Characterizing and Mapping Field Scale Spatial Variability of Surface Horizon Soil Properties and Water Content with Noninvasive EM38

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Introduction

The measurement and characterization of soil physical properties at the field scale is increasingly important in agriculture and natural resource management. Changes in topography, parent material, management practices, erosion, etc., can influence the variability of the soil's physical properties. The Geonics EM38 is a noninvasive geophysical sensor that is used to measure the soils apparent electrical conductivity (Ec_a in milliSiemens/meter) through electromagnetic induction – primarily influenced by clay content, soil moisture content, and salinity. Soil moisture is a significant contributor to Ec_a, allowing the EM38 to be used to measure both the spatial and temporal variation in Available Water Content (AWC) across a landscape. This study combined detailed lab analysis of soil physical properties at 14 discrete locations, within the same field, with EM38 surveys to examine the ability of EM38 to quantify and map soils based on their physical properties and surface soil moisture (0-15cm) in the root zone.

Objectives

1. Determine the ability of an EM38 sensor to measure the spatial variability of soil physical properties at the field scale in coarse-textured/gravelly Piedmont soils of North Carolina and map characteristics using a Geographic Information System (GIS)
2. Calibrate and test the sensors ability to measure temporal variability of soil moisture in the root zone

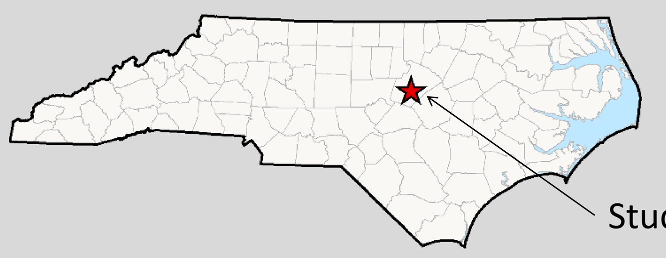
Significance

The ability of an EM38 sensor to perform real-time, on-the go sensing of key soil properties, such as soil moisture, means high resolution maps can be developed that will significantly aid in our understanding and management of soils. These maps can be used to direct soil sampling, placement of soil moisture sensors, and the delineation of management zones/soil restoration areas.

Materials and Methods

Study site description:

- A 1.65 hectare field at the NCSU Lake Wheeler Road Field Laboratory (LWRFL) in the Piedmont region of North Carolina **(Fig. 2)** was selected as the study site.
- The site was selected based on an initial EM38 survey, variable topography, input from LWRFL superintendent, cropping rotation, feasibility of in-season research, and proximity to NCSU campus.



Materials:

- Geonics EM38 geophysical sensor **(Fig. 1)** and 1.5 m tall PVC calibration stand
- Trimble Nomad 9600 DGPS (Differential GPS) unit with Farmworks Mobile 6.1 Software
- Slide hammer soil core sampler with sampling head and core sleeves
- Soil Push Probe

Fig. 1: EM38 sensor in the horizontal dipole position at field site

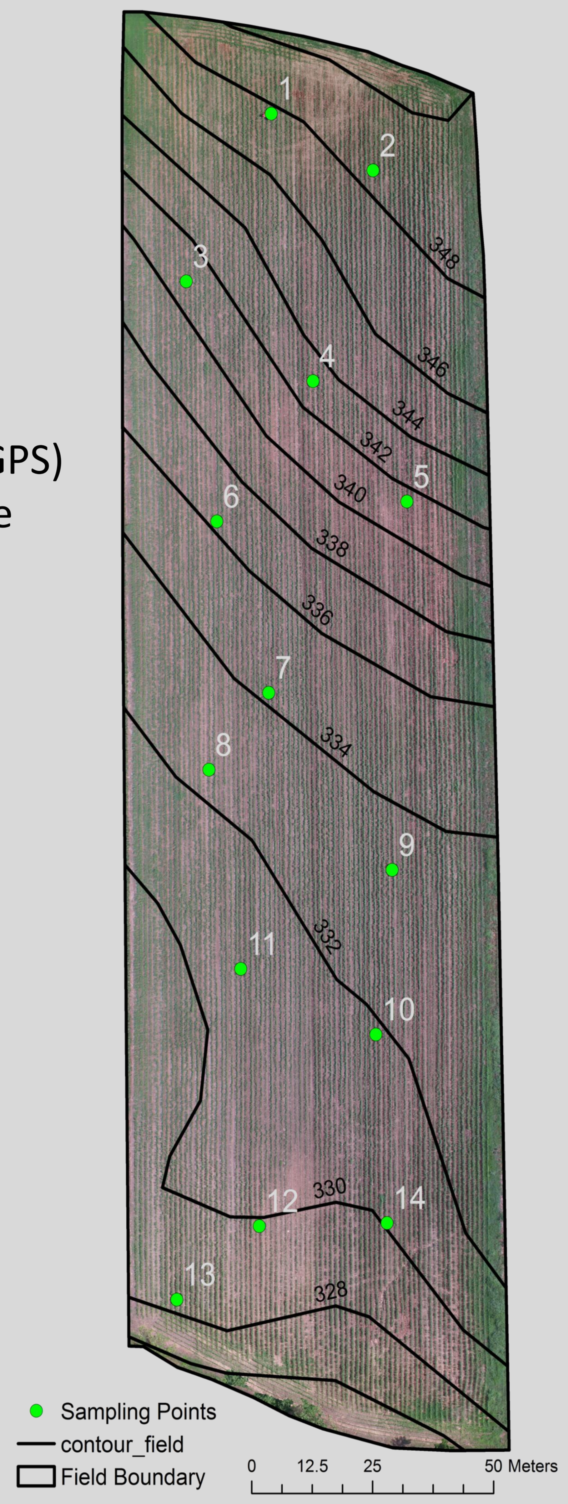


Fig. 2: UAS aerial image acquired at early season sorghum growth 6/26/2015

Experimental Methods

Soil Physical Properties:

- 14 sites selected based on an initial EM38 scouting, surface color, and spacing
- Soil cores were collected along 3 transects **(Fig. 2)**
- Soil cores collected at two depths (top 0-7.5cm, bottom 7.5-15cm) and used to calculate bulk density, volumetric water content, particle size, and water retention

EM38 Measurements:

- Discrete EM38 readings collected at each of the 14 locations
- Six readings were taken within a $2m^2$ area around each sample point
- All measurements were collected in the horizontal dipole mode (EC_a depth to 0.75m)
- Data collected on two separate dates with differing soil moisture, push probe samples were collected to calibrate EC_a to soil moisture

EM38 Survey:

- Field-level surveys conducted along North-South oriented furrows at a 6m transect spacing on two separate dates **(Fig. 5)**

Results

Soil Physical Properties

- Particle size analysis indicates small range of textural variation **(Fig. 3)**
- Gravel fraction within cores varied from 5% to 50% of soil core mass
- Available Water Content varied by 8% between core samples **(Fig. 7)**

EM38 and Soil Physical Properties

- Discrete readings of EM38 were highly variable within $2m^2$ area (σ: 0.4 -3.1 mS/m)
- 52% of EC_a value explained by the clay fraction of the soil matrix **(Fig. 4)**
- No significant relationship was observed between EC_a and bulk density
- Lack of droughty conditions limited ability to calibrate EC_a to soil moisture

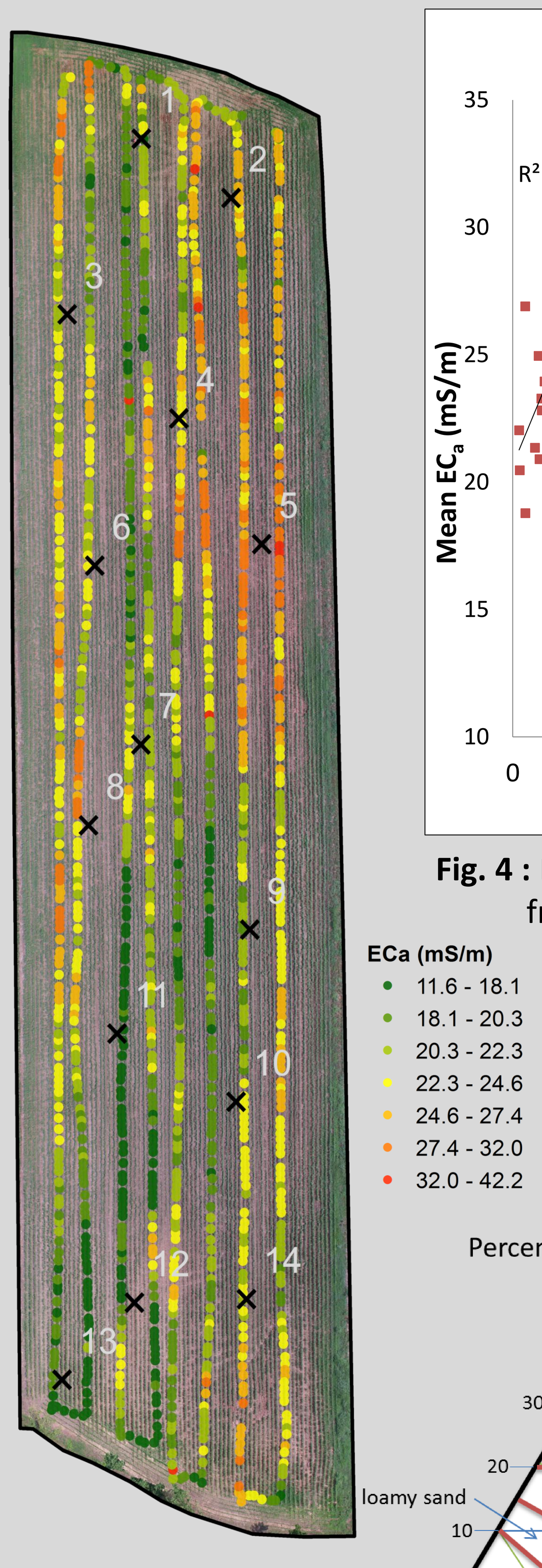


Fig. 5: Point data of EM38 survey taken 6/26/2015, excluding outliers

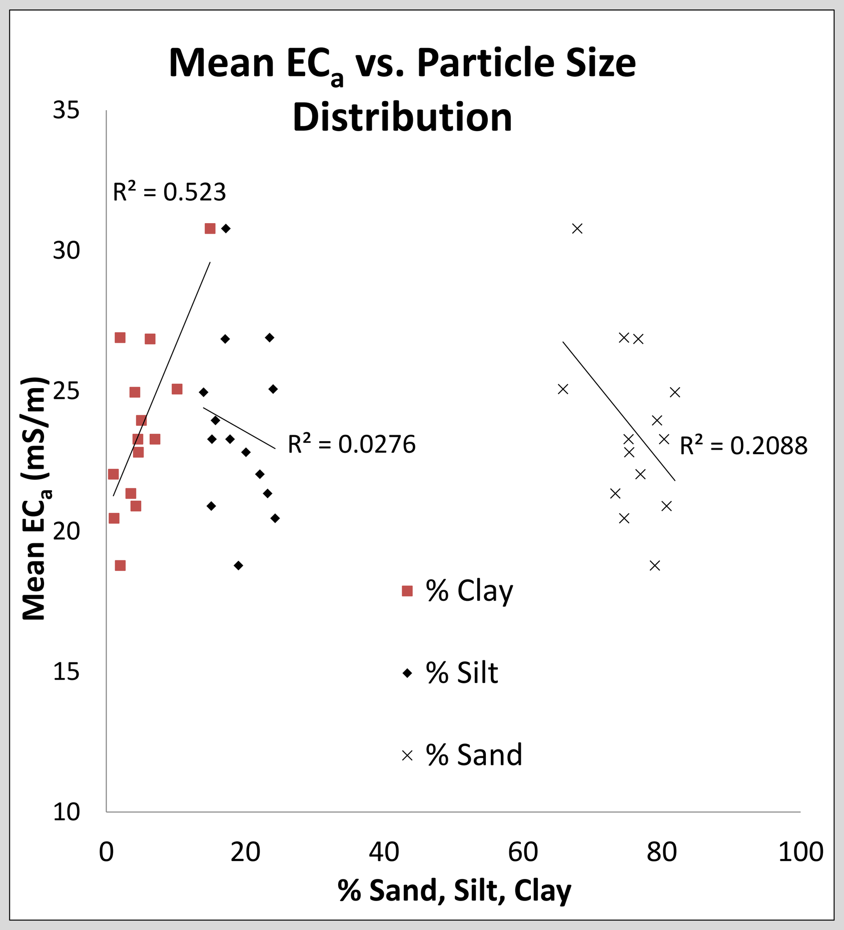


Fig. 4 : Discrete EC_a readings versus soil particle size fractions across the 14 sampling points

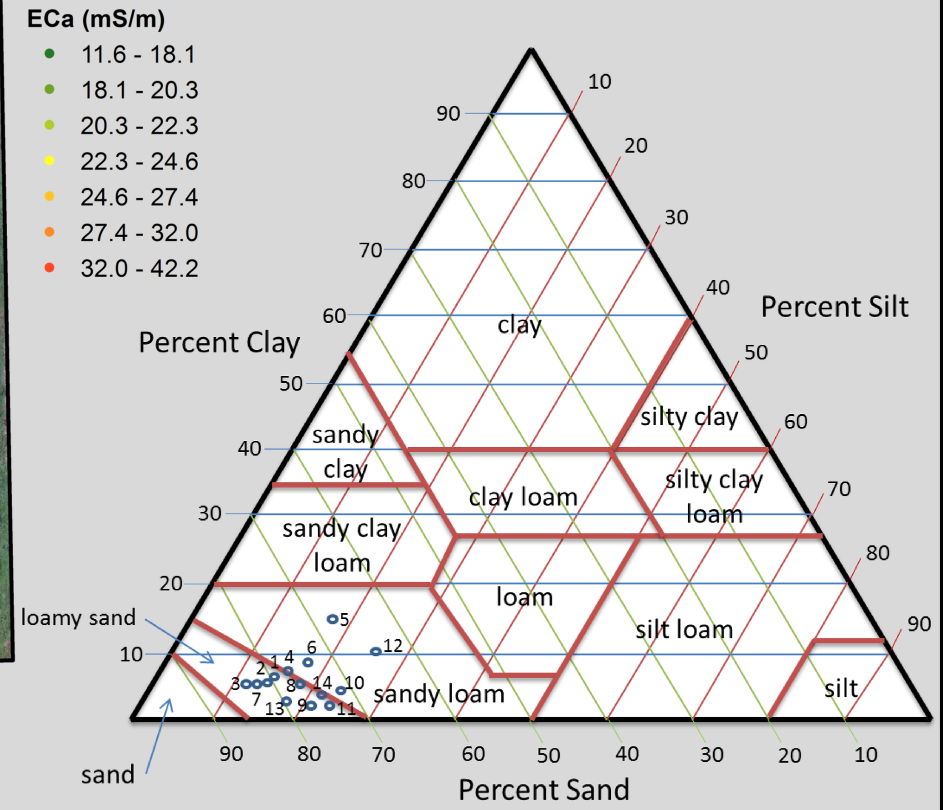


Fig. 3 : Textural classifications of top 15cm of soil profile at sample points

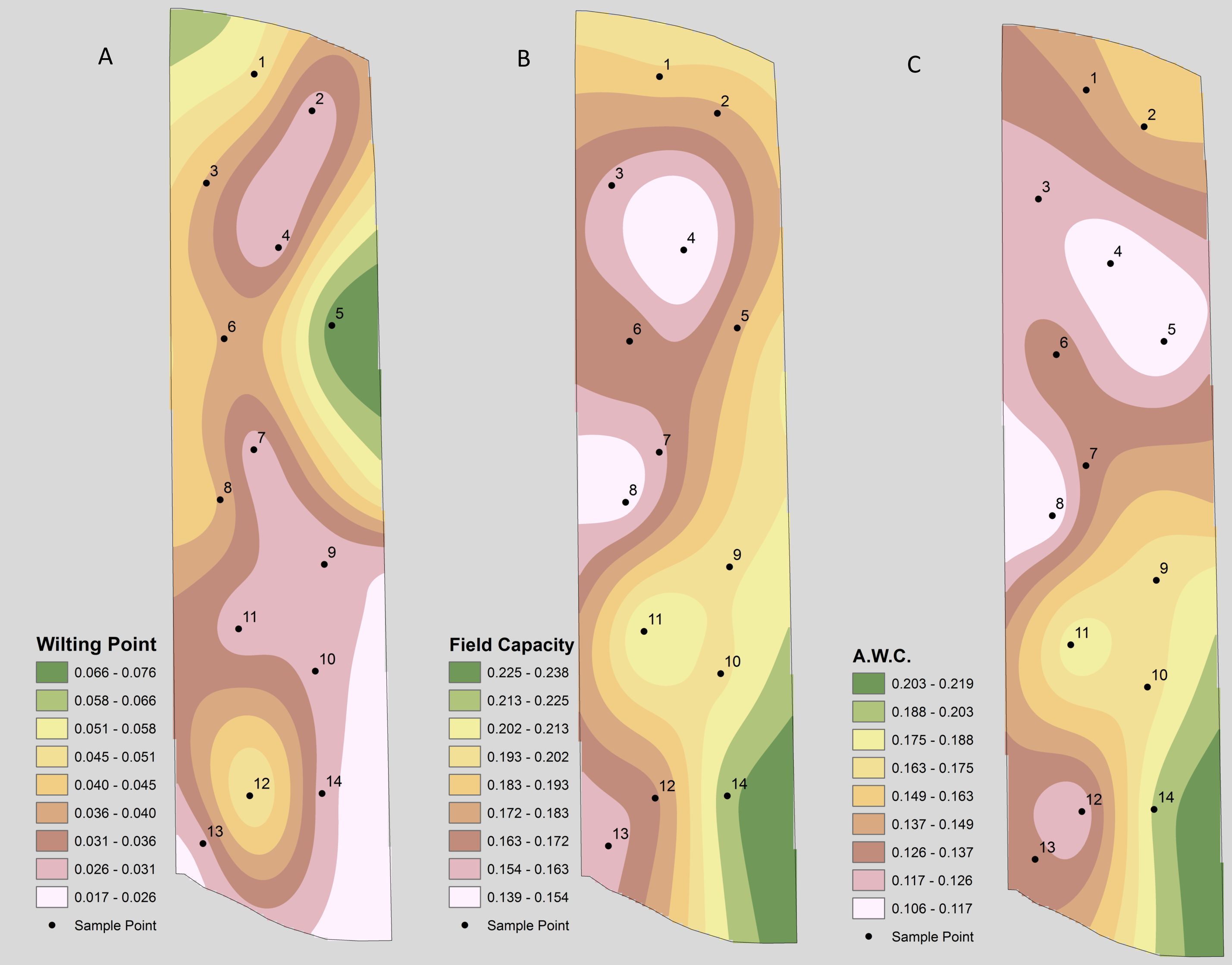


Fig. 6: Interpolations of soil water retention of the field's top .15m (plow layer), A – Field Capacity (FC @ -0.1 bar), B – Wilting Point (WP @ -15 bar), C – Available Water Content (FC – WP), reported as Θv (m^3 water/ m^3 soil). Total AWC within top .15m is $358m^3$ and varied by 11.3%

EM38 Survey

- Areas with high EC_a correspond well to areas of observed plant stress and low available water (higher clay content) **(Fig. 5, Fig. 6 – notably points 5 and 12)**
- High values from EM38 survey correspond well with areas of high surface clay content and observed soil surface color from aerial imagery. **(Fig. 3, Fig. 5)**
- Surveys able to detect spatial variability of soil physical properties at a much higher resolution than physical soil sampling techniques

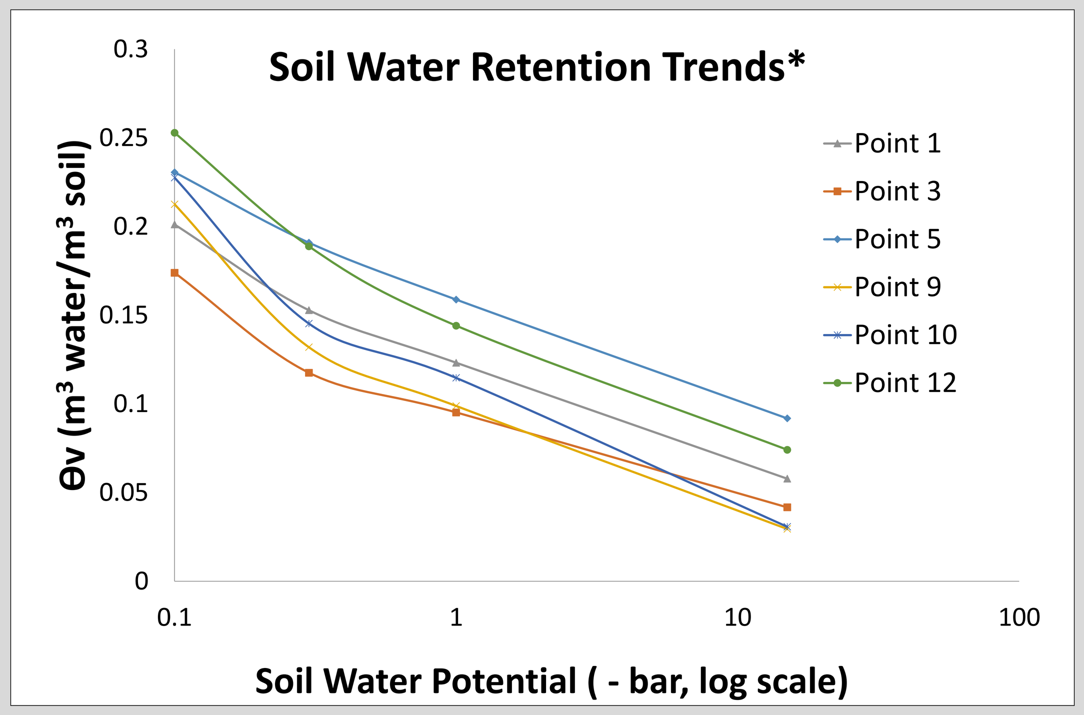


Fig. 7: Water retention data of a subset of sampling points *lines show trends, not water retention curves

Conclusions

- EM38 values are highly related to soil textural properties, particularly clay
- Maps can be developed to estimate soil water content using measured physical properties and spatial analysis
- EM38 is useful for measuring spatial variability of soil physical properties and has applications as a decision support tool to guide soil sampling, instrument placement, planting decisions, water management, etc.
- The resolution of EM38 data collected allows for further differentiation of soil physical properties beyond standard resolution soil surveys
- Variations in EM38 readings over small areas were significant, making interpretations difficult
- EC_a measurements reflect multiple soil properties (i.e. clay, moisture, etc.) and interactions between individual properties may confound data, making characterization difficult

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