Variable Rate Irrigation

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Take Home Messages

- **Soil mapping techniques can be used to better estimate and map the soil water holding capacity under a centre pivot irrigator. This information can then be used to more accurately prescribe irrigation under a precision (spatially variable) management system.**
- **Significant savings in water of 20 to 25% have been predicted from test sites, these are based on the assumption that irrigation would normally be based on the driest zone within the paddock.**
- **It is possible to control an irrigator to deliver in a spatially variable pattern but much more sophisticated planning and operational software is required to control it.**
- **Initial estimates of cost effectiveness have been based on rather simplistic estimates of water saving. Further work is required to calculate optimum operating strategies according to environmental and financial constraints.**
- **Using variable rate irrigation allows complete freedom of what is grown under the irrigator allowing much greater flexibility within the farming system.**

Background

Variable rate irrigation is introduced as a possible method of improving irrigation water use efficiency, where the specific demands of a crop can be met at any point under the irrigator. Centre pivot irrigators are now the most popular system type being installed on New Zealand farms, a trend similar to the rest of the world. It is a method that has the advantage of very low labour demand and a high level of automation. One of the main problems is that it is a relatively inflexible system which has a major impact on the farming system under it.

Traditionally, irrigation uniformity has been a desirable goal, as farmers could have some assurance regarding the level of irrigation water applied at any point under the irrigator. While having reliable application is clearly important the concept of uniform application is challenged. Having total control of the irrigator and its application performance at any point under it will allow farmers and growers to optimise land use. In New Zealand for example where soil variation does not necessary follow sectors of an irrigator it may be possible to opportunistically grow high value crops under parts of the irrigator where soils allow. Dairy farmers want to exclude farm infrastructure such as races and yards as well irrigate according to soil water holding capacity.

While these farm management goals are desirable the main focus of this paper is to illustrate practical methods that can used to improve water use efficiency. This can be achieved through using rigorous soil mapping techniques to map the calculation of soil water availability. This is used to calculate soil moisture status and schedule irrigation to specific points under the irrigator on a daily basis. Improved water use efficiency is seen as a key issue that needs to be faced by the agricultural industry the world over. Irrigation consumes around 70% of allocated freshwaters globally (Jury & Vaux, 2007) and in New Zealand the figure is 80%.

The starting point to mapping daily soil water status is to use apparent soil electrical conductivity (EC). In New Zealand where salinity is not an issue EC mapping is seen as a surrogate measurement for soil texture. The EC map is used as the basis for further investigations of the soil in order to thoroughly characterise the soils within the site. A site from the property of Mr Hew Dalrymple, near Bulls Manawatu is used as an example to show how the water use efficiency could be improved.

A soil EC map was developed from a survey using a high resolution on-the-go RTK-DGPS linked to a Geonics EM38. For the purposes of this example the topographic information and soil water movements were not used as a dynamic element in the calculation of irrigation water requirement. It did however have a major influence of the soil formation processes on the site which is reflected in the EM map.

Three soil zones, as described by Hedley (2008), were selected on the basis of soil EC within the site. The selected zones were used to collect further samples for laboratory analysis of moisture release characteristics and particle size distribution. Three replicate sites were selected in each zone and soils were sampled at four depths (0-150, 150-300, 300-450, 450-600 mm) to obtain one mean value for each zone.

The relationship between available water holding capacity (AWC) and soil EC (Figure1) was used to derive an AWC map (Figure 2), Hedley et al (2008). Zone C had the highest percent sand (94.5%) and the lowest soil EC compared to the other two soil zones (87.3%, 88.3%). Also soil EC increased with plant available water storage capacity (Figure 2).

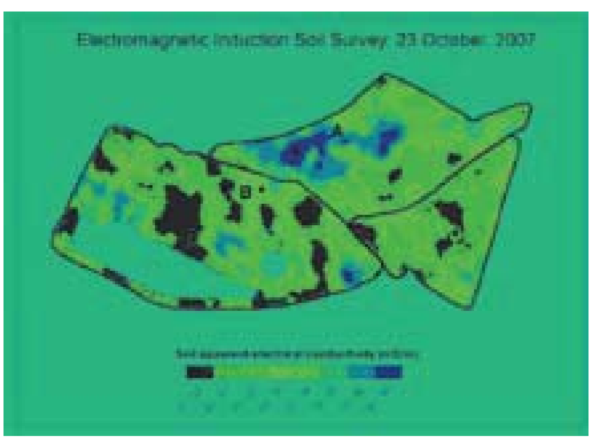

Figure 1 *Map of Soil EC*

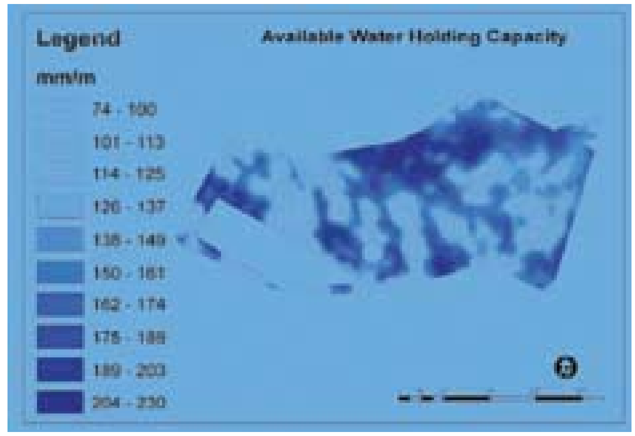

Figure 2 *Available Water Holding Capacity*

A site specific daily water balance was used to predict the drying rate of these soils, so that each soil AWC point value was adjusted on a daily basis from a starting point when the soils were at field capacity (17 November 2007). The trigger for irrigation was set for 55% of AWC, so that the calculated date for irrigation commencement was 28 December (Zone C), 15 January (Zone B) and 16 January (Zone A). The soil water status map derived for 4 January 2008 (Figure 3) identifies that Zone C requires irrigation (marked black). This information can be uploaded as a shapefile to a variable rate irrigator, to programme operation of individual sprinklers on a daily basis.

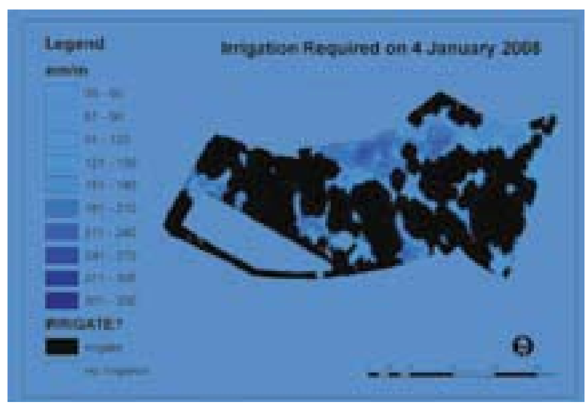

Figure 3 *Map showing areas requiring irrigation on Jan 4th.*

Conclusions

The ability to irrigate soils on a basis of individual AWC introduces efficiencies of water use, including better use of stored water and less use of water overall; as well as maintaining optimum yield because each soil is irrigated to its irrigation trigger point and readily available water is maintained to the plant root zone. An analysis was completed for the growing seasons 04-05, 05-06, 06-07, as

Table 1. *Water savings on field site.*

Site	Area ha	AWC mm/m	Year	Irrigation mm	Total irrigation / season ML	VRI Water Saving		
						ML	%	mm/ha
Uniform Rate Irrigation								
Maize field	22	85	04-05 05-06 06-07	380 430 230	84 95 51			
Variable Rate Irrigation								
Zone A Zone B Zone C	3.5 11.9 6.6	329 214 85	04-05	210 270 380	7 32 = 65 25	19	23	87
Zone A Zone B Zone C	" " "	" " "	05-06	260 320 430	9 38 = 76 28	19	20	87
Zone A Zone B Zone C	" " "	" " "	06-07	100 160 230	3 19 = 38 15	13	25	59

detailed in Table1, a 20 to 25% water saving could have been achieved, for this 22 ha site, other sites on the farm have offered similar savings. The impact of variable rate irrigation on water saving will clearly be site specific and it important that adequate soil mapping work is completed before investment decisions are made. There will also be differences between seasons, temporal variation, depending on weather conditions.

The Foundation for Arable Research FAR (2008) estimate irrigator operating costs as being NZ$1.30 per mm ha-1 , this site would produce a saving in operating costs of between $77 - $113 per ha. Where water charges are in place then clearly there would be a much larger saving. This is based on the rather simplistic assumption that the farmer would irrigate according to the driest zone. This may not be the case, further information such as previous yield maps, could be used to calculate the potential financial return. This is seen as a rather subjective assessment at this stage and further work is required in the optimisation of irrigation at each point under the irrigator, where all environmental and economic factors can be taken into account. In order to achieve Variable Rate Irrigation (VRI) control systems have to be added and more sophisticated software within the overall framework of a GIS system is required. The estimated additional costs is approximately NZ$100 per linear (November 2008) meter of the irrigator.

References

Hedley CB, Yule I, Tuohy M and A Collins (2008) Spatial and temporal prediction of soil water status for variable rate irrigation of sand country cropping land. *In Conference Proceedings* Soils 2008 "Soil - The Living Skin of Planet Earth" Joint Conference of the Australian and New Zealand Societies of Soil Science in conjunction with the International Year of Planet Earth, 1-5 December 2008, Massey University, Palmerston North, New Zealand. 327pp.

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