FARM SCALE TRIALS OF VARIABLE RATE IRRIGATION TO ASSESS THE BENEFITS OF MODIFYING EXISTING SPRINKLER SYSTEMS FOR PRECISION APPLICATION

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Abstract

Farm-scale trials are being conducted to assess the benefits of variable rate irrigation (VRI). Three farms have been selected where existing sprinkler irrigation systems have recently been modified to provide variable rate control of each individual sprinkler. Irrigation is being varied according to soil and crop differences, and is also being shut off over exclusion zones, such as drains and raceways, and for farm operations such as pasture renovation.

Under each VRI irrigator, soil variability has been quantitatively assessed using a mobile soil mapping system, which consists of an electromagnetic (EM) sensor pulled behind an all-terrain vehicle, with an on-board accurate RTK-GPS, datalogger and field computer. The EM sensor measures soil apparent electrical conductivity (EC), and the resulting soil EC maps were ground-truthed and used to define irrigation management zones. Soil moisture sensors have been installed into each zone to monitor real-time soil moisture status. This information is then used for variable rate irrigation scheduling.

Trial plots have been established in each zone at each site to compare a blanket uniform rate of irrigation to all zones with variable rates of irrigation fine-tuned to zone differences.

A goal of this research is to assess irrigation water use efficiency of a VRI system, as well as to develop a precision irrigation system with capability for full automation.

Keywords: variable rate, precision irrigation, soil water

Introduction

Irrigation plays an important role in agricultural productivity and is a major contributor to the New Zealand economy. In 2002/03, irrigation was estimated to contribute around $920 million net GDP "at the farm gate", over and above that which would have been produced from the same land without irrigation. Since then, the area of irrigated agriculture and horticulture has increased by about 25 percent, from 480 000 hectares to around 600 000 hectares. A further 1.9 million hectares of land is capable of being irrigated (New Zealand MAF, 2010). The New Zealand Land and Water Forum have recently developed a strategy for effective national water management, which includes acknowledgement of the need to improve water use efficiency of existing systems (New Zealand Land and Water Forum, 2010).

The modification of existing sprinkler systems for variable rate irrigation (VRI) (Hedley et al., 2010a, 2010b) provides opportunity for improved irrigation water use efficiency; and commercial uptake of VRI in New Zealand over the last two years has enabled research to be conducted to assess environmental and cost benefits of variable rate irrigation.

A soil moisture map is used to vary irrigation according to soil differences. Soils under the irrigator are mapped with an EM (electromagnetic) sensor, which measures apparent soil electrical conductivity (EC), and quantifies soil variability on a basis of texture and moisture differences (Sudduth et al 2005). The EM map is then used to target soil sampling positions for assessing soil available moisture holding capacity (AWC) and a zone map is produced based on soil AWC differences. Our research is using wireless soil moisture sensor networks which radio soil moisture data to a website where it can be accessed by farm staff and researchers. Customised software is then used to produce irrigation plan maps which are uploaded to an automated VRI system.

This paper presents results to date from three farms where existing lateral and centre pivot sprinkler irrigation systems have been modified for variable rate irrigation.

Methods

Site selection

Farm 1: Ashburton: 111 ha linear move sprinkler with VRI modification. Soils range from deep Wakanui silt loams at one end of the irrigator to Rakaia very stony sandy loams at the other end. The land use is mixed cropping, and this season beans, wheat, pakchoi, and either buckwheat or corn salad crops have been irrigated simultaneously under this system.

Farm 2: Fairlie: 170 ha centre pivot with VRI modification. Soils range from very stony Eyre soils to deep clayey Ayreburn soils. The land use is dairy farming.

Farm 3: Manawatu: 75 ha centre pivot with VRI modification. Soils are sandy and are variably influenced by a high and fluctuating water table, so that some areas of the field remain wet in Spring, whereas other zones dry out very rapidly and require frequent irrigation. The most droughty zones are prone to hydrophobicity problems (i.e. once dry they do not wet up easily).

Variable rate modification of the sprinkler irrigation systems

The irrigators have been modified to provide individual sprinkler control using wireless nodes installed on the boom, each node controlling four sprinklers individually (Bradbury, 2010). The sprinklers have been modified with a solenoid valve which pulses the sprinkler on and off. The nodes act as wireless repeaters along the length of the boom, with a GPS node at the far end, and a central controller at the other end. Digital irrigation plan maps are uploaded into the central controller which controls the action of each sprinkler so that irrigation can be varied by time and place, with a resolution of less than 10 metres (Bradbury, 2010).

EM mapping and identification of irrigation management zones

A Geonics electromagnetic EM38 sensor was used with on-board datalogger, RTK-DGPS and Trimble field computer on an all-terrain vehicle (ATV), for simultaneous collection of positional and topographically located apparent electrical conductivity EC (mS/m) data. The method is termed “on-the-go EM mapping” (Adamchuk et al 2004). The map was then used to select at least nine soil sampling positions to investigate the full range of soil EC values. At each position, intact soil cores were collected from three soil depths (0-0.2 m, 0.2-0.4 m and 0.4-0.6 m) to assess available water holding capacity (AWC), (Hedley and Yule, 2008). The sampling depth was selected to reflect the majority of the root zone from which water is extracted by plants. The results were used to define irrigation management zones, based on soil AWC differences. Soil moisture is being monitored in each zone.

Irrigation scheduling

Trial plots have been established under each VRI system to assess the benefits of variable rate irrigation scheduling. We are comparing uniform rate irrigation (URI) scheduling with VRI scheduling. URI schedules a uniform irrigation event to all zones when the most droughty soil zone required irrigation. In contrast, VRI schedules different amounts of irrigation to different irrigation management zones, based on soil water status and crop requirement. Irrigation schedules and yield are being monitored in the trial plot areas this season.

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Results and Discussion

Table 1: Soil characteristics under the three VRI irrigators

Site	Size (ha)	Soil description	Soil electrical conductivity (mS/m)	Available Water-holding Capacity (mm/root zone)
Farm 1 – Ashburton mixed cropping (on Alluvial terrace soils)				
Zone 1	23	Well drained, very stony sandy loam	1-13	67 mm/m
Zone 2	50	Well drained, stony sandy loam	13-53	85 mm/m
Zone 3	22	Mixed sandy loam/ silt loam	53-79	115 mm/m
Zone 4	17	Imperfectly drained silt loam	79-132	163 mm/m
Farm 2 – Fairlie dairy pasture (on Alluvial Fans and Terraces)				
Zone 1	33	Well drained, very stony, shallow	4-13	39 mm/60cm
Zone 2	82	Well drained, stony, shallow	13-28	103 mm/60cm
Zone 3	39	Poorly drained, deep clayey soil	16-28	118 mm/60cm
Zone 4	20	Impeded drainage, peaty topsoil, stony, shallow	24-55	66 mm/60cm
Farm 3 – Manawatu maize (on Sand Plain soils)				
Zone 1	29	Excessively drained, sand	2-5	73 mm/m
Zone 2	36	Well drained, sand	5-8	87 mm/m
Zone 3	6	Imperfectly drained, loamy sand	8-11	160 mm/m

EM values reflect major soil differences at all three farms (Table 1). Therefore the EM maps were used to define different irrigation management zones (e.g. Figure 1). Soil available water-holding capacity (AWC) for each zone was measured, and we found two to three-fold differences in soil AWC between zones at each site (Table 1). This has implications for irrigation scheduling because it suggests that some zones will dry out faster than others and require irrigation earlier.

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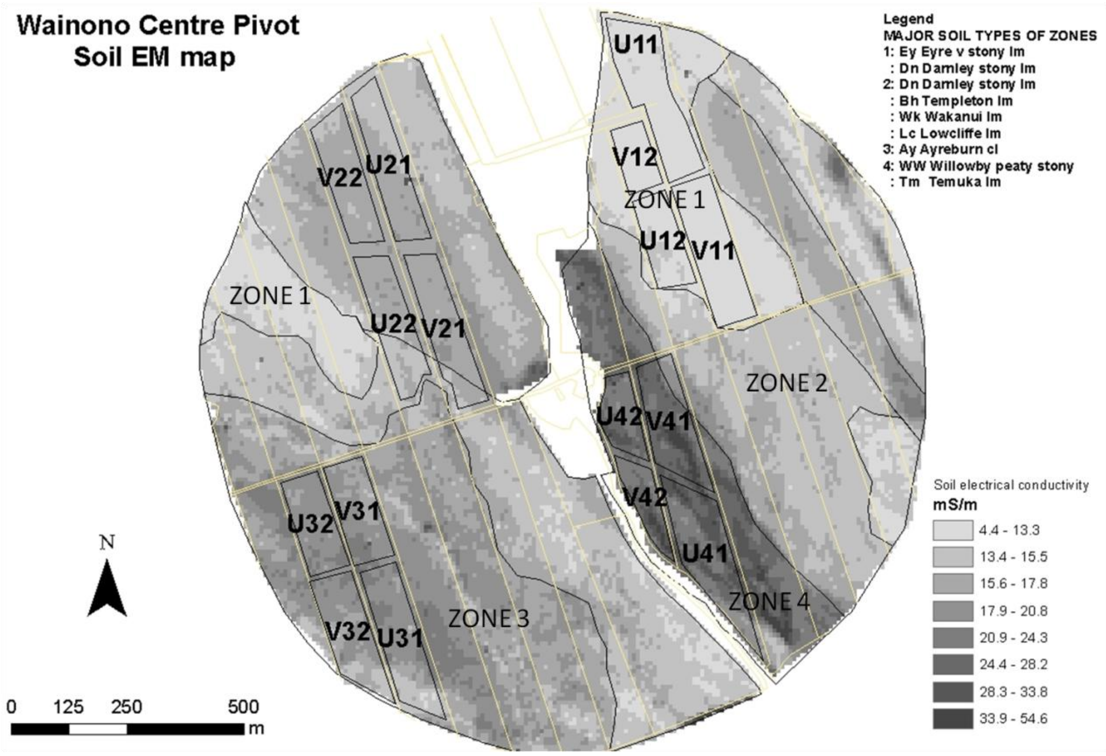
Figure 1: Figure to show trial plots and irrigation management zones overlaid onto the soil EM map for the Fairlie dairy farm centre pivot irrigation system



Some examples of how irrigation is being varied under each system are given in Table 2, and described below.

At the Ashburton site, irrigation is being varied for soil and crop differences (beans, wheat, pakchoi, buckwheat, corn salad) (Table 2). Irrigation commenced on 8 October for the beans and wheat crops, with 15 mm applied to the very stony to stony soils (Zone 1 and 2), and 10 mm to the less stony soils (Zone 3). As the soils continued to dry out the amount of irrigation applied to Zone 3 was increased to 30 mm, as it has the ability to retain and supply this amount of water without leakage. However irrigation was reduced to 20mm and 25mm to the more stony soils. This provided a saving of 15% water for this period of irrigation. The finer soils in Zone 4 were used for shallower rooting seed crops and therefore required less irrigation.

At the Fairlie farm, irrigation commenced in October, when soils in Zones 1 and 2 required irrigation, although soils in Zone 3 and 4 did not (Table 2). Therefore only 115 hectares of the 174 ha pivot area were irrigated in the first two weeks of irrigation, giving a 34% water saving during this period. Irrigation was delayed to Zone 3 because these finer textured soils were able to store and supply more water to the pasture than Zones 1 and 2. Irrigation was also delayed to Zone 4 which has impeded drainage. By December all zones were receiving a uniform rate of irrigation. However, a 60 mm rainfall event in early January restored the soil zones to Field Capacity, so that irrigation could be halted and then recommenced in a staggered fashion again with Zone 1 and 2 being irrigated before Zones 3 and 4, providing further water savings. Also at this farm the VRI system is being used to shut off and vary irrigation to paddocks when pastures are renovated.

At the Manawatu site, irrigation commenced in December with Zone 1 requiring irrigation earlier than Zones 2 and 3. VRI is enabling irrigation to be reduced to wet, low lying areas (Zone 3) and to be shut off over drains. Zone 3 and the drains occupy 14% of the 76 ha irrigated field.

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Table 2: Examples of how irrigation is being varied under each irrigation system this season

Site	Zone	Crop	Irrigation Schedule					
			8-Oct	10-Nov	20-Oct	31-Oct	22-Dec	19-Jan
Farm 1 Ashburton								
	1	Beans	15	20				
	2	Beans or wheat	15	25				
	3	Beans or wheat	10	30				
	4	Pakchoi	0	10				
Farm 2								
Fairlie	1	Pasture			10	10		
	2	Pasture			10	10		
	3	Pasture			0	5		
	4	Pasture			0	5		
Farm 3								
Manawatu	1	Maize					5	6
	2	Maize					2	6
	3	Maize					0	3

Yield is also being assessed in each trial plot at each site, and these data will be used to estimate irrigation water use efficiency (IWUE) (kg dry matter production per mm of irrigation applied) under uniform rate irrigation (URI) compared with variable rate irrigation (VRI).

Summary

The VRI systems introduced onto these three farms are being used for:

- Varying irrigation according to soil differences, e.g.
  - Earlier irrigation of free draining very stony zones
  - Reduced amounts of irrigation to free draining very stony zones, to minimise risk of drainage and nutrient leaching
  - Delaying irrigation to soil zones with larger AWCs
- Varying irrigation according to crop differences
- Reducing irrigation into wet low-lying poorly drained areas
- Excluding irrigation from drains, gateways, laneways, water troughs, streams, pivot circle, and other areas such as irregular field boundaries
- Eliminating overlaps on the linear move irrigators
- Excluding irrigation to paddocks where pasture renovation is occurring
- Excluding irrigation to dairy paddocks the day before they are grazed

These farm management strategies are providing more efficient use of irrigation water.

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