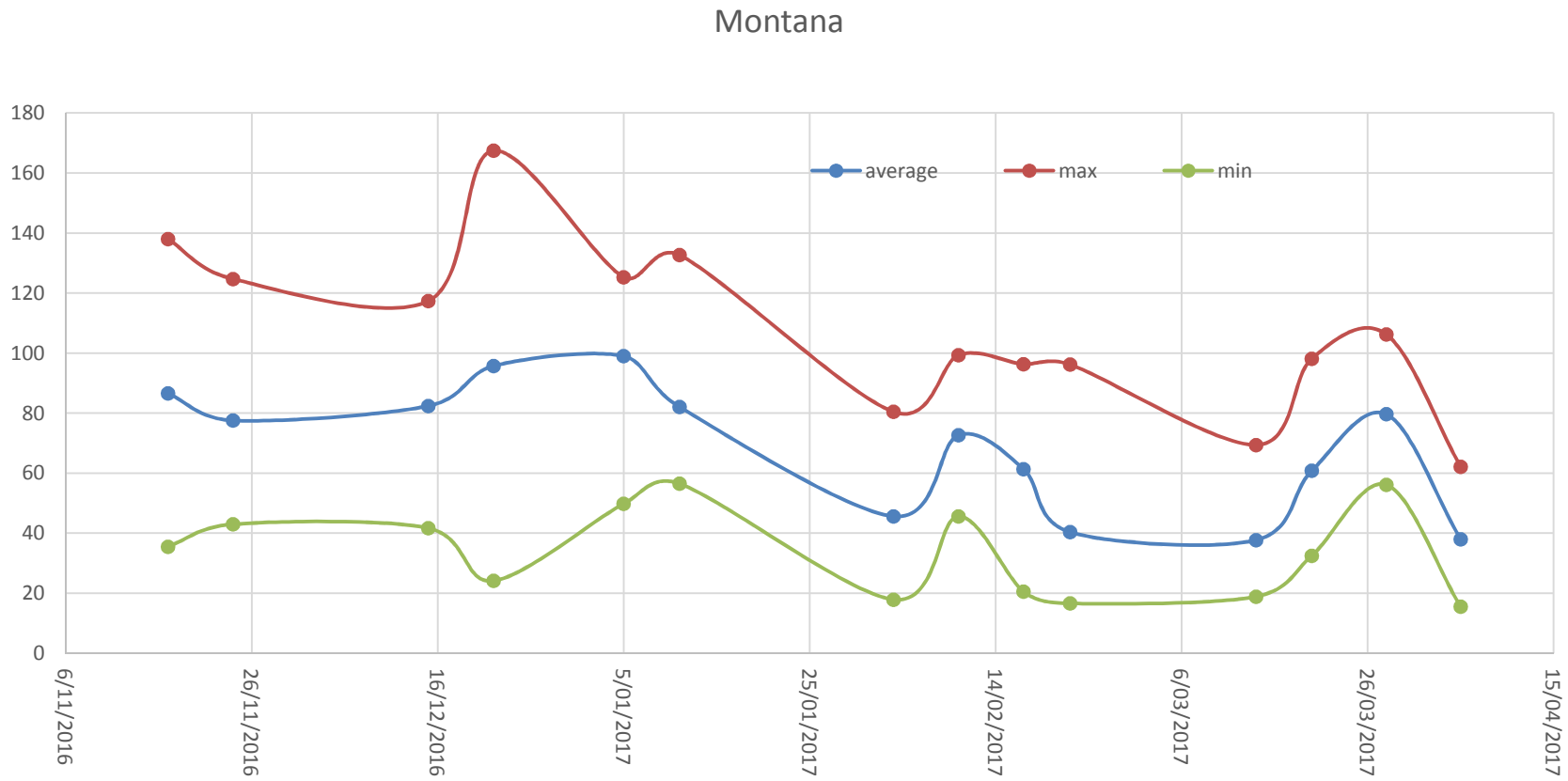
South Riana site



9 day delay cost 60t production

Montana site

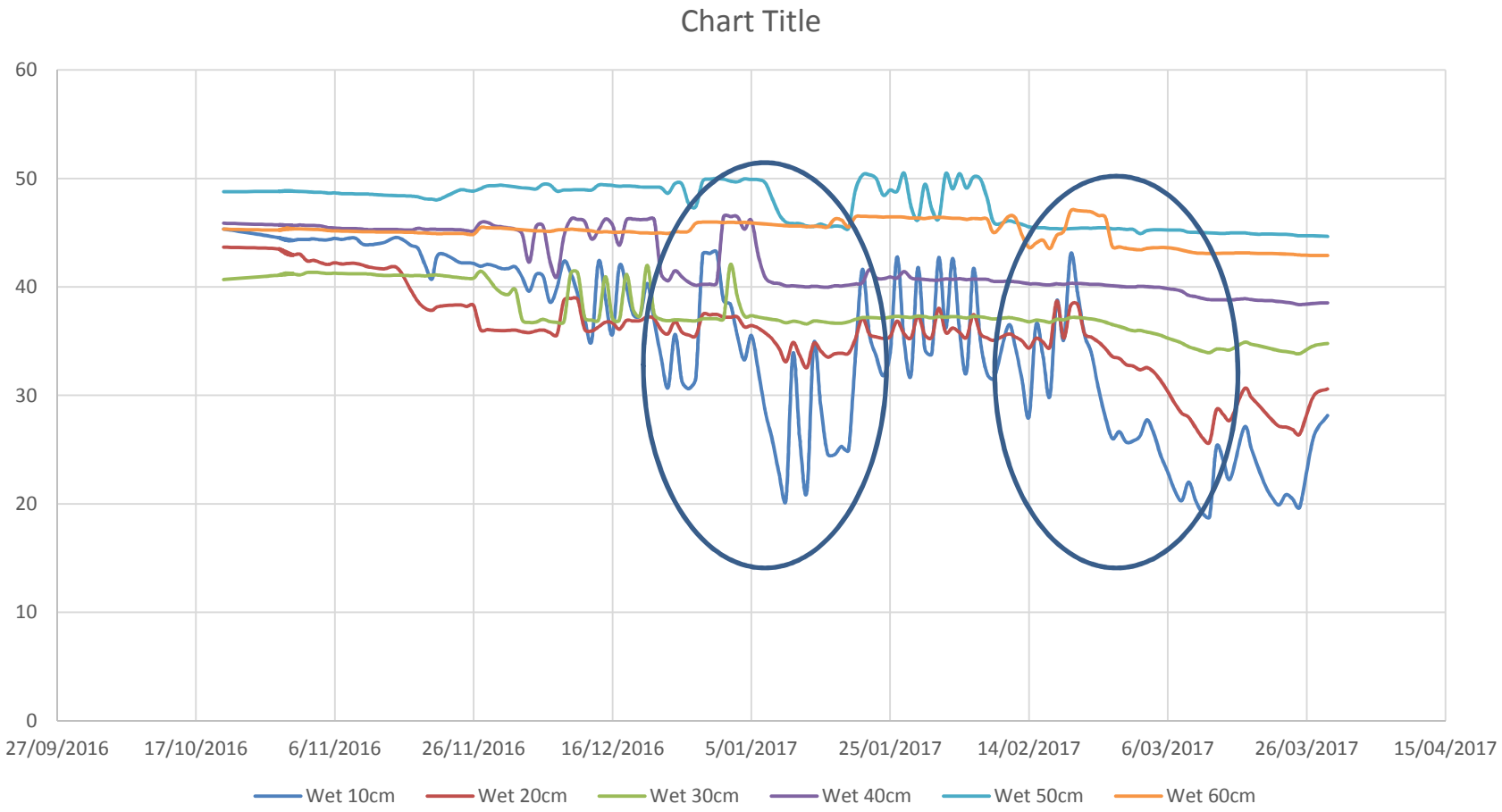
2016/17 Pasture growth rates



Suction issues

Labour change

2016/17 Soil moisture



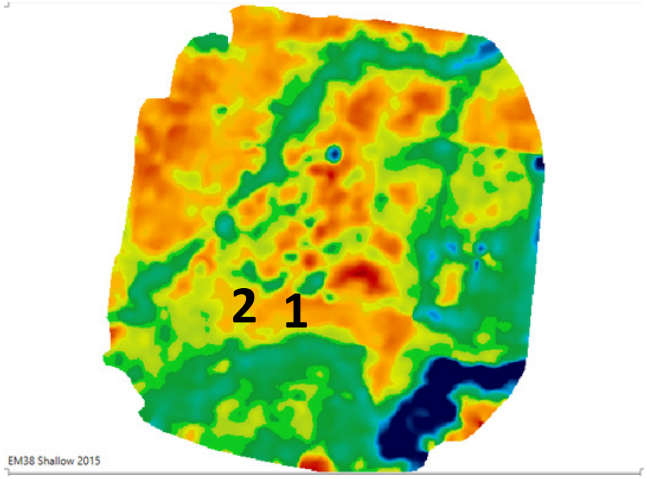
Summary

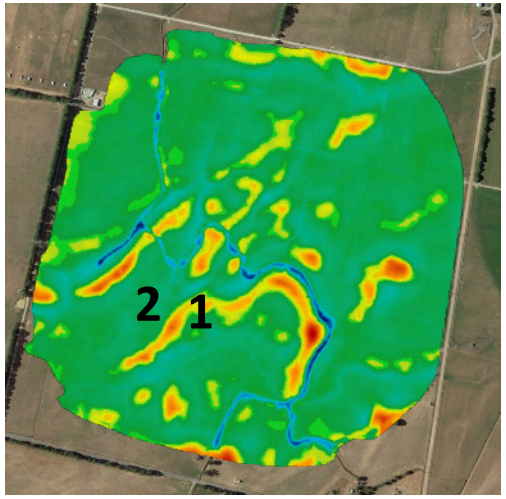
- Don’t delay startup of irrigation
- Beware of the Green Drought
- You can overwater - respond to the season
- Poor watering costs production and money

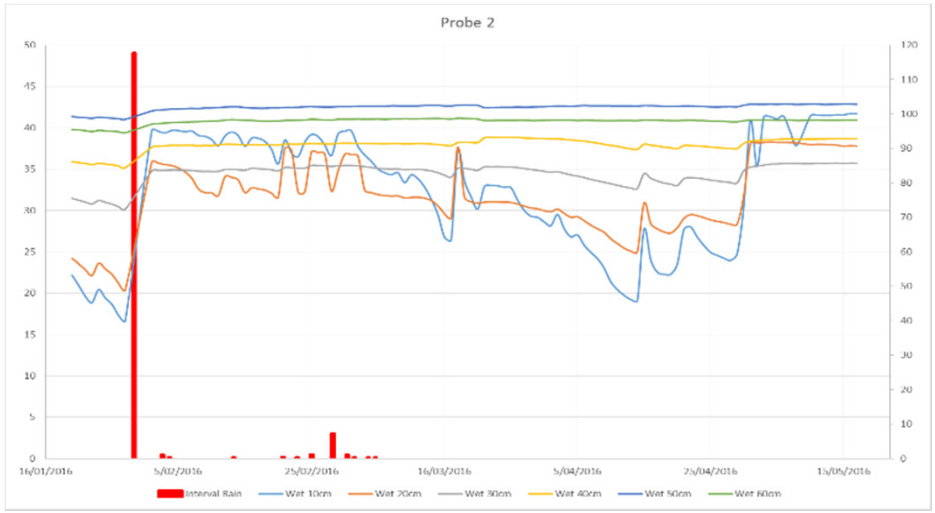
Variable rate irrigation

- Why variable rate irrigation?
- To manage variability due to
  - Management and infrastructure
    - laneways
    - Locking up paddocks for silage
    - Renovation of specific paddocks
    - Different crops under 1 pivot
  - Climate and temporal change
  - Soils and topography

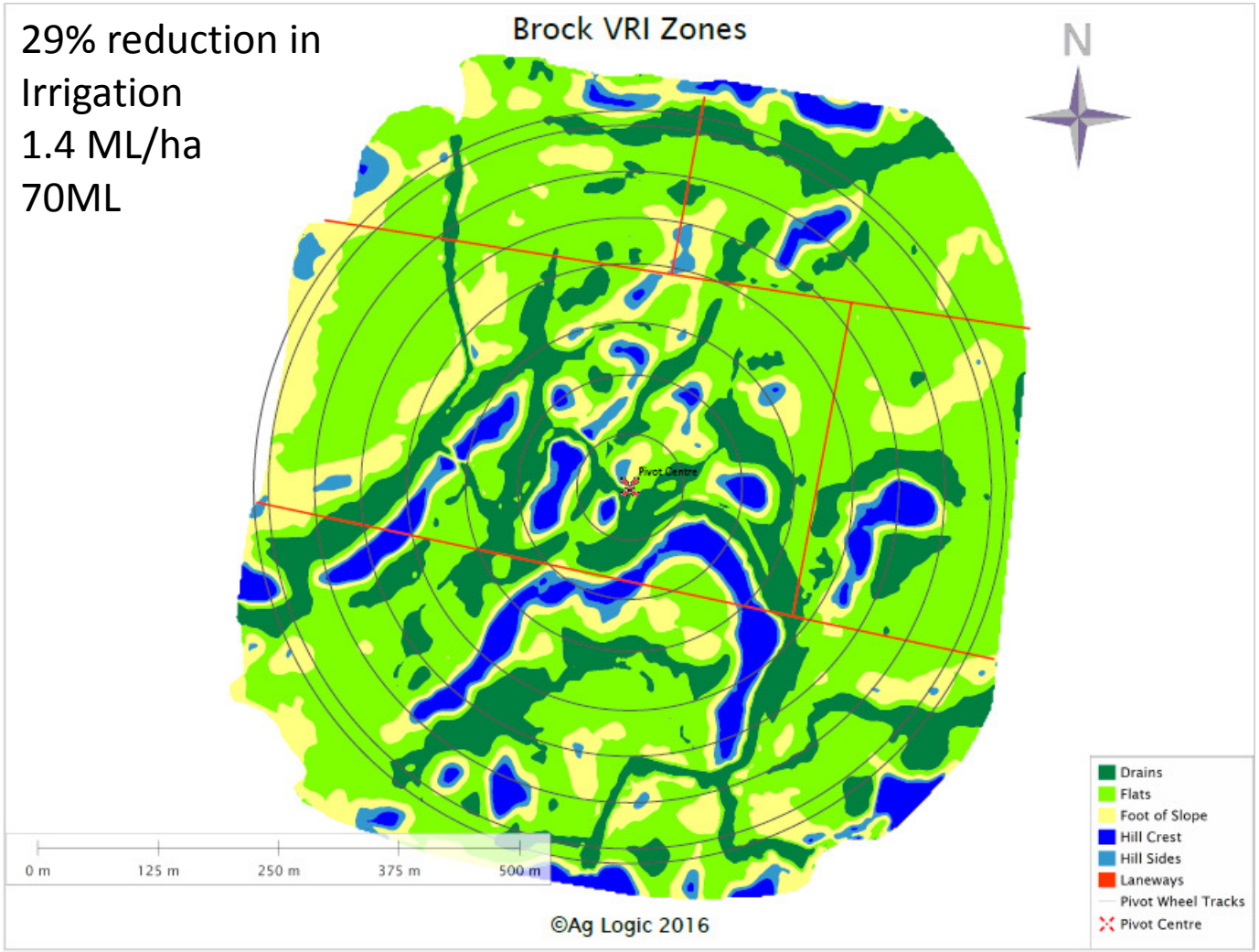
Soils and topography





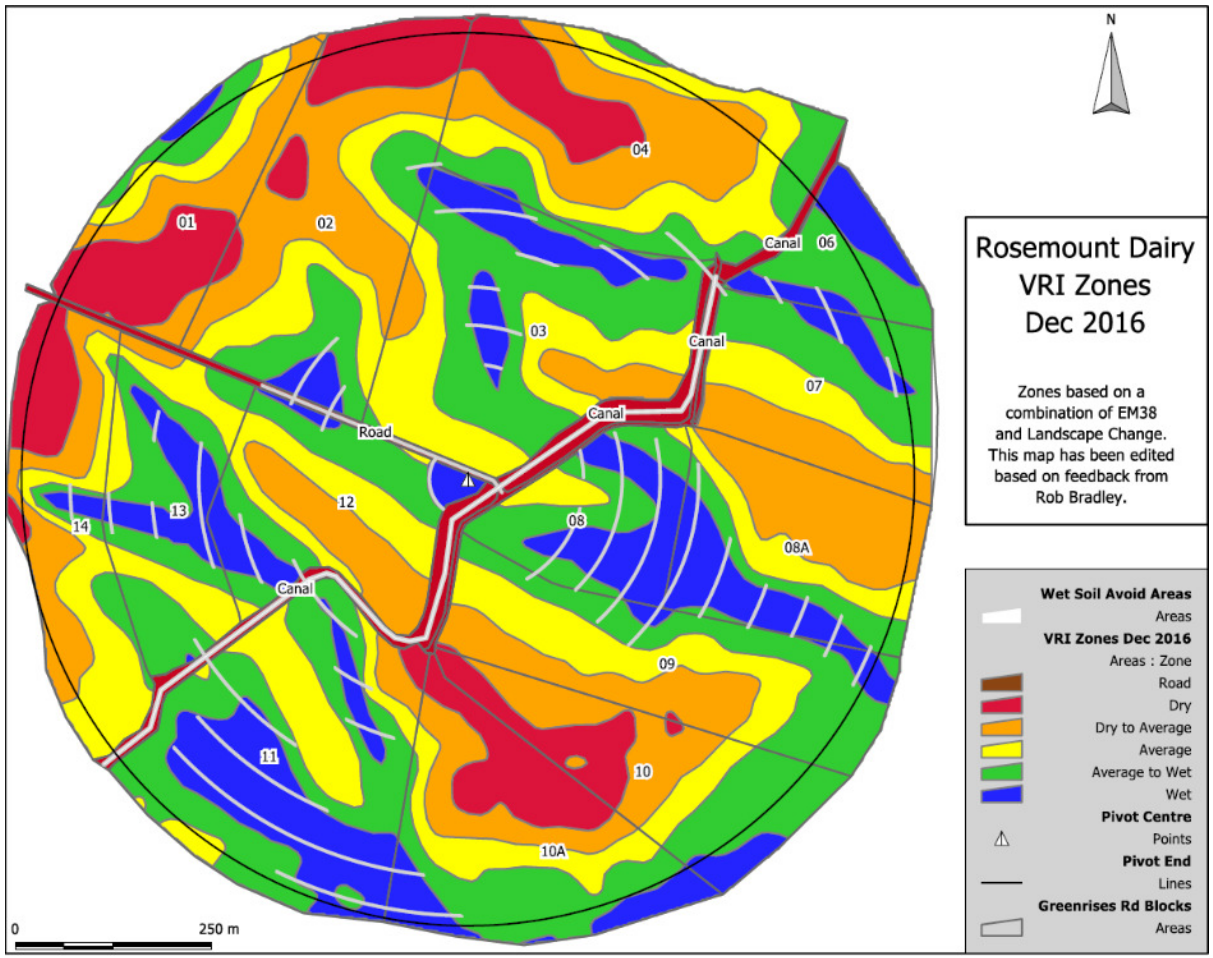


29% reduction in Irrigation
1.4 ML/ha
70ML

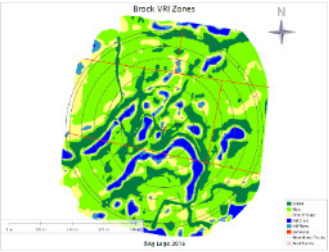


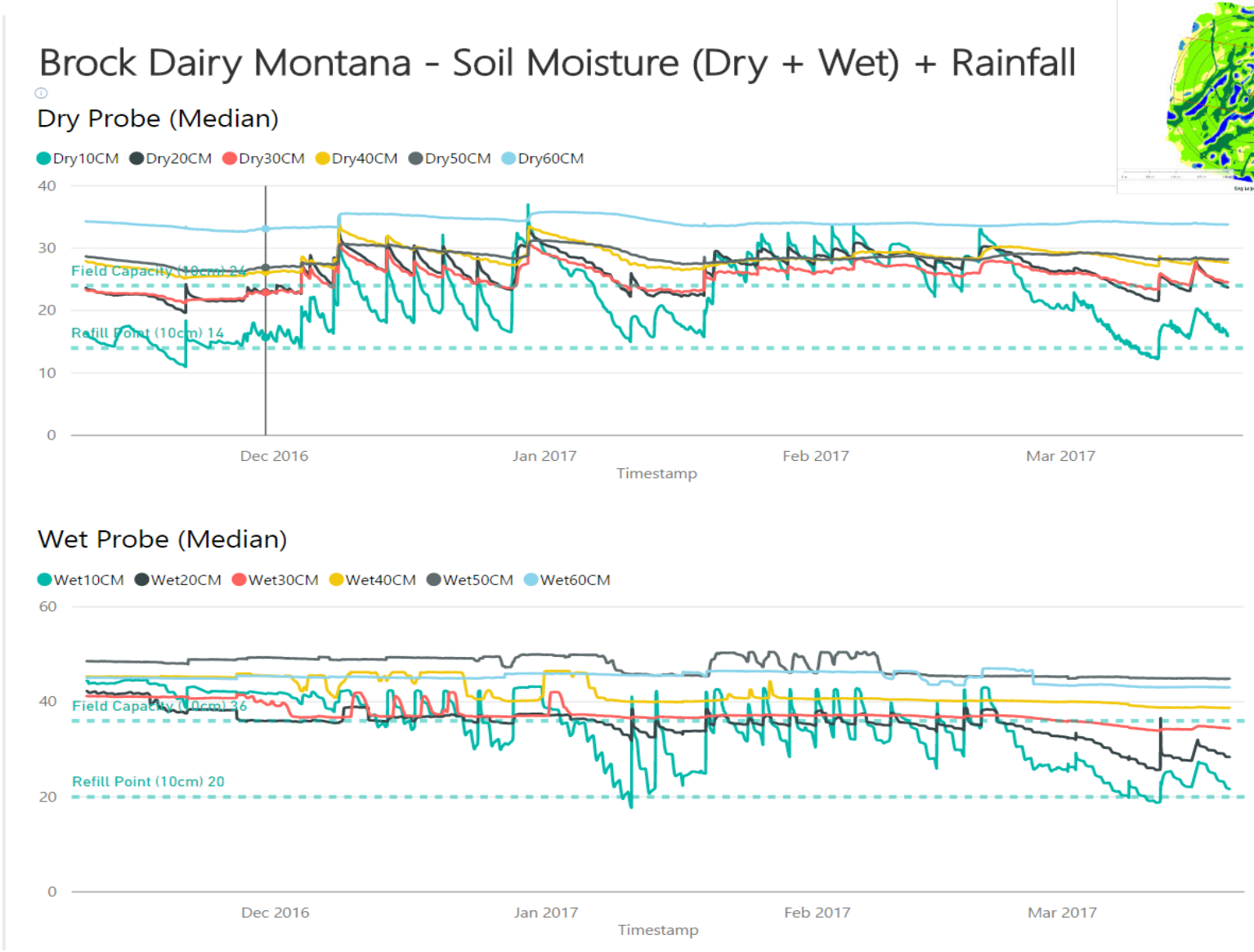
Cressy

34% reduction in irrigation 2ML/ha

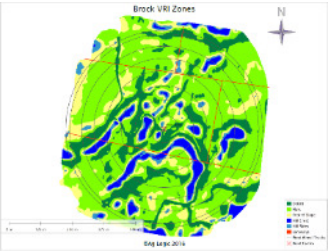


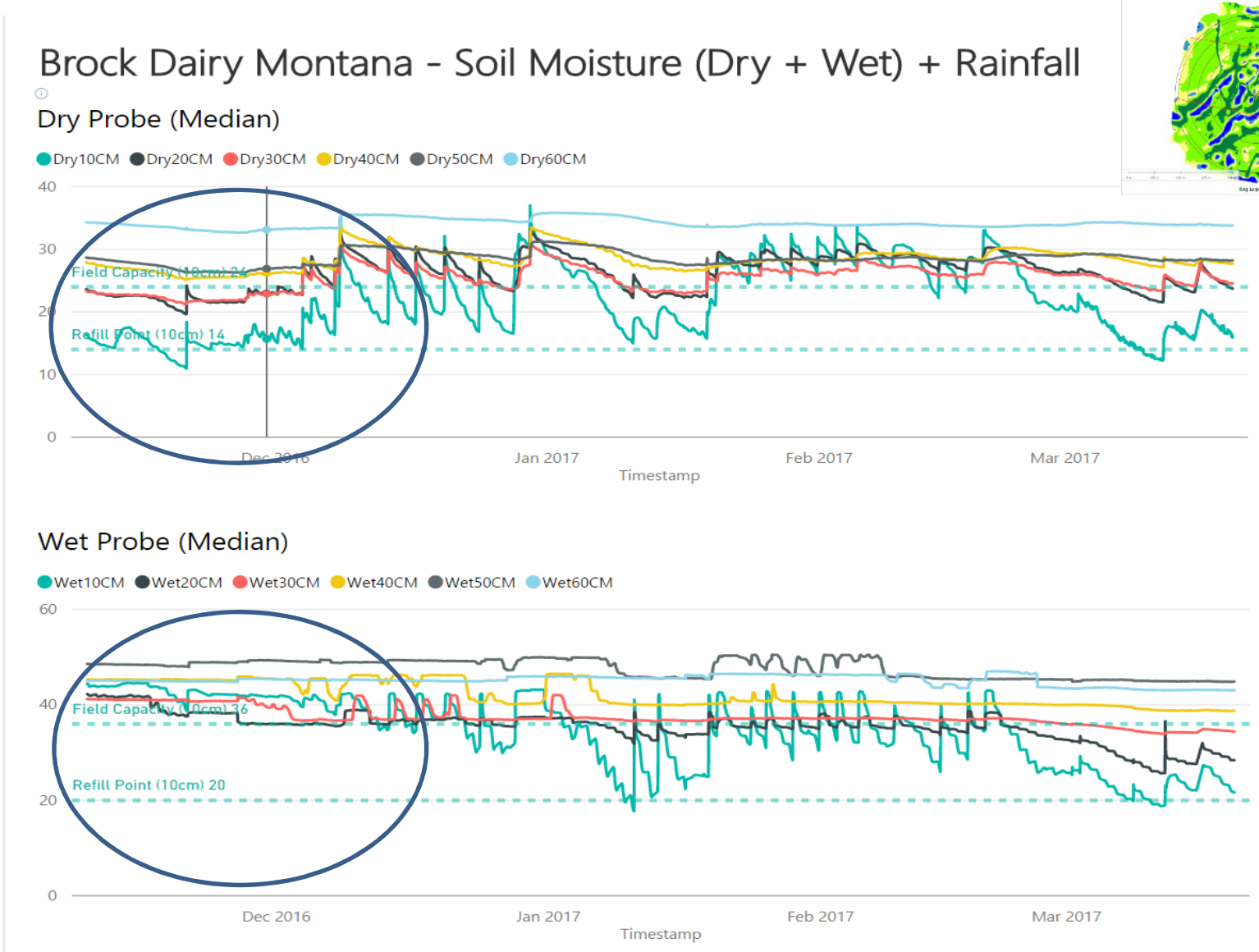
Managing variability over time



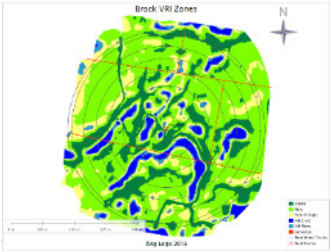


Managing variability over time





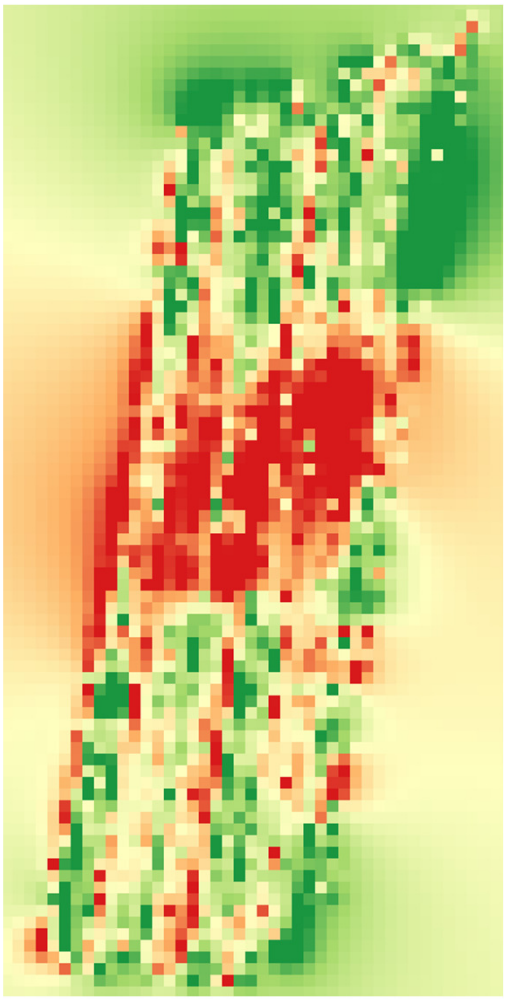
Managing variability over time



PAR - Feedbase - **M & M**

C-Dax yield map - **Hump and Hollow and un-even**

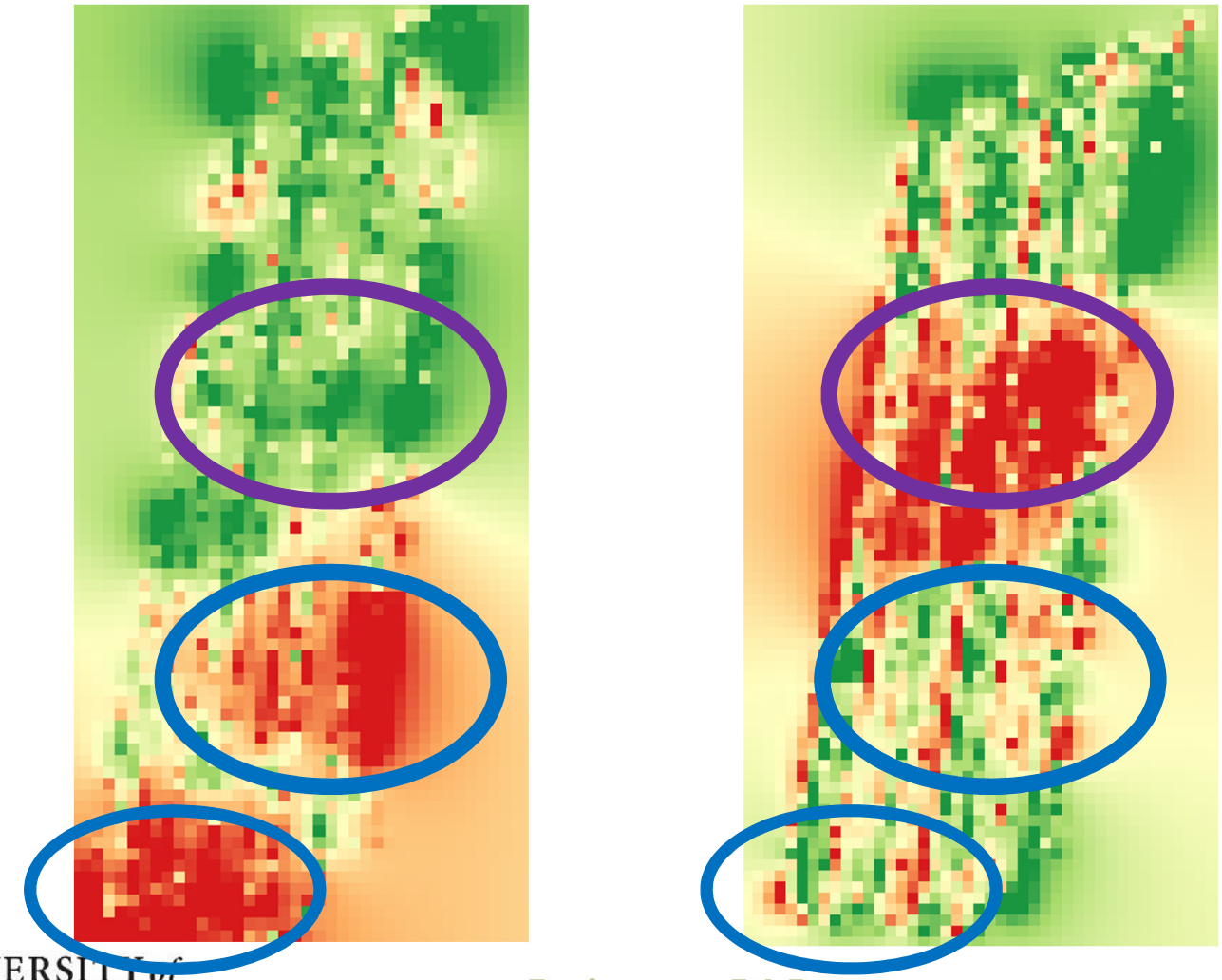
- **Early Dec 2016** - Low, **wet**, no yield **Mar 2017** - High, **dry**, no yield



PAR - Feedbase - **M & M**

C-Dax yield map - **Hump and Hollow**

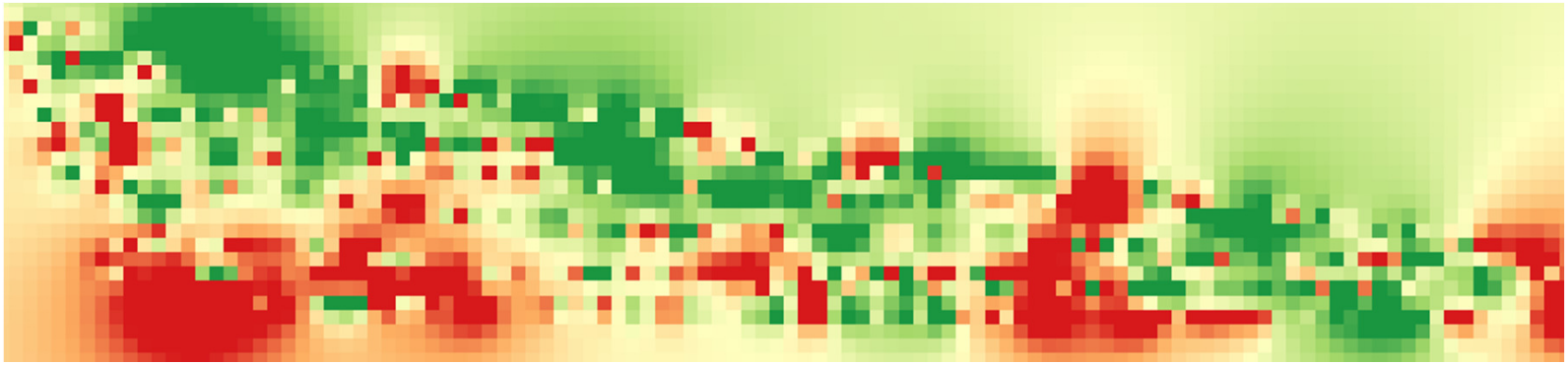
- **Early Dec 2016** - Low, **wet**, no yield **Mar 2017** - High, **dry**, no yield



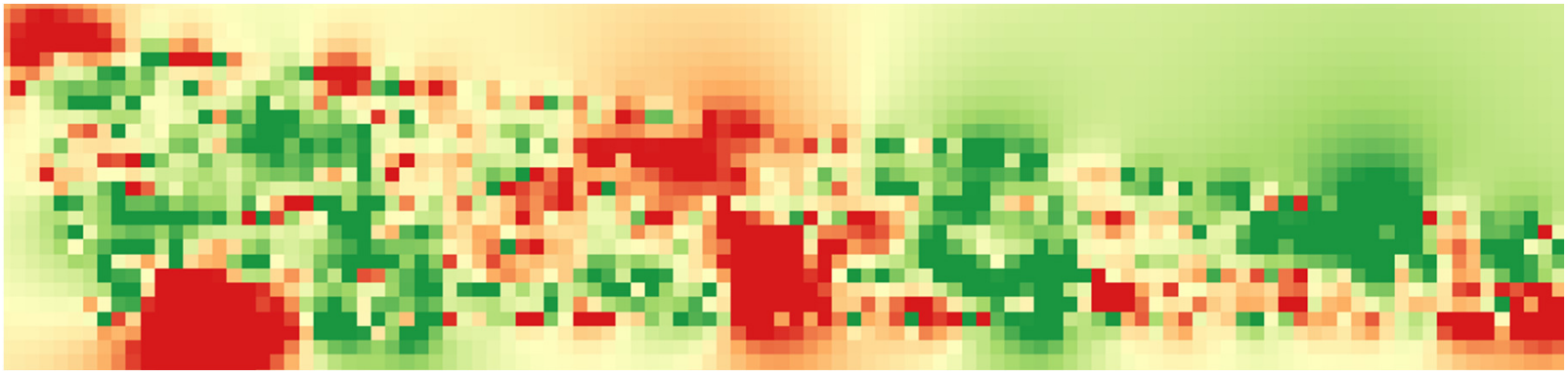
PAR - Feedbase - **M & M**

C-Dax yield map - **Uneven paddock**

- **Early Dec 2016** - Low, wet, no yield



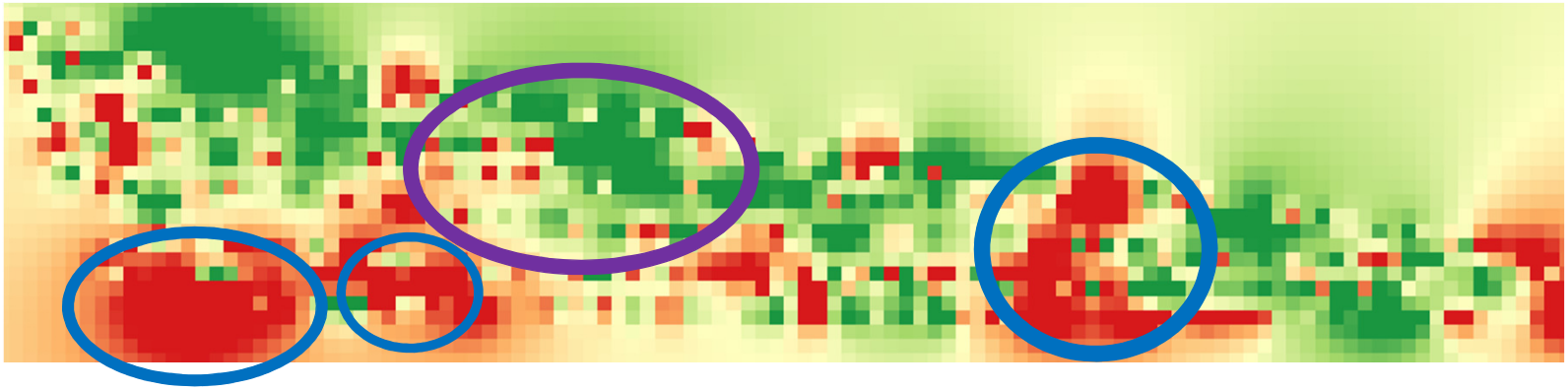
- **Late Feb 2017** - High, dry, low yield



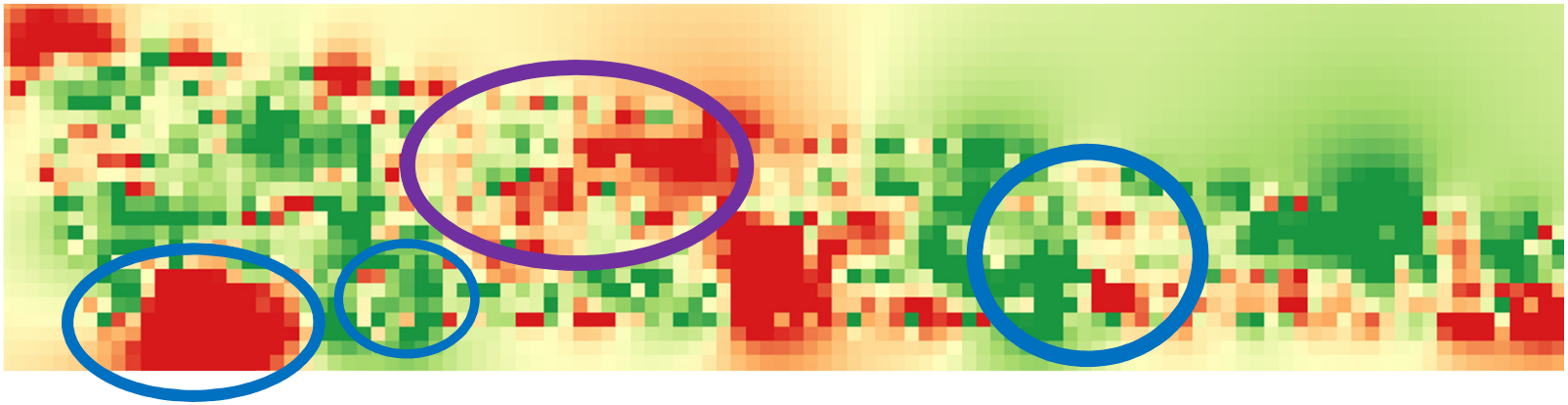
PAR - Feedbase - **M & M**

C-Dax yield map - **Uneven paddock**

- **Early Dec 2016** - Low, wet, no yield



- **Late Feb 2017** - High, dry, low yield



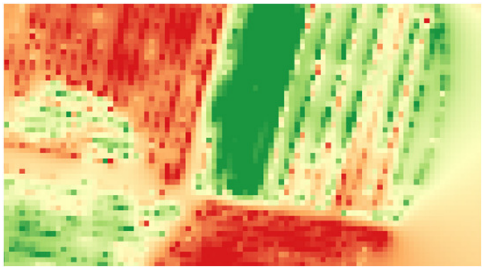
VRI payback (need more data)

Details	Water saving	Improved production	both
Pivot (ha)	55	55	55
Extra production consumed tDM/ha	0	1	1
Value of extra feed $/tDM	250	250	250
Water saving ML/ha	1.4	0	1.4
Value irrigation water saved $/ML	100	100	100
Capital costs $	47225	47225	47225
Years to pay back	9	3	Less than 2

Improved production?

- Can we expect improved production due to VRI technology? (not just improved irrigation scheduling!)
- Depends on the current variability on the site and the reason for this variability
  - Nutrients
  - Compaction
  - Water

Spreader variability? - Montana



Summary

- Need to ground truth your fancy variability maps
- VRI's can save water
- VRI zone management changes through the season
- VRI payback depends on growing more grass
- VRI won't fix a fertiliser, compaction or drainage problem

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From Precision to Decision

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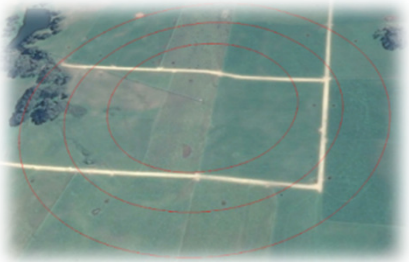
Automation with VARIwise

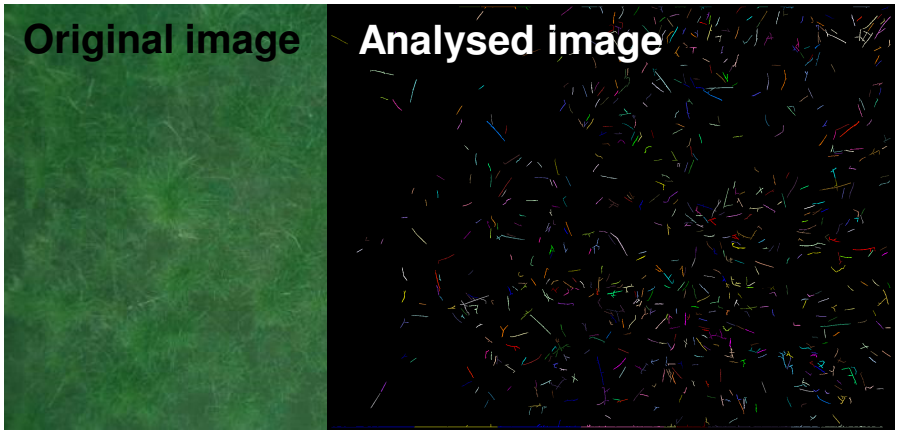
Cameras on Pivots

- Pasture height used for irrigation
- Height is measured using quad bike sensor
- Smartphone-based cameras on pivot upload image and location



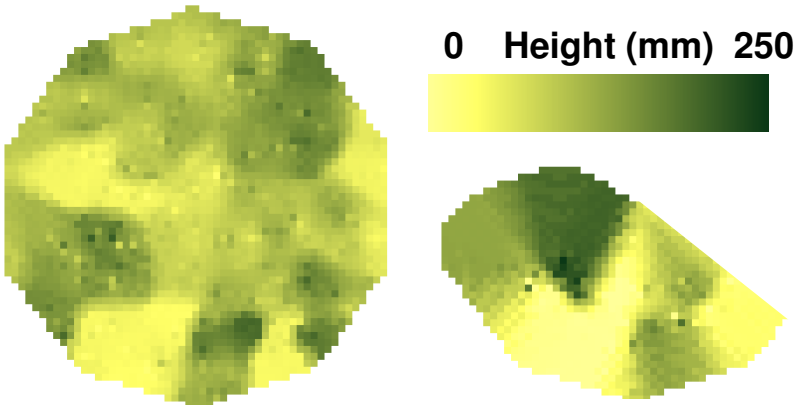
Automated irrigation for dairy pastures

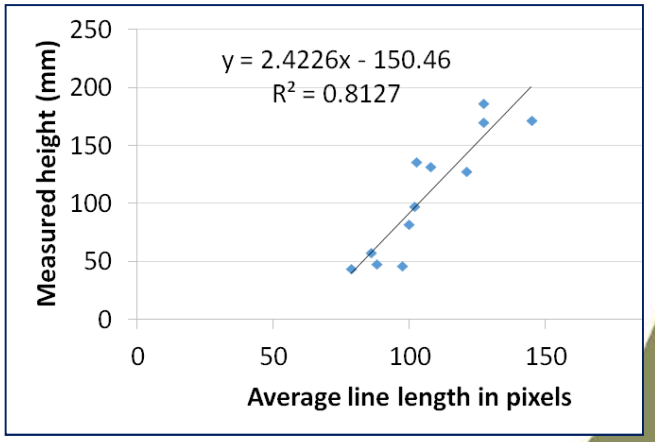
- Image analysis extracts average leaf length in camera image
- Compared with weekly quadbike height data



Height from quad bike sensor

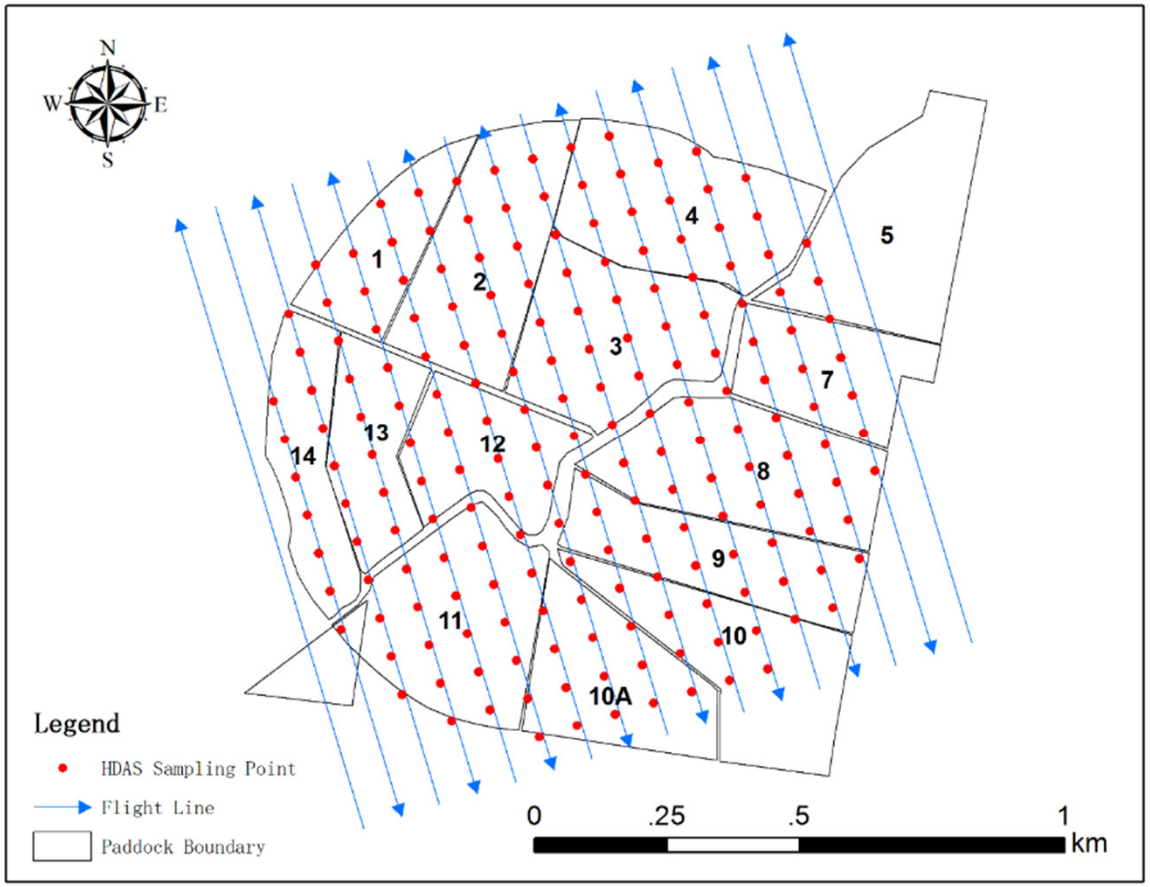
Canopy cover from cameras





Spatial measurement of soil moisture

Sampling grid



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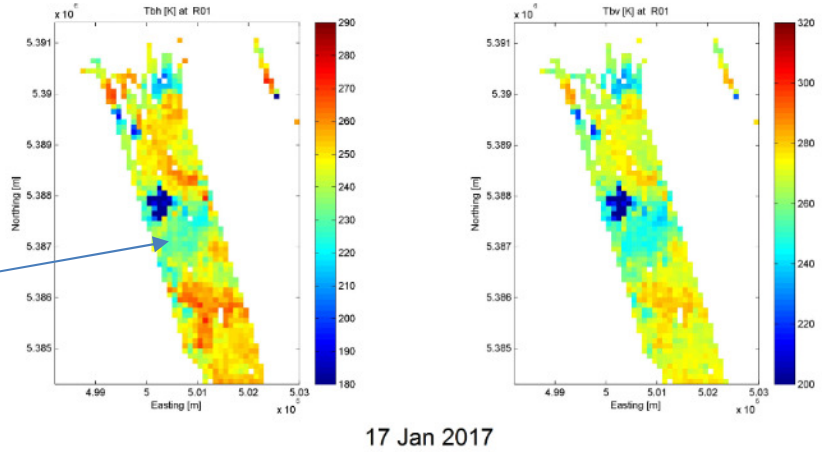
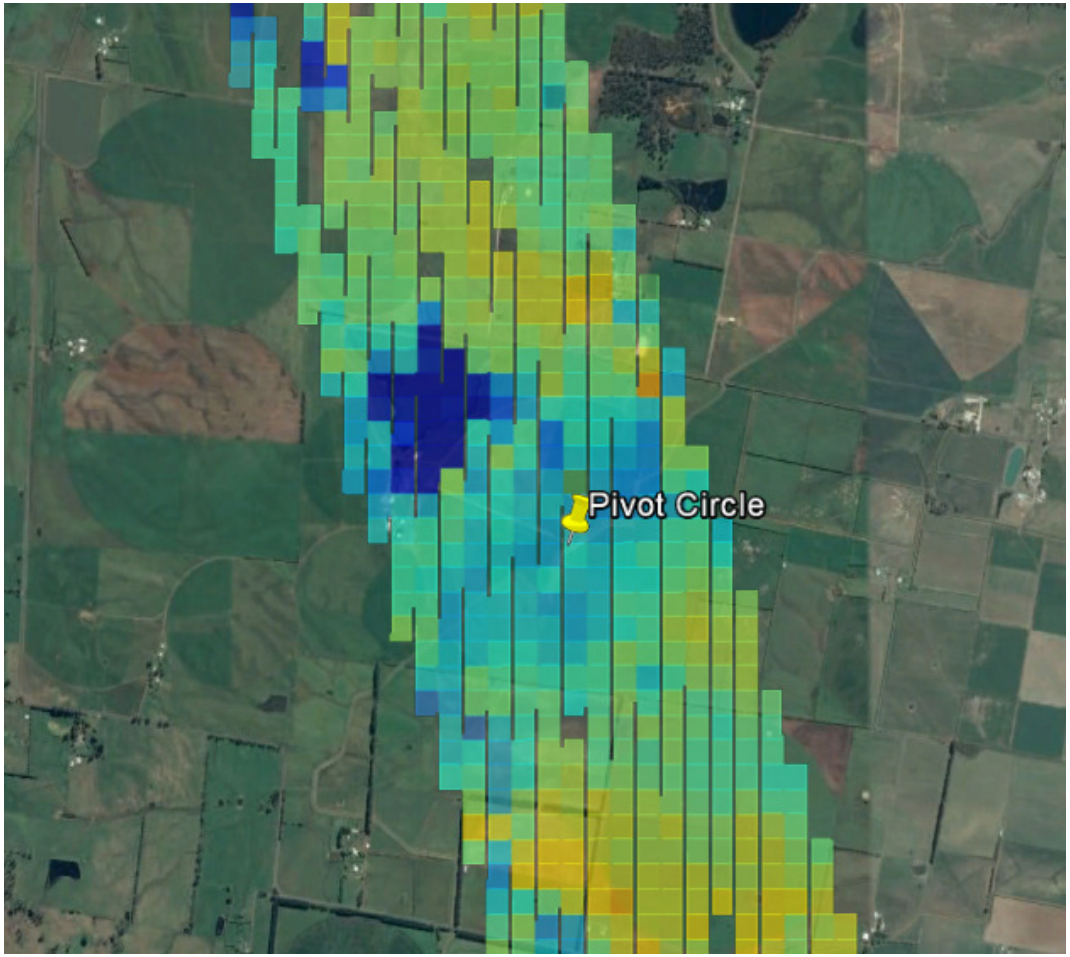
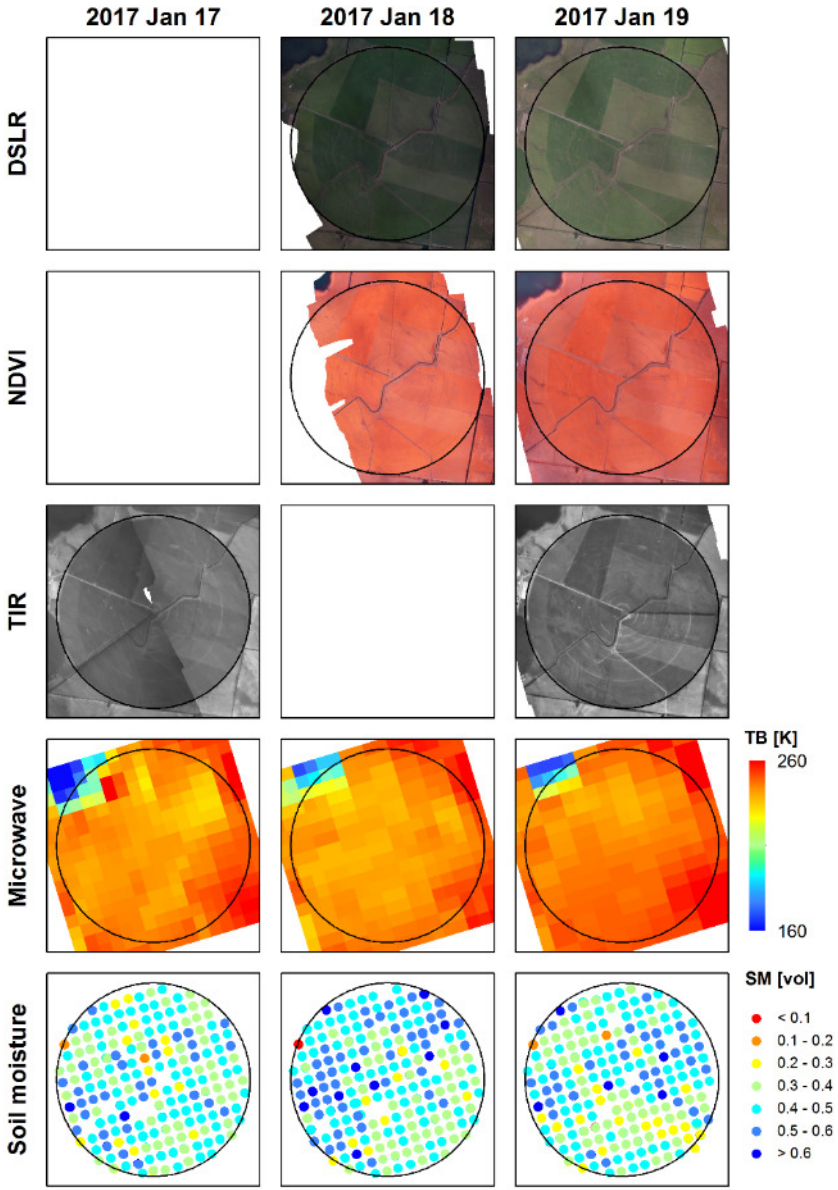
Brightness / temperature maps from Plane

Pivot circle



Preliminary L-Band Radiometer image




2017 Jan 17
2017 Jan 18
2017 Jan 19
DSLR
NDVI
TIR
Microwave
Soil moisture
TB [K]
260
160
SM [vol]
< 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
> 0.6

Where to from here?

- End of season workshops
- 2017/18 planning session

- Autonomous control testing in 2017/18 season
- VRI economic analysis

- engaging beyond the participating farmers
- Measuring impact

Cressy site

Take home messages

- Don’t assume your system is right – checking it could save you lots of money
- Getting irrigation startup and scheduling wrong costs money
- VRI payback depends on growing more grass
- Information alone is not enough – need to go from information to application or precision to decision

Acknowledgements

David McLaren, TIA
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Department of Agriculture and Water Resources

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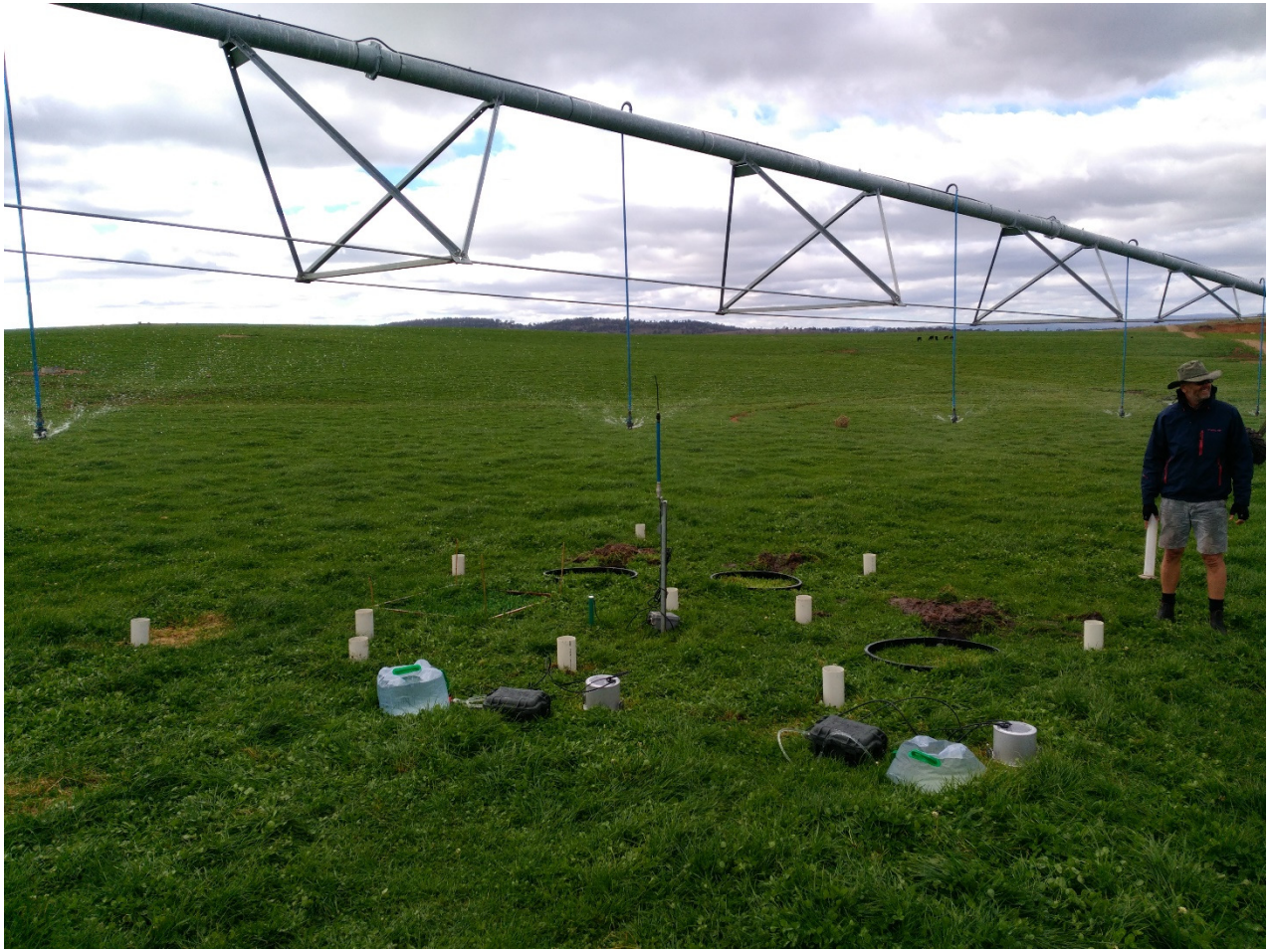
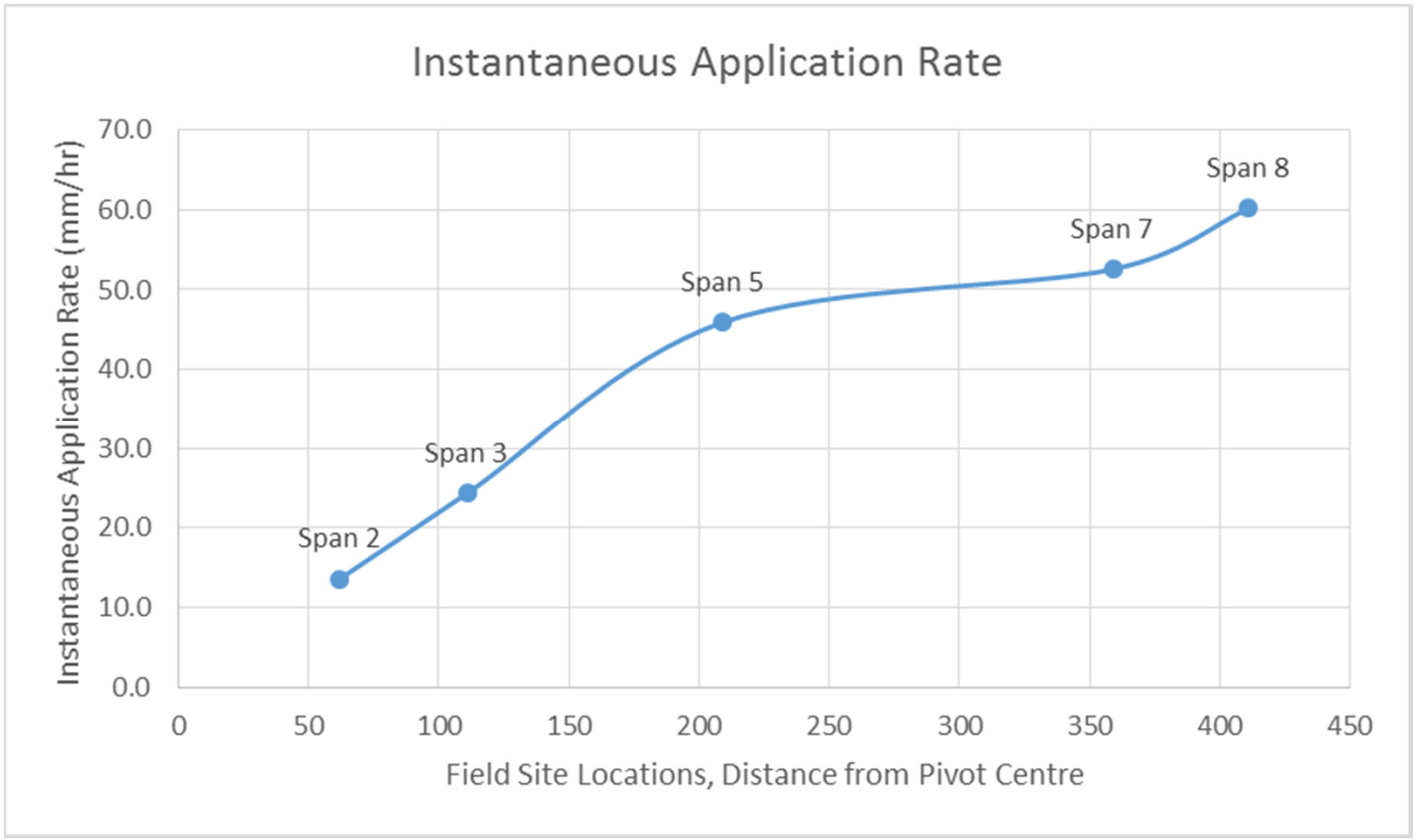
NCEA
National Centre for Engineering in Agriculture

Tunbridge site and infiltration

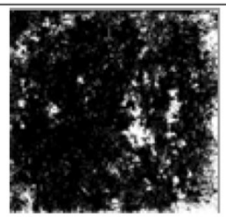
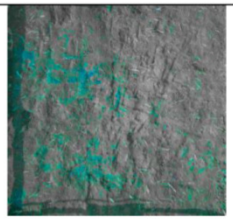
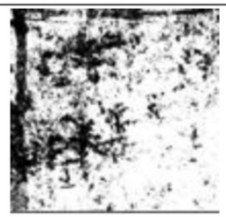
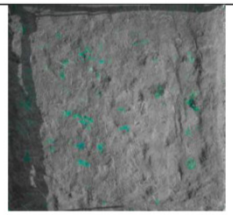
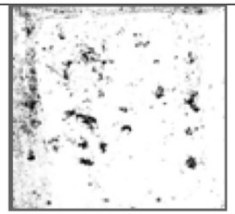
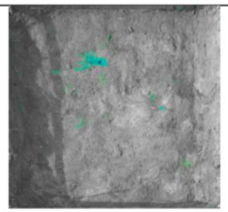
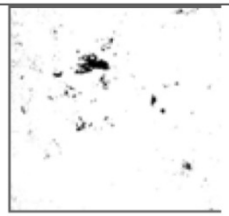
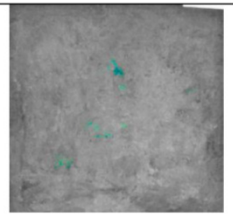
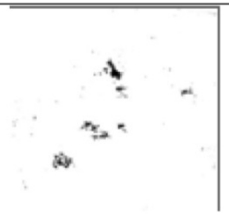
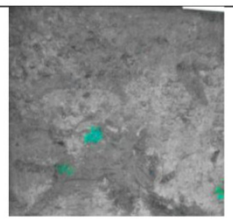
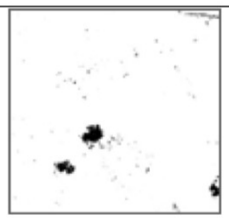
Pivot details

- Pivot length 453 meters
- Area irrigated – 64.4 Ha
- Application rate 59.66 L/s
- Sprinkler package 8mm
- Average application 14.02 mm

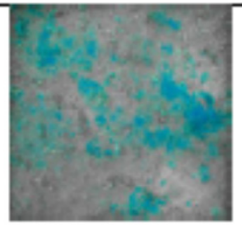
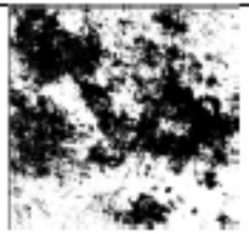
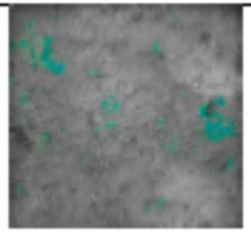
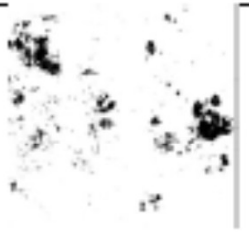
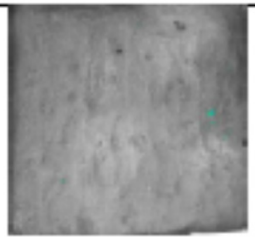
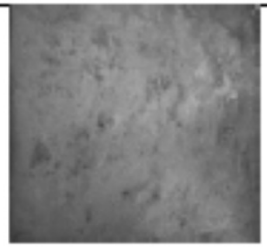



Instantaneous Application Rate
Instantaneous Application Rate (mm/hr)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
50
100
150
200
250
300
350
400
450
Span 2
Span 3
Span 5
Span 7
Span 8
Field Site Locations, Distance from Pivot Centre

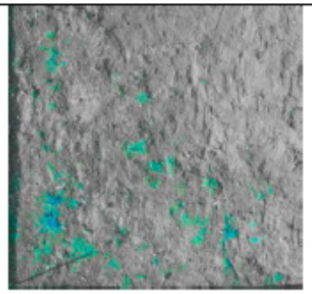
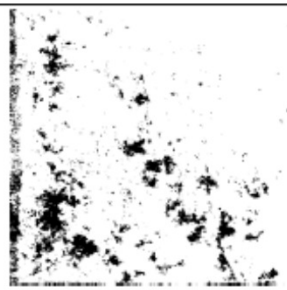
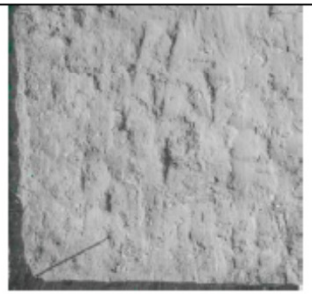
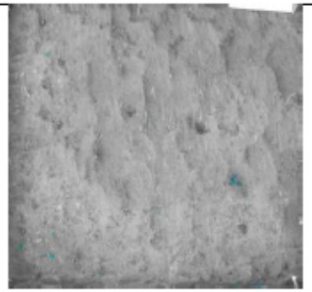
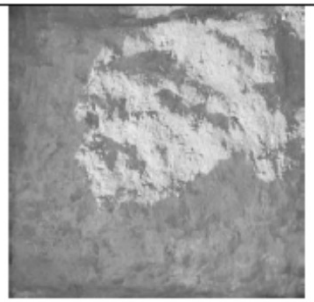
Field Sites	Runoff %
Span 2	23.1%
Span 3	35.8%
Span 5	24.9%
Span 7	41.5%
Span 8	40.3%

Site 1 span 2 ground level			Total no of Pixels: 4267131 Black Pixels: 3630671 85.08 % Black
Site 1 span 2 depth 2.5 cm			27.35 %
Site 1 span 2 depth 5 cm			6.06 %
Site 1 span 2 depth 10 cm			1.82 %
Site 1 span 2_e depth 15 cm			1.00%
Site 1 span 2 depth 25 cm			1.5%

Site 2 Span 5

Site 2 span 5 ground level			46.08 % Black
Site 2 span 5 depth 2.5 cm			6.04 %
Site 2 span 5 depth 5 cm			0.20 %
Site 2 span 5 depth 10 cm			0.00 %
Site 2 span 5 depth 15 cm			0.00 %

Site 3 Span 8

Site 3 span 8 ground level			9.71 % Black
Site 3 span 8 2.5cm depth			0.56 %
Site 3 span 8 5cm depth			0.53 %
Site 3 span 8 10cm depth			0.00 %