Use of Geophysical Methods in Agriculture - Introduction

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East NTSC, 2:00 - 3:00 p.m. 21 August, 2012

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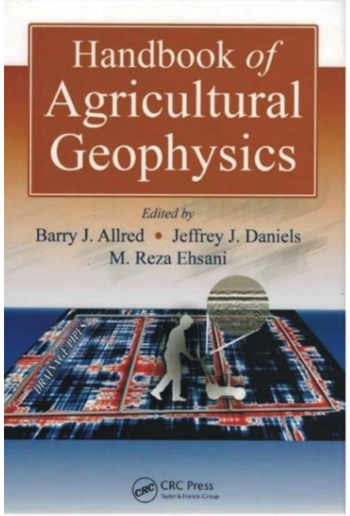
Barry J. Allred, USDA/ARS – Soil Drainage Research Unit

USDA

Agricultural
Research
Service

Recent Agricultural Geophysics Publications



Handbook *of* Agricultural Geophysics

Edited by
Barry J. Allred • Jeffrey J. Daniels
M. Reza Ehsani

CRC Press
Taylor & Francis Group

JOURNAL OF ENVIRONMENTAL AND ENGINEERING GEOPHYSICS

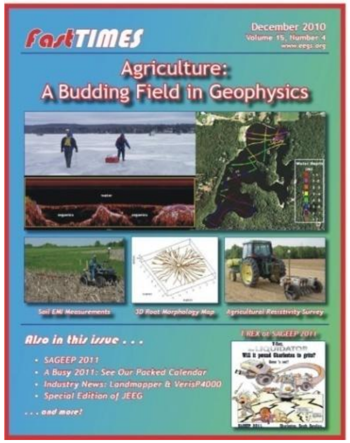
Journal of Environmental & Engineering Geophysics

September 2010 Volume 15 Issue 3
SPECIAL ISSUE
Agricultural Geophysics

Contents

September 2010 Volume 15 Issue 3

The Environmental and Engineering Geophysical Society



FastTIMES

December 2010
Volume 15, Number 4
www.eegs.org

Agriculture:
A Budding Field in Geophysics

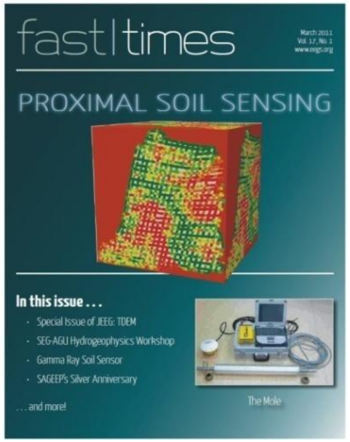
Soil EMI Measurements
3D Root Morphology Map
Agricultural Resistivity Survey

Also in this issue . . .

- SAGEEP 2011
- A Busy 2011: See Our Packed Calendar
- Industry News: Landmapper & VerisP4000
- Special Edition of JEEG

. . . and more!

T-REX at SAGEEP 2011



fast|times

March 2011
Vol. 17, No. 1
www.eegs.org

PROXIMAL SOIL SENSING

In this issue . . .

- Special Issue of JEEG: TDEM
- SEG-AGU Hydrogeophysics Workshop
- Gamma Ray Soil Sensor
- SAGEEP's Silver Anniversary

. . . and more!

The Mole

Recent Agricultural Geophysics Conferences and Workshops

Bouyoucos Conference on Agricultural Geophysics

September 8-10, 2009

Albuquerque, New Mexico

SAGEEP Workshop on the
"Application of Geophysical Technologies to Agroecosystems"

Charleston Marriot Hotel
Charleston, South Carolina
Thursday, April 14, 8:30 - 4:30 PM

Sponsored by

2011 Symposium on the Application of Geophysics to Environmental and Engineering Problems

Visit http://www.eegs.org/sageep to register for the workshop and/or the conference.

Workshop Overview

Geophysical methods have become an increasingly important tool for agricultural landscape management. The workshop covers past developments, present utilization, and future trends of geophysical techniques within agroecosystem topic areas that include soil salinity measurement, assessment of spatial variations of soil properties, precision farming, forestry research, watershed scale mapping, turfgrass investigations, and considerations for data collection/analysis.

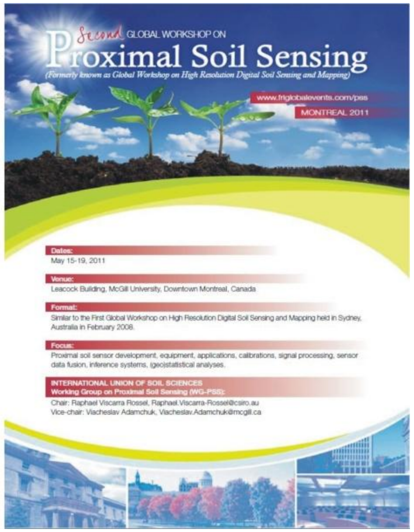
This unique workshop, which ends with a panel discussion focused on future developments, is expected to be highly informative as it brings together the leading authorities on applications of geophysical methods within agroecosystems.

For More Information:
Barry Allred
Barry.Allred@ars.usda.gov
614-292-9806

Historic Charleston, SC

Agenda

8:30 – 9:10	Agricultural Geophysics: Methods Employed, Past Success, and Current Trends ***Barry Allred**, USDA – ARS*
9:10 – 9:50	Soil Salinity Monitoring and Mapping ***Dennis Corwin**, USDA – ARS*
9:50 - 10:10	**Break**
10:10 - 10:50	Use of Geophysical Methods for Characterization of Soil Spatial Variability ***Jim Doolittle**, USDA – NRCS*
10:50 - 11:30	Incorporation of Geophysical Data for Precision Farming ***Hamid Farahani**, USDA - NRCS* ***Dennis Corwin**, USDA – ARS*
11:30 - 1:00	**Lunch**
1:00 - 1:30	Forest Environment Applications ***John Butnor**, USDA - Forest Service*
1:30 - 2:00	Agricultural Geophysics at Watershed Scales ***Bruce Smith**, U.S. Geological Survey*
2:00 - 2:30	Turfgrass Geophysical Surveying (golf courses, athletic fields, etc…) ***Robert Freeland**, University of Tennessee*
2:30 – 2:50	**Break**
2:50 – 3:30	Considerations for Planning an Agricultural Geophysics Survey, Collecting Data, and Interpreting Results ***Ty Ferré**, University of Arizona*
3:30 – 4:30	Panel Discussion and Wrap up "Future Development of Agricultural Geophysics" *Moderator, **Rick Taylor**, DUALEM, Inc.*



Second GLOBAL WORKSHOP ON
Proximal Soil Sensing
(Formerly known as Global Workshop on High Resolution Digital Soil Sensing and Mapping)

www.frigiobalevents.com/pss

MONTREAL 2011

Dates:
May 15-19, 2011

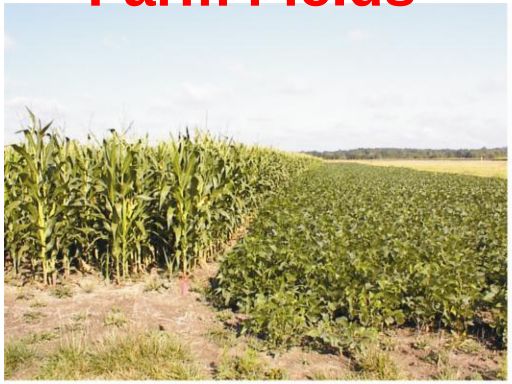
Venue:
Leacock Building, McGill University, Downtown Montreal, Canada

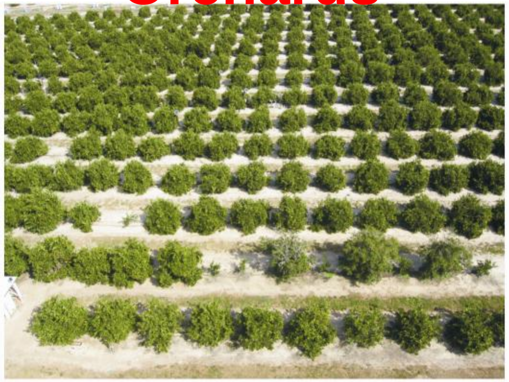
Format:
Similar to the First Global Workshop on High Resolution Digital Soil Sensing and Mapping held in Sydney, Australia in February 2008.

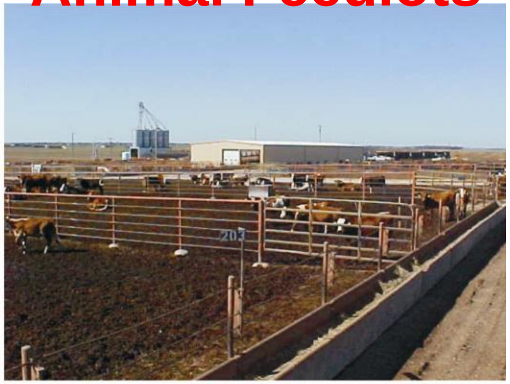
Focus:
Proximal soil sensor development, equipment, applications, calibrations, signal processing, sensor data fusion, inference systems, (geo)statistical analyses.

INTERNATIONAL UNION OF SOIL SCIENCES
Working Group on Proximal Soil Sensing (WG-PSS):
Chair: Raphael Viscarra Rossel, Raphael.Viscarra-Rossel@csiro.au
Vice-chair: Viacheslav Adamchuk, Viacheslav.Adamchuk@mcgill.ca

Geophysical methods can be applied to a variety of agroecosystems.


Farm Fields


Orchards

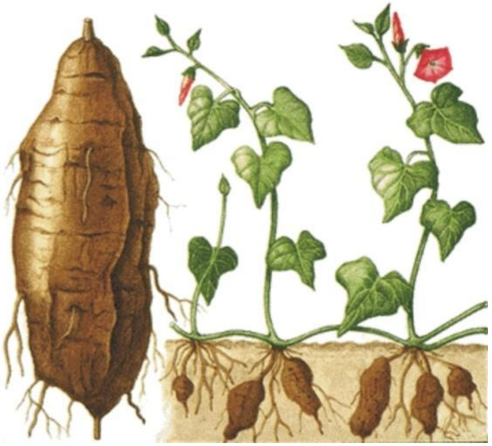


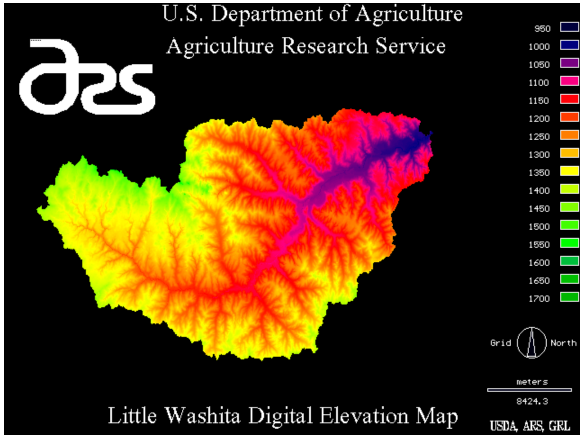
Animal Feedlots


Managed Forests


Turfgrass Areas

Scales of Geophysical Investigation





Agroecosystem geophysical measurements often tend to exhibit substantial variability.

Temporal

Soil Electrical Conductivity = *f*(Temperature, Water Content)
Soil Dielectric Constant = *f*(Water Content)

Spatial

Horizontal Changes
Vertical Changes

To date, the predominant geophysical methods employed for agricultural applications have included resistivity, electromagnetic induction, and ground penetrating radar.

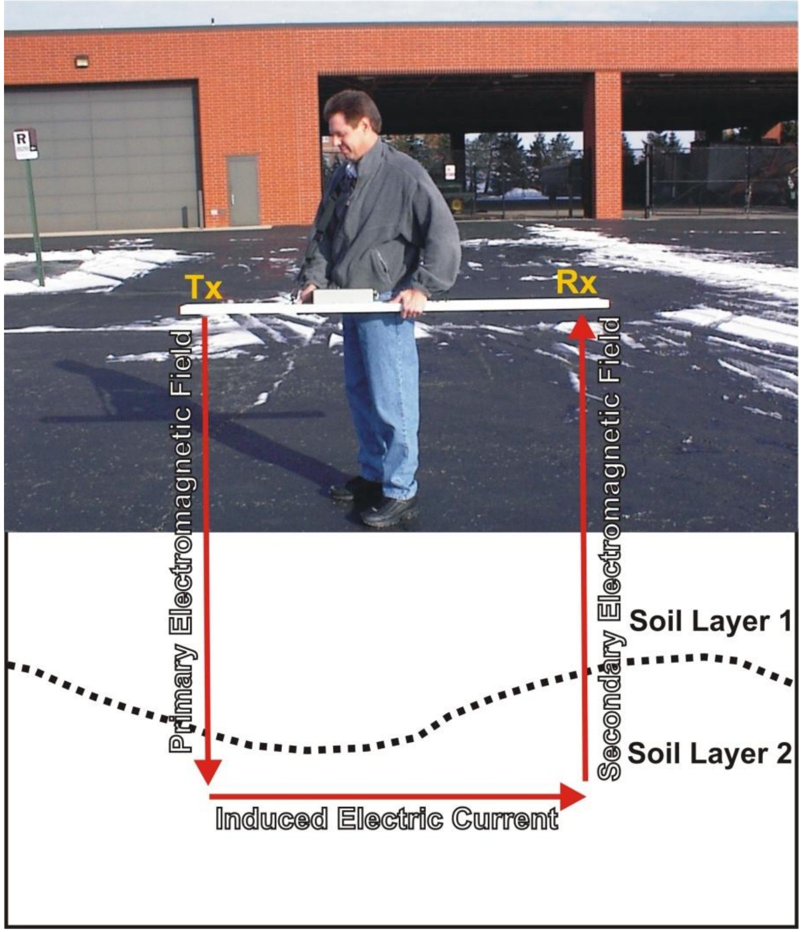
Resistivity

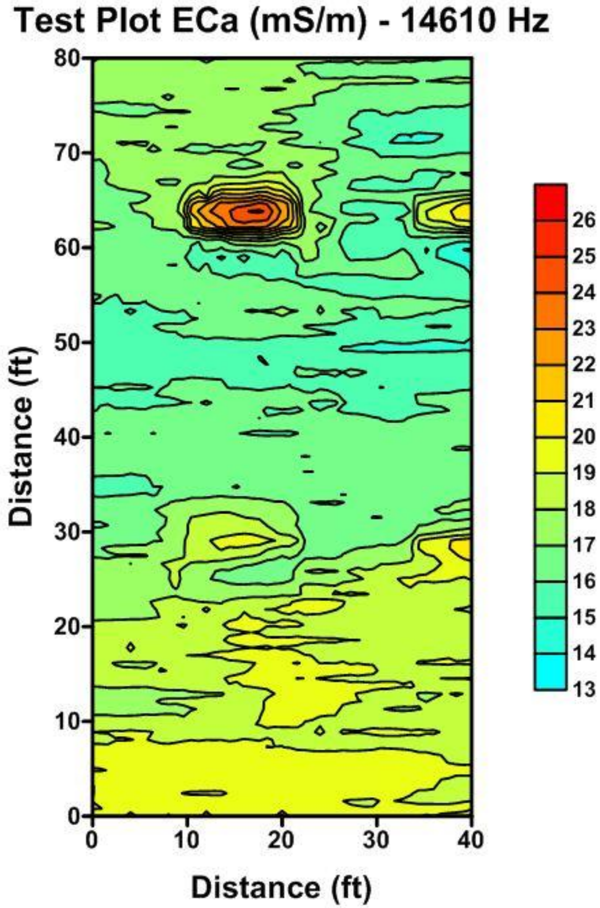
Electromagnetic Induction

Ground Penetrating Radar

Electromagnetic Induction

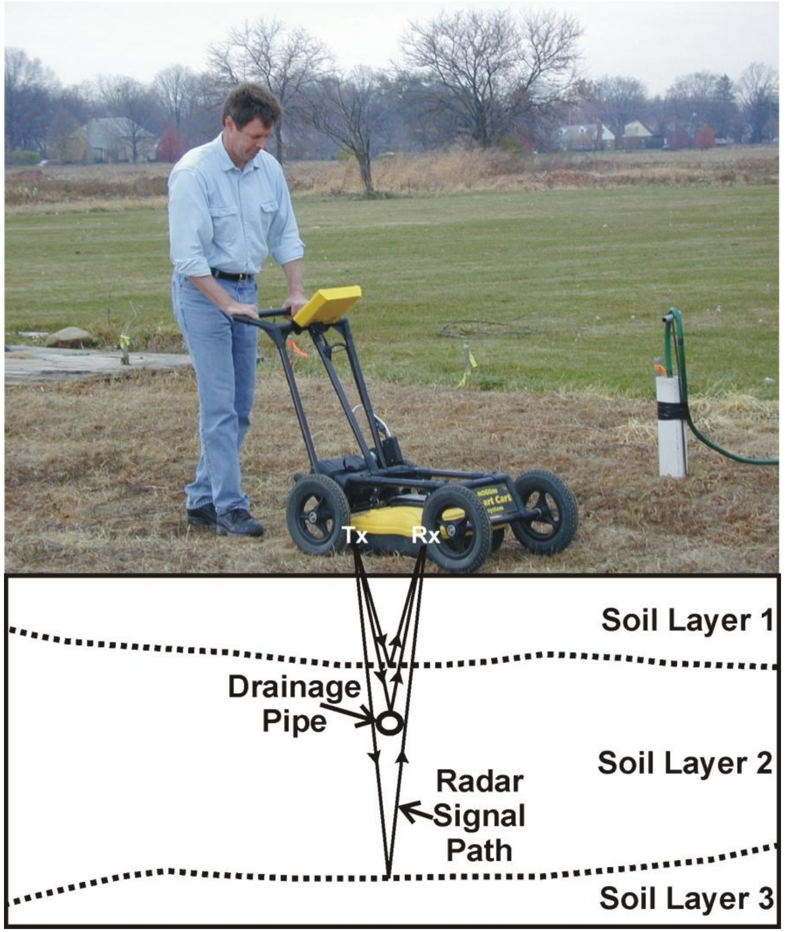
Principles of Operation and Data Analysis

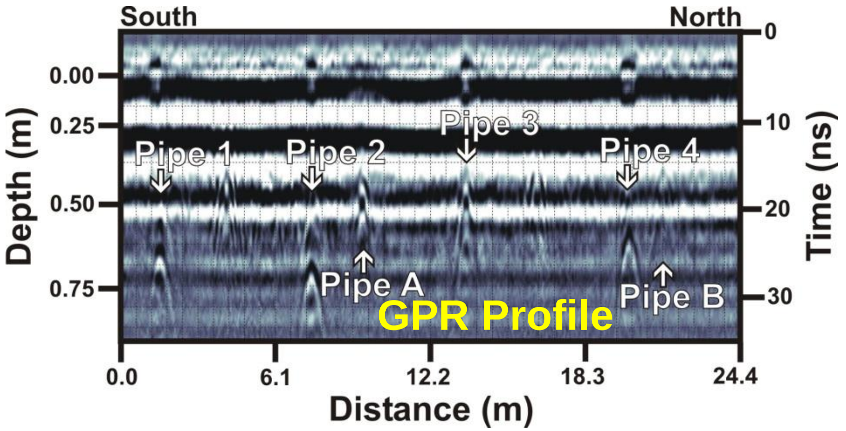


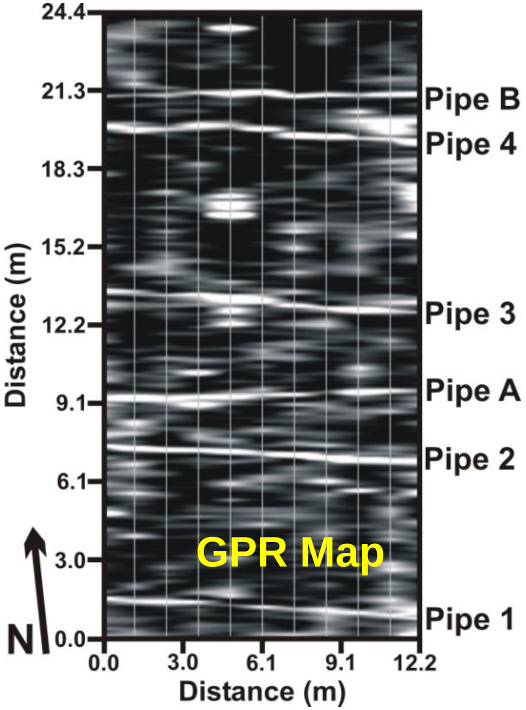


Ground Penetrating Radar

Principles of Operation and Data Analysis



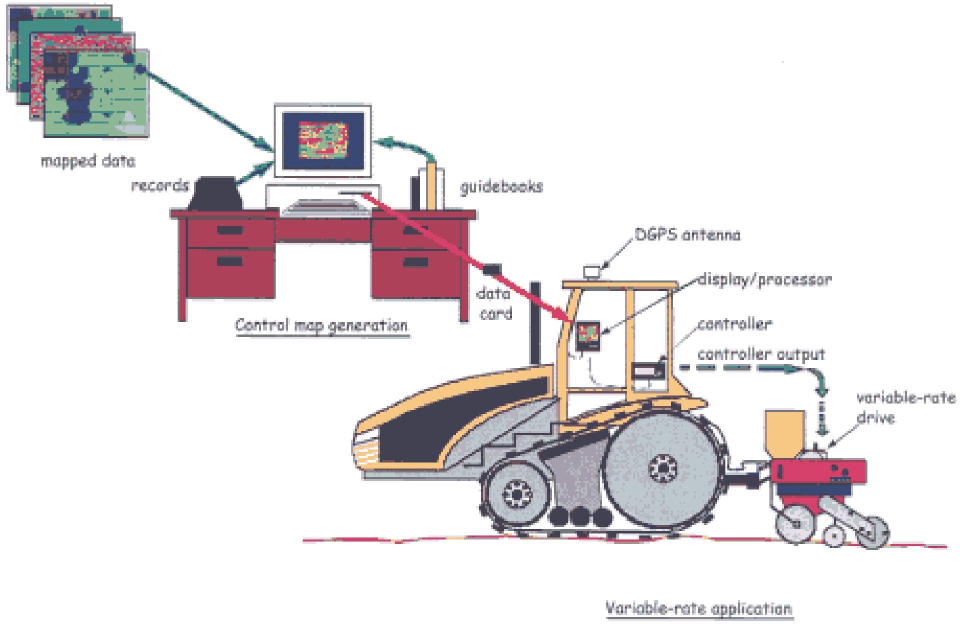


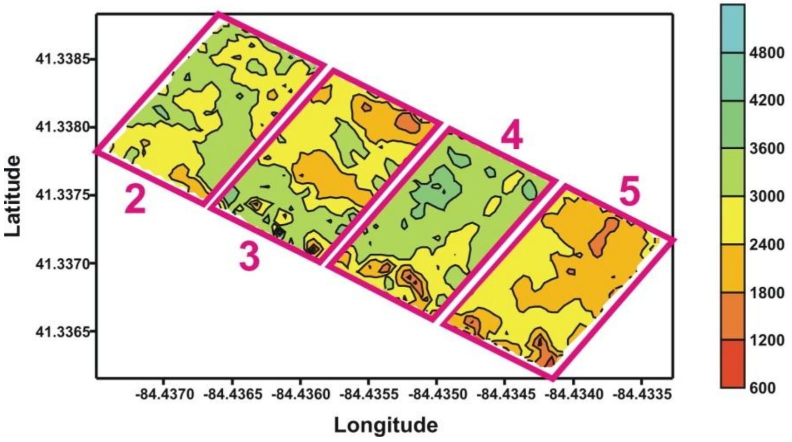


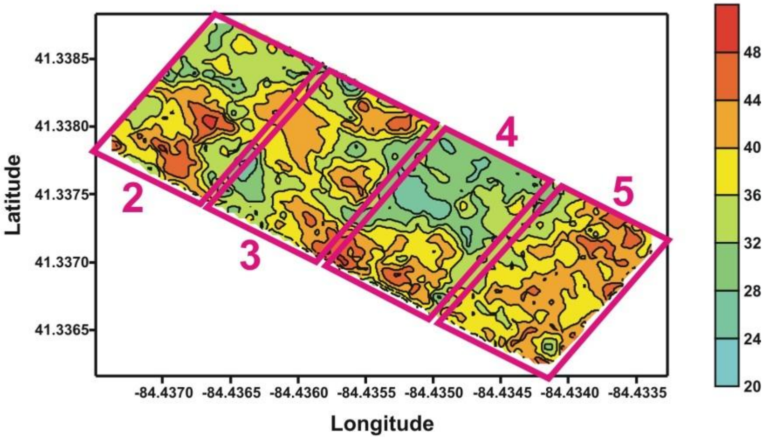
Historical Research Development of Agricultural Geophysics

1) **1930s to 1940s** – Soil water content monitoring using apparent soil electrical conductivity (EC_a) measurements obtained with resistivity methods.
2) **1960s to 1970s** – Soil salinity assessment using EC_a measurements obtained with resistivity methods.
3) **1970s to 1980s** - Use of ground penetrating radar (GPR) for updating and improving USDA soil survey maps.
4) **1990s** - EC_a mapping with resistivity and electromagnetic induction (EMI) methods are used to evaluate soil property spatial variation.

Agricultural Geophysics and Precision Farming




2007 Soybean Yield (kg/ha)


Soil Electrical Conductivity (mS/m)

Some Recent Advances in Agricultural Geophysics

1) **GPR soil suitability maps.**
2) **Soil water content mapping using GPR.**
3) **Tree and crop root biomass evaluations using GPR.**
4) **Soil nutrient monitoring after fertilizer or manure application using EMI and resistivity methods.**
5) **Determination of clay-pan depth using EMI and resistivity methods.**

Some Recent Advances in Agricultural Geophysics (continued)

6) Identification of subsurface flow pathways.
7) Estimation of herbicide partition coefficients in soil.
8) Agricultural field and golf course drainage pipe detection and assessment.
9) Soil drainage class mapping.
10) Mapping of flood deposited sand depths on farmland located near river.

Future Trends in Agricultural Geophysics

Although resistivity, EMI, and GPR are the predominant agricultural geophysical methods at present, and these methods will continue to find new uses; it is quite likely that other geophysical methods (magnetometry, seismic, self-potential, gamma ray spectrometry, etc.) will also find important agricultural applications in the near future.

Possible Examples:

1) **Delineation of hydric soil boundaries with magnetic susceptibility measurements (magnetometry and EMI).**
2) **Soil compaction mapping (seismic).**
3) **Measurement of soil water potential (seismic).**
4) **Leak detection at animal waste storage ponds and treatment lagoons (self-potential).**
5) **Clay content determination (gamma ray spectrometry).**

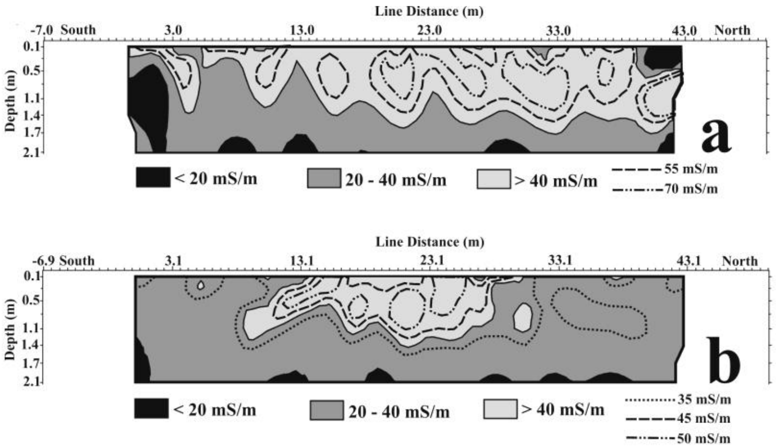
Geophysical equipment may need to be modified for agricultural applications due to rough surface conditions and the need to collect data over large field areas. Seamless integration with RTK-GPS receivers will become commonplace along with multi-sensor platforms.

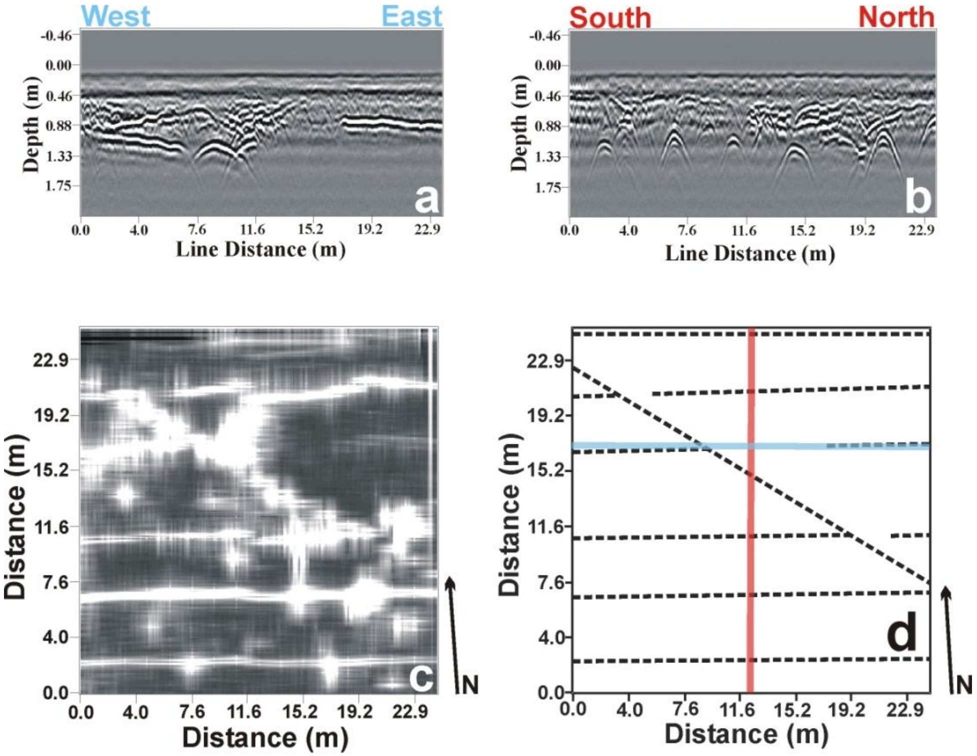
Different geophysical data acquisition approaches may be required where field access is not possible or where large watershed size areas need to be surveyed.

Possible Solutions:

1) **Multi-sensor geophysical systems directly integrated with farm machinery, possibly even allowing on-the-go decisions regarding precision farming operations.**
2) **Geotomography.**
3) **Airborne measurements.**

Increased use of geographic information systems, inverse modeling, and expert system software will improve agricultural geophysics data analysis capabilities.





Outreach efforts for the agricultural community need to accelerate with regard to training on the appropriate use of geophysical methods and to provide information on the strengths and limitations of using a specific geophysical method for a needed agricultural application.

1) **Short Courses**
2) **Workshops**
3) **Field Demonstrations**
4) **Agricultural Group Invited Presentations**

Summary and Conclusions

Use of Geophysical Methods in Agriculture - Introduction

Part 2 Presentation by:

Hamid Farahani, Ph.D.
Water Management Engineer
USDA-NRCS East National Technology Support Center
Greensboro, NC
hamid.farahani@gnb.usda.gov

East NTSC, 2:00 - 3:00 p.m. 21 August, 2012

Use of Apparent (Bulk) Soil Electrical Conductivity (EC) Mapping in Agriculture

Background:

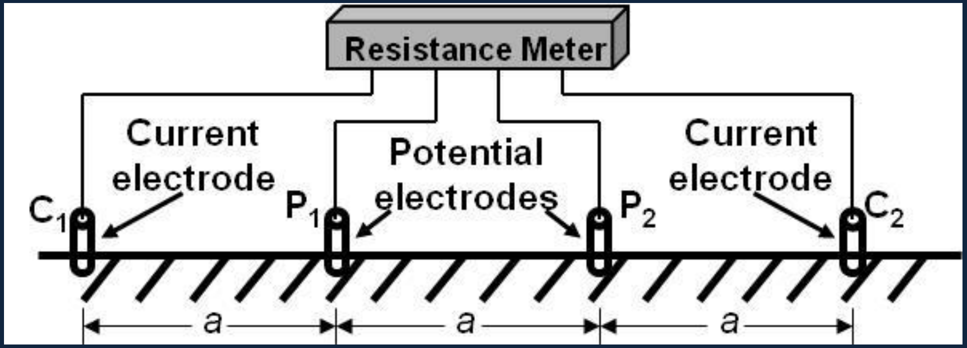
Measurement of soil resistivity dates back to the latter part of the 19th century when Whitney et al. (1897) attempted to infer soil water content and salinity from measurements of soil resistivity using two-probe electrodes.

Gardner (1898) and Briggs (1899) reported additional measurements as part of the early group of USDA scientists investigating soil temperature, salinity, and water content effects on soil resistivity.

Background: cont…

To minimize the difficulties with the unstable two-probe method, Frank Wenner (1915) introduced the theory of utilizing four equally spaced electrodes to measure earth resistivity, and wrote:

"A knowledge of earth resistivity (or specific resistance) may be of value in determining something of the composition of earth."



Electrical Resistivity (ER):

Ability to resist electrical current flow (ohm·meter)

Electrical Conductivity (EC):

Ability to convey electrical current flow (Siemens/m)

- Electrical Conductivity (EC) is the reciprocal of Electrical Resistivity (ER)
- The Siemens (symbolized S) is the SI unit of electrical conductance (an out-dated unit is mho).

The Siemens is also the equivalent of an ampere per volt.

Soil Solution EC *versus* Bulk (or apparent) Soil EC

Soil Salinity Assessment:

Soil salinity refers to the presence of dissolved solutes in the soil solution.

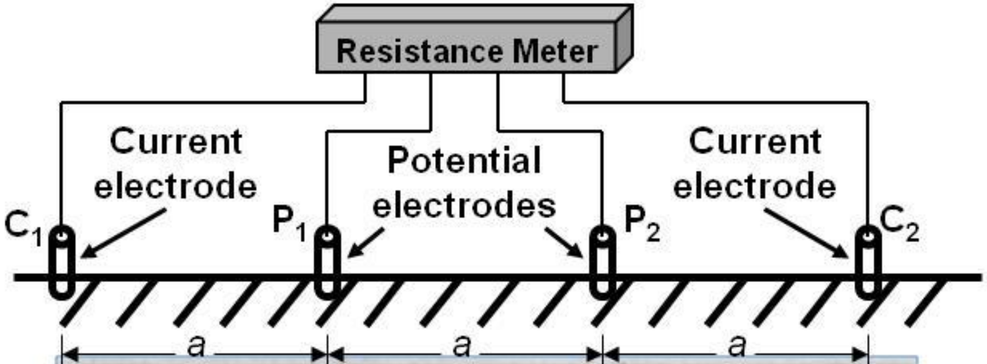
Salinity can be measured by measuring the electrical conductivity (EC) of the soil solution (U.S. Salinity Laboratory Staff, 1954).

Soil EC measurements of solution extracts are time and labor intensive and not practical for the characterization of the spatial variability of soil salinity at field extents and larger.

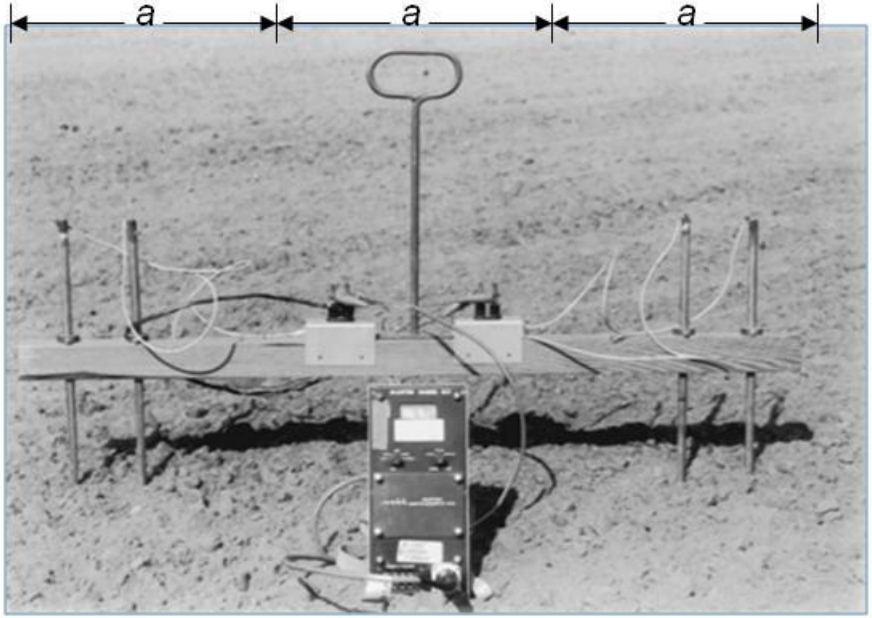
For in-depth reference material, see:
http://www.ars.usda.gov/services/services.htm?modecode=53-10-20-00&locpubs=yes
USDA-ARS, U.S. Salinity Laboratory at Riverside, CA
(Dr. Jim Rhoades, Dr. Dennis Corwin, and many more)

Electrical Resistivity to Measure Bulk EC

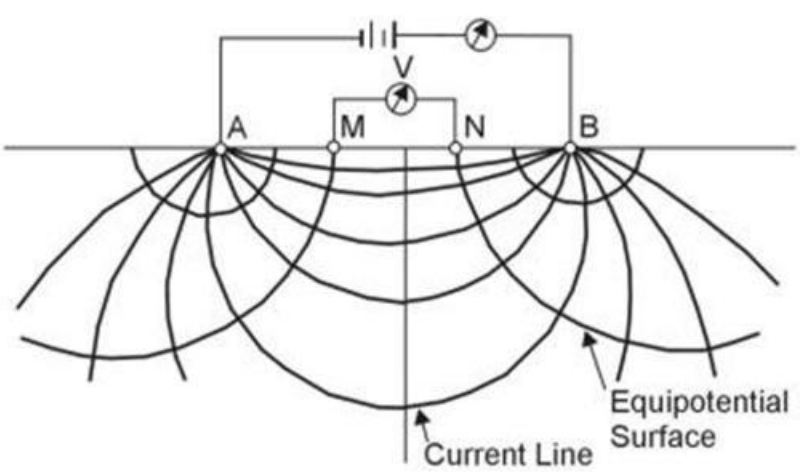
Field-scale Salinity Assessment



Jim Rhoades at the US Salinity Laboratory in California used the technology in 1977 to investigate near-surface agricultural features.

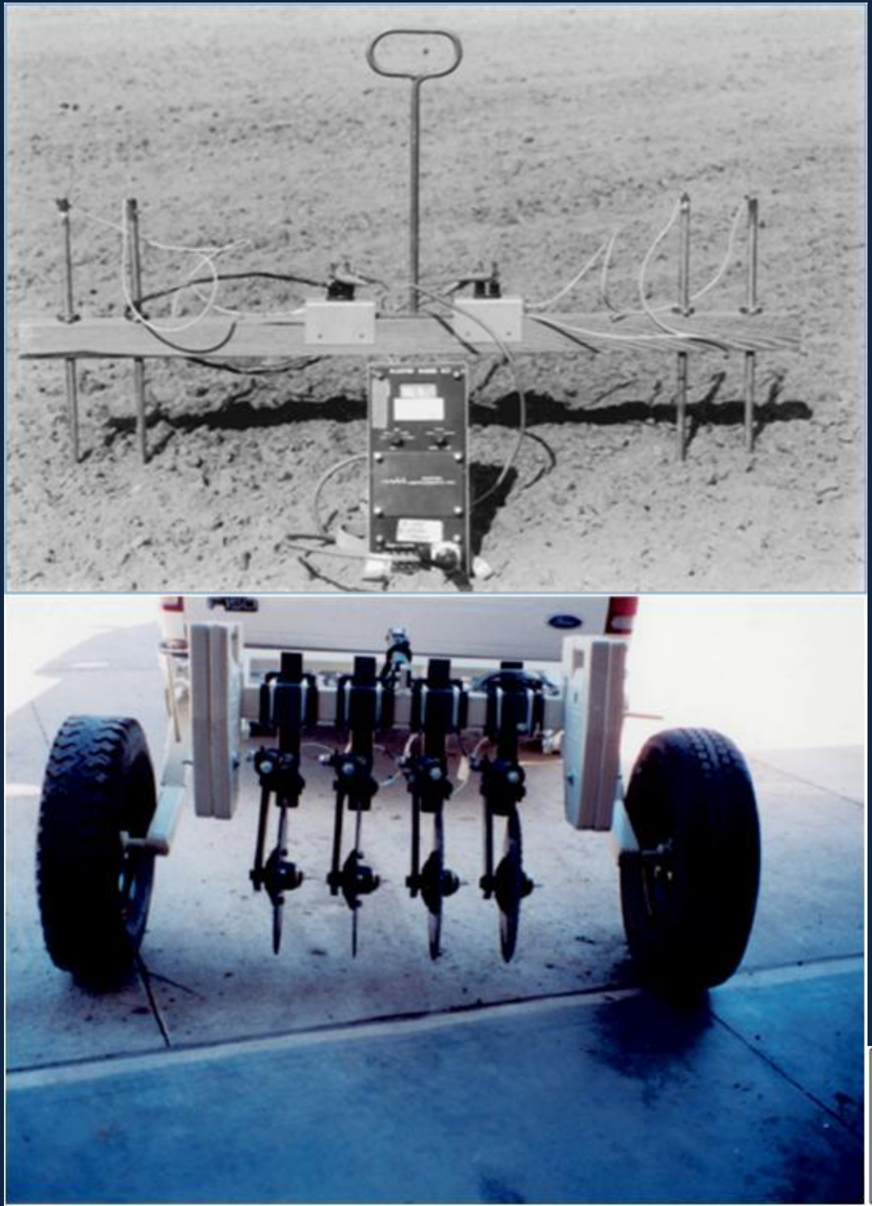


The volume of measurement is roughly πa^3



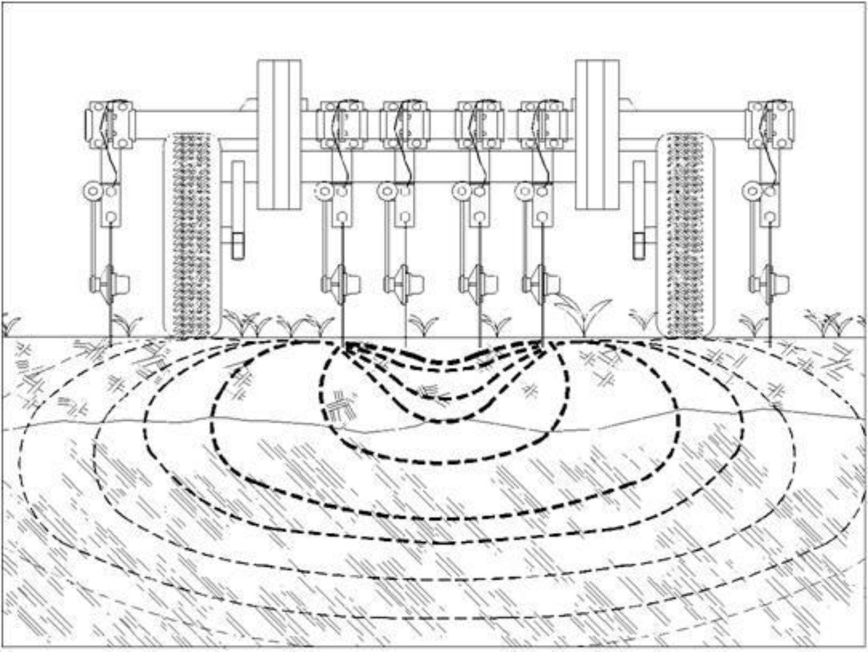
Material from publications by Dr. Jim Rhoades, Dr. Dennis Corwin, and more at U.S. Salinity Laboratory, Riverside, CA

From Salinity to Precision Agriculture



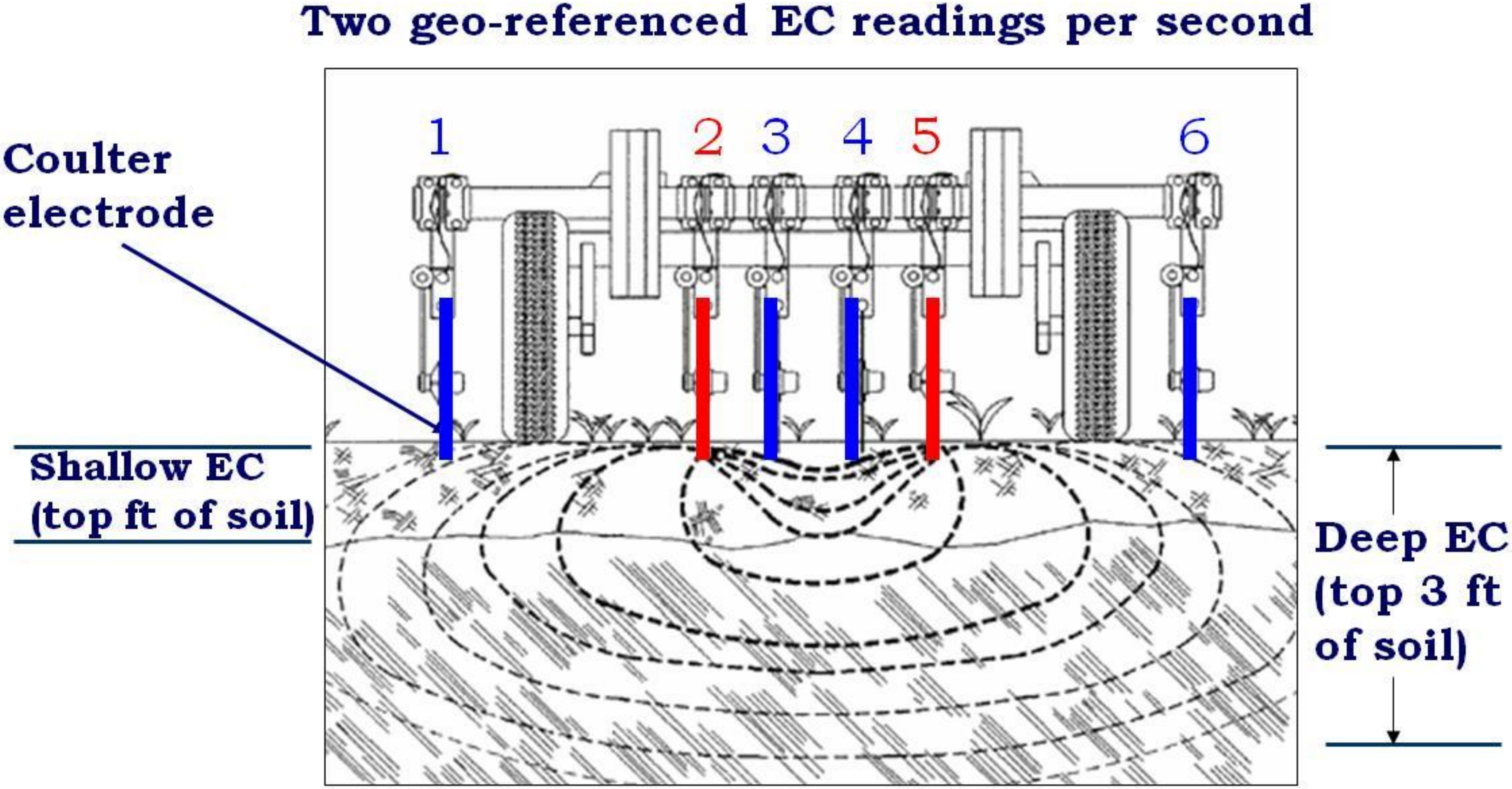
In 1996, Veris Technologies constructed rolling electrodes and added GPS to make a field EC mapping system prototype.

From Salinity to Precision Agriculture

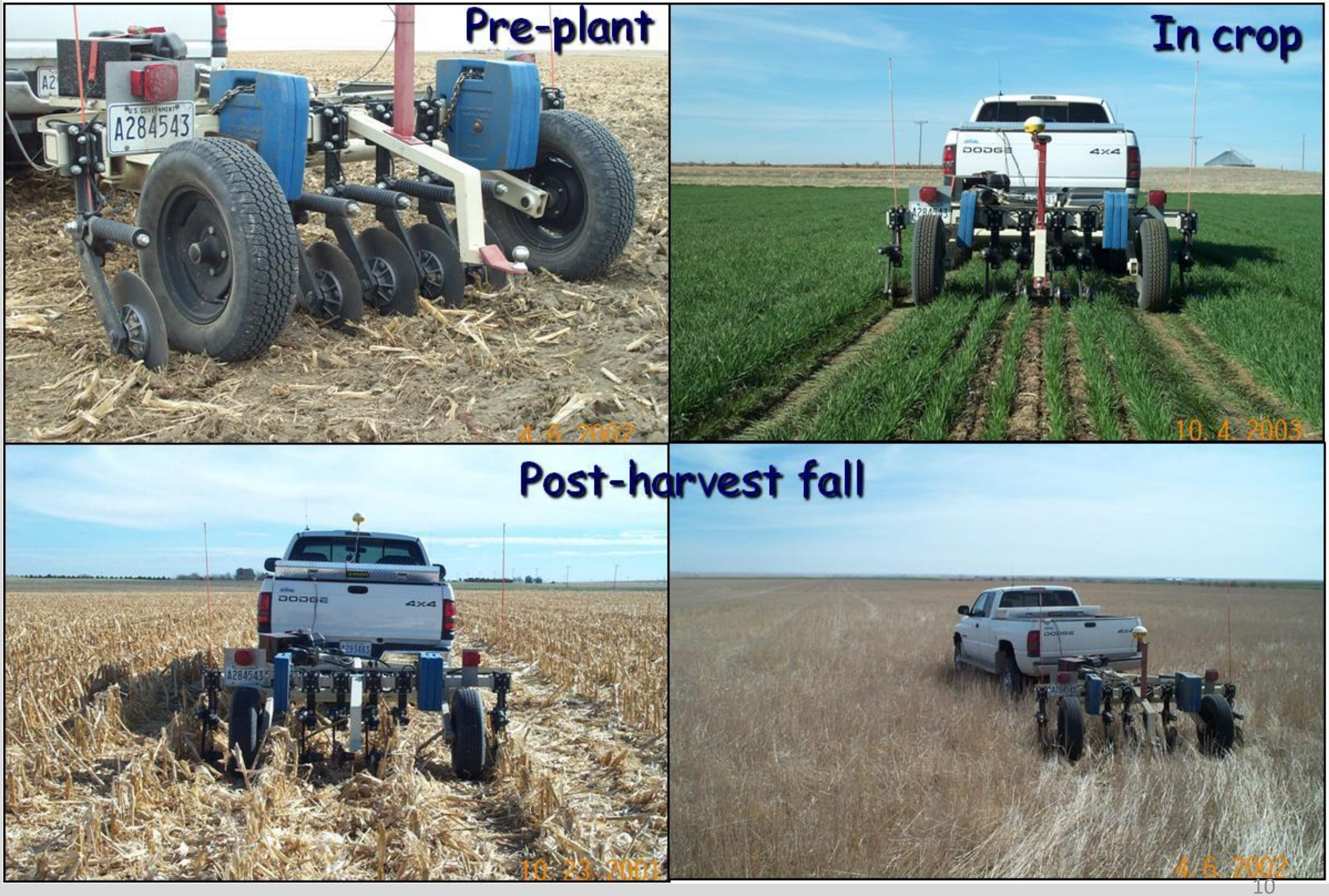


Most commonly used resistivity equipment is the Veris 3100 EC Mapping System (Veris Technologies, Salina, Kansas).

Veris 3100 EC Mapping System



Veris 3100 Soil EC Mapping System

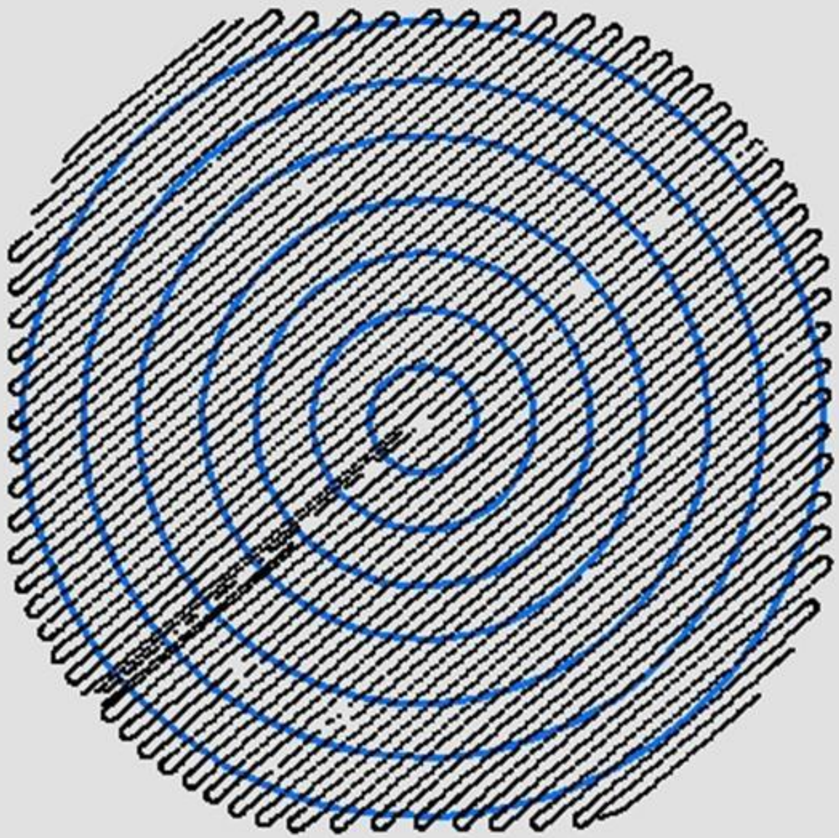


Field EC Mapping

Speed = 4 - 10 mi/hr
Parallel swath = 40 - 60 ft
EC per acre = 70 - 130
30-40 acre mapping per hour


Veris data logger


Parallel guidance inside truck


15 thousand EC points

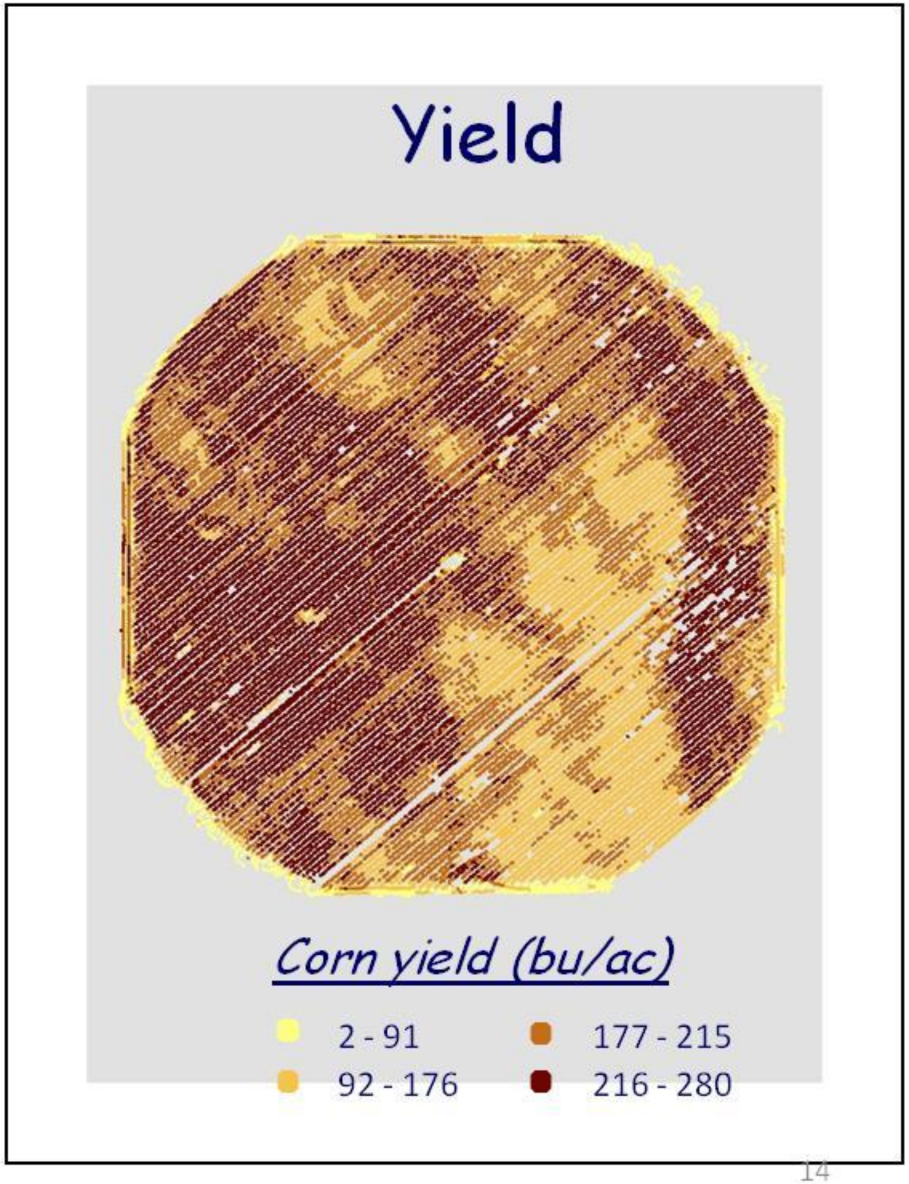
Veris EC data:

Longitude	Latitude	Shallow EC (0 – 1 ft)	Deep EC (0 – 3 ft)
-103.950481	40.299294	12.1	48.9
-103.950468	40.299302	33.1	26.6
-103.950454	40.299311	33.5	26.8
-103.950439	40.299321	37.0	25.1
-103.950410	40.299339	38.5	26.3
-103.950395	40.299348	39.5	26.9
-103.950380	40.299357	76.6	23.2
-103.950366	40.299366	76.1	12.0
-103.950352	40.299376	68.8	27.6
-103.950338	40.299385	35.1	25.8
-103.950323	40.299394	37.6	51.2
-103.950308	40.299404	31.3	57.9
-103.950291	40.299415	36.7	-24.0
-103.950274	40.299426	37.0	-24.0
-103.950161	40.299498	28.0	29.1

Emerging Interests in Bulk Soil EC Mapping (beyond salinity)

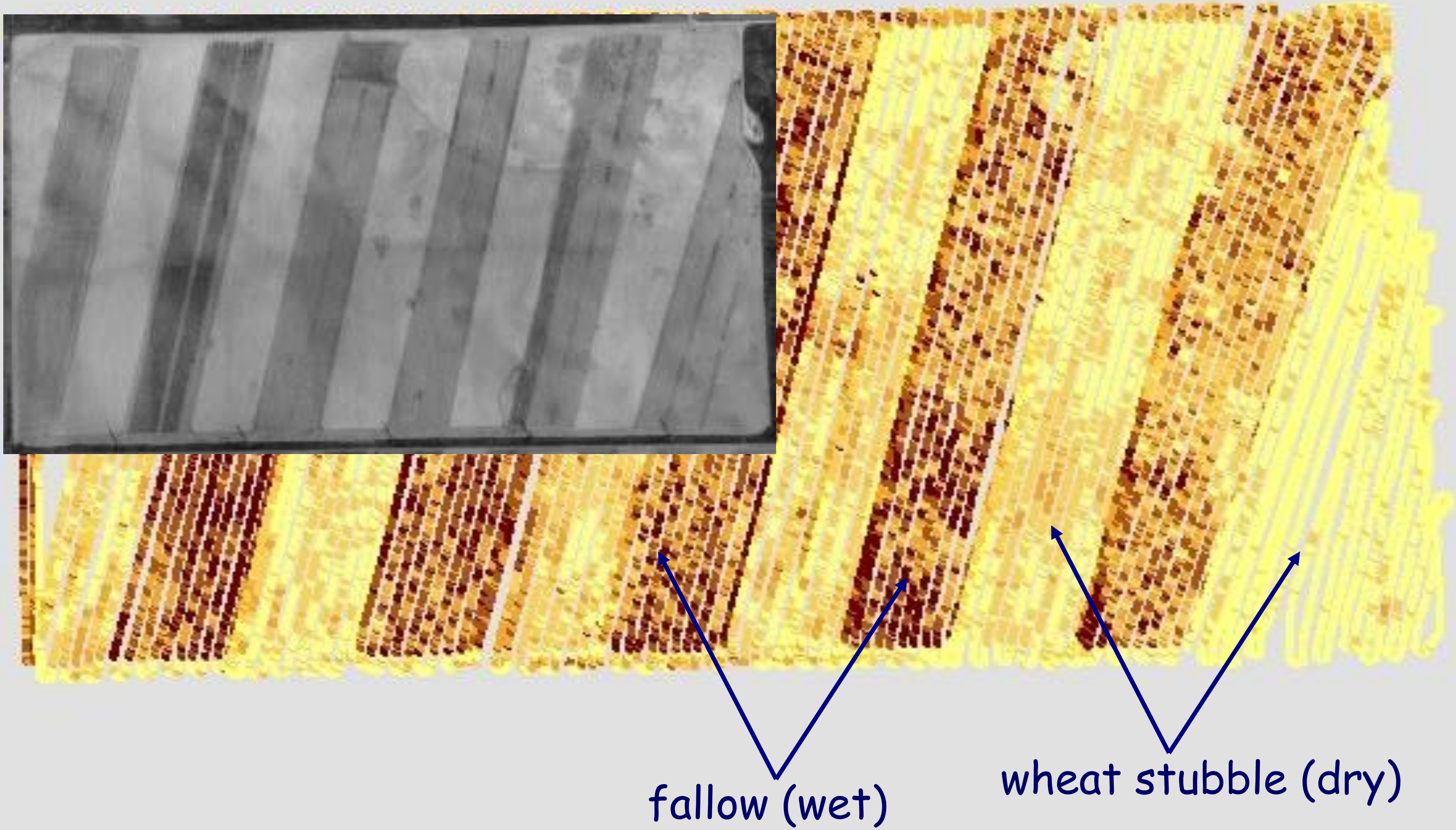
Changes in soil across the field can cause changes in yield

EC maps show the NATURE of soil variability, but not the CAUSE.

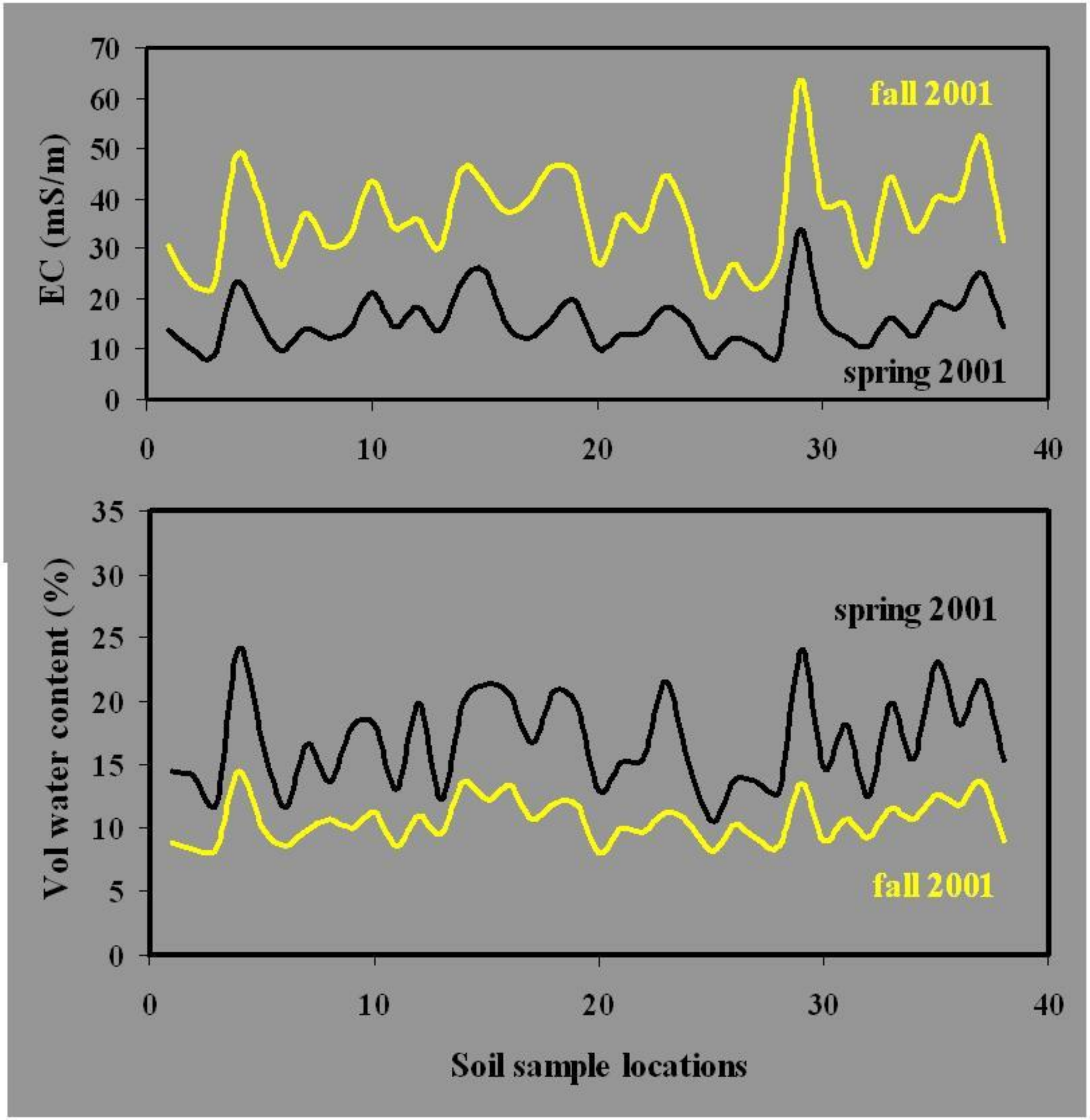


Wheat-fallow strip cropping

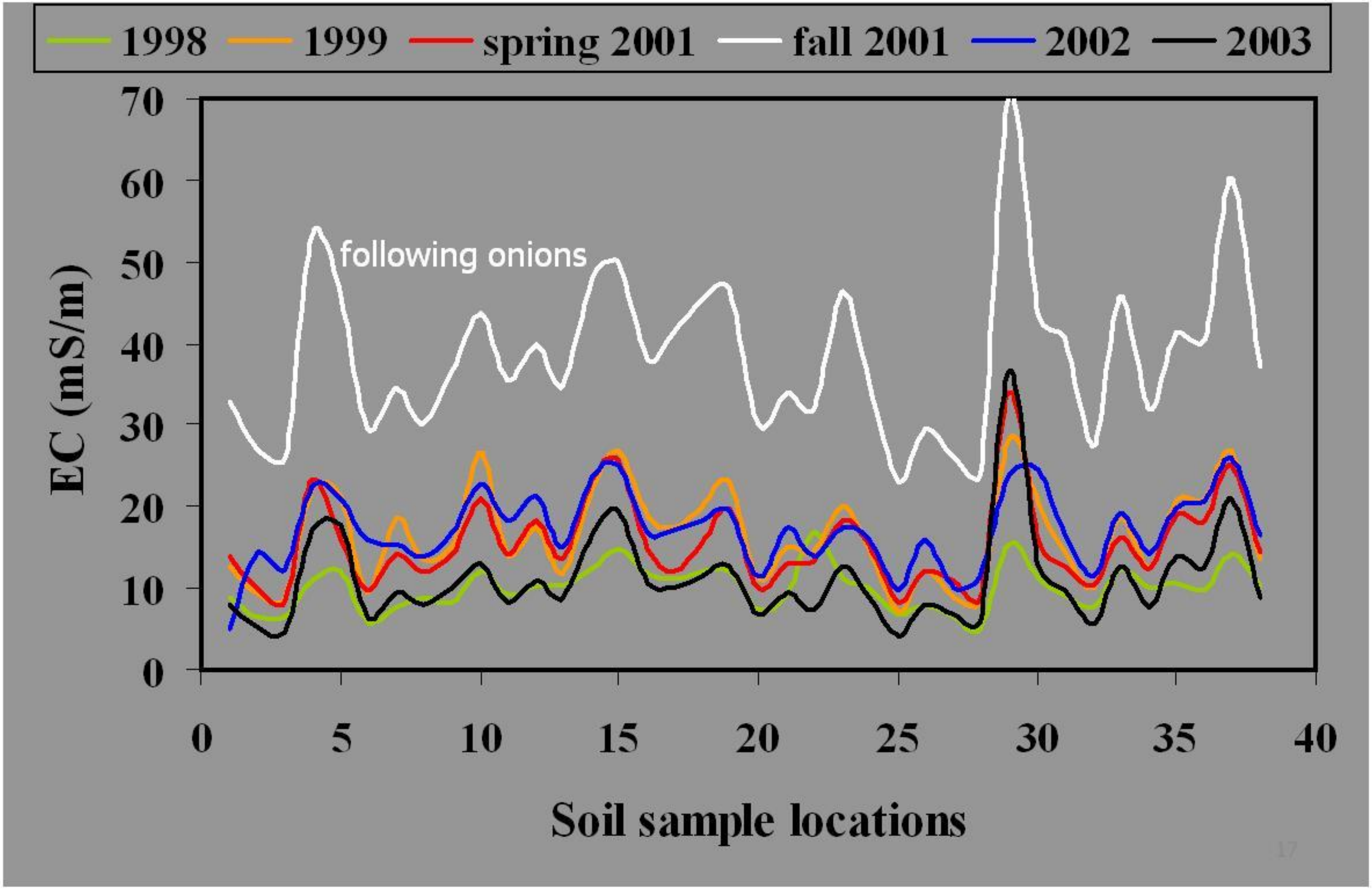
EC response dominated by water and not texture



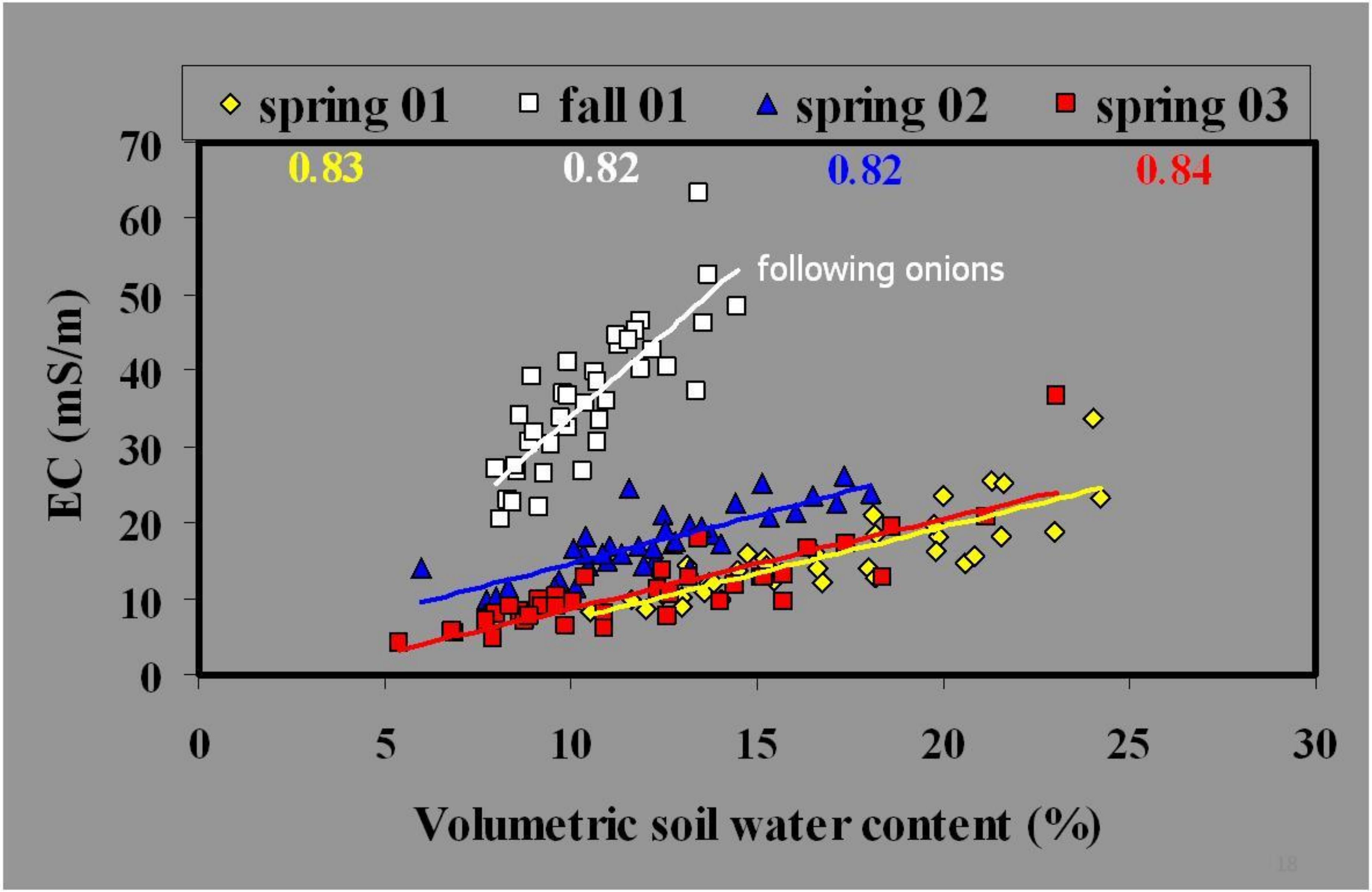
Temporal variability in EC



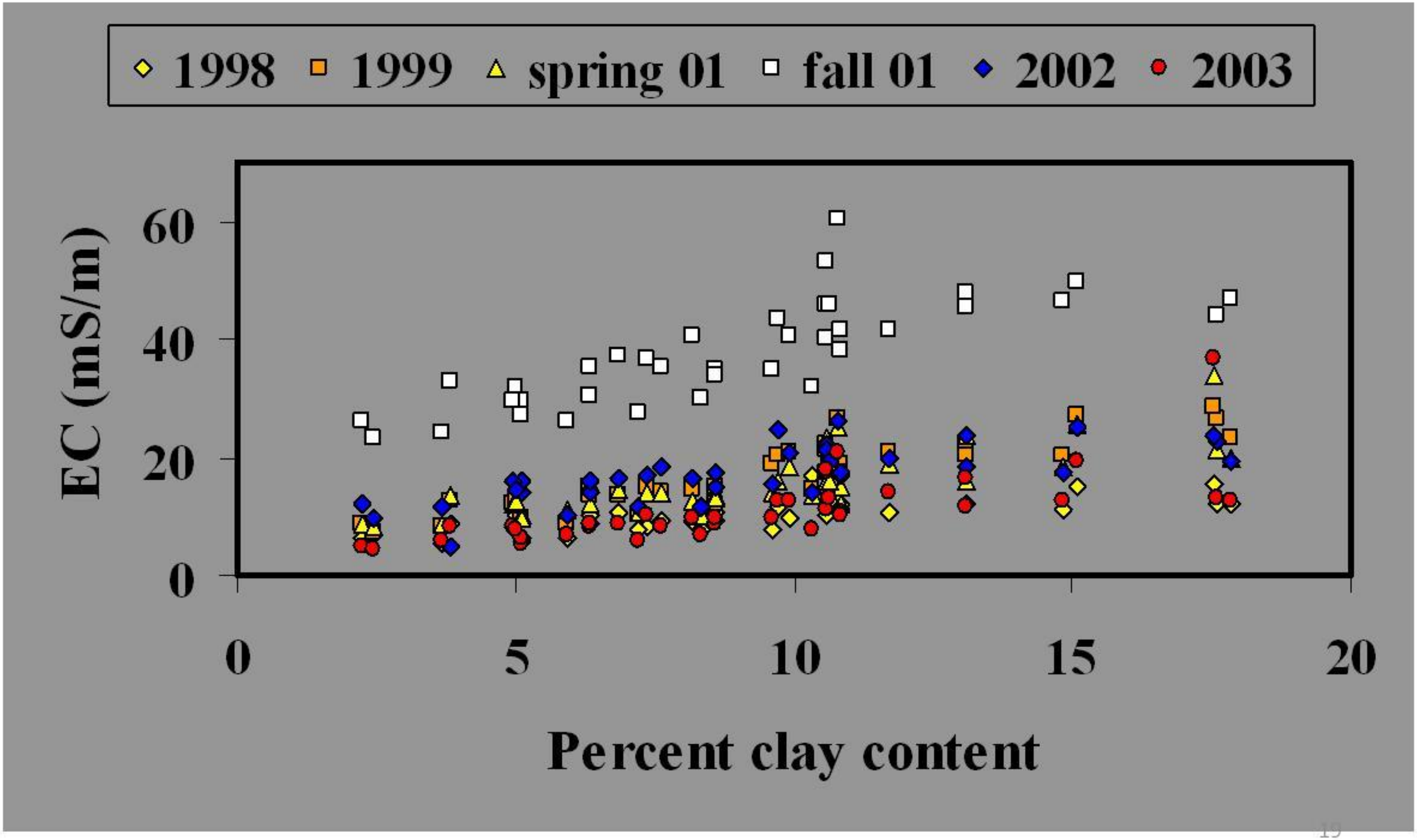
Temporal Variability of EC



EC versus Soil Water (transient soil property)



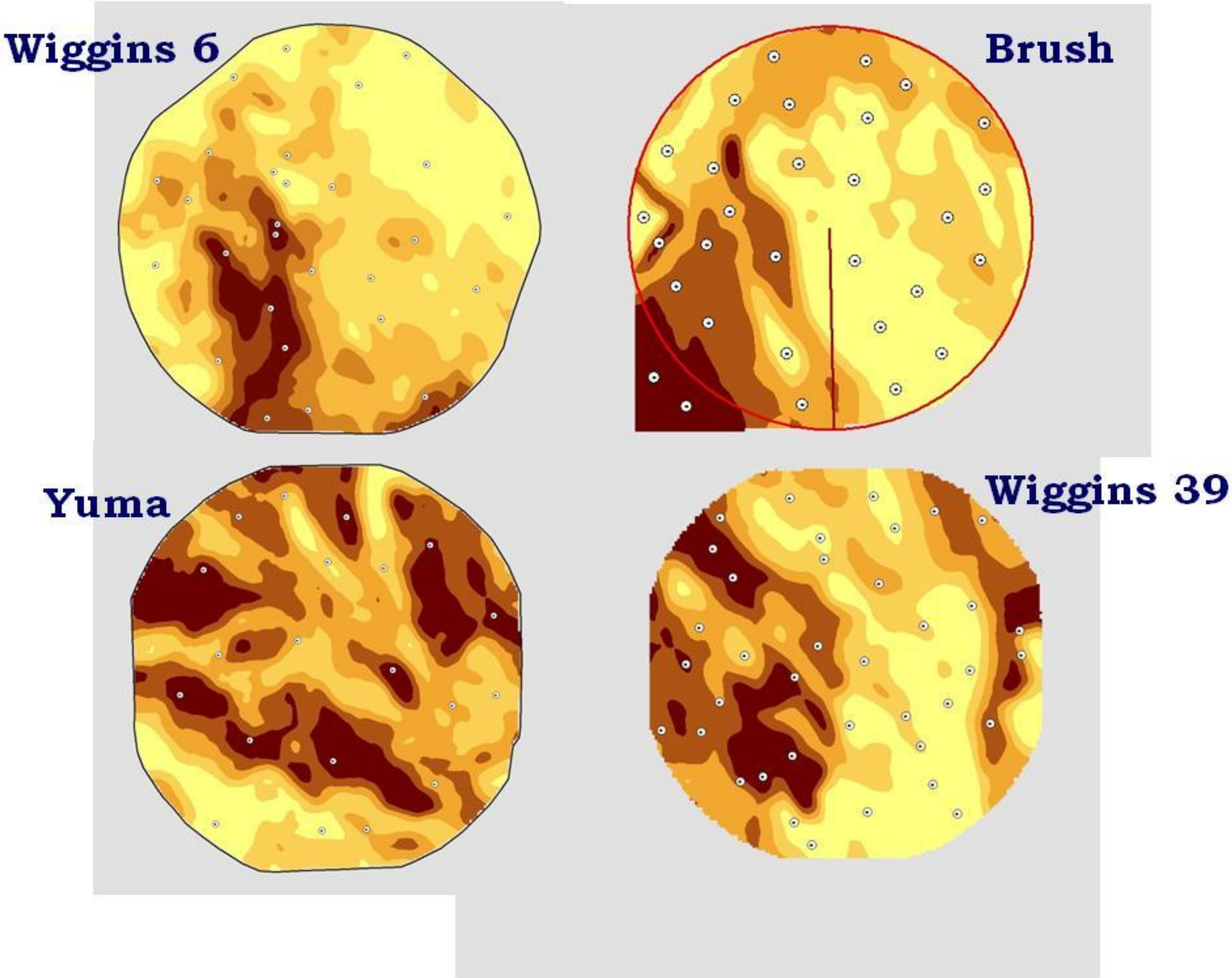
EC versus Clay (stable property)



There is no substitute to good geology.

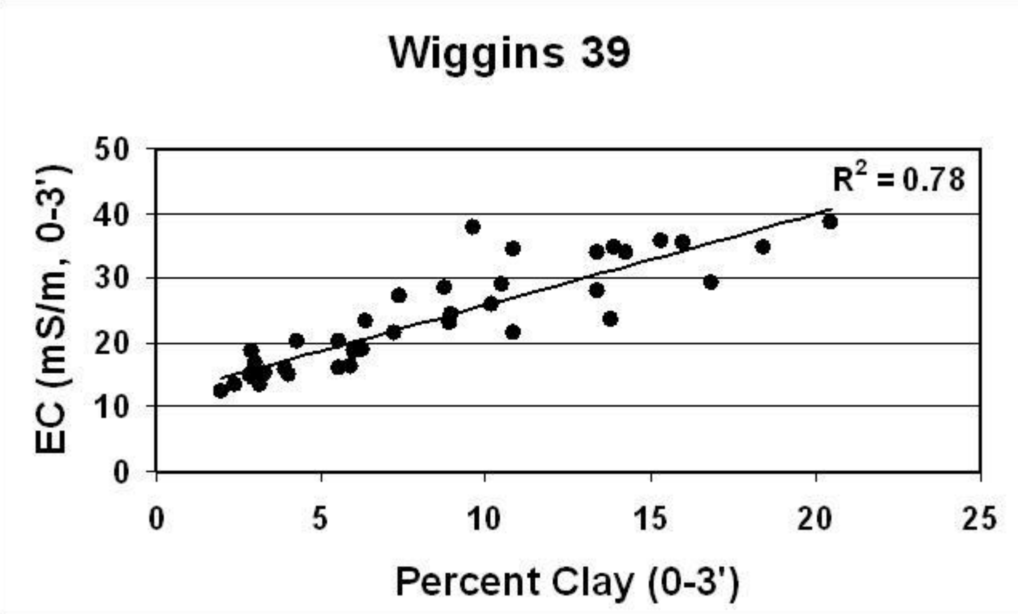
What does EC relate to?

Need soil sampling within EC zones:

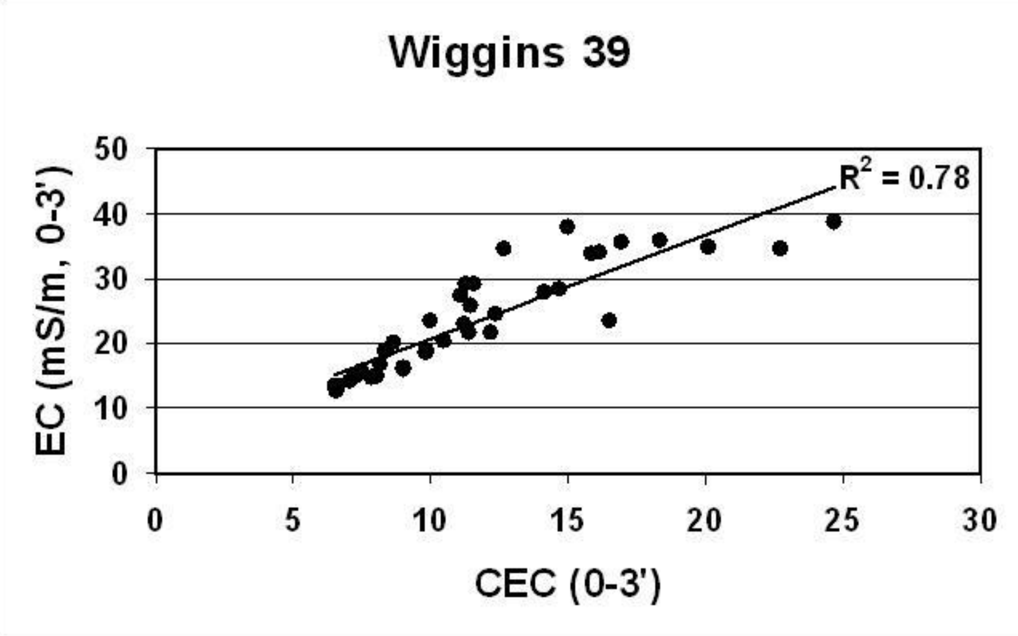


EC relates to:

- Clay (texture)
- Soil water content,
- Ca, Mg (CEC),
- Organic matter.

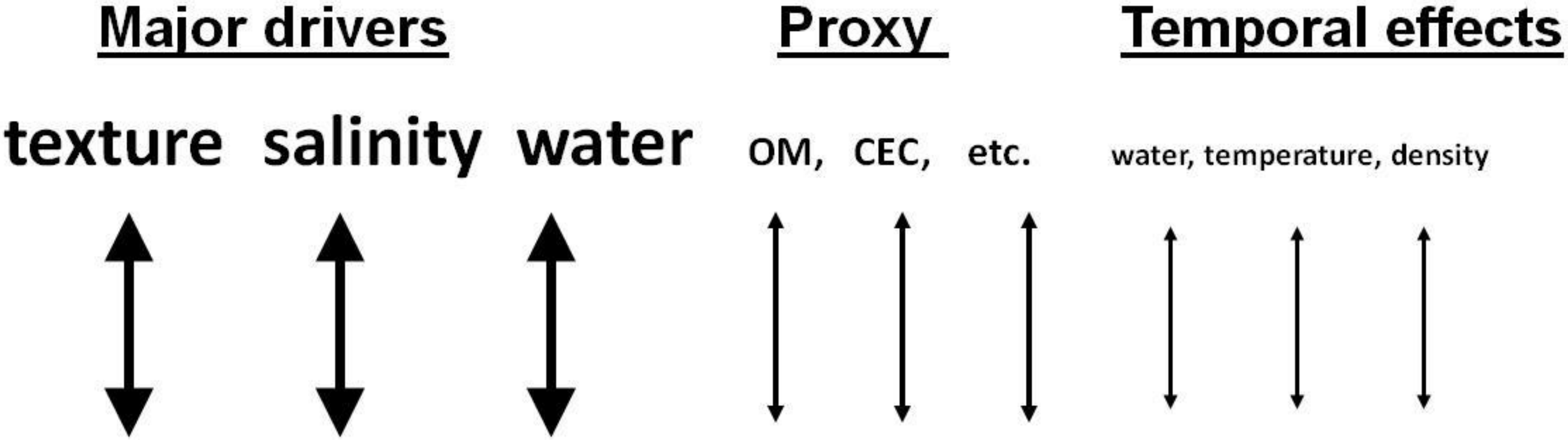


Wiggins 39



Wiggins 39

Lessons Learned
Bulk EC & Soil Property Relations



Major drivers

texture salinity water

Proxy

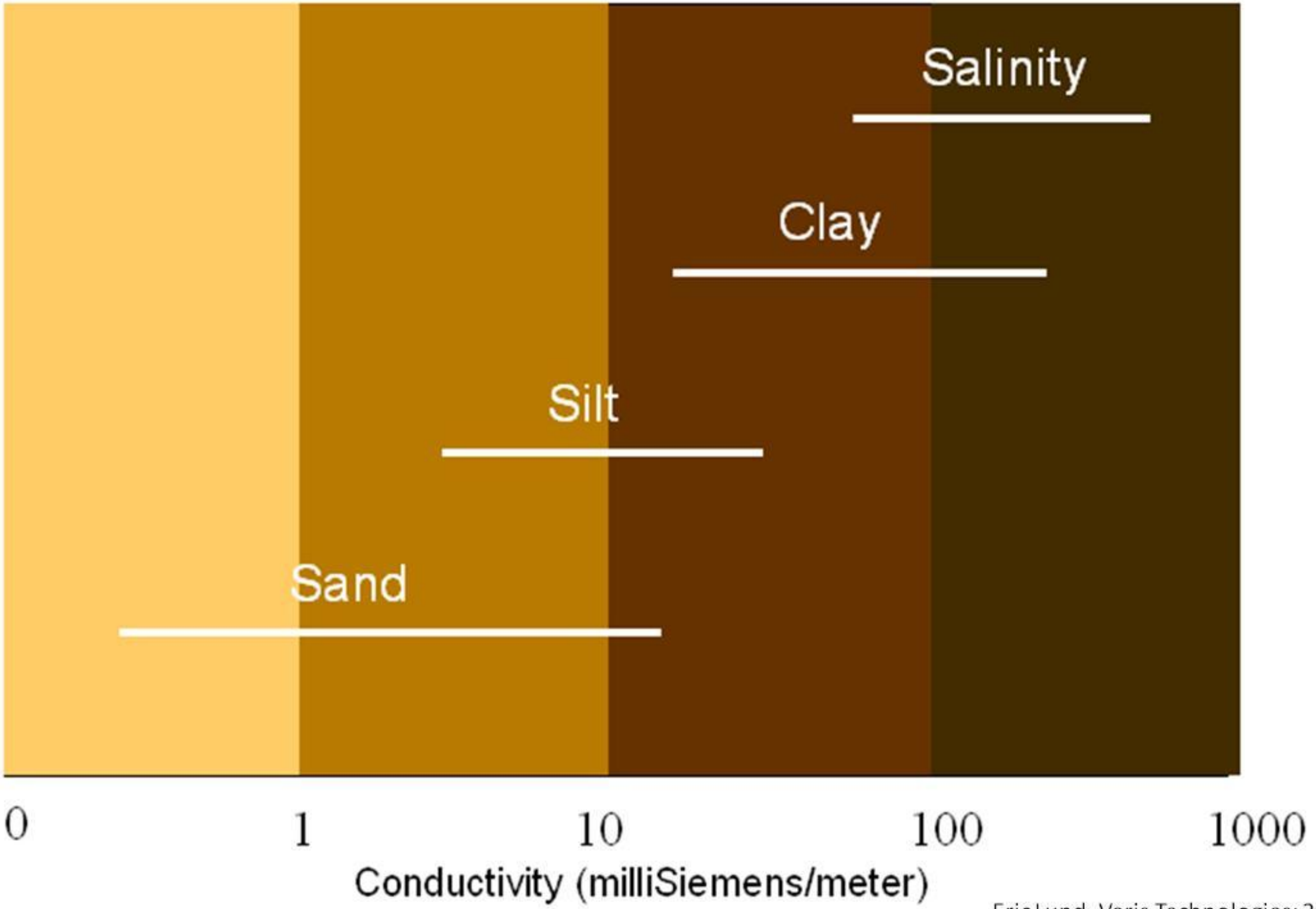
OM, CEC, etc.

Temporal effects

water, temperature, density

Eric Lund, Veris Technologies; 2009

Lessons Learned



Eric Lund, Veris Technologies; 2009

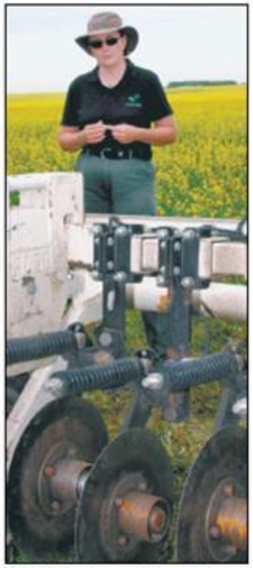
PRODUCTION

Section Editor: Michael Raine

Since the spring of 2008, CropPro mapping consultant Brad Dunnington has logged 40,000 acres, simultaneously mapping EC and topography with this Veris 3100 linked to an AutoFarm RTK GPS unit. (Photo courtesy of Cory Willness/CropPro Consulting)

EC solves mysteries in soil

Electrical conductivity reveals more than salinity



Marilyn Kot bought a used Veris to give her clients in-depth information on soil structure and salinity.

By Ron Lyseng
Winnipeg bureau

BRANDON — If people recognize the Veris 3100 cart, they might conclude soil scientists are measuring salinity.

Because the Veris does such a good job of documenting electrical conductivity (EC), which is the main test indicator for salinity, most producers and agrologists assume it's primarily a salinity instrument.

But people who delve into the mysteries of soil structure have a different take on the Veris. By charting electrical conductivity in a field, they learn a lot about soil structure.

However, it's difficult to make the connection between a scientific instrument that measures electrical conductivity and information that affects a farm's bottom line, which is perhaps why only a small number of Veris carts are used on the Prairies.

> ***"The more EC data we gather, the more we learn, but we also run into more and more questions about what's happening in the soil."***
>
> — Marilyn Kot, AgriTrend

One of them is owned by AgriTrend adviser Marilyn Kot of Francis, Sask.

"Salinity actually wasn't our main reason for investing in the Veris," Kot said, as she demonstrated her Veris 3100 at a recent AgriTrend field day at the Spring Valley Colony south of Brandon.

"We bought the Veris because we wanted to look at other soil properties. EC readings give us a very good indication of soil texture down in the root zone. Once you've run the field to get EC, you need to ground truth the data."

Saline soil is a good conductor of electricity so the higher the reading, the more saline it is.

Kot has mounted a core sampler in her truck cab, allowing her to collect and interpret samples the same day. However, if there's a lot of data, she takes it home for more in-depth analysis. She also looks at yield maps, vegetation maps and data the client may have.

Once she's studied the background, Kot returns to the field with a strategic plan and GPS points where soil samples should be taken to study why problems are occurring.

Kot said the background research is necessary because two areas with distinctly different soil and different problems can show the same bushel numbers on yield maps and the same crop density on Normalized Difference Vegetation Index (NDVI) maps.

"For example, a high knoll might register the same low productivity as a saline pothole, yet the two areas are totally different — opposite in fact," she said.

"That's why I use the yield maps and NDVI as helpful tools only. They can both be deceiving. The Veris shows us the real differences in the soil. When we map different zones based on EC, we know for sure that we're mapping distinctly different soils."

Each soil and zone will have typical yield-limiting factors. These are often verified by historical yield maps, aerial photos, satellite photos and other data.

Kot noticed that electrical conductivity readings do not necessarily correspond to field topography. Even when she takes soil samples, it doesn't follow the expected pattern of lighter soil on the knolls and heavier soil in low areas.

"Sometimes it's upside down. There are no absolutes," she said. "The more EC data we gather, the more we learn, but we also run into more and more questions about what's happening in the soil."

Kot bought her used Veris 3100 for $10,000 and charges $8 per acre to chart electrical conductivity.

"Once your EC is charted, that map is good virtually forever unless you do some major drainage or deep ripping. Electrical conductivity doesn't change."

Kot said ground speed limits how many acres she can cover in a day. All coulters must be in firm contact with the soil at all times to make a complete electrical circuit. If ground speed increases and the coulters jump, the circuit breaks and data must be thrown out.

Side slope salinity seeps

Cory Willness of CropPro Consulting, who has charted electrical conductivity on 40,000 acres near Naicam Sask., said his Veris has been running steadily since he bought it in the spring of 2008.

In that short time, he has discovered salinity problems in fields where nobody suspected they existed.

He also identified fields with side slope salinity seeps, a condition he previously thought existed only in textbooks.

"Around here, we've found fields with 50 to 100 little pockets of salinity scattered through a half section. There's no salt crust or any kind of visual indicator at all, but these are areas where crop doesn't grow," he said.

"The other surprise was all the side slope salinity seeps. We've discovered this on those long sloping fields. The client tells me that for some reason, the crops don't grow well in the centre of his field. It's at approximately a midpoint between the knoll and the low point. With the Veris, that's the place where we get the high EC readings."

He said he's been consulting on some of those fields for more than 10 years and would have said there's no salinity problem. However, the numbers from the Veris don't lie. They explain long-term mysteries of poor production in certain areas.

Producers typically think the side slopes produce their best crops on a long-term average.

The eroded knolls no longer have the best soil and the low spots often have too much moisture. If there's any salinity in the fields, that's where farmers assume it should be.

Willness advises producers to stop trusting their assumptions and get numbers. He said the electrical conductivity numbers generated by the Veris prove side hill salinity is a reality.

"I'm dealing with at least 30 fields that have no salinity down in the depressions. None. All the salinity on these fields is on the side hill, especially if it's a field with a long slope.

"It's a classic textbook case. You have the water recharge on the top of a big hill. The water infiltrates into the soil and runs down until it hits an impermeable layer. Then it's forced to the surface. There doesn't have to be a pothole anywhere in sight.

"The thing about the Veris is it measures EC down deep. Sometimes the worst salinity isn't on the surface. Sometimes it's deep down in the root zone where you can't see it. You can dig down six inches with your shovel, but that's not enough to find the salinity."

> ***"When we compare Veris soil structure maps to yield maps and imagery maps, we're able to figure out what's happening in each area of a field."***
>
> — Cory Willness, CropPro Consulting

In wet years, farmers sometimes complain about the phenomenon of getting stuck in the mud on a side slope where they think it should be dry. They naturally assume all the water should be at the bottom of the slope.

Willness said if producers are getting stuck on a side hill, there's a good chance they're in a saline seep. Water moves the salt along as it goes to the surface, so those are prime areas to check for salinity.

Willness said producers have farmed through these saline areas and kept adding fertilizer.

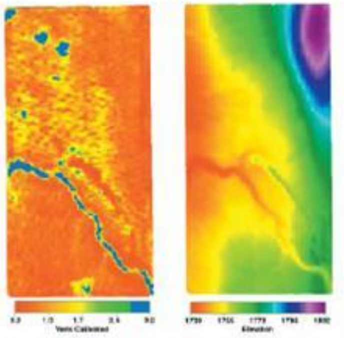
However, adding fertilizer to saline areas is the exact opposite of what should be done.

He said the saline areas are in worse shape today than they were before commercial fertilizers because the nutrient buildup compounds the initial problem found in nature.

"These areas are very high in nitrogen and very high in phosphate, so high that your crops can't grow."

Sow heavy

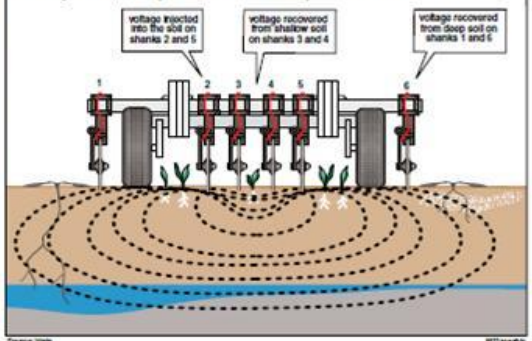
Willness advises his clients to increase seeding rates in these areas because it helps use up excess moisture and nutrients and keep weeds down. They also use variable rate technology to cut off the fertilizer when it's not needed.



On the left is a Veris calibrated map. The index is a Veris reference, but saline areas are in blue. It has both depths merged into one image. For reference the right-hand map is the RTK measured elevation of the field. The field slopes to the west, but the field to the west is still on the down slope. So all the salinity, in blue on the left map, other than the creek system, comes from side-hill seeps. (Image by Cory Willness)

Conductivity tells tales from deep down

As the Veris EC cart is pulled over a field, one pair of coulter electrodes injects a known voltage into the soil. The corresponding pair of coulter electrodes receives that current and measures the voltage drop. Low voltage drops mean the soil has high electrical conductivity, which is a measurement of salinity and an indicator of soil texture in the root zone.



Source: Veris

He said nothing but kochia can grow in fields that exceed a certain salinity reference number, but areas with lower salinity can grow an average crop if the client has a good variable rate program.

While salinity is an important issue, and one that can be solved, the Veris also gives Willness a good idea of soil structure in a field.

"When we compare Veris soil structure maps to yield maps and imagery maps, we're able to figure out what's happening in each area of a field. That's very important in our variable rate zoning procedure."

He equipped his Veris cart with an AutoFarm dual frequency RTK GPS system to chart elevation as he charts electrical conductivity.

CropPro charges a one-time fee of $10 per acre to run the field and create the electrical conductivity and topography maps. The fee includes layering other images and data the client already has. Once the initial field mapping has been completed, CropPro has an annual fee of $3.50 to $4 per acre to soil test and write VRF prescription maps.

"We bought the Veris so we can develop zones as accurately as possible, based on the soil. We don't have to create new zone maps every year like other people do with imagery based services."

For more information, contact Marilyn Kot at mkot@agritrend.com or Cory Willness at crop.pro@sasktel.net or visit www.veristech.com.

Once the Veris has identified distinct soil variations in a field, Justin Cleaver takes core samples that are used to ground truth the Veris data. (WP photo by Ron Lyseng)

Issues

Characterizing (or identifying the causes of) soil EC variability is difficult.

- ❑ Experimental results are mixed and show varying strength of EC versus soil properties relations.
- ❑ The EC versus soil properties relations are not necessarily unique.
- ❑ Absolute values of EC are highly site- and time-of-measurement specific.
- ❑ Temporal stability of maps is quite high.

Use of Apparent or Bulk Soil Electrical Conductivity (EC) Mapping in Agriculture

- Bulk soil EC mapping identifies soil spatial variability

- The underlying principles of soil EC variability is less explored.

- An understanding of the spatial and temporal variability of soil EC and its complex interactions with static and transient soil properties, particularly at low salt concentrations, is needed.

Electrical flow - Metallic or Electrolytic

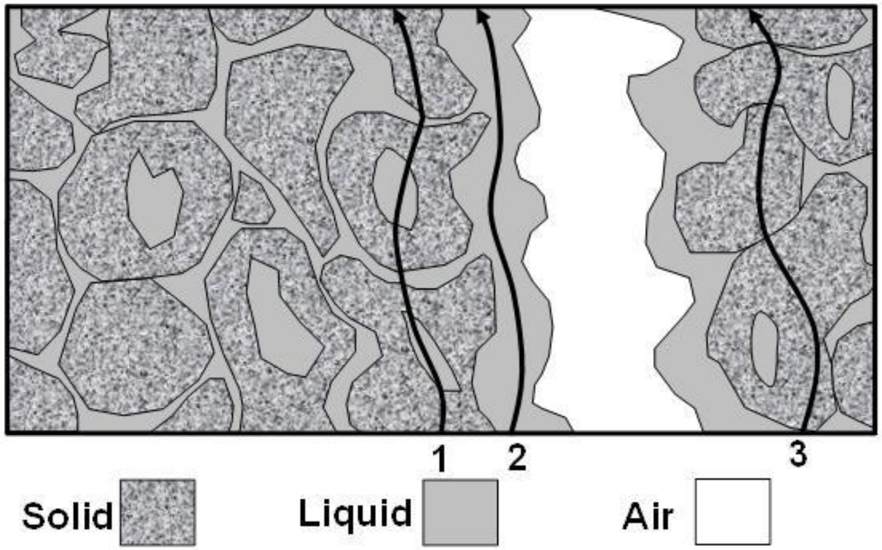
Metallic : Carrier is the electron
Electrolytic: Carrier is dissolved ions

Soil Phases: Air, Solid, Liquid

Air : Insulator
Solid: Insulator
Liquid: Conductor (electrolytic)

> *“This is called practice, but remember first to set forth the theory.”*
>
> *Leonardo da Vinci*

1. Adsorbed soil moisture
2. Free soil moisture (pore solution)
3. Soil particle to particle contact (insignificant)


Pathways of Electrical Conductance

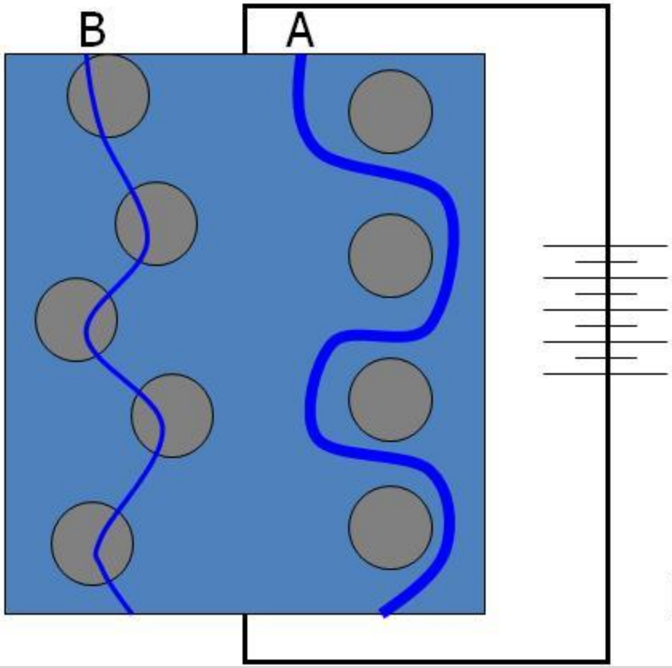
Soil Cross Section

Dennis Corwin, et al., 2005;

Dual-Pathway Soil EC Model

(Shainberg et al. 1980; Rhoades et al. 1989)

$$EC_a = \left[\frac{(\theta_s + 0.64\theta_w)^2 EC_w EC_s}{(0.64\theta_w)EC_s + (\theta_s)EC_w} \right] + (0.36\theta_w)EC_w$$



Bulk Soil EC is a combination of:

A) EC (liquid pathway), θ_w, EC_w

Solution Content & Conductivity

B) EC (solid-liquid pathway), EC_w, EC_s

Surface Conductivity

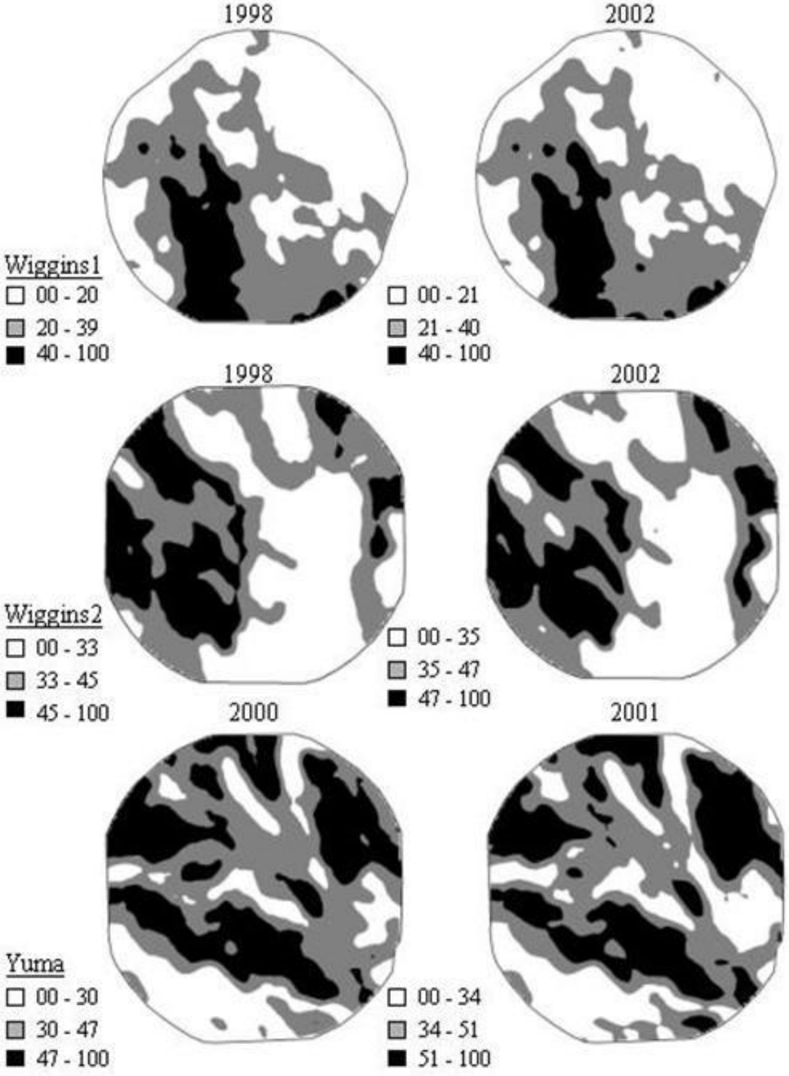
Nearly all are transient properties, except EC_s.

"The good thing about soil EC is it relates to just about everything. The bad thing about soil EC is it relates to just about everything."

Unknown

Eric Lund, Veris Technologies; 2009

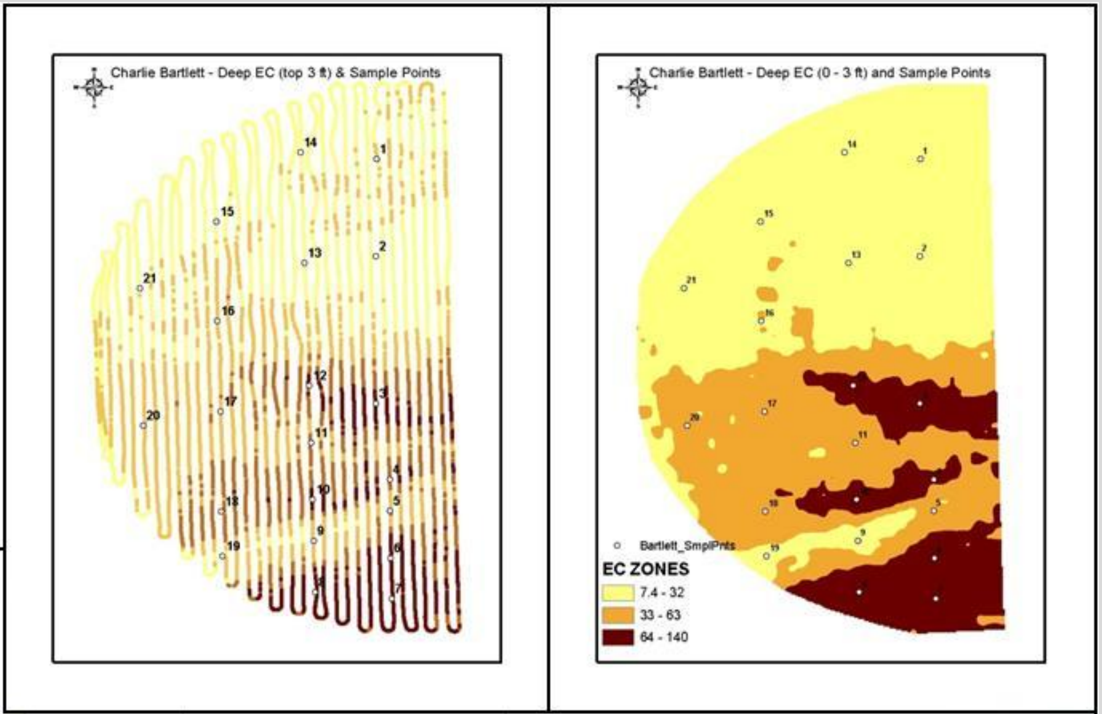
Temporal Stability of EC Maps



Emerging Interests in EC (beyond salinity):

- ✓ Identify field soil variability (surface and subsurface)
- ✓ Guide smart soil sampling within EC boundaries
- ✓ Help place on-farm tests plots and sensors
- ✓ Characterize field soil variability (model parameters, WHC)
- ✓ Identify potential field areas (zones) for varying management
    - ➢ variable rate seeding (top soil)
    - ➢ variable rate nutrients (texture, CEC, organic matter)
    - ➢ variable rate herbicide (binding, bioactivities, clay, organic matter)
- ✓ Refining NRCS soil maps (soil boundaries, unmapped inclusions)
- ✓ Conduct yield-map analysis
- ✓ More… (depth to claypan and bedrock, depth of sand deposits, …)

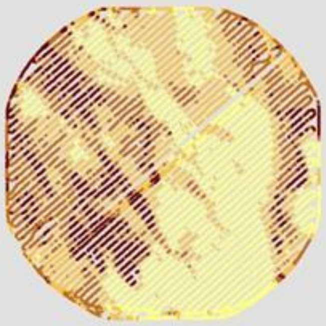
Map field variability, Guide sampling, Develop zones for variable rate inputs



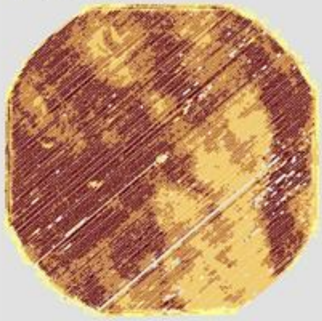
Conclusions (EC in non-saline fields)

- ☐ Soil EC mapping is the simplest and most rapid method of identifying the nature of soil variability
- ☐ EC relates strongly to soil stable properties of texture and organic matter (field productivity)
- ☐ The patterns of EC remain stable over time (no need for remapping).
- ☐ EC versus soil properties relations are time of measurement dependent due to changes in transient soil properties.

EC



Yield



Aerial image

Thank you