Soil Scientists Revisit a High-Intensity Soil Survey in Northwest Illinois with Electromagnetic Induction and Traditional Methods

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abstract

Electromagnetic induction (EMI) and global positioning system (GPS) data were used with geographical information system (GIS) to improve a high intensity soil survey that was completed with traditional methods in northwest Illinois. Apparent conductivity (EC_a) maps provided additional layers of information, which improved knowledge of soils and directed soil sampling. The information provided by EC_a maps and additional soil sampling led soil scientists to recognize different soils and modify mapping concepts. Within the site, EC_a maps assisted the identification and delineation of soil polygons and improved the quality of the high-intensity soil map. While spatial EC_a patterns influenced the judgments of soil scientists, EC_a maps were not accepted as a substitute for a high-intensity soil map.

The availability of computers, digital soil maps and databases, global positioning systems (GPS), geographical information systems (GIS), and geophysical tools is changing the way we observe and map soils. Over the last decade, several studies have reported the synergistic use of these technologies to produce high-intensity maps for site-specific management (Adamchuk et al., 2004; Hedley et al., 2004; Corwin and Lesch, 2003; Godwin and Miller, 2003; Jaynes et al., 1995). In these studies, electromagnetic induction (EMI) was used to predict potential variations in crop yields. As a tool for site-specific management, EMI can be used to direct soil sampling, refine maps of a sparsely sampled soil property that can be related to EMI response, or collect ancillary data (Jaynes, 1996). Though widely used in site-specific management, the integrated use of EMI with allied technologies to produce high-intensity soil maps has been limited (Kitchen et al., 1998).

In Illinois, soil maps prepared at scales larger than 1:12000 are considered first-order or high-intensity soil surveys (Illinois Soil Survey Staff, 1999). Compared with the more common second-order soil surveys, which are prepared at smaller scales and typically on a county-by-county basis by USDA-NRCS, high-intensity soil surveys are prepared for smaller parcels of land using different concepts, field procedures, kinds of map units, and minimum delineation sizes. High-intensity soil surveys entail the collection of very detailed and comprehensive information, and the examination and identification of soils through more rigorous field procedures. Because first-order soil surveys are made to provide more precise information on soils within relatively small parcels of land, they require greater distinctions among small, relatively homogenous areas of soils (Soil Survey Division Staff, 1993). In first-order soil surveys, soil boundaries are observed along their entire lengths and their placement corresponds to changes in soil properties and landscape position (Illinois Soil Survey Staff, 1999; Soil Survey Division Staff, 1993). Map units for high-intensity soil surveys are mostly consociations. These map units are phases of soil series or miscellaneous areas and contain a minimum amount of dissimilar inclusions. Depending on the scale, the minimum delineation size is about 1.4 acres or smaller (Illinois Soil Survey Staff, 1999).

High-intensity soil surveys are expensive, time-consuming, and labor-intensive. To reduce the expenditure of these resources, alternative methods are being explored to ease and expedite fieldwork, provide more information, and improve the assessment of soils and soil properties. The preparation of high-intensity soil maps is a formidable task that will remain principally a private sector pursuit (Mausbach et al., 1993). However, the Soil Survey Division of the USDA-NRCS provides standards, models, guidance, and oversight for the development of high-intensity soil maps, especially as new tools and methods are used to facilitate these surveys.

Electromagnetic induction has demonstrated great potential for identifying inclusions in soil delineations (Fenton and Lauterbach, 1999). Because of its speed and ease of use, EMI has immense advantages over conventional tools and survey methods. Because of the larger number of measurements, maps prepared from EMI data can provide higher levels of resolution than soil maps prepared with conventional tools or survey methods (Jaynes, 1995).

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Electromagnetic induction measures the apparent conductivity (EC_a) of earthen materials. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific depth (Greenhouse and Slaine, 1983). The electrical conductivity of soils is influenced by the type and concentration of ions in solution, the amount and type of clays in the soil matrix, the volumetric water content, and the temperature and phase of the soil water (McNeill, 1980). The EC_a of soils will increase with increases in soluble salt, water, and/or clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

Interpretations of EMI data are based on the identification of spatial patterns within data sets. Though seldom diagnostic in themselves, lateral and vertical variations in EC_a have been used to infer changes in soils and soil properties (Kravchenko et al., 2002; Doolittle et al., 1996, 1994; Sudduth et al., 1995; Jaynes et al., 1993). In many areas, spatial EC_a patterns correspond well with soil patterns shown on soil maps. As a consequence, EC_a maps have been recommended as surrogates for soil maps (Jaynes, 1995).

Mobile and pedestrian EMI surveys are commonly conducted with a field computer, which simultaneously records EC_a and GPS position data. The speed and ease with which data are recorded greatly reduces survey time and makes practical the surveying of large areas. Kitchen and others (2003, 2005) discussed the integration of EMI and GPS data to improve interpretations. The collection of EC_a and position data is seen as a practical method for improving high-intensity soil surveys. A routine and convenient method of interpreting georeferenced EC_a data is with graphic displays. Geographical information systems are considered the most effective tool to organize, manipulate, and display both soil and EC_a data (Corwin and Lesch, 2005). The purpose of this study was to use these technologies to improve the efficacy of survey procedures and the quality of a high-intensity soil survey.

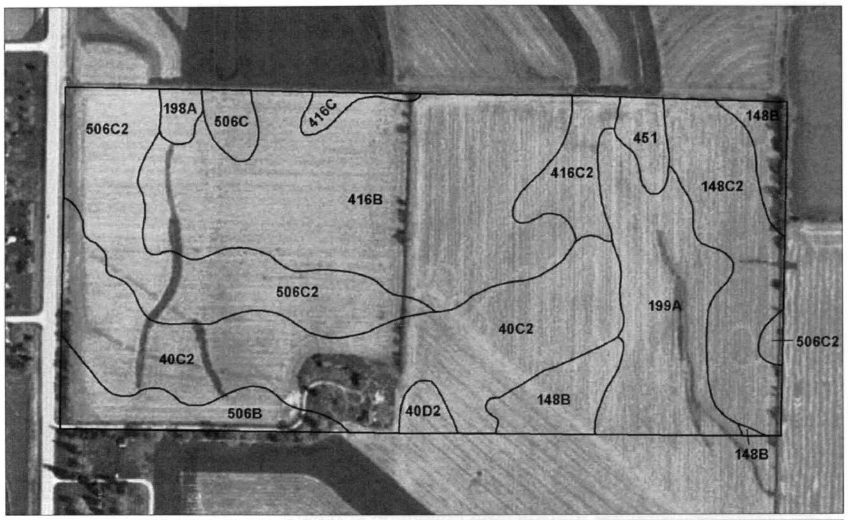

Fig. 1. Soil lines and map unit symbols from the 1976 second-order soil survey plotted on a recent orthophotograph of the study site.

Study Site

An 80-acre site consisting of two cultivated fields was selected for this study. The site is located just north of Freeport, Illinois, in the western half of Section 7, T. 27 N., and R. 8 E. The site is on a loess-covered till plain. The drift mantle is generally thin, and the landscape is largely controlled by the underlying bedrock surface (Ray et al., 1976). The site is underlain by dolomite of the Galena formation. The site is topographically diverse, with slopes ranging from 0 to 10%. Elevations ranged from about 860 to 915 feet. Two intermittent drainageways cross the site from south to north.

A second-order soil survey of Stephenson County, Illinois, was completed in 1976 (Ray et al., 1976). Figure 1 contains the soil lines and map unit symbols from the 1976 soil map (prepared at a scale of 1:20,000 and overlain on a recent orthophotograph of the site at a scale of 1:7920). Table 1 lists the names of the units that were mapped on the site in the 1976 survey. The present taxonomic classifications of all soils mentioned in this study are listed in Table 2.

Within the study site, variations in textural layering and parent materials are large. The boundaries that separate many soil components are not clearly expressed in the landscape. In the 1976 survey, soils were classified as Typic or Aquic Argiudolls, except along the lower portion of one drainageway where the soils were classified as a Cumulic Hapludolls. Soils (Dodgeville, Durand, Hitt, and Proctor) on higher-lying surfaces are well drained or moderately well drained and moderately deep (0.5–1 m) or deep (>1 m) to bedrock. These soils have a thin mantle of loess overlying limestone residuum, till, or medium-textured water-laid deposits (Ray et al., 1976). Soils (Elburn, Lawson, and Plano) on lower-lying surfaces are moderately well drained or somewhat poorly

Table 1. Soil legend for the 1976 second-order soil survey.

Map Unit Symbol	Soil Map Unit Name
40C2	Dodgeville silt loam, 4 to 7 % slopes, moderately eroded
40D2	Dodgeville silt loam, 7 to 12 % slope, moderately eroded
198A	Elburn silt loam, 0 to 2 % slopes
199A	Plano silt loam, 0 to 2 % slopes
148B	Proctor silt loam, 2 to 4 % slopes
148C2	Proctor silt loam, 4 to 7 % slopes, moderately eroded
416B	Durand silt loam, 2 to 4 % slopes
416C	Durand silt loam, 4 to 7 % slopes
416C2	Durand silt loam, 4 to 7 % slopes, moderately eroded
451	Lawson silt loam
506B	Hitt silt loam, 2 to 4 % slopes
506C	Hitt silt loam, 4 to 7 % slopes
506C2	Hitt silt loam, 4 to 7 % slopes, moderately eroded

Table 2. Soil taxonomic legend.

Soil Series	Taxonomic Classification
Ashdale	fine-silty, mixed, superactive, mesic Typic Argiudolls
Blackberry	fine-silty, mixed, superactive, mesic Oxyaquic Argiudolls
Clare	fine-silty, mixed, superactive, mesic Oxyaquic Argiudolls
Dodgeville	fine-silty over clayey, mixed, superactive, mesic Typic Argiudolls
Durand	fine-loamy, mixed, superactive, mesic Typic Argiudolls
Elburn	fine-silty, mixed, superactive, mesic Aquic Argiudolls
Frankville	fine-silty, mixed, superactive, mesic Mollic Hapludalfs
Hitt	fine-loamy, mixed, superactive, mesic Typic Argiudolls
Jasper	fine-loamy, mixed, superactive, mesic Typic Argiudolls
Knight	fine-silty, mixed, superactive, mesic Argiaquic Argialbolls
Lawson	fine-silty, mixed, superactive, mesic Cumulic Hapludolls
Mona	fine-loamy, mixed, superactive, mesic Oxyaquic Argiudolls
Plano	fine-silty, mixed, superactive, mesic Typic Argiudolls
Proctor	fine-silty, mixed, superactive, mesic Typic Argiudolls
Sawmill	fine-silty, mixed, superactive, mesic Cumulic Endoaquolls

drained, and deep to bedrock. These soils form in loess over medium-textured outwash, water-laid sediments, or silty alluvium (Ray et al., 1976).

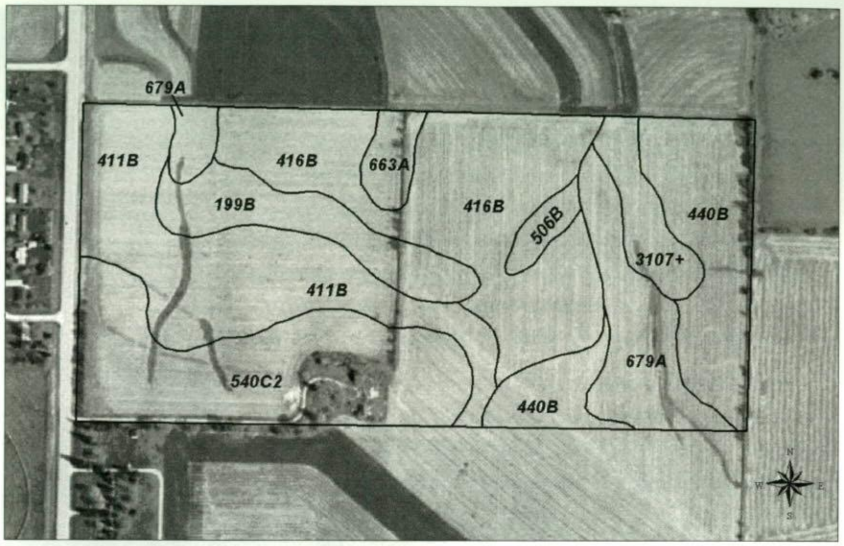

Fig. 2. The soil map of the first high-intensity soil survey of the study site shown on an orthophotograph.

Materials and Methods

Equipment

The EM38 and EM31 meters, developed by Geonics Limited, were used in this study.[1] The EM38 meter was mounted on a sled and towed along the ground surface behind an all-terrain vehicle (ATV). A Deere/Navcom Starfire GPS system was mounted on the ATV and used to collect position data. This system uses real-time kinematic differential correction (~2 cm horizontal accuracy) and maintains a radio link between a base station and the roving ATV. Data from the GPS receiver and EM38 meter were combined using the StarPal data collection software.

A pedestrian EMI survey was conducted with the EM31 meter. The Geonics DAS70 Data Acquisition System was used with the EM31 meter to record and store both EC_a and position data. The acquisition system consists of the EM31 meter, an Allegro field computer, and a Trimble AG114 GPS receiver. Data from the GPS receiver and EM31 meter were merged using the DAT31W software.

All soil maps were scanned and digitized using commercial software (ESRI Arc/Info, version 8.3). All spatial data were imported into ESRI ArcView (version 3.3). A triangular irregular network (TIN) was used to interpolate and convert the EMI and elevation data into a GRID/raster file.

Survey Procedures

In 2001, USDA-NRCS soil scientists, using conventional tools and survey methods and complying with the Illinois standards and specifications for high-intensity soil surveys (Illinois Soil Survey Staff, 1999), completed a first-order soil survey of the site at a scale of 1:7920. Soil scientists used spades and push probes (1-inch diameter; 60 inches long) to examine the soils.

In the fall of 2003, EMI surveys of the site were completed. The EMI surveys were completed with both meters operated in the vertical dipole orientation. When placed on the soil surface in the vertical dipole orientation, the EM38 and EM31 meters have effective penetration depths of about 5 and 20 feet, respectively (Geonics Limited, 1998; McNeill, 1980). Both meters were operated in the continuous mode with measurements recorded at 1-s intervals.

The ATV-mounted EM38 array was driven along parallel traverse lines spaced about 33 feet apart. A pedestrian survey was completed with the EM31 meter held at hip height along parallel traverse lines spaced about 100 feet apart. Although the surveyed area was the same for both instruments, because of these procedures, the sample size was noticeably smaller with the EM31 meter (5690 georeferenced EC_a measurements) than with the ATV-mounted EM38 meter system (11,170 georeferenced EC_a and elevation measurements). In large, open fields, the use of vehicular-mounted EMI systems results in increased sampling density and data acquisition efficiency (Freeland et al., 2002).

[1] Trade names throughout are used to provide specific information. Their mention does not constitute endorsement by USDA-NRCS.

On the basis of spatial patterns appearing on the resulting EC_a maps and knowledge gained through the 2001 high-intensity soil survey, nine pits were excavated to better understand and characterize the soils. Each pit was about 7 feet deep and 3 feet wide. Within each pit, the soil profile was described and sampled for laboratory analysis.

In the spring of 2004, a second high-intensity soil survey was completed at the site by the same soil scientists. Once again, the soil scientists used conventional survey tools and methods in compliance with the Illinois standards and specifications for high-intensity surveys, but were guided by the EC_a maps and the soil descriptions from the excavated pits. This survey was also completed at a scale of 1:7920.

Results

First High-Intensity Soil Survey

The first high-intensity soil survey of the site is shown in Fig. 2. The soil map units recognized in the high-intensity soil survey are listed in Table 3.

The increased resolution of large-scale maps typically results in the depiction of new soil patterns on soil maps (Hewitt, 1993). High-intensity soil surveys almost always produce a larger number of smaller-sized delineations for similar areas than second-order soil surveys (Van Wambeke and Forbes, 1986). In general, this is due to soil scientists being able to identify and record units that are too small to show on second-order soil surveys. In addition, high-intensity soil surveys almost always result in a greater number of map units. Frequently, areas that

Table 3. Soil legend for the May 2001 first-order soil survey.

Map Unit Symbol	Soil Map Unit Name
199B	Plano silt loam, 2 to 5 % slopes
411B	Ashdale silt loam, 2 to 5 % slopes
416B	Durand silt loam, 2 to 5 % slopes
440B	Jasper silt loam, 2 to 5 % slopes
506B	Hitt silt loam, 2 to 5 % slopes
540C2	Frankville silt loam, 5 to 10 % slopes, eroded
663A	Clare silt loam, 0 to 2 % slopes
679A	Blackberry silt loam, 0 to 2 % slopes
3107+	Sawmill silt loam, frequently flooded, overwash

are represented as transitional or included areas on second-order soil survey maps can be represented as distinct soil polygons on high-intensity soil survey maps. These two characteristics of first- and second-order soil surveys were not completely fulfilled within the study site. The second-order survey recognized fewer soil series (7 vs. 9), but more map units (13 vs. 9) and more soil polygons (15 vs. 11) than the first high-intensity soil survey of the site. These differences are attributed principally to the recognition of new soil series and the use of different phases in defining and naming map units. At the time of the second-order survey, soils were examined only to a depth of about 3.3 feet. Since then, new soil series have been introduced, and series concepts, soil depth classes, and phases used to name soil map units have changed. In the early 1990s, the "very deep" depth class was recognized as being greater than 4.9 feet. Many soil series formerly recognized as being deep were reclassified as very deep when this latter criterion was established as a standard depth class.

Differences in series and phase concepts explain some of the disparities in line placement, and the number, location, and size of some soil polygons (Fig. 1 and 2). Comparing the two soil maps, boundary lines are not coincident. This is neither unusual nor unexpected. Valentine (1981) noted that when soil maps are prepared of the same area, but at different scales and intensities of soil mapping, boundary lines seldom coincide. Within the study site, many soils are taxonomically similar and share common limits in drainage, particle-size, and depth classes. As some observed soil properties straddled taxonomic breaks, soil scientists wrestled with the most appropriate taxonomic family and map unit to describe the soils. In less sloping areas of the site, changes in soils lacked adequate external expression, and polygon boundaries were more difficult to distinguish.

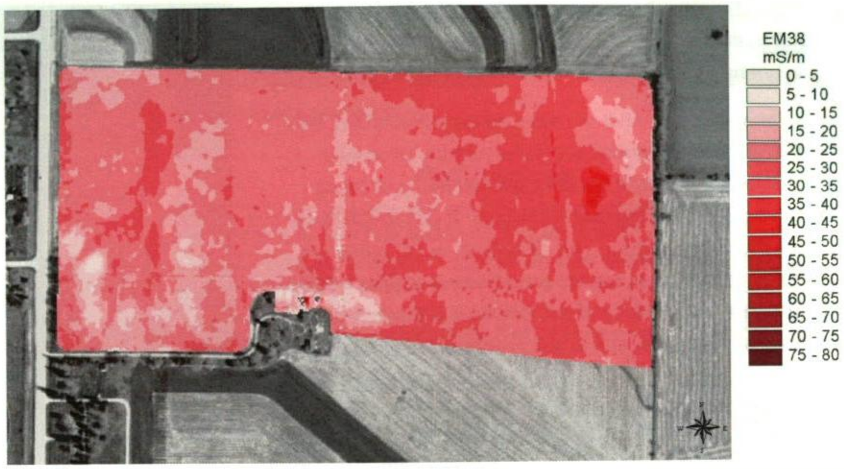

Fig. 3. Plot of EC_a data measured with the EM38 meter in the vertical dipole orientation.

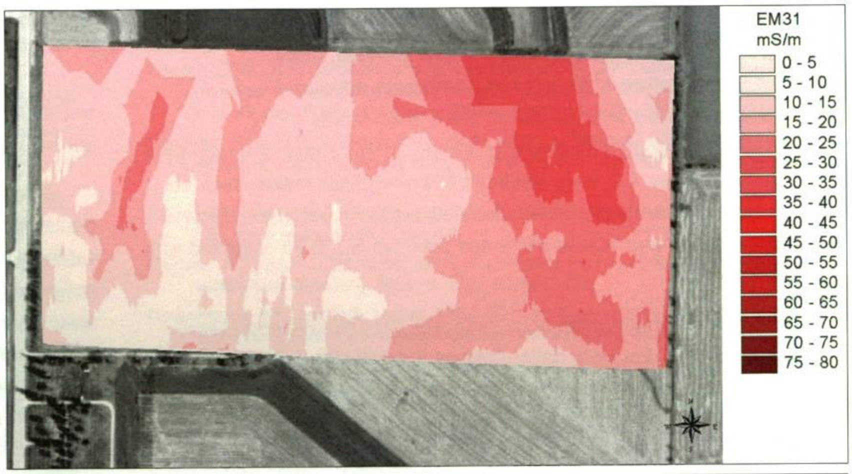

Fig. 4. Plot of EC_a data measured with the EM31 meter in the vertical dipole orientation.

EMI Surveys

A hypothesis of this study was that the EM38 meter would provide more meaningful information than the EM31 meter because of its more limited and appropriate depth of penetration (5 vs. 20 feet). In addition, compared with the pedestrian EM31 survey, the mobile EM38 survey produced a greater number and density of measurements, which resulted in more intensive coverage of the site and the distinction of smaller polygons.

With the EM38 meter, EC_a measurements averaged 22.9 mS/m, with a standard deviation of 4.2 mS/m. With the EM31 meter, EC_a was noticeably lower and slightly more variable. The EM31 measurements averaged 14.9 mS/m, with a standard deviation of 5.0 mS/m. Differences in the measured responses of the two EMI meters were attributed primarily to the greater penetration depth of the EM31 meter. As a consequence, on upland areas, the depth-weighted response of the EM31 meter was more influenced by deeper, electrically more resistive materials (dolomite bedrock).

Plots of EC_a data collected with the EM38 and EM31 meters are shown in Fig. 3 and 4, respectively. Although absolute values vary, broad spatial patterns are similar in both plots. In general, with both meters, EC_a varied systematically with landscape position and soil drainage class. Higher EC_a was measured on lower-lying, wetter swales and drainageways. A relatively narrow drainageway in the western portion of the site is clearly expressed on both EC_a maps. However, the continuity and bifurcation of this drainage system and a second, less clearly expressed drainageway are more distinguishable in the data collected with the EM31 meter. In the eastern portion of the site, a relatively broad, lower-lying swale is distinguished by its relatively high EC_a, which reflects the higher moisture and possibly clay contents of the soils. In both maps, areas adjoining this broad drainageway display intermediate EC_a, suggesting intermediate water and clay contents, and/or depths to bedrock. Lower EC_a was measured on the higher-lying surfaces that dominate the west and southwest portions of the site. A moderate correlation (based on 11 auger observations, $r = 0.666$, significant at 0.02 level) was observed between EC_a (measured with the EM31 meter) and depth to bedrock. In this portion of the site, lower EC_a suggests shallower depths to bedrock. On this higher-lying surface, spatial EC_a patterns suggest that the underlying dolomite has been incised (see Fig. 3 and 4). The EC_a–bedrock relationship found on this landscape component was not replicated on lower-lying surfaces where variations in textural layering and soil water contents confounded interpretations.

Two traverses were completed with the ATV-mounted EM38 meter along a north–south trending field road, which divides the site into two nearly equally sized management units (Fig. 3). Drier and more compact soil materials along this trafficked road are responsible for this lower EC_a

lineation. Traverse lines for the EM31 meter were perpendicular to the roadway and too widely spaced to provide a sufficient number of observations to distinguish this feature.

The greater number of measurements recorded with the EM38 meter produced a greater number of smaller unit areas with intricate spatial patterns. Many of these unit areas are too small and numerous to be identified on a high-intensity soil map. The difference in EC_a between a large number of these smaller unit areas and the enveloping larger unit areas is slight. Slight differences in EC_a suggest slight differences in soil properties. Soil scientists considered many of these unit areas too small and composed of closely similar or identical soils, which do not need or were impractical to delineate as separate soil polygons. In addition, some of the smaller unit areas may reflect artifacts, background noise, or sensor errors.

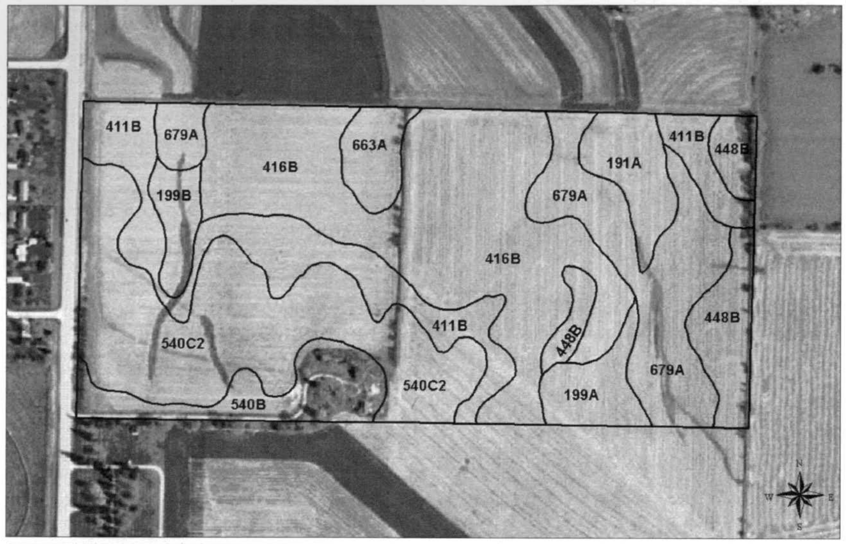

Fig. 5. The soil map of the second high-intensity soil survey of the study site.

Compared with the EM38 data, the EM31 data resulted in spatial EC_a patterns that are less intricate, more continuous and inclusive. As a result, these data appeared more comprehensible and useable to the soil scientists conducting the second high-intensity survey. At this site, in the judgment of the soil scientists, EC_a data collected with the EM31 meter provided better-expressed and more easily identifiable spatial patterns, which resulted in more interpretable unit areas than the EC_a data collected with the EM38 meter.

To better understand the soils, nine pits were excavated in separate soil map units that were delineated on the first high-intensity soil map. Soil scientists used the data collected with the EM31 meter (Fig. 4) to identify a representative site within each of these soil map units. Within each of the selected soil polygons, the most ubiquitous EC_a unit area was selected. The locations of several sampling sites were slightly adjusted based on visual observations made in the field. The pits exposed a larger soil section, which better revealed the properties of the underlying parent material(s) and helped resolve the identification of several soil consociations. In four of the nine pits, the occurrence of either a paleosol, till, lacustrine sediments, or bedrock was outside the established range of the recognized soil. As a consequence, more appropriate soils were used to identify these soil polygons.

Second High-Intensity Soil Survey

With each survey, more information became available to soil scientists about the site. For the first high-intensity survey, mapping rules were applied to this relatively small study site using more rigorous field methods—mapping rules were based on knowledge gained from previous surveys, which covered larger areas and were prepared at smaller scales using different conceptual models and map unit designs. Contradictions occurred where the additional information did not conform to the conceptual models. In the second high-intensity survey, using the knowledge gained from the EC_a maps and the excavated soil pits, soil scientists re-examined and refined their conceptual models of soil–landscape relationships and the rules for predicting the occurrence of soils on the landscape. For areas that are resurveyed with increasing levels of available information, this is an expected iterative process. Within the study site, this cognitive process resulted in the recognition of different soils, refinement of soil boundary line placement, and the delineation of additional soil polygons. The results of second high-intensity soil survey are shown in Fig. 5. The names of the soil map units recognized in this survey are listed in Table 4.

The two high-intensity soil survey maps are broadly similar and depict similar landforms. However, the second high-intensity survey exhibits more intricate soil lines and has smaller and more numerous soil polygons. Compared with the first high-intensity soil survey, the resurvey resulted in the recognition of a lesser number of soils (8 vs. 9), but a greater number of map units (10 vs. 9) and soil polygons (14 vs. 11). Variations in the two high-intensity soil maps are attributed to the variability of soil within the study site, the availability of additional soil information, and the refined judgments of the soil scientists.

This study confirms the difficulty in obtaining repeatable results when fields are resurveyed. Kitchen and others (1998), comparing three different first-order surveys of the same 88 acre field in central Missouri, noted the difficulty of obtaining repeatable results using traditional soil survey methods. Because of their subjectivity, soil boundaries drawn by soil scientists often lack repeatability (Fraisse et al., 2001). In areas that lack abrupt and contrasting soil properties and clear external expression of changes in soils, it is more difficult to accurately and precisely locate boundary lines between soil polygons (Hudson, 1992).

Maps of EC_a helped soil scientists distinguish soils by depth class and recognize additional soil components within drainageways. The EC_a maps helped to refine some polygon boundaries. However, in other portions of the site, spatial EC_a patterns were not clearly related to soils

Table 4. Soil legend for the May 2004 first-order soil survey.

Map Unit Symbol	Soil Map Unit Name
191A	Knight silt loam, 0 to 2 % slopes
199A	Plano silt loam, 0 to 2 % slopes
199B	Plano silt loam, 2 to 5 % slopes
411B	Ashdale silt loam, 2 to 5 % slopes
416B	Durand silt loam, 2 to 5 % slopes
448B	Mona silt loam, 2 to 5 % slopes
540B	Frankville silt loam, 2 to 5 % slopes
540C2	Frankville silt loam, 5 to 10 % slopes
663A	Clare silt loam, 0 to 2 % slopes
679A	Blackberry silt loam, 0 to 2 % slopes

and less useful to soil scientists. Apparent conductivity maps directed soil scientists to (what are believed to be) more representative sampling points (soil pits). Detailed descriptions of soils and parent materials at these sampling points lead to the refinement of conceptual models and the recognition of additional soils and map units.

Discussion

Soil scientists used EC_a maps to improve a high-intensity soil map. However, at this site, EC_a maps were not accepted as substitutes for soil maps. Soil scientists found some boundary lines for EC_a unit areas helpful in identifying some soil map units and locating some soil boundary lines. Nevertheless, at this site, most boundary lines for EC_a unit areas do not coincide with soil map unit boundaries. Many unit areas shown on EC_a maps were too small and numerous to be to be properly identified and delineated on the high-intensity soil map. In addition, most of these smaller EC_a unit areas represent similar, nonlimiting soil inclusions that are recognized in the soil consociations. Other EC_a unit areas were artifacts of field management.

Electromagnetic induction data are valuable to high-intensity soil surveys. Where available, EC_a data provide additional soil information, which can improve the quality of soil surveys. Polygon line placement and polygon content contribute to accuracy and quality of a soil map. Apparent conductivity maps were used to assist line placement and polygon content determinations, and improve a high-intensity soil map. At this site in northwest Illinois, EC_a maps were helpful precursors, but not substitutes for soil maps.

Summary

New technologies can help to make soil surveys more efficient and accurate, and facilitate the refinement of some soil–landscape models. In light of new and additional information, soil maps are not static. As new information become available and is integrated into soil surveys, changes in soil maps are inevitable. In many areas, variations in soils and soil properties can be inferred or associated with changes in EC_a. The EC_a maps provide additional layers of soil information, which can improve the recognition and delineation of soil polygons on high-intensity soil maps. In this study, EC_a maps were used to improve knowledge, identify sampling sites, recognize additional soil map units, and approximate the placement of some soil boundary lines. EC_a maps lead soil scientists to revise soil pattern rules used to predict the occurrence and distribution of soils in the landscape. However, at this site, EC_a maps were not accepted as a direct substitute for soil maps. Examination and interpretation of the EC_a maps resulted in some adjustment to the high-intensity soil map, but not the acceptance of all patterns shown on the EC_a maps. The use of EC_a maps alone to produce soil maps without the tacit soil knowledge of soil scientists is considered ill advised.

Not all soils are equally suited to EMI. Electromagnetic induction works best on soils with abrupt and contrasting EC_a. Here, boundaries of EC_a unit areas are more obvious and sharply defined. As a consequence, boundary line placement is less subjective. Lateral changes of subsurface properties must be interpretable. In general, EMI is most effective in soils where the effects of one property (e.g., clay, water, or salt content) dominate over the other properties. In these soils, variations in EC_a can be more confidently associated with changes in the dominant property. The use of EMI is more successful in soils that have a minimal sequence of dissimilar textural layers. Soils with a large number of dissimilar textural layers are more likely to produce ambiguous interpretations that limit the effectiveness of EMI. Further studies are needed to assess the suitability of EMI for high-intensity soil surveys on different soils and terrains.

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In Memoriam—Roy W. Simonson

Roy W. Simonson
1908–2008

Roy W. Simonson, 100, of Oberlin, a soil scientist, died November 2, 2008 at Kendal at Oberlin.

He was born September 7, 1908 in Agate, North Dakota and was trained in soil science at the North Dakota Agricultural College, where he received his B.S. degree in 1934, and the University of Wisconsin, where he received his Ph.D. degree in 1938. He then accepted a position at Iowa State College to supervise soil surveys and teach classes. There he met and married Susan Miller of Albia, IA.

In 1943, he was offered the position of Soil Correlator for the USDA Division of Soil Survey in the southeast, and moved to Knoxville, TS. At the conclusion of World War II, he was loaned to the Military Geology Unit to spend a year mapping soils on islands in the Western Pacific.

In 1949, Dr. Simonson was transferred to the Washington, DC area to become assistant chief of the Division of Soil Survey. He held that post until1952, when all survey activities were consolidated into the Soil Conservation Service. In this reorganization, he supervised the classification, correlation, and nomenclature of soils throughout the United States as director of Soil Classification and Correlation until retiring in 1973. Over the years, his work included field studies of soils on every continent except Antarctica.

After Roy retired, he taught at the University of Maryland and was editor-in-chief of Geoderma until stepping down in 1988. Roy and Susan moved to Kendal at Oberlin in 1993. He was a Research Associate of Oberlin College from 1994 to 1999.

He is survived by sons Bruce M. (Sue) Simonson of Oberlin; Walter M. (Louise) Simonson of Suffern, New York; four grandchildren; three great grandchildren; and a sister, Grace Gerard of Colorado Springs. He was preceded in death by his wife of 54 years, Susan M. in 1996, parents Otto and Johanne Simonson, five sisters, and one brother.

Memorial contributions may be made to the Stephens Education Fund of Kendal at Oberlin, 600 Kendal Dr., Oberlin, OH 44074. The fund is used to support any Kendal employee wishing to further their education.

Roy's 100th birthday party.