Analyzing Precision Ag Data

A Hands-On Case Study
in Spatial Analysis and Data Mining

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Table of Contents

Forward

When Adam and Eve first picked up a hoe in the Garden of Eden, they practiced *site-specific agriculture*—planting seeds, nurturing the plants and harvesting the yields. With an innate desire to know and to do, mankind has progressed past placing a dead fish in every hill of corn, beans and squash. Now when farmers or ranchers reach into a toolbox, they find bits and bytes and satellite parts along with sockets sets and drill bits. Computers connect combines and crop input applicators to databases driven by the geo-referenced data processed through *geographic information systems* (GIS) applications.

Tracing the effect of site-specific farm management requires a look at where the industry has been, where it is and where it's headed. Harnessing the technologies that make *precision farming* possible promises to empower farmers to meet the economic and ecological objectives of their farm businesses.

Traditional Agriculture

Many modern agricultural producers have spent their careers carefully managing family farms that go back generations. At the heart of *precision farming* lies site-specific management, which involves the ability to collect and control information to accurately and appropriately address parts of fields for actual needs, rather than whole fields for average needs. Site-specific managers can use *information technologies* (IT) to turn their data into decisions.

Such farmers follow a precise process, acquiring raw data, analyzing derived information, adding related knowledge and applying the results with wisdom. They depend on precise devices to deliver precise data to determine precise advice. This requires them to inventory practical variability within their fields, investigate probable causes, instigate possible solutions to address management opportunities on a site-specific basis and evaluate the whole process. Farmers finally have tools for real-time, on-farm research. As a result, they have the potential to produce food and fiber more efficiently.

Current Capabilities

Precision farming allows today's agricultural producers, advisors and researchers to integrate IT with numerous field and office activities. Such tools include *GIS*, the *global positioning system* (GPS), *remote sensing*, *on-the-go sensors*, *monitors* and *controllers*. For example, it's possible today to meter out multiple crop-protection products to specific sites through irrigation systems and applicators with on-the-go sensors as well as track yield and crop quality with growth-simulation software, sensors and remote imaging. Data collected remotely or on-site can be sent via new telecommunication capabilities for near *real-time analysis*. As a result, farmers now have new tools to predict the outcome of site-specific management, weather permitting.

But how many farmers actually use these new technologies? According to Agricultural Outlook, November 2002, ERS-AO-296 (Economic Research Service, U.S. Department of Agriculture)—

Precision Agriculture Adoption Continues to Grow: Corn and soybean farmers have been the most rapid adopters of PA sensing technologies-yield monitor use grew to over 25 percent of soybean acres in 2000 and to over 33 percent of corn acreage in 2001.

Although the share of acreage using VRT has increased marginally across all inputs and crops over time, the most widespread use has been for fertilizer use on corn and soybeans. Many early uses for PA focused on nitrogen and phosphate application to corn and soybeans. The relatively low VRT adoption rates for other crops and inputs likely reflect the small amount of acreage for which geo-referenced yield data are available as well as the scarcity of site-specific agronomic recommendations available to producers in many states (e.g., from an Extension service or from input or technology dealers).

However, by 2000 over 10 percent of all cotton and wheat acreage, 17 percent of all soybean acreage, and over 20 percent of corn acreage were reported to have geo-referenced soil maps--indicating that many fields have some soil information available that would be useful for making spatially variable input decisions. The geo-referenced soil mapping data were generated largely through use of GPS technology in conjunction with soil testing for such attributes as residual nutrient levels and pH. Other survey data indicate that, on about 5-10 percent of corn and soybean planted acreage, yield and/or soil attributes are being geo-referenced while variable-rate application of fertilizer, pesticides, and/or seeds is also being performed. This is the acreage on which PA technologies are being fully utilized to manage inputs.

Focusing in the Future

Behind every technology is a philosophy. Most farmers adopt site-specific technologies the following reasons:

- to discover ways to cut costs,
- to use inputs appropriate to the productive capacity of the site, and
- to optimize their outputs for a safe and stable supply of food and fiber.

Future farmers will be plugged into the planet as never before. They'll use conduits of digital information, piping data to and from their farm fields. They'll connect with channels of electronic communication, as they forge new links in the farm-to-food chain. And they'll work in new ways with new communities of suppliers and customers.

They're not just "farming by the numbers," but they are able to apply more science to the art of farming. They don't want to become entrapped by data-driven technologies; they expect to be empowered with decision-support tools.

Farmers are more like artists than accountants. Sure, they watch the bottom line. But producing a crop puts all their knowledge and wisdom on the line every year, meeting head-on the risks of products, prices and precipitation. Some precision farmers look for future prescriptions of precisely what to do when. Others expect the development of site-specific "recipes" to work for more farmers, giving them more latitude to put their gray cells in charge of the black boxes running their farms—art with science.

Weather remains the number one variable farmers deal with every day. They can't control that variable, but they can seek to understand how to plan and manage variability as a fact of business. As a result, farmers are the front-line integrators of information and technology. They're turning IT and GIS into *geographic management systems* as part of a toolbox of overall farm management tools and techniques aimed at reducing risk and optimizing efficiency.

This becomes even more important when you consider the future structure of agriculture. The industry is moving toward consolidation and vertical integration, along with the adoption of

IT and *biotechnology*. As a result, there may be fewer farmers. This suggests forward-thinking producers must forge new links on the farm-to-food chain.

"What you know about what you can grow" will become the key to farm management. The agriculture industry will become increasingly involved in planting, growing, harvesting and processing "information" along with value-added crops.

Site-specific management drives farmers to accurate record keeping, which will direct their precision farming decision making. This must be the next transition: from precision farming to appropriate agriculture, doing the right thing at the right time in the right place in the right way. Today, the payoff appears to be in the process, rather than in off-the-shelf precision farming products. The economics of the practices are site-specific. What farmers need is "precise advice," which will be determined through more research by farmers, suppliers and universities. At the heart of it all will remain temporal and spatial decision making—made more effective by GIS working in tandem with other spatial information technologies.

Grant Mangold
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Linn Grove, Iowa
November 2002

Preface

"Make everything as simple as possible, but not simpler" *(Einstein)*

Many farmers see *precision agriculture* as an oxymoron. With mud up to the axles and a hundred acres left to plow, precision seems worlds away. Yet *site-specific management* makes sense to a rapidly growing number of producers as years of experience confirm the spatial variability in field conditions and yield. Mapping and analyzing this variability and linking the relationships to management action places production agriculture at the cutting edge of *geographic information systems (GIS)* applications. Its use down on the farm is both down to earth and downright ambitious.

Until the 1990s, maps played a minor role in production agriculture. Soil maps and topographic sheets, for the most part, were far too generalized for application at the farm level. Acquisition of spatial data with the detail and information farmers needed for spatially responsive operations were beyond reach. Management actions were dominated by the principle of *whole-field management* based on broad averages of field data. Weigh-wagon, or grain elevator measurements, established a field's average yield performance. Soil sampling determined the typical average nutrient levels within a field. From these and other data the best overall seed variety was chosen and a constant rate of fertilizer applied, as well as a bushel of other decisions—all treating the entire field as uniform within its boundaries.

Site-specific management, on the other hand, recognizes the variability within a field and is about doing the right thing, in the right way, at the right place and time. It involves assessing and reacting to field variability by tailoring management actions, such as fertilization levels to match changing field conditions. The site-specific approach assumes that managing field variability leads to cost savings and/or production increases, as well as improved stewardship and environmental benefits.

Site-specific farming isn't just a bunch of pretty maps, but a set of new technologies and procedures linking mapped data to appropriate management actions. The *global positioning system (GPS)* locates equipment within a few feet anywhere in a field. On-the-fly data collection devices provide continuous data logging of crop yield and variable rate control units alter the amount of farm inputs as needed. Working in concert, these *intelligent devices and implements (IDI)* effectively apply seeding rates, fertilizers and herbicides, among other inputs, precisely where they are needed for economic and environmental gains. *Geographic information systems (GIS)* technology is used to store, display and analyze these data. It provides the link between crop productivity and field conditions used in constructing "prescription maps" for effective planning and management of farm activities.

Of the three underlying technologies (GPS/IDI/GIS), the extension of GIS from simply pretty maps to map analysis is the least understood yet holds the greatest promise to revolutionize farming practices. *Analyzing Precision Ag Data* is designed to introduce the underlying concepts used in spatial analysis and data mining that are needed to "cross the chasm" from simply mapping to map analysis.

Book Organization

Analyzing Precision Ag Data is organized into eight topics and two appendices that lead the reader from an understanding of the fundamental nature of mapped data through a series of basic procedures used in deriving, analyzing and applying spatial information. A case study approach is used with each topic area describing the application of a set of related analysis techniques. The discussion is followed by a series of hands-on exercises providing practical experience in applying the techniques. The exercises include step-by-step instructions that are thoroughly annotated.

Companion Software

MapCalc software by Red Hen Systems, Inc. is used for the hands-on exercises. A free evaluation version of MapCalc is included with this book. The software includes the basic set of data and operations needed to complete the hands-on exercises; **the evaluation version expires after a two-week period**.

The full *MapCalc Learner* software for individual use contains additional materials and provides for extended experience in map analysis procedures and applications. It contains a basic set of functions for import/export of your own data that is constrained to a field-level (100row x 100col) analysis grid configuration. *MapCalc Academic* is a full, multi-seat licensed educational version for classroom/lab use and contains an additional instructor CD with supporting teaching materials including PowerPoint slides, exercises and quizzes for a several workshop and college-level course offerings. *MapCalc Professional* is licensed for commercial use and includes a full range of features including image data routines, coordinate/datum transformation and an extended set of import/export formats for data exchange.

For more information on the Learner, Academic and Professional versions of MapCalc, visit ***www.redhensystems.com/mapcalc/***. Pricing for the MapCalc versions is US$21.95 for Learner, $495 for Academic and $695.00 for Professional plus shipping and handling.
(September, 2002; prices subject to change)

Case Study Data Set

The data used in this book was provided through joint cooperation among USDA-ARS, Colorado State University, Red Hen Systems and the producer. The geographic coordinates for field have been altered to provide anonymity. The field is a 189 acre center pivot irrigated cornfield on the Colorado high plains. A 50x50 foot analysis grid resolution is used to represent field conditions over four years. Base map layers include:

Tabular Data:
- Field boundary file (.tab file)
- Soil sample data (1997; .tab and .xls files)

Map Data:
- Feature data including field edge and access road
- High resolution digital elevation surface
- Order III soil survey
- Soil properties including percent sand, clay, silt, organic matter (1996)
- Soil nutrients/chemistry including phosphorous, potassium, nitrogen and pH (1996 and 1997)
- Veris conductivity deep and shallow (1997)
- Yield volume, mass and moisture (1997, 1998 and 2000)
- Image data including green, red and derived NDVI (2000)

Intended Audience

This book is ideal for farmers, crop consultants, farm input advisors, technology developers and scientists who are interested in a basic understanding of the concepts, procedures and considerations in analyzing precision agriculture data. The material is presented in an informal manner designed so the reader can grasp the broad issues and then delve into hands-on exercises for practical experience in applying the techniques.

Internet Extended Environment

There are several benefits for readers with a self-published book. Traditionally published texts have inordinately slow publishing cycles compared to the speed of software development and application innovation. This book is printed in small batches and frequently revised to keep the material current. The Internet is a great mechanism for feedback so the book can evolve *with your help*. Please help in identifying sections that need correction or clarification, as well as providing suggestions for extending the current topics or adding entirely new ones—email the author at ***jberry@innovativegis.com***.

In addition, the author's website at ***http://www.innovativegis.com/basis/*** serves as a mechanism for updates, enhancements, extensions and related articles. It is recommended that you periodically check this website for up-to-the-minute information pertaining to the book. Notices and updates for the companion MapCalc software are posted at ***www.redhensystems.com/mapcalc/***.

Acknowledgements

Preparation of a book as complete as this one requires input from several organizations and individuals. *Colorado State University* and the *USDA-ARS* unit in Fort Collins, Colorado graciously shared their field data—numerous students and researchers were involved in the design and implementation of a comprehensive field data collection program far beyond the basic data set used in this book. *Meredith Publishing* supported the "Inside GIS Toolbox" column in the @gInnovator newsletter from 1993 through 2000 that provides the book's framework—Grant Mangold served as editor but provided far more guidance and inspiration than normally is asked of an editor. *Red Hen Systems* provided a critical ingredient—powerful yet inexpensive educational software that is very easy to use. In addition, Neil Havermale, David Wright, Carol Snyder and Elaine McCallum of Red Hen Systems contributed valuable insight over several years into agricultural practices and practical applications—a group of exceptionally bright individuals setting the early course of precision agriculture.

Many Thanks!

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