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**An analysis of the relationship of
apparent electrical conductivity to
soil moisture in alluvial Recent
Soils, lower North Island, New
Zealand.**

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requirements for the degree of

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'Unto God would I commit my cause: which doeth great things and
unsearchable; marvellous things without number:

Who giveth rain upon the earth, and sendeth waters upon the fields'

Job 5:8-9

Abstract

Electromagnetic induction (EMI) sensors can be used in kinematic systems to provide rapid high-density measurement of apparent soil electrical conductivity (EC_a) over large areas. In non-saline soils EC_a has been used as a surrogate measurement for many soil properties including soil texture and moisture, critical properties in precision agriculture. However, complex interactions between soil properties and the irregular depth profiles of EMI measurements have prevented consistent interpretation of EC_a in terms of soil properties. This study uses kinematic surveys and multi-height spot measurements of EC_a with Geonics EM38 Mk2 and EM31 instruments together with field measurements of soil moisture and investigation of EC_a theory to analyse the relationship of EC_a to soil moisture in alluvial Recent Soils at two locations in the lower North Island, New Zealand. Soil samples from these locations were also analysed for bulk density, porosity, texture and the electrical conductivity (EC) of 1:1 soil pastes and extracts. Intact soil cores from one location were analysed for moisture retention properties. Results raise uncertainty about the function of EMI instruments, particularly the nature of temperature effects and the comparability of measurements by different instruments. Effects of soil solution conductivity on EC_a were found to be significant though the soils studied were non-saline. Correlations of soil moisture with EC_a in this study were varied and not in every case significant. The relationship of EC_a to soil moisture in this study was too complex to allow simple use of EC_a for measurement of soil moisture.

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Glossary of Terms

- Ωm** Ohm.metre: standard unit of electrical resistivity.
- Allegro:** The Juniper Systems Allegro CX field computer used for datalogging in kinematic systems.
- ATV:** The all-terrain vehicle or 'quad bike' used for kinematic surveying.
- AWC:** Available water capacity: the water holding capacity of soil between field capacity (~10 kPa soil matric potential) and permanent wilting point (~1500 kPa). Certain literature referred to uses AWC to mean available water content, otherwise referred to as plant available water (PAW). These instances are noted where they occur.
- Burnside:** The study location at Burnside Block, Kumeroa.
- depth profile resolution:** The processing of EC_a data to indicate the depth profile of EC_a measurements.
- EC:** Electrical conductivity.
- EC_a :** Apparent conductivity (of soil): the bulk or generalized electrical conductivity of a soil in response to EMI.
- EC_b :** Bulk liquid phase electrical conductivity of soil according to the 'dual pathway' model of Rhoades et al. (1976).
- EC_s :** Electrical conductivity of soil solids, mainly associated with soil particle surfaces.
- EC_w :** Electrical conductivity of the soil solution; salinity.
- EM31:** The Geonics Ltd. EM31 Mk2 electromagnetic induction meter.
- EM38:** The Geonics Ltd. EM38 electromagnetic induction meter (similar to the EM38 Mk2 but with only the 1m coil spacing).
- EM38 Mk2:** The Geonics Ltd. EM38 Mk2 electromagnetic induction meter.
- EMI:** Electromagnetic induction (in soil).
- ER:** Electrical resistivity.
- GPS:** Global Positioning System, receivers of which were used to contribute location data in kinematic surveys.
- inversion:** The processing of EC_a data to indicate the depth profile of EC_a measurements.
- IP** The 'in-phase' measurement of Geonics EMI instruments, related to the primary electromagnetic signal emitted by the instrument.
- kinematic:** A type of surveying in which sensor measurements and GPS location data are linked and logged while moving.

- LIN** 'Low induction number'. Under LIN conditions the effects of the magnetic fields of EMI at each depth in the soil are de-coupled from effects at adjacent depths above and below, enabling EC_a to be measured via the ratio of the secondary to primary magnetic fields.
- location:** One of the two study locations, Burnside or No.1 Dairy.
- meq/L:** Milli-equivalents per litre; a measure of ionic charge corrected for differing valencies of ions in solution.
- No.1 Dairy:** The study location at Massey No.1 Dairy Farm, Turitea, Palmerston North.
- PAW** Plant available water: the actual water content extractable from soil by a force <1500 kPa.
- proximal sensing in soil:** The detection of a soil property by an electronic sensor close to, but not requiring contact with the soil.
- QP** the 'quad-phase' measurement of Geonics EMI instruments which reads directly as EC_a (mS/m).
- RTK:** Real time kinematic: a type of GPS system in which corrections to a mobile 'rover' receiver are transmitted by a radio link from a stationary 'base station' receiver.
- site:** One of the sites of replicate soil sampling and measurements at one of the two study locations.
- θ :** Theta: the volumetric moisture content of soil.