SHORT, NON-REFEREED PAPER

USING ELECTROMAGNETIC INDUCTION DATA TO ESTIMATE ABRUPT CHANGES IN SOIL CLAY CONTENT WITH DEPTH

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Abstract

Soil surveys for precision agriculture (PA) based on grid point (GP) sampling are notoriously slow and expensive. Surveys conducted with electromagnetic induction (EMI) technology are far more time efficient compared to the GP sampling method and the apparent electrical conductivity (ECa) values obtained are known to relate to a number of soil properties including clay content. The objective of this paper is to propose a relatively simple method to detect abrupt change of clay content with depth from ECa data. Soil surveys were conducted on four sites using the conventional GP and EMI methods. At each grid point soil samples were collected at depths of 0.15-0.30, 0.55-0.70 and 1.15-1.30 m and analysed for clay, silt and sand contents. The EMI survey was conducted with an EM38-MK2 instrument used in both the horizontal and vertical orientations to obtain ECa data for three soil layers, i.e. 0-0.38, 0-0.75 and 0-1.50 m. Differences between depth intervals were interpreted using standard deviations, and the results compared for consistency between clay content and ECa data. Out of a total of 12 estimates, clay content and ECa data led to the same conclusion 10 times (the presence or absence of an abrupt change in clay content with depth). Where they differed, the sum of the standard deviation of the depths compared was smaller than the ECa differences for those depths. The proposed method is useful to add value to EMI data, identifying soils with a duplex character which require a higher level of management.

Keywords: abrupt change, apparent electrical conductivity, clay content, electromagnetic induction

Introduction

The world is fast adopting scanning technology as a tool to analyse substances and objects. The main reason is that it is quick to map soil properties. The technology used is commonly referred to as electromagnetic induction (EMI). The most well-known recent (November 2017) application of this technology was on the Cape Flats which was scanned from a height of about 50 m with a helicopter to search for the best places to drill for water (Christians, 2017). In agriculture this technology is often applied using a motorised vehicle towing the EMI apparatus linked to a geo-reference recording device. Because of the constant drive to extract more information from the scanned data, often all that is required is to add another calibration algorithm or a method of data analysis. The objective of this paper is to propose a relatively simple method to detect the abrupt change in clay content with depth from EMI data. The definition of an abrupt change in clay content as defined by MacVicar (1977) was used because it allowed for large clay differences between soil layers which suits the estimation of clay by EMI. This definition describing the abruptness of a soil is in two parts. Where the clay content of the surface layer is less than 20% in the A-horizon, clay in the B-horizon must be 2x that in A-horizon. If the clay content is more than 20% in the surface layer, then an additional 20% clay is expected in the B-horizon (MacVicar, 1977).

Methods and Materials

Four fields were selected to conduct this work. The first was at Bruynshill and had a uniform Inanda soil form with 41% clay in the topsoil. Others were at Mount Edgecombe with 15% clay in the topsoil of the Westleigh soil form, Paradys near Bloemfontein with 18% clay in the topsoil of the Sterkspruit soil form and Glenside, which was extremely variable, ranging in clay content from 14% for the Westleigh to 37% for the Swartland soil forms. The Glenside site was divided into three distinct regions based on the variability (spatially and vertically) of its clay content (Table 1). Each field was marked out with a grid layout and each point marked with a wooden peg. At each point EMI scans were conducted in both the horizontal and vertical dipole orientations using the EM38-MK2 instrument obtaining apparent electrical conductivity (ECa) data for depths 0-0.38 m, 0-0.75 m and 0-1.5 m. This was followed with soil sample collection at each grid point at depths 0.15-0.30 m, 0.55-0.70 m and 1.15-1.30 m and analysed for clay content. The most appropriate statistical parameters for this work was Confidence Interval (CV), Least Significant Difference (LSD) and Standard deviation (Std dev).

Results and Discussion

Each region was analysed for its mean clay content per depth layer and comparison between layers (Table 1). Comparing soil layers 1 and 2 the difference for the Bruynshill site is significant although the clay content difference is only 2.1% and therefore not abrupt. According to the P-values clay content of only the Mount Edgecombe site was not significant between layers 1 and 2 (Table 1). Applying the rules for abruptness to layers 1 and 2, none could be described as differing abruptly and the P-value statistic (and most other statistical parameters) were therefore not appropriate. The only statistical parameter that had potential was Std dev. It correctly indicated no significantly large clay content differences between layers 1 and 2 and 2 and 3 for the very uniform (spatially and vertically) Bruynshill site (Table 2).

Table 1. Clay content (%) for three depths and six regions.

Depth (cm)	Bruynshill	Mount Edgecombe	Paradys	Glenside		
				Sandy loam	Sandy clay loam	Sandy clay
0-38 (1)	41.2	15.6	18.4	14.6	25.1	37.7
38-75 (2)	43.3	16.5	32.8	20.2	31.1	49.2
75-150 (3)	47.0	34.5	34.5	22.9	31.0	54.4
n - value	75	78	64	28	38	33
P - value (1 vs 2)	<0.001	0.502	<0.001	0.004	0.008	<0.001
P - value (2 vs 3)	<0.001	<0.001	0.034	0.132	0.983	0.002

The Std dev statistic was also applied to the ECa data which correctly indicated no significant large (abrupt) differences between layers 1 and 2. However, significantly large differences were indicated between layers 2 and 3 although the physical difference was only 3.6 mS/m. This was caused by the large population (75, Table 1) for the Bruynshill site and the small Std dev (Table 2). The term 'abrupt' was adopted to describe differences between layers (Table 3). The Std dev statistic was also applied to the other sites and, in 10 out of 12 sites, the Clay content and ECa data resulted in the same conclusion (abrupt or not abrupt, Table 3).

Table 2. Standard deviation (Std dev) of clay content (%) and apparent electrical conductivity (ECa, mS/m) for the uniform Bruynshill site.

Parameter	Mean Clay	Std dev	- Std dev	+ Std dev	Mean ECa	Std dev	- Std dev	+ Std dev
Depth 1	41.2	3.5	37.7	44.7	10.4	4.9	5.5	15.2
Depth 2	43.3	3.6	39.7	46.9	13.9	1.3	12.6	15.2
Depth 3	47.0	5.0	42.0	52.0	10.3	0.7	9.5	11.0

Table 3. Comparison of estimated abrupt changes between clay content and ECa data for soil layers 1 and 2 and 2 and 3.

Site	Bruynshill		Mount Edgecombe		Paradys	
Depth	**Clay**	**ECa**	**Clay**	**ECa**	**Clay**	**ECa**
1 vs 2	NA	NA	NA	NA	Abrupt	Abrupt
2 vs 3	NA	Abrupt	NA	NA	NA	NA

Glenside	Sandy Loam		Sandy Clay Loam		Sandy Clay	
Depth	**Clay**	**ECa**	**Clay**	**ECa**	**Clay**	**ECa**
1 vs 2	NA	NA	NA	NA	NA	NA
2 vs 3	NA	NA	NA	Abrupt	NA	NA

NA = not abrupt

Conclusions

Using Standard deviation in the analysis of EMI data it was possible to identify large changes in clay content between depths. Additionally, because data for three depths are obtained if the EM38-MK2 instrument is used in both horizontal and vertical orientations, it was possible to note between which depth intervals (layer 1 vs 2 or 2 vs 3) the abrupt soil characteristic is occurring and therefore to sense also the approximate depth of sudden change in clay content. It is therefore of value to use data from the EM38-MK2 to flag the possible presence of an abrupt change in clay% in the soil. A Thompson soil sample auger can be used to confirm the presence and depth of such an abrupt clay% change in the soil. Once confirmed the location and size of the area affected by the abrupt soil property can be read from a map created using EM38-MK2 data.

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