

# Final report to DairyTas on Small Grant "Promotion of water use efficiency and pasture productivity in the Tasmanian dairy industry"



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## **Review of the outcomes proposed in the original project plan**

1. *The project will monitor soil fertility, nitrogen (N) use, water use, soil moisture and pasture yield on 3 farm sites and at Elliot Research and Demonstration Station (ERDS).*

This outcome has been exceeded. The project included an additional 2 commercial farm monitoring sites, on which irrigated pasture only was monitored.

2. *The monitoring will accurately relate water use to pasture growth, soil nutrient levels and N fertiliser use.*

This has been achieved through the installation of soil moisture monitoring equipment at all sites, assessment of the quantity of additional pasture grown in relation to the amount of irrigation applied, and the correlation of pasture growth rate to soil fertility levels under both dryland and irrigated conditions. Detailed monitoring of soil fertility, pasture nitrate levels, feed quality and pasture production was undertaken.

3. *Field days at each of the sites will extend the results from the study as well as previous related studies run by the Tasmanian Institute of Agricultural Research (TIAR), Serve-Ag and the Department of Primary Industries and Water (DPIW). Farmers will get a better understanding of how pasture inputs affect pasture production.*

A series of 4 field days were held between 9 and 12 May 2006 on participating farms at Mella, East Ridgley, Mersey Lea and Ringarooma. These field days were well attended by a total of 120 farmers and service providers. Results from the current study (as well as from previous studies undertaken by TIAR and DPIW) were presented.

## **Background**

Staff from TIAR monitored production of 7 forage species under irrigation at ERDS over the last 2 summer seasons and found significant differences in yield and water use efficiency (WUE) between species.

DPIW staff monitored soil moisture, water use and pasture production on a number of dairy farm sites in the summer of 2004/05 and found that substantial differences existed between farms in the amount of additional pasture produced as a result of irrigation (i.e. WUE varied between farms). The limited monitoring at these sites did not enable the reasons for differences in WUE to be identified.

Increased pasture production is a priority on all Tasmanian dairy farms but farmers need to know what response they can expect to get from different water use and irrigation frequency, soil fertility levels and N application. The N-check tests available from Serve-Ag are a useful tool for the management of N fertiliser application. N-check testing and monitoring of pasture production following N application will give farmers a greater understanding about the reliability of the tests.

## **Summary of results**

Due to the short irrigation season, only low amounts of irrigation water were applied, ranging from 1.75 ML/ha at Mersey Lea to 3.29 ML/ha at Ringarooma. The average amount of irrigation applied was 2.5 ML/ha which resulted in an average pasture utilisation of 6.3 t DM/ha. A high level of pasture utilisation was achieved under irrigation on all 6 sites between January and April. The highest level of pasture utilisation was achieved at Ringarooma with 7.5 t DM/ha utilised over this period.

Pasture utilisation under dryland conditions in the same period varied between sites. The lowest dryland pasture utilisation was at ERDS, where only 1.3 t DM/ha was utilised during this period. In comparison, 2.6 and 3.0 t DM/ha of pasture was utilised at Mella and Ringarooma, respectively.

The mean irrigation response across all sites was 1.7 t DM/ML, and ranged from 2.7 t DM/ML at Mersey Lea to 1.35 t DM/ML at Mella. This mean response was significantly higher than the 1.0 t DM/ML often quoted as the dairy industry average.

## **Further studies**

This project has been a pilot study for a larger project "Water Use and Nutrient Management on Tasmanian Dairy Farms", which will intensively monitor pasture production, irrigation and nutrient management on 18 commercial dairy farms across 3 dairy catchments over a 3 year period. This project is funded by the National Landcare Program and is contracted through DairyTas to TIAR.

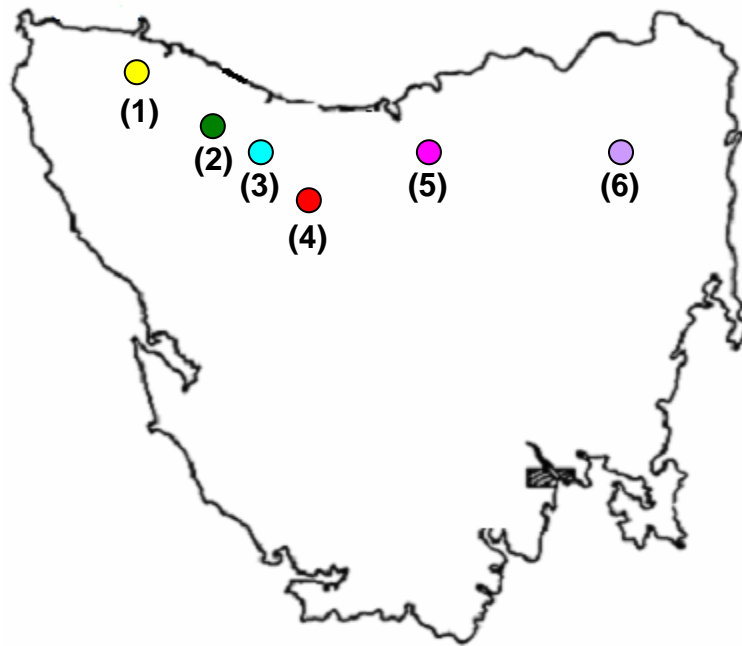
## **Acknowledgements**

We would like to thank the DairyTas Board for supporting this project and the dairy farmers involved for their significant contribution to this project. We would also like to thank Mark Freeman and Lesley Irvine from DPIW Dairy Branch for their support in monitoring ERDS, and Dave O'Donnell and Gordon Tuck from DPIW Vegetable Branch for their assistance with the installation of irrigation equipment.

## **Methods**

### *Location of sites*

Six dairy farms located from the North-West to the North-East of Tasmania took part in this study (Plate 1). Sites were established on commercial dairy farms at Mella, East Ridgley and Riana in the North West, Mersey Lea in the North, and Ringarooma in the North East of the state. An additional site was established at ERDS. Only irrigated paddocks were monitored at the East Ridgley and Riana sites, while both dryland and irrigated paddocks were monitored at all other sites. The irrigation season for 2005/06 was short due to above average rainfall in spring and early summer. As a result of this, detailed pasture assessment under irrigation did not commence until January 2006. Pasture production was monitored intensively at all sites for the following 4 months. Irrigation application ceased in late April 2006.



Site number	Location	Irrigation
1	Mella	K-Line
2	ERDS	Fixed
3	East Ridgley	K-Line
4	Riana	Travelling gun
5	Mersey Lea	Centre pivot
6	Ringarooma	Centre pivot

**Plate 1. Location of monitoring sites and type of irrigation system at each site.**

*Pasture utilisation and growth rates*

The amount of pasture on offer was assessed using a rising plate meter immediately prior to grazing and immediately after grazing, and from these measurements, the amount of pasture utilised at each grazing event was calculated. This was repeated for each grazing event between December 2005 and April 2006 on each site. Growth rates were also calculated from this data. Pasture utilisation and growth rate details for each grazing event are recorded for each site in Appendix A.1.

*Irrigation application*

Flow meters were installed to monitor the quantity of water applied at sites 1, 3 and 4, but not sites 5 and 6, due to the high price associated with installing flow meters on centre pivot irrigation systems. At sites 5 and 6, the quantity of irrigation applied was calculated by recording the average amount of water applied per hour and the

number of hours of operation. At site 2 the quantity of water applied was calculated with rain gages, multiplied by time applied.

#### *Soil moisture*

Hansen data loggers were installed at each site, with 3 gypsum blocks per paddock (irrigated and dryland). Loggers recorded soil temperature (°C) at a depth of 10 cm and moisture levels in centibars (cb) at depths of 10 cm, 25 cm and 40 cm in each paddock except for site 2 where depths of 10 cm, 20 cm and 30 cm were monitored. Loggers recorded soil moisture and temperature every 4 hours throughout the duration of the study.

The information was readily available for farmer monitoring at each site through built-in graphic displays. The logger displayed previous moisture levels as a graph, and farmers were able to adjust their irrigation to maintain soil moisture levels within the optimal range of 30 to 40 cb at the 25 cm soil depth.

#### *Soil fertility and soil nitrate*

Each site was sampled for soil fertility in December 2005 and again in April 2006. Around 30 soil samples were taken along a transect at each site, to a depth of 7.5 cm. The sampling procedure followed guidelines established by the Australasian Soil and Plant Analysis Council: samples were bulked, dried at 40°C for 72 hours and then ground. Samples were sent to CSBP Laboratories in Western Australia for analysis of phosphorus [(P) Colwell and Olsen], potassium (K) and sulphur (S).

A soil nitrate test was performed prior to every 2<sup>nd</sup> grazing between December 2005 and April 2006 at each site. Sampling was undertaken before 9 am to standardise samples, given that soil nitrate changes diurnally. Around 15 soil samples were taken using a 10 mm auger drill to a depth of 30 cm. Samples were frozen and transported to the Serve-Ag laboratory in Devonport for analysis.

#### *Pasture quality and pasture nitrate*

At the same time and location that the soil nitrate test was taken, a strip of pasture approximately 10 cm x 15 cm was cut to an estimated grazing height of 5 cm. These pasture samples were refrigerated and transported to the Serve-Ag laboratory in Devonport for analysis of herbage quality and sap mineral content.

## Results and Discussion

### *Water use efficiency*

As a result of the above average rainfall during the measurement period, relatively low amounts of water were applied, ranging between 1.75 ML/ha at Mersey Lea and 3.29 ML/ha at Ringarooma. The greatest response to irrigation (2.71 t/ML) occurred at East Ridgley under a centre pivot irrigation system, followed by 2.13 t/ML at Mersey Lea under a K-Line irrigation system. Results between farms with the same irrigation systems were not consistent, with the lowest irrigation responses also occurring under K-Line and centre pivot systems at Mella (1.35 t/ML) and Ringarooma (1.37 t/ML), respectively (Table 1).

**Table 1. Details of mean water application and pasture utilisation at each of the 6 sites.**

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Location	Mella	ERDS	East Ridgley	Riana	Mersey Lea	Ringarooma
Irrigation system	K-Line	Fixed	K-Line	Travelling gun	Centre pivot	Centre pivot
Pasture utilised irrigated (kg DM/ha)	6200	5290	6900	4500	7225	7518
Pasture utilised dryland (kg DM/ha)	2625	1285	*1300	*1300	2475	3020
Amount of water applied (ML/ha)	2.65	2.7	2.63	2.31	1.75	3.29
Irrigation response (t/ML)	1.35	1.48	2.13	1.39	2.71	1.37

\*Estimated based on ERDS as a similar climate, as dryland pasture was not monitored at these sites.

Irrigation response was calculated as the difference in utilisation between irrigated and dryland divided by amount of water applied per hectare.

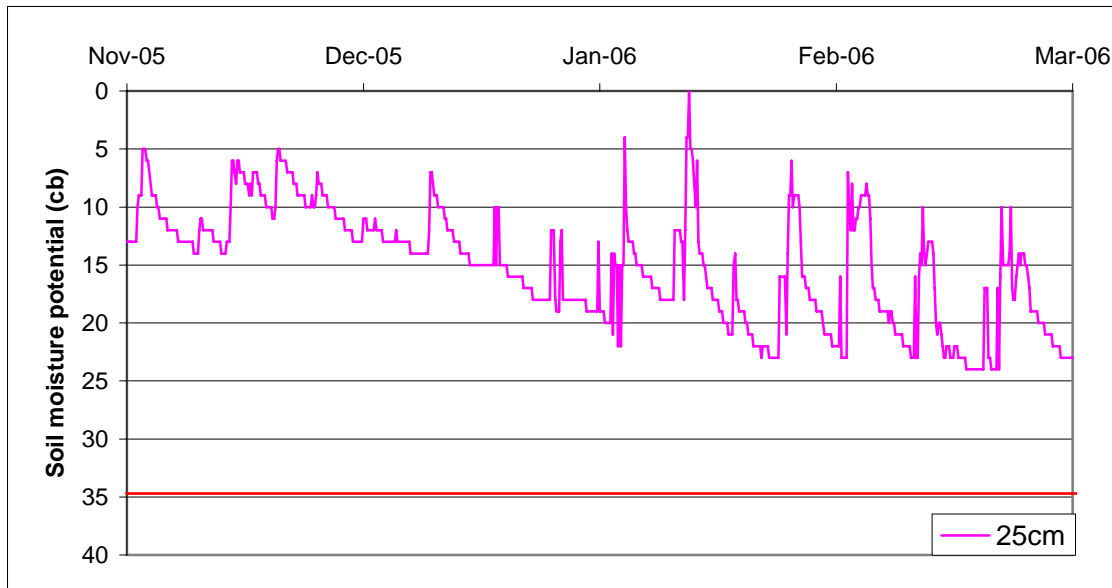
### *Pasture utilisation and growth rates*

The highest pasture utilisation was achieved at Ringarooma, where 7518 kg DM/ha and 3020 kg DM/ha of pasture was utilised under irrigation and dryland conditions, respectively (Appendix A.1). The Riana site had the lowest pasture utilisation (4500 kg DM/ha) under irrigation, while ERDS had the lowest dryland pasture utilisation (1285 kg DM/ha). The growth rate of irrigated pastures was at least twice the growth rate of dryland pastures between January and April (Appendix A.1). Dryland pasture growth rates remained below 35 kg DM/ha across all sites for the majority of the measurement period, while the irrigated pasture growth rates were more variable between sites. The highest irrigated pasture growth rate was measured at Mersey Lea (110 kg DM/ha) during January 2006. Irrigated pasture at Riana displayed the lowest growth rate, remaining below 40 kg DM/ha throughout the measurement period.

### *Soil moisture*

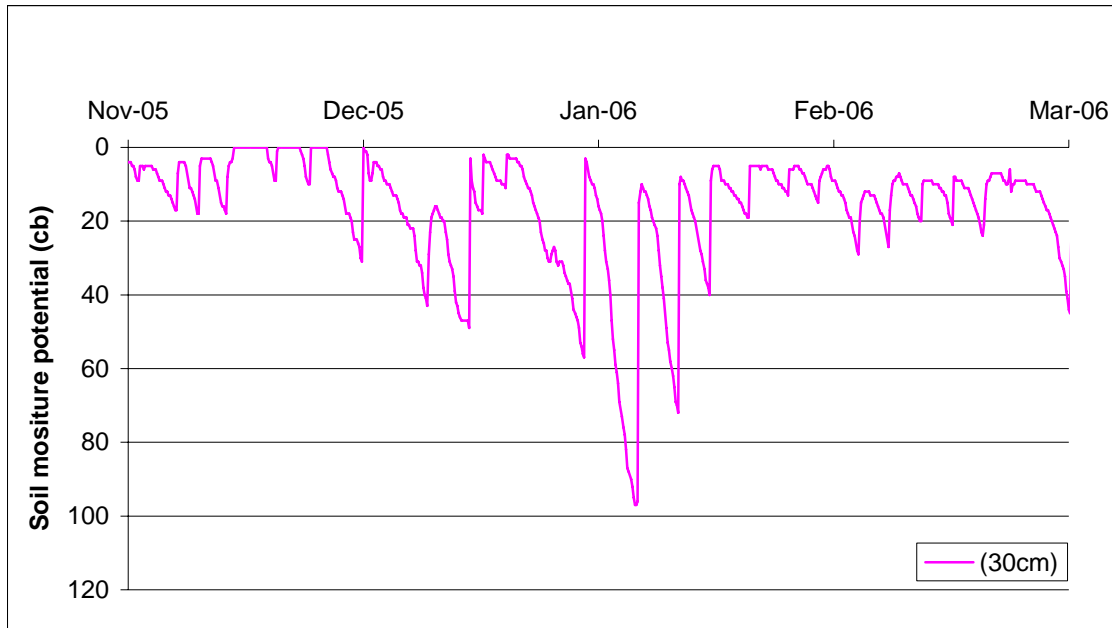
The use of Hansen loggers with built-in displays for immediate recognition of soil moisture levels provided farmers with the opportunity to adjust rates of irrigation accordingly. The outputs from each of the data loggers are given in Figure 1 to 6 for sites 1 to 6, respectively. The following technical note was provided to the farmers involved in the project.

At site 1 soil moisture was maintained at a high level throughout the study as indicated by the 25cm sensor (Figure 1). At this site soil water would have been readily available to the plant and no yield reduction would have occurred as a result of under watering.



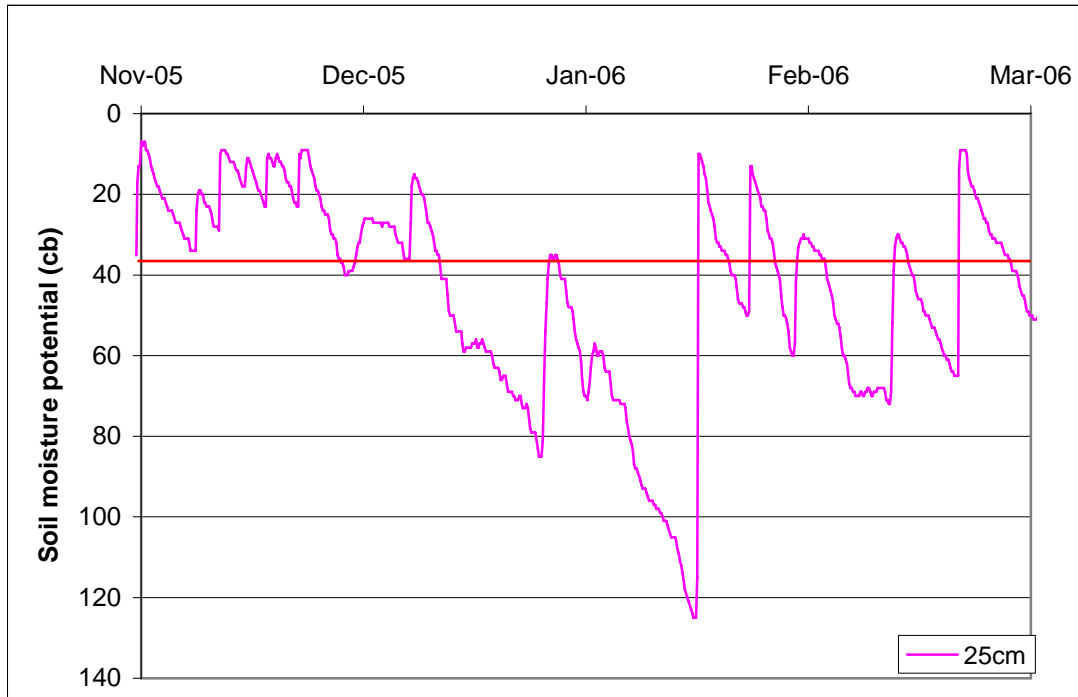
**Figure 1. Soil moisture potential (cb) in irrigated paddock at a depth of 25 cm at site 1. The red line represents the optimal soil moisture potential of 35 cb.**

At site 2 soil moisture was generally maintained at an acceptable level although during January soil moisture declined to a level that would have reduced pasture growth rates (Figure 2).



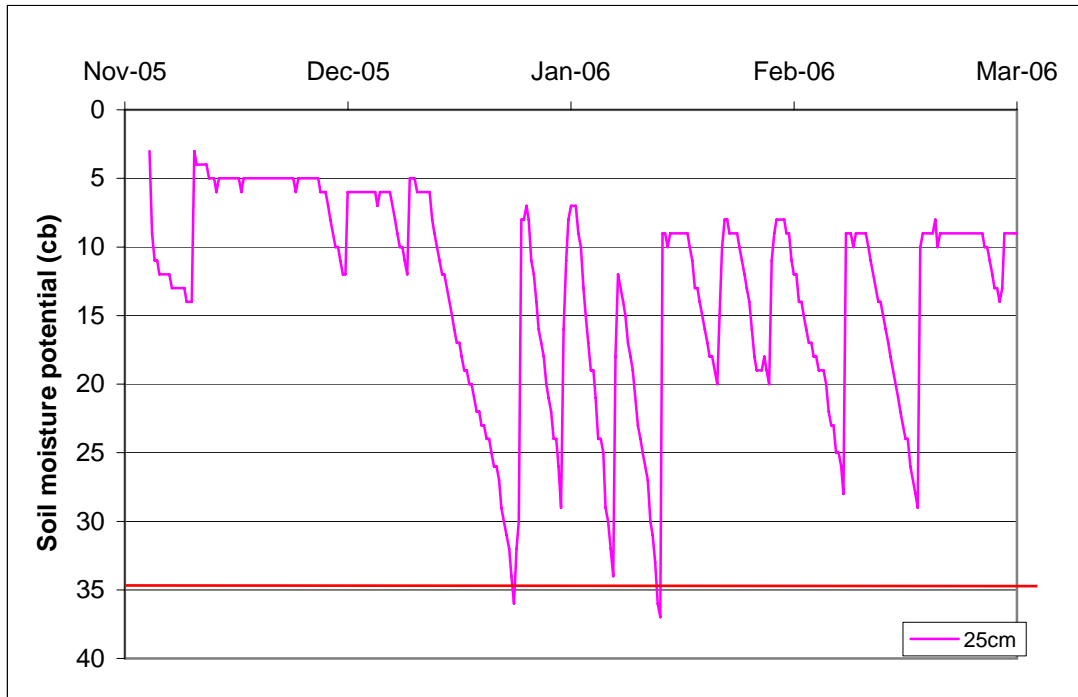
**Figure 2. Soil moisture potential (cb) in irrigated paddock at a depth of 30 cm at site 2.**

At site 3 soil moisture was generally maintained at an acceptable level although during late January and mid February soil moisture declined to levels that would have reduced pasture growth rates. Figure 3 clearly demonstrates that the watering applications were being applied at a 6-7 day interval and while this was sufficient to maintain soil moisture during early summer, as evaporation levels increased, soil moisture steadily declined until a significant amount of water was required to regain field capacity (10 cb).



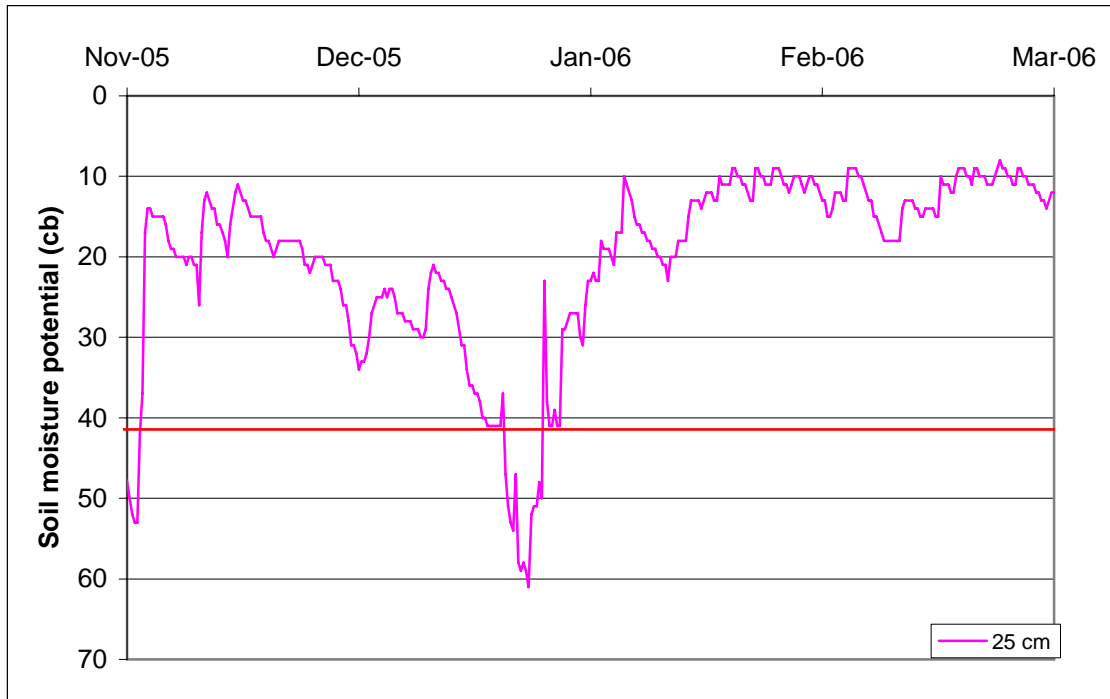
**Figure 3. Soil moisture potential (cb) in irrigated paddock at a depth of 25 cm at site 3. The red line represents the optimal soil moisture potential of 35 cb.**

At site 4 soil moisture was maintained at a high level throughout the study as indicated by the 25 cm sensor (Figure 4). At this site, soil water would have been readily available to the plant and no yield reduction would have occurred as a result of under watering. As with site 3, Figure 4 clearly shows that water was being applied on a regular basis of approximately 6-7 days. The water being applied at this site was sufficient so that soil moisture did not decline to the same extent as at site 3. This could be due to a combination of factors including lower evapotranspiration (as a result of slower pasture growth rates and lower evaporation levels) and higher amounts of applied irrigation. The Hansen data logger output from this site also showed that a significant amount of applied irrigation was passing the root zone and was lost to drainage (this is represented by the spiking of the deepest sensor at depth 40cm in Figure 7). After each irrigation event the soil moisture at a depth of 40 cm at site 3 was reaching a level at or above field capacity, indicating that a substantial amount of the applied irrigation was reaching the deeper soil zone. This demonstrated the inefficiency of watering associated with the use of a travelling gun irrigator.



**Figure 4. Soil moisture potential (cb) in irrigated paddock at a depth of 25 cm at site 4. The red line represents the optimal soil moisture potential of 35 cb.**

At site 5 soil moisture was maintained at a high level throughout spring and summer as indicated by the 25cm sensor. This site was extremely well watered and Figure 5 clearly shows that the centre pivot irrigator allowed for small amounts of water to be applied regularly to maintain soil moisture at an optimal level. No through drainage occurred and all applied water was readily available to the plant. This would have significantly contributed to the high irrigation response that was measured at site 5.



**Figure 5. Soil moisture potential (cb) in irrigated paddock at a depth of 25 cm at site 5. The red line represents the optimal soil moisture potential of 35 cb.**

At site 6 soil moisture was maintained near optimum for the majority of the time and this again clearly demonstrated the benefits that could be achieved using a centre-pivot irrigator. A larger irrigation response was not achieved at this site due to the high level of pasture production that was achieved under dryland conditions (3.0t DM/ha). The soil moisture of the dryland site is given in Figure 7. The soil moisture of the dryland area although becoming quite dry during mid to late summer, regular rain event were able to prevent soil moisture levels falling to levels that would have resulted in the cessation of pasture growth.

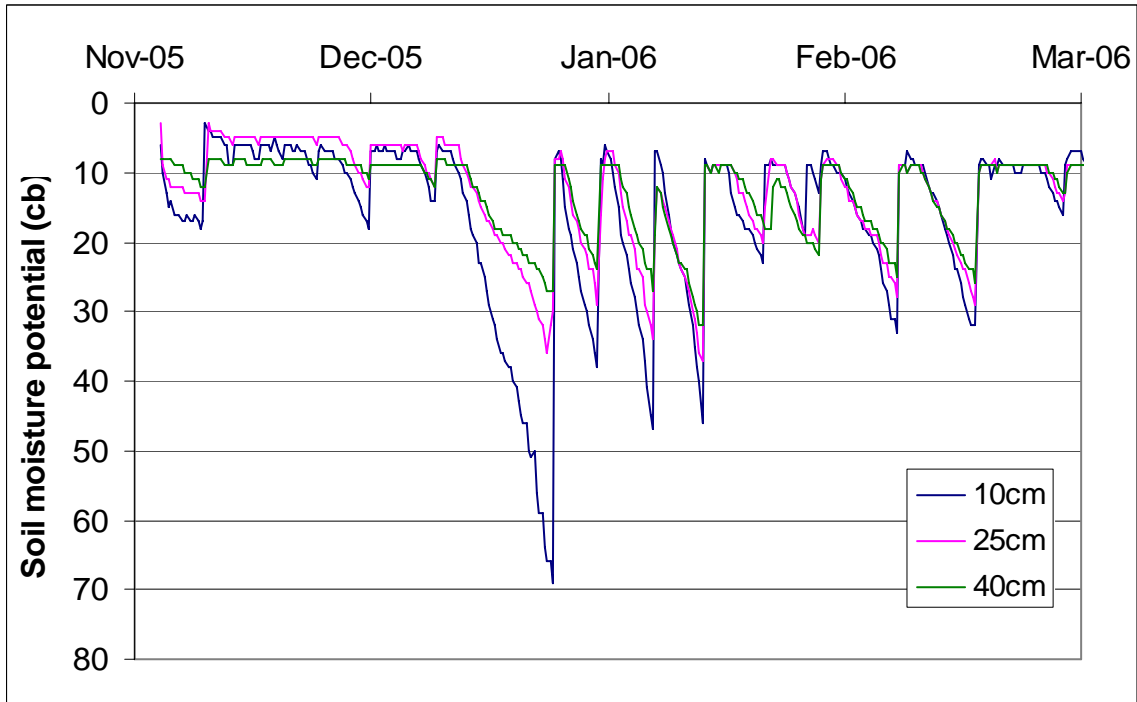


Figure 6. Soil moisture potential (cb) in irrigated paddock at site 6, at depths of 10, 25 and 40 cm. The red line represents the optimal soil moisture potential of 35 cb.

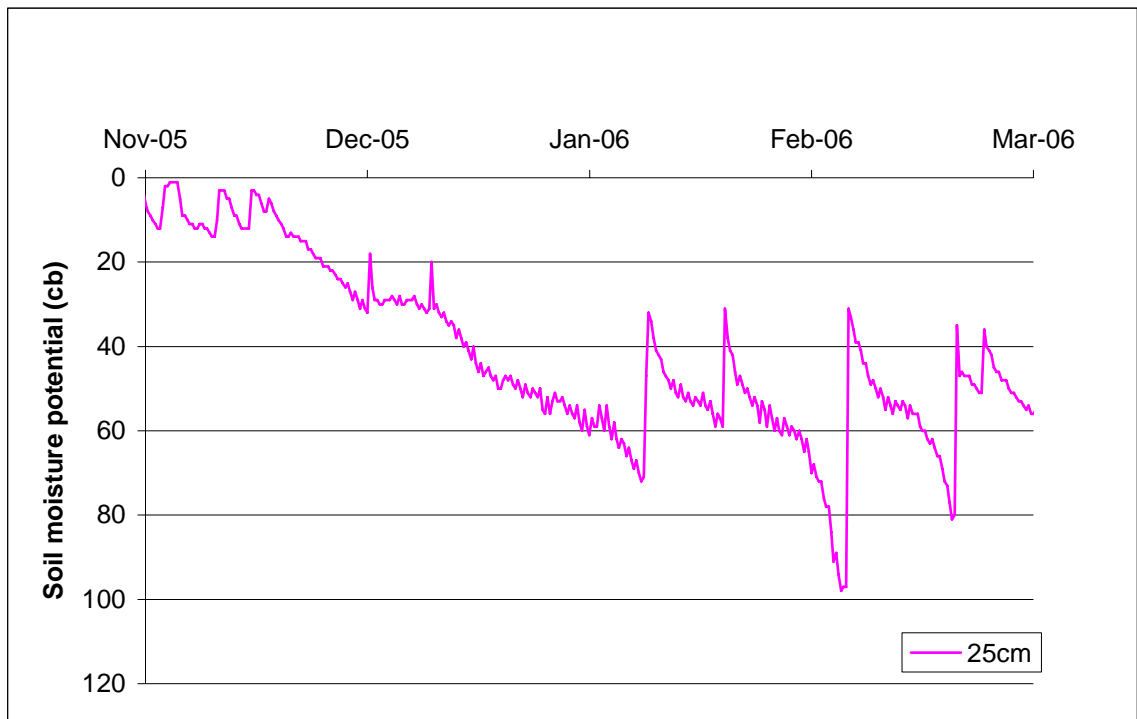


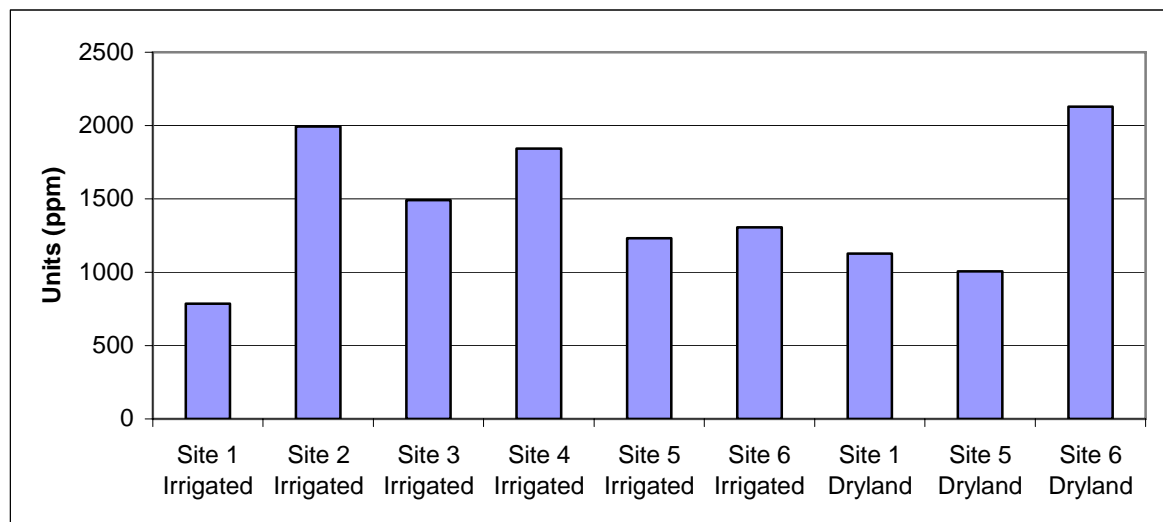
Figure 7. Soil moisture potential (cb) in dryland paddock at site 6, at a depth of 25 cm.

*Pasture nutrients*

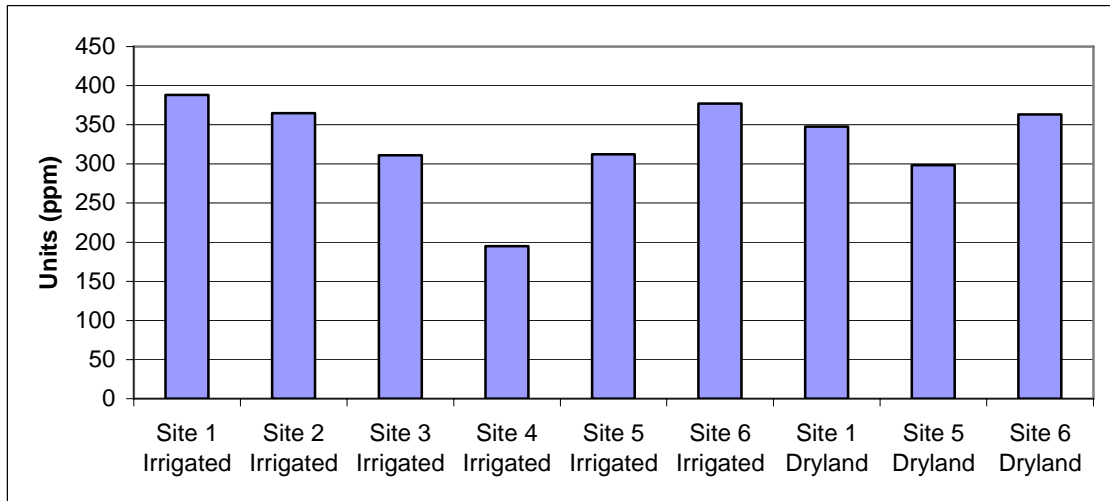
Concentrations of N, P, K, Ca and Mg in pasture (Figures 8-11) were generally within the desired nutrient range across all sites for optimal pasture growth and animal nutrition (Table 2). Levels of S and Cu in pasture were regularly below the desired range, while concentrations of NO<sub>3</sub>, K and Na were regularly above the desired range across all sites, as were concentrations of all nutrients in dryland pasture at Mella and Ringarooma. There appeared to be a general nutrient deficiency in both dryland and irrigated pasture at Mersey Lea toward the end of the measurement period (Appendix A.2 and Figures 8-11).

**Table 2. Optimal range (ppm) for the range of pasture nutrients tested.**

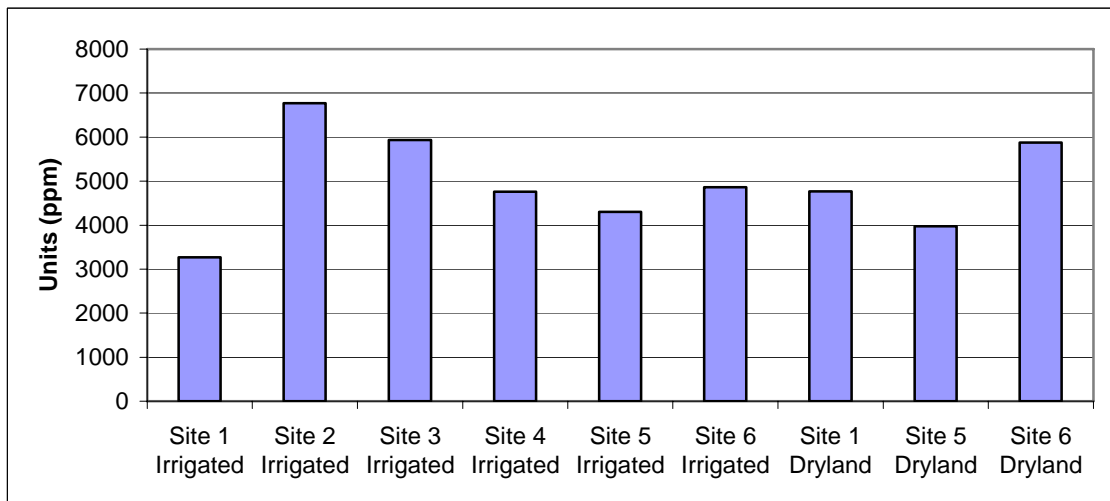
<b>Nutrient</b>	<b>Optimal range (ppm)</b>
Nitrate (NO <sub>3</sub> )	500 - 1100
Phosphorus (P)	300 - 500
Potassium (K)	3000 - 4500
Calcium (Ca)	400 - 700
Magnesium (Mg)	220 - 400
Zinc (Zn)	2.50 - 4.00
Boron (B)	0.60 - 1.20
Sulphur (S)	400 - 600
Copper (Cu)	2.00 – 3.50
Iron (Fe)	4.00 – 10.00
Manganese (Mn)	7.00 – 15.00
Sodium (Na)	< 300.0
Molybdenum (Mo)	0.05 – 0.1



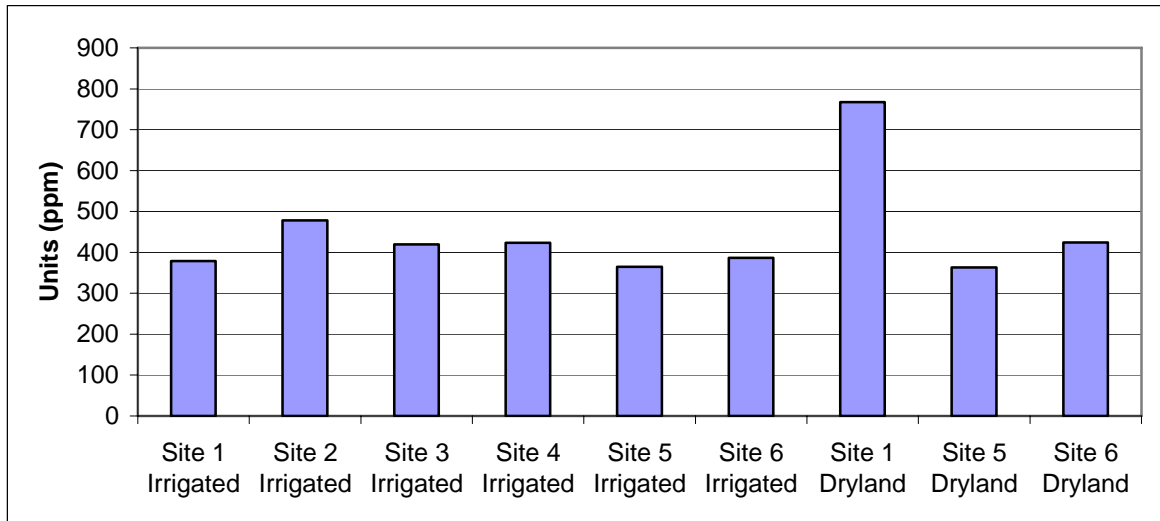
**Figure 8. Mean concentration (ppm) of nitrate in pasture at each of the 6 sites.**



**Figure 9. Mean concentration (ppm) of phosphorus in pasture at each of the 6 sites.**



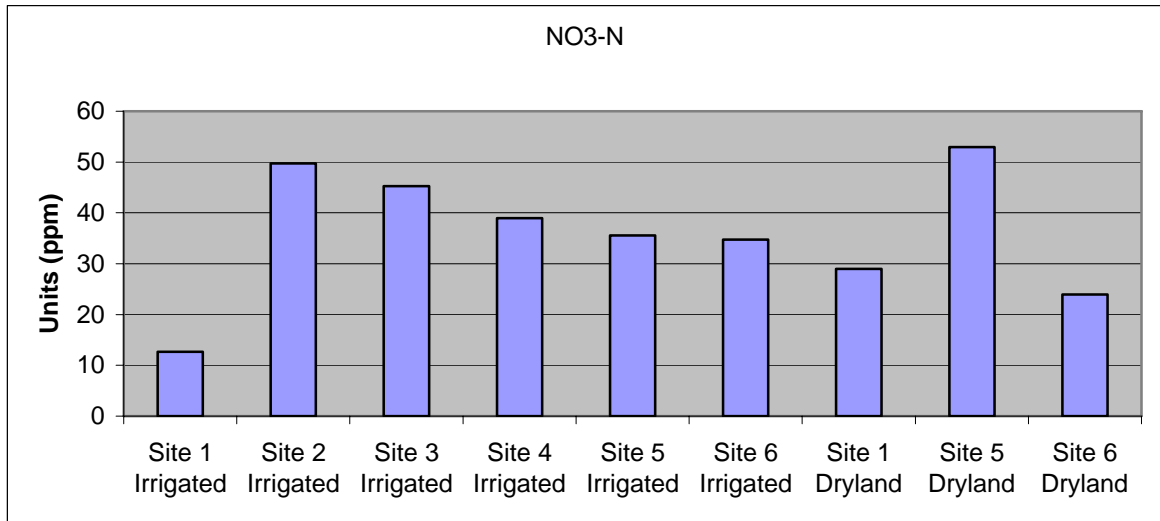
**Figure 10. Mean concentration (ppm) of potassium in pasture at each of the 6 sites.**



**Figure 11. Mean concentration (ppm) of sulphur in pasture at each of the 6 sites.**

*Soil nutrients*

Soil test results showed that East Ridgley had the highest P and K soil concentrations and ERDS the lowest P and K soil concentrations under irrigation. The highest S soil concentration and level of electrical conductivity were at Mella under dryland conditions and at East Ridgley under irrigation. Mean soil nitrate concentrations were higher than the desired range (20 to 30 ppm) in irrigated paddocks of all sites except Mella, where the mean nitrate concentration was below desirable levels. Mean nitrate concentrations in dryland paddocks at Mella and Ringarooma were maintained within the optimal range. The lowest soil pH was consistently measured at Ringarooma under dryland conditions, while the highest soil pH was measured at Mersey Lea in January 2006, and at Mella in April 2006 (Figure 11 and Appendices C-D).



**Figure 11. Soil nitrate concentrations at each of the 6 sites.**

### **Extension activities**

Staff at TIAR and DPIW organised field days over 4 days across the 3 districts: Northwest (sites 1 and 3), North (site 5) and Northeast (site 6). Approximately 120 farmers and industry representatives attended these extension activities.

Each month, farmers and industry partners (Serve-Ag and Impact Fertilisers) field staff received updates on growth rates and pasture herbage mineral levels, generally as an email attachment. The concentrations of nutrients were colour-coded - red being high, green being optimal, and yellow being sub-optimal, in relation to animal requirements. The complete data set is shown in Appendix B, along with colour coding.

## Appendix A.1 - Pasture utilisation and growth rate data.

### Site 1

<i>Irrigated</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
3/11/2005	4/11/2005	810	16
22/11/2005	23/11/2005	895	48
13/12/2005	14/12/2005	975	48
3/01/2006	4/01/2006	1075	66
20/01/2006	21/01/2006	700	44
6/02/2006	9/02/2006	850	87
22/02/2006	23/02/2006	925	63
10/03/2006	11/03/2006	1025	59
27/03/2006	28/03/2006	875	27
11/04/2006	12/04/2006	750	34
28/04/2006	29/04/2006		
<b>Total utilisation</b>		<b>6200</b>	
<i>Dryland</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
2/11/2005	3/11/2005	1210	16
1/12/2005	2/12/2005	700	62
19/12/2005	20/12/2005	925	42
4/01/2006	5/01/2006	775	29
24/01/2006	25/01/2006	600	17
9/02/2006	10/02/2006	325	11
28/02/2006	1/03/2006	375	6
6/04/2006	7/04/2006	550	
<b>Total utilisation</b>		<b>2625</b>	

### Site 2

<i>Irrigated</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
31/12/2005	1/01/2006	1216	
21/01/2006	22/01/2006	679	56
25/02/2006	26/02/2006	2261	50
2/04/2006	3/04/2006	1134	33
<b>Total utilisation</b>		<b>5290</b>	
<i>Dryland</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
24/12/2005	25/12/2005	300	
5/02/2006	6/02/2006	475	17
16/04/2006	17/04/2006	510	2
<b>Total utilisation</b>		<b>1285</b>	

### Site 3

<i>Irrigated</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
23/01/2006	24/01/2006	1400	
6/02/2006	7/02/2006	1044	106
21/02/2006	22/02/2006	601	46
9/03/2006	10/03/2006	1261	57
26/03/2006	27/03/2006	1543	77
16/04/2006	20/04/2006	1045	
<b>Total utilisation</b>		<b>6894</b>	

### Site 4

<i>Irrigated</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
11/01/2006	12/01/2006	1000	
7/02/2006	8/02/2006	750	21
4/03/2006	5/03/2006	900	33
29/03/2006	30/03/2006	850	33
23/04/2006	24/04/2006	1050	38
<b>Total utilisation</b>		<b>4550</b>	

### Site 5

<i>Irrigated</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
	10/01/2006		110
20/01/2006	23/01/2006	1650	104
6/02/2006	9/02/2006	1550	75
24/02/2006		1000	NA
10/03/2006	14/03/2006	1450	62
27/03/2006	29/03/2006	775	39
12/04/2006	13/04/2006	800	
<b>Total utilisation</b>		<b>7225</b>	
<i>Dryland</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
	10/01/2006		58
20/01/2006	23/01/2006	1000	11
6/02/2006	9/02/2006	650	NA
24/02/2006	NA	525	34
10/03/2006	14/03/2006	200	0
27/03/2006	29/03/2006	0	7
12/04/2006	13/04/2006	100	
<b>Total utilisation</b>		<b>2475</b>	

### Site 6

<i>Irrigated</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
6/01/2006	7/01/2006	1900	
31/01/2006	1/02/2006	1433	65
27/02/2006	28/02/2006	1410	57
17/03/2006	18/03/2006	1320	79
8/04/2006	9/04/2006	1455	66
<b>Total utilisation</b>		<b>7518</b>	
<i>Dryland</i>			
Pre- grazing date	Post-grazing date	Pasture utilised (kg Dm/ha)	Daily growth rates
14/01/2006	15/01/2006	1000	
8/02/2006	9/02/2006	870	32
6/03/2006	7/03/2006	540	20
24/03/2006	25/03/2006	395	20
10/04/2006	11/04/2006	215	11
<b>Total utilisation</b>		<b>3020</b>	

## Appendix A.2 - Pasture nutrients.

Site 1

Irrigated Paddock															
Date	NO3	P	K	Ca	Ca:P	Mg	K/(Mg+Ca)	Zn	B	S	Cu	Fe	Mn	Na	Mo
14/12/2005	557	351	2997	804	2	286	3	2.63	0.87	216	1.11	3.81	8.03	614.2	0.39
5/01/2006	391	561	3644	1341	2	508	2	3.08	1.34	384	2.46	6.06	11.73	1077.8	0.31
24/01/2006	336	468	3159	1058	2	503	2	2.92	2.07	449	1.47	5.15	10.61	1296.0	0.16
7/02/2006	891	314	3071	695	2	335	3	3.01	1.04	328	1.06	6.16	6.98	525.0	0.39
24/02/2006	1232	324	3883	978	3	409	3	3.19	0.92	435	2.24	10.74	6.74	571.0	0.15
15/03/2006	1500	354	3396	951	3	487	2	4.29	0.81	442	2.19	13.80	5.08	1345.0	0.20
12/04/2006	588	346	2715	677	2	284	3	2.78	0.92	395	1.43	3.79	4.33	602.0	0.16
<b>MEAN</b>	<b>785</b>	<b>388</b>	<b>3266</b>	<b>929</b>	<b>2</b>	<b>402</b>	<b>3</b>	<b>3.13</b>	<b>1.14</b>	<b>378</b>	<b>1.71</b>	<b>7.07</b>	<b>7.64</b>	<b>861.6</b>	<b>0.25</b>
Dryland Paddock															
2/12/2005	1490	320	4350	969	3	381	3	4.28	1.49	510	1.74	5.00	21.57	835.0	0.15
21/12/2005	815	457	3847	994	2	455	3	4.56	1.29	670	5.10	3.73	32.76	947.0	0.14
6/01/2006	505	471	5195	1386	3	525	3	4.50	1.36	923	2.26	4.77	39.26	745.0	0.22
25/01/2006	2032	385	7293	1737	5	784	3	8.11	2.58	1022	2.86	11.00	36.59	1235.7	0.12
10/02/2006	1022	141	3159	913	6	409	2	5.04	1.00	608	2.11	5.27	26.41	525.6	0.08
1/03/2006	908	312	4762	1524	5	662	2	8.44	1.69	870	3.27	11.45	30.28	931.0	0.09
<b>MEAN</b>	<b>1129</b>	<b>348</b>	<b>4768</b>	<b>1254</b>	<b>4</b>	<b>536</b>	<b>3</b>	<b>5.82</b>	<b>1.57</b>	<b>767</b>	<b>2.89</b>	<b>6.87</b>	<b>31.15</b>	<b>869.9</b>	<b>0.13</b>

Site 2

Irrigated Paddock															
Date	NO3	P	K	Ca	Ca:P	Mg	K/(Mg+Ca)	Zn	B	S	Cu	Fe	Mn	Na	Mo
20/01/2006	2475	231	5644	737	3	531	4	4.30	0.98	319	2.03	4.28	8.62	622.6	0.04
8/02/2006	2895	560	7901	1443	3	917	3	8.44	21.70	836	4.03	19.19	33.47	4167.9	0.17
4/04/2006	610	303	6768	717	2	416	6	2.98	1.64	279	2.81	32.55	23.85	910.0	0.09
<b>MEAN</b>	<b>1993</b>	<b>365</b>	<b>6771</b>	<b>966</b>	<b>3</b>	<b>621</b>	<b>5</b>	<b>5.24</b>	<b>8.11</b>	<b>478</b>	<b>2.96</b>	<b>18.67</b>	<b>21.98</b>	<b>1900.2</b>	<b>0.10</b>

Site 3

Irrigated Paddock															
Date	NO3	P	K	Ca	Ca:P	Mg	K/(Mg+Ca)	Zn	B	S	Cu	Fe	Mn	Na	Mo
10/01/2006	970	293	6149	675	2	258	7	2.57	1.05	467	2.15	14.11	12.86	377.7	0.06
8/02/2006	1489	307	5984	753	2	346	5	3.03	0.93	425	2.62	20.52	11.33	312.7	0.06
10/03/2006	2449	260	5202	449	2	256	7	2.19	0.64	238	1.79	24.82	6.67	353.0	0.05
27/04/2006	1058	384	6383	660	2	323	6	4.43	0.49	549	5.62	15.76	15.30	440.0	0.04
<b>MEAN</b>	<b>1492</b>	<b>311</b>	<b>5930</b>	<b>634</b>	<b>2</b>	<b>296</b>	<b>6</b>	<b>3.06</b>	<b>0.78</b>	<b>420</b>	<b>3.05</b>	<b>18.80</b>	<b>11.54</b>	<b>370.9</b>	<b>0.05</b>

Site 4

Irrigated Paddock															
Date	NO3	P	K	Ca	Ca:P	Mg	K/(Mg+Ca)	Zn	B	S	Cu	Fe	Mn	Na	Mo
10/01/2006	2374	214	6001	722	3	327	6	3.00	1.35	491	2.46	8.53	12.06	320.0	0.04
2/03/2006	1312	176	3514	529	3	264	4	2.28	0.78	356	1.83	10.18	11.14	150.0	0.05
<b>MEAN</b>	<b>1843</b>	<b>195</b>	<b>4758</b>	<b>626</b>	<b>3</b>	<b>296</b>	<b>5</b>	<b>2.64</b>	<b>1.07</b>	<b>424</b>	<b>2.15</b>	<b>9.36</b>	<b>11.60</b>	<b>235.0</b>	<b>0.04</b>

Site 5

Irrigated Paddock															
Date	NO3	P	K	Ca	Ca:P	Mg	K/(Mg+Ca)	Zn	B	S	Cu	Fe	Mn	Na	Mo
24/01/2006	1623	371	5487	678	2	249	6	2.71	0.99	402	0.89	3.68	9.55	156.3	0.08
9/03/2006	1577	330	5152	875	3	287	4	3.10	1.22	463	2.33	4.81	5.57	177.0	0.06
5/05/2006	495	236	2267	438	2	153	4	1.65	0.80	229	2.20	3.52	4.72	158.0	0.04
<b>MEAN</b>	<b>1232</b>	<b>312</b>	<b>4302</b>	<b>664</b>	<b>2</b>	<b>230</b>	<b>5</b>	<b>2.49</b>	<b>1.00</b>	<b>365</b>	<b>1.81</b>	<b>4.00</b>	<b>6.61</b>	<b>163.8</b>	<b>0.06</b>
Dryland Paddock															
24/01/2006	633	413	5338	834	2	326	5	3.01	1.16	482	1.04	4.35	10.99	141.4	0.11
9/03/2006	1932	301	4484	942	3	310	4	3.19	1.24	437	2.67	5.97	5.60	252.0	0.05
5/05/2006	455	182	2102	321	2	118	5	1.49	0.69	171	1.95	3.07	3.16	140.0	0.03
<b>MEAN</b>	<b>1007</b>	<b>299</b>	<b>3975</b>	<b>699</b>	<b>2</b>	<b>251</b>	<b>4</b>	<b>2.56</b>	<b>1.03</b>	<b>363</b>	<b>1.89</b>	<b>4.46</b>	<b>6.58</b>	<b>177.8</b>	<b>0.06</b>

Site 6

Irrigated Paddock															
Date	NO3	P	K	Ca	Ca:P	Mg	K/(Mg+Ca)	Zn	B	S	Cu	Fe	Mn	Na	Mo
10/01/2006	1045	356	5355	794	2	359	5	3.15	0.77	469	1.18	5.16	15.79	359.5	0.14
28/02/2006	811	329	3598	379	1	256	6	3.34	0.56	248	3.32	8.52	7.06	258.0	0.08
11/04/2006	1802	476	6669	702	1	378	6	4.09	1.72	565	2.75	10.89	12.72	542.0	0.07
12/05/2006	1566	347	3827	476		281		3.46	1.21	265	2.15	6.69	7.79	228.0	0.04
<b>MEAN</b>	<b>1306</b>	<b>377</b>	<b>4862</b>	<b>588</b>	<b>2</b>	<b>319</b>	<b>5</b>	<b>3.51</b>	<b>1.07</b>	<b>387</b>	<b>2.35</b>	<b>7.82</b>	<b>10.84</b>	<b>346.9</b>	<b>0.08</b>
Dryland Paddock															
10/01/2006	2230	273	5773	772	3	392	5	3.63	1.01	359	1.34	3.37	25.44	447.7	0.08
28/02/2006	2598	138	4551	474	3	259	6	4.02	0.69	261	2.98	6.16	12.06	246.0	0.05
11/04/2006	2172	508	6362	577	1	394	7	5.53	1.87	532	3.05	11.81	16.22	552.0	0.07
23/05/2006	1515	533	6806	569	1	344	7	4.81	1.70	545	3.96	11.47	16.86	304.0	0.06
<b>MEAN</b>	<b>2129</b>	<b>363</b>	<b>5873</b>	<b>598</b>	<b>2</b>	<b>347</b>	<b>6</b>	<b>4.50</b>	<b>1.32</b>	<b>424</b>	<b>2.83</b>	<b>8.20</b>	<b>17.65</b>	<b>387.4</b>	<b>0.07</b>

### Appendix A.3 - Soil test results (standard).

#### January 2006 results

Site		COLOUR	mg/kg Colwell P	mg/kg Colwell K	mg/kg KCl S	dS/m Electrical Conductivity	pH pH CaCl2	pH H2O	mg/kg Olsen P
1	IRRIGATED	GR	224	603	29.2	0.165	4.8	5.5	82.8
1	DRYLAND	DKGR	128	202	43	0.249	5.2	5.8	46.5
3	IRRIGATED	BR	290	712	45	0.319	5	5.6	65.5
4	IRRIGATED	BR	139	566	19.6	0.181	5	5.7	34
5	DRYLAND	BRGR	179	266	5.2	0.051	5.1	6.1	68.1
5	IRRIGATED	BRGR	168	290	5.8	0.056	5.4	6.3	62.5
6	DRYLAND	GRBR	209	248	20.3	0.138	4.6	5.2	62.8
6	IRRIGATED	GRBR	236	451	17.9	0.19	5	5.6	67.8

#### April 2006 results

Site		COLOUR	mg/kg Colwell P	mg/kg Colwell K	mg/kg KCl S	dS/m Electrical Conductivity	pH pH CaCl2	pH H2O	mg/kg Olsen P
1	IRRIGATED	DKGR	126	265	45.9	0.318	5.7	6.1	48.3
1	DRYLAND	GRBR	264	737	62.4	0.339	5	5.3	78.9
2	DRYLAND	BR	153	238	15	0.167	5.6	6	32.9
2	IRRIGATED	DKBR	124	212	20.1	0.254	5.5	5.9	29.9
3	IRRIGATED	BR	336	1141	38.5	0.32	5.5	5.8	99
4	IRRIGATED	BR	149	510	24	0.237	5.1	5.4	35.1
5	DRYLAND	BRGR	183	325	12	0.101	5.3	5.8	66.2
5	IRRIGATED	BRGR	172	285	14.4	0.092	5.3	5.8	61.9
6	DRYLAND	DKGR	178	279	22.9	0.137	4.5	5	65.1
6	IRRIGATED	BRGR	205	521	28.7	0.226	4.9	5.3	63.4

**Appendix A.4 - Soil test results (Serve-Ag nitrate test).**

**Site 1**

Irrigated Paddock	
Date	NO3-N (ppm)
14/12/2005	11.9
5/01/2006	15.7
24/01/2006	10.7
7/02/2006	9.1
24/02/2006	11.9
15/03/2006	19.5
12/04/2006	10.0
<b>MEAN</b>	<b>12.7</b>
Dryland Paddock	
Date	NO3-N (ppm)
1/03/2006	75.3
10/02/2006	15.1
25/01/2006	35.7
6/01/2006	15.8
21/12/2005	18.7
2/12/2005	13.2
<b>MEAN</b>	<b>29.0</b>

**Site 2**

Irrigated Paddock	
Date	NO3-N (ppm)
20/01/2006	51.2
8/02/2006	28.0
4/04/2006	69.9
<b>MEAN</b>	<b>49.7</b>

**Site 3**

Irrigated Paddock	
Date	NO3-N (ppm)
10/01/2006	47.6
3/02/2006	30.1
10/03/2006	39.2
27/04/2006	64.1
<b>MEAN</b>	<b>45.3</b>

**Site 4**

Irrigated Paddock	
Date	NO3-N (ppm)
10/01/2006	45.2
2/03/2006	32.7
<b>MEAN</b>	<b>39.0</b>

**Site 5**

Irrigated Paddock	
Date	NO3-N (ppm)
24/01/2006	29.5
5/05/2006	19.9
24/01/2006	29.5
9/03/2006	63.4
<b>MEAN</b>	<b>35.6</b>
Dryland Paddock	
Date	NO3-N (ppm)
24/01/2006	33.5
5/05/2006	27.6
24/01/2006	33.5
9/03/2006	117.2
<b>MEAN</b>	<b>31.5</b>

**Site 6**

Irrigated Paddock	
Date	NO3-N (ppm)
28/02/2006	20.8
12/05/2006	48.6
<b>MEAN</b>	<b>34.7</b>
Dryland Paddock	
Date	NO3-N (ppm)
10/01/2006	24.4
28/02/2006	29.6
23/05/2006	17.8
<b>MEAN</b>	<b>23.9</b>