Quantifying the Value of Precise Soil Mapping

Contents:

Summary Points:

- Research shows that soil properties vary widely within 2.5 ac (1 ha) grids and USDA soil types
- Variable rate lime and seed prescriptions based on inaccurate maps can result in economic loss
- On-the-go soil sensors are able to accurately map soil texture, organic matter, and pH, along with topography at a very high resolution
- Two multi-state studies examined the economics of increased map accuracy. One compared pH maps based on grid sampling and Veris pH maps and found the increased density of pH data improved lime application accuracy by more than $14/ac. The other study found precise OM maps had nearly a $10/ac advantage over grid sampling and over $23/ac over USDA surveys in seed prescription accuracy.
- The economic returns from high-resolution soil maps are significant, considering the long-term usage of the maps and the number of applications that can be optimally managed.

Introduction

The challenge of accurately managing soil variability has been an issue since the inception of precision farming, but has become even more critical as growers seek to vary seed populations, nitrogen, lime and gypsum, and irrigation. Conventional soil maps are not precise and were not intended for precision farming usage. Most USDA soil surveys were completed before the advent of GPS, at a scale of 1:15,840 to 1:24,000, and did not identify areas smaller than 2-5 ac (1-2.5 ha). The danger of planting a variable corn population using an inaccurate map is illustrated in Figure 1. As is the case on most fields, a wide range of soil properties are found within soil survey units. Mistakenly planting a low population on highly producing soil would cause significant yield potential losses and over-populating lower producing soils wastes expensive seed and could reduce yield as well.

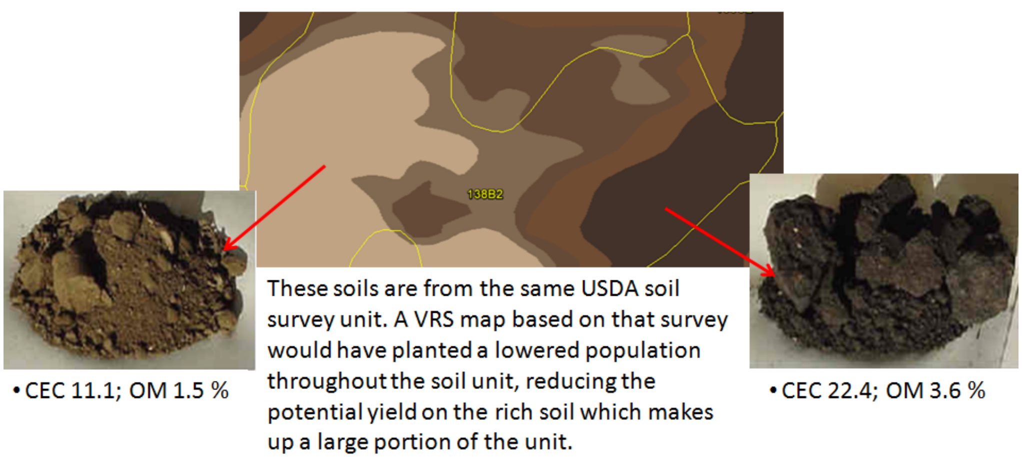
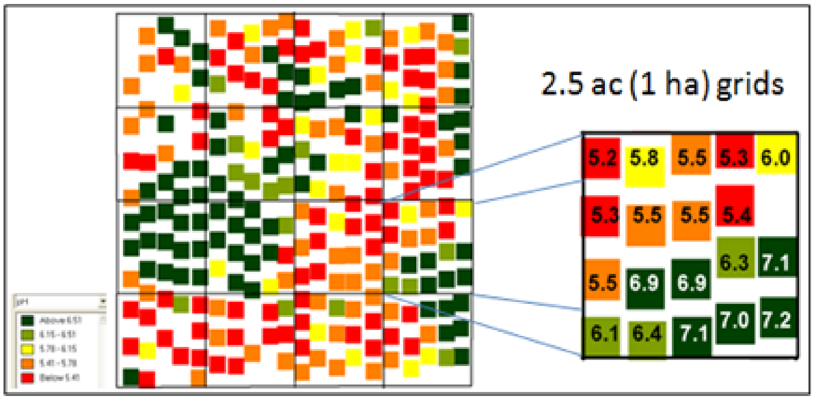


Figure 1. Soil varies widely within soil survey units

An alternative to soil surveys is grid sampling, typically on a 2.5 ac (1 ha) density. The errors in a grid sampling approach are not typically caused by poor lab analyses. Lab-analyzed grid samples are generally accurate at the sample locations. The problem occurs between the samples, where interpolating the grid point value creates an estimate for all the areas between the samples. The area covered by the soil cores in a grid sample represent less than 1% of the grid, and the remaining 99% is estimated from that 1%. As with soil survey units, there can be wide variations within 2.5 acre cells (Figure 2). Depending on where samples are taken, parts of a field will receive unneeded lime, and other areas not have acidity corrected. Both of these errors can cause economic harm.



One lime rate in a 2.5 acre grid will not be the correct amount for all the soil in that grid.

Figure 2. This 40 acre field has as much pH variations within most grid cells as there is in the entire field.

University research has confirmed that pH and other properties often change significantly within the distance between grid points (Bianchini and Mallarino, 2002; Brouder et al., 2005).

Agronomy Journal: (Iowa study)
"Soil pH varied from 5.4 to 8.0 over distances of about 480 ft (150 m) in most transects. In some sections soil pH varied about 2 pH units over a 40ft (12 m) distance…" Bianchini, A.A. and A.P.Mallarino. *Soil-Sampling Alternatives and Variable-Rate Liming for a Soybean—Corn Rotation*. Agronomy Journal Nov-Dec 2002

Soil Science Society Journal: (Indiana study)
"Data points from large grids (greater than or equal to 2 ½ acre) were too far apart to provide much information about the nature of pH or lime requirement change between adjacent sampling locations." Brouder, S.M., B.S. Hofmann, and D.K. Morris *Mapping Soil pH: Accuracy of Common Soil Sampling Strategies and Estimation Techniques* Soil Science Society of America Journal March-April 2005

On-the-go Field Scanning

Soil sensors using GPS have the dense coverage needed to improve the delineation of soil boundaries (Adamchuk et al., 2004). The first commercialized on-the-go soil mapping system was for mapping soil electrical conductivity. Soil EC measurements correlate with soil properties that affect crop productivity, including soil texture, cation exchange capacity, drainage conditions, salinity and subsoil characteristics (Kitchen et al., 2003; Grisso et al., 2009). On-the-go soil pH sensing was commercialized nearly a decade ago with the introduction of the Veris Mobile Sensor Platform (Adamchuk et al., 2004). Soil pH is an important factor in crop production. Nutrient usage, crop growth, legume nodulation, and herbicide activity are all affected by the pH of the soil. Recently, on-the-go soil organic matter mapping became commercially available with the Veris OpticMapper. (Kweon et al, 2012). Soil OM affects the chemical and physical properties of the soil and its overall health. It is a key component of productivity, affecting moisture holding capacity and nitrogen availability.

Veris Technologies produces two multi-sensor platforms that record soil EC, OM, and pH along with topography data (Figure 3). The MSP3 and U3 systems generate highly detailed soil maps of these critical soil properties (Figure 4).

Figure 3.Veris MSP3 and U3 models. (for more information see www.veristech.com)

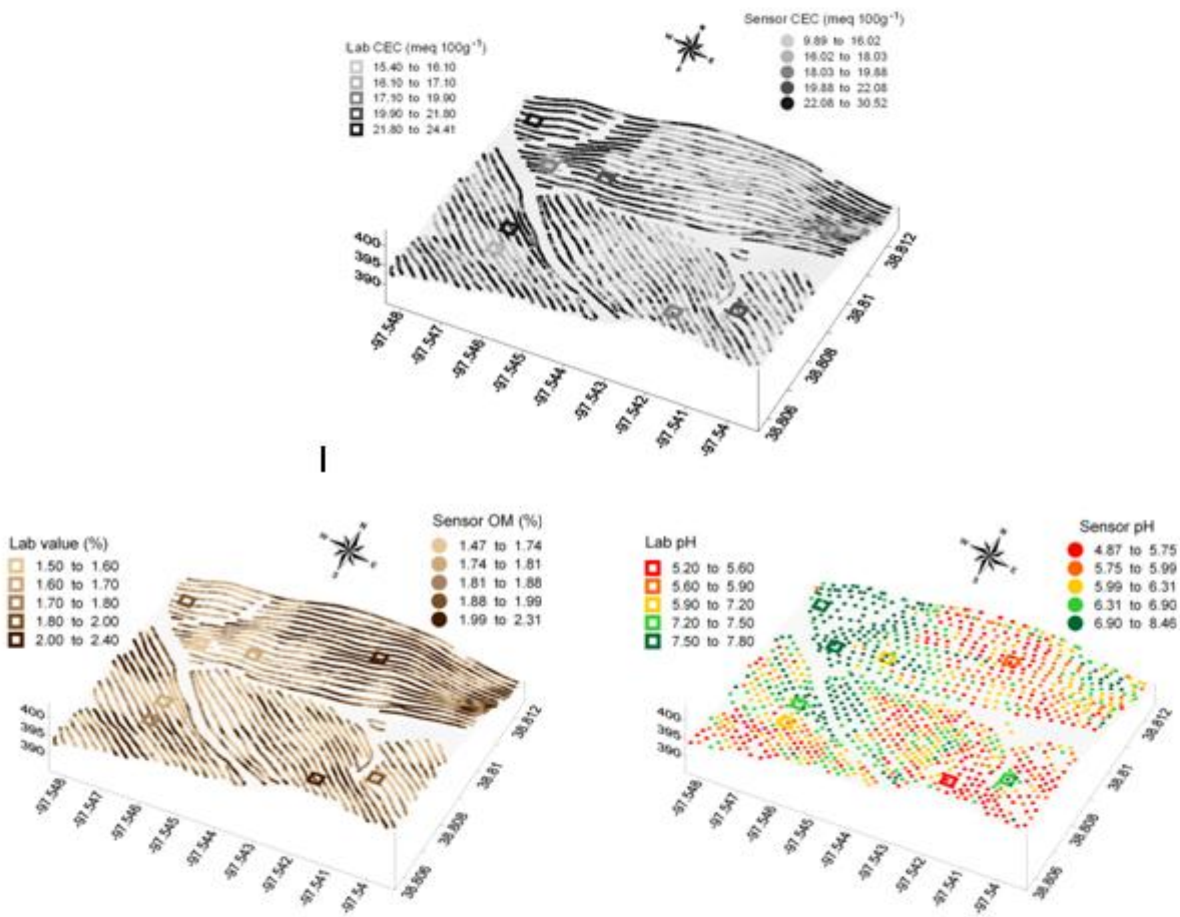


Figure 4. Transect maps of each soil property with calibration samples overlaid.

In a seven-state study, the accuracy of Veris sensing was compared to lab analyzed samples (Kweon , 2012). The results show the sensor values are well correlated with lab data (Figure 5).

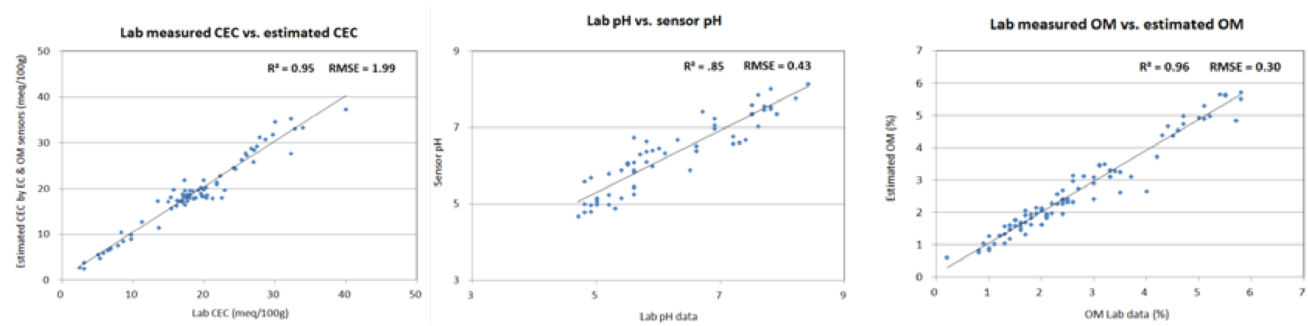


Figure 5. Veris sensing accuracy is validated with lab-analyzed samples.

Cost-Benefit Analysis

As discussed above, errors in using soil surveys and grid sampling can cause economic loss when variable rate prescriptions do not properly match the input rate to the intended soil. Since there is a cost for mapping, typically $10-15/ac, the value of added precision must offset the mapping cost. To help answer that question, two research projects were conducted: 1) a 5-state study evaluating the costs and returns of lime applications based on pH sensing vs. 2.5 ac (1 ha) grid sampling, and 2) a 7-state study comparing costs and returns of variable rate corn population prescriptions using Veris OM sensing, soil surveys, and grid sampling.

1. *Accuracy of variable rate lime prescriptions: (Illinois, Wisconsin, Nebraska, Kansas)*

The objective of this study was to compare the results of sensor-generated lime prescription maps with maps produced from conventional grid-sampling (Lund et al., 2004). Here's the research methodology: each field was grid sampled on 2.5 ac (1 ha) grids and mapped with Veris Mobile Sensor Platform pH sensors; 10 lab-analyzed validation points were placed in the field to check the accuracy of both methods; interpolated lime prescription maps were generated and the amount of lime estimated by each sampling method was compared to the actual lab analysis at the validation points. The difference between the lime that was estimated and the actual lime needed as determined by the lab sample is the error. Figure 6 shows both the grid sampled map with validation points and the Veris pH map with validation points. Figure 7 shows the interpolated maps for each method.

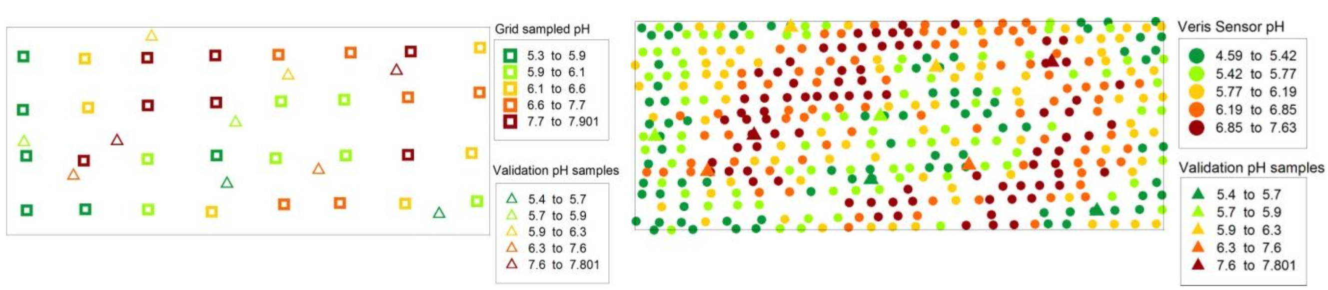


Figure 6. IL field. Left, grid samples with validation points. Right, Veris pH points with validation points.

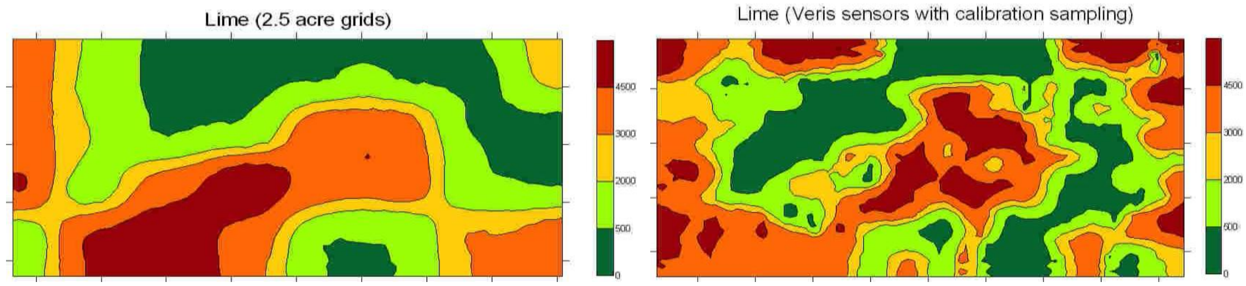


Figure 7. IL field. Interpolated lime prescriptions, from grids (left) and Veris sensing (right).

The same approach was used on all five fields. Results show the extra detail provided by the Veris maps generated an average $14.32/ac advantage in improved lime accuracy, based on a $30/ton applied cost of lime (Table 1). While lime costs vary, the $30/ton is a conservative estimate and the potential for yield improvement was not included. The typical cost of a Veris MSP3 map is $15-20/ac which means the lime accuracy improvement alone covers most of the initial map cost.

	Veris advantage (lbs/ac lime)	Value of precision @ $30/ton lime
KS – 1	1560	$ 23.40
KS – 2	550	$ 8.25
NE	79	$ 1.19
WI	1116	$ 16.74
IL	1468	$ 22.02
Average	954.6	**$ 14.32**

Table 1. Results of 5 state lime study in lbs/ac and dollars/ac.

2. *Accuracy of variable corn population prescriptions: (IA, IL, IN, KS, MO, NE, OH)*

To evaluate the cost:benefit ratio of precision soil mapping for variable rate seeding (VRS), data from a seven-state study was analyzed. There were three parts to the analysis: 1) comparing organic matter (OM) estimations using precise soil mapping to the estimations of interpolated 2.5 ac grid maps and SSURGO soil surveys; 2) to quantify the potential yield benefits of increased precision a VRS model was generated based on increasing corn populations in higher OM areas and reducing rates in lower OM areas; and 3) comparing the economic returns of each approach with the costs of precision soil mapping. Visual examination of the maps from the corn belt states showed variations within overlaid SSURGO soil types and grids (Figure 8).

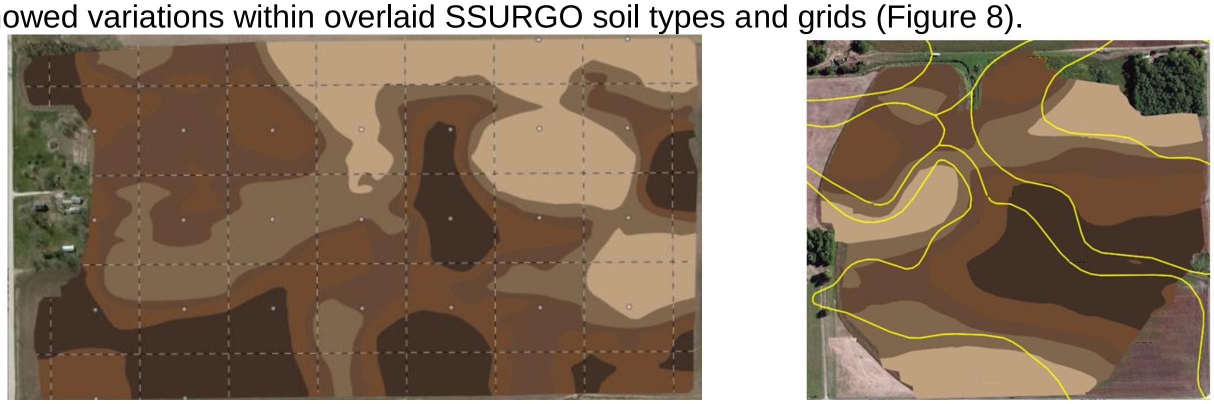


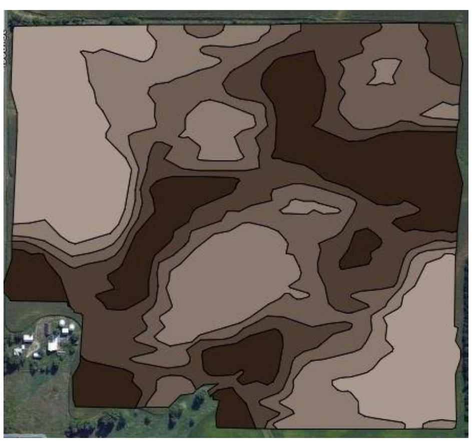
Figure 8. 2.5 ac grids and SSURGO soil surveys from Iowa and Illinois fields overlaid on Veris maps.

Analyzing the discrepancies in the OM estimations showed that while grid sampling achieved better accuracy than SSURGO surveys, the accuracy of both of these methods had significantly more errors than precise Veris soil mapping (Table 2).

	Veris OM map improvement vs. 2.5 ac grids	Veris OM map improvement vs. SSURGO surveys
Ohio	47%	61%
Iowa	56%	69%
Kansas	27%	58%
Indiana	18%	26%
Nebraska	35%	53%
Missouri	35%	49%
Illinois	48%	61%
Average Improved Accuracy	**30%**	**46%**

Table 2. Veris OM mapping showed a 30% improvement in accuracy vs. grid sampling and 46% vs. SSURGO soil surveys.

A VRS model was generated which included each field's nominal corn population, its average OM level and range of OM variability. An example prescription is shown in Figure 9 and the prescription model described in Table 3.



VRS Model inputs	
Average OM	3%
OM range	2.5-3.5%
Nominal rate	32,000
VRS Prescription	
2.5-2.7 % OM	28000 seeds/ac
2.7-2.9 % OM	30000 seeds/ac
2.9-3.1 % OM	32000 seeds/ac
3.1-3.3 % OM	34000 seeds/ac
3.3-3.5 % OM	36000 seeds/ac

Figure 9. Corn population prescription for Iowa field. Table 3. VRS model example for Iowa field.

When higher OM soils received additional seeds, potential yield increases were calculated and when population was reduced on lower capability soils, a seed cost savings was included. The resulting estimations showed potential net returns for ideal VRS prescriptions averaged $25.85/ac with lower returns for prescriptions based on poorer maps (Table 4). These are in line with most of the reported returns for VRS, which helps confirm the model assumptions.

	Benefit for VRS $/ac		
State average	Veris	2.5 acre grids	SSURGO
Ohio	$ 11.78	$ 4.94	$ (2.94)
Iowa	$ 24.89	$ 12.58	$ (0.40)
Kansas	$ 14.87	$ 9.44	$ (15.91)
Indiana	$ 24.22	$ 13.44	$ 4.08
Nebraska	$54.56	$39.97	$22.27
Missouri	$3.71	$1.48	$0.04
Illinois	$ 21.00	$ 12.67	$ 4.33
Avg. Veris benefit/ac	**$25.85**	**$16.20**	**$2.75**
Lost potential/ac		**$9.65**	**$23.10**

Table 4. Net returns per acre for VRS using Veris maps, 2.5 ac grid maps, and SSURGO surveys.

The economic advantages of precise soil maps over SSURGO soil surveys average $23.10 per acre. A visual inspection of SSURGO lines overlaid on Veris maps shows why this amount is so large. Most soil survey units have a significant range of soil variability within them. The economic return of Veris maps over 2.5 ac grid sampling is $9.65/ac. While the missed opportunities for full profit are less than when using SSURGO, the returns per acre cover a significant portion of the Veris mapping cost, especially when considering this is a one-year return and the Veris map will provide improved precision for many years.

Conclusion

There is a cost for misapplying inputs and a benefit for applying inputs correctly; the cost of a suboptimal map and the benefit of a precise map are unique to each field. These multi-state studies, conducted on several fields across a wide area of the central US, shows the average benefit of a Veris EC-OM-pH map over 2.5 ac grid sampling is $23.97/ac, and $23.10/ac over USDA soil surveys. Since the cost of a Veris map is $10-20/ac, the benefits far outweigh the costs, especially when considering the Veris map is a long-term map of slow-changing soil properties. Also, these studies only examined two variable rate applications; precise soil maps can be beneficial for many additional precision programs: improved nitrogent management, soil sampling zones, multi-genetic planting, variable irrigation, and more.

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1925 Clay Ridge
Salina KS, 67401 (785) 825-1978
www.veristech.com