IRRIGATION EFFICIENCIES

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Introduction

Water is a very important issue for dairying in Canterbury and North Otago. In these areas, irrigation by dairy farms uses a lot of water. It has been calculated that twenty 500 ha dairy farms use as much water as the whole the city of Christchurch. Not surprisingly, farmers are under pressure to use water more efficiently, whilst at the same time, they have to maintain pasture productivity to ensure economic survival.

There is considerable scope for many dairy farmers to improve their water use efficiency. A 30% range in annual pasture production among irrigated dairy farms, observed in a recent study, equates to over $1000/hectare/year difference in income between the highest and lowest producing farms. Hence there is considerable opportunity for many dairy farmers both to improve their water use efficiency and to increase their returns by using water more efficiently.

What is irrigation efficiency?

Irrigation efficiency can mean different things to different people. Here are two key definitions:

1. *Pasture water use efficiency*. This is the amount of pasture production per mm of water applied. Optimal water use efficiency occurs when you are producing high pasture yields with low volumes of irrigation.
2. *Application efficiency*. This describes how efficiently your irrigation system is used to apply water. It relates the amount of irrigation applied to the amount of this water that is available for growing the pasture. High application efficiency means that a large proportion of the irrigation applied will be used by the plant, whereas a low application efficiency means that much of that water has been lost to runoff or drainage.

How to optimise pasture water use efficiency

This requires sufficient information to know:

- when to start irrigating?
- when to stop irrigating?
- how much water should be applied?
- when should it be applied?

To do this efficiently requires measurements or calculations of

- rainfall
- soil depth

- soil moisture
- pasture growth response to irrigation
- irrigator application rate and efficiency

Once you have all this information, you can schedule your irrigations to maximise your returns per mm of water applied.

Sunshine and soil moisture

If the daily average soil temperature at 10 cm depth is below 10^{o}C, grass grows very slowly. Therefore there is no point irrigating when soil temperatures are that low.

Above a daily average soil temperature of 10^{o}C, grass growth of a well managed dairy pasture is mainly related to solar radiation and soil moisture. Under New Zealand conditions, the more solar radiation or sunshine, the faster grass grows. For a well managed pasture, the major limitation to grass growth is then soil moisture.

However, soil moisture does not restrict grass growth until the soil has dried to a critical deficit (also called a trigger point or refill point or stress point, Figure 1). After this, grass growth decreases with increasing soil moisture deficits until the soil is so dry that pasture growth stops (called the wilting point). A rough rule of thumb is that the critical deficit is around half the available soil moisture (ASM) in your soil, where ASM is the amount of water the soil can hold between field capacity (when the soil is full of water, and any more water will be lost to drainage or runoff) and wilting point.

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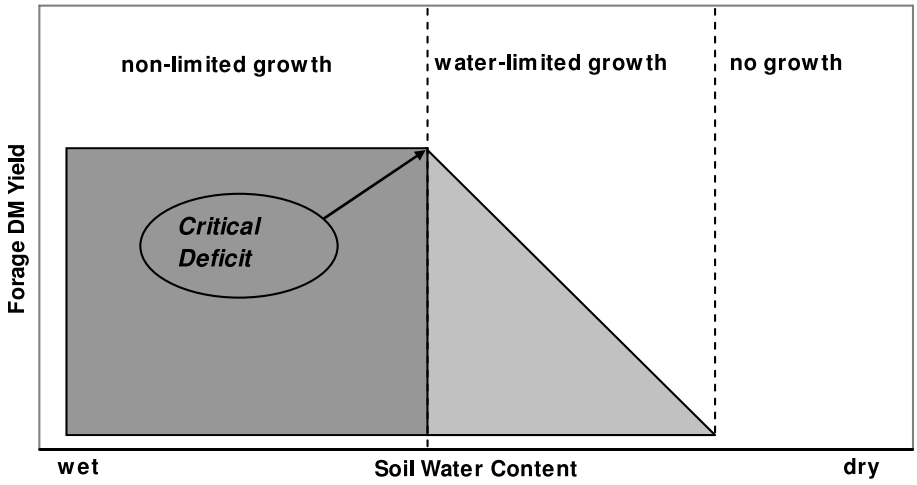

Figure 1: Changes in forage growth with decreasing available soil moisture.

Soil depth

Soil depth to stones or to a pan is important as this determines how much water your soil can hold, and so much and how often you need to irrigate.

The amount of ASM and the size of the critical deficit largely depend on the depth of the soil and the parent material beneath. For instance, gravels hold very little water, so shallow soils overlying gravel material have low ASM and are quick to reach critical deficits. The amount of ASM and the size of a soil's critical deficit will increase with soil depth to about a depth of 1 m (Figure 2), which is the depth from which grass roots will extract water. This means that it is important to know the depth of soil in your paddocks.

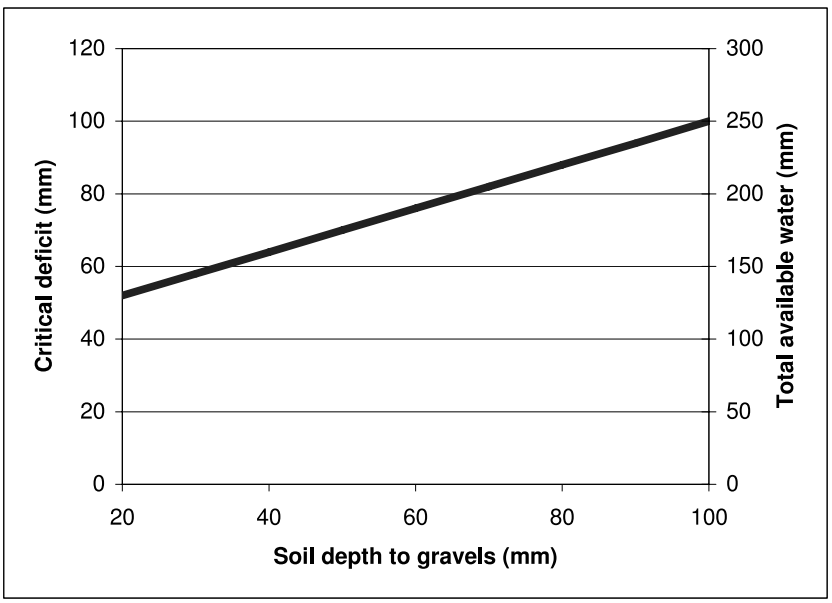

Figure 2: Changes in critical deficits and total available water storage with soil depth.

Knowing when to apply irrigation

It is helpful to understand how much water is in your soil and how this changes. The soil moisture balance is important as it gives an indication of how dry the soil is, and hence whether irrigation is needed and how much water the soil can hold. Like your bank balance, the soil moisture balance is based on your initial balance (soil moisture), credits (rainfall and irrigation) and debits (plant use/evapotranspiration, drainage or runoff). The soil moisture balance is calculated as:

Equation 1: Soil moisture today = Soil moisture yesterday + rain + irrigation - drainage - evapotranspiration

Evapotranspiration is the combined loss of water from the soil surface (evaporation) and the pasture (transpiration) to the air. Its rate depends mainly on solar radiation, but also on how dry the air is, and so can exceed 10 mm/day on clear days under hot dry nor'west conditions.

For irrigation scheduling, it is more useful to use soil moisture deficits, i.e. how much drier the soil is below field capacity. Equation 1 is then modified to become:

Equation 2: Soil moisture deficit today = Soil moisture deficit yesterday - rain - irrigation + drainage + evapotranspiration

Irrigation can be scheduled by making direct measurements of the soil and determining the soil moisture deficit. There are now more accurate devices coming on the market which are cheaper and more user-friendly than in the past, and some can be linked remotely to a computer. Many farmers use a soil moisture monitoring service to measure soil moisture for them, and rely on its interpretation to schedule their irrigation. Cost usually restricts scheduling services to one or two paddocks on a farm.

An alternative method is to calculate the change in soil moisture deficit from the other components in Equation 2, i.e. rainfall, irrigation, drainage, and evapotranspiration. Farmers can measure their rainfall, should know the amount of water their irrigator is applying, and, if they are using good irrigation practice, they should not be applying so much water that drainage occurs. Evapotranspiration is calculated from data collected from weather stations, and is published weekly through the irrigation season in most Canterbury newspapers. A correction factor, based on the soil water holding capacity and pasture cover, is used to convert the

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potential soil moisture to actual soil moisture. With these figures, it is possible to calculate soil moisture deficits for every paddock on the farm.

Dairy Insight has funded a project to develop an Irrigation Calculator using this method to assist in irrigation scheduling and planning on farm. The Calculator has the advantage that it relates actual soil moisture to pasture growth (as in Figure 1), and can be applied to every paddock on a farm. It is designed to be run on a PC, but could be adapted to other IT devices. The Calculator is being designed to be simple to use, but it is based on sound scientific understanding. Crop & Food Research and AgResearch are undertaking the tool development and implementation.

A screen shot of the irrigation scheduler part of the Calculator is shown in Figure 3, and shows a chart very similar to those produced by soil moisture monitoring companies.

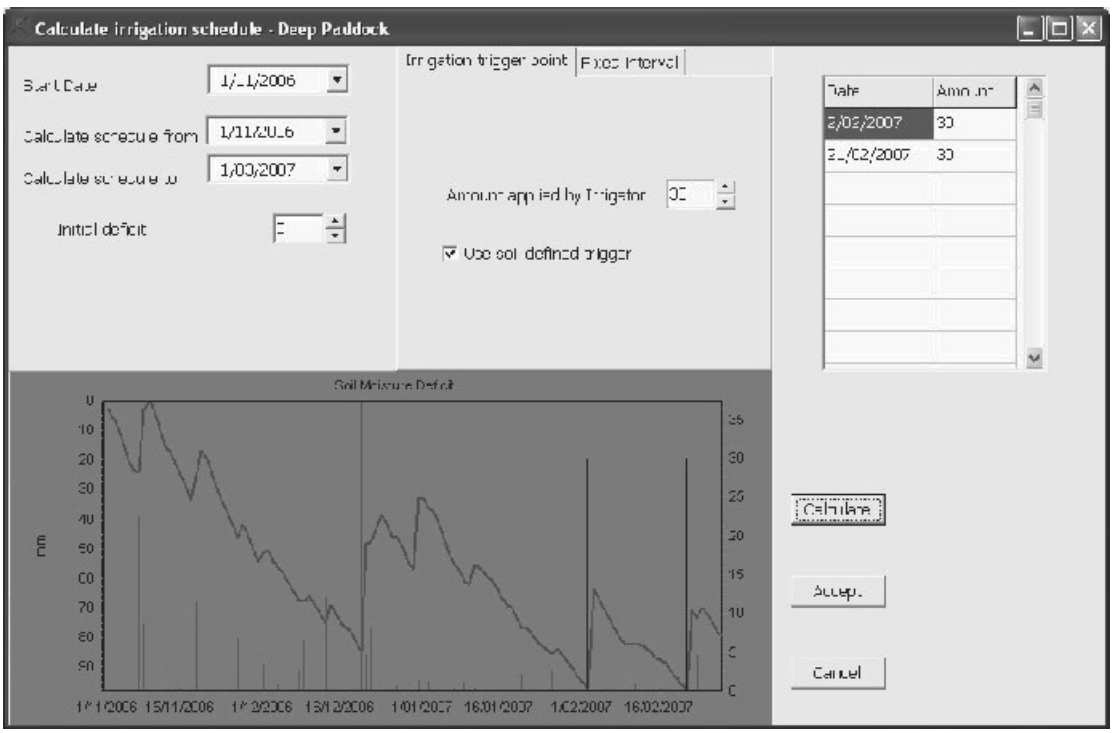

Figure 3: Screen shot of the Irrigation Calculator scheduling page, showing soil moisture deficits

Obviously, any calculator like this needs a starting point. In most winters, rainfall is in excess, so that at the beginning of August in New Zealand, most soils are full. Also, it is wise, occasionally, to check actual soil moistures in your paddock to make sure that consultants and calculators are tracking correctly, because there may be some key factor that is not being recorded properly. It may be that the amount applied by the irrigator is not the same as expected, or that the soil does not hold as much water as assumed. Any problems can be diagnosed easily with some simple measurements.

To maximise production, water has to be applied to avoid deficits that reduce production. So, for any paddock:

- irrigation should start when the soil moisture deficit approaches the critical deficit. Exactly the same rule applies for subsequent irrigations.
- at most, just enough water should be applied to bring the soil moisture deficit back to zero, although ideally a slight deficit should be maintained of at least 10 mm to allow for any subsequent rainfall.
- at the end of the season, irrigation should be stopped when water is no longer limiting grass production – i.e. when growth is again being limited by soil temperature.

Just how this will work out in practice will depend on knowledge of your soil and water applications, rainfall amount and distribution, irrigation system uniformity and operational constraints.

How to optimise application efficiency

Once you know the amount of water your paddock needs and when, then you need to determine whether your irrigator is applying the right amount of water at the correct rate and evenly (known as the system's uniformity).

This is relatively easily checked and all it needs is at least 20 plastic buckets and a reasonably accurate liquid measuring device. For a travelling irrigator, the buckets are laid out across the line of travel, the irrigator is run past them, and the amount in each bucket is measured. For non-travelling systems, a grid of buckets can be laid out. The amount applied is the average contents of all the buckets, and this amount, divided by the time taken for the irrigator to pass over the buckets, gives the irrigation rate.

The common measure of uniformity is called the Distribution Uniformity (DU), which is the total amount in the 25% of buckets containing the least amount of water, divided by the total amount in all the buckets. A system with a lower DU means that a paddock is being watered less uniformly than a system with a higher DU. Different types of irrigator have different inherent DUs, with centre pivots and lateral moves having a design efficiency of around 80-90%, and multiple spraylines around 40-50%. To ensure complete coverage of a paddock with a planned amount of water means that you have to apply the planned amount (say, 50 mm of irrigation) divided by the uniformity. So if the DU is 50%, the planned application of 50 mm is divided by 0.5. This tells the farmer that some areas of the paddock would actually only receive

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25 mm of the planned 50 mm, which means that farmer would need to double the planned application amount to ensure that enough water is applied to those areas that get the lowest amount. However, leaving the irrigator running for twice as long is not desirable, since the well-watered parts of the paddock would then get far too much water (in this case, up to 100 mm), leading to drainage and runoff. To minimise the problem, it is best to ensure that your system is performing to its maximum uniformity, to maximise your pasture production while minimising your water use (and costs!).

Poor set-up and/or maintenance of the irrigators can reduce a system's DU dramatically. Common set-up and maintenance problems include mismatches between pump pressure delivery and irrigation pressure requirement, poorly set variable speed drives, blocked lines and sprinklers, and poorly matched sprinklers fitted along the irrigator arm. Most of the simpler problems are easily fixed. Having the performance of your irrigator evaluated by qualified consultants will point out any sources of reduced performance, and rectifying the problems will soon save you the costs of the evaluation.

Examples of irrigator uniformities found in a recent survey are given in Table 1, and show that the extra amount of water needed to ensure that whole paddocks receive the desired amount of water ranges from 31% to 127% more than what was actually applied.

Table 1: Water applications and Distribution Uniformities measured on five dairy farm irrigation systems, together with the amount of water which would be need to be applied to cover whole paddocks with the amount originally applied.

System type	Amount applied (mm)	DU lower quartile (%)	Minimum amount to water whole paddock with applied amount (mm)	% extra water required
Centre pivot	4.2	76	5.5	31%
Centre pivot	11.6	67	17.3	49%
Rotorainer	50	70	71	42%
Rotorainer	34	57	60	76%
K-line	16.8	44	38.2	127%

Even with a well set-up and maintained irrigation system, significant losses can occur through poor irrigation management, which includes over-watering and under-watering, irrigation too early or too late, and applying water too fast. Applying more water than the existing deficit will result in more water in the soil than it can hold, and so the excess will be lost through drainage and runoff. This just wastes water through drainage and increases pumping costs, as there is no additional grass growth. Irrigating too late, when soil moisture has fallen below the critical deficit, reduces pasture yield, and this cannot be compensated for by

applying more water at a late irrigation. Applying water faster than it can be absorbed by the soil leads to runoff and ponding. Using scheduling tools such as the Irrigation Calculator and changing the system set-up to reduce application amounts and rates can avoid these irrigator operation problems.

How to achieve optimal water use

Ensure your irrigation system is working to specification. Consider having the system's performance evaluated. Ensure that the system is regularly maintained.

Manage your irrigation based on the demands of the pasture by following an irrigation schedule:

- know what your critical/trigger point is before you lose yield
- know how much your irrigator applies
- know when to apply irrigation
- you can apply too much water! Don't irrigate more than the soil can hold.

Make best use of rainfall. Average rainfall in Canterbury over the season is worth about $300/ha. The benefits of rainfall will be mainly realised early and late in the season when water use is lowest. Irrigating too early or too late may just waste water.

Consider whether your system is providing a high application distribution uniformity (DU). If DU is low, replacing it or adjusting it to ensure a more uniform system will produce more grass with much less water.

Acknowledgements

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