Site-Specific Management Guidelines

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SSMG-29

Geographic Information Systems (GIS) in Site-Specific Systems

Summary

The collection and management of data from site-specific crop and soil management systems soon overwhelm the standard farm record system. Geographic information systems (GIS) provide a systematic approach to managing the large amounts of data accumulated, along with the tools necessary for analysis and interpretation. This Guideline reviews some example data sets used to characterize a field and how GIS can help organize and manage the data so that they can be more effectively used in various management decisions.

Data Representation

Data are basically numbers (or other information) that describe observations or measurements of characteristics of a field. Moving from field-average to site-specific management increases the amount of data that are available for decisions, but also increases the challenge of storing and organizing the data. In their simplest form, data in a GIS are displayed as a map of the area of interest. Spatial analysis can be used to link data points to individual points on the maps. Statistics, simulations and models are additional analytical tools that can be applied through the GIS to extract more information from the data to support decisions.

GIS—More than Maps

GIS software provides a structure for presenting data in the form of maps for visual analysis, as points, lines and areas, but the power of GIS goes far beyond the maps. In fact, mapping is a minor part of the use of GIS. The databases associated with GIS and the tools to manipulate those data sets are powerful tools for organizing, analyzing and interpreting data.

Vector and Raster Data

Data are stored in a GIS in two main formats—vector and raster. *Vector* representation of data is probably more familiar and more precise, defining objects as points, connected points (lines) or areas enclosed by lines (polygons). *Raster* representation has advantages, but is somewhat less precise because the entire cell has to be identified with the same representation. Precision depends upon the relative size of the grid cells.

Points

Points are stored as individual (x,y) coordinates in vector format, or as individual column, row (col,row) matrix cells in a raster format.

Lines

Lines are stored as a set of mathematically connected points in vector format, or as connected cells in raster format.

Areas (or polygons)

Areas (or polygons) are stored as a mathematically connected set of points defining the boundary (vector) or as a set of contiguous cells defining the interior (raster).

The different common data representation formats for a GIS are illustrated in **Figure 1**.

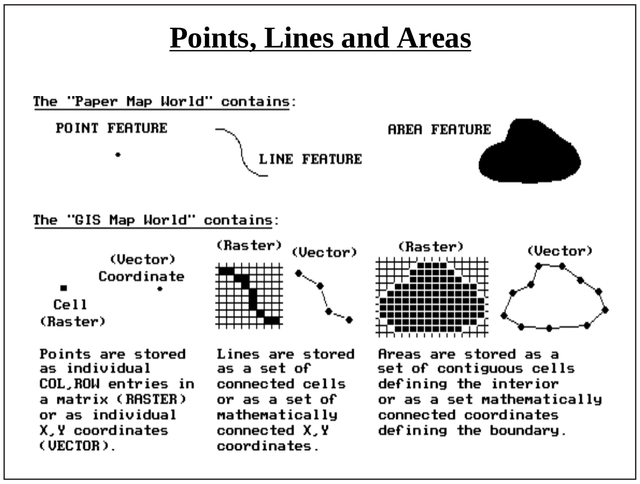

Figure 1. Comparison of vector and raster representation of points, lines and areas. (Berry, 1997)

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Interpretations

A simple analysis of a GIS data set might be to classify the data for further interpretation. For example, the yield map in **Figure 2**, shows yields divided into three classes (<73 bu/A; 73-101 bu/A; >101 bu/A). These classes were defined as "plus and minus one standard deviation unit from the average yield of the field." This approach helps identify areas of the field producing unusually high or low yields. That may be the first step toward identifying "why" the yields are different in those areas.

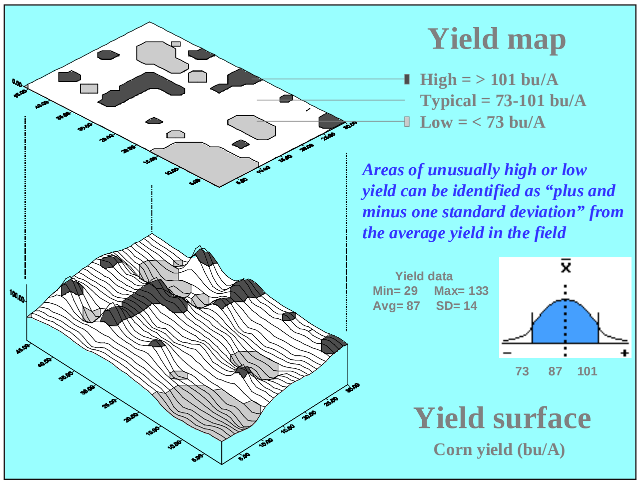


Figure 2. Graphical GIS representation yield statistics for a field. (Berry, 1997).

Field vs Site-specific

When records and analysis deal with only one data point per field, record keeping is simple, but does not support enough detail to characterize the field for site-specific management decisions. For example, if data are recorded for each 40-acre field, a square mile is represented by only 16 data points. Changing to a resolution of 20 meters square per point, the data set expands to about 6,400 data points for that same square mile. At 5 meters square resolution, there are more than 100,000 data points per square mile.

Figure 3 illustrates several different data sets collected for a central Illinois field in a corn/soybean rotation[1]. To demonstrate some of the power of GIS in site-specific management, these data are used with ArcView GIS to help interpret sources of yield variability in the field.

Soil Survey

One of the most basic sources of yield variability is the variation in soil types within the field. **Figure 4** is an Order 1 soil survey map for the field. The data files associated with the soil types provide a detailed database of soil characteristics that can be related to other observations and measurements.

The ultimate integrator of all of the factors affecting a crop is yield. The soybean yield map of the south half of this field (**Figure 5**) represents the combined variability in all of the factors controlling yield.

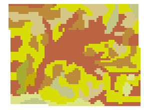
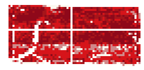
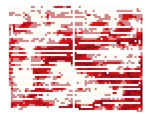
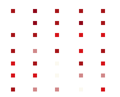
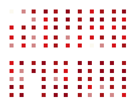
	Thumbnail	Description
1		Order 1 soil survey (NRCS)
2		Yield data (corn/soybeans)— several files (John Reifsteck)
3		Soil conductivity as measured by Veris Technologies. Includes measurements for 0-1 foot and 0-3 feet with each data point. (Veris Technologies)
4		1995 soil tests using 2.5-acre grid (location, phosphorus (P), potassium (K), pH, organic matter, and recommended treatment for P, K, nitrogen (N), and lime. (Illini FS)
5		1.0 acre grid soil samples in two files: (X, Y, P, K, pH, Om, Prec, Krec, Nrec, Lrec) (FAR/USB Project, Univ. of Illinois)

Figure 3. Sample GIS data sets for a central Illinois field. These and other data sets are available for downloading from the internet at http://www.farmresearch.com.

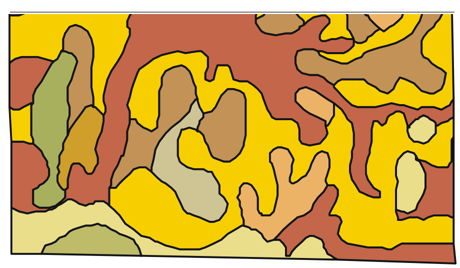


Figure 4. Order 1 soil survey classification for a central Illinois field.

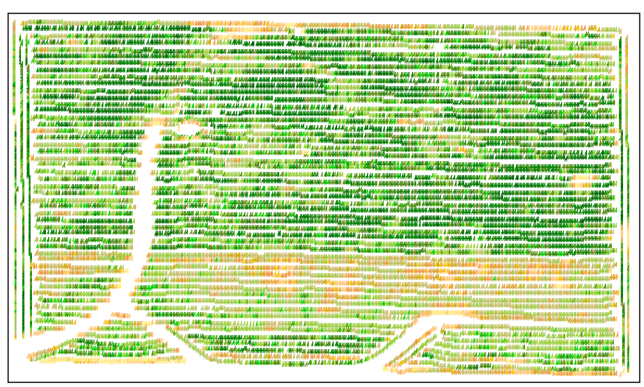


Figure 5. Map of soybean yield data from the field in Figure 4.

Mathematical combination of data points on the yield map helps provide a more workable data set. **Figure 6**

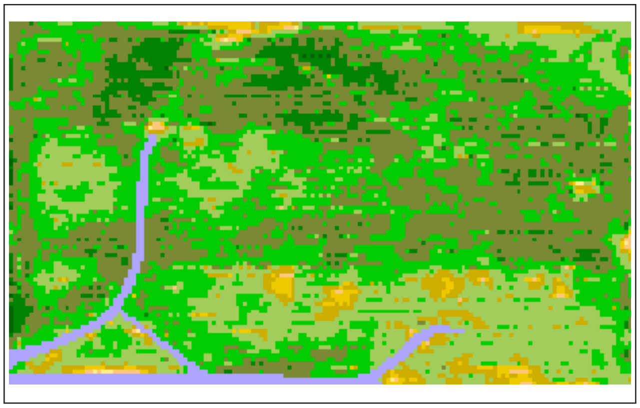


Figure 6. Interpolated soybean yield map from data in Figure 5. (Westervelt, 2000)

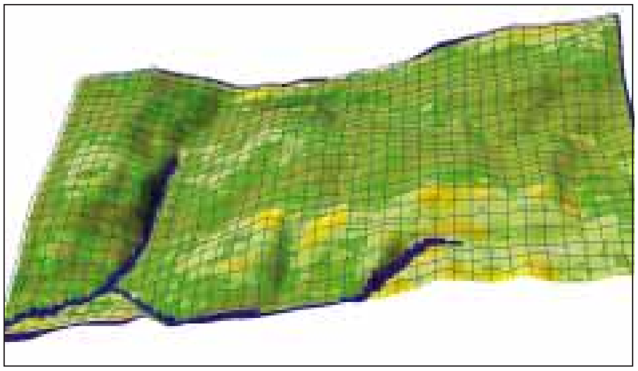


Figure 8. Yield (depicted by variable colors) projected on elevation in 3-dimensional projection. (Westervelt, 2000).

illustrates the interpolation of the data points in **Figure 5** on a 5-meter grid basis, to produce a yield map that can be related to other data sets.

Once variability in yield is determined, the next logical step is to try to identify sources of that variability. It is usually safe to assume that soil property changes across the field are responsible for some, if not most of the changes in yield.

The topography of the field, for example, affects the flow and accumulation of water, which is one of the main factors affecting yield in most fields. **Figure 7** is a representation of the flow rate of water across the south half of the example field, with darker color representing greater intensity of flow. Analysis of topography data with a digital elevation model is used to generate a flow accumulation map, representing the flow of water across the field. Intensity of color indicates relative accumulation of water flow in a given area. Note that water flows generally from the northeast to the southwest.

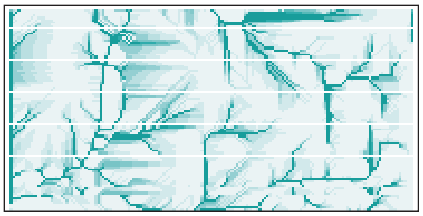


Figure 7. GIS representation of water flow for the field in Figures 5-6. (Westervelt, 2000).

An exaggerated vertical scale helps provide a visual interpretation of the relationship between topographic position and yield (**Figure 8**), but the real power of the GIS is seen when mathematical operations, models, and statistical analysis are used to analyze the relationships between yield and other data layers.

Figure 9 compares yield with water flow and soil conductivity (as measured with an electrical conductivity sensor cart).[2] This 3-dimensional representation is one of the visual applications of GIS analysis. Much more in-depth mathematical analysis is possible with a GIS package. The agronomic relationships among data layers in the GIS may be unknown from previous research, but can be evaluated in a GIS analysis. Once these relationships are determined, field research can be done to test the relationships.

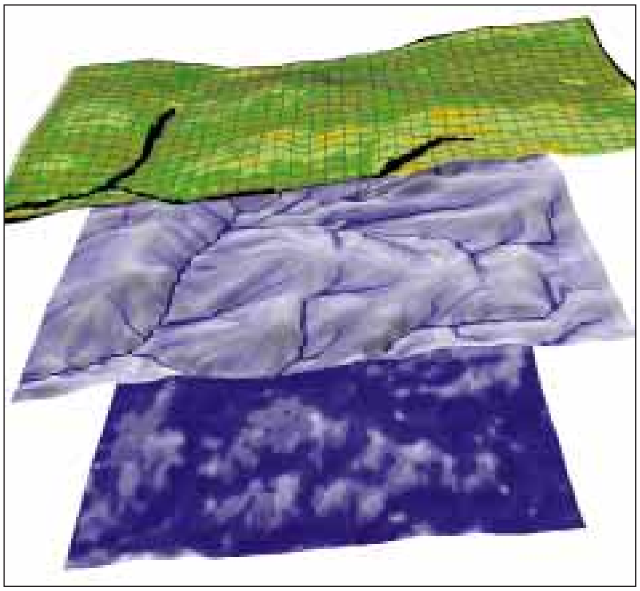


Figure 9. GIS projection of yield, topography, and electrical conductivity for the field in Figures 5-8. (Westervelt, 2000).

Models and Interpretation Tools

Using the data organized in the GIS package with various models increases the power of GIS as an analytical or management tool. Models can range from simple mathematical manipulations of data sets between two maps, or multiple maps, to complex simulations involving large numbers of maps and calculations among them. Applying models on a site-specific basis within fields is impractical without a GIS data management system to organize the data and computations.

The real power of GIS is found in the linking of several data sets, analytical models, and interpretation tools (**Figure 10**). Agricultural users are just beginning to understand and utilize this capability. Some applications depend upon linking and transferring data between the GIS and other software tools such as spreadsheets and databases. **Figure 11** illustrates a series of data layers that might be used to produce a computed profitability map, which might be used by a farmer and his advisers to determine the variability in profit within the field. This map in turn guides decisions on investments in improved fertility, drainage, or other management to focus those dollars where they would produce the greatest return on investment. As the database for each field develops over time, multiple layers of many of the data sets will be added, and the analytical and interpretive power of the GIS increases dramatically.

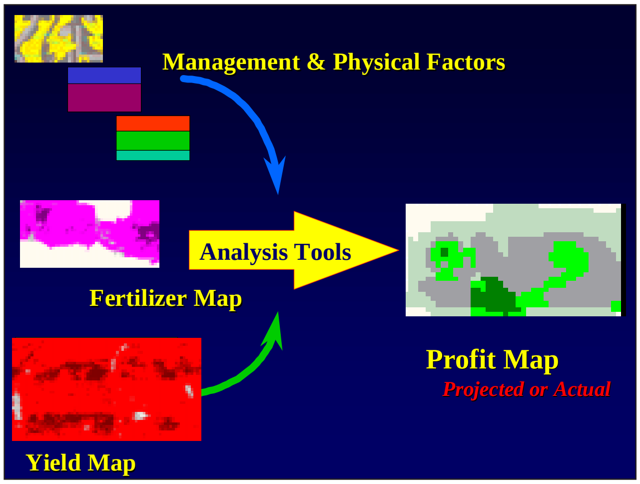


Figure 10. Various data layers and analytical tools, linked mathematically through the GIS, support the development of a computed profit layer for the database (Reetz, 1999).

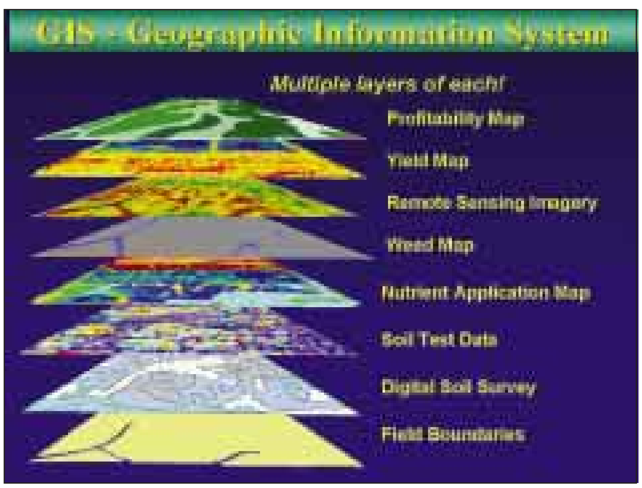


Figure 11. Multiple layers of several data sets are used in a GIS to develop a map of the variability in profit for a field (Rund, 1999).

A site-specific database, along with the software tools to interpret the data, becomes a major asset to the real estate and management resources already in place on the farm. Thus the GIS and associated data add value to the farm. Market value (or cash rent value) of the farm, and the market value of the farmer's management are enhanced. Many farmers use their GIS records to "sell" themselves to gain access to additional farmland or capital for their operation.

The long-term benefits of GIS in the farmer's "toolbox" may be one of the most underestimated values of GIS in site-specific agriculture. The value is only realized when action is taken to utilize the information, but the GIS provides the foundation for good managers to demonstrate their skills. ■

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[1] Adapted from Westervelt and Reetz, 2000. These data sets are available on the Internet at http://www.farmresearch.com .

[2] Veris 3100, Veris Technologies, http://www.veristech.com .

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