SHORT NON-REFEREED PAPER

MEASURING APPARENT ELECTRICAL CONDUCTIVITY: A COMPARISON BETWEEN TWO EM38-MK2® INSTRUMENTS

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Abstract

Electromagnetic induction (EMI) is widely used to improve the understanding of spatial soil variability. EMI sensors measure apparent electrical conductivity (EC_a), which is used as a surrogate measure of selected soil properties, e.g. salinity, water and clay content and cation exchange capacity, through deterministic or stochastic calibration exercises. The objective of this study was to compare EC_a measured with two EM38-MK2® instruments. The broader aim was to identify the extent to which measurements obtained with a new instrument would mirror those obtained with an instrument which needed replacing. Two identical EM38 instruments were used to survey a site near Bloemfontein (Paradys) and another in the KZN midlands (Glenside). Each site was divided into grids which were used to determine positions where all scanning data were collected. EC_a data were obtained by operating the instruments in both their shallow (0.5 m) and deep (1.0 m) settings for both vertical and horizontal dipole orientations. Comparison between the instruments for the shallowest depth (measured in the horizontal position and 0.5 m setting) was weakly correlated at Paradys with an r^2 of 0.45, but obtained an r^2 of 0.99 at Glenside. It was nevertheless concluded that both instruments expose similar 'fingerprinting' characteristics from the sites surveyed. Results obtained for the greatest depth (measured in the vertical position and 1.0 m setting) were also weakly correlated at Paradys with an r^2 of 0.44, but obtained an r^2 of 0.88 at Glenside. It is concluded that both instruments revealed the same fingerprint for both depths at each site and can therefore be used to substitute each other in surveys. However, the observed shift in the data between the two instruments imply that data from the replacement instrument should only after careful consideration be pooled with that of the original instrument.

Keywords: apparent electrical conductivity, clay content, EM38-MK2®

Introduction

The quest to know whether two electromagnetic induction instruments measuring apparent electrical conductivity (ECa) will yield the same response has been investigated by several authors. Ristolainen *et al*. (2009) compared the performance of four different instruments to estimate electrical conductivity, pH, humus, water content and texture. They concluded that the differences between instruments were only minor. Saey *et al*. (2009) compared the ability of two very different instruments to estimate the depth to a contrasting textural layer and concluded that both performed similarly. The objective of this study was to compare the performance of two EM38-MK2® instruments to replace each other in a survey. The broader aim was to identify the extent to which measurements obtained with a new instrument would mirror those obtained with an instrument which needed replacing.

Material and Methods

Two EM38-MK2® instruments manufactured by Geonics Limited, Ontario, Canada, were used in this study. One belonged to the South African Sugarcane Research Institute (SASRI) the other to the University of the Free State (UFS). The instruments were evaluated on two texturally contrasting sites. Paradys near Bloemfontein, which is uniform in clay content (18, 33 and 35%, with CV% of 8.0, 12.3 and 10.8 for depths of 15-30 cm, 55-70 cm, and 115-130 cm, respectively), and Glenside in the KZN midlands, which is variable in clay content (27, 37 and 38%, with CV% of 45.7, 47.8 and 58.6 for depths of 15-30 cm, 55-70 cm and 115-130 cm, respectively). A grid was superimposed on each site and readings taken in the vertical and horizontal dipole orientations at each grid position. These instruments are equipped with a depth selector (0.5 m 'shallow' and 1.0 m 'deep') and data were collected using both settings. The grid spacing for Paradys was 20 x 20 m with eight positions in an East-West direction and eight in a North-South direction (thus 1.96 ha with 64 measuring positions). The grid spacing for Glenside was 4 x 10 m with 11 positions spaced 10 m apart diagonal to the contour and nine positions spaced 4 m apart along the contour (thus 0.32 ha with 99 measuring positions). The data were statistically analysed using a paired two sample t-test (GENSTAT for Windows 14th edition).

Results

There was a relationship in the survey trends obtained by the two instruments for both uniform and variable sites (Figure 1). The worst relationship (Figure 1A) appeared to be where the instruments were used in the horizontal dipole position and 0.5 m setting (shallow) at the uniform Paradys site (Table 1). The large difference in the means is reflected in Figure 1A, where ECa values from the UFS instrument seemed to be consistently higher than that of the SASRI instrument. In Figure 1B this relationship is reversed, with ECa values obtained with the SASRI instrument mostly larger than those obtained with the UFS instrument.

The pattern of the survey site revealed by the scanning EM38 instruments can be regarded as the 'fingerprint' of that field. The smaller variability in ECa of the surface soil layer from the Paradys site is obvious (Figure 1A) when compared to that of the Glenside site (Figure 1C). However, ECa values from the deeper soil layer at the Glenside site (Figure 1D) was less variable (standard error of the mean was 0.86 for SASRI and 0.80 for UFS) than that of the Paradys site (Figure 1B) (standard error of the mean was 1.61 for SASRI and 1.42 for UFS). On closer inspection the increase in ECa values for grid positions 38 to 64 (the area irrigated with saline water) from the Paradys site is partly responsible for this larger standard error. The data in Table 1 further suggest that all paired (SASRI vs UFS) trends in Figure 1 are significantly different. It is, however, of value to consider also the fingerprint trends for each site (Figure 1) where the trend per site and depth are clearly similar. In an effort to quantify the similarity between instruments, linear regressions were performed. The linear regression between SASRI and UFS EM38 obtained ECa data yielded r^2 values that ranged between 0.35 and 0.65 and slopes between 0.54 and 0.94 for Paradys, and r^2 values that ranged between 0.57 and 0.99 and slopes between 0.77 and 0.93 for Glenside (Table 1). Thus, the relationship between instruments was tight for the Glenside site and less so for the Paradys site.

Conclusion

Despite the fact that the SASRI and UFS EM38 instruments differ significantly in their output, the fingerprint trend lines obtained per instrument per site are noticeably similar. This means that they describe the same trend in soil in terms of the graphical patterns obtained and in terms of the number order of the values. Thus, a replacement instrument could be used to establish the variability of a survey site and the fingerprint might look similar to that from the original instrument. However, there was a shift in the data between the two instruments which would have to be kept in mind. Additionally, this means that data from the two instruments should only be pooled after careful consideration.

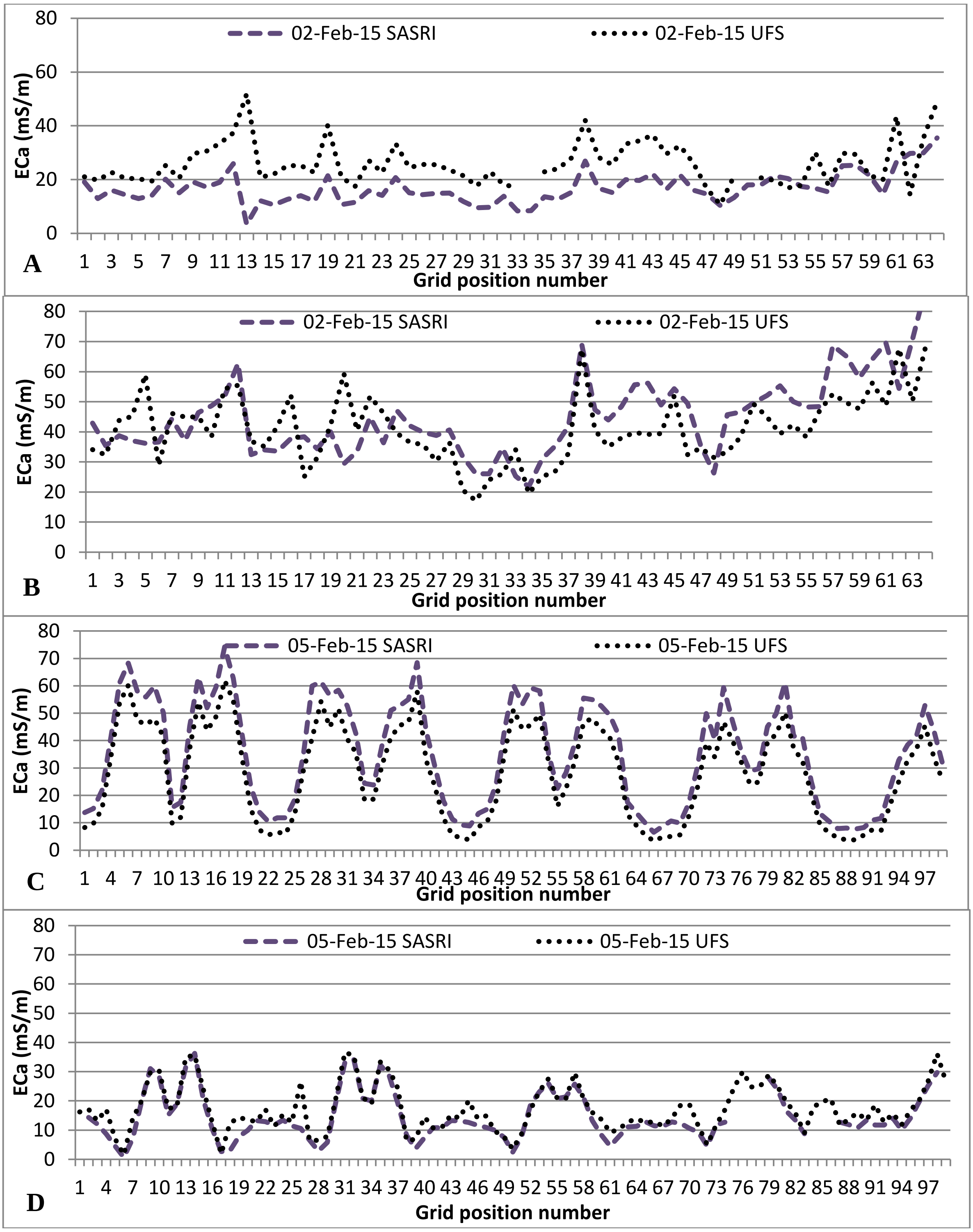

Figure 1. Electromagnetic induction survey trends with SASRI and UFS EM38 instruments for the Paradys (A and B) and Glenside (C and D) sites. Data in this Figure were obtained with the following instrument orientations and settings: (A) horizontal 0.5 m, (B) vertical 1.0 m, (C) horizontal 0.5 m and (D) vertical 1.0 m.

Table 1. Statistical analysis comparing the ECa (mS/m) survey data obtained with the SASRI and UFS EM38-MK2 instruments for two sites: Paradys (2 Feb 2015) and Glenside (5 Feb 2015). Surveys were conducted in the horizontal (H) and vertical (V) dipole orientations and using the 0.5 m and 1.0 m depth settings.

Orientation and (setting)	Paradys				Glenside			
	Mean diff	T. prob	Slope	r^2	Mean diff	T. prob	Slope	r^2
H (0.5)	24.10	<0.001	0.9164	0.45	7.06	<0.001	0.8927	0.99
H (1.0)	10.55	<0.001	0.9399	0.35	12.37	<0.001	0.7710	0.57
V (0.5)	21.76	<0.001	0.5471	0.65	3.62	<0.001	0.8005	0.91
V (1.0)	20.29	<0.001	0.5872	0.44	2.53	<0.001	0.9329	0.88

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