

# EM MAPPING AND ITS USE FOR SITE SPECIFIC CROP MANAGEMENT, INCLUDING VARIABLE RATE IRRIGATION EXAMPLES

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## Introduction

The recent advent of on-the-go mapping systems using electromagnetic sensors and accurate GPS logging provides a new method to map and identify contrasting and variable soil zones. These soil zones may require different management, for example when cultivating, fertilising or planning irrigation schedules.

A map that accurately identifies the boundaries of contrasting soil zones has enormous potential as a very valuable aid to day-to-day farm management decisions. The maps can also be uploaded to computer-controlled equipment for precise guidance. For example, a map of the amount of plant-available water present in the soil on any one day could be used to direct a centre-pivot irrigator with variable rate nozzle control - different amounts of water could be applied to different parts of the field optimizing its use.



**Fig. 1 On-the-go EM soil mapping system**

The Geonics EM38 is one of several ground-based sensors now available for soil mapping. This sensor measures the apparent electrical conductivity (mS/m) of the soil, and provides one mean weighted value to about 1.5 metre

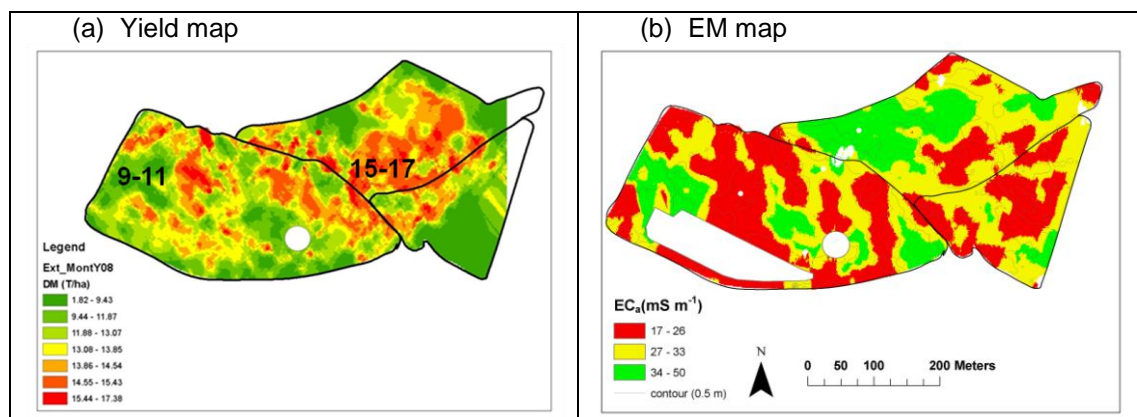
depth. The sensor was developed in the 1980s to investigate salinity issues in the Canadian Prairies and the US – saline soils having characteristically high soil electrical conductivity (EC). However, the sensor was subsequently found to be very useful in non-saline soils for investigating soil texture and moisture differences. Finer textured soils have higher EC values than coarse textured soils, due to better conducting pathways. Similarly, wetter soils have higher EC values than drier soils. It is this interaction of soil EC, soil texture and soil moisture that enables soil EC to be used as a surrogate measure of soil available water-holding capacity.

## EM mapping for zone management

A land owner will often know of particular fields that give significantly variable yields, and wants to know why. The important question is can these variable yields be managed by:

- 1) changing management to improve yields in the low yielding area, or
- 2) reducing inputs to the low yielding area, because these areas will always be low-yielding.

Yield maps (Fig. 2a) define how yields vary, but they can be misleading, because a high-yielding zone in one year can be a low-yielding zone in another year, due to, for example, climatic differences. Several years of yield maps are required before the land manager can start to identify consistently low-yielding areas, consistently high-yielding areas and areas where yield is consistently variable. An EM map (Fig. 2b) helps to explain these yield differences. The EM map delineates wetter, finer textured zones from drier, coarser textured zones.



**Fig. 2 Maize grain production in Manawatu Sand Country: (a) yield map showing large yield differences. Yields are lowest (9-11 T DM/ha) in wet low-lying areas and highest (15-17 T DM/ha) on the sides of sandy knolls. (b) The EM map delineates the wet low-lying areas with a high water table (green zones), and sandy knolls which tend to dry out quickly in summer-time (red zones).**

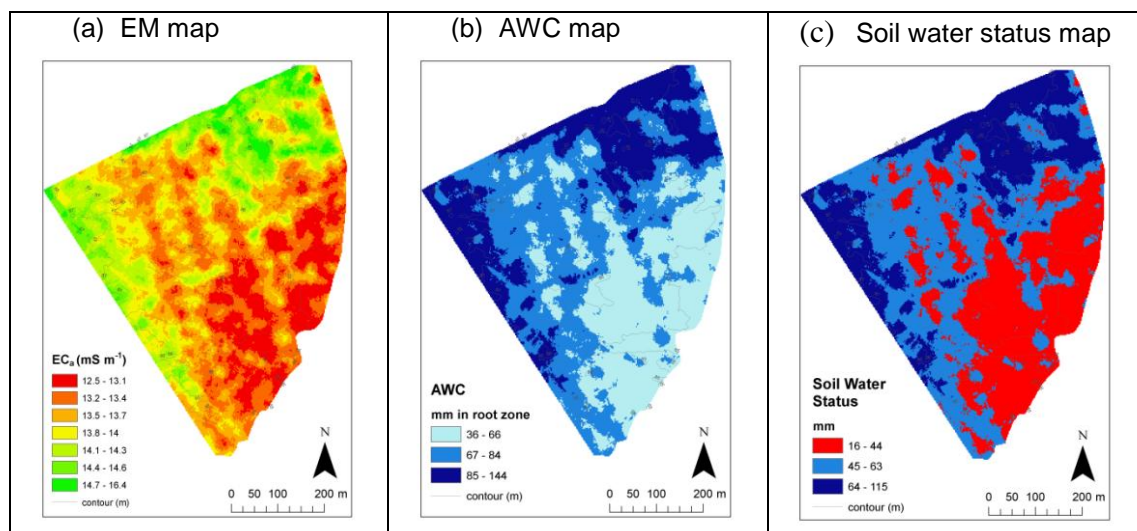
Therefore EM maps can be used for zone management. EM maps define different soil zones, which can then be managed differently to improve yields or to reduce inputs to consistently low-yielding zones. The land manager might consider varying the amount of fertiliser, irrigation or seed rate into

different management zones. This is called precision farming, or site-specific management.

### The link between EM mapping and plant-available water in the soil

Soil EM maps delineate zones of contrasting soils. Targeted soil sampling of these zones is used to develop relationships between soil EC and soil properties, such as the soil available water holding capacity (AWC). Figure 3b shows a soil AWC map derived from an EM map (Fig. 3a).

Soil available water-holding capacity (AWC) is the amount of plant-available water that a soil can hold - i.e. the amount of water held in the soil between Field Capacity and Wilting Point. Field Capacity is defined as the amount of water held in the soils two days after saturation, when initial rapid drainage has ceased. Wilting Point can be estimated as the field moisture content at the end of a significant dry period, when larger pores have completely drained and soil water is mainly sorbed onto clay surfaces and in very small pores.



**Fig. 3 (a) EM map, (b) soil available water-holding capacity map and (c) soil water status map for a 40 ha area of Canterbury soils under a centre pivot. The green zone in the EM map is a fine sandy Waimakariri soil, and the red zone contains 70% stones.**

The AWC map spatially defines the total possible amount of plant-available water in the soil. This map can be used for irrigation scheduling. By calculating how many millimetres of water are used by the crop on any one day we calculate when each zone reaches its “trigger point” for irrigation (Fig. 3c).

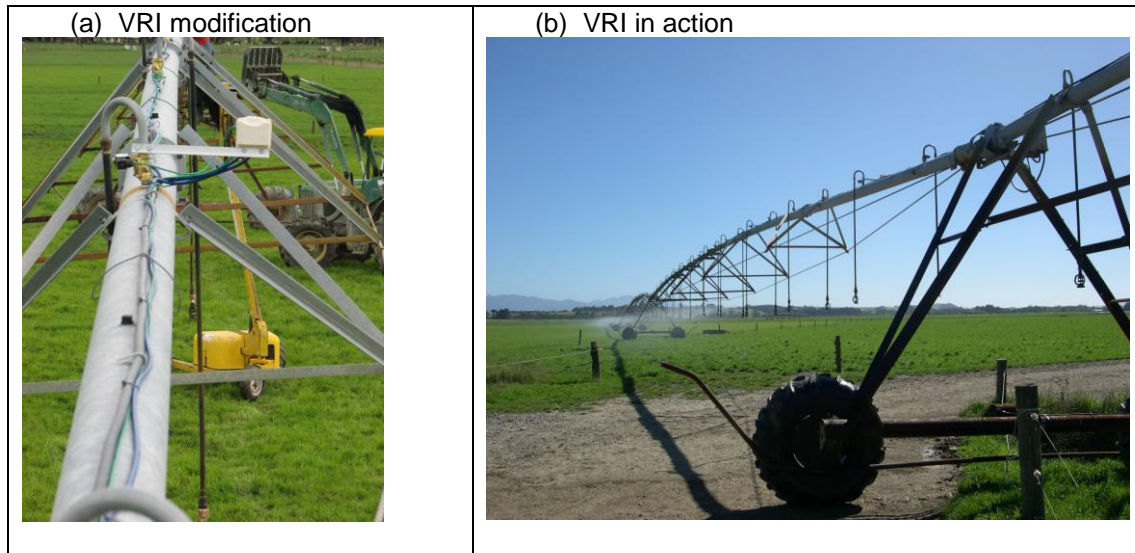
### Irrigation scheduling

The irrigation “trigger point” is the soil moisture below which crop growth slows, due to water stress. New Zealand and FAO guidelines recommend that irrigation should begin when approximately half of the available water has been used. Some research in Nebraska, home of the centre pivot irrigator, suggests that irrigation of maize should begin at 35-40% available water

depletion outside the silking pollination window and 30% depletion during silking.

### Variable Rate Irrigation (VRI)

The soil water status map (Fig 3c) provides the information required for variable rate irrigation. If a sprinkler system is being used, e.g. a centre pivot, individual nozzle control is required to target different irrigation depths to different soil management zones. Individual nozzle control also allows water to be shut off for example when travelling across raceways.



**Fig. 4 (a) Variable rate modification of an irrigator, showing a wireless node operating individual sprinklers, guided by a central controlling unit with customised software at the pivot, and (b) variable rate modification of this centre pivot maintains a dry farm track by shutting off sprinklers as they pass over the farm track, reducing the risk of lameness in dairy cows. Surrounding pastures receive varying amounts of irrigation (Photo 4a is courtesy of Precision Irrigation, [www.precisionirrigation.co.nz](http://www.precisionirrigation.co.nz))**

### Benefits of Variable Rate Irrigation (VRI)

Once a sprinkler system is modified for variable rate application there are multiple benefits, which include:

- keeping water off exclusion zones such as wet ponded areas
- increasing flexibility for mixed cropping
- precision chemigation and fertigation
- improving application accuracy at either end of the pivot
- maintaining optimum soil water levels for plant growth.

Our research has estimated the potential benefits of variable rate irrigation at several sites. Results show that, at these sites, in any one year, variable-rate irrigation saves between 8 and 21% of irrigation water, with accompanying energy and cost savings (\$60 - \$150/ha/year). Runoff and drainage are reduced by up to 55%, which also reduces the risk of nitrate leaching.

Variable rate irrigation enables irrigation water to be used more efficiently because the soil moisture in the root zone is maintained in the optimum range – not too wet and not too dry. It ensures that plant growth is not limited by water stress. It delays irrigation to some soil zones, using the water stored in the soil, maintaining an adequate soil moisture deficit. The amount of irrigation water lost as drainage or runoff is reduced, which also reduces the risk of nutrients being wasted when leached beyond the root zone, or lost as run-off into waterways.

Variable rate irrigation is particularly useful where the crop planting date is staggered. For example, potato crops are often planted in sequential blocks over a period of several weeks. Timing and amount of irrigation is critically important for potatoes. Potatoes are drought sensitive and require adequate moisture three weeks after tuber initiation to avoid common scab. However, over-watering also causes disease. Precision irrigation has been shown to increase potato yields by 20–30 T/ha.

### Ashburton Cropping Farm Case Study

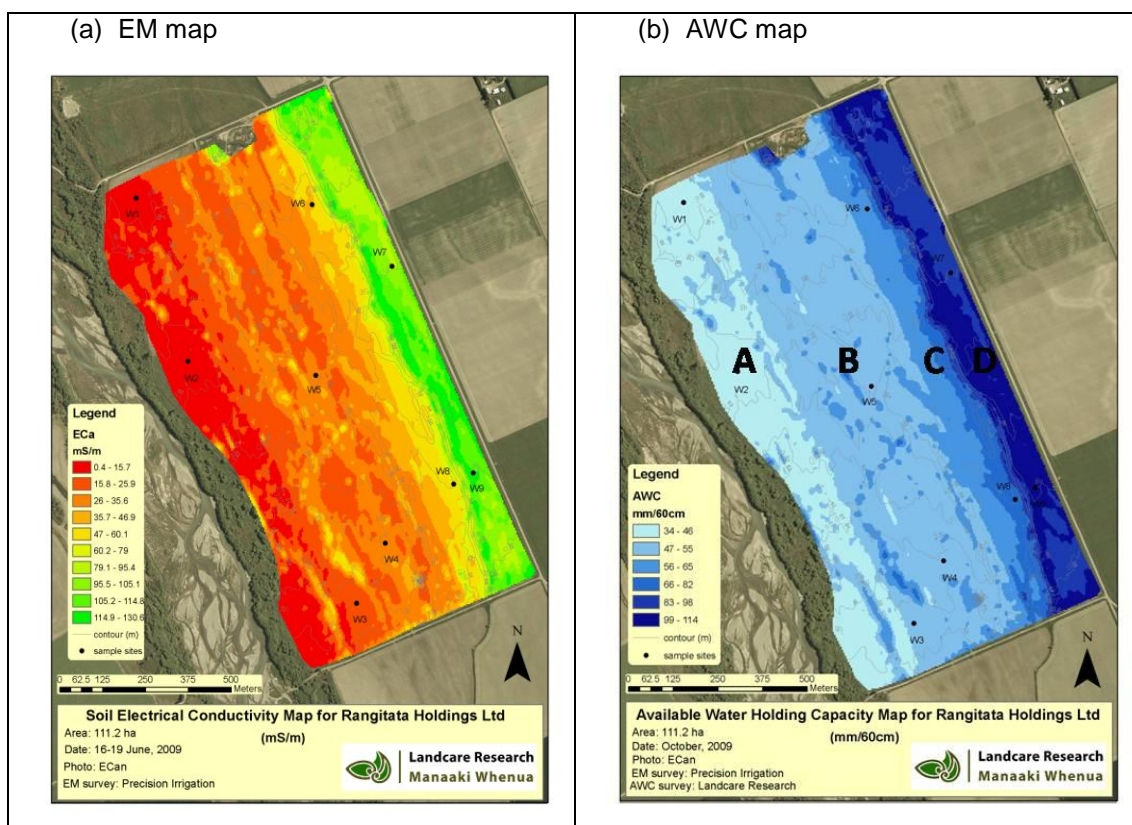
An electromagnetic induction soil survey was conducted at an Ashburton cropping farm. The EM map defines soil differences between the stony Rakaia soils and the deep silty Wakanui soils (Table 1; Fig. 5a).

**Table 1: Soil zone AWC values**

Zone	EC <sub>a</sub> range (mS/m)	AWC range (mm/60 cm)	Mean AWC value (mm/60cm)	Soil description
A	0.5-13.5	34-46	40	Very Stony Rakaia soils
B	13.5-53.0	47-55	51	Stony Rakaia soils
C	53.-79.5	56-82	69	Mixed Rakaia and Wakanui soils
D	79.5-132.0	83-114	98	Deep Silty Wakanui silt loams

EM zones were soil sampled for AWC, and an AWC map (Fig 5b) has been derived. The amount of plant available water held in the four zones varies from 34 mm to 114 mm. This has significant implications for irrigation scheduling. For example, if the soils are at Field Capacity, with no rain and a daily evapotranspiration rate of 3 mm per day, then Zone A can supply water to the crop for about 6 days. Zone B for about 8 days, Zone C for about 11 days and Zone D for about 16 days before irrigation is required.

The soil moisture deficit in each Zone is being estimated every day using daily climate data and a soil water balance. In addition, a wireless soil moisture sensor network will be installed, which will monitor real-time soil moisture in each zone and wirelessly communicate with the Precision Irrigation VRI software. Our goal is to maximise water use efficiency using a fully automated VRI system.



**Fig. 5 (a) Soil EM map and (b) AWC map for an Ashburton cropping farm**

## Conclusions

EM maps delineate soil zones for precision management at the farm and paddock scale. GPS guidance on farm machinery allows precision application of fertiliser, irrigation water, seed etc, if necessary.

EM mapping can be used to map and quantify soil variability for site specific management. AWC maps can be derived from an EM map, which can be adjusted on a daily basis using a water balance and/or daily soil moisture logging (e.g. a wireless soil moisture sensor network), providing spatial information for accurate irrigation scheduling.

Water savings can be made using variable rate irrigation because variable rate irrigation enables better use of stored soil water, and aims to maintain maximum yield potential with no water stress to the plant. As global irrigation demands escalate it is important to improve system efficiencies for the best use of freshwaters. VRI systems, with real-time soil moisture monitoring of soil management zones provide the information required to maximise use of soil water storage and ensure adequate delivery of available soil water to the plant.