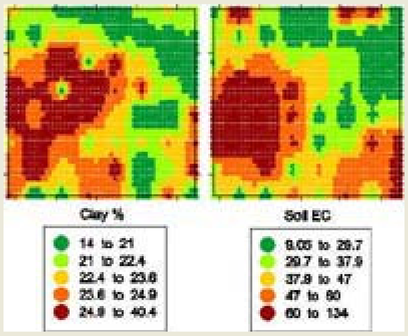
1. What does soil electrical conductivity measure?

Conductivity is a measure of the ability of a material to transmit (conduct) an electrical charge. It is an intrinsic property of the material just like other material properties such as density or porosity. Geo-referenced soil EC data is a map showing how the various soils in a field differ in their ability to conduct electricity.



The value of a soil EC map in agriculture is that it's a rapid, low-cost, and effective surrogate measurement of soil properties, such as soil texture--the relative amount of sand-silt-clay. To collect 50+ soil samples/per acre and have them lab analyzed, would be cost-prohibitive. Yet a Veris EC system collects that many data points per acre, and can produce an accurate map of soil texture variability for a few dollars/acre. The clay content map from Iowa at left was generated using 24 lab-analyzed samples from a 40 acre (16 ha) field. The Veris 3100 mapped the same field in less than one hour--producing the map on the right.

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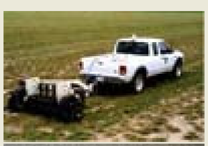
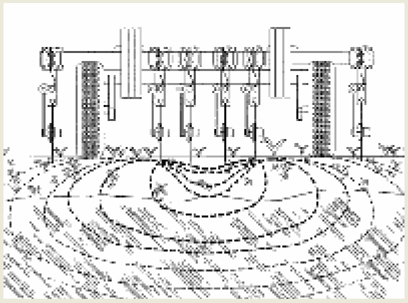
2. How does a Veris EC System work?



Longitude	Latitude	EC shallow	EC deep
-97.5617	38.8086	24.027515	52.9284
-97.5617	38.8087	22.659389	54.9967
-97.5617	38.8088	19.380775	60.5321
-97.5617	38.8089	14.747456	54.7632
-97.5617	38.809	11.219912	42.3537
-97.5617	38.8091	9.12623	31.8186
-97.5617	38.8092	7.382284	23.9689

Veris Soil EC Mapping Systems rapidly acquire EC data from a field. As the cart is pulled through the field, the system acquires conductivity measurements and geo-references them using a GPS receiver. When used on transects of 50' (15m) swaths at speeds up to 15 mph (24 k/h), the system produces between 50 and 100 samples per acre (120-240 per ha). The EC and GPS data are recorded in an ASCII text format on a Veris datalogger or onto a laptop.

3. How deep does the Veris EC signal reach?



As the Veris EC cart is pulled through the field, one pair of coulter-electrodes injects electrical current into the soil, while the other coulter-electrodes measure the voltage drop. While these coulter-electrodes only need to penetrate the soil a few inches, the electrical arrays employed by the Veris system investigate the soil to a depth of approximately 36" (90cm). The Veris 3100 uses two EC arrays to map 0-1’(30 cm) and 0-3’ (90 cm) soil depths simultaneously. The Veris 2000XA uses a single array that is adjustable from 0-2’ (60 cm) up to 0-3’ (90 cm). The effective depths of electrical arrays such as these is well-documented in scientific literature. (Milsom, J. 1989. Field Geophysics. Open University Press, Milton Keynes and Halsted Press, John Wiley & Sons, New York)

4. What are milliSiemens per meter (mS/M)?

These are the standard units of measure of bulk soil conductivity. A Siemen is a measurement of a material's conductance; expressing the value in milliSiemens per meter (mS/meter) removes the volume from the equation—just as a material's density is independent of its volume. An Ohm is a measure of resistance, while Siemens are a measure of conductance. In some scientific literature the electrical measurements of the soil are expressed in resistivity--or ohm-meters.

5. What soil properties affect the soil EC signal?

Heavy clays, with high particle-to-particle contact and high moisture holding capacity are highly conductive. Coarse sands, with limited particle contact and low moisture holding capacity are extremely poor conductors. In the vast majority of farm fields, the primary EC response is due to the soil texture variances within the field. In saline areas, the EC response can be affected by the presence of dissolved salts in the soil's pore water. EC signals from saline spots are typically much higher than the signals from heavy clays. Veris clients in saline areas report that their EC maps reveal the field's soil texture--with saline hotspots clearly visible on the EC map.

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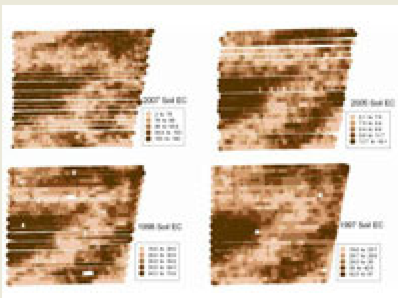
6. What about soil moisture? How will it affect EC readings?



Soil moisture does affect soil EC readings--in fact, a small amount of soil moisture (10% above wilting point) is required for soil EC mapping. It's important to understand the following facts about soil EC and soil moisture:

A soil EC map will consistently show areas of contrasting soil texture. The overall EC values may increase with increased soil moisture, but the relative values remain consistent.

Whether a field is near wilting point, or near field capacity, the finer-textured soils will have higher EC's than the coarser-textured soils. The repeatability of EC mapping is well-documented.

Localized rainfall differences within a field typically do not cause enough of a difference in the overall soil profile moisture to affect the EC readings. This is due to one of the most significant benefits of EC technology--it integrates its signal throughout the soil profile up to 3' (90cm). If one part of a field receives more rainfall than another, or if south-facing slopes are drier than north-facing slopes, surface measurements such as bare soil imagery might be significantly affected. But the EC signal measures much deeper, and is much less affected by these temporal events. In irrigated fields, there can be a significant enough difference in soil profile moisture to create EC differences--such as at the pivot corners. It is advisable to map fields with different irrigation patterns on separate files, to allow for normalizing and re-combining later.

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7. Will Veris soil EC always correlate with the lab EC analysis of a soil sample?

No. In saline fields, the two sets of data are typically well-correlated, but in non-saline fields there is often no statistically significant correlation. To better understand why Veris soil EC (sometimes referred to as "bulk" soil EC) measurements from non-saline fields often do not correlate with lab EC, it's important to understand how the signal moves through the soil. Work done by Dr. Jim Rhoades and others at the USDA Salinity Laboratory in Riverside CA, present an EC model that describes conductance along three pathways acting in parallel: (1) conductance through alternating layers of soil particles and their bound soil solution, (2) conductance through continuous soil solution, and (3) conductance through or along surfaces of soil particles in direct contact with each other. When a soil sample is put into solution or a saturated paste, pathways 1 and 3 are virtually eliminated. These are the "soil texture pathways", as soil texture will determine the amount of contact surfaces, and ability to hold moisture on the soil colloid. In non-saline fields, these pathways contribute significantly to the overall EC signal. In saline fields, pathway 2 dominates the signal response in the field and in the lab analysis.

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8. Since I can't change it, is soil texture worth mapping?

Soil texture relates to factors that have a major impact on productivity, such as: water holding capacity, cation-exchange-capacity (CEC), topsoil depth, and nitrogen-use efficiency. Therefore, EC maps often correlate well with crop yield maps. An EC map is a fundamental layer needed for precision action, such as guided soil sampling, yield map analysis, variable seeding, variable yield goals/N, and land-leveling.

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9. What about soil nutrients? How can soil EC help determine how much fertilizer to apply?

Whether soil will hold, lose, or use nutrients is strongly related to its texture. Mobile nutrients like nitrogen are leached through light soil and lost through de-nitrification in heavy soil. Immobile nutrients like P and K will vary for many reasons--especially due to crop removal variances. Soil pH tends to become acidic sooner in coarser-textured soils than in more buffered finer-textured soils. With soil EC you define the soil texture variability first--then make sure each sample is in the spot to do the most good.

Click here to see how a soil EC map can help guide soil sampling

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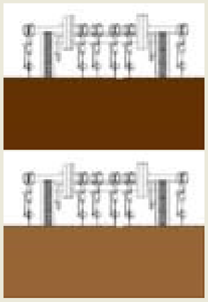
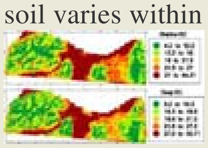
10. How do I interpret EC data from the two depths of EC arrays?

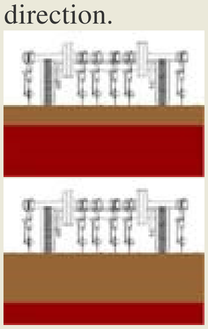
Veris Soil EC mapping quickly reveals that soil varies in three dimensions: X, Y, and -Z. The examples below are simplified scenarios of this variability:



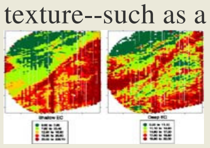
Scenario 1: relatively deep topsoil that has very slight textural changes with depth (-Z); but that deep topsoil varies within the field (X and Y).



In this scenario, the two arrays will show a similar pattern of zones, frequently with slightly higher EC in the deeper array. In this scenario, the patterns on the EC map relate to the soil texture differences in X and Y direction.

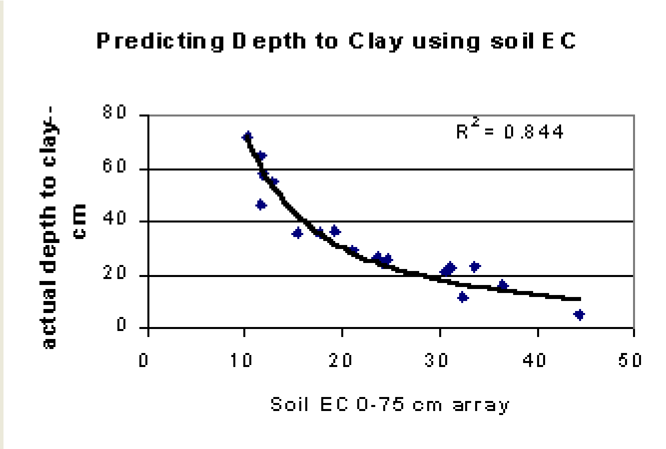


Scenario 2: The depth of the topsoil varies significantly (-Z), and the subsoil has a significantly different texture--such as a claypan, sand lense, gravel, or bedrock.



In this scenario, the two maps often reveals quite different patterns. These differences in EC relate to the differences in topsoil and subsoil textures.

If topsoil is relatively consistent, but there is a lot of variability in the depth of topsoil over clay or gravel (any textural discontinuity), EC can predict depth of topsoil in whole field.



In most fields, there are elements of both scenarios--some variability in topsoil depth, and some X and Y variability as well. Loess soils tend to be deeper and have more XY variability, while alluvial soils tend to be highly variable in all three directions.

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11. Which depth should I use?

If soil samples are to be pulled from the top 6-8", it's advisable to use the shallow EC layer to direct the sampling. For yield analysis or variable rate seeding, the deeper EC is favored—since crops are affected by soil properties throughout their rooting depth. The relationship between the two EC layers can be especially helpful in defining shallow soils or in areas where salinity is moving vertically in the profile. In those situations, looking at a ratio of the deep to the shallow EC, or creating a difference map of the EC values, can provide an additional layer of information.

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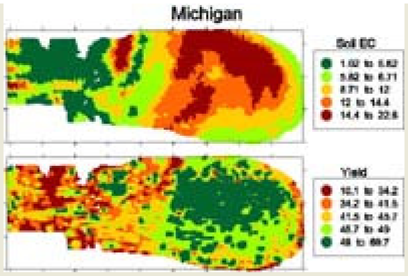
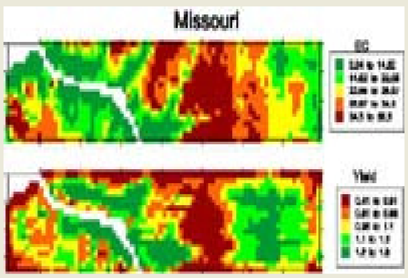
12. Does conductivity correlate to yield?

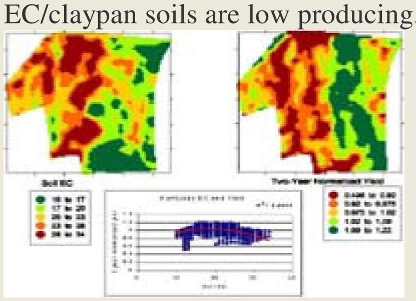
The relationship between a soil EC map and yield data (or crop imagery) is one of the most powerful applications of either data set. Crops grow in soil, and because soil is the primary medium for crop development, a precise map of soil variability is helpful in explaining yield variability. The soil properties that vary on an EC map, such as soil texture, salinity, CEC, soil depth all have a direct impact on yield. As the EC and yield maps are compared, here are some concepts to consider:



The relationship between EC and yield can be positive or inverse. Yields may be higher in high EC areas, or lower in high EC areas depending on the type of clay and the growing conditions for a given year. For example, yields in much of the northern cornbelt tend to increase in high EC areas of the field.



While in the claypan soils of the southern cornbelt, the opposite is true. This is due to the fact that the high EC/clay loam soils in the northern cornbelt tend to be high producing (if properly drained), while the high EC/claypan soils are low producing.



Yields may be best in the mid-range soils, and lower in the low and high EC areas. Loam soils typically produce better than sandy or clayey soils. When the soils on a field cover a wide range of textures, a non-linear relationship may exist.

For more information on the soil EC and yield analysis, download a PDF file of a paper on this topic:

Yield Analysis Paper [PDF] 324 KB

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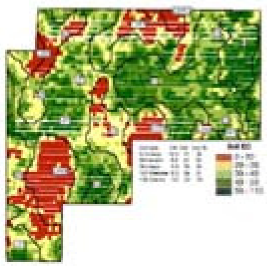
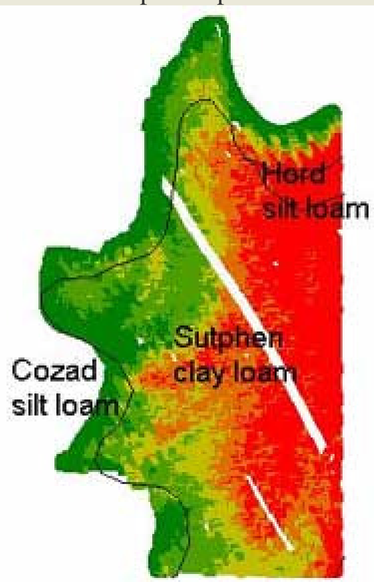
13. How do Veris soil maps correlate with USDA soil maps?

In virtually every field where the Veris and USDA-NRCS soil survey maps have been compared, there is a definite correlation between the two, which one would expect since soil texture is a key element behind both. There are some important differences that generally occur:



Inclusions: The Veris soil map identifies inclusions not found on the USDA maps. (USDA Order 2 soil surveys allow for 2½ to 4 acre inclusions—areas of different soils thought to be too small to identify at the time the maps were created). With site-specific management, an area this size can represent a significant discrepancy. **Errors:** Many of the errors in soil surveys were a result of not having GPS technology available when the surveys were done. Other sources of errors stem from the small number of sites investigated on a given field. The Veris map is geo-referenced, and with a transect width of 50’, there are over 50 data points per acre collected—virtually solid coverage of a field.



Transitions: soils don’t change on a line—but are a continuum. This is evident when a soil survey is overlaid on an EC map. For example, on this field the clay loam Sutphen is gradually changing into a coarser textured soil on the west part of the field. The soil survey indicates this change as an abrupt line, when in reality the transition zone between the two soil types is its own soil type.

Surveys have value...many surveys done at the 1:15,840 scale (or finer) are able to provide important supporting information about the field. Their lines may not be accurate, but these surveys can help supply the "what" information, while the soil EC map provides the "where".

For more information, download this PDF file:

Soil EC Maps and Soil Surveys [PDF] 96 KB

14. Does the field have to be in any certain condition?

The Veris® Sensor Cart is designed to operate in tilled or un-tilled conditions. There needs to be a small amount of soil moisture present--approximately 10% above wilting point. Excess moisture is not typically a problem. EC mapping must not be attempted when the soil is frozen, or if any frost layer is present. Frozen soil has significantly different conductive properties and the EC data collected will not be valid. As described in other FAQ's, soil moisture and density affect EC. For these reasons it is advisable to EC map a field when it is in a single crop and tillage state.

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15. What about soil compaction?

Compacted soil conducts electricity better than un-compacted soil, due to the elimination of airspace and the increased soil particle-to-particle contact. Yet compaction is rarely visible on an EC map. Why not? The compacted layer represents only a small percentage of the volume of soil that is being investigated by the Veris soil EC arrays. Even though a compacted layer is elevating the EC reading slightly, that difference is masked by the overall EC signal changes due to soil differences within the field. In sandy soils, the compaction is more readily evident due to the low EC signal generated through coarse-textured soils.

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16. What about the effects of manure and commercial fertilizer?

Any material containing salts which have been applied to a field will elevate the soil EC, whether it's manure or a commercial fertilizer. Depending on the amount applied, and the rainfall on the field, this effect may last from a few days to several months.

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17. What about outside interference, such as power lines, on the conductivity reading?

The direct contact method that Veris uses has a distinct advantage over electromagnetic induction technology in this regard. There is virtually no possibility of ambient electrical interference with the Veris direct contact method.

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18. Are there any calibration procedures required?

None. All the settings are programmed into the Veris instrument. An occasional check to make sure each of the coulters is electrically isolated from the implement is all that is needed.

19. Can the EC readings drift during operation, due to changes in air temperature or other causes?

No. By injecting the electrical current into the soil, there is no signal drift due to changes in air temperature, nor is there is any instrument drift due to other causes. After completing a large field, Veris customers can drive back across the field and be assured that the data collected hours earlier will be the same.

20. How does the Veris method of rolling electrodes compare to electromagnetic induction methods of measuring EC?

Although these two systems use different methods of measuring soil electrical conductivity (electromagnetic induction vs. direct contact), research has established that measurements by the two devices are strongly correlated to each other, when operated in a controlled, research setting.

When soil EC mapping is conducted in field-scale commercial agriculture, the advantages of the Veris system are numerous:

Simple and Easy to Use: The Veris EC Systems were designed expressly for mobilized mapping of farm fields. The implement is ruggedly constructed of tubular steel and the spring-loaded coulter-electrodes can take the punishment of tough field condition. Direct contact measurements of soil EC are not plagued with interference from nearby metal, utility wires, or engine noise, as is the case with the electromagnetic induction method. Because the position of the electrodes and the current are pre-programmed, with Veris there is no need to calibrate or null any of the settings. The instrument/data logger uses easy-to-understand prompts, enabling non-computer personnel to map effectively.

The Most Reliable EC Data: Research done by the USDA-ARS at Columbia, MO has shown the need to re-calibrate the EMI unit every 30 minutes of mapping. This re-calibration is necessitated by changes in air temperature and also due to instrument drift. Because the Veris electrodes directly inject the signal into the soil, changes in air temperature have virtually no effect on its readings. (EC data collected with both systems are affected by soil temperature). The Veris system requires no nulling or calibration.

A System Built by a Company Committed to Precision Agriculture: When you buy a Veris EC system, you get a system—from generating the electrical signal, to measuring the voltage of that signal as it moves through the soil, converting the analog response to digital, to logging it with a DGPS signal, it's one system from one supplier, designed expressly for agricultural soil mapping. At Veris Technologies our business is helping growers, researchers, consultants, and input suppliers identify and understand soil variability—and devise strategies to optimize inputs accordingly. We're committed to making Soil Specific Agriculture successful.

21. Can I pull Veris Soil EC Systems on the highway?

The VS 3100 and 3150 can be transported on the highway at legal speeds. In most states, the #8303 road kit makes the unit legal for day and night operation. Check with your local department of transportation on specific requirements in your area.

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22. Can I use a Veris EC System in bedded or furrowed fields?

Yes, many of our clients operate their units in these conditions. Depending on the height of the bed or depth of the furrow, you may need to raise or lower some of the electrodes, as shown in this photo. The 3150 model can more easily adapt to crop rows and beds than the 3100.

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23. Can I collect soil EC information while completing a tillage or planting operation?

Yes, if the Sensor Cart is attached to a secondary tillage or planting implement, the conductivity information can be obtained as a field operation is being completed.

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24. What is the suggested swath width?

While it is possible to use any swath the operator chooses, it is our experience that a 50'-70' (15-21m) swath provides a map that adequately identifies the spatial patterns of a field. It also represents a typical spray boom width and consequently the smallest area most growers will variably manage.

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25. Why not use the Veris reading to control a planter or applicator in real time?

The relationship between conductivity and inputs is not simply linear. The highest economic value is in using the Veris soil map in conjunction with other information such as: historical productivity, sample data, and local agronomic knowledge. For example, in some areas, higher conductivity indicates higher clay/CEC, resulting in higher yield goals and additional inputs on those sites. In other regions, the higher conductivity indicates excessive clay, which may limit production—calling for reduced inputs. In both cases, a Veris soil map of the field identifies those sites and allows individual recipes to be created.

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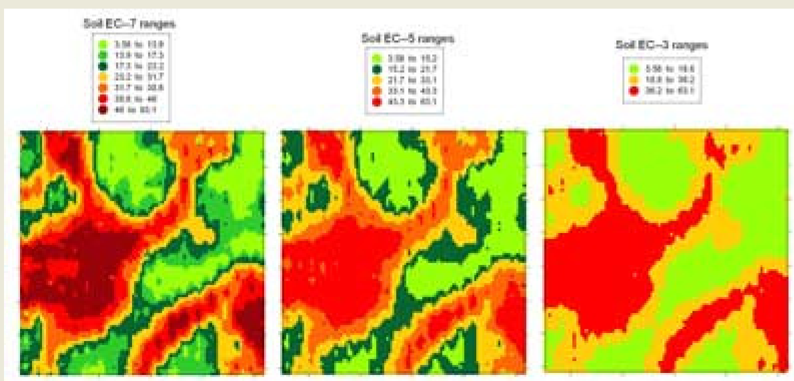
26. How should I theme EC data?

Soil texture is a continuum, and in most cases, soil EC data should be displayed with no artificially imposed breaks. Most mapping software has an option called equal number, which divides the data into ranges containing an equal number of EC points in each range. Typically, three to five ranges are adequate to display the soil EC pattern. Shown here is an EC dataset from an Iowa field displayed with three, five, and seven ranges. The basic pattern is evident on the map with only three ranges, and doesn't change significantly as the number of ranges increase. The detail required will depend on several factors, such as cost of sampling, variable rate equipment responsiveness, and input costs.



When using an EC map for soil sampling, it is recommended that you map the raw data and view it before determining sampling sites. There are frequently small areas of contrasting EC values that may be hidden when data is smoothed or contoured. Even if these areas are too small to sample separately, they likely should be avoided when sampling. Any unnatural pattern in the map, such as streaks, offsets, and noise, alert the consultant and grower of a possible problem. The exception would be man-made artificial patterns from land leveling or other soil-changing activity. It is important to view raw, unprocessed data, since interpolation techniques can mask problem data.

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27. What GPS, and GIS software shall I use?

GPS requirements: NMEA 0183 messages required: GGA, VTG, RMC; 4800-8-none-1, 1 hz update rate serial connection with DB9 connector, female sockets; GPS signal on pin 2, ground on pin 5; no signal or power on other pins

There are several good GIS options to choose from: SSToolbox, Ag Leader/SMS, FarmWorks, SGIS, Mapshots, HGIS.

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28. Can I combine EC data collected at different soil temperatures and moisture contents?

Yes, this is best attempted to combine adjacent fields, as shown here: Normalizing Before attempting to normalize and combine EC data across a large geographic area, ground-truth the meaning behind the EC values with a soil survey or other method.

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29. How would I use EC data in pooled data analysis?

There is increasing interest in aggregating precision ag data into local, regional, and national data warehouses. The primary soils information that is being used with this pooled data are USDA-NRCS soil surveys. As described in the FAQ: How do Veris soil maps correlate with USDA soil maps? soil EC data represents a large improvement over a soil survey in mapping soil with detail and precision.   The question becomes: how can the precision of a soil EC map be used to augment aggregated data analysis, considering that EC provides field-specific--perhaps farm-specific soil information, but EC values alone cannot be compared over a wide area.

Here's how EC can be used in pooled data analysis:

One of the issues in data-pooling regards the quality of the data. If a soil survey has mis-mapped a significant portion of a field, including that field in a data pool will weaken the results. Soil inclusions will buffer the results of any analysis by soil type. A soil survey overlaid on an EC map quickly reveals whether there are significant areas that should be excluded from further analysis. After an analysis by soil type has been completed, apply the information learned using EC map.

For example, if analysis shows that Clarion soil types responds to additional nitrogen, use the EC map to identify the Clarion soils, and apply that nitrogen more precisely. Finally, data analysis centers can use EC to better explain in-field variability. This website has many examples of how EC is being used in many different areas to analyze crop production information.