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Use of Electromagnetic Soil Surveys to Locate Areas of Nutrient Buildup

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Abstract. *Nutrient management of cattle feedlots is a topic of increasing environmental, sociological, and regulatory concern. Buildup of nutrients on feedlot surfaces with associated gaseous emissions, as well as runoff and leaching potential, pose challenges for both producers and regulators. This paper considers spatial and temporal aspects of feedlot surface nutrient distributions with methodologies to improve feedlot surface management. An electromagnetic induction soil conductivity meter was used to survey four feedlot pens at the U.S. Meat Animal Research Center. Soil conductivity was mapped and conductivity zones were identified. Analyses of soil cores from transects across each zone were determined. Preliminary results indicate correlations between* EC_a

and associated volatile solids (r^2 = 0.77 for volatile solids). Volatile solids are closely associated with nutrients (r^2 = 0.92 for total N and r^2 = 0.80 for total P). Identifying areas of intense nutrient buildup holds the promise of site-specific management options, and a subsequent reduction of nutrient loss.

KEYWORDS. Electromagnetic induction, Feedlot, Nutrients, Volatile solids, Total nitrogen, Total phosphorus

Introduction

Open-lot cattle feeding operations face challenges in control of nutrient runoff, leaching, and gaseous emissions. Producers are being pressed to provide comprehensive nutrient management plans to account for nitrogen and phosphorus in order to obtain valid operating permits. Methods have been devised to address nutrient issues at different points in the waste management system. There are several options for nutrient runoff management once the effluent leaves the feedlot due to precipitation events (Woodbury et al., 2003). Nutrient leaching on the feedlot surface is not a concern for surfaces that are tightly packed, and with water tables far from the surface. However, leaching of nutrients from runoff storage facilities is a concern (Ham, 2002). Gaseous emissions from feedlot soils are not fully understood and difficult to control. Assessing and removing nutrient concentrations directly from the feedlot surface presents one option of minimizing environmental impact. Remedial steps taken early in the waste management system increase the effectiveness of treatment 'downstream' in the process. While collecting, loading, and hauling feedlot manures can become a significant fixed cost (Tetra Tech, Inc., 2004), minimizing the number of loads and maximizing the nutrient concentrations promises to lower nutrient transport costs.

Beef cattle manure contains nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, sodium, chloride, iron, and other trace minerals which result in average EC values in the range of 3.7 dS/m (Gilbertson, 1975). Soil may have average EC values of 0.1 to 1.1 dS/m, ranging from non-saline/coarse soil to very saline clay (Smith and Doran, 1996). Accumulation of beef manures has been shown to elevate soil EC, and electrical conductivity methods have been shown to be sensitive to areas of high nutrient levels (Eigenberg, 1996).

The objective of this work is to evaluate a system that will monitor feedlot surface/subsurface conductivity on a spatial basis, and determine correlations among the conductivity values and soil nutrient analysis.

Materials and Methods

A study was initiated in 2003 at the U.S. Meat Animal Research Center, in south-central Nebraska, to assess the association of beef feedlot manure surface accumulation to soil conductivity distribution in beef cattle feedlots. Four feedlot pens (32 m X 89 m each) were chosen at the USMARC feedlot. These four pens had been the source of runoff for a vegetative filter treatment study for which some historical data was available. Pens were rebuilt and reshaped in 2000. Cattle have populated these pens (75 to 85 per pen), receiving standard feedlot rations; pens have received routine maintenance since that time. Sequential EC_a measurements were taken by EMI and GPS. A Dualem-2 was used to measure soil conductivity (centroid of depths approx. 1.5 and 3 m). Maps were generated of soil conductivity from the feedlot.

Zones were created from the ECa data. The zone threshold method presupposes that the ECa of the base feedlot soil ECa will be fairly stable; however, the areas of high manure will be defined by much higher ECa values. The method for establishing a zone threshold began by sorting ECa data in ascending order followed by normalizing the number of points in a spreadsheet (figure 1). The rate of change between the reordered data was determined by sequentially dividing the change in ECa magnitude by the fractional change between points. The rate of change data was filtered using a moving average filter (figure 2). Representative rate of change values from the upturn region were chosen. These points were plotted as a linear relationship (figure 3). The intersection of the defined line and the average baseline value determines the threshold value thus establishing the boundary between high and low manure areas.

Coordinates were downloaded and GPS navigation used to locate feedlot surface coordinates for soil sampling. All soil samples were taken from a surface area of 20 X 20 cm, and to a depth of 10 cm. Soil was thoroughly mixed by hand and stored in sealed plastic bags until analysis. All soil samples were analyzed for total P, soil moisture, and volatile solids. Additionally, soil samples were taken on a traverse across a high conductivity region on orthogonal axes. These soil samples were also analyzed for TKN, total K, EC, and Cl.

Correlation analyses were run to determine associations between horizontal EMI readings and the various soil constituents.

Results and Discussion

Surveys of USMARC feedlot pens were conducted on three dates (6/23/04, 7/13/04, and 10/18/04) in 2004. Each survey date included an EMI survey and soil sampling in each of the pens.

Representative EC_a maps are shown for each of the survey dates in figure 4. The maps have been scaled to highlight the upper 35% of EC_a values. Figure 1 demonstrates an apparent stability in the overall pattern throughout the study period. The highest EC_a appears to center on a region defined by the bunk, waterer, and mound. Surface management in these pens includes the use of manure to build the mound; this is confirmed in the EC_a map. Soil samples were taken on a transect in pen 413 on October 18, 2004. The traverse was chosen, based on the EC_a map for pen 413, with five samples taken in the north-south direction and five samples east-west. Soil cores were also taken at a point of low EC_a in pen 413 and a background reference was taken at a site near the feedlot where no manure had been applied. Results of soil analysis for this set of soil samples are shown in figures 2, 3, and 4. Figure 5 demonstrates the relationship between EC_a and volatile solids ($r^2 = 0.77$); the elevated salt content of manure contributes to the strong association. Corollary associations are shown in figures 6 and 7; total N ($r^2 = 0.92$) is strongly linked to volatile solids as is total P ($r^2 = 0.80$). The combination of figures 5, 6, and 7 suggest the potential use of EC_a maps to delineate regions of high volatile solids and the associated concentrated N and P nutrients. The correlation among EC, Cl, and moisture are shown in figure 8. Electrical conductivity, Cl, and soil moisture are all constituents associated with manures and are correlated with EC_a as anticipated.

Conclusions

The associations that are demonstrated in the preceding data suggest management options that could be employed to deal with nutrients on feedlot surfaces. Feedlot managers are aware of the locations of manure pack, as they are generally visible during scraping the pens. The EMI methods clearly delineate volatile solid concentrations, without mechanically disturbing the pens. Boundaries could be marked and areas harvested without agitating the entire pen. Harvesting the nutrient rich 'sweet spots' would result in a concentrated form of scrapings that could be hauled further, and have greater value at the final destination. Additionally, if the 'sweet spot' were removed, then runoff, leaching, and volatilization would be reduced. Future plans include investigation of odor and ammonia generating potential at the 'sweet spot' site; it is anticipated that a majority of odor and ammonia emissions may originate at that site.

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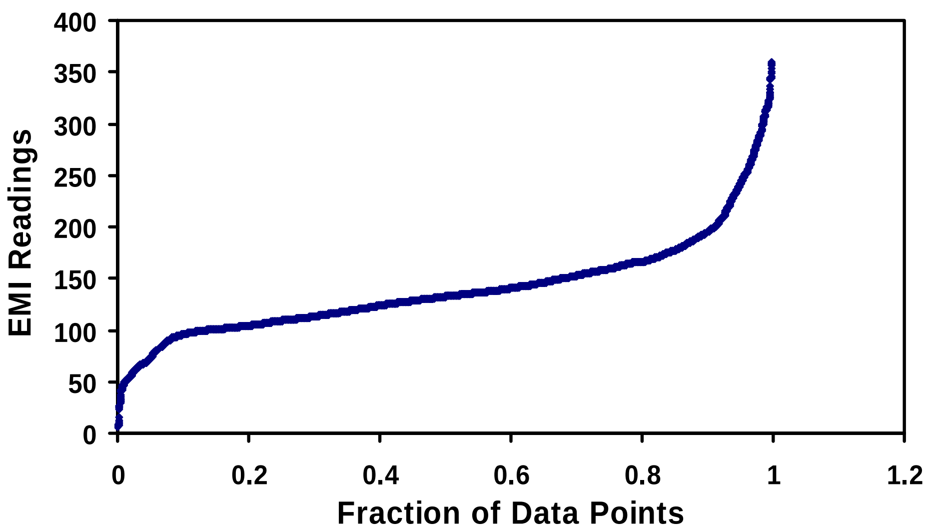

Figure 1. Zones were established by sorting ECa data in ascending order followed by normalizing the number of data points in the spreadsheet to create the horizontal axis. The data shown was from pen 413.

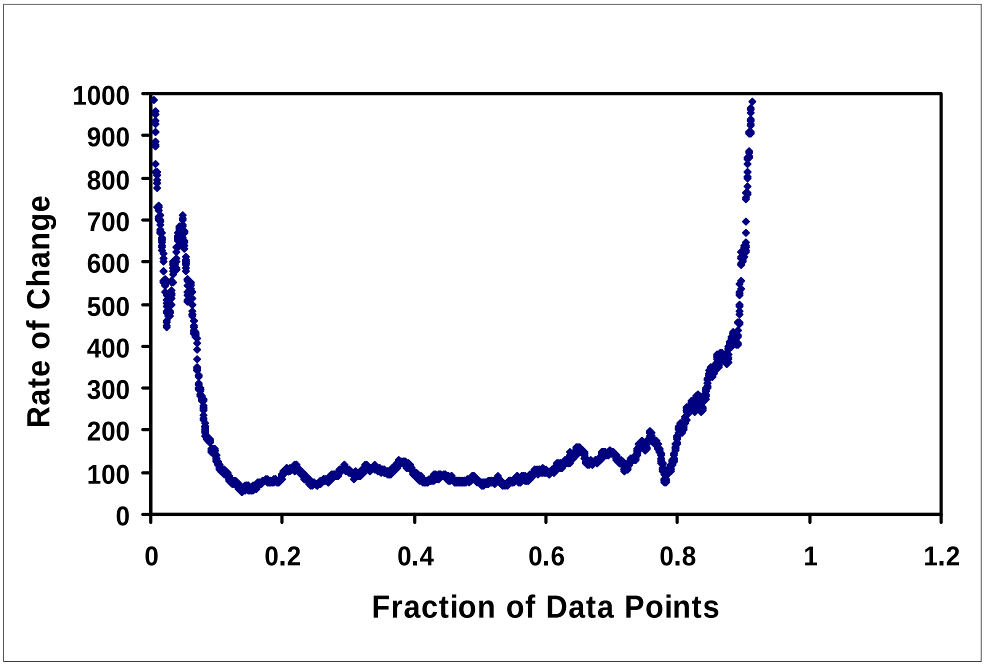

Figure 2. Rate of change of ECa data between the reordered data values was determined by sequentially dividing the change in ECa magnitude by the fractional change between points. The rate of change data was filtered using a moving average filter. The data shown was from pen 413.

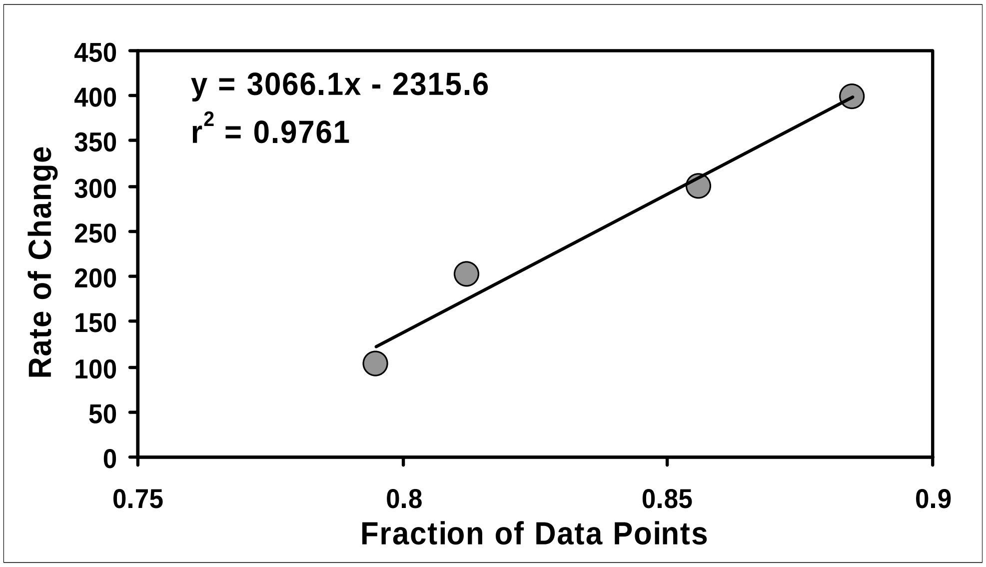

Figure 3. Representative rate of change values from the upturn region were chosen. These points were plotted as a linear relationship. The intersection of the defined line and the average baseline value determined the threshold value thus establishing the boundary between high and low manure areas. The data shown was from pen 413.

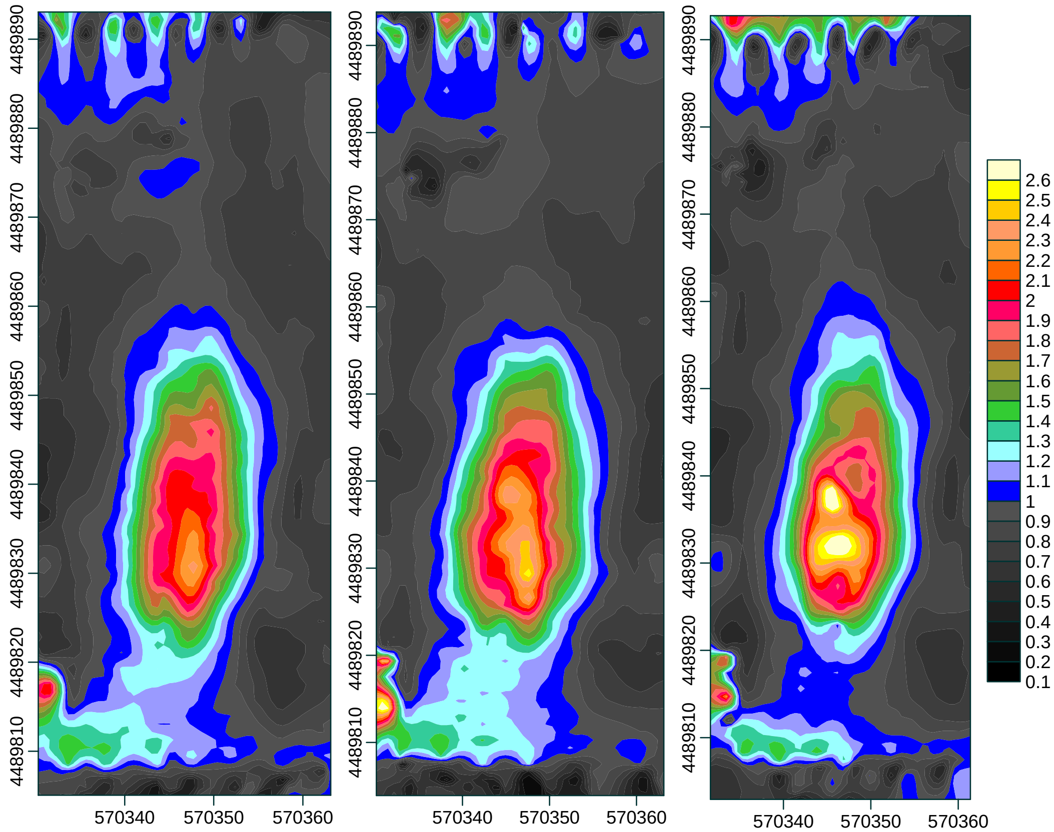

Figure 4. EC_a maps generated on 6/23/04, 7/14/04, and 10/18/10 for Pen 413 at MARC feedlot using the threshold determination method shown in figures 1 – 3, then dividing ECa by the established threshold. The bunk is located at the bottom of the map and waterer at lower left side.

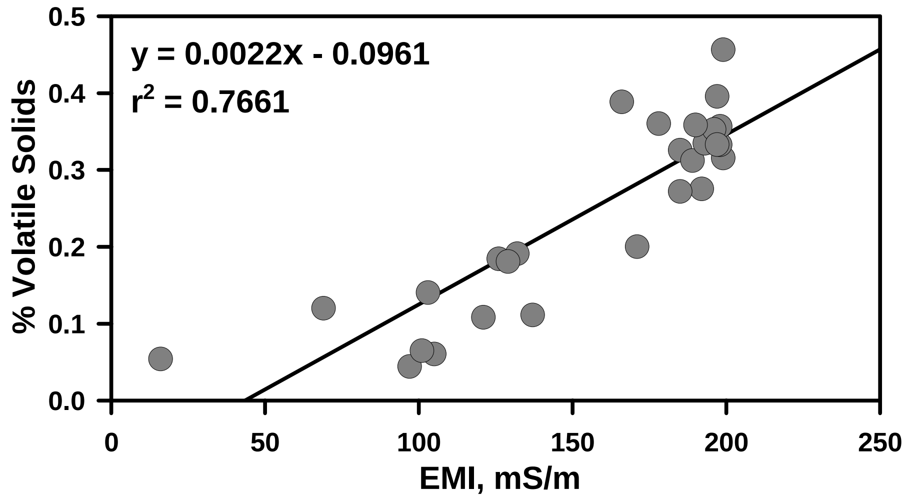

Figure 5. Association of EC_a values using electromagnetic induction (EMI) to volatile solids for data collected 10/18/04 on pens 412-415.

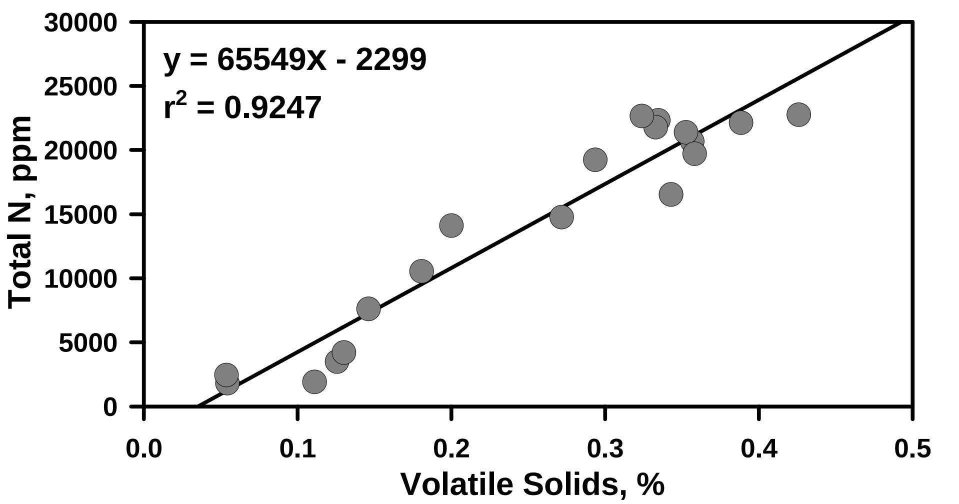

Figure 6. Association of volatile solids and total N based on cattle feedlot data. Data collected 10/18/04 on MARC feedlot pens 412-415.

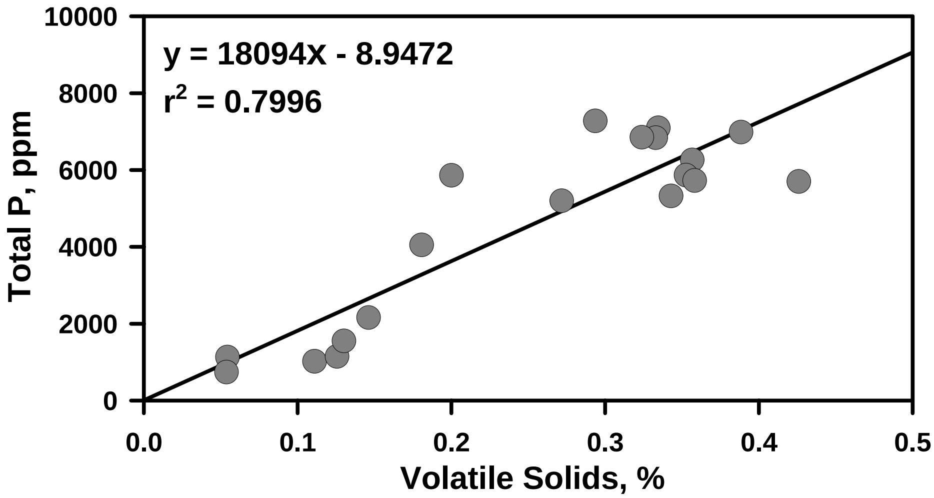

Figure 7. Association of volatile solids and total P. Data collected 10/18/04 on MARC feedlot pens 412-415.

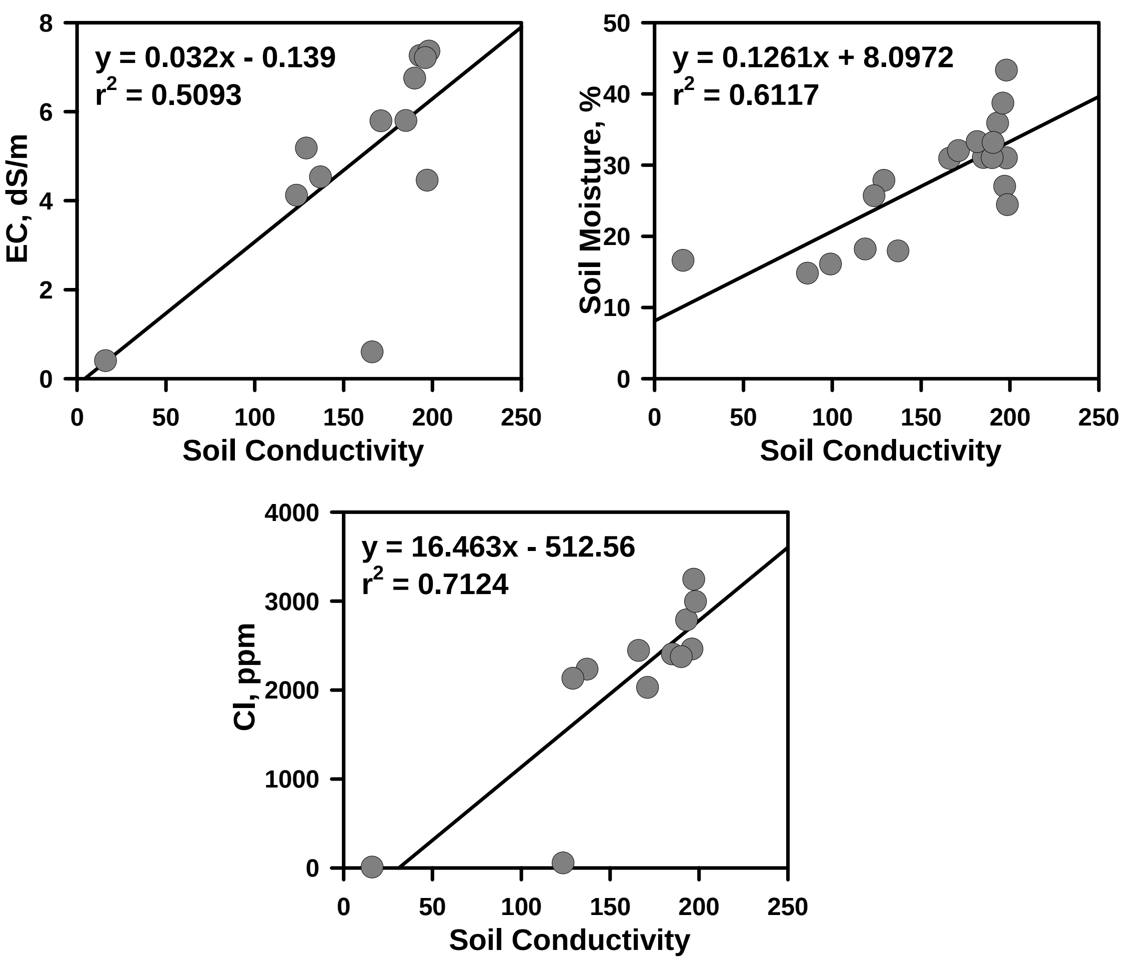

Figure 8. EC_a associations to soil EC, Cl, and moisture.