Topic 1

Overview of the Case Study

1.1 Introduction

Now that precision agriculture is in its second decade, where are we? Yield mapping is gaining commonplace status for many crops and locales. Site-specific management of field fertilization has a growing number of users. Remote sensing applications from satellite imagery to aerial photos and on the ground "proximal" sensing are coming onboard. Irrigation control, field leveling, variable rate seeding, on-farm studies, disease/pest modeling, stress maps and a myriad other computer mapping uses are on the horizon.

Fundamental to all of these applications is the digital nature of a computer map and the procedures required to turn these data into useful information for decision-making. The bottom line for precision agriculture appears to be an understanding that maps are numbers and what one can do with the digital data to enhance their interpretation.

1.2 The Big Picture

Site-specific farming isn't just a bunch of pretty maps, but a set of new technologies and procedures linking mapped variables to appropriate management actions. It requires the integration of three spatial technologies: *global positioning system* (GPS), *geographic information systems* (GIS) and *intelligent devices and implements* (IDI) for on-the-fly data collection (monitors) and variable-rate application (controls) as depicted in the left-side of figure 1-1.

Modern GPS receivers are able to establish positions within a field to few feet. When connected to a *data collection device*, such as a yield/moisture monitor, these data can be "stamped" with geographic coordinates.

As previously noted, GIS is used to map the field data so a farmer can see the variable conditions throughout a field. The GIS also is used to extend map visualization of yield to analysis of the relationships among yield variability and field conditions.

Once established these relationships are used to derive a "prescription" map of management actions required for each location in a field. The final element, *variable rate implements*, notes a tractor's position through GPS, continuously locates it on the prescription map, and then varies the application rate of field inputs, such as fertilizer blend or seed spacing, in accordance with the instructions on the prescription map.

Figure 1-1. Precision Agriculture involves applying emerging spatial technologies of GPS, GIS and IDI.

1.3 Case Study

This case study begins with a series of techniques used to visualize and summarize field data and ends with several techniques that develop maps that can be used to guide management actions. The focus is on methodology (the precision agriculture "toolkit") and not on the scientific results or generalizations about the complex biological, adaphic or physiographic factors driving crop production in the example field. These intricate relationships are left to agricultural scientists to scrutinize, interpret and put into context with numerous other crops and fields.
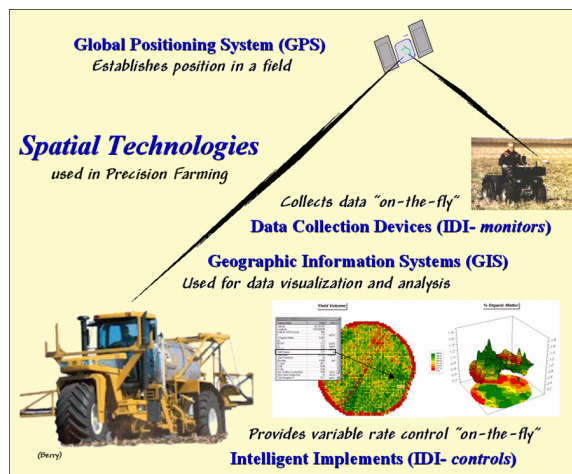
The objective of the series of exercises is to demonstrate the analysis procedures on a consistent data set. The intent is to build a case study for a single field that illustrates the wealth of emerging analytical capabilities that are available to scientists, agronomists, crop consultants and producers.

One might argue that we have "the technical cart in front of the scientific horse." In many instances that appears true. We can collect data, view the numbers as maps or summary statistics, but struggle to make sense of it all. In part, the disconnection isn't technology versus science but the predicament of "the chicken or the egg" coming first.

We have a radically different set of analysis tools than those available just a decade ago. Concurrently, we have a growing number of farmers collecting geo-registered data, such as crop yield, soil nutrients and meteorological conditions. The computer industry is turning out software and machines that are more powerful, yet costing less and less and easier to use. Agriculture equipment companies are developing instruments and implements that respond to "on the go" movements throughout a field. In short, the pieces are coming together.

The next decade in precision agriculture will focus on making sense of the site-specific relationships we measure. The technology is here (an analytical toolbox) to bridge the gap between maps and decisions. Its widespread application will be determined by how effectively map analysis is applied.

Table 1-1 lists the topics that will be covered in this case study series. Most of the topics are discussed in greater detail in the "GIS Toolbox" columns appearing in *AgInnovator Newsletter* (Meredith Publishing, 1993-2001) and are compiled online at—
www.innovativegis.com/basis/pfprimer/

This book demonstrates several of the data analysis capabilities using a consistent agricultural data set. Hopefully, the examples will stimulate innovative thinking and new techniques as much as it outlines how existing

Table 1-1. Workbook Topics
Overview of the Case Study
Mapped Data Visualization and Summary
Comparing Mapped Data
Spatial Interpolation
Characterizing Data Groups
Developing Predictive Models
Analyzing Spatial Context
Generating Prescription Maps

map analysis procedures can be applied. All of the processing is done with the MapCalc evaluation software by Red Hen Systems, Inc. within a standard personal computer environment.

1.4 Some Assembly Required

Before we start wrestling with the details of spatial data analysis, it makes sense to consider some larger issues surrounding its application— the interaction between technology and science, relevant expression of results, and the current field-centric orientation of analysis.

The underlying concept of precision agriculture is that site-specific actions are better than whole-field ones. In applying fertilizer, for example, changing the rate and mixture of the nutrients throughout a field puts more than the average where it is needed and less where it is not needed. However, precise science in the formulation of prescription maps is critical.

To date the infusion of site-specific science has not kept pace with the technologies underlying site-specific agriculture. We can produce maps of yield variation and a host of potential driving factors, from soil properties and nutrients to electric conductivity and topographic relief. We can generate prescription maps that guide the precise application of various materials. Where we used to use one recommendation, we now have several for different locations in a field. So what's the problem?

It's not that there is a problem— it's just that there is far more potential. Introduction of spatial technology has forever altered agriculture for both researchers and farmers. The traditional research paradigm involves sampling a very small portion of a field then analyzing these data without reference to their spatial context and relationships. The most frequently used method develops a "regression model" of one variable on another(s), and then extrapolates the results for large geographic regions.

A classic example is a crop production curve that relates various levels of a nutrient to yield—e.g., the Yield vs. Phosphorous plots you encountered

in Agronomy 101. The interpretation of the curve is that if a certain level of phosphorous is present, then a certain amount of yield is expected. This science, plus a whole lot of field experience is what goes into a prescription—whole-field and site-specific alike. If a map of current phosphorous levels exists, then the application rate can be adjusted so that each location receives just the right amount to put it at the right spot on the production curve.

Current precision agriculture technology enables just that…*site-specific application, but based on state-wide equations (science)*. In fact, the "rules" used in most systems were developed years ago at experiment stations that are miles away from constituent farms. The relations developed are indifferent to geographic patterns of topographic, physical and biological conditions, and are based on non-spatial statistics that intentionally ignore spatial relationships ingrained in the data.

Today, an opportunity exists for site-specific science to "tailor" the decision rules for different conditions within a field. For example, more phosphorous might be applied to southerly oriented slopes than north-facing slopes. But the least amount would be applied in flat or depressed areas. Of course the spatially-specific rule set would change for different soil types and in accordance with the level of organic matter.

The primary difference between non-spatial science and its spatial cousin is the analysis of map variables versus a small set of sample points attempting to replicate all possible conditions and their extent within a field. Until recent developments there wasn't a choice, as the enabling spatial technologies didn't exist a decade ago.

Now that we have spatial tools we need to infuse them into agricultural science. Ideally, these activities will gravitate from the experiment station model to extensive on-farm studies that encompass actual conditions on a farmer's land. In addition, the focus will expand from identifying broad "management zones" to the analysis of detailed continuous map surfaces. Without shifts in our perspective, the "whole-field" approach simply will be replaced by "smaller-field-chunks" (management zones) that blindly apply traditional non-spatial rule sets. Without engaging spatial science, the full potential of site-specific agriculture will be

aggregated into a series of half steps dictated by traditional experience.

In addition to a closer science/technology marriage, the results of their application need to be expressed in new and more informative ways. The introduction of maps has enlightened farmers and researchers alike to the variability within agricultural fields. Interactive queries of a stack of maps identify actual conditions at specific locations throughout a field.

However, simply presenting base map data doesn't always translate into information for decision-making. Further processing is needed to distill these data within a decision context. For example, bushels and pounds per acre could be rendered into revenue, cost and net profit maps under assumed market conditions. As the assumptions are changed the economic maps would change similar to a spreadsheet.

Broadening the geographic focus of precision agriculture is a third force directing the future development. To date, most spatial analysis of farm inputs and outputs stop at the edge of the fields… like agricultural fields are islands surrounded by nothing. This myopic mindset disregards the larger geographic context of agriculture. Increasing environmental concern in farm practices could radically alter our historical field focus in the not too distant future.

For example, the focus might be extended to the surface flows and transport of materials (fine soil particles, organic matter, chemicals, etc.) that connect a field to its surroundings. Like the forest industry, cumulative environment effects within a watershed or airshed might need to be considered before certain farming activities can take place. The increasing urban/farm interface will surely alter the need and methods of communication between agriculture and other parts of society. Spatial analysis can play a key role in how agricultural stewardship concerns are effectively presented.

Precision agriculture is not going away. The blend of modern science and technology is like a locomotive with momentum—difficult to stop. But the direction of the tracks determines where it goes. Decisions by software developers, equipment manufacturers, service providers and farmers themselves, are laying the groundwork for tomorrow's direction. Thinking "out of the box" at this stage is necessary. This case study

is designed to advance your understanding of precision ag data and stimulate potential applications.

_____

1.5 Exercises

The case study companion CD contains the MapCalc Learner software used in the hands-on exercises. The following exercises introduce some of MapCalc's basic capabilities and provide instructions for installing the software. To begin, insert the companion CD into your computer and the main menu will automatically appear.
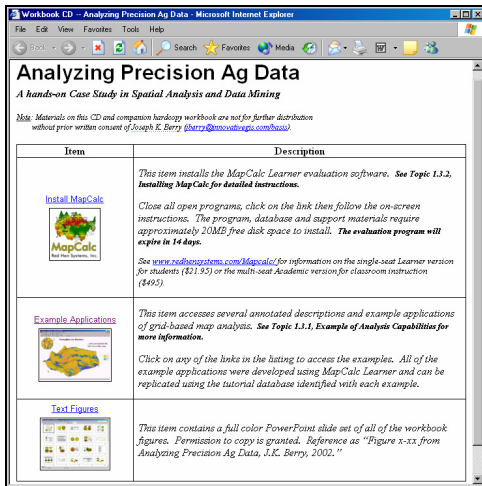

*If this main menu doesn't appear select "**Start**" →
"**Run**" → "**Startup.bat**" from the Windows Task Bar.*

1.5.1 Example of Analysis Capabilities
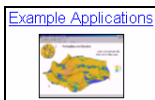
 From the main menu select
**Example Applications → Short Video Demos
→ MapCalc Basics →** and choose **Open** to
launch a short video on basic use of the software including interactive 2D/3D plotting, display types, display navigation, accessing maps for display and graphical overlay.
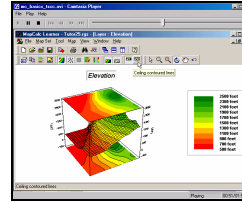

*"MapCalc Basics"
instructional video*

You can replay the video by clicking the "right arrow" button (*Play*) in the upper left portion of the window. Close the video by clicking the "X" button in the upper right portion of the window.

From the "Short Video Demos" menu, select
Calculating Slope and Surface Flow → Open
to launch another short video demonstrating use of some basic map analysis operations. The application describes calculating slope and flow maps using an elevation surface.
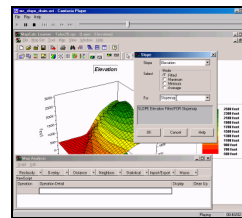
*"Calculating Slope and
Surface Flow" instructional video*

From the Video Demo menu, press the *Back*
button in the top-left portion of your browser window to return to the *Applying MapCalc* menu (see below).
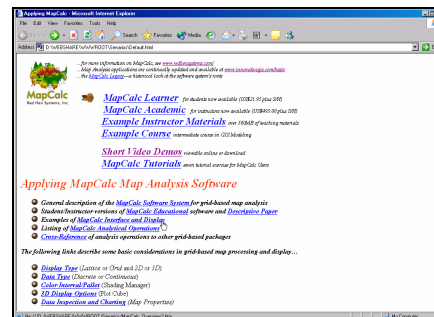

Main Menu for annotated example applications

There are numerous annotated examples of MapCalc operation and applications. For example the *Mapping Surface Flows and Pooling* example applies the slope and flow model described in the second instructional video to the agriculture dataset used in this case study.

As time and interest permits, click on other links of interest to activate additional examples. Examples using the *AgData.rgs* database demonstrate precision agriculture applications.

1.5.2 Viewing Full Color Figures
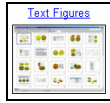
Select the **Text Figures** link to access a PowerPoint full color slide set of all of the workbook figures. Choose **Open** to view the figures provided PowerPoint is installed on your system. Choose **Save** to save the slide set to your hard drive.
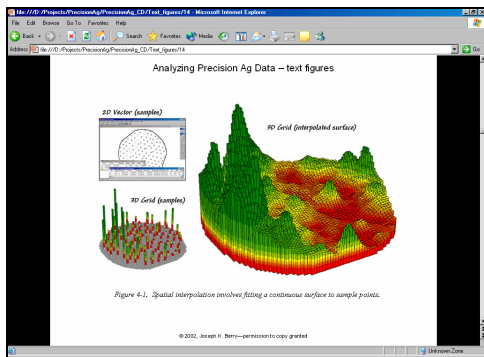

Color display of maps is critical to visual analysis. You are encouraged to refer to the corresponding full color slides as you read the various topics in this book.

Permission to copy and use the slides in presentations and papers is granted. Reference slides as "Figure *x-xx* from <u>Analyzing Precision Ag Data</u>, J.K. Berry, 2002 (BASIS Press)."
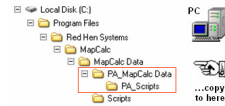
1.5.3 Installing MapCalc

Re-access the main menu for the *Understanding Precision Ag Data* CD and close all other open programs.
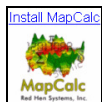
Select the **Install MapCalc** link to begin installing the MapCalc Learner evaluation program. Click on the **Open** button then follow the on-screen instructions using the default specifications (recommended).
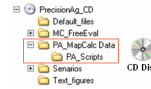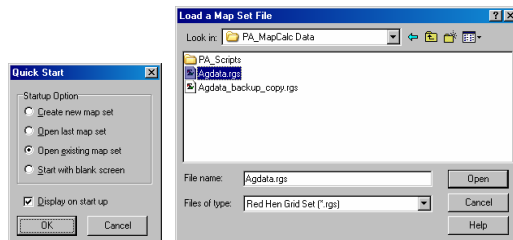

Install the data and support materials by copying the **\PA_MapCalc Data** folder on the CD to the—


…\MapCalc Data folder where the MapCalc program was installed.

Once the program and data are successfully installed, test the system by clicking on **Start→ Programs→ MapCalc Learner→ MapCalc Learner**.

Select **Open existing map set** and browse to the …**\PA_MapCalc Data** folder containing the workbook data and support materials. Specify **PA_AgData.rgs** to access the data base used in this case study.

A three-dimensional elevation map for the field will be displayed.
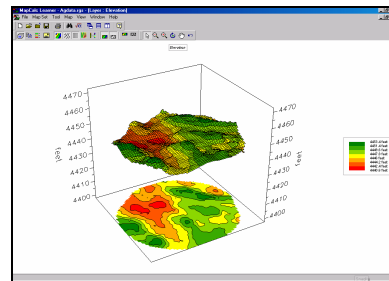
The exercises in Topic 2 on *Interacting with Map Displays* will begin at this point.

You can exit the program by selecting **File → Exit** or by clicking on the "**X**" in the upper-right corner of the MapCalc program window. Do not save any of your changes to the *PA_AgData.rgs* baseline database.