EXECUTIVE SUMMARY

Outcomes from four modelling studies exploring different irrigation strategies at six sites across New Zealand

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Research highlights

- Managing uniform irrigation to a single soil type can result in either a yield penalty or increased drainage.
- Triggering irrigation at a greater proportion of soil water storage is better suited to shallower rooting, high value crops.
- Refilling to a greater proportion of soil water storage results in no difference in yield and increases the potential for higher drainage.
- Variable rate irrigation (VRI) started at the beginning of the growing season produced similar outcomes and reduced irrigation requirement when compared with uniform irrigation management.
- Outcomes where uniform irrigation was followed by VRI from the middle of the growing season were dependent on site soil variability.

Background

Tools and recommendations that enable agricultural irrigation practices to improve water use efficiency (WUE), reduce run-off, drainage, and subsequent nutrient losses, are seen as key components of achieving fresh-water policy goals. Improvements in the sophistication of control of irrigation application systems such as lateral and centre-pivot irrigators provide the opportunity to manage irrigation at a finer spatial and temporal scale.

A modelling framework was developed and shown to be a useful tool for the estimation of a range of biophysical and economic system outcomes across multiple growing seasons in response to different irrigation management approaches in spatiotemporally complex systems. The framework was applied to four modelling studies across six sites in Canterbury and the Hawke's Bay with both maize and potato, which represent a deep-rooted crop of lower value and shallower-rooted crop of higher value, respectively. Scenarios were run for 35 different growing seasons, from the 1980/1981 to 2015/2016 season, to capture the effect that inter-annual variability in weather had on irrigation strategies and outcomes. Modelling studies addressed four aspects of deficit irrigation management. In this context, deficit irrigation is an irrigation scheduling practice that keeps the soil water above a trigger point, typically one that does not allow a crop to get into stress, but does not fully recharge the soil to field capacity.

They were identified by the Maximising the Value of Irrigation Industry Advisory Group at their biannual meeting on 28 August 2018. These were:

- soil type used to inform deficit uniform irrigation
- trigger deficit used in deficit uniform irrigation
- refill point used in deficit uniform irrigation
- variable rate irrigation strategies.

Soil type

Where variability in soil properties associated with the storage and movement of water exist under a single irrigator, managing uniform deficit irrigation to the soil type that stores the greatest amount of plant available water (PAW) results in lower irrigation being applied, leading to greater crop stress compared with managing irrigation to a weighted mean of all soil types present. In maize, this does not result in a substantial yield penalty and can increase gross margins. However, in potato, the yield penalty reduces gross margins. This irrigation strategy can also reduce drainage and increase WUE. Analysis of seasonal and site characteristics indicate that the magnitude of the effect of irrigating to the soil type that stores the greatest amount of PAW, relative to a weighted mean strategy, is largely driven by characteristics associated with within-season rainfall, variability in PAW storage and irrigation system capacity.

Conversely, managing uniform deficit irrigation to the soil type that stores the least amount of PAW, results in greater irrigation being applied, which in turn can lead to lower crop stress, compared with managing to a weighted mean of all soil types present. In maize, this does not result in a substantial yield benefit and can decrease gross margins. However, in potato, the modest yield benefit can increase gross margins. There is, however, a trade-off with this strategy as there is an associated increase in drainage and decrease in WUE. Analysis of seasonal and site characteristics indicate that the magnitude of the effect of irrigating to the soil type that stores the least amount of PAW, relative to a weighted mean strategy, is largely driven by characteristics associated with within-season absolute or average rainfall.

Therefore, across sites, managing irrigation to the soil type that stores the greatest amount of water is better suited to deeper rooting crops of lower value such as maize, as any small yield penalty in areas with lower soil water storage were outweighed by water saved across the whole site. This is especially the case in drier growing seasons or in irrigation systems with low capacity. In contrast, in most cases, a uniform irrigation strategy that manages to a weighted mean of the PAW in soil types present is better suited to higher value, shallower rooting crops such as potato, as productivity is increased without the associated trade-off of increased drainage losses seen with uniform irrigation managed to the soil that stores the least. The exception to this may be in growing seasons with low rainfall, whereby this strategy can have significant benefits to yield.

Trigger deficit

Managing uniform irrigation with a trigger deficit of 60% of PAW storage, compared with a 50% PAW storage trigger deficit, results in greater irrigation being applied, which in turn can lead to lower crop stress. In maize, this does not result in a substantial yield benefit and can decrease gross margins. However, in potato, yield benefit can increase gross margins. There is, however, a trade-off with this strategy as there is an associated modest increase in drainage and decrease in WUE. Analysis of seasonal and site characteristics indicate that the magnitude of the effect of irrigating with a 60% PAW trigger deficit, compared with a 50% PAW trigger deficit, is largely driven by characteristics associated with within-season rainfall, and in potato, on-site PAW storage.

Therefore, across sites, if deficit irrigation is managed uniformly, managing to a 50% PAW trigger deficit is best suited to deeper rooting crops of lower value such as maize. In contrast, a uniform deficit irrigation strategy that manages to a 60% trigger deficit, and provides a margin above the 50% stress point at times of high water demand, is better suited to higher value shallower rooting crops such as potato and can result in benefits to yield and gross margins, especially in growing seasons with low rainfall or at sites with greater water storage. The exception to this is in growing seasons with high rainfall, as this strategy can result in increases in drainage.

Refill point

Managing uniform irrigation by wetting back up to a refill point of 90% of PAW storage, compared with a 70% PAW refill point, results in greater irrigation being applied and has little effect on crop water stress. In both crops there is little to no yield difference and in maize this practice can decrease gross margins, while in potato there is marginal difference. There is also an associated increase in drainage and decrease in WUE. Analysis of seasonal and site characteristics indicate that the magnitude of the effect of irrigating with a 90% PAW refill point, compared with a 70% PAW refill point, is largely driven by characteristics associated with variability in PAW storage.

Therefore, across sites, if deficit irrigation is managed uniformly, managing to a greater refill point results in no difference in yield and increases the potential for higher drainage and lower WUE. A lower refill point also requires more frequent and smaller applications of water, and leaves greater storage available to store water during rainfall events. This is especially the case in sites with high variability in PAW storage.

Variable rate irrigation strategies

Managing deficit irrigation using VRI started at the beginning of the growing season, compared with uniform irrigation, results in less irrigation being applied, and on some sites this can lead to a modest increase in crop stress, while on others a reduction. Neither result in any difference in yield, which leads to increases in gross margins in maize and no difference in gross margins in potato. There is also an associated decrease in drainage and increase in WUE. Analysis of seasonal and site characteristics indicate that the magnitude of the effect on crop stress of VRI started at the beginning of the growing season, compared with uniform irrigation, is largely driven by characteristics associated with within-season rainfall. Variability in PAW storage onsite determines the magnitude of effect on irrigation applied, WUE and drainage.

Managing deficit irrigation uniformly at the start of the growing season, then switching to VRI from the middle of the growing season is akin to ‘mining’ the stored soil PAW in those soil types with greater storage when demand for water is greatest rather than earlier in the season when demand is lower. Compared with uniform irrigation, on some sites this practice results in increases in irrigation being applied, while on others a reduction in irrigation. This in turn has a mixed effect on crop stress. Across sites, there is no difference in yield in maize and an increase in yield in potato, which leads to increases in gross margins. Outcomes relating to WUE and drainage are also mixed across sites. Analysis of seasonal and site characteristics indicate that the magnitude of the effect of VRI started in the middle of the growing season, compared with uniform irrigation, on crop stress and yield is largely driven by characteristics associated with within-season rainfall, while the variability in PAW storage onsite determines whether this strategy has a positive or negative outcomes in terms of irrigation applied, WUE and drainage.

Therefore, from this study, where variability in soil properties associated with soil water storage and movement exist under a single irrigator, VRI started at the beginning of the growing season produced similar outcomes and reduced irrigation requirement when compared with uniform irrigation management across all sites. Outcomes from management where VRI was started in the middle of the growing season, compared with uniform management, were dependent on site characteristics. While, like other irrigation strategies, the proportional difference in crop stress and yield are greater in growing seasons with low rainfall, sites with greater variability in PAW storage may save a greater amount of irrigation, have higher WUE and reduce drainage by a greater amount through the adoption of VRI strategies.

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