Methods for the analysis of salt-affected soils

Rich Ferguson, David Hoover

United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Soil and Plant Science Division (SPSD), Kellogg Soil Survey Laboratory (KSSL), Lincoln, Nebraska, USA

INTRODUCTION

This poster offers an overview of approaches used by NRCS-SPSD to assess salt-affected soils. There are three current approaches: 1. Conventional laboratory analysis; 2. Predictive laboratory analysis; 3. Proximal sensing. "Conventional" analysis refers to traditional wet-chemical approaches.

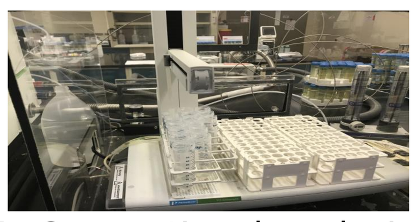

Fig 1. Conventional analysis

Regarding predictive analysis, the interconnectedness of soil properties is exploited to estimate certain soil properties as functions of others – by statistically "connecting the dots" among the various soil properties. A growing example of this is mid infrared (MIR) spectrometry, that uses MIR spectral features to reliably estimate many soil properties.

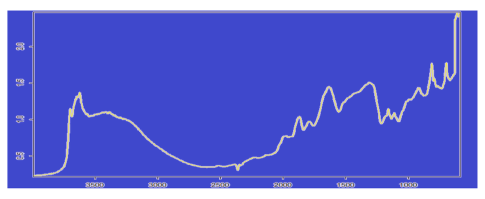

Fig 2. An MIR spectrum

For proximal sensing, NRCS-SPSD uses electromagnetic induction (EMI) to assess soil salinity, for characterizing soil water content, assessing variations in soil texture, determining the depth to subsurface horizons, etc. For EMI to be an effective sensing tool, the soil property being investigated must influence the "apparent" soil conductivity.

Fig 3. EMI in action

METHODOLOGY

NRCS-SPSD methods for conventional analysis of salt-affected soils are listed in Table 1, and documented in the SSIR-42 (KSSL Laboratory Methods Manual). A fundamental parameter is electrical conductivity. Method 4F1 employs a 1 to 2 soil water mixture; the EC measurement determines whether a saturated paste extraction (4F2) is warranted.

Table 1. KSSL methods

Conventional Laboratory Method	Method Code, NRCS Soil Survey Investigations Report-42
Electrical conductivity - "predict"	4F1
Saturated paste extraction	4F2
EC	4F2
Cations: NH_4^+, Ca^{2+}, Mg^{2+}, K^+, Na^+	4F2
Anions: Cl^-, SO_4^{2-}, HCO_3^-, NO_3^-, etc.	4F2
pH	4F2
Ammonium acetate (pH7) exchangeable Ca, Mg, K, Na	4B1
Cation-exchange capacity (pH 7)	4B1
Exchangeable sodium percentage (ESP)	4F3
Sodium adsorption ratio and (SAR)	4F3
Gypsum	4E2
Calcium Carbonate Equivalent	4E1

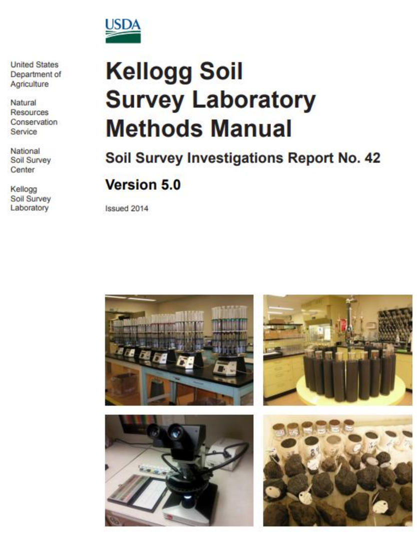

Fig 4. KSSL methods manual

MIR analysis requires spectral data collection on known samples (e.g. archived soils) capturing the compositional variability of targeted soil resources that calibrations are intended to serve. Calibrations are then derived by modeling the MIR spectra to the reference data (e.g. gypsum, carbonates, etc.)

For EMI, an electric current flows through a coil, producing a magnetic field near the soil surface. The soil responds with a secondary electric current detected by the instrument. Spatial conductivity patterns are then mapped and correlated with soil salinity.

RESULTS

Established, conventional analysis methods need little introduction on their merits. The focus today will be on MIR and EMI.

Fig 5 illustrates the growing coverage of the KSSL MIR spectral calibration library obtained by scanning samples in the expansive KSSL soil archive. As the MIR spectral library expands to underrepresented areas (in the USA and globally), more soil compositional variability is captured in local calibrations, making MIR more broadly applicable and more accurate.

Fig 5. Growing MIR coverage in the USA; KSSL soil archive

NRCS-SPSD piloted the use of MIR at its Salina, Kansas field office. A diverse group of true test samples from a >200,000 km² target area were also analyzed at the KSSL using conventional methods. Comparison results are in Fig 6.

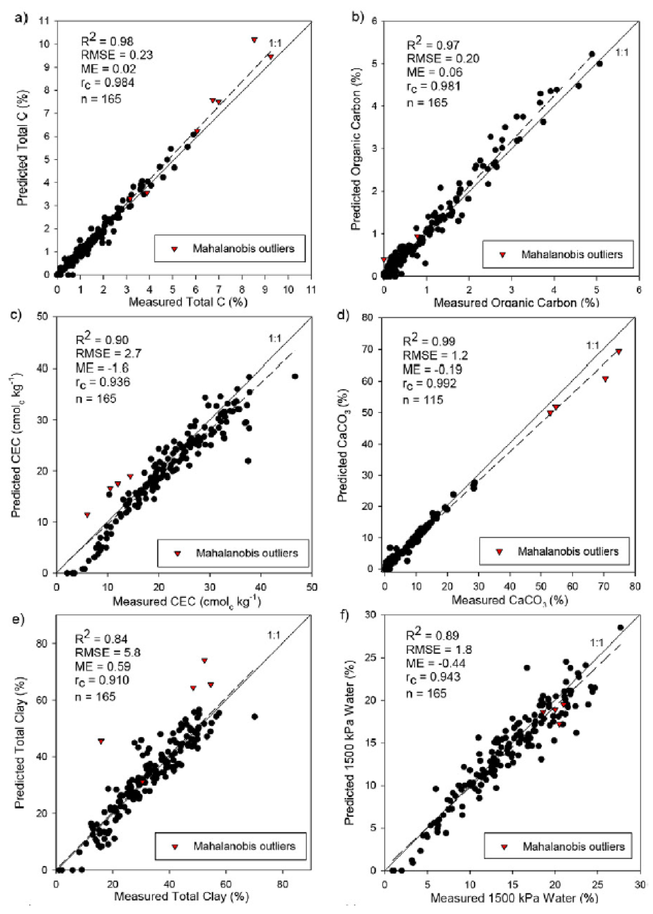

Fig 6. Pilot project results

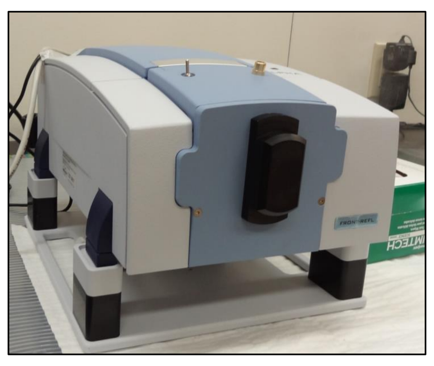

Fig 7. Field office MIR spectrometer

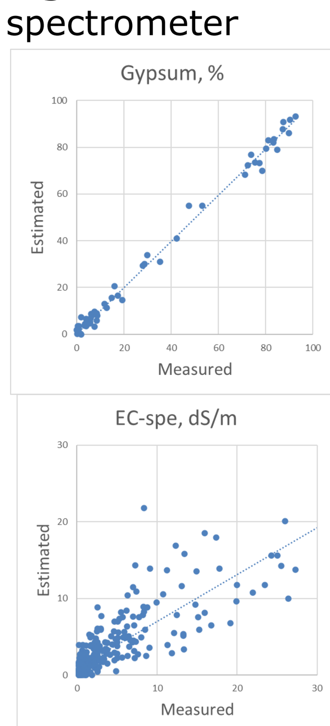

Fig 8. MIR advantages and limitations

Fig 8 illustrates advantages and limitations of using MIR to assess salt-affected soils for Southwestern USA soils.

EMI is used to assess differences in soluble salt contents across landscapes. EMI can be tied to laboratory data to calibrate EMI performance. Studies have confirmed that EMI provides reasonably accurate estimates of soil salinity at field scales; e.g. Fig 9. It takes only 4 hours to map 20 hectares by foot! Longer instruments can observe down to 6 meters!

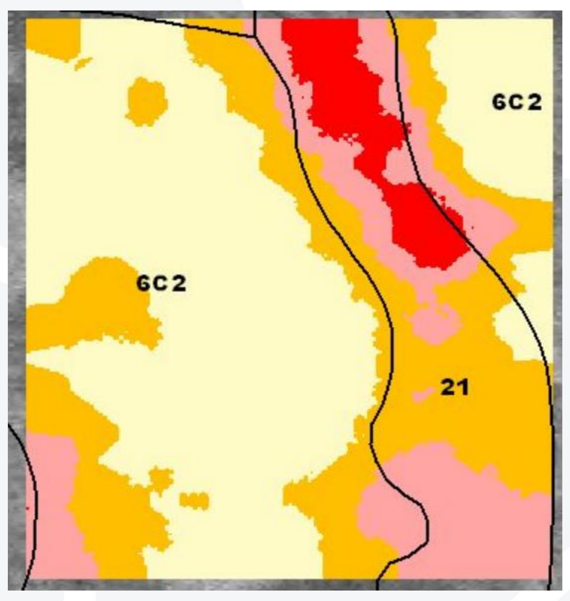

Fig 9. Example of EMI-derived salinity map

CONCLUSIONS

A goal of soil characterization is to make decisions regarding best use and management of soils affected by salinization or sodification.

Conventional analyses have a time-honored place in soil science. Quality reference data collections are now powering predictive methods like MIR spectroscopy to rapidly and reliably estimates many soil properties. Success has resulted in further investment by NRCS-SPSD in MIR, now deployed from Puerto Rico to Alaska.

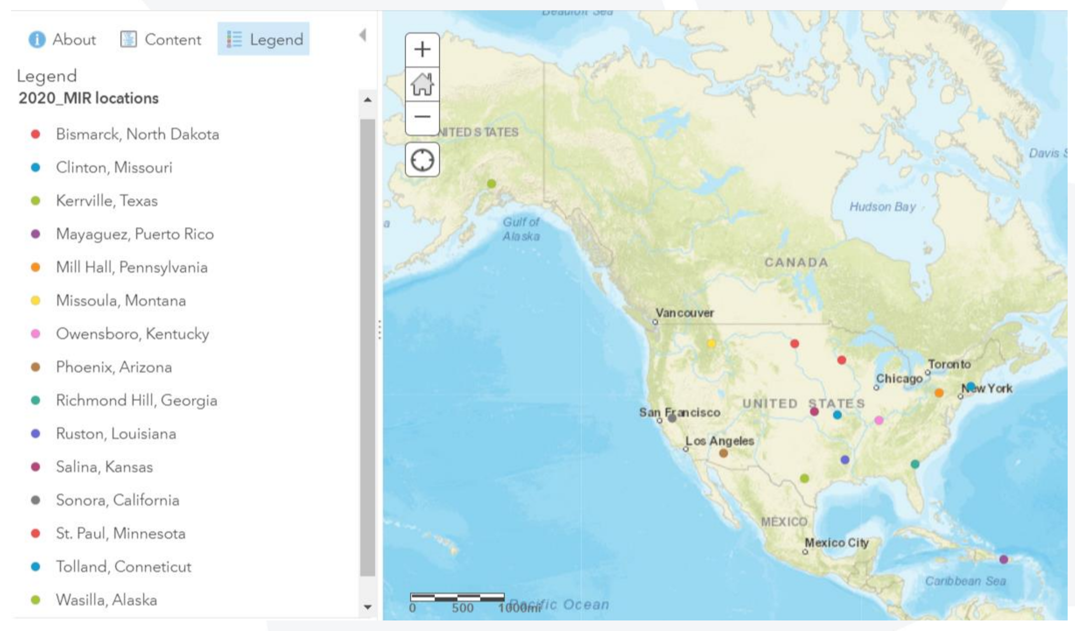

Fig 10. Current MIR deployment at NRCS field offices

Many, but not all, soil properties lend themselves to being accurately estimated from MIR spectra. Gypsum and calcium carbonate equivalent afford spectral calibrations with attractive RMSEs. EC? Not as good! Reason: Soil properties (like gypsum) with well defined spectral features result in better calibrations! (Good news: EC is easy to measure; also, alternative modeling approaches under development stand to improve errors.)

EMI offers a fast proximal sensing method for assessing soil salinity at field scales and is useful for guiding irrigation water and drainage management, as well as precision agriculture.

REFERENCES

Doolittle et al. 2014. The use of electromagnetic induction techniques in soil studies. Geoderma 223: 33-45, and references therein.

Seybold et al. 2019. Application of mid-infrared spectroscopy in soil survey. Soil Science Society of America Journal 82:1746-1759, and references therein.

Soil Survey Laboratory Investigations Report No. 42, version 5.0, 2014, and references therein.

All images courtesy of USDA-NRCS-SPSD

For more information, please contact dave.hoover@usda.gov or rich.ferguson@usda.gov

GLOBAL SYMPOSIUM ON SALT-AFFECTED SOILS

20 - 22 October, 2021