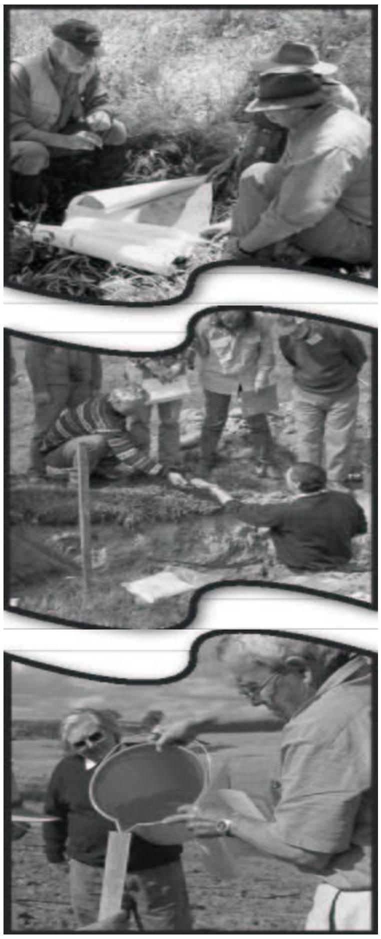
WATERWISE ON THE FARM

IRRIGATION EFFICIENCY
PRINCIPLES TO PRACTICE

Scheduling and Benchmarking



Perth Region NRM

CARING FOR OUR COUNTRY

Version: WA 20 September 2011

These materials are part of the WaterWise on the Farm education program Introduction to Irrigation Management. They were developed by NSW Agriculture staff from the Water Management subprogram with major input from Lindsay Evans.

INTRODUCTION

The aim of the *Introduction to Irrigation Management* course is to give you the skills to help you manage your irrigation system more effectively and to improve your water use efficiency.

The *Introduction to Irrigation Management* course consists of four workshops that cover the skills and knowledge you need to develop an irrigation and drainage management plan.

This workshop introduces you to techniques for

- scheduling your irrigation according to crop water use and soil RAW
- creating a water budget
- irrigation benchmarking.

An **irrigation schedule** gives you greater control over your water use because it enables you to determine how much water your crop requires at any given time, and plan your irrigation to suit.

Much like a financial budget, a **water budget** estimates how much you have and what you might achieve with it: that is, how much water you need for the season, and how much you will be able to grow with the water that you have.

Benchmarking is a process of recording past performance so that you are aware of what you (or your industry) are capable of. Understanding what you have achieved in the past helps you in maintaining that performance as well as plan for improvements.

The skills and knowledge gained from this workshop will help your irrigation management and improve water use efficiency in your enterprise.

LEARNING OUTCOMES

By the end of this workshop you will be able to:

- determine crop water requirements
- compare irrigation scheduling methods and tools
- develop an irrigation schedule
- develop a seasonal irrigation budget
- identify the information you need to benchmark water use efficiency for your farm
- identify the benefits of using water use efficiency benchmarks for your farm
- present data and information in appropriate forms.

Workshop activities

To achieve these outcomes, workshop activities include:

- Determining crop water requirements
- Developing a sample irrigation schedule
- Reading and interpreting scheduling tools
- Completing calculations for a seasonal irrigation budget
- Gathering benchmarking information.

Assessment

The course is competency based. By completing assessment activities during the course, you will demonstrate that you have met the learning outcomes listed above. This method of training and education benefits both you and the trainers, as any topics that have not been clearly covered may be quickly reviewed.

*Workshop Program**

(**The order of the program may vary to accommodate participants and local conditions.)*

There are five topics in this workshop:

1. crop water use
2. scheduling
3. tools of the trade
4. water budget
5. benchmarking

The workbook for this workshop contains some of the activities for these topics.

CONTENTS

IRRIGATION SCHEDULING

Irrigation is the act of supplying water from dams, rivers or bores to meet crop water needs between rainfall events. As irrigators, we need to calculate the best time to irrigate and how much water to use so that we may produce our crops and sustainably manage our water resources. We need to know how to deal with times of water shortage, and how to make the most of limited supplies by targeting a key stage of crop growth or a key enterprise.

To use water wisely, we need to accurately determine our crop water requirements and manage our water to meet these requirements.

The amount of water available for the crop to use significantly affects the yield of the crop. Too little or too much water will reduce the crop's yield (Figure 1).

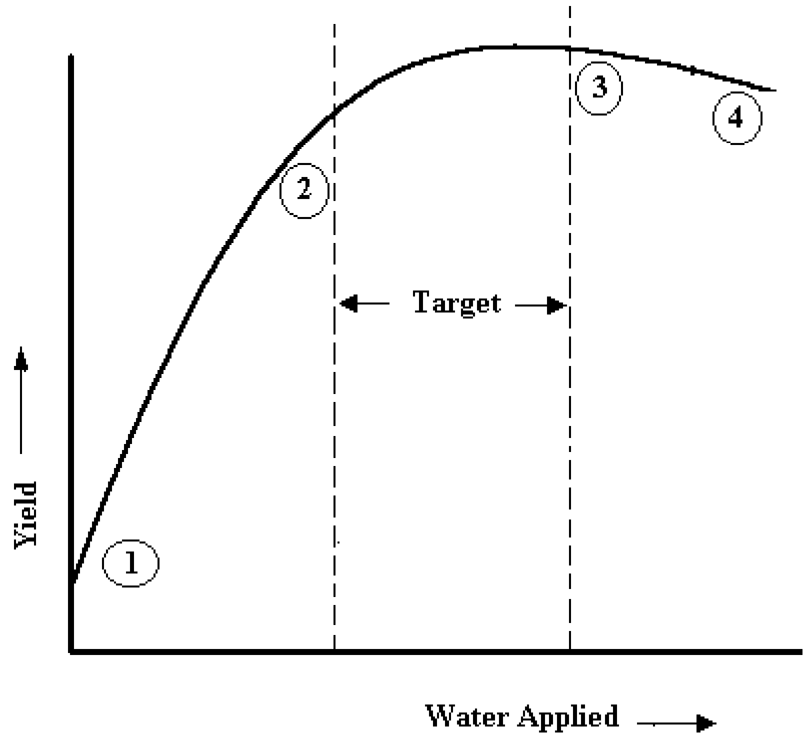


Figure 1: Yield related to water applied

- ① Without irrigation, yield depends on rainfall only.
- ② Irrigation contributes to continued yield increase.
- ③ More water causes no increase in yield.
- ④ Too much water, and yield declines due to waterlogging.

In general, our irrigation should aim for the 'target' water application, so we can achieve the full potential yield of the crop. For many crops there are times when we need to control the amount of water accurately. This control is needed to achieve certain product specifications such as sugar levels in wine grapes. In other crops, it is essential not to stress crops at specific times such as fruit set or flowering so that maximum yields are produced.

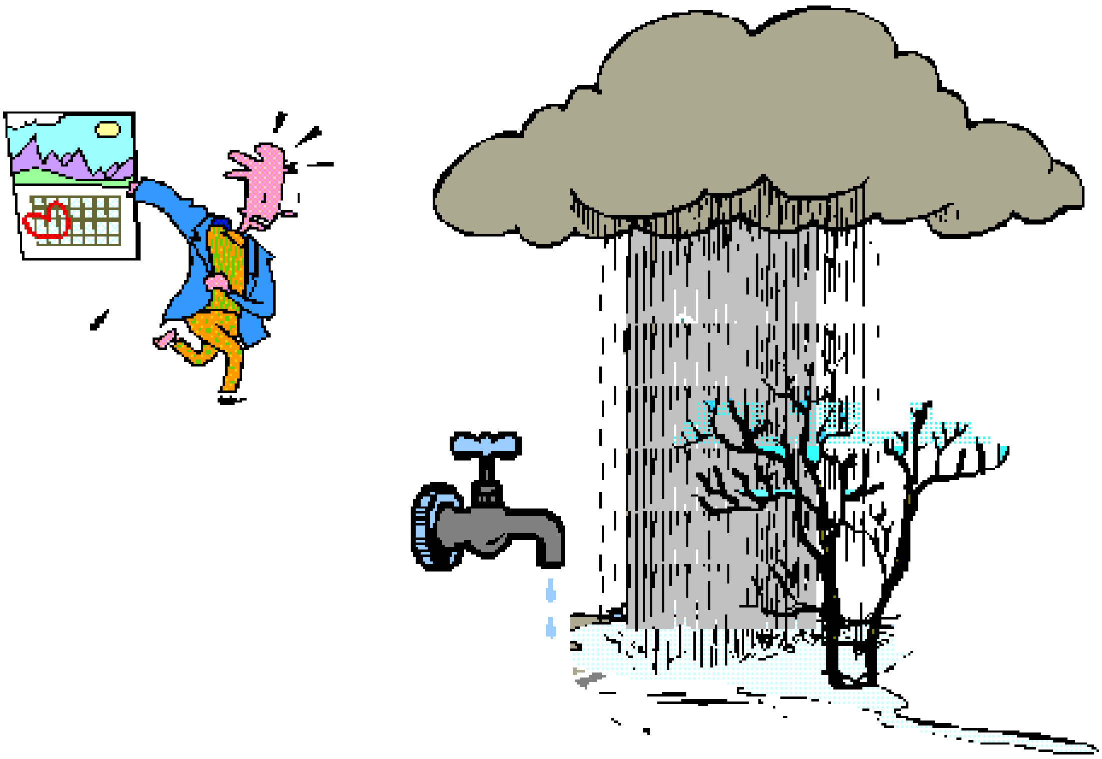
Developing an irrigation schedule

An irrigation schedule tells us when we need to irrigate our crops as well as how much water to apply. Put simply, a schedule tells us when an event should occur. An example of a simple time-based schedule is a train timetable.

Many irrigation schedules are simple time-based schedules. This type of schedule often develops through management or infrastructure constraints: for example, having only one travelling big gun, which needs to get around the entire farm in three weeks.

The disadvantage of this type of rigid schedule is that water may be applied when the plant does not need it, so that the crop may be subjected to waterlogging. Alternately, the crop may be subjected to droughting if water is not applied when needed.

An irrigation schedule should take into account effective rainfall, crop water use, and irrigation practices. It should tell us the right time to deliver the right amount of water for our particular crop.



"to irrigate or not to irrigate – that is the schedule!"

To create a schedule for applying irrigations, we subtract the amount of water used by the crop from the amount of water that we have estimated is held in the effective rootzone (the readily available water, or RAW).

Daily water balance

So far, in this workshop series, we have estimated how much water our soils are capable of holding as well as how much of that soil water is available for the plant (the RAW). We also determined how much water our irrigation systems apply to the field.

To manage water efficiently, we need to determine when to ‘fill up’ the rootzone to the predetermined RAW of the soil. The difference between how much water has been used by the crop each day and the amount of water still held within the effective crop rootzone of our soil is referred to as the daily water balance. That is, how much water the crop used since we last irrigated.

The timing of our irrigations or irrigation schedule is determined by plotting the daily water balance, so that we may predict when to refill the plant rootzone, and how much water to supply. The daily water balance tells us ‘how much fuel is left in our tank’, and how fast it is being used.

Another factor to consider when developing an irrigation schedule is the amount of effective rain that we have received (or expect to receive).

Effective rainfall

Not all the rain that falls is available for the crop to take up. Rain may be lost from run-off, drainage below the root zone of the crop, or interception by foliage, leaf litter or mulch. Because of this, light showery weather with rainfall less than 5 mm is widely considered as non-effective for most crops.

When estimating effective rainfall, consider the time that the rainfall event occurred and its intensity. If the rain occurs just after irrigation, or when the soil profile is saturated, it may go to run-off or deep drainage. A heavy downpour on drier soil may also lead to run-off if there is insufficient infiltration.

Effective rainfall is the proportion of any rainfall event that is stored within the crop rootzone and available for use by the crop.

Other factors affect the infiltration of water into the crop rootzone, and therefore the amount of effective rainfall. These factors include non-wetting soils, soil structure, organic matter content, cracks, soil temperature, and wind.

Different crops have different abilities to access rainfall at different times of the year. In general, crops may be grouped into three categories depending on their root depth. This means that the crop root depth will determine how effective the rainfall has been.

Effective rainfall information is scarce, and is not always provided by weather stations and other sources of weather data. Your trainer may supply the effective rainfall fractions for your area.

Historical rainfall figures are available for some areas from the Bureau of Meteorology - www.bom.gov.au

Dept of Agriculture and Food – www.agric.wa.gov.au

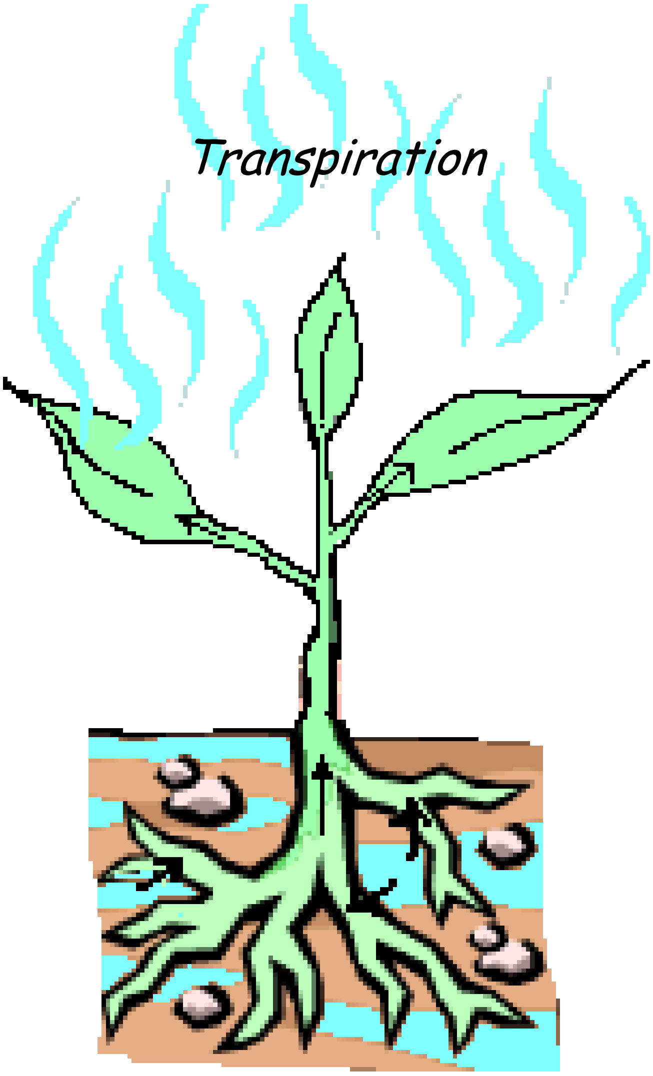
To determine the effective monthly rainfall, we subtract 5mm per rainy day from the recorded rainfall data.

Total rainfall - (5mm x no. rainy days) = Effective rainfall*

* Effective rainfall should not exceed available water. If it does, then available water should be used as the effective rainfall figure (anything further will be lost to deep drainage and/or runoff so shall not be effective).

CROP WATER USE

Plants use water to live. They use it in a process known as **transpiration**: the root hairs take up water from the soil and it travels through the stem towards the leaves, where it evaporates into the air through pores in the surface skin of the leaves. (As the water evaporates out, the negative pressure this creates is transmitted back down to the roots and 'pulls' more water through the whole plant.)



Soil water is also used when it **evaporates** from the soil and other exposed surfaces.

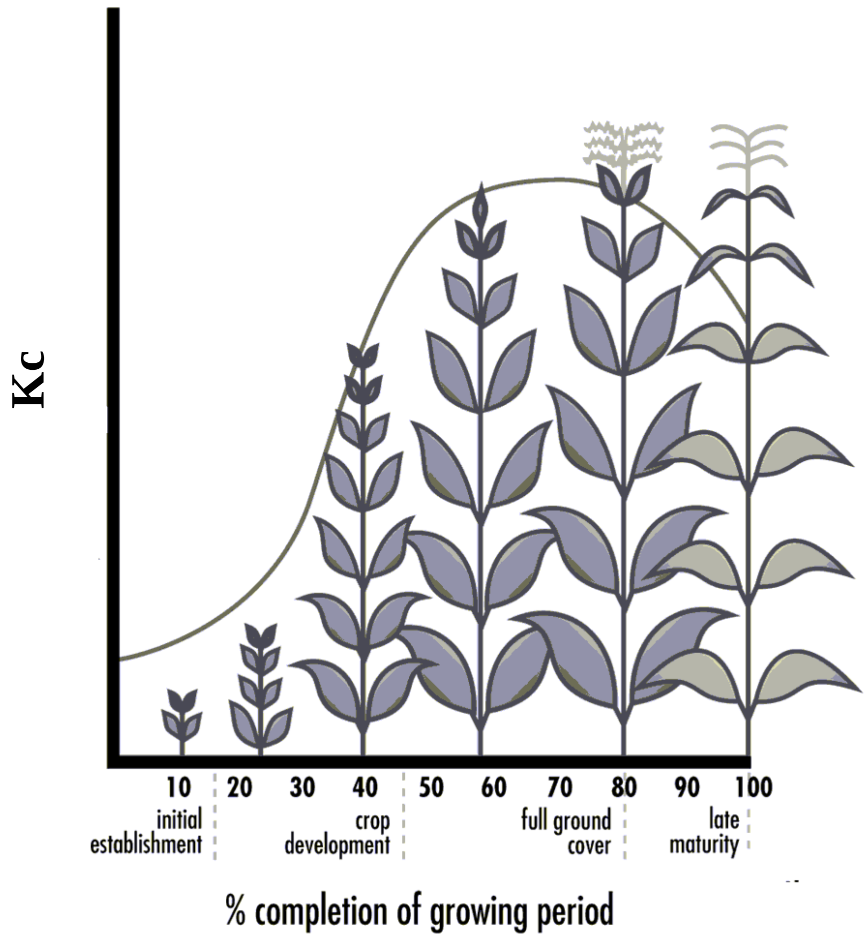
The combined loss of soil water through evaporation and transpiration is known as **evapotranspiration: evapo**ration from the soil, and **transpiration** through the plant.

Measuring the evapotranspiration (abbreviated to **ET**) will tell us the **crop water use**, that is, how much water the crop is using. For any given climatic condition, crop water use will depend on the type of crop and its stage of growth.

Crop growth stages

Crop water use will vary with climate, weather conditions and stage of crop development. Figure 2 indicates the change in water use as the crop develops and matures.

Figure 2: Variation in crop water use over the growing season



In the early stages of growth, the crop's water requirements are low, but, as the crop grows and nears maturity, the crop water use also grows. It can be clearly seen that the crop needs much more water when it is mature than when first established. Perennial tree crops also have different stages of growth that will have higher or lesser water requirements, but once the crop has matured (or fruited), the water use tapers off. This is when the plant starts dying and drying off (senescence), or shutting down for dormancy.

The amount of water used varies according to crop type and environment. For example, at peak growth, a lucerne crop uses about twice as much water per day as a grape crop.

Specialised techniques for some crops

Effective irrigation scheduling generally aims to avoid stress to the plant. There are, however, some specialised management techniques that may be used in some crops or where water resources are limited, for instance:

Citrus: Prevent water stress during flowering to maximise fruit set. Avoid stressing Valencia in particular, as they are likely to be carrying crop and have to meet the demands of keeping the fruit as well as the flowers. Maintain water levels from flowering to late December to avoid fruit drop.

Rice: High water levels at early pollen microspore (EPM) stage reduce the risk of sterile grains. Precise control of water level at tillering and panicle initiation also helps in the production of higher yields.

Vines: Although it is accepted practice to avoid water stress during flowering, fruit quality can be improved by selectively stressing the plant at specific growth stages. Seek further information if you are interested in these techniques.

Stone fruit: Avoid any water stress during flowering and keep water up during the 4 to 6 weeks prior to harvest to ensure adequate fruit size.

Vegetables: Avoid any water stress during the life of shallow-rooted plants as it can lead to a reduction in yield.

"Designer Stressing"- A specialised Irrigation Technique

What drives crop water use?

Crop water use is driven by the weather conditions of the environment that the crop grows in. Weather conditions include:

Sunlight: Sunlight provides the energy that drives water use. The more sunlight that hits the plant, the greater the photosynthesis will be and the greater the transpiration rate. The energy received by the plant is affected by **aspect** of the crop to the sun (for example north slope of hill in winter).

Increasing sunlight increases crop water use.

Humidity: The amount of water vapour in the air.
In a high humidity environment, a plant uses less water than it does at the same temperature in a dry environment. This is because the air surrounding the plant already has high water vapour content and is therefore less able to remove the water vapour coming out of the plant's leaves. (This is much like a wet sponge trying to soak up more water).

Increasing humidity decreases crop water use.

Wind speed and water use: Evapotranspiration increases as the wind speed increases. This is because the wind removes the water vapour that the plant is transpiring. The more water vapour removed the more water vapour the plant can transpire.

Increasing wind speed increases crop water use.

Temperature and water use: Hotter temperatures increase the rate of transpiration because hot temperatures usually correspond with increased sunlight.

Increasing temperature increases crop water use.

These four climatic features of the crop's environment determine the evapotranspiration, and set the **peak water use** of the crop. However, some **farming practices** (such as tillage, cover crops, fertiliser, pest and disease management, and plant density) can strongly influence the crop’s actual water use.

Measuring the water used by crops is an essential tool for scheduling irrigations. By calculating the crop water use, we can manage our farm water resources more effectively, delivering the exact amount of water that the crop needs at a particular time.

Measuring and estimating crop water use

There have been many methods developed for measuring crop water use. These methods may be grouped into three categories:

- plant-based methods:
  information from the plant itself, including direct observations

- weather-based methods:
  data from climatic factors including sunlight, temperature, wind and humidity

- soil-based methods:
  methods which monitor how much water is taken up by the plant from the soil.

The methods and tools used to calculate crop water use vary considerably. Selection of a method or tools depends on your circumstances, needs, and personal preference.

Monitoring crop water use is an important part of irrigation management. The records of crop water use become an integral part of benchmarking and improving water use efficiency.

The following sections outline the features of the three different categories of crop water use monitoring tools.

Plant-based methods

Our crops or enterprise are often the focus of our attention. We can easily recognise signs of water stress such as wilting and organise the application of water.

Some farmers may irrigate when a section of the crop starts to show signs of wilting. If the wilting plants are growing in light soil types (which hold less soil water in the rootzone), then this may show that the rest of the crop needs irrigating. However, if the plants growing in the lighter soil are doing well, it may indicate that any plants on heavier soils are being over-watered.

In many cases, however, waiting until the plant wilts or shows signs of water stress before we irrigate means that crop is already under water stress. This means that the crop is unable to readily access water. In response to this stress, plant growth slows. This type of water stress may reduce the final yield or quality of our product.

Wilting and signs of plant stress may be the result of factors other than the lack of water. For example, some plants roll their leaves on a hot, windy day despite the fact that soil water content is adequate. Other plants only show wilting when water is severely limited. Wilting is also a sign of waterlogging or root disease.

Because of these factors, monitoring the plant is ***not*** recommended as the only or prime method of monitoring crop water use.

More technologically advanced methods of plant monitoring, including sap flow and pressure bomb meters, do work well, but are not in common use by farmers. These methods are usually costly and complicated and are primarily used in research.

Weather-based methods

Measuring the four aspects of ET (evapotranspiration) for each crop is a daunting task and impractical for most irrigators. To overcome these difficulties, we use the ET of a reference crop (called the **ET_o**).

Using a reference crop and ET_o

The reference crop is usually an actively growing, unstressed block of pasture (‘**reference crop**: extensive surface of green grass cover of uniform height, actively growing, completely shading the ground and not short of water’).

The evapotranspiration of other crops may be determined by comparing them to the reference crop. The characteristics of crops, such as crop height, leaf size, and maturity, may mean that they use water at a different rate to the reference crop. To account for the effect of different crop characteristics, crop coefficients **(K_c)** have been developed. Crop coefficients take into account the crop type and stage of growth.

The K_c enables us to calculate how much water a crop uses in comparison to the reference crop.

- For example, if a crop has a Kc of 1.1, then this crop uses 1.1 times as much water as the reference crop.
- If you have another crop with a Kc of 0.8, then this crop uses only 0.8 times as much water as the reference crop.

Crop coefficients are particular to areas, ET data and crops. It is important that the K_c you use is applicable to your situation.

Converting pan evaporation figures

If you do not have access to ET data, then your reference crop evapotranspiration (ET_o) may be determined by using the Pan evaporation method.

This method uses a US Class A Pan instead of a reference crop. Data from the pan is multiplied by a pan coefficient (K_p) to give the ET_o figure. (The pan coefficient may be found in Table 18 of FAO Irrigation and Drainage Paper Number 24.)

Pan evaporation × pan coefficient = evapotranspiration (ET_o)

Estimating daily crop water use

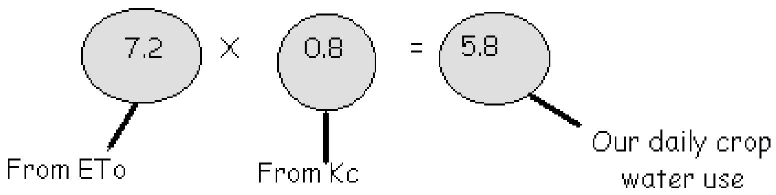
With our ET_o data, we can simply estimate our crop's daily water use. The ET_o is multiplied by the crop coefficient K_c to obtain the daily crop water use (or ET_{crop}).

$$ET_o \times K_c = \text{daily crop water use } (ET_{crop})$$

For example, our weather station reports an ET_o of 7.2 on 1 January.

Our crop of lima beans has a K_c in January of 0.8.

To determine our crop water use, we multiply ET_o by the K_c:



We can calculate that on 1 January our lima beans used 5.8 mm of water.

Using this formula, we can estimate how much water our crop has used each day. The daily crop water use builds up a picture of crop water use over the season and helps us to manage our water applications.

Using pan evaporation figures and crop factors

As previously explained, if you do not have access to ET data then your reference crop evapotranspiration (ET_o) may be determined by using the Pan evaporation method. A-class Pan evaporation is measured throughout Australia at most weather stations.

In Western Australia many weather stations do not record all of the parameters required to calculate ET. To calculate crop water use from pan evaporation figures, we multiply the pan evaporation by the crop factors

Crop factors have been calculated for various crops in some regions, and your trainer should be able to provide these. (If crop factors are not available, then you can use evaporation figures with a pan coefficient, together with FAO crop coefficients to provide an estimate of crop water use.)

Activity 1: Calculate the crop water use (‘ET_{crop}’)

Weather-based irrigation scheduling

To schedule irrigation using weather data, we calculate the daily water balance:

Water balance:

Irrigation	**+**	**effective rainfall**	**-**	**crop water use (the ET_{crop} figure)**	**=**	**remaining readily available water**

The ET_{crop} figure is calculated from ET_o and K_c. Understanding the soil water balance provides a management tool for improving irrigation management and achieving better crop production.

A scheduling sheet (Table 1) is used to keep track of crop water use, irrigations, and rainfall events. The scheduling sheet works in much the same way as a bank balance sheet or accounting book, but the 'money in the bank' is the available rootzone water, and the crop water use is the withdrawals. In the same way that we should not let our bank accounts become overdrawn, we should not allow the water balance to become 'overdrawn'.

By monitoring the crop water use, we may predict when we are likely to run out of water. This will allow us to 'deposit more water into our account': that is, schedule the next irrigation.

The sample scheduling sheet provided is one example of scheduling using weather-based data. It allows the calculation of crop water use and identifies when irrigation may be required and when there were effective rainfall events. Your trainer may have different examples of the scheduling sheet, but they all work on the basic principle of monitoring crop water use in relation to the amount of water held in the effective rootzone.

Sample scheduling sheet

The following example of a scheduling sheet outlines a typical water balance.

In this example, the irrigation system is capable of evenly applying 7 mm/h. The rootzone RAW is capable of holding up to 42 mm of water.

Table 1: Scheduling sheet

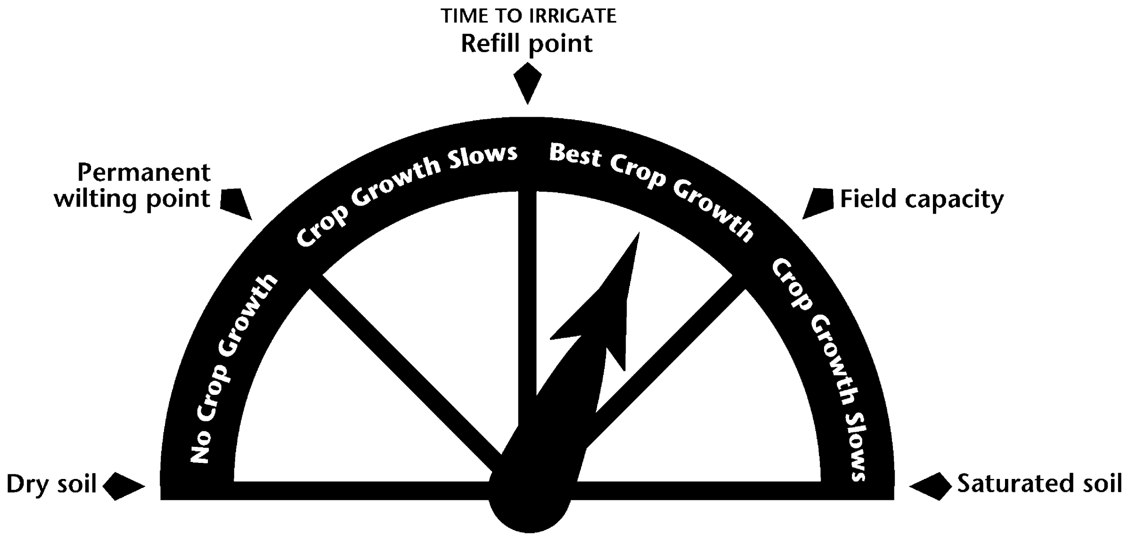
	A	B	C (A × B)	D	E (E from previous day − C + D)
Date	**Evap**	**K_F**	**ET_{crop}**	**Effective rain or irrigation (mm)**	**Remaining RAW**
Remaining RAW (from past record or soil moisture monitoring tools)					Rootzone at field capacity after heavy irrigation (42)
27 Dec	8.1	0.8	6.5		42 – 6.5 + 0 = 35.5
28 Dec	9.5	0.8	7.6		35.5 – 7.6 + 0 = 27.9
29 Dec	10.2	0.8	8.2		27.9 – 8.2 + 0 = 19.7
30 Dec	9.8	0.8	7.8		19.7 – 7.8 + 0 = 11.9
31 Dec	7.6	0.8	6.1		11.9 – 6.1 + 0 = 5.8
1 Jan	6.5	0.8	5.2	7-hour irrigation *7 hours at 7 mm/ hour = 49 mm*	5.8 – 5.2 + 49 = 49.6 = 42 + 7.6 = (RAW + run-off)
Comment: the rootzone can only hold 42 mm, therefore we lose 6.5 to run-off or deep drainage.					
2 Jan	10.1	0.8	8.1		42 – 8.1 + 0 = 33.9
3 Jan	8.3	0.8	6.6		27.3
4 Jan	11.3	0.8	9.0		18.3
5 Jan	3.6	0.8	2.9	Rain, 15 mm *ie 20 mm - 5 mm*	30.4
6 Jan	8.8	0.8	7.0		23.4
7 Jan	8.5	0.8	6.8		16.6
8 Jan	7.7	0.8	6.2		10.4
9 Jan	8.0	0.8	6.4		4.0
10 Jan	8.9	0.8	7.1	7-hour irrigation	42 + 3.9 lost
11 Jan	6.0	0.8	4.8		37.2
12 Jan	10.0	0.8	8.0	Rain, 25 mm *ie 30 mm - 5 mm*	54.2 42 + 12.2 (RAW + run-off)
13 Jan	7.0	0.8	5.6		36.4

Activity 2: Irrigation scheduling with weather data

Complete the irrigation scheduling sheet in your workbook.

Soil water based methods

In the soil workshop, we determined that soils held a certain amount of water – much like a fuel tank. As we 'drive' our crop or enterprise, we use up this stored water.

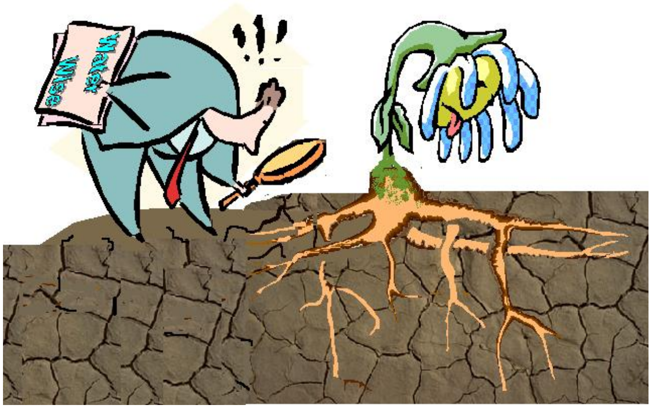


If we know how much water is in the soil to start with, we can therefore directly determine the crop water use by estimating how much water is lost from the soil. Just like looking at our fuel gauge as we travel.

There are three basic approaches for determining the volume of water in the soil.

1. **gravimetric,** as with a dig stick or drying a soil sample in an oven
2. **volumetric,** using nuclear or electrical methods (for example, gypsum blocks) to calculate the amount of water present in the soil
3. **tension,** as in tensiometers. Tension is the effort a plant needs to use to extract water held by the soil.

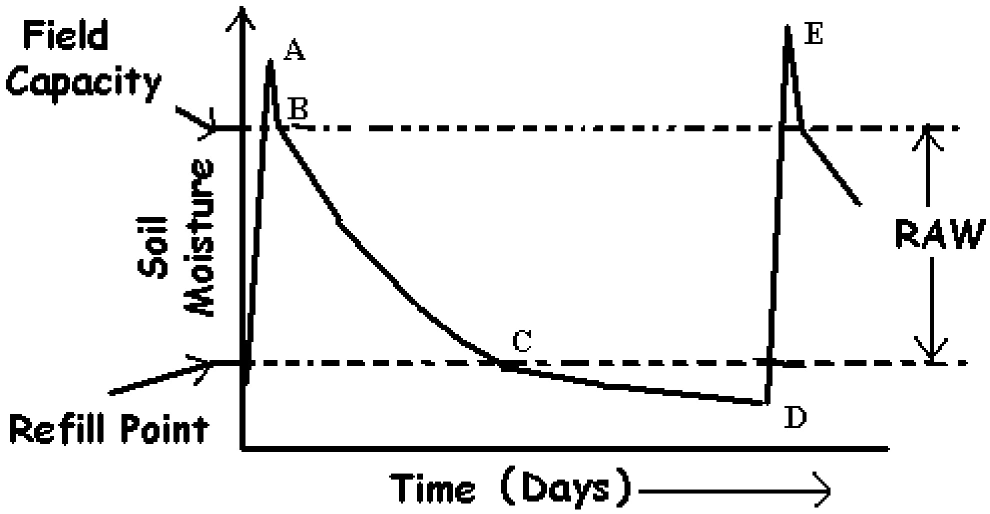
New soil water monitoring tools are constantly becoming available and each has advantages and disadvantages. Your group co-ordinator should be able to provide information on these.



What do soil water monitoring tools tell us?

Soil water monitoring tools show how the water content varies over time. By plotting the data on a graph, we can see how water is lost from the soil over a period of time (Figure 3).

Figure 3: Soil drying cycle



The line in the graph represents the amount of moisture in the soil. It also shows when water is added to the soil, as during a rainfall event or irrigation.

This graph displays the cycle of irrigation and drying over time. The soil water is topped up through irrigation or rain, and then used by the crop (or lost as run-off, drainage and evaporation). Using the soil water data and other information such as our RAW and MAR we may manage or water use more efficiently, applying only as much as the crop needs when it needs it.

Notes on figure 3:

A to B	Immediately after the initial irrigation, water exceeds the 'full point' and some water is rapidly lost to vertical drainage or run-off.
B to C	Water is held by the soil and is readily available to the crop, so there is unrestricted growth. Gradual decrease in water lost from the soil as it is taken up by the plant.
C to D	The readily available water has been used and the crop has difficulty extracting more. The daily use is lower and the crop is under stress.
D to E	Irrigation (or rain) has entered the profile after D.

This cycle is repeated throughout the season.

Selecting sites for soil water monitoring

When monitoring soil water, only a small amount of soil is sampled. It is therefore extremely important to select monitoring sites that are representative of the irrigated areas. Selecting monitoring sites is easier on properties where soil surveys have been conducted and water distribution uniformity is good.

Wheel tracks and areas where soil is compacted should be avoided, as should disturbed soil, outside rows, or areas near stunted or sick plants.

Placing the soil water monitors in 'representative' sites involves knowing how the locations relate to the rest of the field. The aim is to select positions that will indicate the water-holding capacity for the whole irrigated area. The locations should include the whole rootzone of the crop, and represent a crop of a height and yield that is average for the irrigated area.

To supply data that is representative of the irrigated area, the soil moisture monitoring tools must also supply data from different depths of the rootzone. That is, we need a vertical picture of the soil moisture as well as a horizontal picture.

By using more than one sensor site, you will get a better idea of what is happening across the whole area. Locate sensors in, for example, the higher/lower or drier/wetter parts of the field. This will give you a better picture of the soil and its water.

Soil water monitoring tool: tensiometer

Soil-based irrigation scheduling

The aim of soil-based moisture monitoring is to determine when the readily available water (RAW) has been used. Instead of estimating crop water use, as in weather-based scheduling, soil-based scheduling directly monitors the level of soil moisture.

As the crop uses moisture, the soil moisture decreases. This decrease in moisture may be 'observed' (measured by soil moisture monitoring tools) to estimate the most appropriate time to irrigate and refill the rootzone RAW.

Readings from soil moisture monitoring tools may be plotted on a graph (Figure 4). This will display the drying pattern of the soil and help you estimate the optimum time to irrigate.

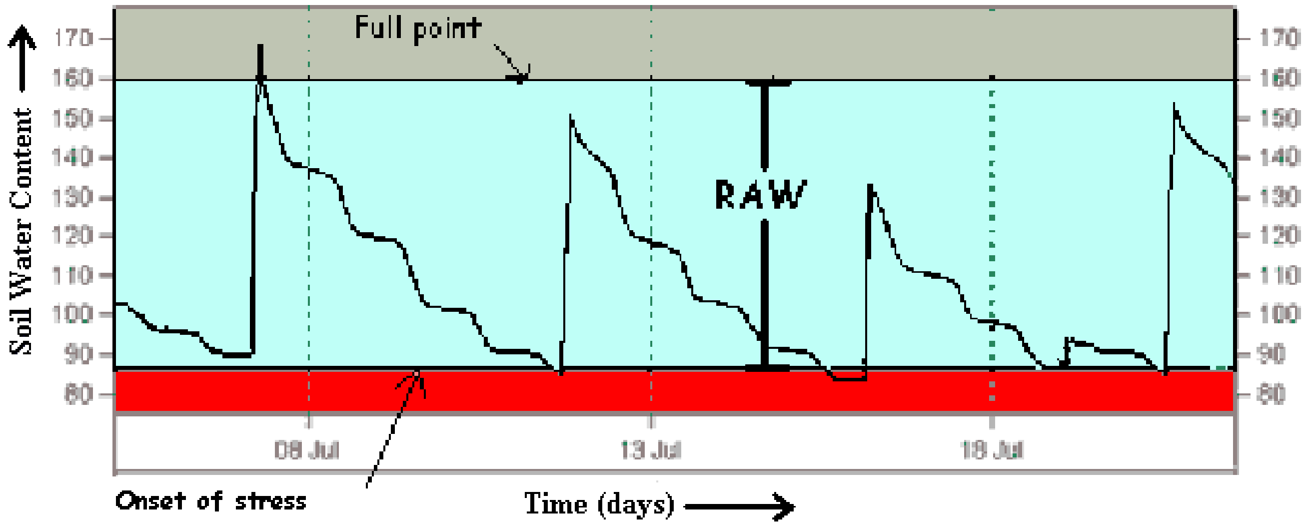
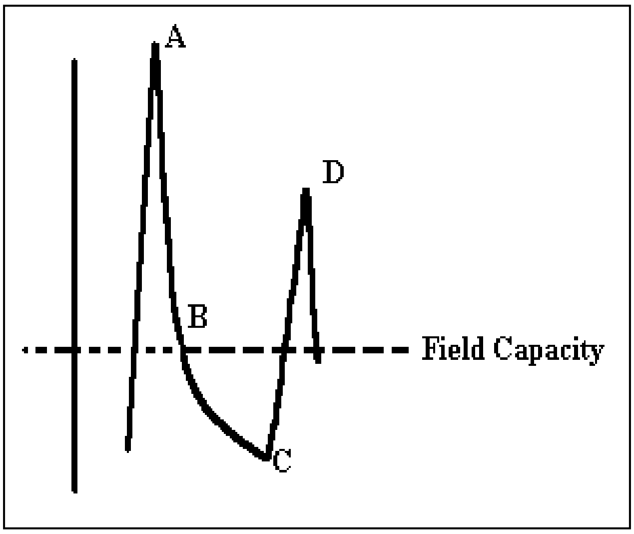


Figure 4: Soil water content

To schedule irrigation events using the soil moisture data we indicate on the graph the field capacity (full point) of the soil and the point where our RAW has been used (onset of stress). In figure 4, the soil has reached field capacity with a soil water content of 160. The onset of stress is indicated at a soil water content reading of 85. To determine the field capacity and the onset of stress, we need to look more closely at the graph.

Field capacity may be found on the graph by the indication of a rapid drop in soil water content after irrigation or rainfall has filled the profile (Figure 5). The rapid drop in soil water (A down to B) is the profile draining (due to gravity) to field capacity.



After reaching field capacity, the soil holds onto the water until the plant uses it. Crop water use and evaporation is indicated by a less rapid decrease in soil water (B down to C).

Irrigation events (or rainfall events) are indicated by the sudden rise in soil water content (C up to D).

Figure 5: Indication of field capacity

By plotting our daily soil water content, we may see our soil water approaching the point where plant stress begins (Figure 6).

At this point, the RAW has been used and we need to irrigate.

At refill point, the plant has to work harder to extract water from the soil and therefore the loss of water from the soil slows.

This is indicated on the graph when the slope of the graph starts to decrease and 'level out' (E to F).

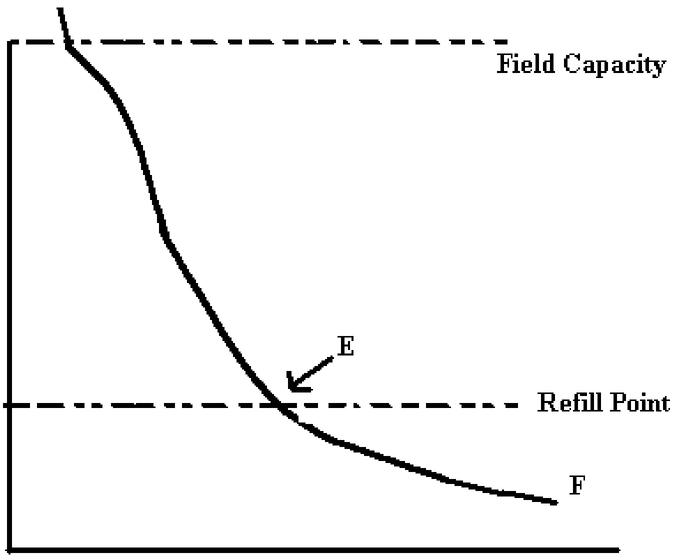


Figure 6: Indication of refill point

In any soil-based monitoring, it is important to remember that the measurements are taken from a small part of the rootzone. To ensure an accurate ‘picture’ of your soil water content, readings need to be taken at ‘representative sites’ as well as different levels of the rootzone.

The purpose of taking readings at different levels is to determine when to start irrigating so that only the rootzone remains wet. Monitoring your soil water at different depths may reveal over-irrigation, when water passes beyond the root zone, or insufficient irrigation, where water fails to wet the entire effective rootzone.

The advantage of monitoring the soil water level below the surface is that it may indicate some available water, even when the surface soil is dry. This information will help you manage your irrigation and improve your water use efficiency.

The benefit of using soil moisture monitoring tools is that you can match the supply of water needed by your crop to the amount of water that your irrigation system is capable of supplying within your management structure. This is particularly important during times of peak water requirements of your crop.

Activity 3: Irrigation scheduling with soil monitoring tools

Plot crop water use from soil moisture monitor readings.

Where both weather data and soil water monitoring tools are available for irrigation scheduling, they provide a cross-check of crop water use. For this reason, the use of both tools together is often recommended, particularly in high-value crops.

WATER BUDGETING

We all budget to make the best use of our resources. We budget our money, time and other resources so that we are 'not left short' later down the track. A budget therefore is part of risk management. We try to foresee the risks associated with our decisions and plan to minimise any negative aspects.

As irrigators, we need to budget our water so that we can reduce the risk of not having enough water for our crops. At the beginning of each season, we estimate the area of crop we can irrigate with our available water or determine how much water we will need to produce our intended crop.

A water budget is the estimation of

- how much crop can be grown with the available water (this is particularly relevant for annual crops)

  or

- how much water is needed to achieve the required quantity and quality of production (particularly for perennial crops).

Water budgeting allows you to plan your irrigation management and make the changes you need during the season.

Creating a water budget will be influenced by a number of factors such as:

1. the annual water requirements of the crop
2. the climate and its variability
3. the available water supply (licence, access rights, water sharing plans, security).

Annual water requirements of the crop

Your water budget for the season will be determined by your crop water requirements, irrigation system efficiency, capacity to access water and the quality criteria sought by markets. When developing your water budget, you need to consider:

- What are the annual water requirements for your crop?
- Rainfall (will it be a dry year, wet year or a median rainfall year)?
- What scope is there to adjust water within acceptable quality and quantity boundaries? When can the plant have less water without affecting yield or quality?

Climate variability

The climate is the combination of a number of elements such as rain, wind, and temperature. These elements will not only vary from day to day, but also from season to season, and region to region. By investigating the climatic elements of your area, you will be able to identify critical periods in your cropping cycles where an adequate water supply will be required. Information critical to your water budget includes:

- What is the median rainfall?
- What is the probability of above or below median effective rainfall?
- When does rainfall occur? How will this affect irrigation, dam supplies, or extraction limits?

Investigating the climate, past rainfall records, and current climatic patterns (for example Southern Oscillation Index (SOI) and El Niño), we may ‘predict’ that the season will be wetter than a median year and plan accordingly. Conversely, we may be cautious, reducing our risk by predicting a drier than median year. Our ‘predictions’ will then affect the outcome of our water budget equations and therefore our management for the season.

Information on climate variability and records of climatic data may be found at the BOM website (Bureau of Meteorology) or your local Department of Agriculture representative.

Available water supply

The supply of water depends on licence conditions and the source of water.

Regulated rivers: Allocations on regulated rivers (those with large dams that control the flow of the river) may not be fully met due to high demands, or low dam holdings due to poor rainfall. Our water budget (and consequently our plantings) should be based on an expected allocation percentage.

Unregulated rivers: On unregulated rivers and streams (those rivers and streams without dams), it is important to maintain environmental flows. This means that irrigator access to the flow may at times be restricted. Irrigators on unregulated rivers and streams also need to determine their irrigation requirements for the season accurately and determine the risk and risk management strategy for their enterprise.

To estimate the available supply of water, answer these questions for your enterprise:

- What are the daily extraction limits and the flow regime?
- Will full or part allocations be made?
- Can allocations be transferred or purchased? What are the costs and benefits?
- Is water quality an issue at high or low flows?
- What is the recharge rate at peak pumping times?
- How much water, if any, is recirculated?
- What are the typical run-off rates into your water storages, and how do these vary across the year and seasons?
- What is the total on-farm storage capacity?
- What are the management constraints?

Calculating the water budget

Area that can be irrigated

The maximum area of crop that can be irrigated is determined by the amount of water that reaches the crop.

The amount of water that reaches the crop is determined by the crop water requirements, the irrigation system capacity and efficiency, and the availability of water.

The following formula uses these factors to give an estimate of the area that can be irrigated:

Area = irrigation water available ÷ annual crop water requirement × irrigation system efficiency

Irrigation system efficiency can be calculated from the system evaluation you did in workshop 2, or from the values in Table 2.

Table 2: Estimated irrigation system efficiencies

Note: These figures are for systems less than 5 years old and properly installed and maintained.

System	Efficiency range
Drip irrigation	85–95%
Under-tree fixed micro sprays	80–95%
Under-tree mini spinner sprinklers	80–85%
Bike shift and spraylines	80–85%
Fixed overhead nursery sprinklers	80–85%
Travelling irrigators	65–75%
(Border check)	40–60%
(Furrow)	30–60%

Example 1: What area of crop can be grown with the available water?

You are growing maize under a travelling irrigator and you have **60 ML available for the season**.

Your system is about **75% efficient**, as found, for example, in the system evaluation workshop. We can convert this percentage into a decimal to make it easier to work with in the calculation: to do this conversion, we divide the percentage figure by 100:

$$75 \div 100 = 0.75$$

Maize uses about **10 ML/ha** of water in a season. In a median season for this example area, rainfall supplies about 3 ML/ha. This means that the annual crop water requirement is only 7 ML/ha.

Area that can be irrigated: sample calculation

Area = Irrigation water available ÷ Annual Crop water Use x Irrigation system efficiency*		
Area		**A**
Irrigation Available	60 ML	**B**
Crop water use	7 ML/ha	**C**
System Efficiency	75 % (0.75)	**D**
Area = B ÷ C x D		
	60 ML ÷ 7 ML/ha x 0.75 = 6.45 ha	

The maximum area of maize we may sow in a year of median rainfall, with our full allocation/entitlement, is **6.5 ha.**

Example 2: What area of crop can be grown with the available water?

You are growing lucerne under bike shift irrigation. You have **80 ML available for the season**.

For this example location**, lucerne uses 6 to 9 ML/ha** in a season (an average of 7 ML/ha).

If you assume that **below-average rainfall** during the growing season will supply 1.5 ML/ha, then the annual crop water requirement for this example will be **5.5 ML per hectare**.

Your system is about **80% (0.80) efficient** (from Table 2).

Area that can be irrigated: sample calculation

Area = Irrigation water available ÷ Annual Crop water Use x Irrigation system efficiency*		
Area		**A**
Irrigation Requirement	80 ML	**B**
Crop water use	5.5 ML/ha	**C**
System Efficiency	80 % (0.80)	**D**
Area =	**B ÷ C x D**	
	80 ML ÷ 5.5 ML/ha x 0.80 = 11.6 ML	

The maximum area of lucerne we may sow with our full allocation/entitlement is **11.6 ha.**

Sample calculation: Irrigation water required for given area.

We may not receive our total allocation or have access to our full entitlement. This means that we need to calculate the **required irrigation** for a reduced crop area.

By simply rearranging the equation, we can determine how much water we need to achieve our production goals:

What if, instead of the maximum area of 11.6 ha, we intended to plant **10 ha** of lucerne?

The crop water requirement is still 5.5 ML.

The system is, as before, **80% efficient.**

Then, the calculation for the water budget would be:

Irrigation water available = Area to sow ÷ Irrigation system efficiency* x Annual Crop water Use		
Area	10 ha	**A**
Irrigation Available	Unknown	**B**
Crop water use	5.5 ML/ha	**C**
System Efficiency	80 % (0.80)	**D**
Irrigation =	**A ÷ D x C**	
	10 ha ÷ 0.80 x 5.5 ML/ha = 68.7 ML	

So, if we intended to plant 10 hectares of lucerne, then we would require **69 ML of irrigation water**. This allows for just over 10 ML (14%) reduction of our 80 ML allocation.

Risk management

Those factors that have the potential to limit or impede production are known as risks. Risk management is the process of identifying potential risks, determining the chances of those risks occurring, estimating their impact, and developing strategies and tactics to avoid or minimise their impact.

One of the biggest risks in irrigation is lack of water. To manage this risk, we need to determine the amount of water we can expect for the season, and plan actions to address any shortfalls.

For example, if we predicted a dry year from long-range weather forecasts, then our irrigation requirements would be higher. This risk is compounded as other demands on the water resources are increased:

- On unregulated rivers, this would mean that the cease-to-pump would be more common and protracted.
- On regulated rivers, it could indicate that the allocations may be reduced because the dams have failed to fill.

Possible risk management strategies could include increasing on-farm storages before the season, planting less, or trading more allocation.

Other options for securing your water and managing the risk could include:

- reducing water use by improving irrigation system efficiency
- joining a roster group
- accessing groundwater*
- using harvestable rights storages
- accessing town water
- changing enterprises and enterprise management
- constructing on-farm storages.

* Note that if looking at water extraction, you should contact your nearest Department of Environment for information.

Risk assessment

Managing risk involves a decision process by the manager that compares the costs and benefits of the management strategies against the potential risk.

This calculated risk determines your water management for the season. Part of your risk assessment should also include considering the crop you intend to grow, recognising its growth phases and identifying critical phases where water stress must be avoided to maintain quantity and quality of production.

Sample calculation: Irrigation water required for given area in a wet year

For example, we may 'predict' a **wet season** (high rainfall, low evapotranspiration) for our area because of past rainfall records and a predominant La Niña.

If a wet season occurs, our lucerne crop may only require a total irrigation of 2 ML/ha. The allocation for this enterprise is still 80 ML, and the system efficiency remains at 80%. The area planted is 12 hectares.

This makes our water budget:

Irrigation Requirement = Area to sow ÷ Irrigation system efficiency* x Annual Crop water Use		
Area	12 Ha	**A**
Irrigation Available	Unknown	**B**
Crop water use	2 ML	**C**
System Efficiency	80 % (0.80)	**D**
Irrigation =	**A ÷ D x C**	
	12 ÷ 0.80 x 2 = 30	

On this calculation, less than half of our allocation will be needed during a wet season.

Sample calculation: Irrigation water required for given area in a dry year

However, there may be indications for a **dry season** (low rainfall, high evapotranspiration), such as past rainfall records and a predominant El Niño.

If the dry season occurs, then our irrigation requirement may be the full 7 ML/ha.

The rest of the information remains the same.   Our water budget therefore becomes:

Irrigation Requirement = Area to sow ÷ Irrigation system efficiency* x Annual Crop water Use		
Area	12 Ha	**A**
Irrigation Available	Unknown	**B**
Crop water use	7 ML	**C**
System Efficiency	80 % (0.80)	**D**
Irrigation =	**A ÷ D x C**	
	12 ÷ 0.80 x 7 = 105	

For this dry year, this crop would require 105 ML. This is well over the allocation.

What could be done in this situation?

Possible solutions:

- Reduce the amount of area irrigated for production, and use sufficient water for the rest of the lucerne to survive, but with reduced production.

- Reduce the length (the duration) of your irrigation season.
  For example, stop irrigating in February, instead of March or April, thus reducing the season by at least two cuts. If you assume the lucerne requires approximately 1.5 ML/ha/cut, and you have 12 ha of lucerne, the saving made from not doing those two cuts is 36 ML. This reduces the overall estimated water use to 69 ML (105 – 36), which is within the allocation.

This example was for lucerne. The solutions and techniques will vary for other crops. For instance, in tree or vine crops, regulated deficit irrigation could be a solution, or the purchase of additional water. In cereals and vegetables, a reduction in the area sown may be a better option.

Activity 4: Water budgeting

Complete a water budget for the irrigation situation in your workbook for a dry year (decile 1 rainfall) and a median rainfall year.

IRRIGATION BENCHMARKING

This section outlines how to start benchmarking your irrigated agriculture enterprise and explains some measures of irrigation performance commonly used. When used properly, benchmarking can be one of the most powerful management tools to help ensure the future viability of your enterprise.

Benchmarking may apply to one or more farms, one or more fields, or components of your own irrigation systems. Benchmarking can help you to identify the performance factors that made up the production as well as highlight those aspects of production that may be improved.

Any aspect of farm or business may be benchmarked. In this workshop we focus on water use, but you may take the process much further through the evaluation of your farm performance and planning improvements. Benchmarking is the foundation for continuous improvement in your enterprise and industry.

What is benchmarking?

The term **benchmark** originated from surveyors who would 'mark' a point of reference. In short, a benchmark is a level. One way of looking at benchmarking is as a process of measuring your performance and comparing it against the performance of others. Benchmarking will enable you to **learn from your own past performance** and the performance of others to continually improve your performance.

Much like an athlete has his/her 'personal best', we have our 'production best'. That is, we know what we are capable of achieving under given conditions. We may then use this benchmark to determine whether it was better or worse than that of others. This may allow us to identify what we did right or wrong and therefore improve our future performances. Moreover, just as athletes may build towards the world record, we also may build towards the record– or, in our case, the industry's best practice.

Put simply, benchmarking means identifying or systematically measuring the performance of your business. Through the benchmarking process, you will be able to identify opportunities to continually improve your performance. There are many reasons for improving your business performance. Some of these include:

- increased profitability
- increased productivity
- improved water use efficiency
- increased quality of product
- reduced costs and labour.

Improving your performance starts with identifying where you stand at present, by recording the different aspects of your enterprise. In other words, you need to put some marks on the bench.

Activity 5: Identifying and creating benchmarks

Complete Activity 5 in your workbook.

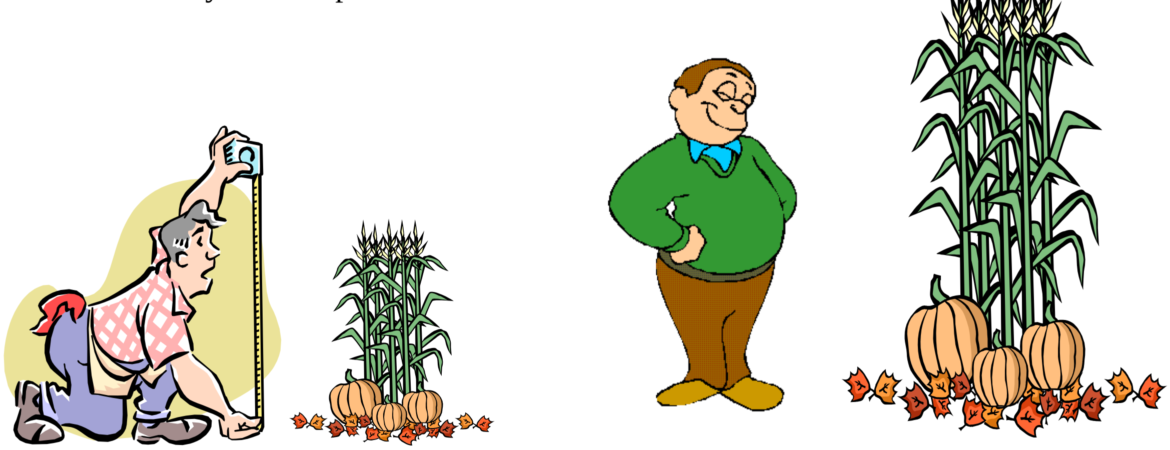
Carrying out benchmarking

Benchmarking calls for gathering information about your business, analysing that information, and planning actions. In general, there are four steps in the benchmarking process:

1. Analyse your business as it is.
2. Create your business benchmarks and compare them with your competitors.
3. Identify strategies to improve your performance.
4. Implement the strategies.

Through the process of benchmarking, you will identify the key areas of your business, systematically measure the performance of these areas, and compare them against your past performance as well as those of your competitors (other growers). Gathering accurate and reliable statistics about your key areas is the secret to successful benchmarking and consequently successful business.

To analyse your business, you need good records from your enterprise, collected over several seasons. Not everyone will have these records readily available, but, if you intend to improve your bottom line, it is important to collect and analyse records of your enterprise.



You need to measure and record the different aspects (inputs and outputs) of the farm, such as:

- area
- rainfall
- irrigation water use
- production (tonnes, milk, trays, bushels and so on)
- inputs (fertiliser, chemicals)
- number of trees (cows, bays, rows, and so on)
- costs and labour.

Record keeping

Record the performance of the different areas of your production directly onto record sheets. Using standardised data collection sheets will help you read and process the information. The record sheets should be designed to record all the appropriate details as well making space for comments and observations.

Below is a simple example of the type of information you need to record for a particular crop or irrigation unit to carry out irrigation benchmarking. How these measures are actually obtained will depend on your crop type, region, and the information available.

Grower name:			Date:	
Crop/unit surveyed:				
Application rate	mm/hour			
Average RAW for area	mm/m			
Total area of crop	ha			
Year	**1999–2000**	**2000–01**	**2001–02**	**2002–03**
Season rainfall				
Seasonal water use (ML/ha)				
Yield (amount/ha)				
Measure of quality (if applicable)				
Gross return ($/ha)				

Measurements of your total farm production are also useful.

Grower name:		Date		
Year	**1999–2000**	**2000–01**	**2001–02**	**2002–03**
Yield				
Seasonal water use				
Gross production				

Key performance indicators

The measurements you record of the key areas of your business are known as key performance indicators (or KPIs). Use the KPIs to make direct comparisons with the performance of other growers in your industry.

It is important to remember that the KPIs are for your use: while considering each of the KPIs standard in your industry, you should concentrate on those aspects of your business that are important and meaningful to you.

The basic KPIs that irrigators use in benchmarking include:

- yield
- water use efficiency
- economic value.

Key performance indicators vary for each particular business and industry. Since no businesses are exactly alike, you need to find common ground to make useful and reliable comparisons. Common ground is found by using ratios created by measuring the KPIs against particular units. The ratios used will depend on your particular industry. Ratios used in irrigation include:

- tonnes per hectare (t/ha)
- litres per hectare (L/ha)
- megalitres per tonne (ML/t)
- megalitres per hectare (ML/ha).

By observing the practices of your competitors, you may be able to identify strategies to help improve your performance.

Yield

The amount of farm product is the traditional way of representing the performance of an agricultural enterprise. Production may be measured in many ways: for example, kilograms, tonnes, and bales. Fruit growers may measure their production in cartons or pallets, whereas dairy farmers measure their product in litres.

In many industries, the amount of product is compared against the area over which it was grown (ha). This gives us the **yield**. You may readily compare your yield against your past yields as well as those of other growers. This may give you an indication of where your performance stands within your industry.

Yield	**=**	**Total product**	**÷**	**Area of crop (ha)**

The Total product may be measured by a number of techniques, including:

- sale of product
- crop harvester measurement
- processor (mill, silo, packing shed) records
- field measurement

The area of the crop is the area used to produce the product. For example, a dairy farmer will use the number of hectares used to support the herd, whereas an orchardist will naturally use the area covered by the producing trees. The area may be determined by a number of techniques, including

- farm plan/survey
- land title
- aerial maps
- crop harvester recorder
- GPS
- Manually

The total amount of produce that you create may also be compared against:

- the amount of irrigation applied (ML)
- the total water available to the crop from irrigation and rain (ML)

Water use benchmarks

As irrigators, we are concerned with the amount of water used to produce our crops. If excessive amounts of irrigation water are used to achieve a high yield, then that yield has been achieved through inefficient use of the water.

A water use index benchmark is the comparison of the amount of product to the units of water applied to produce that product. The water use index benchmark may be applied to the field or to the whole farm. In situations where water is scarce, this can be the most important performance measure.

Irrigation water index	=	amount of production	÷	irrigation water use delivered to field

In addition to benchmarking the overall farm water use, you should also record the field application efficiency and distribution system efficiency, for comparisons within your irrigation enterprise. Analysing these records will help you identify where improvements can be made.

As climatic conditions may change dramatically from one season to the next, the amount of water applied to the crop from irrigation may also vary greatly. To compare production against water used from one year to the next, we need to add rain to the amount of irrigation water applied to get the total water delivered to the crop. This will give a realistic water use index benchmark that may be compared between seasons.

Gross production water use index	=	amount of product	÷	total water applied (ML)

Total water applied is the volume of water metered plus the effective rainfall. Effective rainfall is the actual rainfall multiplied by the effective rainfall fraction for your region. Get your effective rainfall fraction from your local department of agriculture.

Irrigation efficiency benchmarking

Irrigation efficiency benchmarks may also be developed to monitor your irrigation system performance. You may develop benchmarks for each section of your system.

Supply system

On farm distribution efficiency	=	water received at field inlet	÷	water received by field	x	100

Field application

Field application efficiency	=	water retained in soil and available to crop	÷	water received at field inlet	× 100

Recording the benchmarks of your irrigation system performance will help you to continually improve your efficiency and water use index.

Economic value

Any performance measure that includes a dollar value goes beyond the simple comparison of yield. It also takes into account the quality and monetary return obtained for the crop.

This performance indicator may need adjustment to ensure variations outside the direct influence of the farm (such as transport damage) do not give a skewed picture.

As before, dollar production can be compared against area grown, irrigation water applied, total water applied and crop evapotranspiration. These measures may also be used to compare one crop against another, as you would do with gross margins. This can be very useful when deciding the best crop to grow with the amount of land and water available to you.

Area ($ per hectare)

Economic return for area planted	=	gross production ($)	÷	area of crop (ha)

Irrigation economic water use index ($ per ML)

Irrigation economic water use index	=	gross production ($)	÷	irrigation water applied (ML)

Total water use index ($ per ML)

Gross production economic water use index	=	gross production ($)	÷	total water applied (ML)

Crop water use ($ per millimetre)

Crop economic index	=	gross production ($)	÷	evapotranspiration (mm)

Performance measures may be affected by conditions other than irrigation management. Your overall farm management (fertiliser usage, varieties, sowing dates, disease, frost) will affect yields, just as varying market prices will affect returns. For this reason, average yields and returns over a number of seasons are used to compare against others over those same seasons.

Comparing your performance

Benchmarking is often used for evaluating how productive an irrigated enterprise is, and how efficiently the irrigation system is using water. Simply stated, benchmarking compares how your enterprise operates with the industry standard.

Comparison of records can be made within the farm (between bays, fields, blocks, and paddocks) or between fellow growers.

For example, a group of growers in southern NSW collected benchmarking information for their production (Figure 7). The identity of each grower was hidden to enable confidentiality to be maintained, and the chart below was produced. It shows there is a large range in water use efficiency within the group.

This range is often seen in the benchmarking information of groups. For example, a group of athletes will have also have a range of times to run a race. The range is due to differences in their training, equipment, determination, physiology, health, and fitness levels.

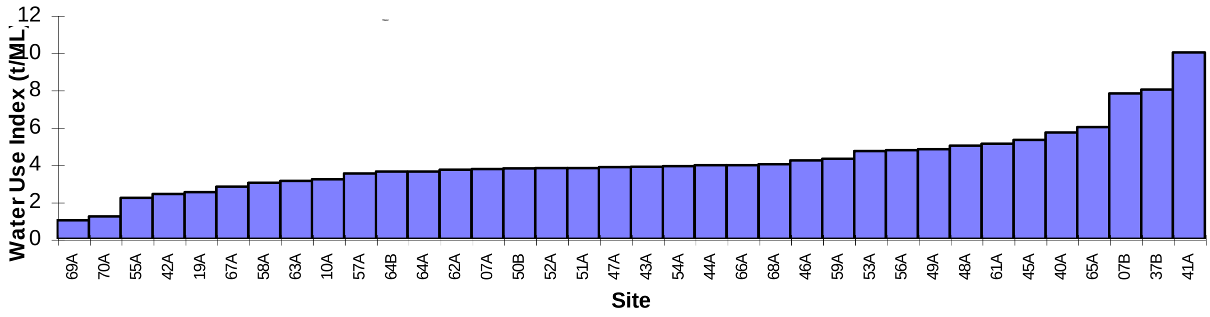


Figure 7: Water use index for sample growers

The top performer in this group produced nearly ten tonnes of product for each megalitre of irrigation water used, while at the other end a grower only produced one tonne. It would, of course, be important to consider the quality and other circumstances of this production. The purpose of benchmarking is not to point out poor performance, but to indicate the level of performance that is possible.

Example: Barry Bloggs' basic benchmarking

Barry Bloggs grows "anytyypa" fruit on 50 irrigated hectares. He delivers his fruit to the "Dalocal" fruit packing shed.

To help with his management plans, Barry decided to benchmark, using yield and water use index as his key performance indicators. To analyse his business, Barry collected the following information.

Name: *Bazza*	Crop: *Anytyppa*	Date: *Jan 2003*		
Performance measure	**Source**	**2002**	**2003**	
Number of cartons	*Packing shed "Dalocal"*	*1901*	*1982*	A
Area of crop	*Farm plan*	*50 ha*	*50* ha	B
Area irrigated	*Farm plan*	*50 ha*	*50* ha	C
Irrigation water applied	*Estimated from pumping times*	*160 ML*	*150* ML	D
Rainfall (over the season)	*Rain gauge*	*1250 mm*	*1500 mm*	E
Fertiliser	*Tax invoice*	*2 tonnes*	*2 tonnes*	F

To calculate his KPI, Barry selected and measured the following aspects of his enterprise:

Benchmark key performance indicators

2002	2003
Yield = total production ÷ area of crop	
Yield = A ÷ B = 1901 ÷ 50 = 38 cartons/ha	Yield = A ÷ B = 1982 ÷ 50 = 39.6 cartons/ha
Irrigation water use index = amount of product ÷ irrigation applied to field	
Irrigation WUI = A ÷ D = 1901 ÷ 160 = 11.9 cartons/ML	Irrigation WUI= A ÷ D = 1982 ÷ 150 = 13.2 cartons/ML

By comparison, the AFC (Anytyppa Fruit Cooperative) stated the following figure in their 2002 annual report:

Yield	highest yield: 45 cartons per hectare average yield: 38 cartons per hectare
Irrigation water use index	best: 16 carton/ML average: 10 carton/ML

Validity of benchmarks

The value of benchmarking is greatly increased when the measurement has been obtained consistently and accurately. Written records, also, are more accurate than relying on memory.

(Our memories are not perfect and may be corrupted by time and emotions. The classic example of 'imperfect memory' is the angler's tale of 'the one that got away'.)

Records of the inputs and outputs of your business, such as crop area, quantity of produce, soil water-holding capacity, rainfall received and water applied need to be accurate, derived from accurate measuring systems, and recorded.

For example, if water use is a factor you want to use in benchmarking, then your performance would more accurately gauged by using flow meters rather than estimating the water use from pumping times. You would have more confidence in the measure of this indicator, and consequently in its relationship to a benchmark, if you used flow meters. Its validity would be around 90%, compared with an estimate of water use which might have around 50% confidence, or a 'guess-timate' with no records to inform it, of around 10% confidence.

Deciding on which performance indicators to measure as well as how to measure them determines the validity of the benchmark comparison. The more confidence we have in our performance figures, the better our ability to plan and manage our irrigation.

Activity 6: Irrigation benchmarking

Complete Activity 6 in your workbook. Discuss the sample benchmarking data.

How did Barry compare?
What confidence may Barry place on his benchmarks?
In your groups, discuss Barry's performance, KPIs, and validity.
What are some of the KPIs that you could start monitoring?