Estimating annual irrigation water requirements

Findings from the "Sustainable dairy farm systems for profit" project

M5 Project Information Series - Studies on Mutdapilly Research Station and subtropical dairy farms 2001 to 2005

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OVERVIEW

IN a highly competitive water market of reducing supplies and increasing price, dairy farmers need to accurately predict the irrigation water requirements for the forages they grow. They need estimates of water requirements for years when rainfall is below, at, or above average.

Dairy farmers will need to know their farm irrigation requirements to respond to water resource allocation plans for their region, and to maximise the production of forage from water.

Use the following steps to calculate water requirements for your farm from rainfall records and forage water-requirement tables.

1. Calculate effective rainfall - for each month, average for the year, average for the best and worst years.
2. Select forage types; determine the growing season by month for each forage.
3. Estimate the irrigation water required for each forage.
4. Make allowance for losses and inefficiencies.
5. Multiply the area of each forage type by irrigation requirements to give total irrigation ML in low, average and high requirement years.
6. Make allowance for future production targets.

INDUSTRY BACKGROUND

UNTIL recently there has been limited information on the water requirements of the diverse range of forages grown in the subtropical dairy regions of northern Australia. Farmers had previously drawn on their own experience, anecdotal evidence, limited records, irrigation equipment specifications, or visual observations. While these strategies may have been sufficient in the past, farmers are now experiencing greater water allocation uncertainty and increased government legislation – and they need to be more accurate in the use of water on their farms.

To satisfy the region's year-round and growing demand for fresh packaged milk, the majority of dairy farmers already rely on supplementary irrigation for forage production - because of the increasing unreliability of summer rainfall, and characteristically low rainfall during the cool season.

At the point of deregulation in 2000, the industry estimated that dairy farms in the region needed to at least double milk output within 10 to 15 years to remain viable. A key to making that 'leap' is to maximise (and utilise) the production of homegrown forage from available water - both rainfall and irrigation.

In 2000, an audit of water use on Queensland dairy farms was conducted under the *Rural Water Use Efficiency Initiative*, partnered by the Department of Natural Resources, Department of Primary Industries and Fisheries and Queensland Dairyfarmers Organisation to gauge the amount of irrigation water used on farms at that time. Based on a 1997 water stock take, the audit estimated that Queensland dairy farmers were using an average of 11.0 ML/ha on their irrigation areas - 5.1 ML/ha in winter and 5.9 ML/ha in summer. These figures represent the type of anecdotal evidence used over recent years to estimate dairy farm water use and requirements.

Queensland Government
Department of Primary Industries and Fisheries

RESEARCH INTO FORAGE WATER REQUIREMENTS

IN response to the urgent need for a more precise indication of forage water use, and its relationship to forage yield and dairy farm productivity, research was undertaken for 3 years from 2002 to 2005 as part of the *Sustainable dairy farm systems for profit* project at Mutdapilly Research Station and on commercial farms. The research determined the total water requirements for a range of forages used on dairy farms; the efficiency with which they use water to produce forage and milk; and the main factors affecting their water use efficiency. The research has provided information on planning forage according to water availability and improving the use of limited water supplies.

Average total water use (effective rainfall + irrigation) for a range of typical forages grown at Mutdapilly is presented in *Table 1*. This data was collected under conditions of restricted irrigation – due to limitations in both water availability and infrastructure. More water would have been used if available, and dry matter (DM) yields would subsequently have been higher.

The ryegrass and forage sorghum were double cropped, as were the barley and maize. In these examples, total water requirements for 12 months for the irrigation area would be the combined sum of both crops.

TABLE 1. TYPICAL dry matter yields and water use per hectare for a range of forages evaluated in the Mutdapilly M5 farming systems project (2002-2005). NOTE: *Forages were watered with travelling irrigators under conditions of restricted irrigation.*

Forage type	Yield (kg DM/ha)	Water (ML/ha)		
		Effective rainfall #	Irrigation	Total water
Annual ryegrass +	9,200	1.9	3.4	5.3
Perennial temperate mixtures	9,900	4.5	4.3	8.8
Lucerne	13,000	5.8	5.1	10.9
Forage sorghum +	16,600	2.9	1.7	4.6
Barley silage	8,400	1.0	1.2	2.2
Maize silage	19,800	2.8	2.5	5.4

100 mm effective rainfall over 1 ha = 1 ML   # See the next section for definition and calculation of effective rainfall.

+ Annual ryegrass and forage sorghum were double cropped.

ESTIMATING ANNUAL IRRIGATION WATER REQUIREMENTS *- Using forage water requirements and historical rainfall charts*

A NUMBER of factors affect the volume of irrigation water required for your farm:

- forage(s) grown
- forage water requirements
- average rainfall pattern
- probability of above or below average rainfall
- losses due to evaporation from storages and application inefficiencies.

"**Be Realistic**" when calculating water requirements for your farm. Look at the best and worst scenarios, and make allowance for water that you will need to support continued business growth.

(i) Calculate effective rainfall – daily, then monthly, then annually.

Rainfall effectiveness is determined by its duration and intensity, and refers to the amount of rainfall that infiltrates, is stored in the soil, and is available for plant growth. Light falls may just wet the surface and be lost to evaporation, while a proportion of heavy falls may be lost in runoff.

Coastal dairy regions such as Gympie and Dayboro are more likely to experience a larger difference between actual and effective rainfall, compared with inland dairy regions - because of the higher number of rainfall events throughout the year (*Table 2*).

TABLE 2. AVERAGE yearly rainfall from 1996 to 2005.

Region	Total rainfall (mm)	Effective rainfall (mm)	Effective rainfall as % of total rainfall
Mutdapilly	707	596	84
Gympie	993	783	79
Dayboro	1,086	848	78

Effective rainfall during the growing season was calculated by excluding daily rainfall events of less than 5 mm/day, and including only the first 50 mm of heavy falls in daily totals. For crops with a preceding fallow period it was estimated that 20% of rainfall during the fallow was stored as soil water. The length of a fallow is calculated from the time the previous forage received its last graze or was harvested, to the time of planting the next forage. The amount of water stored during fallow is of greater significance on land growing a single forage crop each year, when the length of fallow may exceed 4-5 months.

These calculations are a guide only. True effective rainfall values will depend on intensity, duration and interval of rainfall events; fallow management; soil cover; time since previous irrigation; and depth of root zone.

In your own calculations, try to use a minimum of 10 years' rainfall data from your locality. Use daily rainfall figures to calculate daily effective rainfall, and then add up by month, then by year. Daily rainfall data files dating back more than 40 years can be purchased from the Bureau of Meteorology website www.bom.gov.au/silo.

Rather than basing calculations on a calendar year, use a 12 month period that doesn't split an important irrigation or rainfall season. For example, Mutdapilly relies on winter irrigation, so annual effective rainfall was calculated from April to March. If your farming operations rely on raingrown summer crops then it may be appropriate to base calculations on a financial year, July to June, to avoid splitting summer rainfall season between calendar years.

Look at the worst 3 years and the best 3 years to obtain your likely range of requirements. *Table 3* gives an example for Mutdapilly. The average rainfall from 1996 to 2006 using a 12-month period from April to March was 596 mm; the lowest 3-year average was 457 mm, and the highest 3-year average was 786 mm.

TABLE 3. MONTHLY sum of effective rainfall (mm) for Mutdapilly Research Station from 1996/97 to 2005/06.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
1996/97 (H)	51	265	7	32	40	24	44	44	98	134	36	11	786
1997/98 (L)	18	48	0	20	0	23	88	63	117	31	128	10	545
1998/99	82	64	5	31	48	93	19	101	24	27	47	50	592
1999/00 (H)	5	21	45	43	19	63	107	40	132	142	117	74	807
2000/01 (L)	9	21	20	6	0	0	46	70	48	49	13	13	295
2001/02	53	39	0	37	7	7	66	84	105	36	131	60	623
2002/03	17	11	31	0	37	20	36	42	131	45	120	82	571
2003/04 (L)	65	24	72	7	0	8	129	7	40	0	113	67	531
2004/05 (H)	11	5	0	0	11	14	86	97	141	235	88	77	765
2005/06	5	31	81	0	5	21	122	82	86	83	17	21	552
Average	**33**	**51**	**26**	**20**	**17**	**27**	**74**	**63**	**92**	**82**	**88**	**49**	**596**
Lowest 3 years	31	31	31	11	0	10	87	46	68	27	85	30	457
Highest 3 years	22	97	17	25	23	34	79	60	123	171	80	54	786

Rainfall sourced from Amberley 1 April 1996 to 31 March 2001, and Mutdapilly Research Station from 1 April 2001 to 31 March 2006

(H) Included in highest 3 years annual rainfall from 1996 to 2006

(L) Included in lowest 3 years annual rainfall from 1996 to 2006

(ii) List the forages you would irrigate each year, and the typical growing period for each forage - from planting until last grazing or harvest

Table 4. shows the typical growth periods for the main forages grown at Mutdapilly.

TABLE 4. THE TYPICAL period of growth for a range of forages at Mutdapilly Research Station.

Forage type	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Annual ryegrass (summer crop sorghum)	■	■	■	■	■	■	■					
Perennial temperate mixtures	■	■	■	■	■	■	■	■	■	■	■	■
Lucerne	■	■	■	■	■	■	■	■	■	■	■	■
Forage sorghum (winter crop ryegrass)									■	■	■	
Barley			■	■	■	■						
Maize								■	■	■	■	

(iii) Estimate the amount of irrigation that each forage will need.

Subtract likely average effective rainfall each month for the forage growth period from total water requirements for the forage (from Table 3). Allow for the best and worst 3 years.

EXAMPLE:

Calculating irrigation requirements for annual ryegrass grown at Mutdapilly Research Station.

Growth period includes April, May, June, July, August, September, October (*Table 4*).

Average effective rainfall for those months (from *Table 3*): 33+51+26+20+17+27+74 = 248 mm.

100 mm/ha=1 ML

Total water supply as rainfall and stored soil water: 248 mm= 2.5 ML/ha

Annual ryegrass water requirements (from *Table 1*) is 5.3 ML/ha.

So in an average year you will need 2.8 ML/ha (5.3 – 2.5) of irrigation for the annual ryegrass crop.

Repeat for the worst 3 years and best 3 years to calculate your range of water requirements, and to produce a table similar to *Table 5* for Mutdapilly.

(iv) Make allowance for losses between the pump and plant growth for your type of irrigator

The figures used to calculate forage water requirements at Mutdapilly Research Station in *Table 1* were measured under a big-gun traveller irrigator. Unless you have an accurate efficiency figure for your system, use the Mutdapilly figures (*Table 1*) if you use a traveller irrigator. If you use a solid set, multiply the figures by 0.9, and by 0.8 for centre pivot or lateral move equipment.

EXAMPLE.

What is the likely maximum irrigation requirement for annual ryegrass at Mutdapilly, irrigated by a centre pivot?

From *Table 5* in a low rainfall year, annual ryegrass is calculated to require 3.3 ML/ha irrigation under a traveller. Multiply by 0.8 for centre pivot efficiency = 2.7 ML/ha total irrigation water requirements under a centre pivot.

TABLE 5. ESTIMATED likely effective rainfall (ML/ha) for the growth period for a range of forages, total water required (ML/ha), calculated irrigation requirements (ML/ha) at Mutdapilly Research Station.

Forage type	**Likely effective rainfall in a range of rainfall years**			**Total water required for the crop or pasture**	**Irrigation required in a range of effective rainfall years**		
	Low	Average	High		Low	Average	High
Annual ryegrass (summer crop sorghum)	2.0	2.5	3.0	5.3	3.3	2.8	2.3
Perennial temperate mixtures	4.6	6.2	7.9	8.8	4.2	2.6	0.9
Lucerne	4.6	6.2	7.9	10.9	6.3	4.7	3.0
Forage sorghum (winter crop ryegrass)	2.1	3.1	4.3	4.6	2.5	1.5	0.3
Barley	0.5	0.9	1.0	2.2	1.7	1.3	1.2
Maize	2.3	3.3	4.3	5.4	3.1	2.1	1.1

"Average" is the average effective rainfall from 1996 to 2005

"Low" refers to the worst 3 years

"High" refers to the best 3 years

(v) Calculate total irrigation requirement for the farm.

Multiply the area of each forage type by the total irrigation water requirements calculated for each forage in (iii) and (iv), and add them together to determine the annual irrigation water requirements for your farm.

EXAMPLE. The total irrigation water requirement for the irrigated pasture farm at Mutdapilly (Farmlet M4) and typical irrigated pasture farms located at Gympie and Dayboro were calculated using effective rainfall averaged over the last 10 years. For the purpose of the example, it was assumed that all farms used big-gun travellers. The irrigation water requirements per farm ranged from 60 for Dayboro to 442 ML for Mutdapilly *(Table 6)*.

If the average of the lowest 3 years of effective rainfall was used, total irrigation water requirements increased to 590 ML per farm for Mutdapilly, 252 ML for Gympie and 90 ML for Dayboro.

TABLE 6. EXAMPLES of a range of whole-farm irrigation water requirements calculated for the modelled Mutdapilly heavily irrigated pasture farm (Farmlet 4) at Mutdapilly, and for irrigated farms located at Gympie and Dayboro, using. average effective rainfall calculated from 1996 to 2005.

Farm	Forage type	Water requirement (ML/ha/year)	Average effective rainfall (ML/ha)	Irrigation requirement (ML/ha)	Area (ha)	Irrigation required for each forage (ML)	Total irrigation required (ML)
Mutdapilly	Ryegrass/sorghum	9.9	5.3	4.6	45	207	442
	Perennial temperate mixture	8.8	6.0	2.8	40	112	
	Lucerne	10.9	6.0	4.9	25	123	
Gympie	Ryegrass	5.3	2.8	2.5	80	200	200
	Kikuyu*	4.6	5.6	0	32	0	
Dayboro	Ryegrass - kikuyu*	9.9	6.9	3.0	20	60	60

* Kikuyu water requirements estimated to be similar to forage sorghum

(vi) Estimate any likely extra water requirements to support future increases in milk production to maintain business growth and viability.

Give some thought to future irrigation requirements, rather than current use, in any submissions to regulatory authorities.

ESTIMATING ANNUAL IRRIGATION WATER USAGE - *using water meter or electricity records*

Water meter. The simplest and most accurate way to calculate irrigation water usage is by fitting a water meter downstream from the pump, and keeping records. If meter readings are taken before and after each irrigation run, it is possible to calculate the volume of water applied to each forage. If you have water-use records for more than one year, you can compare irrigation usage between years to determine how usage varies with the amount of effective rainfall.

Electricity records. If water meter readings are not available, the volume of irrigation water applied can be calculated using electricity readings by one of two methods:

A. If you have had a pump efficiency audit, you will know the volume of water applied per kilowatt hour. The volume of water applied during a 12-month period can be calculated from electricity records by multiplying the total kilowatt hours specified in your electricity records by the volume of water applied (L)/kilowatt hour (1,000,000 L = 1ML). Be mindful that if electric motors other than the irrigation pumps are connected to the same electricity meter, you will be overestimating water usage by this method.

B. If you don't know the volume of irrigation water being applied per kilowatt hour you can make some assumptions. Firstly add together your 12 months electricity invoices, subtract $700 for living, and 0.5c/L for milking. Unless there are other electricity uses on the farm, the remainder of the invoice represents the cost of irrigation. Depending on the type of irrigator that you use, divide the electricity cost of irrigation by $60 for a high-pressure big gun traveller to determine the ML applied, or by $40 for a low-pressure centre pivot or lateral move irrigator.

USEFUL RULES OF THUMB

SOME forages are much better than others at converting water into fodder for cows.

- Tropical species are two to three times (3.0 to 3.7 tonnes DM/ML) as efficient as cool-season species (1.1 to 1.9 tonnes DM/ML).
- Crops can be twice as efficient as pastures.
- A double-crop of short-rotation annual ryegrass followed by a summer forage crop of sorghum or maize has been shown to produce the highest forage yield in a year for the least amount of water in southeast Queensland.

FORAGES have very different water requirements and different yield potential.

- Irrigated forage sorghum can produce 13 to 19 tonnes DM/ha from less than 5 ML.
- Irrigated maize requires a minimum of 6 ML applied strategically over its growing season, but will potentially yield more than 20 tonnes DM/ha.

IRRIGATION timing and volume need to be adjusted throughout the growing season to meet plant requirements.

- For example, ryegrass requires the least amount during autumn seedling establishment when plants are immature and evaporation is low. During spring, water application needs to double to meet plant growth requirements and higher evaporation losses. As plants mature, go to seed, and dry off, water requirements will reduce.

FINE tuning grazing and fertiliser management can greatly improve water-use efficiency – up to 100%.

UNDERSTAND the terms

- 1 megalitre (ML) = 1,000,000 litres
- 1 litre of water applied evenly to 1 square metre will water to a depth of 1 mm
- 10,000 litres will water a hectare to a depth of 1 mm
- 100 mm (4 inches) of effective rainfall or irrigation equals 1 ML/ha
- 20 mm of stored soil water is equivalent to 100 mm of rainfall

M5 INFO SERIES

The M5 Info Series will provide dairy farmers and the industry with a wide range of information from the *Sustainable dairy farm systems for profit* project.

Water-use efficiency topics will include a summary of findings from the *Sustainable dairy farm systems for profit* project; the water use efficiency of commonly used forages; the water use efficiency of different farming systems; how to manage the farm for most efficient use of water; and planning forage according to water.

Other related topics in the M5 Info Series are available at www.dairyinfo.biz.

M5 Info Series - 202 - Steps to making efficient use of water

M5 Info Series - 204 - Water use efficiency of forages on subtropical dairy farms

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