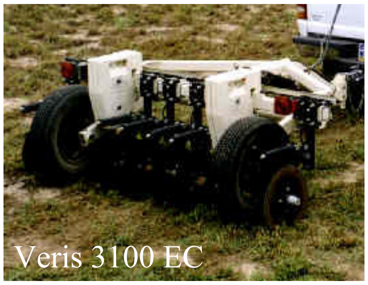
Veris
technologies

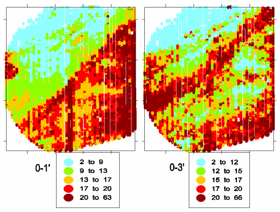
Technology for
carbon measurements.

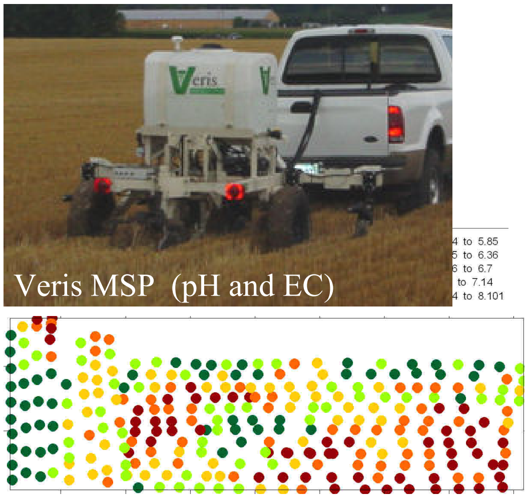
Veris, NIRS, and Soil Carbon

- Veris Technologies, Inc.
- Near Infrared Spectroscopy (NIRS) and soil C
- The challenges of measuring C for offset payments
- Results from a measurement case study
- Future issues

Veris Technologies tools for precision agriculture







Veris Technologies clientele: crop consultants, fertilizer suppliers, growers, research institutions

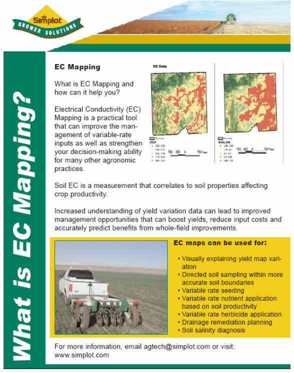

Indiana


Washington


United Kingdom


Louisiana

Veris Technologies clientele: crop consultants, fertilizer suppliers, growers, research institutions



What is EC Mapping?

EC Mapping

What is EC Mapping and how can it help you?

Electrical Conductivity (EC) Mapping is a practical tool that can improve the management of variable-rate inputs as well as strengthen your decision-making ability for many other agronomic practices.

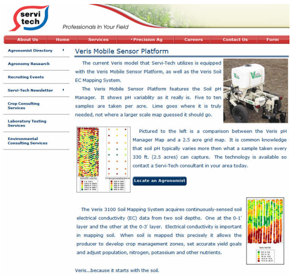
Soil EC is a measurement that correlates to soil properties affecting crop productivity.

Increased understanding of yield variation data can lead to improved management opportunities that can boost yields, reduce input costs and accurately predict benefits from whole-field improvements.

EC maps can be used for:

- Visually explaining yield map variation
- Directed soil sampling within more accurate soil boundaries
- Variable rate seeding
- Variable rate nutrient application based on soil productivity
- Variable rate herbicide application
- Drainage remediation planning
- Soil salinity diagnosis

For more information, email agtech@simplot.com or visit: www.simplot.com



Veris Mobile Sensor Platform

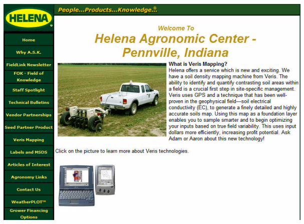
The current Veris model that Servi-Tech utilizes is equipped with the Veris Mobile Sensor Platform, as well as the Veris Soil EC Mapping System.

The Veris Mobile Sensor Platform features the Soil pH Manager. It shows pH variablity as it really is. Five to ten samples are taken per acre. Lime goes where it is truly needed, not where a larger scale map guessed it should go.

Pictured to the left is a comparison between the Veris pH Manager Map and a 2.5 acre grid map. It is common knowledge that soil pH typically varies more then what a sample taken every 330 ft. (2.5 acres) can capture. The technology is available so contact a Servi-Tech consultant in your area today.

The Veris 3100 Soil Mapping System acquires continuously-sensed soil electrical conductivity (EC) data from two soil depths. One at the 0-1' layer and the other at the 0-3' layer. Electrical conductivity is important in mapping soil. When soil is mapped this precisely it allows the producer to develop crop management zones, set accurate yield goals and adjust population, nitrogen, potassium and other nutrients.

Veris...because it starts with the soil.



Welcome To

Helena Agronomic Center - Pennville, Indiana

What is Veris Mapping?

Helena offers a service which is new and exciting. We have a soil density mapping machine from Veris. The ability to identify and quantify contrasting soil areas within a field is a crucial first step in site-specific management. Veris uses GPS and a technique that has been well-proven in the geophysical field—soil electrical conductivity (EC), to generate a finely detailed and highly accurate soils map. Using this map as a foundation layer enables you to sample smarter and to begin optimizing your inputs based on true field variability. This uses input dollars more efficiently, increasing profit potential. Ask Adam or Aaron about this new technology!

Click on the picture to learn more about Veris technologies.

"Advanced Ag Solutions brings fresh solutions to farming, with a maximum focus on profitability. I'm a more productive farmer because of that!"

-Fayette County Farmer

Veris Technologies
Soil EC Mapping System

The Future of Agricultural Technology

The Veris 3100 is a complete soil mapping system that acquires continuously-sensed soil electrical conductivity (EC) data from two soil depths. The complete system uses six coulter-electrodes and an instrument that creates and processes the signal to log and download the EC data.

Unique to the Veris technology is the ability to acquire soil EC data from two depths simultaneously. This feature provides Advanced Ag Solutions with information about the top 0-1' (0-30cm) as well as the 0-3' (0-91cm). The top layer typically shows effects of management induced variability - such as tillage, and soil redistribution, while the deeper array more closely identifies the natural patterns of soil variability. Together, the two data sets provide insights into the depths and properties of the different soil horizons.

The Veris system generates the electrical signal, measures voltage of that signal as it moves through the soil, converts the analog response to digital, and logs the geo-referenced results. And it's designed expressly for continuously-sensed field mapping.

The Veris technology allows Advanced Ag Solutions to obtain a better understanding of exactly what your farm requires and ways to improve growth. This tool is helping to change the face of Agriculture for the future.

Benefits of Veris MSP Mapping:

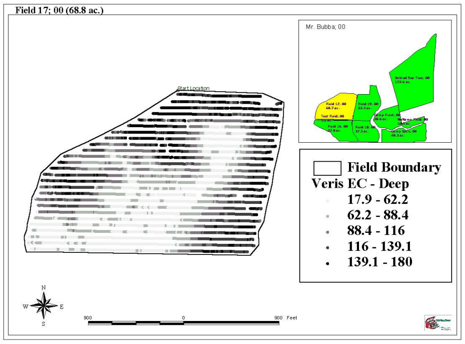
- *Map soil texture to predict water holding capacity -still our biggest determinant of yield!*
- *Identify and correct areas where yields are lower than zone's potential*
- *May substitute yield maps in nutrient maintenance programs*
- *Manage for profit rather than soil test result*
- *Intensify pH sampling without breaking the bank!*
- *Successfully run VR seed, lime, P&K, Nitrogen, chemicals and more!*

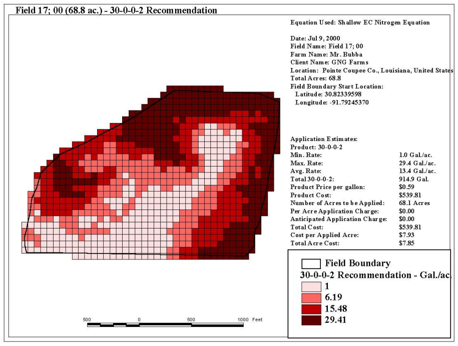
Continued...

Advanced Ag Solutions offers integrated crop management, risk management tools, and farm-trusted research as well as, fully supports the Qualified Grower Network.

150 East Alta Lane • Connersville, IN 47331
Phone: 765.827.6369 • Mobile: 765.265.6767
Email: Info@AdvancedAgSolutions.com
www.AdvancedAgSolutions.com

Veris Technologies EC mapping applications: site-specific applications of seed, nitrogen, lime, nematicides, water.





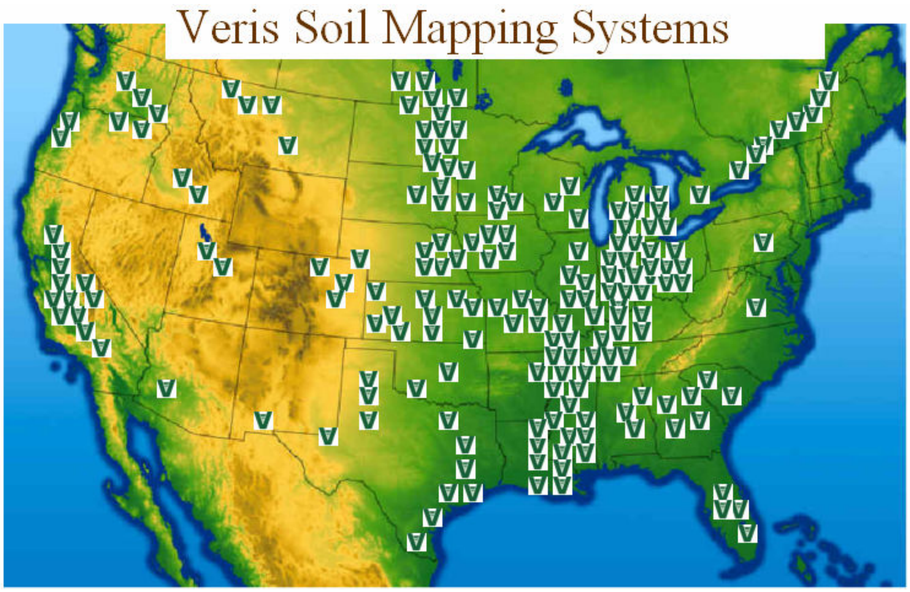
Equation Used: Shallow EC Nitrogen Equation

Date: Jul 9, 2000
Field Name: Field 17; 00
Farm Name: Mr. Bubba
Client Name: GNG Farms
Location: Pointe Coupee Co., Louisiana, United States
Total Acres: 68.8
Field Boundary Start Location:
Latitude: 30.82339598
Longitude: -91.79245370

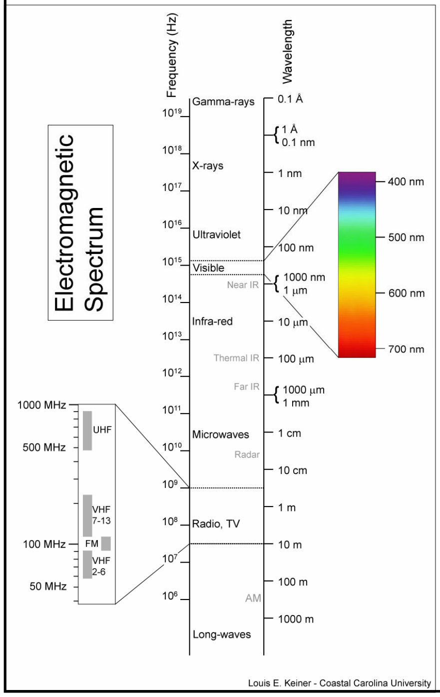
Application Estimates:
Product: 30-0-0-2

Min. Rate:	1.0 Gal./ac.
Max. Rate:	29.4 Gal./ac.
Avg. Rate:	13.4 Gal./ac.
Total 30-0-0-2:	914.9 Gal.
Product Price per gallon:	$0.59
Product Cost:	$539.81
Number of Acres to be Applied:	68.1 Acres
Per Acre Application Charge:	$0.00
Anticipated Application Charge:	$0.00
Total Cost:	$539.81
Cost per Applied Acre:	$7.93
Total Acre Cost:	$7.85

Veris Soil Mapping Systems



+ 24 foreign countries



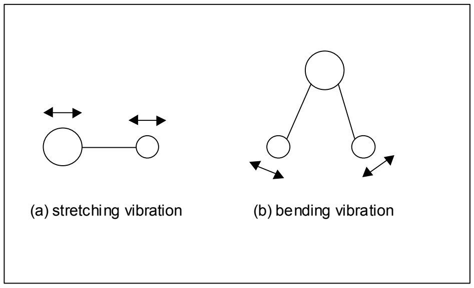
Louis E. Keiner - Coastal Carolina University

Near-infrared spectroscopy (NIRS)

The discovery of the infrared region in 1800 is credited to William F. Hershel's famous work, "Experiments on the Refrangibility of the Invisible Rays of the Sun", read April 24, 1800 at the Royal Society.

Near-infrared spectroscopy is at work in various settings—medical, pharmaceutical, food and beverage production

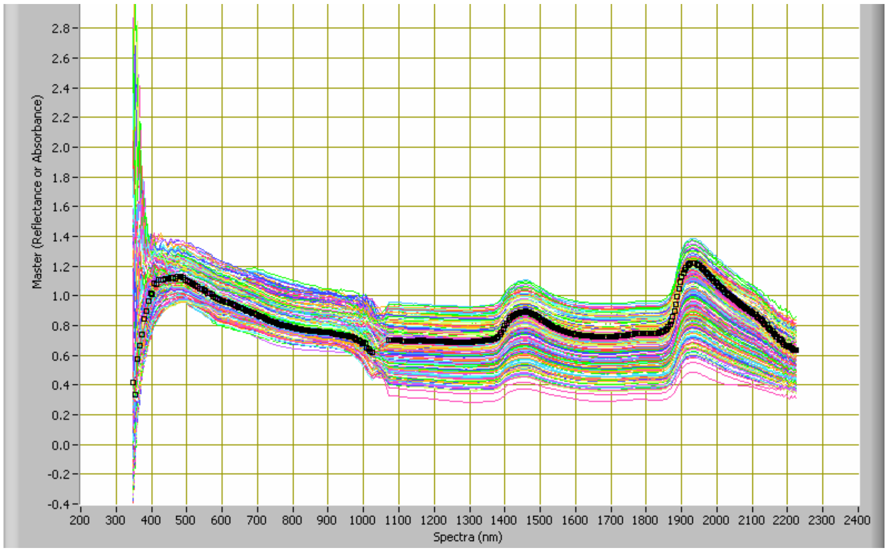
Near-infrared spectroscopy (NIRS)


(a) stretching vibration

(b) bending vibration

Molecules in soil that are exposed to light vibrate due to the force of the electric field. This vibration absorbs optical energy so that less light is reflected off the soil. The bonds that absorb the most in the near infrared region are C-H, N-H and O-H.

Near-infrared spectroscopy (NIRS)



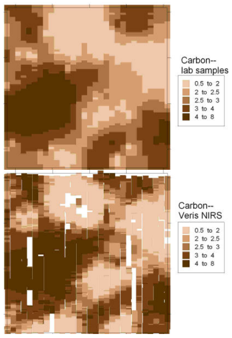
NIRS measurements of soil

Sudduth, K.A., Hummel, J.W., 1993. Soil organic matter, CEC, and moisture sensing with a portable NIR spectrophotometer. Transactions of the ASAE, vol 36, pp. 1571-1582.

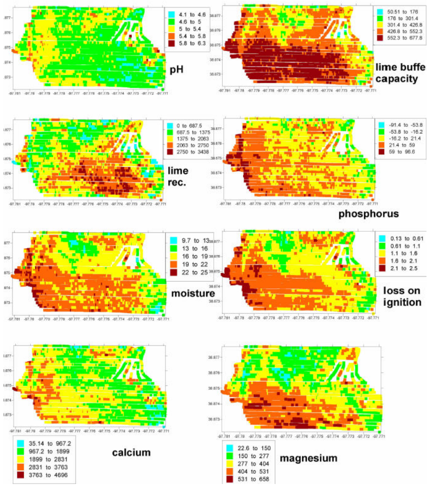
Chang, C.W., **Laird, D.A.,** Mausbach, M.J., Hurburgh, Jr., C.R., 2001. Near-infrared reflectance spectroscopy – principal components regression analysis of soil properties. Soil Science Society of America Journal 65, 480-490.

Reeves, J.B., McCarty, G.W., Meisinger, J.J., 1999. Near infrared reflectance spectroscopy for the analysis of agricultural soils. Journal of Near Infrared Spectroscopy 9 (1), 25-34.

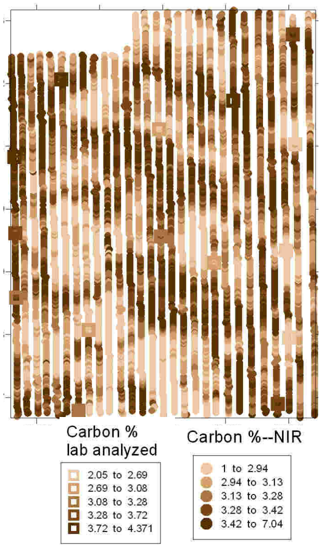
2002



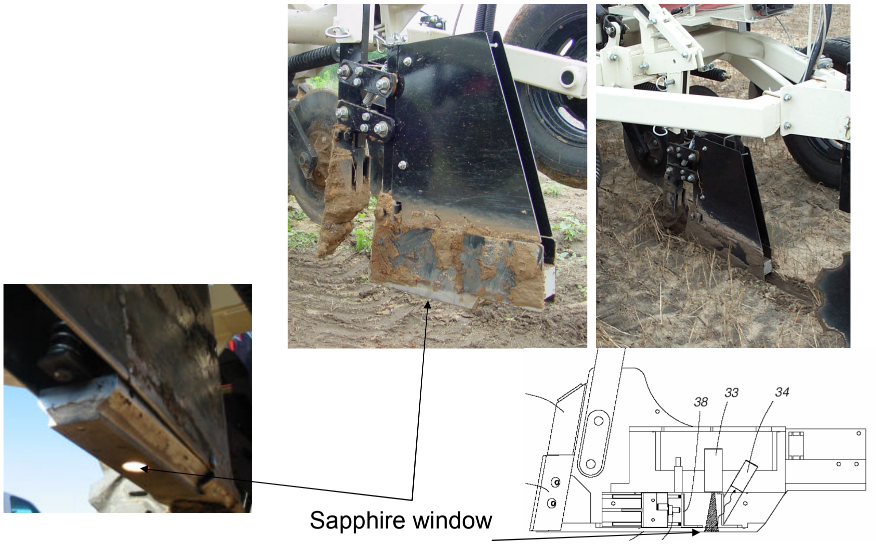
2002-2006
Multi-field studies in GA, MI, IA, IL, KS, MT



Veris VIS-NIR Technology
2006: ‘shank’ model in production



Veris VIS-NIR Technology
‘shank’ model



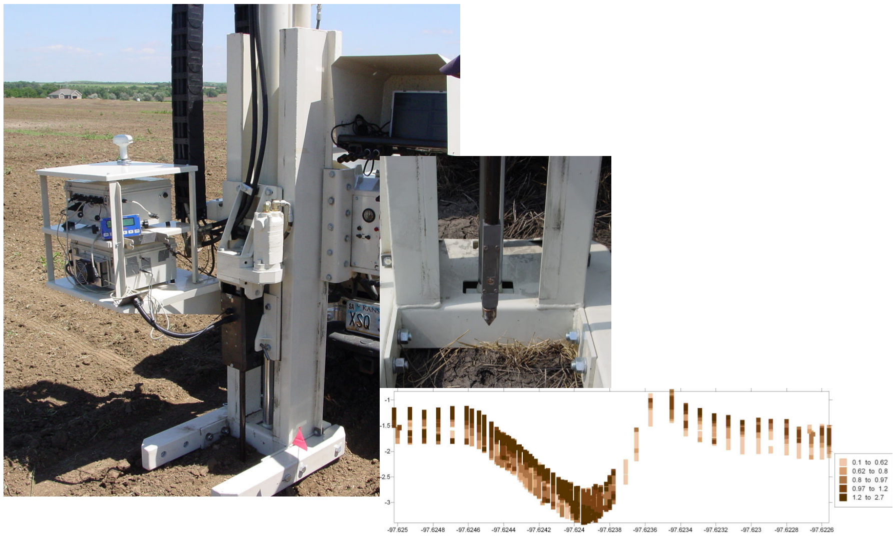
Sapphire window

Veris VIS-NIR Technology 'shank' model

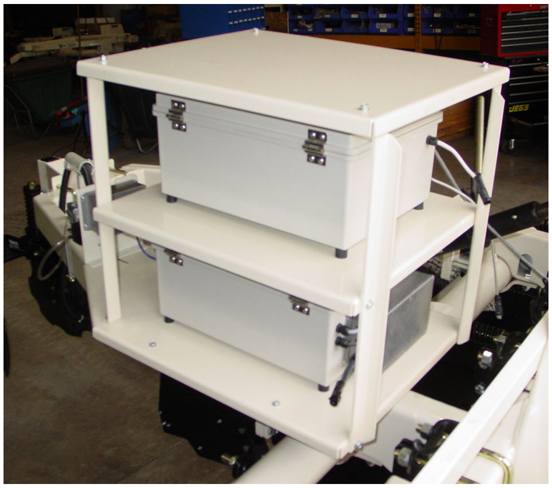
Initial Customers:
USDA-NSTL, Ames IA
Louisiana State University, Baton Rouge LA
Utah State University, Logan UT
Washington State University, Pullman WA
USDA-NSDL, Auburn AL
University of Kentucky, Lexington KY
Rodale Institute, Emmaus PA (2008)

Also Romania and Denmark research institutions

Veris VIS-NIR Technology 2008: 'probe' model

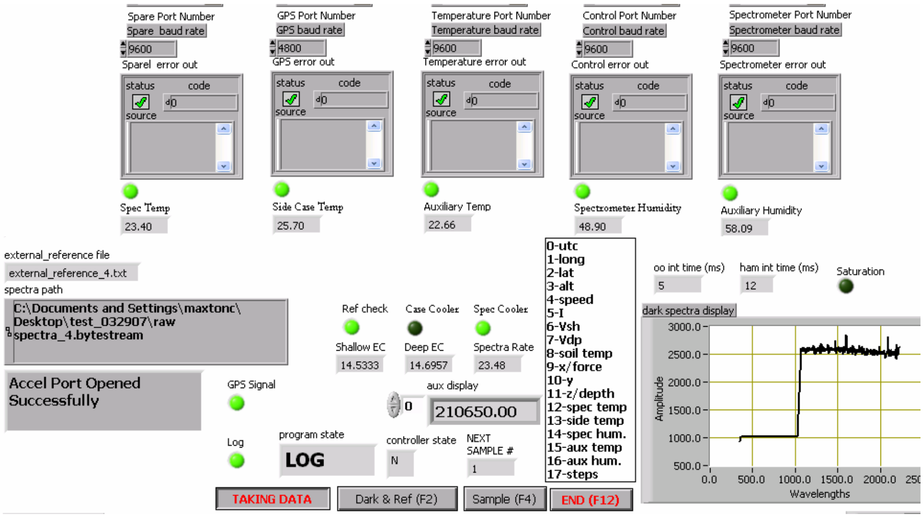


Veris VIS-NIR Technology
In-field instrumentation



20 spectra/second
386 measurements
8 nm resolution
3-4 MB/acre

Veris VIS-NIR Technology
In-field instrumentation



Spare Port Number
Spare baud rate
9600
Sparel error out
status ☑ code 0
source

GPS Port Number
GPS baud rate
4800
GPS error out
status ☑ code 0
source

Temperature Port Number
Temperature baud rate
9600
Temperature error out
status ☑ code 0
source

Control Port Number
Control baud rate
9600
Control error out
status ☑ code 0
source

Spectrometer Port Number
Spectrometer baud rate
9600
Spectrometer error out
status ☑ code 0
source

● Spec Temp
23.40

● Side Case Temp
25.70

● Auxiliary Temp
22.66

● Spectrometer Humidity
48.90

● Auxiliary Humidity
58.09

external_reference file
external_reference_4.txt
spectra path
C:\Documents and Settings\maxtonc\Desktop\test_032907\raw spectra_4.bytestream

Accel Port Opened Successfully

GPS Signal ●

Log ●

program state
LOG

Ref check ●
Case Cooler ●
Spec Cooler ●

Shallow EC
14.5333

Deep EC
14.6957

Spectra Rate
23.48

aux display
0
210650.00

controller state
N

NEXT SAMPLE #
1

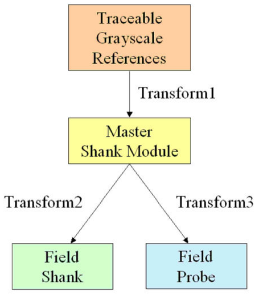
0-utc
1-long
2-lat
3-alt
4-speed
5-I
6-Vsh
7-Vdp
8-soil temp
9-x/force
10-y
11-z/depth
12-spec temp
13-side temp
14-spec hum.
15-aux temp
16-aux hum.
17-steps

oo int time (ms)
5

ham int time (ms)
12

Saturation ●

Veris VIS-NIR Technology
In-field instrumentation


Traceable Grayscale References

Transform1

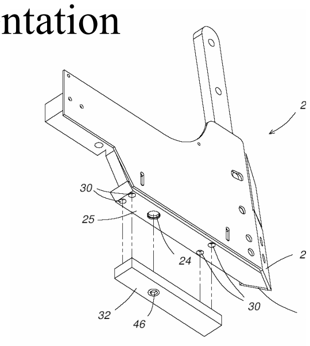
Master Shank Module

Transform2

Transform3

Field Shank

Field Probe



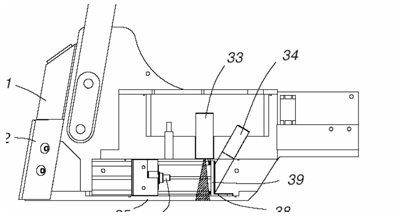
A)The first transform is used to calibrate the master instrument to the Avian reflectance standards. B) Then each slave instrument is given a master transform, which makes the data comparable to data taken on the master instrument.

C) A system check transform using external references compensates for any instrument variation due to wear. This ensures that over time the instrument will give the same readings as it did when it was first built.

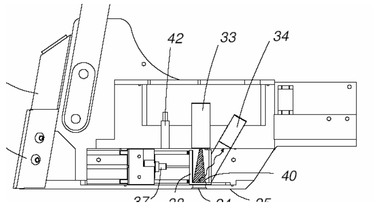
Veris VIS-NIR Technology
In-field instrumentation

D) An internal dark and reference shutter is used to compensate for drift in the spectrometer and light source. (Automatically every 10 minutes.)

Dark



Reference



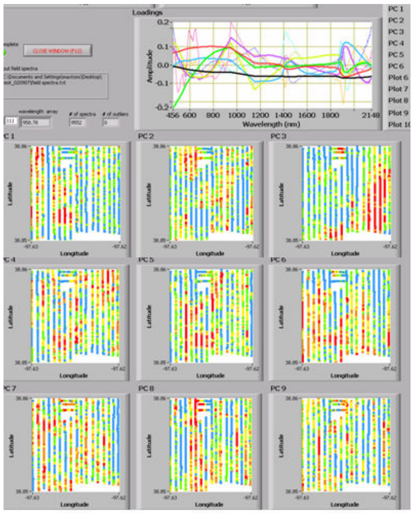
Veris VIS-NIR Technology
Data processing and management:

Principle Components Analysis (PCA) compression of data

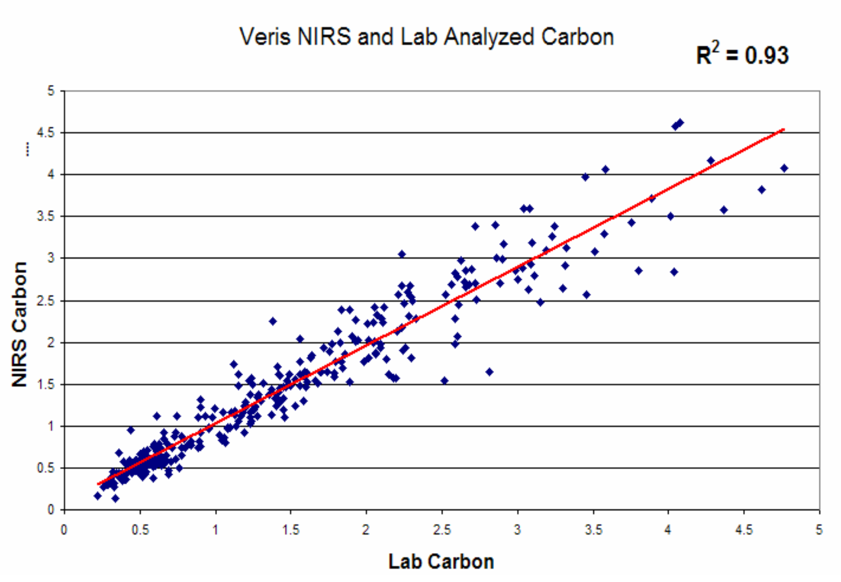
Clustering (fuzzy c-means algorithm) for soil sample locations

Partial least squares (PLS) regression for calibrating to a target soil property

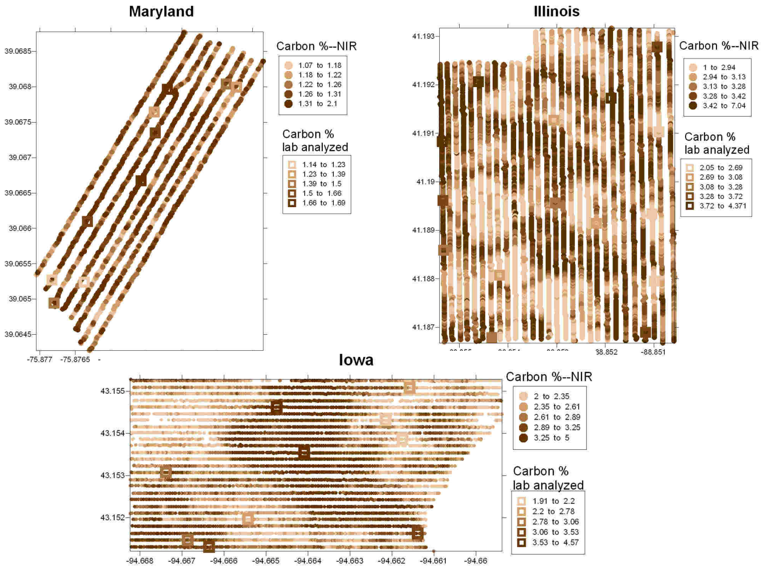
Leave one out cross validation



Veris VIS-NIR Technology Results:

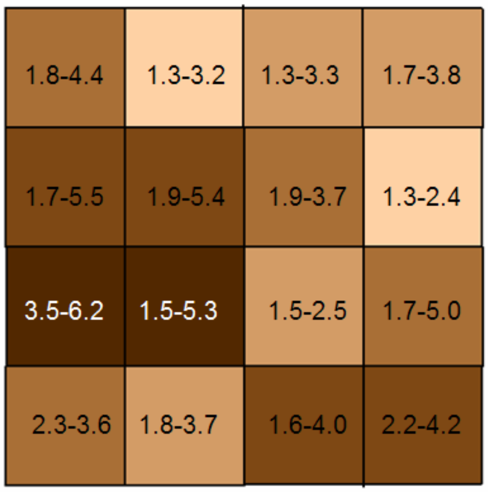


Veris VIS-NIR Technology Results:



Soil variability—an issue for measuring C.

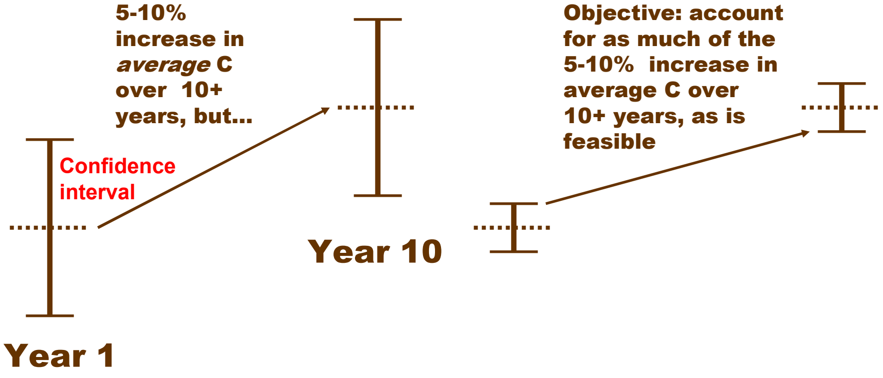
Soil variability—an issue for measuring C.



1.8-4.4	1.3-3.2	1.3-3.3	1.7-3.8
1.7-5.5	1.9-5.4	1.9-3.7	1.3-2.4
3.5-6.2	1.5-5.3	1.5-2.5	1.7-5.0
2.3-3.6	1.8-3.7	1.6-4.0	2.2-4.2

Carbon variability within 2 ½ acre grids (% C).

The challenge: measuring soil C with reduced confidence intervals.



5-10% increase in *average* C over 10+ years, but…

Confidence interval

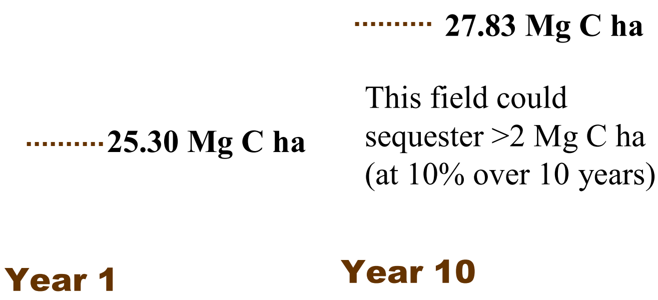
Year 10

Year 1

Objective: account for as much of the 5-10% increase in average C over 10+ years, as is feasible

The impact of confidence intervals…

FIELD NAME	*N*	*Mean C Mg C ha*	*Expected C change 10 years (10% increase in mean C)*	*Std. dev.*	*90% conf interval*	*110% of mean--start of seq.*	*90% of mean--10 year seq.*	*Difference based on conf. Interval*	*% of expected C increase accounted for*
Markley	18	25.30	27.83	7.26	2.28	27.58	25.55	-2.03	-80%

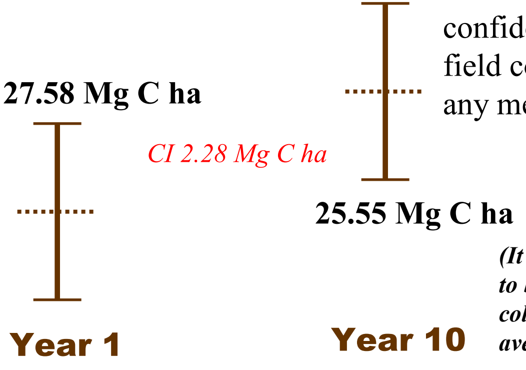


This field could sequester >2 Mg C ha (at 10% over 10 years)

The impact of confidence intervals…

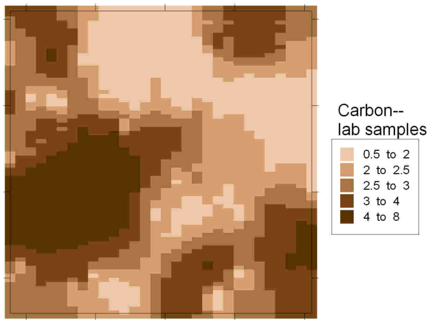
FIELD NAME	*N*	*Mean C Mg C ha*	*Expected C change 10 years (10% increase in mean C)*	*Std. dev.*	*90% conf interval*	*110% of mean--start of seq.*	*90% of mean--10 year seq.*	*Difference based on conf. Interval*	*% of expected C increase accounted for*
Markley	18	25.30	27.83	7.26	2.28	27.58	25.55	-2.03	-80%

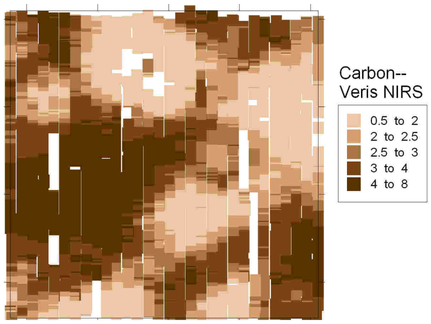
But based on the confidence interval, the field couldn’t achieve any measurable C.



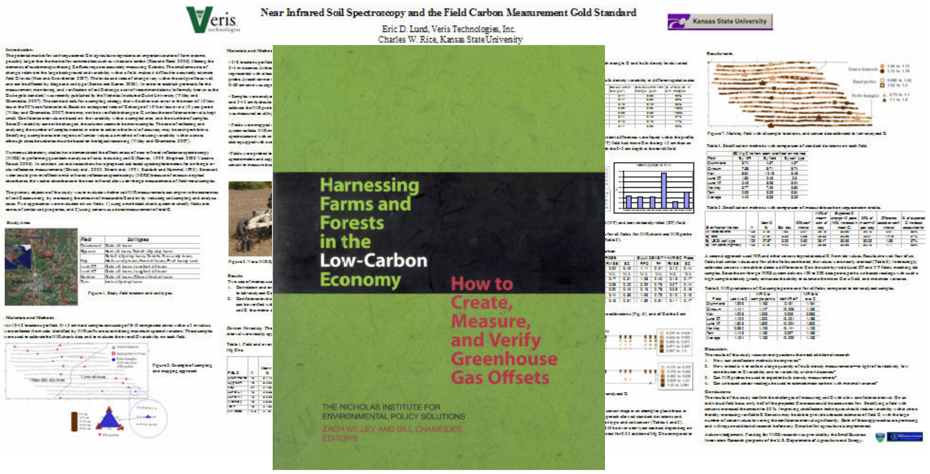
(It would take 60 samples to break even and 240 to collect 50% of the mean average increase)

Can VIS-NIRS carbon ‘survey’ maps reduce confidence intervals?





Can VIS-NIRS carbon ‘survey’ maps reduce confidence intervals?



Near Infrared Soil Spectroscopy and the Field Carbon Measurement Gold Standard

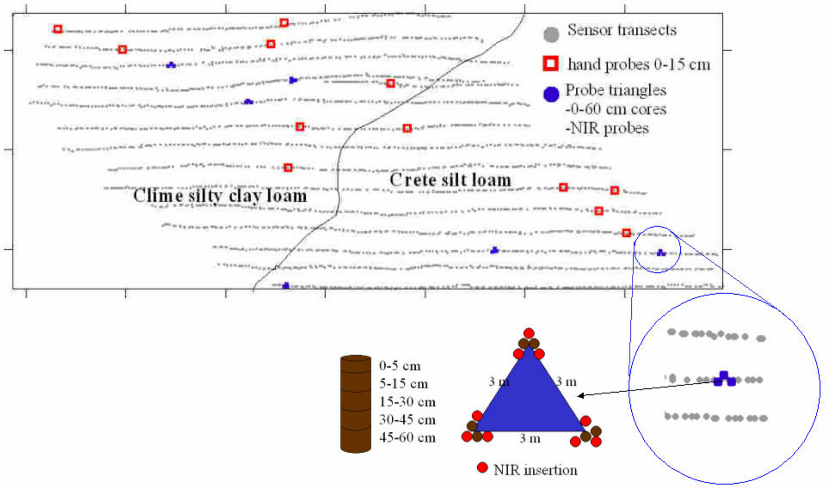
Eric D. Lund, Veris Technologies, Inc.
Charles W. Rice, Kansas State University

Harnessing Farms and Forests in the Low-Carbon Economy

How to Create, Measure, and Verify Greenhouse Gas Offsets

THE NICHOLAS INSTITUTE FOR ENVIRONMENTAL POLICY SOLUTIONS
ZACH WILLEY AND BILL CHAMEIDES, EDITORS

Case study: 6 Kansas Fields



C case study: 6 Kansas Fields

Variability—within triangle, within field, within profile

% of carbon measurable with lab analysis only (without sensors)

% of C measurable if VIS-NIR sensors and lab analysis are used

C variability found on 6 Kansas Fields

Carbon varibiability at different spatial scales-- 0-15 cm hyd. cores			
FIELD NAME	Std dev within field (MgC/ha)	Std dev within 10m triangle (MgC/ha)	% of field var. in 3 m triangles
Drummond	4.57	2.44	53%
Gypsum	8.71	6.07	70%
Kejr	10.18	1.72	17%
Lund CT	2.46	1.64	67%
Lund NT	3.08	2.36	77%
Markley	7.26	3.01	41%
Tarn	5.25	2.29	44%
ALL 6 KS FIELDS	7.82	2.79	36%

C variability found on 6 Kansas Fields

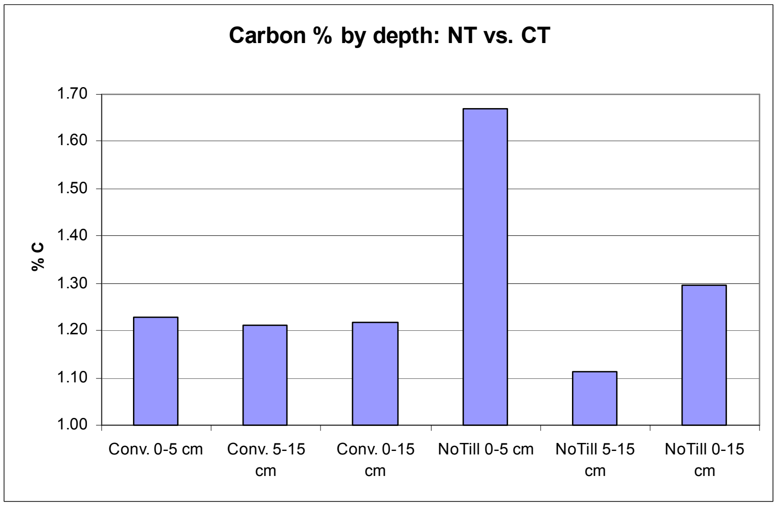
Confidence intervals and ‘countable carbon’

FIELD NAME	*N*	*Mean C %*	*Std. dev.*	*90% conf interval*	*110% of mean-- start of seq.*	*Expected C change 10 years (10% increase in mean C)*	*90% of mean--10 year seq.*	*Difference based on conf. Interval*	*% of expected C increase accounted for*
Drummond	15	31.10	4.57	1.59	32.69	34.21	32.62	-0.06	-2%
Gypsum	18	32.62	8.71	2.76	35.38	35.88	33.12	-2.26	-69%
Kejr	24	21.30	10.18	2.74	24.04	23.43	20.69	-3.35	-157%
Lund CT	15	29.55	2.46	0.85	30.40	32.51	31.65	1.25	42%
Lund NT	15	30.96	3.08	1.07	32.03	34.06	32.99	0.96	31%
Markley	18	25.30	7.26	2.28	27.58	27.83	25.55	-2.03	-80%
Tarn	18	27.30	5.25	1.65	28.95	30.03	28.38	-0.57	-21%
All fields	123	27.87	7.82	0.91	28.78	30.66	29.75	0.97	35%

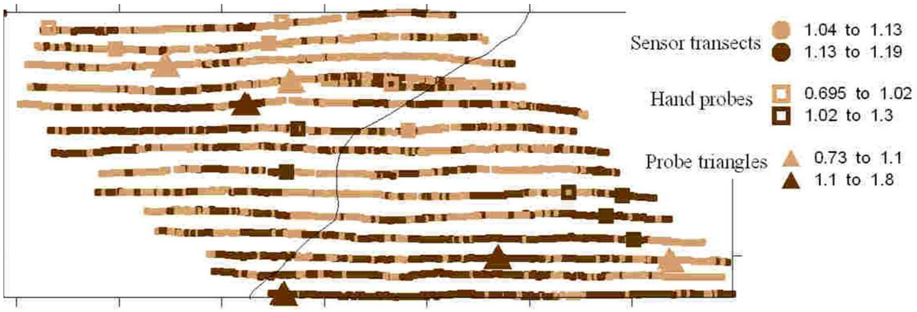
BD variability found on 6 Kansas Fields

Bulk Density varibiability at different spatial scales (0-15 cm hyd. cores)			
FIELD NAME	Std dev within field (g/c³)	Std dev within 10m triangle (g/c³)	% of field var. in 3 m triangles
Drummond	0.11	0.09	82%
Gypsum	0.11	0.09	82%
Kejr	0.16	0.10	63%
Lund CT	0.06	0.06	100%
Lund NT	0.08	0.08	100%
Markley	0.11	0.10	91%
Tarn	0.13	0.10	77%
Average 6 FIELDS	**0.11**	**0.09**	82%

C variability found on no-till (NT) and conventional tillage (CT) fields



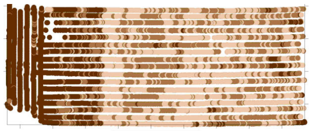
Veris VIS-NIR results

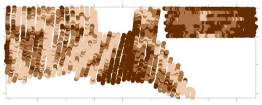


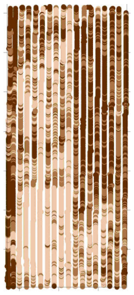
Veris VIS-NIR results

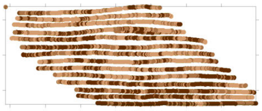
	% C--NIR SHANK				
Field	N	R²	RPD	RMSE	SD
Gypsum	12	0.93	2.34	0.14	0.34
Kejr	15	0.85	1.88	0.2	0.38
Drummonc	12	0.53	0.88	0.05	0.05
Lund_CT	10	0.92	2.34	0.07	0.15
Lund_NT	10	0.82	1.11	0.11	0.12
Markley	14	0.91	1.69	0.11	0.19
Tarn	12	0.92	1.83	0.08	0.15


Gypsum C%


Kejr C%

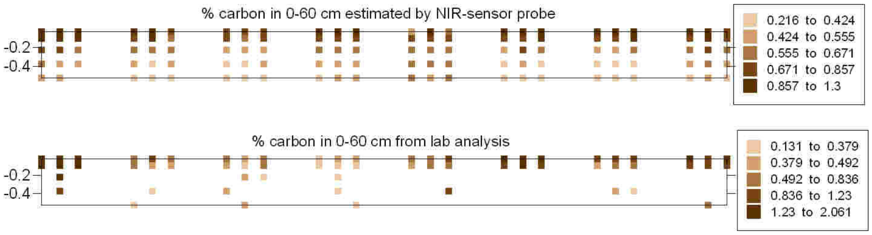

Lund CT (west) and NT (east)


Drummond C%


Markley C%


Tarn C%

Veris VIS-NIR results


% carbon in 0-60 cm estimated by NIR-sensor probe

% carbon in 0-60 cm from lab analysis

	% C–NIR PROBE					BULK DENSITY			
Field	N	R^2	RPD	RMSE	SD	RPD	R^2	RMSE	SD
Drummond	42	0.69	1.81	0.22	0.40	1.11	0.21	0.12	0.14
Kejr	51	0.89	3.06	0.17	0.51	1.28	0.40	0.13	0.17
Lund_CT	33	0.88	2.89	0.08	0.22	2.09	0.76	0.07	0.14
Lund_NT	38	0.77	2.09	0.20	0.42	2.16	0.78	0.08	0.18
Markley	45	0.84	2.52	0.14	0.35	1.95	0.73	0.10	0.19
Tam	52	0.74	1.97	0.16	0.31	1.59	0.61	0.11	0.17

Veris VIS-NIR results

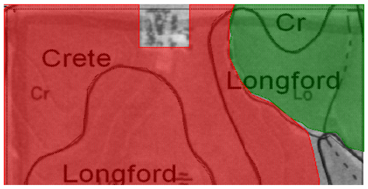
	SD Mg C ha from each stratification method		
Field	By NIR	By field	By soil type
Drummond	3.74	4.57	4.57
Gypsum	7.38	8.71	8.74
Kejr	8.84	10.18	6.48
Lund CT	1.80	2.46	2.6
Lund NT	2.45	3.08	3.04
Markley	3.77	7.26	5.82
Tam	2.95	5.25	5.34
Average	4.42	5.93	5.23

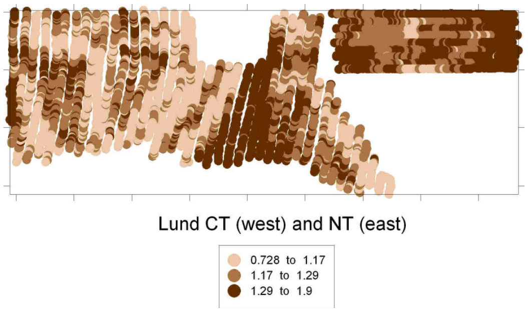
Veris VIS-NIR results

Stratification Method	*N*	*Mean C %*	*Std. dev.*	*90% conf interval*	*110% of mean–start of seq.*	*Expected C change 10 years (10% increase in mean C)*	*90% of mean–10 year seq.*	*Difference based on conf. Interval*	*% of expected C increase accounted for*
All fields as one	123	27.87	7.82	0.91	28.78	30.66	29.75	0.97	35%
By field	123	27.87	5.93	0.68	28.55	30.66	29.97	1.418	51%
By USDA soil type	123	27.87	5.23	0.60	28.47	30.66	30.05	1.58	57%
By NIR zone (high-low)	123	27.87	4.42	0.51	28.38	30.66	30.15	1.77	63%

Veris VIS-NIR results

Field	***% C--lab***	*NIR C-field*
Lund NT	1.305	1.303
Lund CT	1.199	1.188
All six fields	1.154	1.153




Lund CT (west) and NT (east)

Veris VIS-NIR results—implications of sensor ‘readings’ serving as ‘samples’.

FIELD NAME	*N*	*Mean C Mg C ha*	*Expected C change 10 years (10% increase in mean C)*	*Std. dev.*	*90% conf interval*	*110% of mean-- start of seq.*	*90% of mean--10 year seq.*	*Difference based on conf. Interval*	*% of expected C increase accounted for*
Markley	18	25.30	27.83	7.26	2.28	27.58	25.55	-2.03	-80%

FIELD NAME	*N*	*Mean C Mg C ha*	*Expected C change 10 years (10% increase in mean C)*	*Std. dev.*	*90% conf interval*	*110% of mean-- start of seq.*	*90% of mean--10 year seq.*	*Difference based on conf. Interval*	*% of expected C increase accounted for*
Markley	3000	25.30	27.83	7.26	0.18	25.48	27.65	2.18	86%

Future Considerations

More public-sector research needed on C field measurements and establishment of standards: (stratification and sensor-samples)

Veris will continue to improve its stratification methods with spectral calibrations and libraries.

Nitrous oxide emissions from agriculture—can precise maps of soil C and N help develop site-specific prescriptions of nitrate N?

Under a full-blown offset program, what % of acres will be measured?

Future Considerations

Auditing a % of acres or measuring every acre?

Consider this hypothetical: if the price per acre of carbon offsets is $10/yr, over a 10 yr contract the full payment could be as much as $100. If validation choices are:

1. Auditing X% of acres--$5/ac cost…50% discount of C
2. Measuring every acre--$20/ac cost…20% discount of C

Scenario 1 nets C seller $45/ac over 10 yrs.
Scenario 2 nets C seller $60/ac over 10 yrs.

Also, detailed C-N maps may help reduce NOX emissions; CSP and EQIP funds may be available to cover mapping costs.

Summary…

- On-the-go VIS-NIR measurements can be collected with commercially available equipment
- NIR shows potential to improve carbon measurements and reduce confidence intervals
- More public sector research needed on measurements of C using VIS-NIR

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