EM38 in All-Steel Vineyards - a Cautionary Tale

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Take Home Messages

1. **Distortion strong in all-steel systems**
   - **Unlikely with all-wooden posts due to poor loop paths**
2. **Keep to centre of row spacing (within 20 cm of track)**
   - **Dnote that deviation > 20 cm results in deviation >10% EC_a**
3. **Trellis loops CAUSE offset in EC_a**
4. **Do not survey row spacings < 3.0 m as loop currents cause further modulation in EC_a**
5. **Do not include regions of different trellis-types in a single area for processing (eg surface fitting)**
6. **Evidence suggests distortion is an additive effect**
   - **Soil detail superimposed on trellis effect**
7. **Possibility of correction protocol (Clark et al) based on 'handful' of adjacent post measures**
8. **If in doubt- dig a hole !!**

Note: a more detailed description of this work can be found in Lamb, D.W., Mitchell, A. & Hyde, G. (2005) "Vineyard trellising comprising steel posts distorts data from EM soil surveys", Australian Journal of Grape & Wine Research 11: 24-32.

Background

The need to measure and map spatial variations in soil characteristics, including texture, water content and salinity within agricultural fields has driven the development and application of electromagnetic (EM) induction soil survey instruments such as EM-38 and EM-31. EM soil survey technologies work on the principle that a small transmitter coil in contact with the soil, energised with a sinusoidal current of low frequency, typically ~10 kHz, produces a time-varying primary magnetic field (H_P) in the sub soil. Where the primary field lines pass through an electrically conductive medium, in this case the soil, local electromotive forces (EMFs) are induced, and depending on local soil conductivity, eddy currents are induced to flow. These eddy currents in turn generate their own secondary magnetic fields (H_S), in much the same as the way the primary magnetic field was originally generated in the EM unit. The individual current loops are not influenced by others nearby. Consequently, the net secondary magnetic field at the receiver is the sum of the independent secondary magnetic fields from each of the individual current loops.

This process of electromagnetic induction results in a secondary magnetic field that is 90° out of phase with the primary field. The sensor coil is designed to measure this out-of-phase component, hence the notion of quadrature. At low induction numbers (that is, the ratio of the distance between transmitter and receiver coils, to conductor skin-depth), the apparent conductivity in the vicinity of the transmitter coil is determined by the ratio of the magnitudes of the out-of-phase secondary to primary magnetic fields. When operated in both vertical and horizontal dipole mode, the axis of symmetry of the primary field lines are, respectively vertical and horizontal. In both modes it can be shown that the primary field lines extend out to the sides of the EM unit along the horizontal plane of the ground. When used in an established vineyard for an EM survey, the EM sensors are moved along transects in the inter-row spacing. Unlike 'open' agricultural fields, vineyards offer highly conductive loops (placed in a vertical plane) which comprise steel trellis posts, wires and a portion of the ground (between the posts) in the vicinity of these sensors. It is likely that the secondary magnetic fields induced by current flowing in these highly-conductive loops may add to secondary magnetic fields generated by the conductive earth beneath the sensor, and therefore modify the overall conductivity estimates returned by the sensor. Noting that EM surveying technologies are being increasingly deployed in established vineyards, an investigation of the possible artefactual effects from steel vineyard trellising on EC_a values from EM devices is warranted.

This presentation describes the results of a detailed investigation into the effects of VSP trellising with varying row spacing on apparent conductivity as measured using an EM-38 unit in vertical dipole mode. Implications for ongoing application of this technology in established vineyards are discussed, and key issues for further investigation are identified.

Test site and ancillary field measurements

- The investigation was undertaken in the centre of a 12 ha field (Paddock 15A), located at Kirby Farm (University of New England Rural Property) in the New England Region of Eastern Australia.
- The test site, measuring 85 m x 70 m (approx. 0.6 ha) was selected within this field on the basis of being flat and of uniform soil type, predominantly Chromosol/Ferrosol with a clay loamy A horizon (0-20 cm) and clayey B horizon, and exhibiting low EC_a variability.
- This test-site incorporated the region to be occupied by the trellises and a 20 m wide buffer around the extent of the posts/wires. Within this test site, sixteen rows of VSP trellising, each row 30 m in length, were progressively erected, and then progressively dismantled.
- Each row of completed trellising comprised 150 x 2700 mm (6"x 8') treated pine end-posts, four 2.7 m steel "gripfast" posts, a dripper guide-wire, cordon wire, grab wire and four foliage wires (2 pairs). The wire used was 2.5 mm high-tensile "flexabel". The steel posts were driven 70 cm into the soil.
- Soil temperature readings at a depth of 60 cm and air temperature were recorded at 30-minute intervals throughout the course of the experiment.

Electromagnetic (EM-38) surveys

- Measurements of apparent soil electrical conductivity were completed using a Geonics® EM-38RT unit (Geonics Ontario, Canada) operated in vertical dipole mode. Prior to conducting each set of measurements throughout the course of the experiment, the instrument was switched on and warmed up for a period of 15 minutes, and zeroed following the standard Geonics protocol. Immediately following the zeroing procedure, the unit was placed on the ground at a pre-designated calibration point and the ECa measured and checked to ensure it was repeatable to within 5%.
- Two-dimensional surveys were completed by towing the EM-38 unit behind an all-terrain vehicle (ATV) on a rubber sled at a speed of 10 km hr[1]. The EM-38 unit itself was placed in a thermoplastic case (with styrofoam insulation on either side and a cover over the top to reduce case temperature fluctuations). The distance between the unit and the surface of the ground, as dictated by the bottom of the case and thickness of the rubber sled was approximately 15 mm.
- The continuous output data stream from the EM-38 unit was fed into a Trimble TSCe® datalogger along with the DGPS location information, every second, from a Trimble differential global positioning system (DGPS) (Trimble, Sunnyvale California, USA). With each survey, the ATV was driven between, and around the trellis rows (to cover the entire buffer and trial region) by following previously defined lines (marked in paint) on the ground. This particular requirement was considered crucial as it was the only way to guarantee that post-processing of the point-EC_a data into surfaces would not be influenced by the varying locations of point data that would have occurred in each survey.

Sequence of trellis manipulation and ECa measurements

- Two-dimensional EC_a surveys were conducted in sequence, corresponding to the following trellis manipulations; the bare field prior to trellis erection, after erection of the steel and wooden posts (ie no wires), following installation of all wires, following removal of all but the dripper wires (ie only dripper wires remaining), following removal of dripper wires (no wires- only posts remaining) and following removal of posts (return

Figure 1.
Two-dimensional EC_a maps generated for (a) bare field, (b) wooden end posts and steel posts only, (c) posts and dripper wire, (d) posts and all wires. (•) = steel posts, (+) = wooden end posts. Treatments, outlined by the grey squares within each map are, from left to right; 2.5 m 3.0 and 3.5 m row spacings respectively.

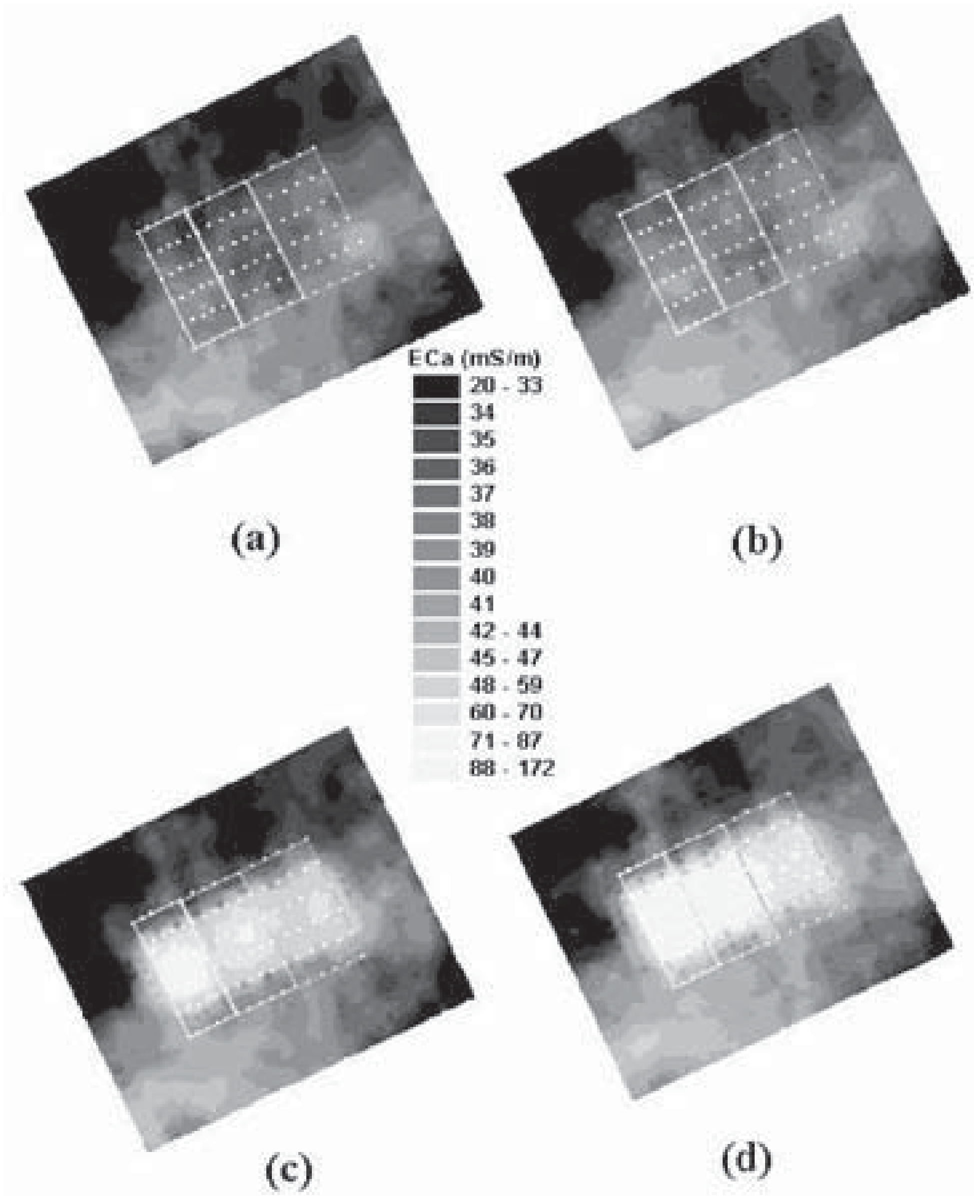
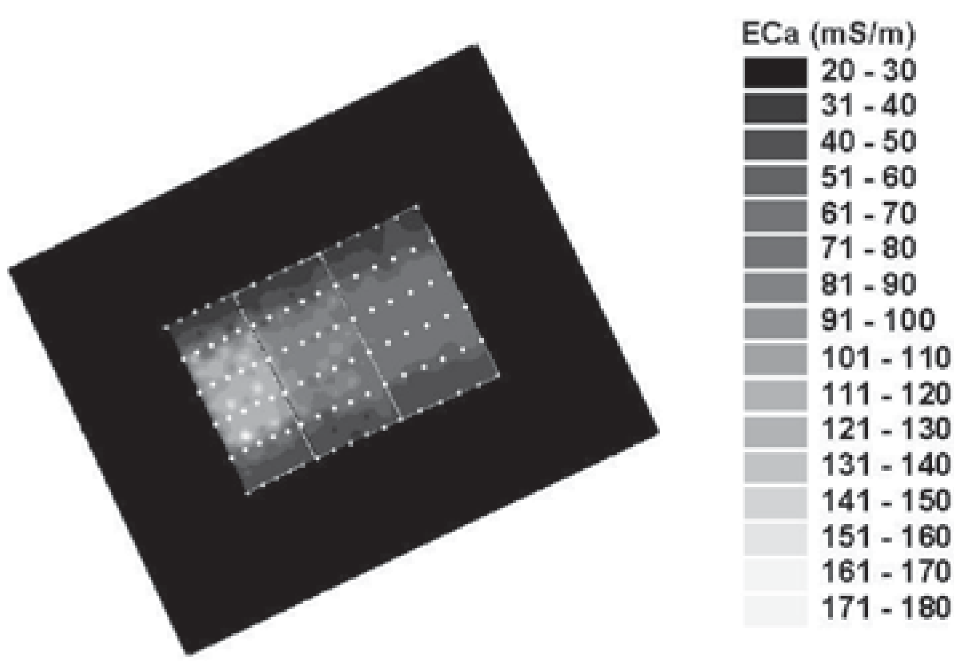


Figure 2.
Re-scaled 2-D ECa map for full trellising in place. (•) = steel posts, (+) = wooden end posts. In this grey-scale coding the bare field EC_a values range from 20-40 mS/m. The bare field map would thus appear uniform and coloured black, the same as the buffer region in this figure. Treatments, outlined by the grey squares are, from left to right; 2.5 m 3.0 and 3.5 m row spacings respectively.



to bare field configuration). The first EC_a survey was conducted in the bare field at 0830 (AEST) and the final survey conducted in the bare field at 1630 (AEST). Within the measurement limit of the sensor, the 60 cm soil temperature did not vary throughout the entire experiment and the air temperature varied by a maximum of 2.7 °C. After zeroing the instrument prior to each survey, the EC_a value recorded at the designated calibration point varied by only 2 mS/m (approximately 4.2%) between the first two sets of measurements, and remained fixed at 48 mS/m for subsequent measurements.

The effect of trellis manipulation on the 2-D ECa maps

- The EC_a maps created from each 2-D survey are shown in Figure 1. Comparison between the EC_a maps of bare field and that of steel posts (Figures 1(a) and (b)) indicate that there is little influence of the steel trellis posts on the resulting 2-D maps. Comparison of these figures with Figures 1(c) and (d), however, indicates a significant influence of the dripper guide-wire and subsequent addition of cordon, grip and foliage wires on the 2-D maps. Here, due to the EC_a scaling used, the high-end portion of the grey-scale values are saturated.
- The influence of the final full trellis structure on the EC_a maps is further highlighted in Figure 2, where EC_a grey-scale have been re-scaled to enhance the high-end values. The map of Figure 4 suggests an along-row edge effect whereby the EC_a values increase from the buffer region values (or that of the bare field) to a maximum in the centre of the trellising. In the case of longer rows, we speculate that the EC_a values would then level out to what would amount to be an offset to the bare field values.
- In Figure 2, however, it can also be seen that when all trellis wires are erected, the ECa values along the 2.5 m row spacing are modulated, with local maxima coinciding with the EM unit located midway between steel posts along each row. There is also a suggestion in the data of an along-row modulation for the 3 m row spacing map but no such modulation for the 3.5 m row spacing.
- The mechanism of the along-row modulation observed in the 2.5 m row spacing segment of Figure 2 may be explained as follows. As the EM sensor is moved along the rows, more of the magnetic flux either side of the sensor is intercepted by the conducting loop comprising the ground, steel posts and above-ground wires because the sensor is midway between the posts (a greater loop area presented to the primary magnetic field). The necessity of a closed conducting loop is particularly illustrated given the ECa map for the steel posts only (without wires) is the same as that of the bare field. (Figures 1 (a) versus (b)).

Conclusions

- Electromagnetic induction soil survey techniques (eg EM31/38), measure apparent electrical conductivity (ECa) and work on the principle that electric current is induced below the ground surface by a low-frequency oscillating magnetic field. The return magnetic signal produced by the underground current is detected.
- All-steel vineyard trellising act as large antennae and distort the electromagnetic response of these sensors.
- An artificial vineyard was 'built' and then dismantled in a single day and the EM38 surveys compared.
- The EC_a profile of the bare site (ie without vineyard) was found to be modified by the trellising, with the least modification from steel posts only, and the degree of modification progressively increasing with the addition of wires up to to the final trellis assembly.
- The EC_a values were found to increase from a range of 20-50 mS/m for the bare field to a range of 100-130 mS/m for the assembled trellising, with the amount of increase greatest for the smaller row spacing.
- The results indicate that extreme care must be exercised by an operator to ensure that the EM-38 antenna/sensor unit remains mid-row throughout any transects and that changes in trellising structure/row spacing may introduce artefacts in EM-38 maps.

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NOTE: use of commercial product trade names, for example EM38, does constitute an endorsement of these particular products.