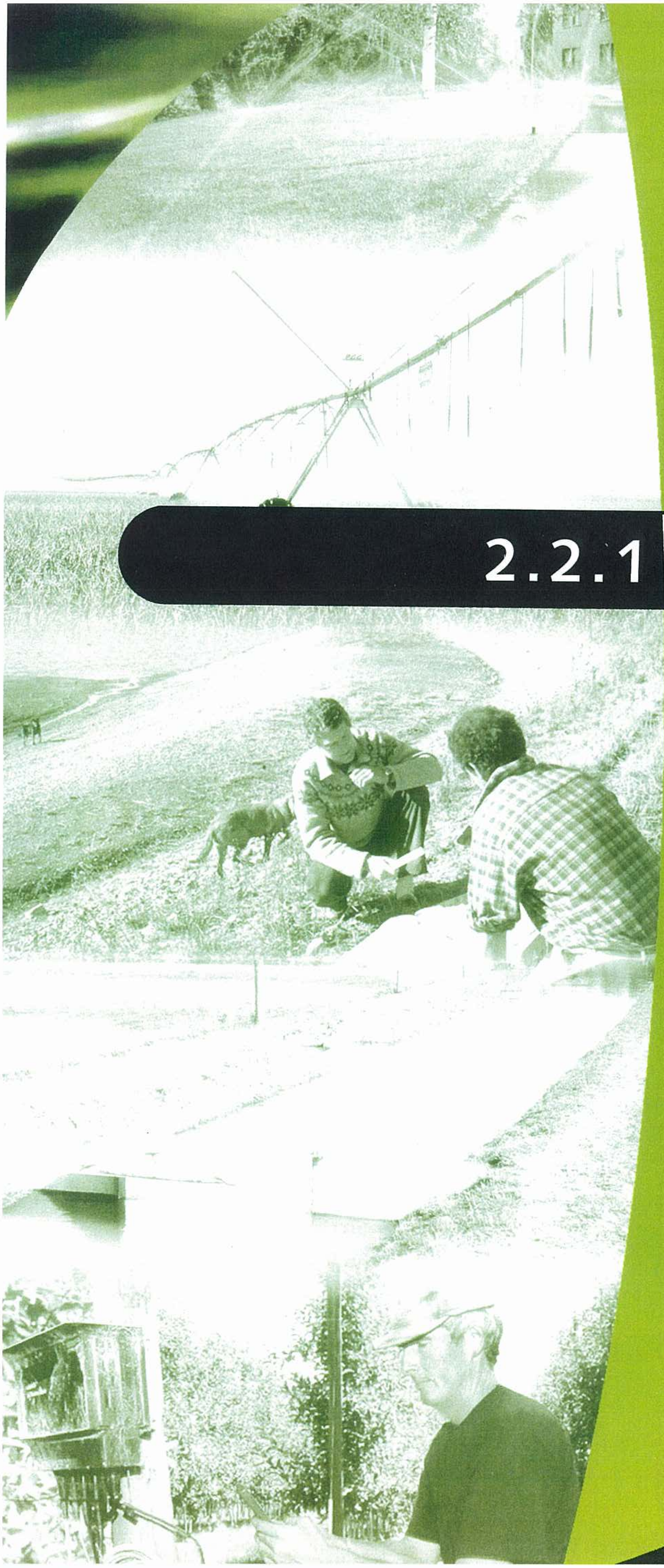
2.2.1 ALL SYSTEMS



How to irrigate with limited system capacity

This decision must be made when there is not enough water to fully irrigate crops to achieve the maximum yield. When there is insufficient water to meet the crop demand, irrigation management strategies that best use the available water must be considered.

Limited system capacity

Insufficient capacity to irrigate an area may result from water supply factors, such as:

- mandated flow restrictions on "run of river" schemes,
- mandated restrictions on groundwater allocation
- low storage volumes
- seasonally low groundwater levels.

Insufficient capacity can also result from system limitations, such as:

- low yielding wells, either natural or as a result of poor maintenance
- inadequate system design.

No matter what the reason for limited system capacity, potential yield will not be achieved unless appropriate management strategies are considered.

Management options

The key choices available are:

1. ***Irrigate as usual, and hope that it will rain.*** This is not a prudent management option. There is no guarantee of rainfall before damaging yield loss has occurred.
2. ***Reduce irrigated area to allow the amount of irrigation applied to closely match the full irrigation requirement.*** Irrigated crops will reach their potential, while those reverted to dryland may still produce a level of profitable return. The strategy must also consider other management adjustments (e.g. reduced fertiliser, herbicide etc.). This should be the preferred strategy on shallow soils. Choose the better crops or the highest return/value crops for irrigating. Drop out the poorer or least value crops.
3. ***Reduce the amount of irrigation.*** This strategy will only work if near normal rainfall occurs. If there is less than normal rainfall, all the yields will be less than the fully irrigated potential yields. There will also be quality issues, e.g. pinched grain, small fruit.
4. ***Substitute lower water demand crops.*** This is an option if there is a demand for the final product. For example, corn uses significantly less water than spring barley, winter wheat less than spring wheat. This strategy benefits those with poor yielding wells and when storage is not full at the start of an irrigating season.
5. ***Stagger planting dates.*** Peak water use by crops occurs when leaf area is at a maximum. Planting can be staggered so that lower water use periods of some crops coincide with peak water use periods of other crops. This strategy requires some lead-time to plan, so usually applies to those irrigators dependent on stored water, poor yielding wells and deep aquifers that have received no winter recharge, or to those with low system capacity.
6. ***Delay irrigation until "critical" times.*** While crop research conclusively shows irreversible yield loss occurs whenever the critical deficit is not relieved by irrigation, there are critical times when irrigation can be applied to save potential yield. For example:
   - Irrigating peas at the end of flowering and beginning of pod fill;
   - Irrigating grain crops during reproductive and grain fill growth stages.

   This strategy is not well suited to flood irrigation systems, because dry and cracked ground does not convey water well. It is best suited to centre-pivot and other spray systems.
7. ***Manage soil moisture levels to maximise the benefit of rainfall.*** Applying this strategy is important whenever system capacity is limited. Knowing the soil water content will allow management of soil moisture to low levels to maximise storage of any rainfall without exposing the crop to yield reducing deficit.
8. ***Start early and stay ahead.*** This strategy requires careful management so as not to waste water. Knowledge of the soil moisture content is essential in order to permit frequent small irrigations and thus

maintain high soil water levels, while avoiding over-irrigation. It is always better to be an irrigation ahead than one behind. The major disadvantage is that little benefit is gained from rainfall events, because there is so little storage space in the soil.

9. ***When mixed cropping, irrigate crops first and pasture last.*** Pasture will recover, a failed crop will not.

10. ***Keep crop residue on the surface to minimise soil evaporation, improve infiltration and intercept rainfall.***

Summary

- If limited system capacity is a reality, adopt a strategy to maximise the use of the available water, especially rainfall.
- Irrigate crops that will provide the best economic return.
- When deciding how to irrigate, don't count on it raining.

June 2001

When to start irrigating pasture

The "Golden Rule" for starting pasture irrigation is to start before you are compelled to. The aim is to always avoid moisture stress, and this will require planning ahead. In almost all situations this will mean starting well before the critical deficit is reached, so that a complete irrigation cycle can be completed before any crop gets to its critical deficit point.

What to consider

- **DO NOT** wait to start when the pasture is showing signs of moisture stress. Yield loss will have already occurred, and it is impossible to catch up if there is no significant rainfall.
- **DO NOT** watch and wait for the neighbour to start, or begin on a "traditional" day!
- Be prepared to start early.
- The three important factors to consider are: Current soil moisture content; Expected crop water use; System capacity.
- Soil moisture measurement and predicted crop water use are the best and most certain factors to use to determine the start date. Farmers with low capacity systems must be prepared to start irrigation early to avoid falling behind.

How to determine start date

- Measure the current soil moisture in some key paddocks to find out how much moisture is readily available.
- Divide this amount by the current or expected daily crop water use.
- The answer is the number of days before **all** the pasture must be irrigated.
- Compare this number of days to the irrigation return period, and start a few days earlier to allow for start-up problems. For those with centre-pivots, the start of irrigation can be delayed until necessary.
- The soil moisture deficit will usually be well above the critical deficit (see Section 3.1.4), so start with light applications and build up to the full irrigation depth later in the cycle.
- If irrigation has to start early in the spring, crop water use will be 50-60% of the maximum of later in the season. The first "round" can be completed with smaller applications. This may also allow the utilisation of night rates and reduce power costs.
- The amount of water applied (or net to the root zone) must be sufficient to keep the soil moisture above the critical deficit until the next irrigation can be applied.
- On deeper and heavier soils, irrigation can start later. But be careful when starting, because excessive irrigation, when combined with rainfall, will make the pastures difficult to traffic and manage (graze). The wet soils may also result in lower production.

In some cases (e.g. run-of-river schemes), the start time may be limited to when water is available or to a mandated start date. If this delays the start of irrigation, irrigate as much area as possible, so that the next irrigation will not be missed.

Key considerations

- Be prepared for an early start.
- Start early and before you are compelled to.
- Very seldom can you catch up moisture deficits.

June 2001

When to stop irrigating pasture

In New Zealand, winter rainfall generally eliminates soil moisture deficits that may remain at the end of the irrigation season. It makes sense, therefore, to leave the soil as dry as possible at the end of the season. Farmers irrigating pasture, particularly on dairy farms, are faced with the decision of when to stop irrigating at the end of the season. Grass growth and evapotranspiration slow into the autumn, reducing the demand for water. The interval between irrigations becomes longer, and the probability of rain falling before critical deficits are reached, increases. The decision of when to stop irrigating depends, however, on a number of factors, such as grass growth rate, the need for grass production, and general farm management, as well as soil moisture and rainfall considerations.

Management options

1. **Carry on irrigating at your normal irrigation interval until rain brings all paddocks up to field capacity.**

   Advantages

   - If system capacity is not limiting, soil moisture will be kept at high levels regardless of climatic conditions.
   - Lowest risk in terms of losing production through insufficient soil moisture.

   Disadvantages

   - An overly conservative approach.
   - Will almost certainly be over-irrigating.
   - Extra costs of unneeded irrigation (electricity, labour, wear and tear).
   - Leaching of nutrients.
   - Potential contamination of groundwater.
   - Potential waterlogging of soils, causing reduction in growth.
   - Potential pugging of soils by livestock, as soils tend to dry out more slowly.

2. **Carry on irrigating according to soil moisture status, assuming that rain will not fall.**

   Advantages

   - Can change return interval according to demand, reducing number of irrigations.
   - Only irrigation that is actually needed will be applied.
   - Pasture production is not limited through lack of moisture.
   - Low risk.

   Disadvantages

   - Entails the time and expense of measuring soil moisture or using a water budget.
   - May irrigate just before rain falls, reducing the benefit of rainfall.

3. **Stop irrigating in the belief that sufficient rain will fall.**

   Advantages

   - Lowest cost.
   - No avoidable leaching of nutrients.
   - Reduces potential for waterlogging and pugging.
   - Greater opportunity to make full use of rainfall, if it falls.

   Disadvantages

   - Highest risk.
   - Still have to decide when to make the decision to stop.
   - If rain does not fall, will lose pasture production.

4. **Modify return intervals and depth of water applied, allowing for probability of rain.**

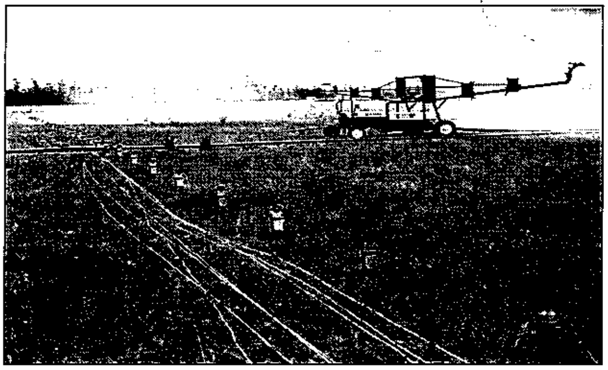
   This is the best option. It involves carrying out a forward calculation of likely irrigation demand based on likely evapotranspiration and a probability of rainfall, and then modifying depth of water applied and return intervals.

   Advantages

   - Can change return interval according to demand, reducing number of irrigations.
   - Allows for efficient use of rainfall.
   - Only irrigation that is actually needed will be applied.
   - Pasture production is not limited through lack of moisture.
   - Low risk.

   Disadvantages

   - Entails the time and expense of measuring soil moisture or using a water budget.
   - May irrigate just before rain falls, reducing the benefit of rainfall.
   - Requires calculation of likely future demand.
   - Requires calculation to be updated if rainfall or unusually high evapotranspiration events occur.



June 2001

When to start irrigating crops

The "Golden Rule" for starting crop irrigation is to start before you are compelled to. The aim is to always avoid moisture stress, and this will require planning ahead. In almost all situations this will mean starting well before the critical deficit is reached. The decision for crops is more complex than for pasture, because there is more than one crop to consider.

What to consider

- **DO NOT** wait to start when the crops show signs of moisture stress. Yield loss will have already occurred, and it is impossible to catch up if there is no significant rainfall.
- **DO NOT** watch and wait for the neighbour to start, or begin on a "traditional" day!
- Be prepared to start early.
- The important factors to consider are:
  - Current soil moisture content
  - Critical deficit of the crops being grown
  - Growth stage and root depth of the crops
  - Expected crop water use
  - System capacity.
- Soil moisture measurement and predicted crop water use are the best and most certain factors to use to determine the start date. Farmers with low system capacity must be prepared to start irrigation early to avoid falling behind.

How to determine start date

- Measure the current soil moisture in the crops planted and growing. Determine how much readily available moisture is left for each crop.
- Divide this amount by the current or expected daily crop water use.
- The answer is the number of days before **each** crop must be irrigated.
- Compare this number of days to the irrigation return period, and start a few days earlier to allow for start-up problems. For those with centre-pivots, the start of irrigation can be delayed until necessary.
- Start with the crops that need water first. Depending on the season, this could be either shallow rooted spring sown crops or autumn sown crops that have used large amounts of water. Young crops will come under moisture stress before the critical deficit (refer Section 3.1.4), because the root system is only partially developed.
- The soil moisture deficit could be well above the critical deficit (see Section 3.1.4), so start with light applications and build up to the full irrigation depth later in the cycle. This applies particularly to those with limited system capacity.
- If irrigation has to start early in the spring, crop water use will be 50-60% of the maximum of later in the season. The first irrigation can be completed with smaller applications. This may also allow the utilisation of night rates and reduce power costs.
- The amount of water applied (or net to the root zone) must be sufficient to keep the soil moisture above the critical deficit until the next irrigation can be applied.
- Irrigation can start later on deeper and heavier soils. But when starting in the early to mid spring, do not apply large irrigation amounts. With the additional effects of rainfall, the paddock may become difficult to traffic, and the wet soil may result in yield loss.
- Heavier soils are also conducive to small irrigations early, and before the critical deficit is reached, to maintain a high soil moisture reserve and so provide a buffer when high demand conditions prevail.

In some cases (e.g. run-of-river schemes), the start time may be limited to when water is available or to a mandated start date. If this delays the start of irrigation, irrigate as much area or as many crops as possible, so that the next irrigation will not be missed.

Key considerations

- Be prepared for an early start.
- Start early and before you are compelled to.
- Very seldom can you catch up moisture deficits.
- Irrigate the crops that need water first.

June 2001

When to stop irrigating crops

A mistake commonly made by crop farmers is to stop irrigating too early. The last irrigation is vital – it is the payoff time for all the management that the crop has had beforehand. It is often the difference between a good crop and an outstanding crop. The decision to stop irrigating crops is much more complex than the decision for pastures.

What to consider

Predicting the last irrigation is a balance between:

- Stopping too soon, thus reducing potential yield, and
- Irrigating later than necessary, resulting in reduced storage of out-of-season rainfall, increased potential for leaching and added production costs.

This decision requires knowledge of how much water is available in the root zone and how much more is required to reach harvest maturity.

Determination of soil moisture content and availability requires a soil moisture measurement (refer to Section 2.4.1 or 3.1.4).

How much more water is required by the crop to reach maturity depends on the crop growth stage. As maturity is approached, crop water use declines and is less than the mid-growing season peak. The time until maturity can be estimated from known or published guidelines for growth stage duration. For example:

- Wheat takes 35-45 days from flowering to end of grain fill.
- Barley takes 35-45 days from flowering to end of grain fill.
- Maize takes 35-40 days from dough stage to "black" layer.
- Green peas take 20-30 days from end of flowering to pod fill.
- Stone fruit take 20-30 days for final fruit swell stage.

A simple comparison of available soil moisture and the requirement to reach maturity will determine if further irrigation is necessary.

Apply the last irrigation so that all the readily available soil moisture is just used up when the crop reaches maturity. Applying more than necessary is wasteful and could be damaging to the crop and harvest conditions.

Consequences of poor decisions to stop

Stopping irrigation too soon or too late adds to crop production costs, as described here.

Stopping too soon before the crop reaches harvest maturity will result in:

- Loss of potential yield.
- Decreased crop quality.
- For grain crops, there can be grain abortion, small grain, increased screenings and reduction in the 200-250kg/ha/d accumulation of grain yield.
- For fruit crops, there can be smaller fruit, decreased fruit quality such as reduced soluble solids, and delayed maturity.
- For wine grapes, there can be reduced berry size, reduced acidity, increased pH, reduced soluble solids, and delayed maturity.
- If the critical deficit is exceeded, there could be premature leaf senescence (dying) and reduced carbohydrate storage in perennial crops for next season's production.

Irrigating later than necessary or applying more water than required to reach maturity can result in:

- Difficult harvest conditions, e.g. excessive regrowth of ryegrass and grain crops, wet soils for machinery, and encouragement of disease.
- Return of some crops, such as fruit trees and wine grapes, to vegetative production and not fruit development.
- Potential for wet soils (especially if it rains) and leaching of nutrients.
- Significant reduction of potential for out-of-season storage of rainfall.

Key considerations

- Measure soil moisture content.
- Estimate time until crop maturity.
- Apply only enough water to reach maturity.

June 2001

What to do when it rains

Some knowledge of when it is going to rain and how much will fall would solve all irrigation management problems. As this is most unlikely, it is important to make the best management decisions when it does rain.

What to consider

- Not all rainfall is effective. The crop canopy intercepts some, some is redistributed at the surface (especially during intense falls like thunderstorms), and some is lost to deep drainage (down old root holes, cracks in the soil etc).
- Rainfall is very variable. The same amount does not fall everywhere, even on the same farm.
- Rainfall does conform to some patterns.
- Monthly rainfall is usually less than the average.
- More important is the range and distribution of monthly rainfall – there are more 20-40 mm rainfall events than >60 mm events.
- Some months have greater variability than others. For example, in some areas December has wide ranging rainfall totals.
- Without any rainfall, almost all irrigation systems will fail to cope with crop water use demand.
- Rainfall is incorporated into irrigation design to extend the system capacity.
- Because of rainfall variability within a season, there is almost always a period when the irrigation schedule cannot be met.

What to do when it rains?

The keys to determining "what to do when it rains" are monitoring, measurement and recording.

The decision to continue to irrigate when it rains requires consideration of:

- How much rain has fallen.
- How effective is the rainfall, and how has soil moisture content changed.
- How long will the rainfall last.

To balance these factors requires monitoring and measurement:

- Measure and record rainfall on the farm (refer to Section 2.4.2).
- To determine the effectiveness of the rainfall, a soil moisture measurement should be done. There is no room for a mistake in soil moisture content resulting from a poor assumption. There are several methods to measure soil moisture (refer to Section 2.4.1).
- How long the increase in soil moisture content (the effective rainfall) will last depends on crop water use and the prevailing climatic conditions. For example, 20 mm of effective rainfall in December, when crop water use is near the maximum, is likely to last no more than 4-5 days, while in October or March, when crop water use is much lower, 20 mm is likely to last 7-8 days.

How much rainfall is useful?

The table (over page) provides guidelines as to what to do when it rains – different amounts and different times of year – depending on your system capacity. The primary difference between smaller and larger system capacity is that, with smaller systems, you must be more vigilant to avoid falling behind with irrigation. Be prepared to start irrigating again at the first sign of hot, dry weather. Larger capacity systems have greater catchup ability.

Time of year	Rainfall	System capacity <3 mm/ha/d	System capacity >3 mm/ha/d
Before mid-October	<25 mm	Stop irrigating. Prepare to start at the first sign of hot, dry weather.	Stop irrigating. Re-start dictated by soil moisture levels.
	>25 mm	Stop irrigating. Re-start dictated by soil moisture levels.	Stop irrigating. Re-start dictated by soil moisture levels.
Mid-October to March	<25 mm	Continue irrigating.	Continue irrigating. Adjust amount or return interval.
	25-50 mm	Continue irrigating. Adjust amount or return interval.	Stop irrigating. Prepare to start at the first sign of hot, dry weather.
	>50 mm	Stop irrigating. Prepare to start at the first sign of hot, dry weather.	Stop irrigating. Re-start dictated by soil moisture levels.
After March	<25 mm	Continue if dry. Adjust amount or return interval.	Stop irrigating. Prepare to start at the first sign of hot, dry weather.
	>25 mm	Stop irrigating. Re-start dictated by soil moisture levels.	Stop irrigating. Re-start dictated by soil moisture levels.

June 2001

How to irrigate to maximise efficiency

Efficiency is all about "production without waste" – in this case "irrigation without waste". For an irrigating farmer, this means making the maximum use of each and every litre of water delivered to a crop. Every effort must be made to avoid wasting water that is delivered to a crop, to prevent the critical deficit being reached.

Efficient irrigation applies the right amount of water in the right place at the right time, so that plant growth can be maintained at its highest potential rate.

How is water wasted?

Water can be wasted in two main ways:

Deep drainage

Water is lost to deep drainage below the root zone of the crop. This "lost" water is only of benefit to groundwater recharge and not to the crop. Deep drainage occurs when:

- Too much water is applied.
- The water application is too uneven.
- Irrigation is followed immediately by a significant rainfall.

Redistribution

Irrigation water is lost to redistribution within a paddock because:

- The application rate is too high, and the water flows off high places and into low places (see Section 3.1.4, Sheet 5: *How fast can water be applied to the soil?*).
- It is too windy. High winds can blow water to specific areas of the paddock. The result is over-irrigation of some areas and under-irrigation of other areas.
- The irrigation system has an inherent non-uniform distribution pattern.

Additionally, small amounts of water can be wasted because of overlooked maintenance, such as:

- Leaking hydrants that often only require a new rubber seal.
- Leaking PVC mainline.
- Leaking delivery hoses.

How to eliminate waste and improve efficiency

Eliminating waste and maximising irrigation efficiency require a good understanding of the soil, water and plant relationships. This understanding will allow you to:

- Assess and maintain the readily available water in the soil.
- Meet the crop needs to optimise growth.
- Apply sufficient water to match these two requirements.

a) Reducing the loss to deep drainage is straightforward: measure, monitor and record. Then schedule irrigation appropriately.

   - Measure soil moisture, crop water use, and rainfall to calculate the appropriate amount of water to apply. There is nothing to be gained through applying more than the current soil moisture deficit or the critical deficit.
   - Monitor the weather, and delay or reschedule irrigation if rainfall is forecast.
   - It is equally important to *record* soil moisture content, rainfall, and your irrigation decision, so that the next irrigation decision is made easier.
   - Match the amount of water required and the amount of water applied.

   Do not irrigate by convenience (i.e. a set standard run time). Such an approach will inevitably result in deep drainage and waste.

b) To reduce the redistribution of water may be more difficult.

- Avoid irrigating in extremely windy conditions. There may be little or no gain from irrigating in such conditions.
- If the season remains windy and your irrigator is susceptible to wind, reduce lane spacing (refer to Section 2.2.7, *Practical tips*).
- Reduce the application rate of the irrigator. This can only be achieved by increasing the wetted footprint or decreasing the flow to the irrigator.
- The detrimental effects of high application rate can also be reduced by leaving enough surface roughness, e.g. clods in grain crops, organic residue on the surface.

c) The simplest way to reduce delivery system waste is to keep up-to-date with maintenance:

- Repair leaking hydrants.
- Find and repair leaks in PVC mainline.
- Repair or replace leaking delivery hoses.

d) Peak irrigation efficiency will be sustained with regular irrigator system maintenance (refer to Section 2.3, *Maintenance and troubleshooting*). Examples are:

- Replacing worn nozzles with a new nozzle of the same size.
- Checking the uniformity of application with catch cans.
- Checking pump pressure(s).
- Checking water level in the well (refer to Section 2.2.2, Sheet 2: *How groundwater level fluctuations affect pumping*).

System upgrade

Upgrading your existing irrigation system to improve efficiency should be considered if changes to the management of your system do not raise efficiency to an adequate level (refer to Section 3.3, *Upgrading existing systems*). If a new system is being installed, ensure it is the most efficient system suitable to your circumstances. While an efficient system may be more expensive to purchase and install, it is cheaper to run and maintain (refer to Section 3.2, *Choosing a system*).

Summary

- Irrigating to maximise efficiency means getting the most for the least, i.e. applying the least water for the most return.
- The greatest improvement in irrigation efficiency will be gained from irrigation scheduling – the careful measurement, monitoring and recording to determine irrigation requirements.

Efficiency will only be sustained with careful and diligent maintenance of all aspects of your irrigation system, from the water source to the application system.

June 2001

How to optimise the use of rainfall

Plants use a given amount of water per season regardless of whether the water comes from rainfall or from irrigation. Every millimetre of rainfall that can be effectively used reduces the amount of irrigation water that needs to be applied. This sheet gives guidance on how to make the most effective use of rain when it does fall.

Why is it important?

The closer that soil moisture is to field capacity, the more likely that any rain that falls will be lost to deep drainage. Conversely, the drier soils are, the less likely that rainfall will drain below the root zone of plants. Given that the total water used by an irrigated crop in a season does not vary significantly, the more rainfall that can be used, the less irrigation required. Using rainfall effectively reduces irrigation costs and minimises deep drainage.

Methods

The basic strategy to obtain the most efficient use of rainfall is to keep soil moisture as close as possible to the stress point or critical deficit for the crop. This leaves the soil as dry as possible to accommodate any rain that falls, but does not cause any significant yield loss. How well this can be achieved depends on the irrigation system type and capacity, crop type, soil type, the time of year and the risk that soil moisture dries out too much.

The key to optimising the use of rainfall is knowing what level of moisture is in the soil at any time. This requires monitoring, measurement and recording. It is vital that soil moisture is measured and that trends in water use are monitored.

Systems with short return intervals

This includes systems that have the ability to apply small depths of water frequently, typically every 1-3 days. Systems with this high catch up ability are permanent systems such as automated trickle and microsprinkler systems and fixed centre pivots. To optimise water use with these systems:

- Monitor soil moisture (refer to Section 2.4.1).
- Determine critical deficits for each crop on a monthly or if possible, two weekly basis (they will change throughout the year).
- Calculate irrigation system capacity in mm/day.
- Obtain information about evapotranspiration (ET) for your area so that you can predict the likelihood of three consecutive days of given values of ET throughout the irrigation season.
- If the ET values are less than the irrigation system capacity, operate the irrigation system so that soil moisture is maintained just above the critical deficits.
- Systems with high capacities may be able to operate in this way throughout the irrigation season.
- If the ET values are likely to be higher than the irrigation system capacity, maintain soil moisture at a level that will reduce the risk of critical deficits being exceeded. These values will change throughout the year and are best calculated using a spread sheet.

Example

Return interval	3 days
System capacity	5 mm/day
Critical deficit at time of irrigation	30 mm
Crop ET expected at time of irrigation	12 mm over 3 days (average of 4 mm/day)
Depth of application	15 mm (= 5 mm/day x 3 days)

Because system capacity is higher than the expected ET, apply 15 mm of water when soil moisture approaches 30 mm deficit. Remember that it could take 3 days to irrigate the total area so allow for the time it will take to get around the area. This is particularly important at the start of the season and when restarting after substantial rainfall.

If expected ET was 18 mm over 3 days, irrigation needs to take place much sooner to prevent the critical deficit being exceeded. The additional water (1 mm/day, which is the amount ET exceeds system capacity) needs to come from water stored in the soil. The deficit at the time of irrigation depends on how long the ET rate is likely to exceed the system capacity. It may be expected to average 5.5 mm/day over 10 days and 5 mm/day over 20 days.

With the ability to irrigate regularly, it is unlikely that the additional water required would exceed 10 mm, so if high ET periods are expected, it would be prudent with this example to irrigate when the soil moisture deficit is at about 20 mm, refilling the soil to a 5 mm deficit. Irrigation application efficiency would be maximised, some storage would remain to utilise rainfall and the risk of exceeding critical deficits would be minimised.

Systems with longer return intervals

This includes systems that are operated over several paddocks such as rotary booms, linear booms and movable pivots that apply water over 7-15 days or more. Because the irrigation machines are moved each day over several areas or paddocks, it is not physically possible to cover the area quickly.

The same principles apply as for the systems with short return intervals except that full account has to be taken of the time it takes to irrigate around the rotation. This means that crop ET estimates have to be extended to the longer return interval.

Example

Return interval	10 days
System capacity	5 mm/day
Critical deficit at time of irrigation	60 mm
Crop ET expected at time of irrigation	48 mm over 12 days (average of 4 mm/day)
Depth of application	50 mm (= 5mm/ day x 10 days)

If one rotation has been completed, soil moisture in each paddock will vary according to the date that each paddock was last irrigated. Following on with the same watering schedule, each paddock could be irrigated when the soil moisture deficit approached 60 mm, because system capacity exceeds predicted crop ET. Irrigation should take place at say 55 mm deficit to allow for a margin of error. Applying 50 mm would leave the soil with a 5 mm deficit after irrigation.

If Crop ET over 12 days was expected to be 66 mm (5.5 mm/day), it would be necessary in this example to maintain soil moisture after irrigation as close to field capacity as possible to provide additional storage of water in the soil. Even then, the critical deficit would be exceeded because the soil has insufficient moisture to act as a buffer to carry the crop through the high ET period.

Precautions

Although maintaining soil moisture as close as possible to critical deficits results in optimum use of rainfall, higher application efficiency and reduces irrigation required over the season, it also introduces some risk. In particular, ET rates could exceed estimated values or critical deficits may be different to that assumed. Also, there is no allowance for unexpected stoppages or breakdowns.

The risk depends on ET rates at the time, the sensitivity of the crop to soil moisture deficits and the catch up ability of the system.

Low value, less sensitive crops being watered with short rotation irrigation systems during low ET periods are the lowest risk and can be managed with soil moisture deficits close to the critical deficit.

High value, more sensitive crops watered with long rotations during high ET periods are at greatest risk and should be managed with as small deficits as is practically possible.

December 2001

How to handle soil variations

The likelihood of obtaining optimum production is greater on uniform soils than on soils that have large variations in water holding capacity. It is difficult to irrigate variable soils efficiently because they create difficulties with matching irrigation applications to soil moisture deficits. A number of methods can be used, as follows.

Irrigate on the basis of meeting demand in the lower water holding capacity soils in the field

It provides:

- lowest risk in terms of losing production through insufficient soil moisture

but:

- is an overly conservative approach
- will almost certainly be over-irrigating the higher water holding capacity soils
- extra costs of unneeded irrigation – electricity, labour, wear and tear
- leaching of nutrients
- potential contamination of groundwater
- potential water-logging of soils causing reduction in growth.

Although this method is commonly used, it would not be recommended as the optimum method on most properties, particularly where water is short and water quality through leaching of nutrients is an issue. On high value crops with higher than average available soil moisture, it has some value.

Irrigate different soil types separately

This method has the advantages of:

- water is applied more precisely to match soil moisture deficits
- only irrigation that is actually needed will be applied
- production is not limited through lack of moisture
- low risk.

However, it:

- will probably be very expensive to set up
- is probably not a realistic option on most farms
- has time and expense of measuring soil moisture or using a water budget using ET figures.

This is an ideal approach and would be highly recommended from a water application efficiency perspective. However, the expense of setting up the system usually negates the benefits of more efficient water use. It is probably worthwhile for high value crops in water-short areas.

Modify both return intervals and depth of water applied

This requires timing irrigation according to the requirements of the low water-holding capacity soils, but applying sufficient depth of water to meet the requirements of the high water-holding capacity soils.

The advantages are:

- return interval can be changed according to demand, reducing number of irrigations
- production is not significantly limited through lack of moisture
- low risk.

The disadvantages are:

- lower water holding capacity soils will be over-watered
- leaching of nutrients
- potential contamination of groundwater.

This is probably the most suitable approach for most irrigation systems.

Example of irrigating two soil types

Assume you have a paddock with soils with water-holding capacities ranging from 140 mm (Soil A) to 80 mm (Soil B) and allowable soil moisture deficits are approximately half these amounts. You wish to determine your return interval and application depth for the field.

One of the problems you have is that crops on the better soils tend to use more water because they are more vigorous. So you need to work out the return interval based on the soil of lowest water holding capacity and apply enough water to satisfy the highest ET demand.

	Soil A	Soil B
Water holding capacity	140 mm	80 mm
Allowable percentage deficit	50%	50% (i)
Allowable soil moisture deficit	70 mm	40 mm
January (ET-rainfall) exceeded 10% of time over 10 days	50 mm	(ii)
Assume irrigation efficiency of 80%, gross depth over 10 days	62 mm	
Average depth per day required	6.2 mm	

Calculate return interval based on Soil B, because it has the lowest water holding capacity.

$$\text{Return interval} = \frac{40 \text{ mm}}{6.2 \text{ mm/day}} = 7 \text{ days}$$

Calculate depth applied based on allowable deficit for Soil A, because it has the highest water holding capacity.

Depth applied = allowable soil moisture deficit = 70 mm

So, irrigation system should be capable of applying 70 mm of water every 7 days.

Notes:

(i) This will be based on your soil type, crop type and ET rate. Normally a maximum 50% depletion of total available soil moisture is allowed for growing pasture, but this may be increased slightly, to 60-70% during low ET periods and decreased slightly during high ET periods. For example, if your soil holds 100 mm of water, normal allowable depletion would be 50 mm, but this could be extended to 60-70 mm during cooler weather.

(ii) To determine this figure, you must have access to data that gives the probability of rain falling during the hottest and driest return interval and the ET for that time.

June 2001

Example calculation of when to stop irrigating pasture

The following procedure can best be implemented in a computer spreadsheet and revised as necessary.

Suggested calculation

Current date		1 April	
End of season date		31 May	
Allowable soil moisture deficit		60 mm	(i)
Current soil moisture deficit		20 mm	(ii)
Current water available		40 mm	(iii) = (i) - (ii)
Expected useful rainfall (April/May)		50 mm	(iv)
Total available water (April/May)		90 mm	(v) = (iii) + (iv)
Pasture evaporation/transpiration (ET) based on average ET			
April	30 days at 2.5 mm/day	75 mm	
May	31 days at 1.8 mm/day	56 mm	
Total ET (April/May)		131 mm	(vi)
ET		131 mm	(vi)
Less available water			90 mm (v)
Net irrigation required		41 mm	(vii)
Irrigation efficiency		80%	(viii)
Net irrigation required		41 mm	(vii)
Divided by efficiency as a decimal		0.8	(viii)
Gross irrigation required		51 mm	(ix) = (vii) ÷ (viii)

This calculation has determined that in all probability you will still need to apply about 50 mm of water to satisfy soil moisture deficits from the current date until the end of the season. This does not mean that all of the 50 mm of water should be applied at the next irrigation. The depth of water applied and frequency of irrigation should continue according to soil moisture deficits, remembering that the deficits may be increased in cooler periods.

The calculations should be revised weekly or after significant rainfall. If the calculation shows that no further irrigation is required, irrigation can cease for the season.

Note:

(i) This will be based on your soil type. This example assumes a maximum 50% depletion of total available soil moisture is allowed for growing pasture, but this may be increased slightly, to 60-70% during low ET periods in the autumn. For example, if your soil holds 100 mm of water, normal allowable depletion would be 50 mm, but this could be extended to 60-70 mm during cooler weather.

(ii) This must be either measured using soil moisture measuring equipment, or estimated using a water balance.

(iv) To determine this figure, you must have access to data that gives the probability of rain falling up till the end of the season. You must also decide on the risk that you are prepared to take. Using average monthly rainfall, ie. the depth of rain that is expected to fall 50% of the time, is probably too risky, because at least half of the time you will not get that rainfall. Using zero rainfall is too conservative, as some rain generally always falls over several weeks. The minimum value to use is probably the lowest rainfall that has occurred during the time period you are considering.

(vi) This is similar to rainfall expected, but you can usually use the average monthly ET figures for your region because of the longer time period and lower rates. If you want to lower your risk you can increase these figures a little.

(viii) Refer to Section 3.2.1 for estimates of irrigation efficiency. Remember your irrigation efficiency could be a little higher than in mid summer because of cooler conditions, and in many areas less wind.

June 2001