AN INCOMPLETE HISTORY OF PROXIMAL SOIL SENSING

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Presentation goal:

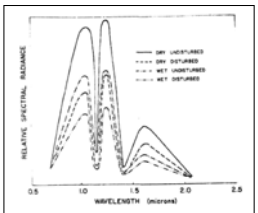
- Describe some of the history of proximal soil sensing, with particular emphasis on:
  - Diffuse reflectance spectroscopy
  - Soil electrical resistivity/conductivity
  - Tillage draft and soil strength
  - Soil chemical constituents
- Apologies in advance for the things I've left out – after all, the title does say "incomplete"!

Diffuse reflectance spectroscopy of soil

- Had its beginnings in the color descriptions long used by soil scientists
- Although a human "sensor" was still used, a key step toward quantification was the Munsell color system developed in the early 1900s and adopted by USDA in the 1930s

Diffuse reflectance spectroscopy

- In the 1960s the literature exploded with numerous reports of spectral characteristics of soils and other natural features
  - Earth observation satellites – Landsat program began in 1966
  - Remote sensing and photo interpretation for intelligence gathering in "natural scenes"



From Myers and Allen, 1968

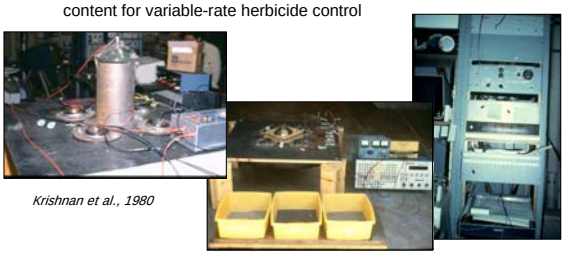
Diffuse reflectance spectroscopy

- In the 1970s several groups were active:
  - The Laboratory for Agricultural Remote Sensing (LARS) at Purdue University collected diffuse reflectance data from numerous soils in field and laboratory experiments

Montgomery, O. L. and Baumgardner, M. F., "The Effects of the Physical and Chemical Properties of Soils on the Spectral Reflectance of Soils" (1974). *LARS Technical Reports.* Paper 134.

Diffuse reflectance spectroscopy

- In the 1970s several groups were active:
  - Soil scientists and engineers at the University of Illinois began a project to relate soil reflectance to organic matter content for variable-rate herbicide control



Krishnan et al., 1980

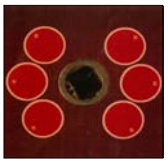
Diffuse reflectance spectroscopy

- In the 1980s research prototypes moved to the field:
  - Ongoing University of Illinois research focused on near-infrared reflectance over a wide range of wavelengths


Sudduth, 1989; Sudduth and Hummel, 1993

Diffuse reflectance spectroscopy

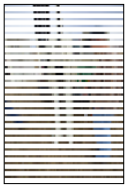
- In the 1980s research prototypes moved to the field:
  - Purdue University research using red light led to the first commercial reflectance-based sensor and control system



Shonk and Gaultney, 1991

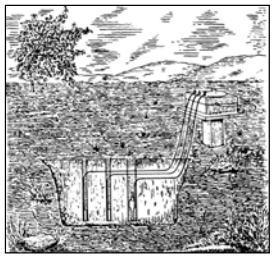
Diffuse reflectance spectroscopy

- After a bit of a gap, work relating diffuse reflectance to soil properties took off in the last 10-15 years
  - New calibration methodologies
  - Different soil properties
  - Global vs. local calibrations
  - Availability of prototype and commercial instruments for both lab and field use

Soil electrical resistivity/conductivity

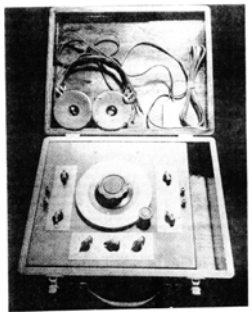
- In the late 1800s researchers at the US Bureau of Soils were investigating resistance measurements for soil moisture determination



Briggs, 1899

Soil electrical resistivity/conductivity

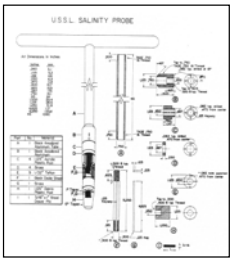
- In the mid 20th century, resistance measurement kits for moisture content were developed and tested



Bouyoucoos and Mick, 1948

Soil electrical resistivity/conductivity

- In the 1970s researchers in the arid west of North America used apparent conductivity as a measure of soil salinity with four-probe arrays, four-electrode hand probes, and early electromagnetic induction (EMI) instruments



Rhoades and van Schilfgaarde, 1976

Soil electrical resistivity/conductivity

- In the 1990s, EC_a began to be used to define variability in non-saline areas and various mobilized systems were reported

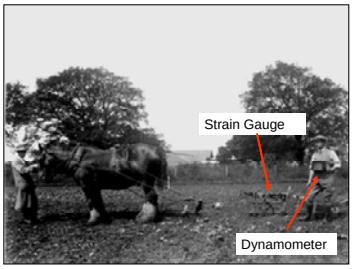
Carter et al., 1993

Soil electrical resistivity/conductivity

- Today a variety of commercial instruments are available to measure apparent conductivity of soils.
- Research continues on new applications
- Development of new sensing approaches is also ongoing

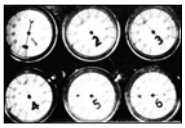
Tillage draft and soil strength

- The first known recording dynamometer for measuring tillage strength was developed in the 1920s by Keen and others



Tillage draft and soil strength

- Similar work was carried out in the 1930s in the USA, but forces were observed on gauges rather than being automatically recorded



Clyde, 1937

Tillage draft and soil strength

- Work on tool-soil interaction forces continued through the mid 20th century at places like Silsoe Research Institute in the UK and the National Soil Dynamics Lab in the US

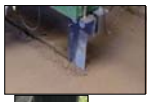
Field tests at Silsoe
Date unknown

Tillage draft and soil strength

Tillage tool tests in circular soil bin
National Soil Dynamics Lab
Date unknown

Tillage draft and soil strength

- In the last 20 years, focus has increased on measuring spatial variability of soil-tool forces, as an indication of site-specific compaction
  - USDA-ARS, Auburn, AL (Raper et al.)
    - On-the-go Soil Strength Sensor (OSSS)
    - One sensor tip, moves up and down



  - University of Nebraska (Adamchuk et al.)
    - Integrated Soil Physical Properties Mapping System (ISPPMS)
    - Blade-based sensor, measures total force and depth trend

Tillage draft and soil strength

- Cranfield University, UK (Godwin et al.)
  - Instrumented flaps on leading edge of a shank
  - Eight flaps to 40 cm depth

- University of Kentucky (Wells et al.)
  - Soil Coulterometer
  - Measures horizontal and vertical forces while oscillating between 10 and 30 cm depth

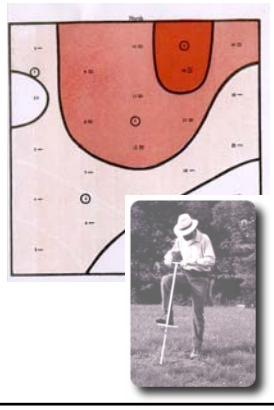
Tillage draft and soil strength

- University of California (Upadhyaya et al.)
  - Compaction Profile Sensor (CPS)
  - Five sensor tips to 40 cm depth

- USDA-ARS, Columbia, MO (Sudduth et al.)
  - Soil Strength Profile Sensor (SSPS)
  - Five sensor tips to 50 cm depth

Soil chemical constituents

- In the early 20th century, researchers were documenting variability in fields and suggesting that farmers map that variability and apply inputs accordingly
- This map shows grid soil samples tested for pH and suggested management zones for variable-rate lime application *(Linsley and Bauer, 1929)*

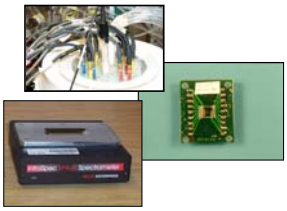


Soil chemical constituents

- Prototype field systems for soil nitrate and pH appeared in the 1990s

Soil chemical constituents

- Soil pH sensing is now commercially available
- Development continues on approaches for sensing nitrate, potassium, phosphorous and other soil nutrients



Summary

Hopefully this review has shown how past accomplishments, some perhaps nearly forgotten, form the foundation for today's research and development in proximal soil sensing technology

So, as you do your part to advance the field of proximal soil sensing, keep in mind these two old sayings:

There's nothing new under the sun

Those that do not remember the past are doomed to repeat it