Water productivity of irrigated forages in Northern Victoria

Introduction

The dairy industry in northern Victoria and southern New South Wales is reliant upon cheap forages to keep the cost of production low. Traditionally, irrigated pasture has been the cheapest and major source of energy and other nutrients for dairy cows. However, the declining availability of irrigation water in recent years has become a limiting factor.

This has caused dairy farmers to rethink their mix of irrigated forages and to consider dryland forages in order to optimise their use of irrigation water and rainfall.

Water productivity (the amount of forage produced per unit water used) is one way of comparing forages. However, other factors such as nutritive characteristics and growing, conservation and feeding out costs, also need to be considered by farmers and their advisers when deciding which forage system will best suit the needs of their farm.

Comparing the water use of forages grown on different sites and or in different seasons can be difficult due to differences in rainfall and evaporation rates between seasons and years. Therefore, when comparing the dry matter (DM) production, water use and water productivity of a range of forages, it is important that they are grown at the same site in the same year.

This brochure compares a range of irrigated forages that are typically used by the dairy industry in northern Victoria/southern NSW. The data presented is based upon two recent experiments conducted near Kyabram in northern Victoria.
The first experiment compared a number of annual and perennial forages over a three year period. The second experiment monitored three maize crops on two commercial farms over a two year period.

For each of the forage systems, DM production, forage quality and water use were measured and water productivity was calculated. These comparisons of forage types provide useful data to dairy farmers who are looking at their mix of forages and are aiming to optimise their forage production under conditions of limited water availability.

What was done?

**Annual and perennial forages:** The growth and water use of a range of forage systems was measured in an experiment that ran from autumn 2004 to autumn 2007. These forages included three perennial (perennial ryegrass/white clover, tall fescue / white clover and lucerne) and two annual (Persian clover / Italian ryegrass and subterranean clover / Italian ryegrass) systems.

The Persian clover received its first irrigation in mid-February and last irrigation in late November. The subterranean clover received its first irrigation in early March and last irrigation in late October. The forages were border-check (flood) irrigated.

The forages were grazed and or mown for hay, and fertilised according to best management practices specific for each system. The amount of DM removed was measured at each grazing and forage conservation cut.

**Maize:** The growth and water use of three maize crops grown on local farms was measured in the summers of 2003-04 and 2004-05. Two of the crops were spray irrigated while the other crop was border-check irrigated.

**Measuring water use:** For both experiments, the volume of irrigation water applied and any runoff from irrigation and/or rainfall was measured. The soil water content for each forage system was regularly measured to 1.3 metres as changes in soil water content can be an important part of the water balance, particularly for annual forages.

The water productivity of each forage was calculated two ways, using either irrigation or total water used.
What was found? Annual and perennial forages

Forage production

- Forage production was higher from the perennial pastures (perennial ryegrass and tall fescue), lucerne, and Persian clover systems than from the subterranean clover systems in both 2005 and 2006 (Figure 1).
- The proportion of forage that was removed by grazing was 100 per cent for the perennial pastures, 50 per cent for the annual pastures (Persian and subterranean clover) and zero per cent for lucerne in both 2005 and 2006. (Note that some farmers are grazing lucerne with potentially little impact upon dry matter removal).

Valuing conserved forages

The production of the conserved forages in this brochure refers to that which was cut in the paddock. It ignores the loss in DM that occurs during the conservation, storage and feeding out processes. These losses can be in the order of 20–40 per cent of the forage as initially cut.

The production figures also do not include the loss of feed quality, and the costs incurred, during the conservation, storage and feeding out processes. Considering forage production in terms of how much forage is actually consumed will result in lower DM production and water
productivity values than those presented, with the size of the decline depending on the losses involved and the proportion of the total yield that is conserved. Therefore, the costing of conserved forages should be on the basis of the quantity and quality of the feed consumed.

![Figure 1](image-url)  
**Figure 1.** Forage removed from 5 pasture types by either grazing or conservation in 2005 and 2006. The pasture types are: perennial ryegrass/white clover (PRG), tall fescue/white clover (Fes), lucerne (Luc), Persian clover/Italian ryegrass (PC) or subterranean clover/Italian ryegrass (SC).

**Water use**

*Irrigation water use:*

- Irrigation water use in 2005 was closely related to the length of the growing season, with around 8.0–8.5 ML/ha used for the perennial pastures and 3.5–4.5 ML/ha used for the annual pastures (Figure 2).
- Irrigation water use in 2006 was substantially higher than 2005, with around 12.0 ML/ha used for the perennial pastures and 4.5–7.0 ML/ha used for the annual pastures.

*Rainfall:*

- Rainfall in 2005 (490 mm) was higher than the long term average (455 mm) and that in 2006 (230 mm).
- Some runoff following rain in 2005 for both the perennial (70 mm) and annual (<20 mm) systems reduced the amount of effective rainfall (defined as rainfall less runoff).
- Net changes in soil water content during any year were small except for lucerne in 2005 when it declined by 130 mm (1.3ML/ha).
Figure 2. Irrigation and effective rainfall inputs for five pasture types in 2005 and 2006. The pasture types are: perennial ryegrass/white clover (PRG), tall fescue/white clover (Fes), lucerne (Luc), Persian clover/Italian ryegrass (PC) or subterranean clover/Italian ryegrass (SC). The soil water used was a result of a decline in soil water content over the growing season. Effective rainfall is rainfall less any runoff. For the irrigation water, it is assumed that any runoff has been captured and reused.

Total water inputs:

- Total water inputs were related to the length of the growing season, being greater for the perennial than for the annual forages, and greater for the Persian than for the subterranean clover, in both years.
- Total water use for the perennial pastures was higher in 2006 than in 2005 (14.2 vs 12.8 ML/ha) due to higher evaporation rates.

What controls water use?

The water use of a forage depends upon its characteristics and the environmental conditions in which it is grown. Key forage characteristics include canopy cover (the proportion of the ground that is covered) and canopy height.

Key environmental characteristics include rainfall and factors that drive evapotranspiration such as temperature, humidity, windspeed and solar radiation. Therefore, plant water requirements are much higher during hot/dry periods than during cool/moist periods.

Forage nutritive characteristics

Metabolisable energy (ME) content
The average ME content of the forage removed by grazing was relatively similar for the annual and perennial pasture systems in both 2005 (11.9–12.4 MJ/kg DM) and 2006 (11.7–12.5 MJ/kg DM) (Table 1).

The ME content of the forage removed by conservation in 2005 and 2006 was higher for Persian clover (10.9–11.2 MJ/kg DM) than for either lucerne or subterranean clover (8.7–10.2 MJ/kg DM).

**Crude protein (CP) content**

With the exception of lucerne, the grazed forages had higher CP contents than the conserved forages.

Lucerne had a much higher CP content than the conserved Persian and subterranean clover due to their low legume contents in both 2005 (72% in Persian and 43% in subterranean clover) and particularly in 2006 (<20% in both Persian and subterranean clover).

Both the ME and CP contents of the conserved Persian and subterranean clover were lower than when grazed due to increased plant maturity and lower legume content.

**Table 1. Metabolisable energy and crude protein contents of grazed and conserved forages**

<table>
<thead>
<tr>
<th>Year</th>
<th>Perennial ryegrass / white clover</th>
<th>Tall fescue / white clover</th>
<th>Lucerne</th>
<th>Persian clover / Italian ryegrass</th>
<th>Subterranean clover / Italian ryegrass</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metabolisable energy content (MJ ME/kg DM)</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Grazed</td>
<td>2005 11.9</td>
<td>12.1</td>
<td>-</td>
<td>12.4</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>2006 11.7</td>
<td>11.7</td>
<td>-</td>
<td>12.5</td>
<td>12.4</td>
</tr>
<tr>
<td>Conserved</td>
<td>2005 -</td>
<td>-</td>
<td>10.2</td>
<td>11.2</td>
<td>8.7</td>
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<tr>
<td></td>
<td>2006 -</td>
<td>-</td>
<td>10.0</td>
<td>10.9</td>
<td>10.1</td>
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<tr>
<td><strong>Crude protein content (%DM)</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Grazed</td>
<td>2005 18.4</td>
<td>25.1</td>
<td>-</td>
<td>29.8</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>2006 22.1</td>
<td>24.2</td>
<td>-</td>
<td>29.0</td>
<td>22.2</td>
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<tr>
<td>Conserved</td>
<td>2005 -</td>
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<td></td>
<td>2006 -</td>
<td>-</td>
<td>22.1</td>
<td>13.4</td>
<td>11.3</td>
</tr>
</tbody>
</table>
A The feed qualities of the conserved forages are at the time of cutting and ignores the losses that occur during the conservation, storage and feeding out processes.
B Cut twice in both years.
C Cut once in both years. The 2005 cut was delayed due to wet weather and this reduced the ME content.

**Water productivity**

Irrigation water productivity in 2005 was higher for the annual (3.0–3.7 t DM/ML) than for the perennial systems (2.1–2.7 t DM/ML) (Figure 3).

The higher irrigation water use in 2006 than in 2005 (due to lower rainfall and higher evaporative demand) meant that irrigation water productivity was lower in 2006 than in 2005 for both the annual (1.7–2.7 t DM/ML) and perennial (1.2–1.9 t DM/ML) systems.

When the total water used (defined as irrigation plus rainfall less runoff less increase in soil water content) was included in the calculation of water productivity, the differences between the forage systems were much smaller in both 2005 (1.2–1.7 t DM/ML) and 2006 (1.1–1.5 t DM/ML).

**What is water productivity?**

Water productivity is the amount of forage produced per unit of water used. Forage output can be described in terms of either dry matter (DM) (t DM/ha), metabolisable energy (ME) (MJ ME/ha) or crude protein (CP) (kg CP/ha) produced. Water inputs (ML/ha) can be described in terms of either irrigation water applied (assuming any runoff is captured and reused) or total water applied (irrigation plus rainfall less runoff less increase in soil water content). (100 mm of rainfall is equivalent to 1 ML/ha).
Figure 3. Irrigation and total water productivity for five pasture types in 2005 and 2006. The pasture types are: perennial ryegrass/white clover (PRG), tall fescue/white clover (Fes), lucerne (Luc), Persian clover/Italian ryegrass (PC) or subterranean clover/Italian ryegrass (SC). For the irrigation water, it is assumed that any runoff has been captured and reused. Total water comprised irrigation plus rainfall less runoff less increase in soil water content.

What was found? Maize

- The spray and border-check irrigated maize crops both yielded in the order of 18 to 21 t DM/ha.
- The higher growing season rainfall in 2004-05 than in 2003-04 (240 vs 100 mm) meant that 2.6 ML/ha less irrigation water was used on the spray irrigated crop in the second year.
- The total water used by the spray irrigated crop was 1 ML/ha lower in 2004-05 than in 2003-04 due to lower evaporation rates.
- The irrigation water productivity was markedly higher in the wet than in the dry year (5.6 vs 3.1 t DM/ML), however, the difference between years in total water productivity was much lower (3.2 vs 2.7 t DM/ML).
- The border-check crop was grown on the flat rather than on beds. Growing it on beds may have increased its yield but would have also increased the labour requirements during irrigation.
- The maize at the time of cutting had an ME content of 11 MJ/kg DM and a CP content of 7.0% DM. These figures ignore any losses that occur during the conservation, storage and feeding out processes.

Table 2. Dry matter production, water use and water productivity of 3 maize crops.

<table>
<thead>
<tr>
<th></th>
<th>Spray 1</th>
<th>Spray 2</th>
<th>Border Check</th>
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<tbody>
<tr>
<td>2003/04</td>
<td></td>
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<td>2004/05</td>
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Irrigation water productivity was generally higher for the winter growing annual than for the perennial forage systems. This was a result of:

- the seasonal distribution of rainfall which meant that rainfall comprised a higher proportion of total water use for the winter growing annuals than for the perennial systems in both 2005 (55% vs. 35%) and 2006 (31 vs 17%).
- the water requirements of forages are largely driven by the environment and was lower during cool/moist than during hot/dry periods. Thus because they don't grow over summer, annual pastures used 40-60% less irrigation water than the perennial forages for only a 20-40% reduction in forage production.
Irrigation water requirements in 2006 were 50 per cent higher than in 2005 due to both lower rainfall and higher evaporation rates. These differences in irrigation water requirements highlight considerable year to year variation as low rainfall years are usually high evaporation years, and vice versa.

Maize had a high irrigation water productivity compared to both the annual, and particularly to the perennial, forages. This was evident during both wet and dry years. However, maize is often expensive to grow and conserve and there are many factors that need to be considered before it is included in the forage mix on a dairy farm.

When selecting which forage to grow, there are many factors that need to be considered. These factors include: forage yields, nutritive characteristics, the proportion of the forage which is removed by grazing versus conservation, the time of year when it can be grazed, growing, conservation, storage and feeding out costs, (and the losses in dry matter and feed quality associated with these processes), and how well a forage fits a farmer's system.

Therefore, in farming situations where irrigation water is scarce, water productivity is one among many factors that need to be considered when deciding which forage system will best suit the needs of a farm.

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