

SPRAY IRRIGATION: IS YOUR SYSTEM UP TO SCRATCH?

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Introduction

Throughout eastern areas of both the North and South Island water available for irrigation is becoming limited. Intensive pasture operations such as irrigated dairy farms require a reliable and sustainable source of irrigation water to maximise dry matter production. Pasture irrigation will be either 'flood' irrigation (border dyke) or spray irrigation. The majority of flood irrigation systems receive their water from an irrigation scheme and the delivery is by roster. The spray irrigation systems are supplied on demand from irrigation schemes or groundwater. Because access to water for irrigation is becoming limited, better use of the water is essential. There are two ways farmers who use irrigation can make better and increased use of existing irrigation water – improve system uniformity and improve application efficiency. Small changes in either or both are often not expensive but the savings and cost-benefit are usually significant.

Water availability

There is little doubt that the availability of water for irrigation from rivers and groundwater is close to the limit. Figure 1 illustrates the current position of water availability from the three sources used to supply water for irrigation.

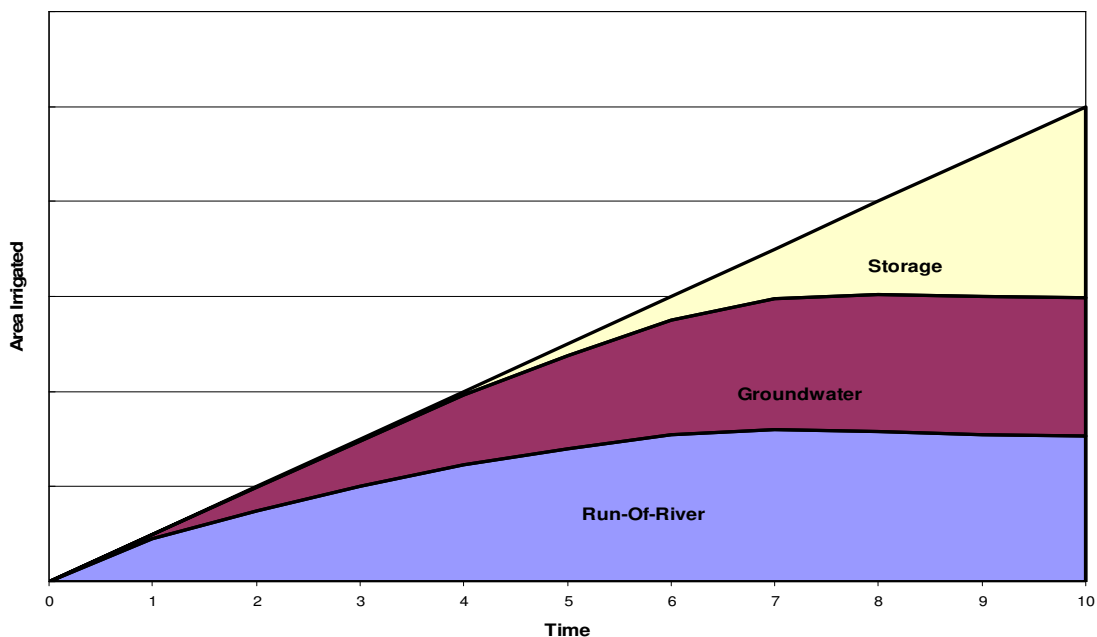


Figure 1: Current availability of water sources for irrigation (from J Bright, Aqualinc)

Clearly there is little if any water available from Run-of-River sources. There is also little argument that access to groundwater is also reaching its limit. The future source(s) of irrigation water is storage. However storage cannot be developed and accessed immediately. It will take several years to gain resource consent, design and construct storage schemes (and the associated delivery system). Therefore the water currently consented for irrigation use is about all there is to be had. Irrigation auditing has shown there is the potential to make better use of this water to extend the land area that can be irrigated and increase production with the same volume of water, especially spray irrigation systems.

Spray irrigation systems

The spray irrigation systems can be divided into three broad categories:

Travelling irrigators such as rotating boom, static boom, hard and soft hose guns, and linear irrigators. These irrigators have a drag hose or “wind” in a hard hose

Center pivot irrigators

Towable or moveable systems such as long lateral and forms of tow-line.

Each system has its place for spray irrigation whether by preference, physical features and shape of the farm, or price constraints.

There are inherent features and management practices that influence the effectiveness and efficiency of each system. There are misconceptions of spray irrigation that are for the most part misguided. Table 1 shows the common losses (inefficiencies) from spray irrigation.

Table 1: Loss type, range and typical values for spray irrigation systems

Loss Component	Range	Typical
Leaking pipes	0-10%	0-1%
Evaporation in the air	0-10%	<3%
Wind blowing water off target (drift)	0-20%	<5%
Interception (canopy losses)	0-10%	<5%
Surface runoff (spray irrigation)	0-10%	<2%
Uneven/excessive application depths and rates	5-80%	5-30%

Clearly the greatest loss and therefore inefficiency in spray irrigation is the last factor – Uneven or excessive application depths and rates. The uneven application is mostly an inherent feature of the system, i.e. uniformity of application or how even the depth of water is applied across the wetted footprint. Excessive application rate is also an inherent feature of the irrigator type or the design of the irrigation system. Excessive application depth is a management issue that affects application efficiency (how much of the applied water is retained in the plant root zone) and is a matter of operator choice. There is a realistic expectation and achievable efficiency for each of the systems.

Table 2: Attainable application efficiencies of spray irrigation systems

Irrigation Type	Efficiency Range
Solid Set	67-85%
Side Roll	65-85%
Gun	58-75%
Center Pivot	77-90%
Linear Move	77-90%
Rotating Boom	65-80%
Static Boom	55-85%

(From AJ Clemens and NZAEI 1985)

The expected application efficiency is a combination of the **system uniformity** and the **management practices**. A system with poor uniformity can never work efficiently and even a system with high uniformity can be managed badly to have poor application efficiency. Improvements in either uniformity or application efficiency or both will result in more water to irrigate more area and/or savings in pumping costs.

Irrigation system uniformity

Irrigation Application Uniformity is a critical factor in determining the potential efficiency of any irrigation system. It is commonly measured by a coefficient such as the Distribution Uniformity Coefficient (DU_{iq}). This is a measure of how evenly water is applied by an irrigation system but it is not itself an efficiency measurement. In a perfect system the $DU_{iq} = 1.0$ and each plant would receive exactly the same amount of water. Unfortunately irrigation is not and will never be perfect, so the distribution uniformity is never equal to 1. The additional cost to install and run a perfect system would be more than any benefits gained, so a lesser uniformity is generally accepted.

The uniformity that can be achieved will vary with different types of irrigation. Good systems will have DU_{iq} of 0.80 to 0.85. Many though are less than 0.65 – 0.75. It is possible for DU_{iq} to be higher than 0.90 particularly with drip-micro irrigation, lateral move and centre pivot irrigators. If a system has low uniformity there will be areas that will be considerably over-watered while others do not receive enough. Both under and over watered areas will lose yield and have reduced crop quality. In the over-watered areas water will be wasted and valuable nutrients may be leached. Uniformity should be considered when the application depth is calculated (if it is calculated). If the average application depth just meets pasture needs, half the plants are over watered, and half are under-watered. A reasonable balance is to adjust the application depth so the average needs of the lowest quarter are met. The better the uniformity, the less wastage there will be reaching the target depth across the crop. As part of a Sustainable Farming Fund project On-Farm Irrigation Evaluation a number of irrigation systems have been audited. Results from two audits in Figures 2 and 3 illustrate the importance of high uniformity.

Center Pivot Collector Distribution

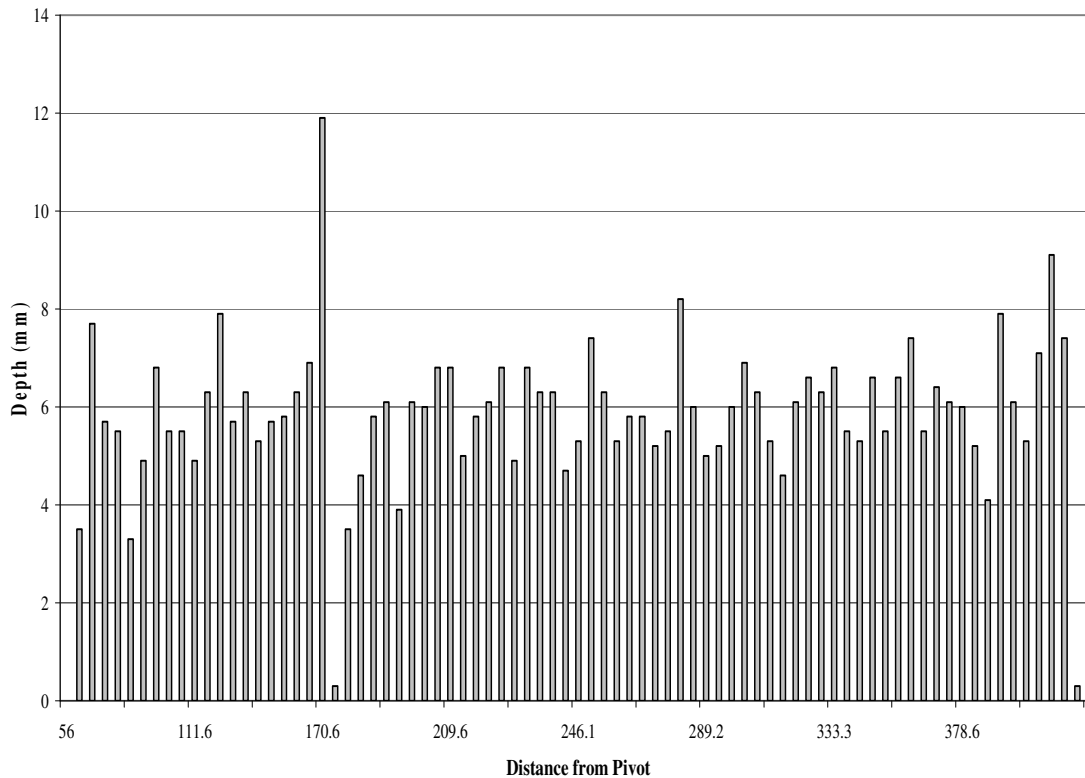


Figure 2: Distribution of application depth from a center pivot with a measured $DU_{lq} = 0.86$.

Most of the high and low values measured in this audit can be eliminated by regular “maintenance”, for example, ensuring drop pipes are not tangled in the irrigator structure and the sand trap is regularly cleaned. Eliminating these faults would have improved the DU_{lq} to 0.9 or better. The implication for this center pivot with a target application of 30mm with a measured $DU_{lq} = 0.86$ is:

- Target application = 30mm
- Low quarter mean = 25.8mm
- Overall mean = 30mm
- $DU_{lq} = 25.8/30 = 0.86$

This means that if the aim is to water 7/8 of the paddock with 30mm:
 Would need to apply $30\text{mm}/0.86 = 34.9\text{mm}$
 The total application depth needed = 34.9mm
 And the wastage (34.9-30mm) = 4.9 mm (sufficient water for one day irrigation)

Volume Caught Accounting for Overlap

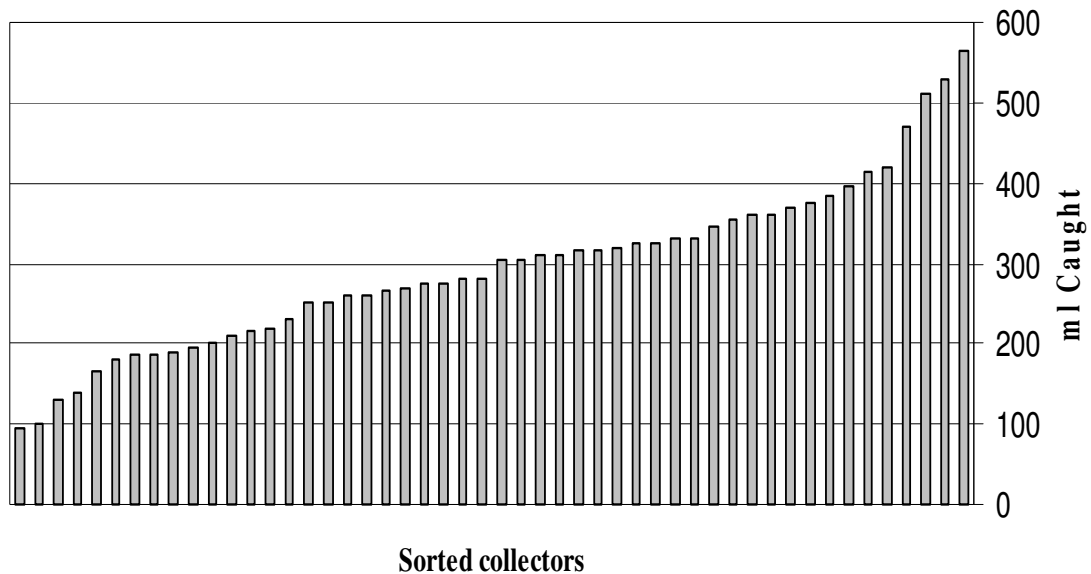


Figure 3: Distribution of application volume from a tow line with a measured $DU_{1q} = 0.44$.

The data presented have been sorted low to high. The spatial distribution was very scattered (reflected by the low DU_{1q}) so that there was an almost random scatter of high and low catches. The implication for this tow line system with a target application of 30mm with a measured $DU_{1q} = 0.44$ is:

Target application = 30mm
 Low quarter mean = 13mm
 Overall mean = 30mm
 $DU_{1q} = 13/30 = 0.44$

This means that if the aim is to water 7/8 of the paddock with 30mm:
 Would need to apply $30\text{mm}/0.44 = 68\text{mm}$
 The total application depth needed = 68mm
 And the wastage (68-30mm) = 38 mm, sufficient water to carry out another 1.3 irrigations.

The value of higher uniformity is demonstrated in Table 3. The results illustrated in Figures 2 and 3 are compared assuming the water was pumped from the same deep bore in the Te Pirita area of Canterbury. The daily operating cost for the bore and center pivot is \$750.00 or \$31.25/hour.

Table 3: Comparison of the cost of applying wasted water as a result of DU_{iq} differences

System	DU_{iq}	Extra water/irrigation	Hours to apply extra water	Cost of Extra Water
Center pivot	0.86	7.5mm	1.72	\$53.71
Optimum	0.9	3.3	0.76	\$23.62
Additional Cost c.f. what could be achieved				\$30.09
Tow Line	0.44	38mm	12.7 ¹	\$396.83
Optimum	0.85	5.3	1.77 ¹	\$55.15
Additional Cost c.f. what could be achieved				\$341.68

¹ Assuming an application rate of 3mm/hour.

Initially Table 3 suggests there is little in the way of hours and dollars to be saved by improving the uniformity. However considered the savings are over an irrigation season when there may be say 2000 hours of irrigation. This number of hours would be equivalent to $15 \times 30\text{mm}$ irrigations resulting in a cost The results presented for the tow line system are disappointing. There are significant improvements and savings to be made

Irrigation system application efficiency

Application Efficiency compares how much of the applied irrigation water is retained in the pasture root zone and is used for crop growth. For most systems the best option may not to be 100% efficient—if your application efficiency is 100%, you are most probably under-watering and those areas that receive the least water will be subjected to drought stress. The exception is center pivot irrigation. In this case the soil profile is not (or should not be) refilled to field capacity, so except for the non uniformity component, application uniformity should approach 100%. Because distribution uniformity must also be considered, application efficiency is almost always likely to be less than 100%. While it is (theoretically) possible to achieve 100% application efficiency from an irrigation system with poor DU_{iq} , there will be significant areas with drought induced yield loss. On the other hand, even a system with high DU_{iq} will have poor application efficiency if it is not managed well. If the application depth is not matched to the soil moisture deficit, then application efficiency will always be less than 100%. This can be simply demonstrated by comparing common application depths with readily available water. In Table 4 the implication of different application efficiencies are compared for a shallow low water holding soil which is extensively developed for dairying in Canterbury. The same pumping cost used for the uniformity comparison in Table 3 is used.

Table 4: Comparison of the cost of applying wasted water as a result of application efficiency < 80%

Irrigator	Delivered	Measured	Effective	Excess	Extra	Extra Cost
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	Irrigation	Efficiency	Irrigation	Water	Hours	
Center Pivot	510 mm	85%	435 mm	-34 mm	-20.9	Saved \$652
Center Pivot	528 mm	77%	407 mm	19 mm	83	\$2591
Center Pivot	536 mm	73%	391 mm	47 mm	205	\$6409
Center Pivot	875 mm	65%	569 mm	164 mm	716	\$22364
Rotary Boom	381 mm	81%	309 mm	-5 mm	-3.1	Saved \$96
Rotary Boom	375 mm	80%	300 mm	0 mm	0	\$0
Rotary Boom	580 mm	72%	418 mm	58 mm	36	\$1112
Rotary Boom	335 mm	63%	211 mm	71 mm	44	\$1361
Rotary Boom	770 mm	47%	362 mm	318 mm	195	\$6095
Rotary Boom	720 mm	42%	302 mm	343 mm	210	\$6574

Excess Water = Delivered Irrigation – (Effective Irrigation ÷ 80 Application Efficiency)

Extra Hours (Center Pivot) = mm ÷ 5.5 mm/day × 24 hours/day irrigating

Extra Hours (Rotary Boom) = mm ÷ 37.5mm/run × 23 hours/run

Where 37.5mm/run = 30mm Readily Available Water in the root zone ÷ 80% Application Efficiency

Extra Cost = extra hours × \$31.25/ghour

The examples presented in Table 4 reflect the standard of irrigation management. Some operators saved money based on an acceptable application efficiency of 80%. Other examples demonstrate that gut feeling management has and probably still is costing the farm dollars for wasted water. Even a small drop below 80% application efficiency costs to say 77% is cost to the farm. The examples clearly show even the best systems, when poorly managed can result in significant losses, both of water and dollars. There is no excuse for a center pivot system to be managed as poorly as some of the examples presented. The examples also show that “lesser” systems can be very well managed to attain high Application Efficiency.

Conclusion

As access to water for irrigation becomes more and more restricted, then better use must be made of existing water for irrigation. Improvements in irrigation system uniformity and application efficiency will release existing water so that more area could be irrigated, water could be saved, energy could be saved and money could be saved.

Fact: If uniformity can be raised from 0.70 to 0.90, half as much area again can adequately irrigated with a given volume of water. Alternatively, a poor system can never work efficiently.

Fact: If Application Efficiency can be raised from 70% to 80% significant amounts of water, energy and money can be saved.

