Investigating the potential of deficit irrigation strategies to improve the efficiency of water use in irrigated temperate pastures Phase II

Final report to DairyTas

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Executive summary

This document is a final report to DairyTas for the project titled ‘Investigating the potential of deficit irrigation strategies to improve the efficiency of water use in irrigated temperate pastures Phase II’.

The research in this project was successfully completed according to the project schedule outlined in the DairyTas small grant proposal. The principle aims of the project were to:

- Monitor pasture performance and water use efficiency from different deficit irrigation strategies.
- To quantify the effects of differing nitrogen application rates under deficit irrigation strategies.
- To quantify the effects of deficit irrigation on herbage quality for the pasture samples collected in phase 1 of the project.
- To model the results of the study and extend outcomes to differing soil types and regions by running model simulations for different dairy regions over a number of years.
- To communicate results of the study through presentations of the findings at field days and in the Pasture PLU$ newsletter.

This project encompassed a 2.0 ha experimental site located at Elliott research and demonstration station. The trial design was a randomized split plot design with four replications. There were five irrigation treatments (main plot) by three nitrogen treatments (subplot treatments). A rainfall deficit (potential evapotranspiration minus rainfall) of 20 mm was used to schedule irrigation at which point 20, 16, 12, 8 or 0 mm of irrigation water was applied, referred to as irrigation treatments 100, 80, 60, 40 and 0%, respectively. The nitrogen treatments were 0, 1.5 and 3.0 kg N/ha.day which was applied within 1 week after each grazing event. The experimental site was grazed by 60 Holstein Friesian heifers each time the 100% irrigation treatment regrew between 2.5 and 3.0 leaves/tiller. A calibrated rising plate meter was used to estimate the pre- and post-grazing pasture biomass for each plot. The difference between the pre- and post-grazing pasture biomass estimates was used to calculate the amount of pasture utilised at each grazing event. The marginal irrigation water use index (MIWUI) was calculated as marginal production due to irrigation/irrigation water applied, while the nitrogen response rate for each nitrogen treatment was calculated as the marginal production due to nitrogen/nitrogen applied.

Pasture performance

There were a total of seven grazing events between October 2008 and April 2009. The first irrigation occurred on 20th October 2008 and there were total of 18 irrigation events. This equated to 360, 288, 216 and 144mm of irrigation being applied to 100, 80, 60, and 40% irrigation treatments, respectively. The total rainfall for the experimental period was 456mm. The cumulative pasture consumption for each irrigation treatment by nitrogen application is given in figure 1. There was a significant ($P < 0.05$) irrigation by nitrogen interaction on the cumulative pasture consumption.

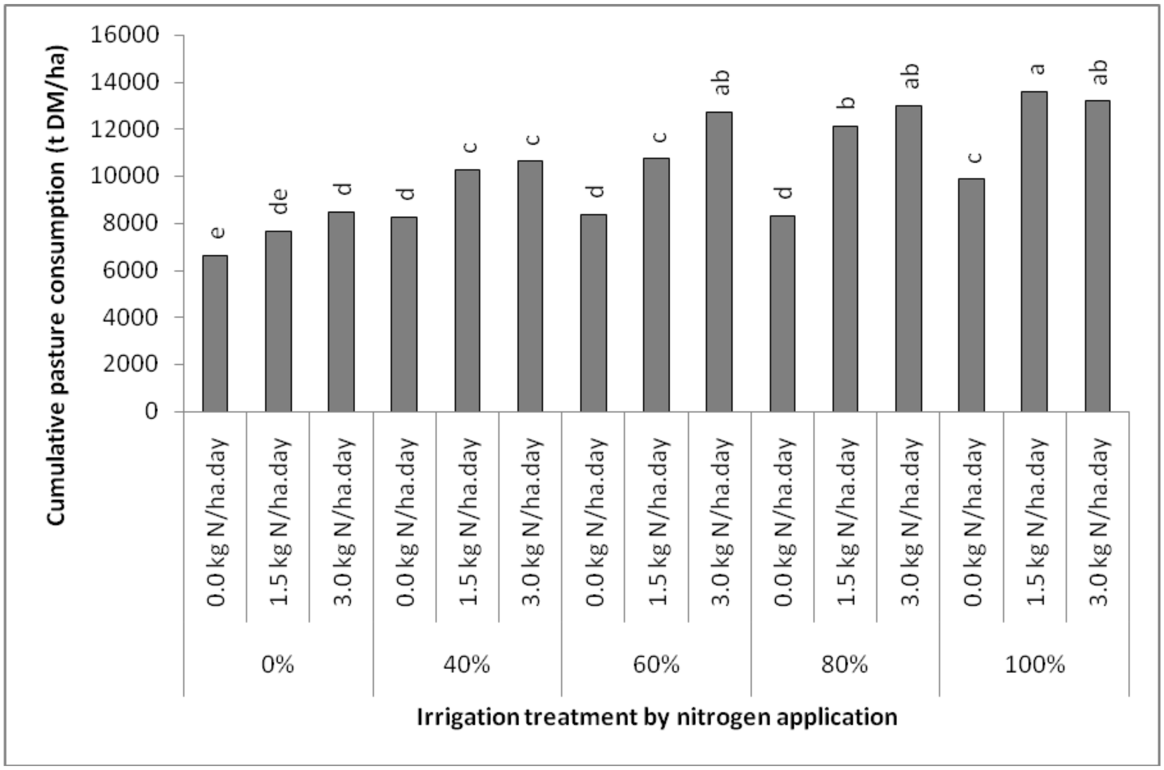

Figure 1. The cumulative pasture consumption for each watering by nitrogen treatment between October and April. Means with differing subscripts above columns indicate a significant difference at P = 0.05.

The highest pasture consumption was 13.6t DM/ha and this was achieved by the 100% irrigation treatment with 1.5kg N/ha being applied. This was not significantly ($P > 0.05$) different to the 100%, 80% or 60% irrigation treatment when 3.0 kg N/ha.day was applied. The cumulative pasture consumption from the rain-fed treatment when some nitrogen was applied was not significantly ($P > 0.05$) different to the 40, 60 or 80% irrigation treatments when no nitrogen was applied. This highlights the reality that irrigation influences the response of other inputs. To achieve maximum responses from irrigation other management factors, like nitrogen usage and grazing management, have a significant influence of the irrigation response observed.

Water use efficiency

There was no significant ($P > 0.05$) irrigation treatment effect on the marginal irrigation water use index (MIWUI), defined as the marginal production due to irrigation divided by the irrigation applied. There was also no significant ($P > 0.05$) nitrogen by irrigation treatment interaction on the MIWUI. The mean MIWUI across all treatments was 13.7kg DM/mm. The mean MIWUI for each irrigation treatment under the three differing nitrogen rates and averaged across all three nitrogen rates is given in Figure 2.

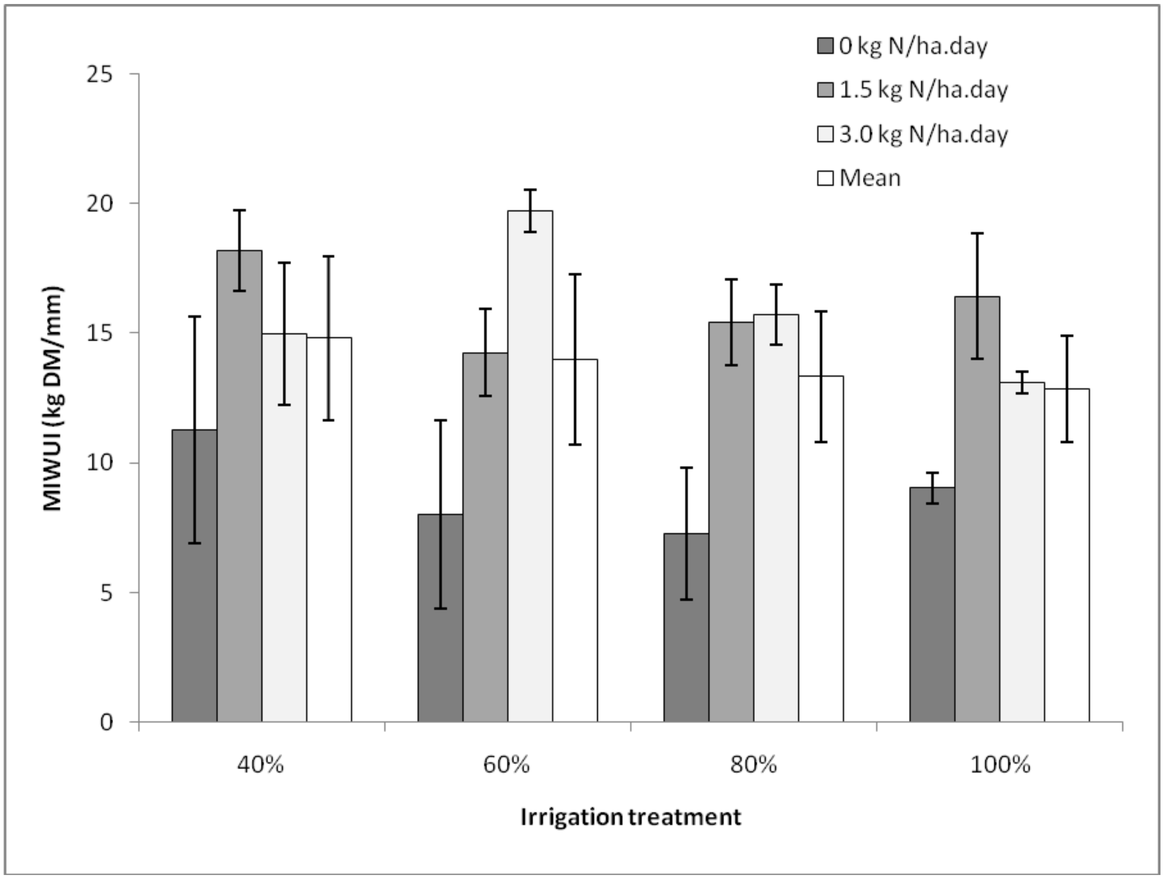

Figure 2. The mean marginal irrigation water use index (kg DM/mm) for each watering by nitrogen treatment between October and April. Standard error of mean shown as error bars.

There was a significant nitrogen effect on the MIWUI. The mean MIWUI across the irrigation treatments when zero nitrogen was applied was 9.0 kg DM/mm. This was significantly lower than that achieved when 1.5 or 3.0 kg N/ha was applied, which were not significantly ($P > 0.05$) different to each other.

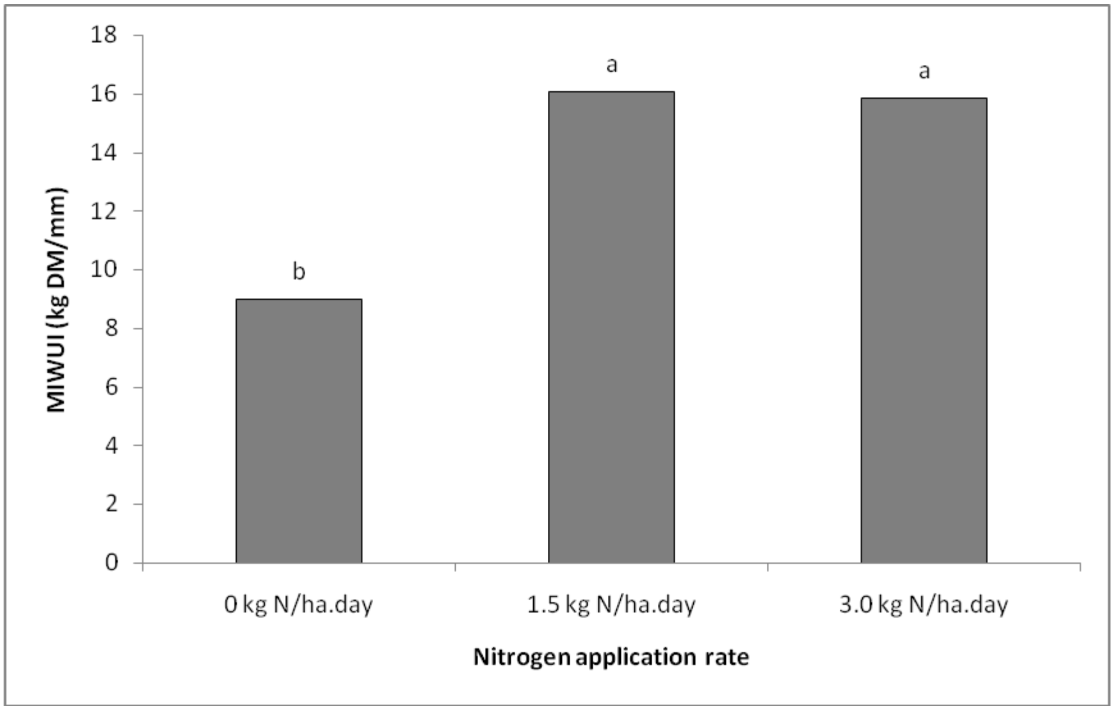

Figure 3. The mean marginal irrigation water use index (kg DM/mm) for three nitrogen application rates (0.0, 1.5, 3.0 kg N/ha.day) between October and April. Means with differing subscripts above columns indicate a significant difference at P = 0.05.

Nitrogen efficiency

There was a significant ($P < 0.05$) nitrogen rate, irrigation treatment and irrigation by nitrogen interaction on the nitrogen response (figure 4). The highest mean nitrogen response over the duration of the trial was achieved with the 80% irrigation treatment with nitrogen applied at a rate of 1.5 kg N/ha.day. This resulted in a mean nitrogen response of 18.4 kg DM/kg N. This was significantly ($P < 0.05$) higher than all other treatments except that achieved at 1.5 kg N/ha.day with the 100% irrigation treatment. The mean nitrogen response rate across the irrigation treatments was significantly ($P < 0.05$) higher at 1.5 kg N/ha (11.7 kg DM/kg N) than at 3.0 kg N/ha (6.2 kg DM/kg N). The mean nitrogen response rate for the 100, 80, 60, 40 and 0% irrigation treatments was 11.1, 13.5, 9.2, 6.6 and 3.9 kg DM/kg N, respectively. There was no significant ($P > 0.05$) difference in the mean response between the 100% and the 80% treatment while the rain-fed treatment condition had a significantly ($P < 0.05$) lower mean nitrogen response rate than all other treatments.

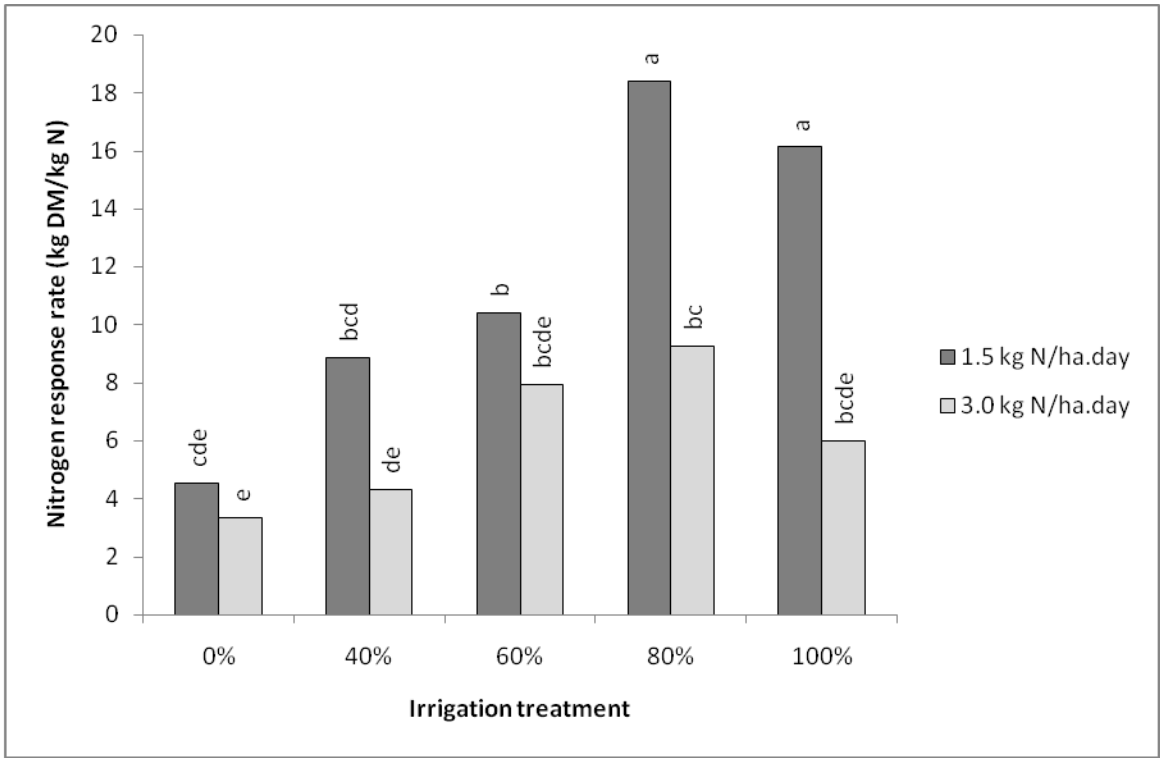

Figure 4. The mean nitrogen response rate (kg DM/kg N) for each watering by nitrogen treatment between October and April.. Means with differing subscripts above columns indicate a significant difference at P = 0.05.

Although there was no significant (P < 0.05) difference in the nitrogen response rate between the 80% and 100% treatment, the mean nitrogen response for both nitrogen rates were both strongly explained by a third order polynomial. This highlights the interaction between water applied and nitrogen application rate on nitrogen response.

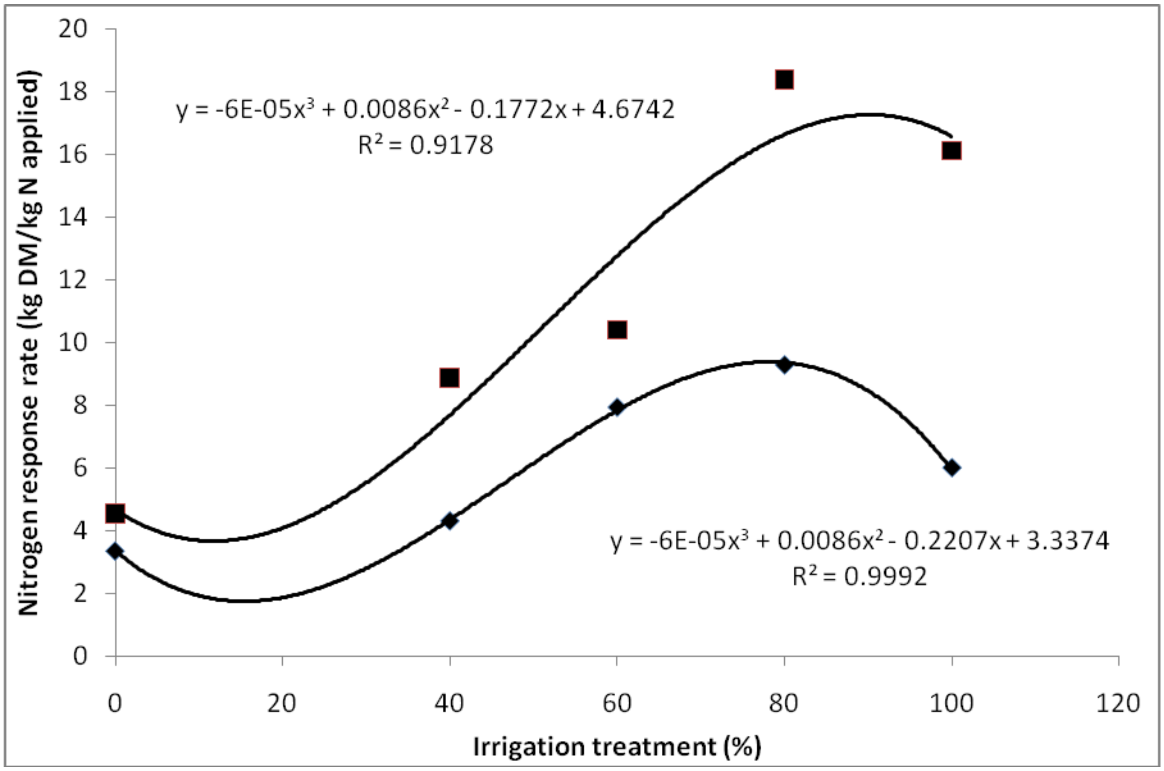

Figure 4. A third order polynomial fitted to the mean nitrogen response rate (kg DM/kg N) for each irrigation treatment with nitrogen applied at rate of 1.5 kg N/ha.day (■) and 3.0 kg N/ha.day (♦).

Nitrogen response rates were significantly ($P < 0.05$) higher when applied at a rate of 1.5 kg N/ha.day then when applied at a rate of 3.0 kg N/ha.day. As irrigation treatment increased between 40% and 80% the nitrogen response rate increased. At an irrigation rate of 100% nitrogen response rate declined as explained by the third order polynomial given in Figure 4. This was most likely in response to high a level of through drainage associated with the 100% treatment in comparison to the other treatment. This highlights the importance of accurate irrigations scheduling and also having a high (>90%) distribution uniformity of the irrigation delivery system. Where irrigation delivery systems have low distribution uniformity or irrigation scheduling is poor resulting in irrigation applications exceeding water requirements, through drainage will increase. Although over watering has the potential to reduce pasture production in response to anaerobic conditions, the N response rates shown in Figure 4 indicate that where over watering occurs N response rates will decline. Nitrate is a very mobile ion in the soil. As water passes the root zone, as a result of overwatering, nitrate leaching will also increase resulting in a lower level of nitrate available to support plant production.

Herbage quality

The experimental site provided a medium for the research and demonstration of a number of other activities. This included Ms. Janice Perry undertaking a School of Agricultural Science Honours study entitled 'Investigating the effect of deficit irrigation on perennial ryegrass (*Lolium Perenne)* morphology and herbage quality'. A copy of Janice abstract is given in appendix 1. A full copy of her thesis can be accessed from the School of Agricultural Science.

Modelling outcomes

DairyMod, a mechanistic biophysical model developed for the Australian dairy industry (Johnson *et al.* 2008), was validated using the experimental data and was then used to extrapolate the results across years and 5 dairy regions of Tasmania. The model uses daily weather information and comprises soil water, soil nutrient, pasture growth and animal production modules. The model is sufficiently versatile to simulate the range of environments represented by the pastoral regions of Australia (Johnson *et al.* 2008). Validation of the model by Cullen *et al*. (2008) has shown strong agreement between modelled and actual data across a number of pastoral systems in Australia and New Zealand.

Modelled data were validated against the experimental data using a range of model evaluation statistics, based on the work of Tedeschi (2006). These statistics were calculated separately for pasture utilised across all irrigation treatments. The statistics calculated were: mean bias, the difference between measured and simulated mean; r^2, coefficient of determination; mean prediction error, a measure of general model efficiency expressed as % of mean (Bibby and Toutenburg 1977); model efficiency, the proportion of variation explained by the modelled value with a value of 1 indicating a perfect fit; variance ratio, the amount of variance in the measured and modelled data-sets with a value of 1 indicating the same amount of variance; bias correction factor, which indicates bias from the *y*=*x* line with a value of 1 indicating no bias; and the concordance correlation coefficient, which is a simultaneous measure of accuracy and precision with an ideal fit indicated by a value of 1. Further details of these statistics are available in Tedeschi (2006).

There was strong agreement between observed versus modelled pasture consumption data (Figure 5).

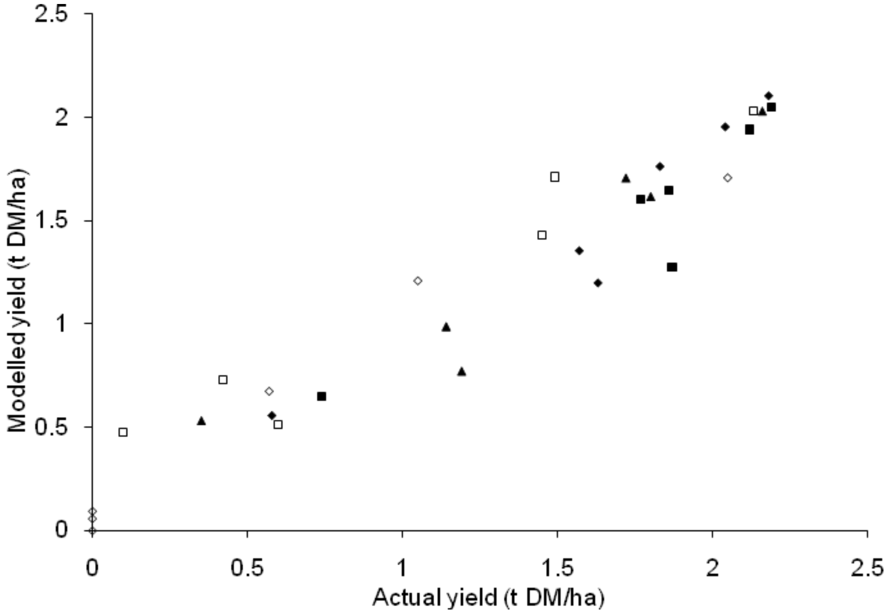

Figure 5. Actual and modelled pasture consumption (t DM/ha) for each irrigation treatment 100% (■), 80%(♦), 60%(▲), 40%(□) and 0%(◊) for each grazing.

Summary statistics between the observed data and the modelled data indicated that 93% of the variation can be accounted for by the model with a bias correction factor of 0.99, indicating little bias between the 1:1 relationship (Table 1).

Table 1. Summary statistics indicating model performance of DairyMod for pasture consumption in each irrigation treatment and grazing event.

Summary statistic	
Measured mean	*1.21*
Simulated mean	*1.29*
Mean bias	*-0.08*
r^2	*0.93*
Mean prediction error	*18.5%*
Modeling efficiency	*0.88*
Variance ratio	*0.87*
Bias correction factor	*0.99*
Concordance correlation coefficient	*0.95*

Following validation of the model using data from the experimental site, simulations for 5 dairy regions in Tasmania (Table 2) were run for a 40 year period (1968-2007). Site specific climatic data and soil physical properties were used (Table 1). Daily climate data for each site were obtained from the Bureau of Meteorology SILO database (Jeffery *et al*. 2001).

Table 2. Site details (latitude, longitude, soil type, plant available water, readily available water, mean annual rainfall, mean annual potential evapotranspiration, and mean monthly rainfall over the irrigation season (October to April)) for 5 Tasmanian dairy regions.

Site	Latitude/ Longitude	Soil type[a]	Plant available water[b] (mm/cm)	Readily available water[b] (mm/cm)	Mean annual rainfall[c] (mm/yr)	Mean annual potential evapotranspiration[c] (mm/yr)	Mean monthly rainfall (mm)[c]						
							Oct	Nov	Dec	Jan	Feb	Mar	April
Elliott	41.1°S 145.8’E	Red Ferrosol	1.4	0.7	1191	794	106	77	76	50	55	57	92
Scottsdale	41.2 °S 147.5’E	Brown Dermosol	1.5	0.7	1001	854	87	69	68	61	40	51	81
Smithton	40.8 °S 145.1’E	Hemic Organosols	2.0	0.9	1106	788	100	82	71	50	50	57	92
Deloraine	41.5 °S 146.6’E	Brown Kurosols	0.9	0.4	951	862	94	64	64	51	46	50	73
Bushy Park	42.7 °S 146.9’E	Black Vertosol	1.9	0.4	576	901	58	53	51	41	35	39	47

[a] Isbell (1996)

[b] Cotching *et al*. (2002a, 2002b, 2002c, 2008 pers comm.)

[c] Bureau of Meteorology - http://www.bom.gov.au

Simulation for each of the five sites where undertaken using DairyMod with the following parameters:

Pasture was cut to a residual of 1.5 t DM/ha and defoliation occurred at the 3.0 leaf stage of regrowth. Three differing N management scenarios were simulated to examine the interactions between deficit irrigation approaches and N applications on pasture production, water use efficiency, N leached and total water lost to through drainage and runoff. The three differing N management scenarios were:

- No N applied, from here on referred to as the zero N treatment
- 30 kg N/ha applied immediately following each defoliation, from here on referred to as the rotationally applied N treatment
- N applied at a rate of 30kg N/ha when the soil N status fell below 10ppm, from here on referred to as the N non-limiting treatment

Five irrigation treatments were simulated and consistent of applying 20 (I100%), 16 (I80%), 12 (I60%), 8 (I40%), and 0 mm (I0%) of irrigation water at a rainfall deficit of 20 mm. The rainfall deficit was calculated as the difference in potential evapotranspiration minus rainfall.

Simulation results

For each region there was a significant ($P < 0.05$) irrigation by N interaction on the mean yearly pasture production, MIWUI, and total N leached (Tables 3 to 5). The mean yearly pasture production in each region was highest with I100% with N applied to be non-limiting. In all regions, except Deloraine, this was not significantly ($P > 0.05$) higher than I80% with N applied to be non-limiting. In each region the lowest mean yearly pasture production occurred with I0% with zero N applied. This was significantly ($P < 0.05$) lower than for all other treatments.

The mean yearly MIWUI for each region exceeded 2t DM/ML when N was applied to be non-limiting with the I60% or I80% treatment. When N was applied to be non-limiting there was no significant ($P > 0.05$) difference in the mean MIWUI between the I60% and I80% treatment in each region. The mean MIWUI for I60% and I80% when N was applied to be non-limiting was significantly ($P < 0.05$) higher than the corresponding mean MIWUI for I40% and I100% in each region. In each region, I100% with zero N resulted in the lowest mean MIWUI. This was significantly ($P < 0.05$) lower than for all other treatments. When zero N was applied, I40% resulted in the highest MIWUI in each region. This was significantly ($P < 0.05$) higher than I80% and I100% treatment, but not significantly ($P > 0.05$) different to the I60% treatment.

For all regions the highest amount of N leaching occurred under I0%, when either N was applied rotationally or to be non-limiting. For I40%, I60%, I80% and I100% the mean yearly total of N leached increased with increasing yearly totals of N applied, in each region. For all regions except Bushy Park, significantly ($P < 0.05$) more N leaching occurred under the I40% than the I100% when N was applied to be non-limiting.

Table 3. The mean simulated yearly pasture production (t DM/ha.year) for a 40 year period (1968- 2007) for five dairy regions of Tasmania under five irrigation approaches and three differing nitrogen management scenarios.

Irrigation	Nitrogen	Location				
		Bushy Park	Deloraine	Elliott	Scottsdale	Smithton
I0%	0 N	4.58	4.33	5.44	5.75	6.33
	Rot. applied N	5.75	5.88	7.53	7.99	8.52
	N Non-limiting	5.77	6.48	8.51	8.86	9.22
I40%	0 N	6.31	6.15	6.80	7.10	7.48
	Rot. applied N	8.56	8.95	10.29	10.74	11.15
	N Non-limiting	8.69	10.20	12.48	12.60	12.87
I60%	0 N	6.96	7.13	7.28	7.59	7.94
	Rot. applied N	10.80	11.29	11.89	12.44	12.78
	N Non-limiting	12.33	15.19	16.40	16.59	16.64
I80%	0 N	7.02	7.33	7.30	7.61	8.00
	Rot. applied N	11.66	12.29	12.54	12.99	13.47
	N Non-limiting	14.57	18.56	18.54	18.58	18.64
I100%	0 N	6.98	7.29	7.28	7.58	7.99
	Rot. applied N	11.63	12.35	12.55	12.96	13.46
	N Non-limiting	14.97	19.75	18.92	18.88	18.87
LSD (P =0.05)		0.57	0.53	0.53	0.55	0.50

Table 4. The mean simulated MIWUI (t DM/ML) for a 40 year period (1968- 2007) for five dairy regions of Tasmania under four irrigation approaches and three differing nitrogen management scenarios.

Irrigation	Nitrogen	Location				
		Bushy Park	Deloraine	Elliott	Scottsdale	Smithton
I40%	0 N	0.84	0.82	0.68	0.65	0.59
	Rot. applied N	1.38	1.40	1.40	1.33	1.36
	N Non-limiting	1.44	1.72	2.04	1.83	1.91
I60%	0 N	0.76	0.83	0.60	0.57	0.53
	Rot. applied N	1.63	1.60	1.45	1.43	1.44
	N Non-limiting	2.14	2.64	2.67	2.50	2.55
I80%	0 N	0.57	0.66	0.45	0.43	0.41
	Rot. applied N	1.42	1.42	1.24	1.19	1.25
	N Non-limiting	2.14	2.72	2.53	2.35	2.41
I100%	0 N	0.45	0.52	0.36	0.34	0.33
	Rot. applied N	1.13	1.14	1.00	0.95	1.00
	N Non-limiting	1.79	2.38	2.10	1.93	1.97
LSD (P =0.05)		0.19	0.15	0.15	0.16	0.16

Table 5. The mean simulated yearly amount of nitrogen leached (kg N/ha.year) for a 40 year period (1968- 2007) for five dairy regions of Tasmania under five irrigation approaches and three differing nitrogen management scenarios. Mean yearly nitrogen application (kg N/ha.year) shown in parenthesis.

Irrigation	Nitrogen	Location				
		Bushy Park	Deloraine	Elliott	Scottsdale	Smithton
I0%	0 N	12.1 (0)	25.8 (0)	28.2 (0)	21.7 (0)	26.4 (0)
	Rot. applied N	115.4 (174)	112.4 (171)	123.3 (206)	116.9 (215)	132.9 (233)
	N Non-limiting	61.8 (122)	112.3 (211)	131.8 (289)	113.2 (277)	128.0 (287)
I40%	0 N	9.3 (0)	16.9 (0)	14.6 (0)	10.8 (0)	12.5 (0)
	Rot. applied N	87.3 (219)	75.4 (212)	67.5 (239)	67.4 (248)	71.2 (266)
	N Non-limiting	55.6 (203)	98.1 (330)	108.4 (445)	95.7 (419)	101.8 (437)
I60%	0 N	5.0 (0)	6.4 (0)	4.4 (0)	4.3 (0)	3.7 (0)
	Rot. applied N	35.8 (249)	17.7 (245)	23.5 (266)	20.2 (276)	23.8 (295)
	N Non-limiting	44.1 (374)	61.2 (548)	76.8 (616)	60.0 (594)	68.3 (614)
I80%	0 N	3.8 (0)	3.3 (0)	2.9 (0)	3.0 (0)	2.3 (0)
	Rot. applied N	26.9 (260)	10.5 (256)	17.9 (271)	15.2 (282)	17.8 (300)
	N Non-limiting	43.8 (474)	58.3 (682)	71.2 (694)	58.7 (672)	62.4 (688)
I100%	0 N	4.5 (0)	3.3 (0)	2.8 (0)	2.7 (0)	2.4 (0)
	Rot. applied N	30.0 (260)	10.4 (256)	17.4 (270)	15.6 (282)	18.4 (300)
	N Non-limiting	55.8 (501)	64.1 (733)	78.0 (713)	61.7 (687)	64.6 (697)
LSD (P =0.05)		14.8	12.3	13.8	11.9	12.3

For each region there was no significant ($P > 0.05$) irrigation by N interaction on the mean yearly totals of water lost to through drainage or runoff. There was a significant ($P < 0.05$) irrigation treatment on the mean yearly totals of water lost to through drainage or runoff (Table 6). In all regions, the amount of water lost to through drainage or runoff increased with increasing amounts of irrigation and was significantly ($P < 0.05$) higher under I100% than I80%, I60%, I40% and I0%. In all regions, except Bushy Park, there was no significant ($P > 0.05$) difference in the mean yearly totals of water lost to through drainage or runoff between I0% and I40%.

Table 6. The mean simulated yearly amount of water (mm/year) lost to through drainage and runoff for a 40 year period (1968- 2007) for five dairy regions of Tasmania under five irrigation approaches. Mean yearly irrigation amount (mm/year) shown in parenthesis.

Irrigation	Location				
	Bushy Park	Deloraine	Elliott	Scottsdale	Smithton
I0%	133 (0)	421 (0)	590 (0)	431 (0)	439 (0)
I40%	158 (209)	445 (224)	619 (198)	462 (208)	470 (196)
I60%	184 (313)	465 (336)	651 (297)	494 (312)	504 (295)
I80%	246 (418)	518 (448)	718 (396)	564 (416)	573 (393)
I100%	346 (522)	617 (560)	814 (495)	665 (520)	669 (491)
LSD (P =0.05)	20	46	54	40	42

The modelling undertaken in this study provides an indication of the water and N requirements for maximising pasture productivity in five differing dairy regions of Tasmania and has shown that a deficit irrigation approach could potentially increase farm productivity under limited water resource conditions.

Communication of results

Results of the study are communicated by contributions to *Tassie Dairy News* and a field day is planned for September 2009 to coincide with the start of the irrigation season. In addition, the results of the deficit irrigation work undertaken in 2007/08 and 2008/09 were presented as part of national irrigation workshop in Melbourne in May 2009. The results will also be presented as part the professional development events for agricultural consultants and field officers coordinated by NRM North, in conjunction with the Tasmanian Institute for Agricultural Research in August 2009.

Other activities

In addition to Ms Janice Perry undertaking a School of Agricultural Science Honours study, the CSIRO Information and Communication Technologies centre demonstrated and tested the use of their soil moisture sensor network and HydroTas demonstrated the use of their Adjenti units.

Conclusion

The observed experimental data and simulated results from the current study suggest that the obtainable marginal water use index is much higher than the current industry standard of 1 t DM/ML. This study has therefore shown that the opportunity exists for irrigated pasture systems to better manage an increasingly scarce resource while still maintaining economically feasible yields.

Project team

The project supervisor and principal investigator was Richard Rawnsley. Mark Freeman and Danny Donaghy were also investigators on the project. Technical support was provided by Peter Chamberlain and Karen Christie. Lesley Irvine assisted in coordinating grazing for the experimental site. .

References

Bibby J, Toutenburg H (1977) ‘Prediction and improved estimation in linear models.’ (Wiley: Berlin)

Cotching WE, Cooper J, Sparrow LA, McCorkell BE, Rowley W (2002a) Effects of agricultural management on dermosols in northern Tasmania. *Australian Journal of Soil Research* 40, 65-79.

Cotching WE, Cooper J, Sparrow LA, McCorkell BE, Rowley W, Hawkins K (2002b) Effects of agricultural management on vertosols in Tasmania. *Australian Journal of Soil Research* 40, 1267-1286.

Cotching WE, Hawkins K, Sparrow LA, McCorkell BE, Rowley W (2002c) Crop yields and soil properties on eroded slopes of red ferrosols in north-west Tasmania. *Australian Journal of Soil Research* 40, 625-642.

Isbell RF (1996) ‘Australian soil and land survey handbook: the Australian soil classification.’ (CSIRO Publishing: Collingwood, Victoria)

Jeffrey SJ, Carter JO, Moodie KM, Beswick AR (2001) Using spatial interpolation to construct a comprehensive archive of Australian climate data. *Environmental Modelling and Software* 16, 309-330.

Johnson I R, Chapman DF, Snow VO, Eckard RJ, Parsons AJ, Lambert MG, Cullen BR (2008) DairyMod and EcoMod: Biophysical pastoral simulation models for Australia and New Zealand. *Australia Journal of Experimental Agriculture* 48, 621-631.

Tedeschi LO (2006) Assessment of the adequacy of mathematical models. *Agricultural Systems* 89, 225-247.

Appendix 1. - Abstract taken from Ms Janice Perry honours thesis.

Pasture as the dominant feed source is crucial to maintaining a low cost of production for the Australian dairy industry. Perennial ryegrass (*Lolium perenne* L.) is the most popular fodder species used in temperate pasture systems because it is easy to grow and has a high nutritive value. However, growth rates, pasture quality and persistence are reduced in summer due to high temperatures and water stress. Irrigation has been used to overcome this with approximately 70% of Tasmania dairy farms having some irrigation.

Water availability has been decreasing in recent years due to drought, and high water demands have also increased the price of water. The increase of pasture water use efficiency is an important issue facing Australian dairy farmers. Deficit irrigation is one option farmers can used to increase water use efficiency of pasture. Farmers with limited water resources are faced with the decision of whether to fully irrigate a small area of pasture or to deficit irrigate a larger area of pasture. Research has already been conducted showing the effects of deficit irrigation on pasture yield and that the water use efficiency is improved with deficit irrigation; however there is little information about the effect of deficit irrigation on pasture quality and morphology. These are import factors that influence pasture persistence, dry matter (DM) production, stocking rates and milk quality.

The aim of this study was to determine the effect of deficit irrigation on perennial ryegrass pasture quality traits including crude protein (CP), neutral detergent fibre (NDF), percentage DM, DM digestibility (DDM) and metabolisable energy (ME) content. A further aim was to ascertain whether deficit irrigation affects morphology traits such as leaf elongation rates, specific leaf area, root DM distribution, plant number, tiller density and production of daughter tillers.

A field study at Elliott research station using the perennial ryegrass cultivar Impact was conducted under commercial grazing and irrigation management. Five irrigation

treatments, 100, 80, 60, 40 and 0% were replicated four times in a random block design. Irrigation was applied when evapotranspiration equalled 20mm. This was calculated using a Class A pan, as well as rainfall and a crop factor. Pasture herbage samples were collected monthly from November to March and herbage quality results calculated via near infrared spectrophotometry. Morphology measurements were taken over the same sample period.

The major finding of this study was that in the deficit and fully irrigated pastures, CP, NDF, DDM and ME were not significantly different ($P>0.05$) throughout the sample season. However under water stress, dryland CP was significantly ($P<0.05$) lower and NDF levels increased. Consequently, the increase in NDF levels reduced dryland ME and DDM. Dryland DM% followed a similar pattern of no significant difference at 100, 80 and 60% irrigated treatments, however in times of water stress the 40% irrigation treatment was significantly higher ($P<0.05$) than the other irrigated treatments but also significantly lower ($P<0.05$) than dryland.

There was no significant difference ($P>0.05$) in root DM distribution between the treatments in January. However, in April the 100% irrigation treatment had significantly less ($P<0.05$) root DM in the bottom 6-30 cm of a 30 cm deep soil sample and significantly more ($P<0.01$) root DM in the top 0-5 cm. Analysed at ($P<0.01$), the dryland treatment contained significantly less roots in 0-5 cm and significantly more roots in the 6-30 cm soil sample. There was also less total root DM over all treatments in the April sample compared to the January sample.

Specific leaf weight declined from December to February over all treatments, however the severity of the decrease was sharper under water deficit. At the January sample, both the dryland and the 40% irrigation treatment recorded specific leaf weight that was significantly lower than the other treatments. This pattern also occurred in February, however it was not significant ($P>0.05$).

Tiller elongation rate (mm/day) was measured in January and February. There was a reduction in elongation rate with a reduction in water, with the greatest reduction recorded for 60, 40 and 0% irrigation treatments.

Tiller density (number of tillers/m^2) in the irrigation treatments was lower in the December and February samples compared to March. Tiller density in the dryland and the 40% treatment was significantly lower ($P<0.05$) in February. The number of daughter tillers over all treatments was significantly lower ($P<0.05$) in February and March compared to December. In February, a greater number of daughter tillers were produced with higher applications of irrigation. Plant numbers were also reduced from January to February over all treatments. However in March there was an increase in plant numbers in the dryland and 60% treatments.

It was concluded that deficit irrigation up to 60% under optimal grazing will have no effect on pasture quality; however there will be a reduction in production most likely due to changes in morphology. Therefore farmers with limited water resources are better to deficit irrigate a larger amount of area than fully irrigate a smaller area because although pasture yield will be reduced, over a larger area, total pasture production is greater. Replication of this experiment would increase the significance of the findings. Replication under different seasonal temperatures, rainfall patterns and common irrigation methods would make the findings more usable for a wider range of farmers. Repeating this experiment over a series of seasons would also show the long term effects of deficit irrigation. Also conducting the experiment on other pasture species would be beneficial to the industry.