SMARTER IRRIGATION FOR PROFIT 2

Tocal Dairy Optimisation Site

TECHNICAL REPORT

SITE BACKGROUND

Dairy Optimisation Site Coordinator: Peter Smith

Owner: NSW Department of Primary Industries (DPI)

Manager: Matt Brett

Location: Lower Hunter Valley, DairyNSW Region, NSW, Australia

Climate: Subtropical, with irrigation used year-round to supplement rainfall, but predominantly between July and February–March. An Italian ryegrass/chicory/clover mix is over-sown into kikuyu annually in Autumn, with the peak Summer window (January–February) being kikuyu pasture with some remnant red and white clover.

Herd size: Calving herd of 280–300 cows, all-year-round milking on 225ha

Irrigation site and set-up: Milking platform of 130ha with 80ha of mixed irrigation, of which 37ha is irrigated by three centre pivots that comprise the optimisation site: a 4-span, full circle (19ha), 3-span, full circle (14 ha) and 2-span, part circle (4ha). The system is designed to operate the smallest pivot on its own or any combination of the three, through to all three pivots concurrently, which is the common practice.

Irrigation season: Season One (2019–20) included the final summer of a five-year drought that broke in February 2020; Season Two (2020–21) and Season Three (2021–22) had record rainfall with major flooding.

In Seasons One and Two, pasture measurements were undertaken weekly in a complementary project with Hunter Local Land Services (LLS) and the University of Sydney. The aim of that project was to validate the accuracy of Pasture.io in a subtropical dairy pasture system. Due to reliability concerns over the methodology and results however, a combination of measured and Pasture.io data was used to determine growth rates (kgDM/ha/day). For Season Three, manual pasture cuts under exclusion cages were undertaken at each grazing event from 7 August to 7 December 2021, delivering reliable growth data.

Site questions

- Will improved scheduling of irrigation and nitrogen applications extend the Italian ryegrass/clover/chicory pasture into early summer?
- Will scheduling irrigations in response to soil moisture and water balance data improve pasture growth rates across the September–February period compared to the current approach of set applications?

Australian Government
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Dairy Australia

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- Will adjustments to irrigation decision-making have to be made if irrigation timing is based on readily available water (RAW), instead of a fixed frequency (timing) or amount?
- How will decisions be implemented given the personnel and skills available?
- What are efficiency gains in energy and water use with an irrigation strategy based on depleting and refilling the RAW zone?

Key messages

- In Seasons Two and Three (record rainfall and flooding), irrigation was still applied according to soil moisture data (IrriPasture and soil probes, when available) during dry/hot spells between rain events, improving growth and energy efficiency.
- In Seasons Two and Three, SWAN Systems Weatherwise forecasts and IrriPasture were used to evaluate the risk of applying irrigation versus delaying irrigation to allow forecasted rain to replenish the RAW zone. There were times when irrigation after rainfall was delayed too long, which affected yield.
- Scheduling irrigation to supplement rainfall events rather than using a fixed irrigation schedule improved water efficiency because water stress and waterlogging were minimised. In Seasons Two and Three, energy efficiency was improved by not irrigating when rainfall was forecast.
- Using water balance tools (IrriPasture and SWAN Systems Weatherwise) to determine the irrigation schedule and monitoring the effectiveness of rainfall and irrigation (IrriPasture and soil moisture monitoring) to maintain RAW were deemed 'easily explainable and understood' by both the farm manager and staff at Tocal, so informed irrigation decisions could be made with confidence when the manager took leave.

Technologies and strategies used

- Four 40-cm EnviroPro® capacitance probes with ICT International® loggers and telemetry were installed in the pivot area. A LoRa-WAN® network collected the logged data to a central base station that sent it on to a cloud-based platform, Grafana®, providing real-time data to a smartphone via an app.
- *Note: Failure of two of the four probes in Season One, and all of the probes for most of Season Three, limited access to soil moisture data. This issue highlighted the need for good on-ground and local support for farmers using this technology.*
- AgSense® (renamed Valley 365®) is proprietary software installed on each centre pivot, allowing the irrigators to be remotely controlled (timing on/off, rate, speed). Although the irrigation applied can be logged through this system, it was found to be inaccurate at Tocal.
- Bureau of Meteorology Automatic Weather Station (BoM AWS) at Tocal Dairy provided daily evapotranspiration (ETo) and rainfall.
- The tools most used and valued by Matt Brett and reference group members were:
  - Soil moisture monitoring using the EnviroPro®/ Grafana® equipment, when available.
  - SWAN Systems Weatherwise forecasts. One member reported avoiding severe yield impacts by irrigating when SWAN Systems forecast no rainfall, despite other sources indicating otherwise.
- IrriPasture was established for each of the pivot areas in Seasons Two and Three:
  - **Pros:** More reliable than the soil moisture equipment. ETo graphs show the point at which underwatering affects growth.
  - **Cons:** Manually entering irrigations. The tool reports irrigation is needed when soil is at or near field capacity according to soil moisture monitoring data. IrriPasture commences calculations for water use by plants on the next calendar day after rainfall, when in real terms draw-down may not occur for a number of days after substantial rainfall events.
- In Season One, dry and hot conditions led to the application of 12mm, 3–4 times mid-week, and further 12mm applications over weekends until substantial rainfall broke the drought in early February of 2020.
- In Seasons Two and Three, rain events with breaks of high temperatures over several days resulted in large daily ETo variation. Scheduling was changed to respond with periods of not irrigating to allow excess water to be used by the plants. Forecast data was also carefully considered to determine when to apply the next irrigation. In Season Two soil probe data was available, so plant use and the effectiveness of irrigations were better monitored, but ongoing malfunctions made this technology unavailable throughout Season Three.

Findings

Yield, energy and water data collected over the three seasons is detailed in Table 1. Figures 1 and 2 show the growth rates for Seasons Two and Three from dry matter (DM) measurements, the modelled yields and Pasture.io yields.

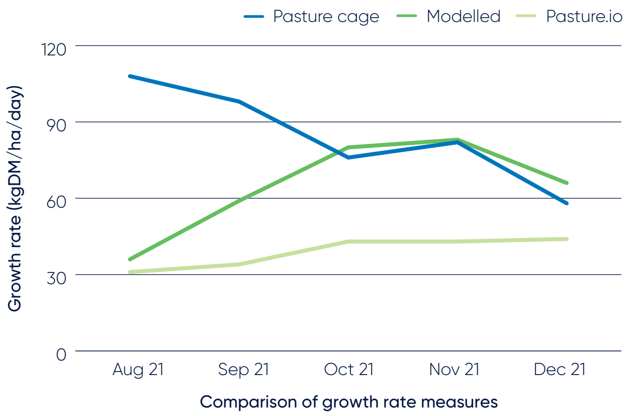
Table 1 Seasonal metrics results

Production*	Season One	Season Two	Season Three
Growth rate (kgDM/ha/day)	56.96	67.05	85.78
GPWUI (tDM/ML) rainfall and irrigation	0.69	1.28	1.61
Energy per irrigated ML (kWh/ML)	379.01	292.93	344.46
Energy per tonne DM (kWh/tDM)	109.82	110.72	47.07
Energy used per ML irrigation per m head (kWh/ML/m head)	4.57	3.53	4.15
Costs	**Season One**	**Season Two**	**Season Three**
Water costs per tonne DM ($/tDM)	$3.80	$11.09	$4.01
Energy costs per tonne DM ($/tDM)	$23.04	$19.65	$3.33
Energy costs per ML water ($/ML)	$79.53	$52.00	$24.38
Energy costs per ML irrigation per m head ($/ML/m head)	$0.96	$0.63	$0.29
Total cost per tDM ($/tDM)	$26.84	$30.75	$7.34
Total cost per hectare ($/ha)	$85.63	$125.76	$67.36

*January and February data used Seasons One and Two (DM determined primarily by Pasture.io), early September to early December data used Season Three (DM determined by cuts).

Figure 1 Season Two: comparison of growth rate measures

Figure 2 Season Three: comparison of growth rate measures



- In Seasons One and Two, comparisons between seasons were not made due to differences in the timing of data collection, the variation in climatic and weather events, and data reliability concerns about the DM measurements. Caution is needed when comparing seasons at this site.
- In Season One, baseline metrics for the site were determined during extreme drought in early summer followed by high rainfall. In Season Two, very wet conditions were experienced, so irrigation was infrequent and soil moisture levels were mostly above refill. The ryegrass/clover/chicory mix persisted well into early summer on free-draining soil, but due to the rainfall and infrequent irrigations, it was not possible to determine the effect of improved irrigation scheduling and nitrogen application. The pasture did not persist well on the heavier soils due to waterlogging. Extremely wet conditions were experienced throughout Season Three, but supplementary irrigation was applied cautiously during times of higher ETo when rainfall was not predicted in coming days.
- Figure 2 shows that average growth rates in the first part of the season were substantially higher than modelled in Season Three, with a closer relationship from October to December. Overall, the season exceeded the modelled data by 17%. October and December were the only months in which growth rates dropped below the modelled outcomes (–13%). In October there were two incidences of soil moisture declining to near, or just under, the refill point. Although irrigations were applied, they were too late after rainfall events and soil moisture remained low until another rainfall event. This was a very variable period, with forecasted rain falling in isolated cells across the region, but not necessarily always as predicted at Tocal. In December, saturated conditions prevailed and likely affected the measured yield.

- Irrigation was started earlier in Season Two than in Season One because the soil moisture probes indicated a decline in August. The irrigation scheduling was then informed by SWAN Systems Weatherwise forecasts.

Irrigation is generally applied during off-peak power but is not restricted to those times only. Efficiency gains in energy and water use were made by irrigating to maintain RAW.

Table 2 shows that energy use was approximately the same for Seasons One and Two, but the proportion of irrigation water was more than double in Season Two. Energy efficiency increased by approximately 100%. In Season Three, the energy (kWh/tDM) was approximately half that of Season One, but the proportion of irrigation water remained about equal, delivering an improvement in energy efficiency. Energy efficiency (kWh/ML/m head) was within the industry benchmark across all three seasons and improved (Table 1).

Table 1 Energy used to produce 1 tonne of dry matter (DM) compared to plant water requirement

	Energy use (kWh/tDM)	Irrigation proportion of plant water requirement
Season 1	109.8	20%
Season 2	110.7	48%
Season 3	47.1	22%

- Ongoing Autumn rainfall and saturated conditions in 2022 prevented a second irrigation system evaluation being conducted to assess system performance improvement following adoption of most of the recommendations in the 2019 report.

Changes as a result of the 2019 evaluation at Tocal:

- System capacity of 12–13mm/day of all three pivots meets the peak water requirements of kikuyu (7.8mm) in January. If irrigation is restricted to periods of off-peak power only, system capacity would remain adequate, though disruptions to operation may sometimes require peak power operations to lift soil moisture.
- Across the whole system, pump efficiency was low and the variable frequency drive (VFD) should be adjusted to better match energy demands. When all three irrigators are operating concurrently, energy efficiency is improved, which likely affected the overall improvement in energy efficiency measured in Seasons Two and Three.

Distribution uniformity was 'adequate' on all pivots. Issues identified were: high to low application variation along the 2-span pivot radius, likely affecting the yield in the outer circle areas of the pivot; three sprinklers not operating as specified on the 3-span pivot; and variation in the heights of the sprinklers on the 4-span. All three pivots had problems with low output and incorrect angling of the end-guns, resulting in low application rates. The system supplier restored the sprinklers to specification, re-angled the end-guns, recalibrated the 4-span panel and adjusted the operating pressure to the manufacturer's recommendations.

Irrigation system evaluation

Table 3 Comparison of irrigation system evaluation metrics

Evaluation year		Flow rate (%)	System capacity (mm/day)	Co-efficient of uniformity (%)	Distribution uniformity (%)	Application V panel (%)	Pump efficiency (%)	Energy use (kWh/ ML/m)	Average application rate (mm/h)	Centre pressure (%)	End pressure (%)
2019	4-span	-4	12	77	74	-9	61	4.6	49	+118	+66
	3-span	+2	13	85	78	-2	66	4.2	40	+42	-
	4-span	0	13	80	78	+3	39	7.2	18	+154	off scale

Reference group support

- The reference group primarily comprised local service providers plus two dairy farmers and a beef operator. The service providers included a farm agronomist, irrigation technical consultant and regional Local Land Services, DairyNSW and NSW DPI representatives.
- Reference group meetings were mainly conducted via online for a variety of reasons.
- Reference group members contributed their views and discussed key principles such as RAW, ETo and rainfall and soil probe information. Data from Tocal were used to inform the irrigation decisions on their own farms.
- A total of 14 *Monthly Irrigation Requirement Reports* were delivered to the reference group members, DairyNSW, NSW DPI, Mid-Coast Dairy Advancement Group (MCDAG) and Hunter Dairy Development Group (HDDG) by the coordinator. The reports were published in the eNewsletters of the dairy groups, resulting in an overall readership of 3,900 over the three years and were the primary source for disseminating the activities and data of the site. The reports included:
  - SWAN Systems Weatherwise forecast for ETo/rainfall at the optimisation site.
  - ETo and rainfall data for the previous seven days recorded at the Tocal BoM AWS.
  - IrriPasture available soil moisture graphs for each pivot and Grafana® soil moisture graphs for the 4-span pivot (when available).
  - commentary on the information and its effect on irrigation requirements and management.
  - short item on relevant weather or irrigation-related issue (e.g. seasonal climate outlooks).
  - upcoming events for the group.
- Seasonal articles published in printed newsletters (DairyNSW's *Milk Flow* and the combined newsletter of the MCDAGs and HDDG, *Dairy Doings)* communicated the site's activities and learnings to over 4,500 dairy farmers and local service providers.
- A stand-alone field day and workshop were conducted at Tocal, with presentations on the site results also made at five regional events and webinars by the site coordinator to optimise extension, involving 135 attendees.

MORE INFORMATION

Cath Lescun, Dairy Australia
National Soils and Irrigation Lead
E: Cath.Lescun@dairyaustralia.com.au

dairyaustralia.com.au/smarterirrigationforprofit

smarterirrigation.com.au

Dairy Australia Limited ABN 60 105 227 987
E enquiries@dairyaustralia.com.au
T +61 3 9694 3777
F +61 3 9694 3701
dairyaustralia.com.au

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