IRRIGATION 101

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The pressure is on. Water use is being metered, allocations are being limited, farm plans are mandatory, Overseer is penalising poor irrigation performance and finances are tight. The bar is constantly being raised. Good irrigation performance is being demanded from many quarters.

In the past, the focus was on production, growing grass and turning that into milk. That hasn’t changed, but what has changed is the need to grow quality grass with as little water as possible. Minimising drainage below the pasture root zone to reduce nitrate leaching is as important as growing grass.

So what is good irrigation and how can it be obtained? How can you optimise grass quality and growth while minimising leaching? What are the key things you need to do?

The first thing is to understand your soil and crop characteristics. The second thing is to ensure that you have an irrigation system that is realistically able to apply the required depth of water. Thirdly, you need to know how much water to apply. Fourthly, you need to apply that depth of water. Finally, you need to monitor your performance.

Evapotranspiration

Crops use most of their water to transpire (sweat) to stay cool – perhaps 95%, with 5% going into the plant. Some more water is evaporated from the soil surface or from plant surfaces. Frequent, light irrigations will incur more evaporation than less frequent heavy applications. The combination of evaporation and transpiration is known as evapotranspiration (ET), as illustrated in Figure 1 (from University of Nebraska).

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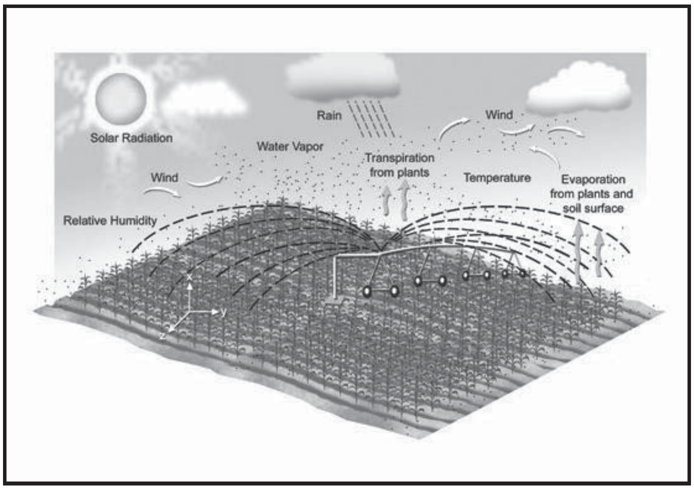

Figure 1: Evaporation and Transpiration = Evapotranspiration

Potential evapotranspiration (PET) is the term often referred to in climate publications or in the press. It is normally the ET from 100 mm high pasture that is not under any stress (moisture or disease). Actual evapotranspiration (AET) is the ET that actually occurs, taking into account things like pasture height and condition, which relates more to leaf area than anything else. In our conditions, most of the time AET is less than PET, especially after harvesting or grazing, but may be higher going into the summer, when there is greater leaf area.

A good irrigation system will have the ability to deliver water to crops and pasture in the right volume at the right time to deliver optimum production. It will apply water efficiently, be cost effective in terms of the initial capital investment and on-going running costs and it will be reliable.

Soils

The right irrigation volume is determined by the soil properties (profile available water or PAW) and crop characteristics, especially rooting depth and the ability of the crop to accommodate soil moisture stress.

The total amount of water held in that depth of soil, the amount available to plants and susceptibility to leaching depends on the type of soil (soil texture), as illustrated in Figure 2 (from Sabine Grunwald).

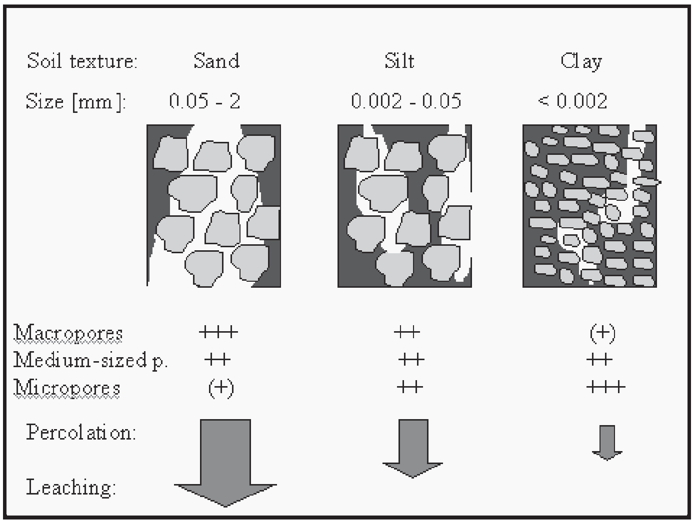

Figure 2: Relationship between soil texture, grain size, pore size and leaching potential

Soil has a mixture of large holes (macropores) and small holes (micropores). The more macropores there are, the greater the potential for leaching. Sands and gravels have the highest leaching potential, while silts and clay have the lowest potential.

Soil water states

There are three basic kinds of water in soil, as illustrated in Figure 3 (from Seeya Later Irrigator magazine). Gravitational water is water that drains through the macropores and results in leaching. If soil is saturated, this water will drain out. Capillary water is held in the micropores and is available for plant use. It does not drain out. It is of most interest to irrigators as it is used to replace crop water use. Hygroscopic water is also held in micropores, but is too tightly held by the soil particles to be used by plants.

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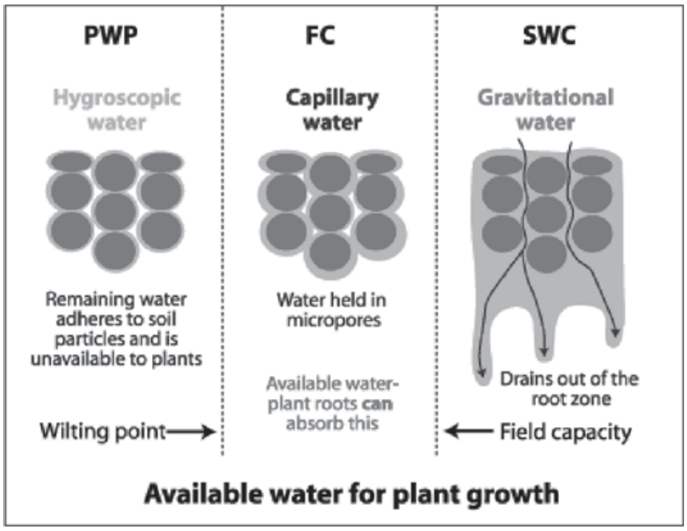

Figure 3: Soil water types

There are several terms used to describe soil moisture states. The key ones are:

- Saturation (SWC) – moisture content when the soil is completely wet
- Field capacity (FC) – water remaining after gravitational water has drained out
- Refill point (RP) – the soil moisture content when irrigation is applied
- Stress point (SP) – the soil moisture content when plant growth begins to slow
- Permanent wilting point (PWP) – plants are unable to abstract moisture and die
- Dry – nothing left.

Figure 4 (from The COMET program) illustrates the relationship between some of these parameters for a range of different soil types.

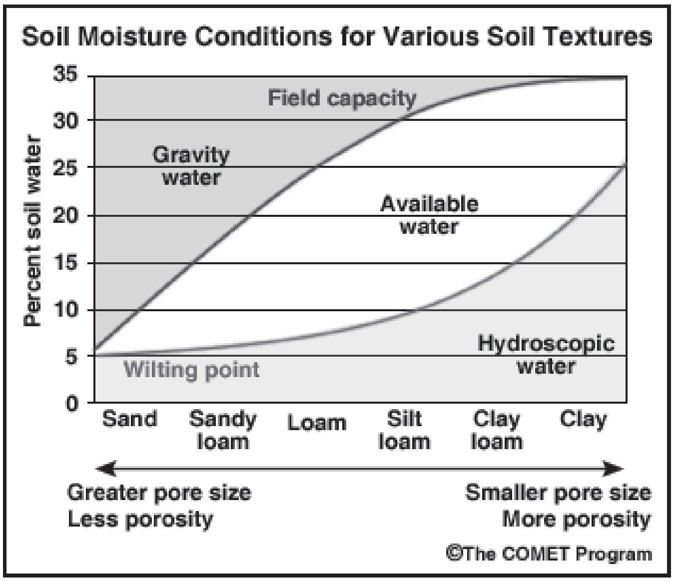

Figure 4: Percentage soil moisture for different soil textures.

In Figure 4, 'Wilting Point' should be referred to as Permanent Wilting Point for consistency. Note that some soils like clay hold a lot of water but don't release much of it, but others like sandy loam don't hold much but release most of it. One of the best soils to irrigate is silt loam.

Published soils data (such as S-Map) may be available to give you indicative information about the soils on your farm. Keep in mind that these maps are prepared at a large scale and that soils at specific locations may vary from the published data. You could employ a soils expert to come in and prepare a detailed soil map for you. Another alternative is to use EM mapping. However, EM mapping must be carried out at the right time and be properly calibrated.

Although there is no substitute for getting a proper soil analysis done, Table 1 (from www.decagon.com) presents some of these parameters for a range of different soil types. The numbers in the table can be used as a starting point.

To convert these percentages to mm water holding capacity, you need to multiply the percentage for each soil type by the depth of that layer (measured in mm), down to the depth of crop or pasture roots. Pasture typically has an active rooting depth of 400-600 mm. If stones are present, you need to estimate the percentage of stones and multiply the calculated mm water holding capacity by that percentage as well.

Table 1: Estimates of moisture content (% volume) for FC and PWP for different soil textures

Texture	FC (v%)	PWP (v%)
Sand	10	5
Loamy sand	12	5
Sandy loam	18	8
Sandy clay loam	27	17
Loam	28	14
Sandy clay	36	25
Silt loam	31	11
Silt	30	6
Clay loam	36	22
Silty clay loam	38	22
Silty clay	41	27
Clay	42	30

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As plants abstract water, soil moisture content falls. The more it falls, the harder it is for plants to extract more water. There is a point, which we refer to as the stress point (SP), or critical deficit, where plants can't extract water fast enough to stay cool; they come under stress (usually wilt) and growth slows. Plants at that stage are using what we call survival water.

The difference between FC and SP is known as readily available water (RAW). The aim with irrigation is to keep soil moisture in the range between FC and SP so that plants have access to the RAW.

Plant available water PAW (mm) for a specific rooting depth = FC (mm) – PWP (mm)

Readily available water RAW (mm) = FC (mm) – SP (mm)

Survival water (mm) = SP (mm) – PWP (mm)

You will see soil moisture referred to as % soil moisture, mm/100 mm, mm, or sometimes even soil tension or suction (kPa). Figure 5 (from Seeya Later Irrigator magazine) illustrates the various soil moisture states and an example of how the numbers vary with the different states.

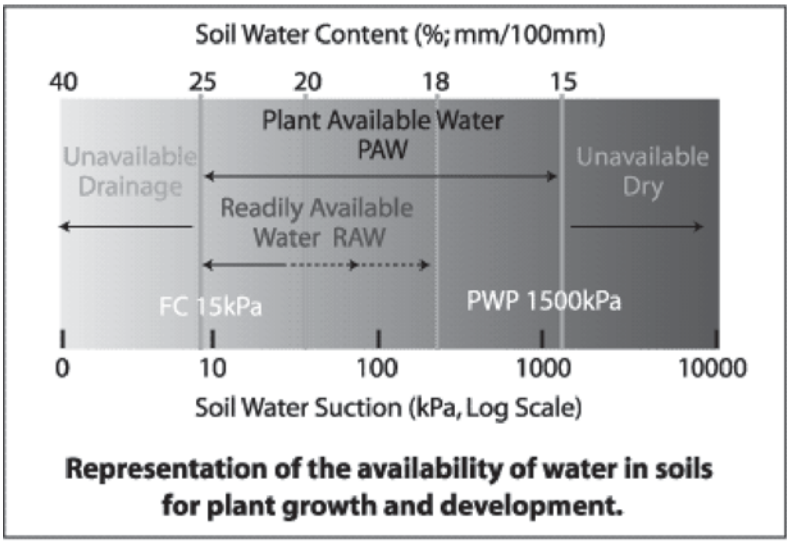

Figure 5: Soil moisture states

The soil water content numbers in this example would be appropriate for a sandy clay loam, so should not be used for other soil types.

Stress points

The aim with irrigation is to keep soil moisture between field capacity and the stress point by applying water when soil moisture is at the refill point. The amount of water that the system is designed to apply should not exceed the difference between field capacity and the refill point.

For systems like centre pivots, application depth can be easily controlled (usually) to stay within these limits. For other systems, it may not be so easy, especially on the lighter soils.

Field capacity can be determined from soil moisture measurements, from some soil maps (watch rooting depths), from properly calibrated EM mapping or estimated from Table 2).

Stress points depend on the type of crop and the magnitude of ET on a particular day. For pasture, many people assume that the stress point is at 50% of the difference between field capacity and permanent wilting point. In the absence of further information, that can be used, but if we are serious about improving efficiency and reducing drainage, we need to be operating at a higher level than that.

If we look at pasture, stress points vary according to ET. The higher the ET, the more moisture needed in the soil to prevent stress. It is why you see grass temporarily wilting on hot days even though soil moisture may be above 50%. The following figure shows an example relationship between month (which determines average PET) and stress point.

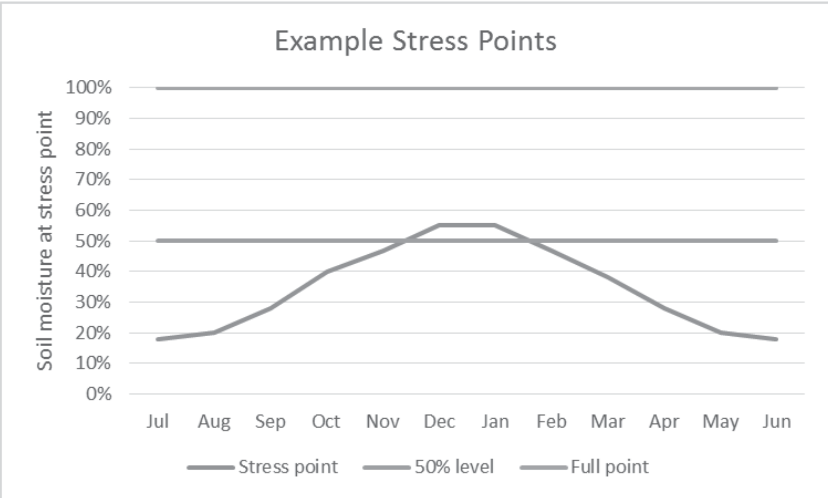

Figure 6: Example of how stress points change by month or ET

We can use that knowledge to reduce water use and minimise drainage throughout the year.

Ideally, to minimise water use and drainage, we could apply small depths of water when soil moisture is just above the stress point. That would leave space in the soil for rainfall and

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variations in application. However, applying small depths is less efficient and much more risky (what happens if an irrigators breaks down, or water is turned off!)

The other risk is that your system doesn't have the capacity to keep up in extended periods of high crop water demand. Virtually all pasture irrigation systems have a system capacity (mm/day) that is lower than peak ET. During those times, you need to use soil moisture storage as a reservoir to prevent moisture falling below the stress point. You need to apply water at an appropriate refill point, knowing that you will lose some ground during hot dry periods, so that you stay above the stress point.

Realistically, you are best to keep a margin for rainfall storage, but not apply too little too often. On pivot systems, the optimum is to apply 3 to 5 days worth of water per application.

For irrigation systems that have high catch-up ability, for example systems on a reliable water supply with an irrigation system capacity of 5-6 mm/day and short return intervals (fixed pivots are an example), you can maintain the soil moisture at a smaller safety margin above the stress point.

For irrigation systems that have low catch-up ability, for example irrigation systems on a less reliable water supply with a lower system capacity and longer return intervals (such as guns, booms), you need to ramp the soil moisture up to a greater margin above the stress point as you come into the summer, to stop soil moisture going too low during hot dry periods. You also need to ensure that the depth of water applied does not cause the soil moisture to exceed the full point.

Figure 7 presents the same stress point as shown in Figure 5, but also includes example refill points for systems with high catch-up and low catch-up ability.

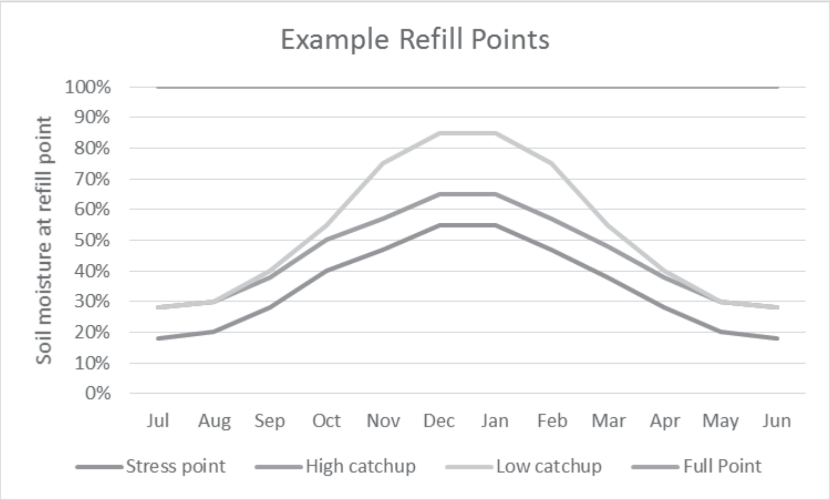

Figure 7: Example of how stress points change by month or ET

Figure 6 and Figure 7 are examples of how more efficient irrigation strategies can be developed. Note that different crops have different stress points and respond differently at times of high ET and high soil temperatures in different soil types. It is important that you obtain expert advice on what the best irrigation strategy will be for your particular circumstances.

Efficient irrigation

Poor design constrains efficient irrigation. If a system is poorly designed, efficiency will be low, regardless of how well the system is managed. If it is properly designed, it has the potential to be efficient. A significant amount of effort by Irrigation NZ and others has gone into improving design – codes of practice, standards, industry training, qualifications, and accreditation. Things have improved, but there is still progress to be made.

You need to know exactly how well your irrigation system is performing. It is surprising how many irrigation operators don't know how much water their system is applying, or how well. Several companies are involved in carrying out irrigation evaluations and the findings tell us that while some systems are performing well, for others, the results are often not good. Too many irrigation firms are still not finishing the job. Farmers need to insist on installations being properly finished and tested.

Another problem is unreliable or untimely water supplies. If you are serious about using water efficiently and minimising drainage, you need to irrigate at the most appropriate time, not when you are forced to. You need to move to a 'just in time' basis rather than 'just in case'. Whatever you can do to get to the position where you can control the timing of irrigation events, you should do so.

Unwanted stoppages are another problem. Some of those stoppages can be avoided through good maintenance – keeping pivot wheel tracks in good condition for example. Some power faults are hard to avoid, but there may be ways of improving things.

Limited user training has clearly been a problem in many instances. Irrigation NZ has been running courses for operators recently with good success. Those courses introduce the basics of irrigation management, and we strongly suggest that irrigation operators attend these courses.

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Inefficiency

Let's look at where water is not being used efficiently. The following table (Table 1) provides some guidance on where inefficiencies occur.

Table 2: Typical losses from spray irrigation (as percentage of water applied)

Source of loss	**Typical loss**
Leaking pipes	<1%
Evaporation	<5%
Blown away by wind	<5%
Watering non-irrigation areas	<2%
Interception	<2%
Surface runoff	<5%
Uneven/excessive application	5-30%

Table 2 tells us that watering on hot days (evaporation) is not a major issue. Yes, it is better to irrigate at night, but evaporation in the air is low in New Zealand, typically less than 3%.

What Table 2 emphasises is that uneven application is a major issue. It results in some parts of a field getting too much water and other parts not enough. The under-watered parts lose production while the overwatered parts result in drainage below the root zone, both of which are to be avoided. Uneven application is caused by factors such as poor design/ installation or irrigating in windy conditions, with some systems being affected more than others. Although Table 2 shows that very little water is blown off an irrigated area, wind has a big effect on uniformity. Generally, you are better to irrigate on hot calm down days than on cool windy days.

Uneven application due to poor design is unacceptable. But, we still see sprinkler spacing being too wide, wrong nozzle setup, or wrong VRI settings, for example.

Another cause of uneven application is irrigators that apply water too quickly to the soil, causing redistribution and runoff. The application intensity exceeds the ability of the soil to absorb the water. It can normally be seen by water ponding on the soil surface and redistributing from the high spots to the lower areas in a field. It manifests itself as low distribution uniformity or uneven application and has the same consequences of low production in some areas and excessive drainage in others.

Figure 8 illustrates this effect. If you are seeing water ponding on the soil surface, you probably have an application intensity problem. You should seek advice on how to fix it.

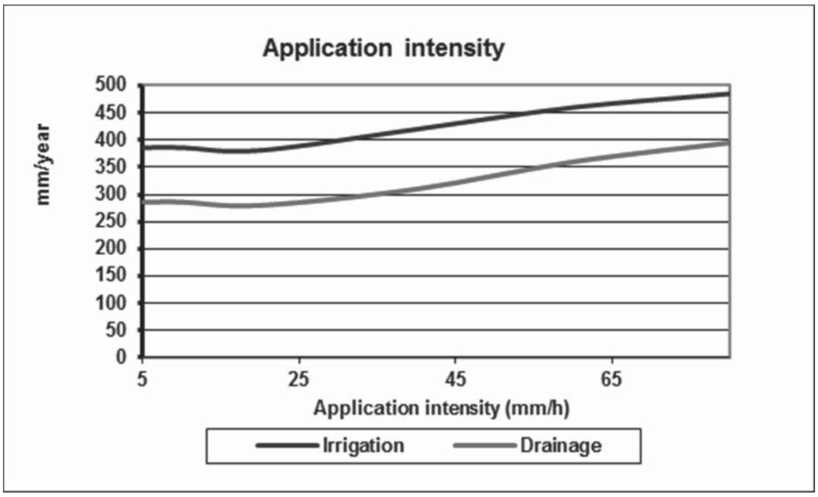

Figure 8: Relationship between application intensity, irrigation water use and drainage

Table 2 also tells us that excessive application depth is a major factor in low efficiency. Excessive application is caused by applying more water that the soil can hold. The depth of application exceeds the ability of the soil to hold that depth of water. The excess drains below the root zone of the soil and is lost to the crop. The way to ensure that doesn't happen is to apply the required depth of water at the right time.

Measuring and monitoring

Let's assume that you understand your crop, soils and your irrigation system characteristics and performance. How do you know how well you are doing with irrigation management? It is totally unrealistic for you to measure irrigation efficiency or drainage below the root zone. That is normally left to the scientists or engineers.

What you can do and must do is to monitor crop water use. For pasture, there are two main methods:

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- Soil moisture measurements;
- Climate measurements.

Soil moisture measurements

The recommended soil moisture measurement methods for irrigation of pasture are:

- Hire a consultant
- Tensiometers (traditionally not commonly used, but new devices are becoming available)
- Neutron Probes – these devices are usually used by a consultant, who will tell you when to irrigate and how much water to apply
- Buried TDT devices (Aquaflex cables are an example)
- Buried TDR devices (Decagon probes are an example)
- Hand held TDR or other meters
- Electrical resistance meters of various types
- Capacitance meters.

Regardless of which method you choose, it is very important that you have the units calibrated and understand what the readings mean.

Other than which method to use, the key decisions with respect to implementing a soil moisture measurement system are how many units you need and whether you want to use manually operated units or automated units. Some measurement devices are used to take readings manually, while others record soil moistures on a continuous basis. Our strong advice for pasture is to use automated, telemetered units.

You can and should measure soil moisture in enough places to give you good guidance about moisture in the different soil types on your farm and how much water to apply over your whole irrigated area. Ideally, you should be using properly calibrated sensors in at least at two depths. You need to monitor soil moisture to see how much of the time you stay within the field capacity to stress point range. If you are using variable rate irrigation (VRI) to manage applications, you may need more sites.

Climate stations

The most common method of determining PET is through the use of weather stations. PET figures calculated from weather station data are sometimes printed in local newspapers. However, irrigators are advised to consider installing their own climate stations that are capable of determining both daily PET and daily rainfall.

Climate station data on its own does not tell you when to irrigate and how much to apply, which means that you need to use the climate data to track pasture water use over your farm.

Before investing in a climate station, make sure that you have the means to utilise the data that it produces.

Water metering

You may have to measure water use at the point of supply for compliance, but you should also record water use (water applied) on a paddock basis.

You should calculate annual water use for paddocks and the irrigated area. It is useful to calculate kg DM/ha or kg MS/ ha per cubic metre of applied water or per millimetre of applied water. These indicators vary according to the type of season (wet, dry or average), but are very helpful in assessing overall performance.

If you have any information on dryland production, you can subtract that production from the total to give you a figure for grass growth due to irrigation. That should be in the range of 14-18 kg DM/ha/mm applied, so if it is lower, you probably have a problem.

Summary

Good irrigation performance is now a requirement, not an option.

The need to grow quality grass with as little water as possible, while minimising drainage below the pasture root zone to reduce nitrate leaching, is paramount.

You need to understand what is required to achieve good irrigation performance. That includes:

- Understanding the soils on your farm
- Understanding your crop characteristics and water needs
- Having an irrigation system that is efficient and realistically able to apply the required depth of water at the right time
- Having a reliable water supply
- Monitoring water use through soil moisture measurement or weather stations
- Using the data to know when to apply water and in what quantity
- Using indicators to monitor your performance.

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Once these items are adopted and implemented, you will be in a position to achieve a high level of irrigation performance.