

Irrigation Efficiencies

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Introduction

Irrigation has been a frequently discussed subject in New Zealand for many years. A book called Practical Irrigation was written by John McKeague and published in Ashburton in 1899, 100 years ago. Although there were some small developments in irrigation from that time, it wasn't until the 1930s that state-funded irrigation schemes progressed as we know them today. All of the early schemes were surface water irrigation schemes - border strip irrigation and wild flooding. Spray irrigation was introduced on private schemes in the 1960s and later on into some of the state-funded schemes. However, even in the early 1980s the majority of the new schemes utilised border strip irrigation.

The interesting thing about these developments is that the surface water irrigation systems were often constructed on soils that were likely to result in low water use efficiency. In fact, in some of the later schemes, provision was made for drainage to prevent water-logging of farms at the bottom of schemes. Using water efficiently did not appear to be high priority.

The situation is changing rapidly. Irrigation efficiency is one of the key issues facing irrigation farmers and water managers in New Zealand. The general population is now much more environmentally aware than in the past and sees inefficient water use as a threat to environmental sustainability. Farmers may be forced to irrigate efficiently by being allocated water on an efficient basis. To maintain access to water, there will also be more pressure on farmers to demonstrate that they are using water effectively and efficiently. On most of the irrigated dairy farms in the South Island, irrigation is a necessary part of the farming enterprise, because without irrigation, dairy farming would not be viable in these areas. Maintaining access to water, therefore, is vital.

Why improve efficiency

The key objective of dairy farmers is to be profitable. Profit depends on milk production, which depends on pasture quantity and quality, which in turn depends on irrigation. Irrigating efficiently, therefore, is a way to minimise the irrigation inputs needed to maintain optimal soil moistures, to obtain optimum pasture quantity and quality and ultimately higher profits.

Efficient irrigation has environmental benefits - less stress on water resources, lower losses of water and nutrients to groundwater and surface water resources, and better public perception

of irrigation.] Farmers must now practise environmental responsibility if irrigation is to be sustainable, because without a sustainable supply of water there is no profit. The key for farmers is to irrigate efficiently to improve both economic performance and environmental performance in a complementary way.

Definitions of irrigation efficiency

Irrigation efficiency means different things to different people. However, the three key factors that need to be considered are water use (which has both environmental and financial implications), energy use (mainly financial but also environmental), and labour and capital (largely financial and social), all of which determine the effectiveness of irrigation. The common thread is profitability, and this drives efficiency from a farmer's perspective.

There are many definitions of efficiency relating to water use, but one of the most common relating to on-farm irrigation efficiency is:

Water usefully used by a crop
Total amount of water delivered to the farm.

Given today's technology, it is possible to design an irrigation system that could achieve close to 100% water use efficiency, but it would be so expensive that it would not be financially viable. Considering water use efficiency alone does not give the full picture. For example, under-irrigation could significantly increase water use efficiency, but would result in lost production and profit.

How water use efficient are irrigation systems

Table 1: Typical irrigation system losses

Component	Irrigation System Losses	
	Range	Typical
Open channels	2 – 50%	5-20%
Leaking pipes	0 – 20%	0 - 1%
Evaporation in the air	0 – 10%	<5%
Wind blowing water off paddocks	0 – 20%	<5%
Interception	0 – 5%	<2%
Surface runoff off paddocks	0 – 20%	0 - 10%
Uneven/excessive application depths	5 – 80%	5 - 30%

There is very little published data in New Zealand on irrigation efficiency, mainly because it is not easy to measure. Mostly we use overseas data that may be related to New Zealand conditions. Table 1 presents typical losses for the components of irrigation systems.

Evaporation losses are much less than is commonly thought, even on hot days. More water is in fact lost from being blown off the irrigated area than actually evaporates. Interception losses are often counterbalanced by a reduction in evapotranspiration, so are usually ignored.

Typically, pressurised irrigation systems have water use efficiencies of 50-90% and surface water schemes 20-80%.

What are the key factors affecting irrigation efficiency?

Irrigation efficiency depends on how well an irrigation system is designed and how it is managed or operated. Design sets the platform for future operation and management. Poorly designed systems will always perform poorly.

[Recent research shows that the greatest potential for improvements in water use efficiency can be gained from better system design, typically 5-40%]. Most losses are inherently design-related, caused by excessive or uneven application of water. This is due to incorrect matching of the irrigation system to soil water holding capacities and soil infiltration rates, or systems that do not apply water evenly.

[Better irrigation management could potentially improve systems by 5-20%]. Irrigation management is about applying the right depth of water in the right place at the right time. There is abundant evidence to show that soil moisture measurement or irrigation scheduling is required to manage irrigation effectively and efficiently. However, a survey carried out for MAF Policy two years ago showed that only a small percentage of farmers are using these techniques. Many are still guessing or copying what their neighbours do.

The difficulty for most farmers is that significantly improving the design of their systems may be very expensive, so the effort may be better directed at improving irrigation management. However, low cost improvements in design should be made first.

What research has been done?

In the past, most of the research into the performance of irrigation systems was carried out by the New Zealand Agricultural Engineering Institute (now Lincoln Ventures Ltd), and by the Ministry of Agriculture through its irrigation research stations, eg. Winchmore, and the MAF engineering advisory network.

More recently, MfE, AgMardt and MAF Policy have taken an active interest in irrigation research. They recognise that even though there are many very efficient irrigation systems in New Zealand, there are also a significant number that are not.

MfE have funded research into contamination of groundwater through leaching of fertilisers and chemicals under irrigation, and are currently funding research on water allocation issues and how they relate to irrigation efficiency.

AgMardt are providing funding towards a project that will measure irrigation efficiency for a range of irrigation system types. The purpose of the project is to determine practically achievable values that farmers and water managers can use as efficiency benchmarks, and to give farmers information that they can use when choosing system types.

MAF has highlighted the need for farmers to achieve sustainable irrigation through improved efficiency and to be able to demonstrate the results of those improvements. MAF regard this as extremely important if New Zealand is to retain access to world markets. A number of projects have been completed with the aim of helping farmers achieve sustainable irrigation. These include determination of indicators of sustainable irrigation - things that farmers can measure or calculate to illustrate irrigation performance. Other projects include best management practice guidelines, testing of the principles of the guidelines, surveying irrigators to determine current irrigation management practices, and research into problems related to irrigation design.

One of the problems that research has highlighted is that many farmers do not have the incentive, time or resources to obtain and apply the best available information, whether it is basic irrigation facts or information on advanced technologies and techniques. There is a need to get the information out to the farming community in a format convenient to farmers.

For this reason, all of the recent research and current knowledge about irrigation design and management is being collated and will be presented in the form of an irrigation handbook. This handbook, which will be made widely available to farmers, will be the most comprehensive irrigation manual ever produced in New Zealand.

Dairy farm irrigation research

Two of the MAF policy projects involved the calculation of irrigation indicators and testing of irrigation best management practices on dairy farms over the last two years. One farm used spray irrigation (a centre-pivot irrigator), and the other farm used border strip irrigation.

To monitor and improve irrigation management on these farms, continuous soil moisture monitoring and flow measurement was carried out. Using this data, it was possible to calculate a number of performance indicators relating to irrigation. These included irrigation/production

performance (cubic metre of water used per kg MS), and water use efficiency (as defined previously).

Irrigation/production performance for the spray irrigated property improved significantly from 7.8 m³/kgMS in 1998 to 5.0 m³/kgMS in 1999. The improvement was due to a combination of an increase in milk production and more efficient water use.

Irrigation/production performance for the border strip irrigated property improved from 25.8 m³/kgMS in 1998 to 23.8 m³/kgMS in 1999. Again, the improvement was due to an increase in milk production, but more water in total was used in achieving that production.

Water use efficiency was calculated to be 78% for the spray irrigated farm and 43% for the border strip irrigated farm in 1998. Water use efficiency figures for 1999 have not yet been calculated, but preliminary results show that water use efficiency has probably increased on the spray irrigated farm and decreased on the border strip irrigated farm.

Irrigation operating costs (operation, maintenance and energy) were much lower on the border strip farm than the spray irrigated farm.

What causes low efficiency

Spray irrigation

With spray irrigation systems, some of the more common design reasons for low water use efficiency and low energy efficiency on dairy farms are:

- *Big variation in operating pressures.* This is usually caused by installing pipe sizes that are too big or too small, or by stretching the system out with additional pipe.
- *Water supplies or wells in the wrong place.* There has always been a tendency to put a well close to the power lines, often at the bottom of a property to save money on line installation costs. This is a significant cause of poor hydraulic performance.
- *Poor pump selection.* Pumps that are too big are probably more common than pumps that are too small. On systems with multiple pumps, incorrect pump sizing is leading to over-pumping of wells, poor hydraulic performance and wastage of energy.
- *Falling groundwater levels.* Many systems were designed on the basis of have lowered levels to the point where pumps need to be throttled. groundwater levels remaining high. However, droughts and increased water use
- *Use of pressure regulating valves to solve pressure problems.* PRVs are sometimes necessary, but they shouldn't be used as a substitute for proper design. They add friction loss to the system, which is paid for in additional electricity costs.

- *Lack of flexibility not allowing the right amount of water to be applied.* This refers to systems that apply a fixed depth of water that exceeds the water holding capacity of the soil.
- *Return intervals too long.* Although system capacity may be adequate, many systems are designed on a rotation that is too long, resulting in moisture stress and lost production.
- *Application rates that are too high.* This causes surface redistribution and big variations in application depths. Some areas get far too much, other areas too little.

The more common operational factors causing low efficiency are:

- *Application depths are unknown.* Many farmers do not know how much water their systems are applying. They rely entirely on what the equipment supplier told them.
- *Soil water holding capacities and stress points are unknown.* It is very difficult to design and to manage an irrigation system efficiently without this basic knowledge.
- *Not turning off after rainfall.* Once they start, many dairy farm irrigators continue non-stop irrigation throughout the season unless extremely heavy rain falls.
- *Not adjusting return intervals to evapotranspiration rates.* There are opportunities, particularly in the early and latter part of the season where return intervals can be lengthened by turning systems off for a few days. Many farmers do not do this.
- *No soil moisture measurement or water budgeting.* Too many farmers are still guessing about when to irrigate, particularly in the early and latter part of the season and after rainfall.
- *Poor maintenance.* Mechanical or operational failures result in downtime and inadequate watering where irrigation system capacity is limited.
- *Unreliable and inexperienced labour.* This has been a significant problem, particularly on the larger irrigated dairy farms.

Surface irrigation

One of the biggest problems with most surface irrigation schemes is that water is only available on a fixed roster, which on some soil types on some schemes, is too long. This became apparent particularly with dairy farms on light soils in Mid Canterbury over the last two years. Unfortunately, significant infrastructural changes would be required to reduce return intervals on some schemes. However, some farmers have converted to spray irrigation within the schemes and achieved very good results.

Water allocation policies that result in changes to available flow can cause farmers to irrigate when water is available regardless of whether they need to or not. Although most

surface irrigation schemes don't involve pumping, using water unnecessarily causes leaching of nutrients, and undesirable environmental effects.

Poor original construction or poor maintenance of races, sills and border strips contributes to inefficient watering. Poorly graded borders, uneven sill heights and weedy headraces are common causes.

What can farmers do to improve efficiency

Fix up the small things first

This comment refers primarily to maintenance. Fixing the leaks in hoses and pipelines, and cleaning out supply headraces to prevent overtopping should be a priority. These items are often easy to fix and result in an immediate improvement in efficiency. Other items such as making sure that correct nozzles are fitted to irrigation systems or replacing worn nozzles should also be a priority as should be keeping up with all maintenance schedules.

Improve irrigation management

In general terms, the most immediate and cost-effective way for any farmer to improve efficiency is to only irrigate when water is actually needed, and turn off if it is not. For systems with pumps, this results in immediate savings in energy use, and less opportunity for adverse effects on the environment. For gravity supplied surface systems, turning off also has immediate benefits through reduced leaching of nutrients and lower fertiliser requirements. However, water availability needs to be carefully considered before making a decision not to irrigate, particularly when on rostered systems or supplies subject to river water management plans.

The irrigation system should be managed to use both irrigation water and rainfall as effectively as possible. A crop only uses a given total amount of water in a season. Using as much rainfall as possible reduces the amount of irrigation water needed. To manage an irrigation system effectively, knowing what the system is capable of and how much moisture is in the soil is vital. Very few systems have water meters on them, so put some rain gauges under the spray irrigator to see how much is being applied. Measure soil moisture, or at the very least, use a water budget. Irrigate at night as much as possible to reduce the wind effects and evaporation.

Improve the design of the system

If all of the simple problems have been addressed, and irrigation management is as good as it can be, a close look at the system design is advised.

Look for evidence of uneven or excess application depths or high application rates on spray irrigation systems. That is where the biggest potential for improvement can be made. Again, rain gauges can be used to find out how much variation there is. If you see water running out of the gate or even forming ponds in the hollows, then design or management changes are strongly advised.

Sometimes, doing simple things like changing nozzle sizes or operating pressures to reduce application rates and improve uniformity can help. Putting less water on more often may also be a useful way of improving efficiency, but do not apply too little too often. If problems with surface redistribution cannot be solved by these means, a change in sprinkler type or perhaps a change in irrigation method may be necessary.

If problems with high or low pressures are evident, a detailed analysis carried out by a competent irrigation engineer is really the only way to find out what is wrong and to investigate options for improvements. A farm adviser may also need to be involved to assess financial benefits. Many farmers avoid making design improvements because they have the impression that the changes will not be profitable. However, don't make the mistake of assuming that the changes will be too expensive, because often the payback time is very short.

Use new or proven technology. Irrigation scheduling services or soil moisture sensors are available at reasonable cost. Variable speed drives for pumps may be an option, but must be compared with other alternatives to assess their suitability. Better ranges of sprinklers, and adjustable gun angles for windy conditions are available. Border-strips can now be regraded using laser technology.

Monitor performance

Irrigation is most effective if clear objectives with measurable performance criteria are specified. The two most important things to measure are how much water is being applied, and soil moisture levels. Without measuring both of these items, it is almost impossible to monitor irrigation performance.

The MAF research projects have shown that calculating indicators is a very effective way of monitoring performance and providing comparative information to evaluate improvements.

Further information on these methods will be included in the irrigation handbook, which is presently under development.

Summary

[Irrigation efficiency is one of the key irrigation-related issues facing dairy farmers today. Not only must farmers strive to be irrigating effectively and efficiently, they must also be able

to demonstrate that they are doing so. This is essential for irrigation to be financially and environmentally sustainable, and to maintain access to water.

Recent research carried out for MAF Policy has shown that although many farmers are irrigating efficiently, a significant number are not, and very few can demonstrate efficient use of water.

There are a number of basic rules that farmers can follow to improve efficiency. Keeping up with maintenance of the system should be high priority. Improving irrigation management by measuring soil moisture and water use, and applying irrigation scheduling techniques should also be high priority. Improving the design of the system, including the use of new technology, should be considered where design is limiting performance. Finally, monitoring on-going performance should be given priority.

Although a lack of easily available information on methods to improve efficiency has meant that many farmers do not know how to go about making improvements, a comprehensive irrigation handbook presently being developed will soon be available to farmers.

Bibliography

McKeague, J. 1899. Practical Irrigation. *Ashburton Newspaper Co Ltd.*

Workshop Summary. Irrigation Efficiencies - types, timing, soils

Some key terms

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| Saturation point - | point where any added water will actually run off the soil surface |
| Field capacity - | point where any added water will not move down the soil profile |
| Wilting point - | point at which the plant available water is so low that the plant will wilt |
| Permanent wilting point - | point at which the plant will die due to lack of water uptake |

The aim of any irrigation scheme is to keep the water balance in the soil between the soils field capacity and it's wilting point. This "zone" is known as the soils "available water holding capacity." Generally the coarser the soil the lower will be it's holding capacity. Therefore coarse soil will need irrigating more often than a fine or silt soil. However, a coarse soils will also require less water to take it from the wilting point back up to field capacity. This answers the little and often question. The coarse soil will need a small amount of water more often than a fine soil.

Farmers should know their soil type and it's water holding capacity and should measure their soil moisture. They need to understand how much water they are applying versus how much they need to apply.

Irrigation does not affect soil temperature.

Potential environmental issues exist with access to water and energy efficiencies. How many farmers can demonstrate efficient water use?

The types of irrigation and their respective efficiencies range from flood irrigation being least efficient at 45% to spray irrigation at around 75 to 85%.

Future issues to deal with/research opportunities:

- Pasture cover - it's effect on amount of water required per pass and on transpiration rate
- Dropping paddocks out in a dry spell versus applying less than optimal water over the whole area.
- Leaching of nutrients under irrigation.
- Efficient use of water, electricity, and labour
- The best way to save on all aspects is to turn the system off!