Enhancing Farm Management and Record Keeping with GIS

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Submitted Abstract

GIS data, like all information, is not, by itself, necessarily useful or profitable. The organization, analysis, and form of the information are often as critical in determining its usefulness as the information itself. Currently, the farmer with a GIS experiences inefficiencies in collecting, sorting, organizing, and analyzing data into a useful form. However, a GIS can be an effective means for organizing, analyzing, and communicating farm data. This presentation outlines the typical steps a farm manager must take to build and implement a useful farm data set.

Introduction

Advances in information technology have allowed agricultural producers and agribusiness to acquire large amounts of production data more efficiently. These advances have also refined the concept of farm management toward a more detailed, precise site-specific level. However, even with the increased ability to capture and retrieve more detailed farm information, empirical economic evidence of higher farm profitability is limited.

The limited evidence of profitability does not necessarily prove that site-specific information technologies are unprofitable. In fact, much agricultural economic research suggests it is, or may be, profitable.[i] Limited empirical evidence may simply suggest that the factors affecting the relative profitability of farm management using site-specific information may not be obvious.

The variability of agricultural production and the idiosyncratic nature of farm management may obscure the observation of profit enhancing information technologies. Variability of yields makes the identification of statistically important profit factors difficult. The specific nature of individual managers and management teams causes the observation of improvement in overall management efficiency to be difficult.

The focus of much discussion of GIS in farm management is on the production evidence of profitability. One reason economic studies of precision agriculture have focused on variable rate application of fertilizer because it was the first technology to be commercialized and it generated the most data (Bullock, D. S., J. Lowenberg-DeBoer and S. M. Swinton 2002). Discussions of farm business management benefits from GIS are less frequent. Management factors such as learning and applying technical GIS skills and the time cost of collecting, organizing and analyzing GIS data are not always clear, easily quantifiable observations. However, detailed, intra-firm, farm management actions may benefit from GIS technology. These type management actions and the benefits (real and potential) of GIS are the focus of this paper.

Enhancing Farm Record Keeping with GIS

As mentioned above much economic work has focused on specific field management and the focus here is more toward the management of the whole farm business. When discussing GIS here it refers to a spatial database that includes data from global positioning systems (GPS). GIS is the spatial database that uses GPS raw data. Therefore, in the context of this paper, discussion of GIS generally does not consider the details of GPS technologies.

From the state of the farm management industry today, GIS offers ways to enhance record keeping and mapping. Most of the enhancements from GIS records involve more detailed and increased efficiency in recording, storing, retrieving and communicating farm spatial information.

Map records are not new in the agricultural industry. Farm records have long been kept in field map form. Typically, farm records are contained in a "field book" of information on each field or farm. The field book is used to record information and is also used to communicate with others involved in the management of the farm. Today, the typical field book contains some computer generated information but most are hand written. Also, most of today's field maps are whole field, or large area of field based. This is not to say that farm managers are not keeping necessary information but rather detailed, sub-field information was not as valuable to farmers before the advent of GPS technologies.[ii] GIS datasets offer the potential to enhance the field book by making it electronic based and geo-referenced as well as add new “pages” to the field book.

Maps and Information Currently In Use

Today a typical farm management field book may contain the following pages of information[iii]:

Management Plans and Records

- Crop map or plan – a page with farm and field boundaries, roads and crops;
- Maps of inputs -- hybrid and variety map, pesticides, fertilizer, tillage;
- Fertility, soil tests – map of soil sample numbers and pages of results;
- Irrigation map;
- Yield history – usually whole field or farm;

Property Description

- Soil Map – map of soil types and descriptions of associations;
- Aerial photograph – copy from USDA office (not digital);
- Tile maps – where available, measurements, flow directions, sizes (hand written);
- Building map – locations and descriptions, wells, pivots, livestock facilities;
- Plat map.

In addition to the above farm management items other items kept includes ownership records, operating arrangements (leases, custom work, etc.), tax parcel numbers, easement records, Farm Service Agency records (farm numbers, FSA acreage, base yields, reported acreage for example), NRCS program acreage, insurance records and marketing contracts. A GIS which could efficiently organize and retrieve such information according to field location would be an enhancement of farm record keeping on most farms.

GIS Enhancements

A "GIS field book" potentially increases efficiency of farm recordkeeping and may increase what records are able to be kept and accessed; that is, by recording information that was not previously recorded. As mentioned in the onset of this paper GPS technologies allow the recording of much more information than ever before. GPS technologies are making explicit information that was once recorded only in the minds of farmers. A primary example of this is GPS yield monitors that assign values to yields within the field. This is making historically implicit data explicit, thereby improving communication between individuals involved in management of the farm.[iv]

The potential increases in a GIS data set over traditional farm records are almost limitless. The obvious examples are recording farm yields and inputs. Items such as site-specific harvest yield and moisture maps, fertility maps, pest problems and pesticide applications are just a few of the in-field records that benefit from a GIS dataset structure. Some of the more overall management records that may be enhanced with a GIS include maps such as those for building and tile, field boundary, easements and accesses, operating arrangements, tax information and many of the items mentioned above.

Often discussion about agricultural GIS goes directly to the sub-field level. However, farm management like most business management includes decisions about items other than production decisions. Ansoff (1965) introduced the concept of separating operational decision making from strategic decision making. In farm management operational decisions may be considered as how much fertilizer to apply, seed to buy, when to plant and harvest and what type of pesticides to use. Strategic decisions may include adding an employee, aligning with a particular seed company, using leasing to grow the farm and things like contracting to produce specialty crops. A GIS may facilitate these decisions as well as production decisions. The usefulness may depend on the structure and organization of the GIS.

Business Management

While a GIS can enhance farm record keeping, GIS data is not, by itself, necessarily useful or profitable in farm management. The development of primary data in the GIS is just the initial step and much of agriculture is in this early phase (Westervelt and Reetz (2000: 7). The organization and form of the data may be critical in determining its usefulness as information. Ideally the most useful data are gathered, organized and stored to suit a particular purpose. That is, a GIS organized without a purpose is less productive and profitable than one organized to support a particular function.

The problems and potentials of detail GIS management in agriculture are similar to those of general business. The capturing and generation of customer data has been made more efficient with business information technologies. One primary example of this is store scanner data. As customers make purchases the data are captured through the scanner. Businesses are able to collect large, detailed records about purchases. If these data can be tied to individual consumers then the potential for more detailed, targeted marketing increases.

A difficulty facing many businesses is how to structure their detailed data set to best support and improve their business management. A recent work by D. Zahay and A. Griffin (2002) on customer information systems (CIS) and business management addresses a key point. As they stated, "Many businesses are making significant investments in the collection and storage of customer information in the hopes of improved customer relationships, and ultimately, business growth. However, research is needed to understand whether and how managing customer information in a particular strategic marketing context provides a sustainable competitive advantage." They looked at business service firms and concluded that a "strong" CIS without a "clear" strategy may not result in an increase, or an advantage, in firm performance.

Zahay and Griffin (2000) address issues relevant to business management as well as farm management. One is that a CIS (or a GIS) needs to be structured to fit a business plan. An unstructured or improperly organized data set may not be useful or profit enhancing to a manager. This raises some issues with agricultural research and GIS data management. What is the best strategy for use of farm GIS technologies? What level of advantage is sought with the use of GIS? Is it to increase the competitive advantage of a farm manager vs. another, or is it an aggregate strategy to make U.S. agriculture more competitive with the world?

In a recent publication, a farmer from Kansas stated that farming is a slim profit margin business and that innovations like biotech soybeans "… are adopted rapidly by everybody so there's little competitive advantage for individual farmers." This particular farmer was commenting on the use of his GIS for on-farm research. He was looking for any advantage over his competition, other farmers. He further stated that if he could "... find five thing that each improve our profit margin by 1% then we've significantly improved our situation."[v] This farmer is strategizing to gain competitive advantage.

Much of the recent attention of economic work on GIS is toward profitability of GPS and GIS technology for farm production management. Less attention has been given to the profitability of GIS technologies in the management of the farm business.

GIS Data Organization

As stated above, it is important to have a plan in mind when beginning to structure a farm management GIS data set. The GIS data set should be supportive to farm decision making and administration. A brief look at the basis for economic decisions about site-specific farm management is illustrative.

An economic model for farm management decisions with a spatial component was expressed by Bullock and Bullock (2000). The general form adapted from what the authors presented may be as follows:

$$\max \ \text{profit} = \pi\,(p, y, w, x), \text{ where } y = y\,(x, c, z)\,.$$

The variables include p, is output price, y is output quantity, w is a vector of input prices, and x is a vector of manageable inputs. Profit is the usual composite profit maximization function where production, y, is a function of x, c, which is a vector of unmanageable, non-stochastic site characteristics and z, which is a vector of uncontrollable, stochastic factors (weather).[vi] Variables y, x, c vary with fields and may be indexed with latitude and longitude.[vii]

This basic model provides insight for the categorization of GIS data. To be useful to decisions in this context data about variables may be categorized as manageable inputs, unmanageable site characteristics (non-stochastic for the time period considered) and unmanageable stochastic factors. Managed inputs include fertilizer, pesticides and seed. Site characteristics that are not manageable may include soil type characteristics (Bullock et al. used soil nitrogen and soil depth) and drainage (not manageable in the short run). Clearly the most obvious, unmanageable and stochastic data is weather. GIS based information from weather stations are an example of data used for this information.

This basic economic model to site specific farm management decision making offers a basis for beginning to categorize and organize GIS data. The basic concepts of manageable data vs. uncontrolled is a useful delineation of data. In addition, recognizing the difference between stochastic and non-stochastic site date may prove useful to the farm decision maker. However, there are many more detailed operational and strategic plans a farm manager may have and one method of organization of GIS data may prove more useful than another.

Creating and Organizing a GIS

The organization of a GIS can affect the types of analyses that may be done with the data set. The process of creating a farm GIS involves a series of steps. Clearly the first is to obtain the GPS referenced data. This discussion will focus on the creation of a GIS after GPS data are collected.

The most basic farm GIS would include a boundary map, yield map and soil tests. As noted above a main map is just a boundary map of the fields and non-tillable areas of the farm. This can be obtained by taking GPS receivers out to the field and making a map. However, if a producer has hired GPS referenced soil tests then the soil testing agent will likely have electronic boundary maps of the farm. Yield maps may be gathered directly from data cards, burned onto CDs or attached to email. Soil test map files should be provided from a soil testing service.

Once data collected it has to be organized. In windows data may be organized by filenames and folder names and location. Some items to consider include what information is useful in a file name. Make sure field names can be identified from a grouping of files; this will help identify files that may get moved into the wrong folders etc. Consider whether to name fields (for example, the 'schoolhouse 80') or use a numbering system. Sometimes names familiar to a farm management team may not be recognized in communication with outside consultants, fertilizer dealers and others. Organization may also be done by other criterion such as landowner or location.

Folder names are equally important to the efficiency of the farm GIS. Decisions whether to keep a folder for each field or for each farm or landowner can affect the availability of data. In addition, some parts of a GIS farm record will contain static files and others will be updated periodically. For example, files of field boundaries and soil types will not change often. However, yield maps and soil tests folders must be updated. Again, the combination of multiple years' yield files in one folder may work to your advantage if analyzing multiple years' data however, it could be less cumbersome to create a separate folder for each year. Finally, a folder for raw data is helpful, in case an analysis damages a file then the original will still be available.

Team Concept and Communication

While organized to increase the actions, efficiency and precision of record keeping, GIS may also improve communication between a farm management "team". The term "team" herein refers to the typical individuals involved in the management of a farm. The farm management team typically includes the primary farmer, partners (family members and/or hired labor), agronomist (either independent consultant or input supplier employee), accountant and often an attorney. Communication between individuals may be enhanced with GIS data and maps.[viii]

Precision farming efforts may also be an effort of several individuals involved in the farming operation. As Lowenberg-DeBoer (2000) stated, "Use of precision farming technology is often a team effort. It is rare individual who has the combination of agronomic, economic and electronic skills needed to be successful at precision farming." (p. 3). A GIS should be organized so that the entire team can understand the data.

Enhanced communication may offer benefits outside the farm management "team". GIS could improve business relationships and lead to new business. The GIS maps communicate spatially in ways not previously available. For example, a yield map sent to an absentee farm owner might communicate the severity of problem better than any amount of verbal or written descriptions. In addition, presenting GIS information to other farm owners and lenders may lead to new business relations. Posting GIS maps on a web site offers additional ways of communicating spatial farm information.

Research Needed

A GIS organized with a plan for its use will be more supportive in the management of the farm than a GIS data set simply collect. Organizing a GIS may be done in-house or by consultant but even with technology advancements, it is not a low cost effort currently. GIS may still be time inefficient, even if the farm manager purchases some GIS services. However, once in place, a GIS is potentially a tool to improve the efficiency of data organization, use and overall management. Research is needed to reduce the inefficiencies in GIS data management.

On average, farmers tend to view GIS as a tool to improve their management. In a survey by Popp et al. (1999), 92% of farmers thought that precision agriculture use would be influenced by "improved management ability" this was followed by 83 % that agreed with the statement that it would improve cost efficiency and net returns. Popp et al. re-surveyed the same people in 2001 and 100% agreed with these statements. While improved management ability was cited as a main factor encouraging use of precision agriculture what exactly improves in management was not specified. Improved management may not be production only, but maybe also be gains in efficiency in the cost and quality of information gathered from record keeping.

Much of the work in agricultural economics is based on varied rate fertilizer analysis and simulations. There is little on the human capital costs. Lambert and Lowenberg-DeBoer, (2000, p. 11) note a dearth of economic information about the human capital and information costs. They reported that 69% of the studies did not include human capital costs and 56% of the studies did not mention information costs.

Lowenberg-DeBoer (2000: p.7) noted that much economic analysis of site-specific farming focuses on changes in input amounts and costs. He said that other costs that are often omitted include: data collection, data analysis, software and skill costs. GIS related costs that he cited are in data analysis and skill costs. There is a time cost associated with data analysis "…converting raw data into usable form". As far as skill, Loweberg-DeBoer said "[F]armers are not born with the ability to analyze precision farming data. This is a learned skill." (p.7). Also as pointed out by Lowenberg-DeBoer, these costs are most clear when this service is purchased from a crop consultant but still exist when farm "team" or family members provide the service. These costs include formal education as well as on-the-job, learning-by-doing. These costs may not be explicit however they are relevant to the decision of adopting site-specific techniques and GIS data in farm management.

Murrell (2001) noted that surveys' have indicated that farmers cite economic analysis of precision agriculture as a research area of "… perhaps the greatest need" and farmers have requested "…complete lists of expenses for technologies. Some unforeseen expenditures have been incurred by early adopters of PA technologies (Murrell cites Fauntas, 1998; Swinton etal., 1997). Murrell further suggests computer system requirements and estimates of time required to learn new technologies need to be added to complete economic analyses. Specifically the computer system requirements are relevant to decisions based on the cost of information. Time of learning is relevant to deciding the human resource costs of using precision agriculture.

The suggestions from farmers and researchers, to include computer system requirements and estimates of time required in economic analyses, may be more compatible to an agribusiness management approach to analysis than a traditional, economic analysis. The issues of system requirements and time of learning may be considered internal firm organizational issues. Relevant queries include investigating which GIS functions are performed in house and which are contracted for outside the farm. At a time where some are wondering why precision agriculture has not been adopted in greater numbers the answers may be in the relatively understudied human capital costs and organizational issues (of GIS) inside the farm management business.

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ENDNOTES

[i] Lambert and Lowenberg-DeBoer (2000) reviewed 108 PA studies that mentioned economic figures under the presumption that "… the general tendency of a large group of studies should be a reliable indicator" of the profitability of PA. They found that 63% of studies with economic figures found positive net returns for PA. In addition, they found 73% of studies with economists as authors also found positive net returns.
[ii] Bullock and Bullock (2000) argued that precision technology and information are economic complements and that "… before the development of precision technology such information [GIS] was worth relatively little to the farmer." (p. 96).
[iii] This list is based on experience and the "Farm and Ranch Management Manual" 4th Edition. American Society of Professional Farm Managers and Rural Appraisers, Inc. (1972).
[iv] This also enhances the information flow up and down the food industry value chain (see Schroeder, Sonka, Hofing (1999))
[v] Reichenberger, L. "Take On-Farm Research to the Bank", The Furrow, 2002: 10-16.
[vi] What distinguishes this as a site-specific profit function is the inclusion of the site characteristics variable in the production function, y. Previous production functions do not include the site characteristic variable (Bullock, Loweberg-DeBoer and Swinton (2002): 238). In Bullock et al (2002) the authors estimate this model using soil-borne nitrogen levels and soil depth as examples of site characteristics that affect yield and vary spatially.
[vii] The variable z may also vary spatially but was held constant for Bullock et al. (2002).
[viii] Some benefits to GIS in farm management are not unique to GIS they just reflect an increase in the quality and quantity of information recorded by the firm. This is similar to information technologies in general. For example, in discussing computer adoption on farms, Sonka (1986) discussed the use of expert consultation and the influence of computers. As he stated "Effective use of that [external] expertise is often a function of the availability of internal firm data. The value of computerised systems may be enhanced if there are significant advantages to the use of external consultants." (p.725).

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