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Dominance of Geographic Information System in Developing a Database for Precision Farming

T. J. Deepak and M. S. M. Amin

INTRODUCTION

Agricultural systems are continuing to change in response to economic, technological and social trends. Agriculture practices are being questioned not only by farmers but the public at large. Farmers adopt new technology that concerns the profitability and environmental impacts. Mechanization brought many types of equipment to use. Technology brought the genetically modified products. The hard work of the researchers and agricultural experts has brought this new technique called Precision farming, Precision Agriculture or Site Specific Management of soils and crops.

Precision farming is a new concept to this world and a great evolution in the agricultural field. Increase in the population has led to many disasters, diseases and conflicts, changes must take place in agriculture in order to increase the yield and reduce the demand. It is gaining popularity largely due to the introduction of technological tools, which are effective in the agricultural community. This tools are cost effective, accurate and user friendly. These new inventions rely on computers, data collecting sensors, GIS and GPS techniques.

GIS technology and satellite remote sensing in Precision farming is used to integrate all kinds of information and applications with a geographic component into one, manageable system. The aim of the developer is to properly utilize GIS to organize, manage, monitor and distribute geographic information culled from various databases while maintaining data integrity and focusing on project direction. This paper presents a review of the new concept precision farming and the dominance of GIS as one of the major components in an array of technologies required for the success of Precision farming.

PRECISION FARMING OVERVIEW

Precision farming is information based, decision-making farming system designed to implement new agricultural process by perfectly managing and executing each step to maximize the agricultural production with the available technology and resources. It is technologically sound as well as being economical and environmentally justifiable (Rasher, 2001).

Improving the agricultural process by precision farming will definitely benefit the farmers and growers by maximizing the financial returns and producing more to the needful world. Precision farming enables the farmers to reduce production cost and increase the potential for greater yield (Kazuhiko, 2001).

Precision farming is a new concept, which is becoming very popular in this informative world. Precision farming may be listed as a new era for agriculture, which will bring changes, provide data for decision-making, but the constant will be use of the soil in a responsible sustainable way to produce food for the world’s population. Precision farming can be defined as a comprehensive system designed to optimize agricultural production (Kazuhiko, 2001).

Certain questions arise when we discuss about precision farming 1. Is precision farming a tool that is used to manage and determine cost? Or a management input that needs to have a specific cost benefit tied to it? The first argument maintains that precision farming is a tool for decision-making. It has been stated that farmers do not determine the cost effectiveness of a wrench, they are tools that are used to produce a crop. Like a computer and record keeping software, no specific cash return is realized but rather it has to be used to enhance decision-making.

BASIC COMPONENTS OF PRECISION FARMING

There are five major components of technology used for PF management practices. They are Geographical Information Systems (GIS), Global Positioning Systems (GPS), Sensors, Variable Rate Technology (VRT) and Yield Monitoring (YM). Figure 1 shows the basic technological components of precision farming.

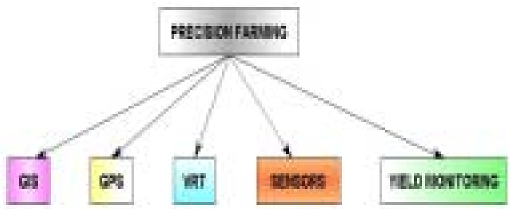

Fig. 1. Components of precision farming

The Precision farming has some more components, which are stated below

Observations: The observations are important with respect to the precision farming, since soil mapping, weed and pest mapping, disease mapping, crop growth, total yield are to be observed carefully in the field for analysis.

Analysis: To manage the multi-layer geo-spatial information we require maps, photographs, topography, field observations, climatic data, previous agronomic data and tested results etc. Once the above stated criteria are satisfied the analysis can be made

Timely and Precise Response: To get fine scale variation using variable rate technology for soil amendments, plant nutrients (N, P, K macro and micro), P^H stabilizers, herbicides, pesticides and plant nutrients etc, can be applied to the field precisely according to the requirement.

Assessment: The precision farming techniques have the ability to review all management decisions harvest yield monitoring, financial return in dollars per hectare and production cost. The above stated abilities could then be compared every year to assess the efficiency.

Objectives of Precision Farming: Precision farming has five main objectives it approaches the field

1. Increased production efficiency
2. Improved product quality
3. More efficient chemical application
4. High energy conservation
5. Soil and ground water protection

BENEFITS TO USERS

Precision farming is the management of an agricultural crop at a spatial scale smaller than the individual field. Mineral nutrient levels, soil texture, soil chemistry, moisture content and pest patterns may all vary widely from location to location. At its most fundamental level, precision farming is based on information management, and is made possible by a confluence of new technological developments. It provides the opportunity to increase profitability and reduce the environmental effects of farming by more closely matching the application of inputs such as pesticides and fertilizers with actual conditions in specific parts of the field.

SUCCESS OF PRECISION FARMING

The real power of GIS lies in its ability to analyze and model data. Overlay maps and algebra operations will produce action plan maps

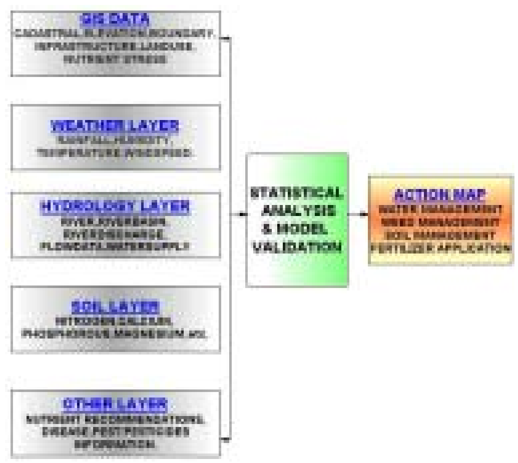

Fig. 2. GIS database model for paddy in precision farming

and variable rate treatments or applications (Shariff and Zainal, 2001)

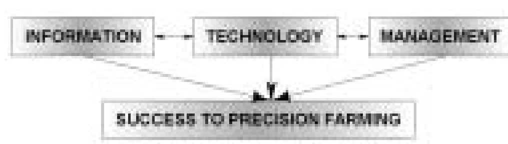

Fig. 3. Key factors for precision farming's success

Precision farming depends on three major factors (Rasher, 2001) as shown in Figure 3.

Information: The first major factor in the modern informative agriculture field is that we require timely and accurate information in all the phases of production. Precision farming must seek out to find the information and use the available information at each step in the process of production.

Technology: The second major factor in the modern agricultural field. Technology is rapidly developing day by day and the farmers must adopt themselves to the changes that will benefit them. A computer is a very good example. A computer will help the farmer to organize and manage the data more effectively. The GPS has enabled the farmers to locate positions in the fields. The GIS can be used to create maps of fields. Sensors are available in the market that can be used to monitor soil properties, crop conditions, harvesting and give instant results or feedback which can be used to adjust or control the operation in the field.

Management: The third major factor in the modern informative and technological agricultural field is management. Management combines both technology and information in to one single system. Without proper management precision farming will not be effective. Farmers must be taught how to interpret the information available and how to use the available technology to get better results from the field. This will lead to make sound production decisions.

GIS AN OVERVIEW

The GIS is a software system designed specifically to manage large volumes of geocoded spatial data derived from a variety of sources. The capabilities of GIS are to accept input data, to serve as a clearing house for data, to store, retrieve, manipulate, analyze, overlay and display these data based on the requirements of the user and to create both tabular and cartographic output which reflect these requirements.

The GIS refers to computer software that provides data storage, retrieval, and transformation of spatial (field) data and attribute data. The GIS software for precision farming management will store data, such as soil type, nutrient levels, etc, in layers and assign that information to the particular field location. A fully functional GIS can be used to analyze characteristics between layers to develop application maps or other management options. The field location is usually stored by the latitude and longitude of that position, which is typically found using a Global Positioning System (GPS). Several maps can be created showing the variability of nutrient levels, soil type, topography, pest incidence and yield. Most of the GIS software packages have some form of data smoothing or contouring (kriging). The accuracy of a smoothed map depends on the sampling or distance between sample points (location where data was taken) and the smoothing technique.

The functional GIS is the nucleus of precision farming. It provides the platform for processing, automating tasks and analyzing data to provide derived information to support decision-making. The functional GIS technology is an upcoming field to this informative and technologically developing world.

As shown in figure 4, GIS is a powerful tool capable of creating and manipulating maps, with the necessary links to retrieve, manipulate and update data from a database (Singh and Fiorentino, 1999). Both maps and attribute data constitute abstractions or simplifications of the real world.

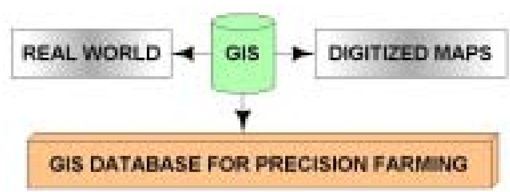

Fig. 4. General configuration of a GIS in precision farming

Most of the geographical databases contain both spatial and nonspatial attributes, which are mounted on relational database management systems (RDBMS). However, spatial data has unique characteristics that limit the use of standard query languages. The usage of GIS is becoming familiar for management of resources. Before introducing GIS technology, only few people had the skills to use Geographic information to help the farmers in decision-making and problem solving. But now GIS has become the standard tool for better performance and faster results compared to the older methods.

GIS A KEY TO SUCCEED IN PRECISION FARMING

The introduction of GIS and GPS is being utilized by most of the farmers in America and Europe for precision farming and they have been successful in achieving their goals. Most of the users and researchers confirm that GIS is the key in making precision farming to be a successful one in accomplishing their work to the full and correct extent (Kazuhik, 2001). Currently there are many software's entering the market to fulfill the requirements of the users. But this GIS is one, which satisfies the users by making queries and getting the probable answers and allows the user to make decisions at each and every stage of the work. GIS plays a major role in decision making and monitoring with respect to agriculture. In addition to data storage and display, the GIS can be used to evaluate present and alternative management by combining and manipulating data layers to produce an analysis of management scenarios. In addition to data storage and display, the GIS can be used to evaluate present and alternative management by combining and manipulating data layers to produce an analysis of management scenarios that will be benefiting the users and farmers in decision making.

PRELIMINARY STEPS IN CREATING A GIS DATABASE

The prime steps to be considered before creating a GIS database are given below

1. Identifying the problem to be solved
2. Gathering data to solve this problem and creating a spatial database
3. Performing the analysis
4. Presenting the results of the analysis

Specifically, we need to create a Vector dataset by hand, and then create the digital version of this dataset in GIS-ARCVIEW/ARCINFO or any other GIS software.

Developing a GIS Database: There are two distinct stages involved in developing a GIS database 1. Data acquisition and 2. Data preparation. The data plays a major role in GIS application. Many potential applications for GIS exist in the agriculture field. A GIS database consists of a number of data layers, a few or many according to the application. Data layers often used in precision farming include soils, land use, topography, rainfall, evaporation, runoff, stream network and boundaries. The two main methods of database development are obtaining existing digital data and converting existing paper maps to digital format through manual digitizing or by automated scanning.

Data Sources: The potential sources of data for GIS database include the primary and secondary sources. These two sources of data should be considered well before achieving the outputs. The primary sources are the data that have to be collected directly from the field ofcourse data collection is accompanied by DGPS for location of the sampling sites. For example crop yield, soil samples, water samples etc. Secondary sources include the paper maps, aerial photographs and digital databases that exist already. The secondary data source can be obtained from government departments or from survey departments and also from private organization.

Data Input: The data input to the GIS database can be accomplished in many ways. Regardless the source of the data, still it has to be entered to the GIS database for getting the output for precision farming. The method of entering data depends on factors such as the data source, format, required output, available hardware, software and type of use.

The primary data sources can be entered to the GIS database in many ways. Indirect methods include recording the values in the field manually on notebook and then entering them in the GIS software using a computer. Direct field measurements could be recorded through the data logger, resulting in a digital data record and that in turn could be transferred to the GIS format, with any needed format conversions.

The secondary data are from other digital sources and they must be converted to the required format for the GIS. Digital data can be obtained through electronic media, such as tapes, diskettes, CD etc. Conversion of paper maps to digital format can be achieved by manual digitizing or scanning. Techniques used to convert other analog materials include photogrammetric digitizing, Coordinate geometry and key entry. Several factors must be considered in selecting the mode of data input. If the data source were a paper map, manual digitizing or scanning would be appropriate. If the data source were an image then scanning would be perfectly suitable. Digitizing is better for vector format and scanning is better for the raster format.

Quality of Digital Data: The quality of the GIS results depends on the quality of the GIS database. A great quantity of data is available for developing GIS database for precision farming applications. However, more important is the quality rather than the quantity, regardless of the technique used to develop the database. It is the responsibility of the user to confirm the quality of the database used in GIS analysis.

Integrating Data From Other Sources: The development of a quantitative and quality GIS database usually involves in the integration of data from multiple sources with varying accuracies, scales, geometric structures, spatial resolutions and other characteristics. The differences in these data layer characteristics must be considered in the integration of the data to ensure an acceptable quality database.

Updating and Managing Database: Once the database is created, it is essential to know how to manage, maintain and update. A data directory is very much essential for effective management of the GIS database. The directory defines the entities, their attributes, associated domain values, convey the meaning to the database administrator and the user. The database management helps the user to manage the data and organize them for future analysis. A specific backup for all the data is very much required in order to have a record. There are many applications in precision farming where it is necessary to recover the previous versions of the information to determine changes that have occurred over time.

Globally Data Base Management System (DBMS) deals with the management of information, that is

1. Information distribution
2. Information quality control
3. Information consistency maintenance.

DBMS plays a major role in interface between data and the data users. Besides the fact that the whole set of data is centralized, DBMS offers query tools that allow a faster and more efficient access to the information. The development of communication network increased the accessibility to information (Collet et al., 1996).

GIS Capabilities

1. The GIS software has common features and components as other software
2. Data acquisition and preparation tools for the creation of the database
3. A geographical database management system will be derived
4. Data exploitation tools for information retrieval from the database
5. Data analysis tools.

Major difference in using GIS software is that depending on the purpose it offers complex capabilities for different processing stages. It is important to know the way it processes the spatial information. The object-processing mode considers spatial objects as units of description, while image-processing mode is based on arbitrary and regular units of description, referred to as cells. These two approaches process the spatial information in a different manner and require a specific data structure, vector and raster respectively.

Benefits of GIS Database

The evaluation and comparison of GIS software requires a clear understanding of the nature of GIS and its related concepts. There are comprehensive benefits that are achieved by using GIS, data is well organized and stored in a place such that the users have a constant access over them. Easy to retrieve the data and update in GIS database since it is user friendly and flexible. Maps, reports created with GIS have good graphic quality and are more consistent. An important function of GIS in agriculture is to store layers of information, such as yields, soil survey maps, remotely sensed data, crop scouting reports and soil nutrient levels. Geographically referenced data can be displayed in the GIS, adding a visual perspective for interpretation.

CONCLUSION

Precision farming technology could revolutionize agriculture, according to a recent report from the National Research Council (NRC), but most are in the early stages of development and will need extensive research before they are proven effective. It is clear that many farmers are at a sufficient level of management that they can benefit from precision farming management. Questions remain about cost-effectiveness and the most effective ways to use the technological tools we now have, but the concept of "doing the right thing in the right place at the right time" has a strong instinct. Ultimately, the success of precision farming depends largely on how well and how quickly the knowledge needed to guide the new technologies can be found.

There is a general concern for quality and access to data. For producers and support system to do an adequate job of analysis and research, data must be freely exchanged. Government agencies that collect data have made data available, though it may not be readily accessible for some people. This may be due to lack of computer skills, GIS skills, or telecommunication/internet access. Developing a database for precision farming is important and required with respect to the production and farmers.

Database created using GIS is useful for researchers, farmers and for decision makers in the field. It is user friendly and can provide timely information to the users to take a firm decision Thematic maps will be produced with the final reports that are very useful and comprehensive to the new users. Future updates can be made with GIS to implement better technology.

KEY WORDS Precision Farming. GIS Database. Raster Data. Vector Data.

ABSTRACT The advent of information technology and the hard work of multidisciplinary researchers and experts have brought this new technique called precision farming. Precision farming is a new concept to this world and a great evolution in the agricultural field. Improving the agricultural process by precision farming will definitely benefit the farmers and landlords by maximizing the financial returns and produce more to the needful world. GIS refers to the computer software that provides data storage, retrieval and transformation of spatial (field) data. GIS software for precision farming management will store data such as soil type, nutrient levels etc., in layers and assign that information to the particular field location. GIS is the nucleus of precision farming. It provides the platform for processing, automating tasks and analyzing data to provide derived information to support decision-making. Creating a GIS database will definitely help the farmers, researchers, government and other authorities in the field. Once the database is created it is very important to update and manage them properly. Major difference in using GIS software is that it offers complex capabilities for different processing stages. GIS helps in storing large volume of data for future analysis and can be updated by retrieving them whenever it is required, the results are produced in the form of informative thematic maps**.**

REFERENCES

Abler, R.F.: Awards, rewards and excellence keeping geography alive and well. *The Professional Geographer,* **40:** 135-140 (1988).

Aronoff, Stan: *Geographic Information Systems: A Management Perspective.* 2nd Edition. WDL Publications (1971).

Amin, M.S.M.: Soil mapping/soil fertility mapping for Precision farming. *Workshop on Precision Farming for Rice Cultivation at Sawah Sempadan, Selangor, Malaysia* (2000).

Antenucci, J., Brown, K., Croswell, P., Kevany, M. and Aecher. H.: *Geographic Information Systems: A Guide To the Technology.* Van Nostrand Reinhold (1991).

Arlinghaus, Sandra L.: *Practical Handbook of Digital Mapping: Terms and Concepts.* CRC Press (1994).

Baker, N.T.: Utilization of a geographic information system to identify the primary aquifer providing ground water to individual wells in eastern Arkansas. *Water Resources Bulletin,* **29:** 445-448 (1993).

Burrough, P. A.: *Principles of Geographic Information Systems for Land Resources Assessment.* Clarendon Oxford (1986).

Burrough, Peter and Mcdonnell, Rachael: *Principles of Geographic Information System* 2nd Edition (1998).

Chan, Chee Wan: GPS application in precision agriculture *Paper presented to the DSMM/UN/USA/JUPEM WORKSHOP IN MALAYSIA* on the use of GNSS 20-24TH August 2001 (2001).

Chrisman, Nicholas: *Exploring Geographic Information Systems* (1997).

Collet, C. Consuegra, D. and Joerin, F.: *GIS Needs and GIS Software.* Kluwer Academic Publishers. pp115-142 (1996).

David, J. Maguire: *Geographical Information System Principles and Applications* (1992).

David. M. Mark et al.: The GIS History Project (1996).

Demers, MichaeL N.: *Fundamentals of Geographic Information Systems.* John Wiley Sons, New York (1996).

Fowler, M. et al.: Development of a Geographic information system for on farm management: *Proceedings of the 21st Annual Conference on Water Policy and Management.* Denver, Colorado, ASCE pp.132-135 (1994).

George, B. and Korte, P.E.: *The GIS Book,* 4th Edition, pp.160-164 (1997).

Jayasekera, A.A. and Walker, W.R.: Remotely sensed data and Geographic Information Systems: For management and appraisal of large scale irrigation projects in the developing countries. *Proceedings of an International Conference on Advances in Planning, Design, and Management of Irrigation Systems are Related to Sustainable Land Use,* Organized by the cif, of the Katholieke Universities Leuven in corporation with the ECOWARM.vol:2 (1992).

Kazuhiko, Ohmiya. Precision Agriculture in Japan Application of GPS in Agriculture, *Paper presented to the DSMM/UN/USA/JUPEM WORKSHOP on the use of GNSS 20-24TH* August 2001 (2001).

Kiyoshi, Honda: A Research Article on Remote Sensing and GIS Activities in Asian Institute of Technology (2000).

Mattingly, S.B.: Using Geographic Information Systems to manage a multipurpose waste project. *Proceedings of* *the 21st Annual Conference on Water Policy and Management. Denver, Colorado,* ASCE: pp.33-36 (1994).

Maguire, D. J.: An overview and definition of GIS. In: D. J. Maguire, M. F. Goodchild and D. W. Rhind (Eds.), *Geographical Information Systems: Principles and Applications* (Vol. 1). Longman Group, Harlow, UK. Rasher, M.: pp.9-20 (1991).

Michael, N. Demers: *Fundamentals of Geographic Information Systems* (1997).

Rasher: The use of GPS and mobile mapping for decision based Precision Agriculture, *Paper presented to the DSMM/UN/USA/JUPEM WORKSHOP on the use of GNSS 20-24TH August 2001* (2001).

Shariff, Rashid, Egenhofer, Max, J. and Mark, David M.: A Research Article on Natural-Language Spatial Relations Between Linear and Arial Objects (1997).

Shariff, Rashid and Zainal, Abidin En. Hasan.: *GIS application for paddy in Precision farming, Workshop on Precision farming for rice cultivation at Sawah Sempadan, Selangor, Malaysia* (2001).

Schueller, J.K.: A review and integrating analysis of spatially variable control of crop production. *Fertilizer Research* 33.Dorderecht, The Kluwer. pp. 1-34 (1992).

Sun, F Shih.: Satellite data and Geographic Information System for Rainfall Estimation. *J. Irrigation and Drainage Engineering, ASCE.* **116:** 577-587 (1990).

Stafford. J.V.: Introduction –Spatially variable field operation.*Computers and Electronics in Agriculture* pp.99-100 (1996).

Star, J. and Estes, J.: *Introduction of Geographic Information Systems* (1990).

Singh, V.P. and Fiorentino, M.: *GIS in Hydrology.* Kluwer Academic Publishers (1996).

Tomlinson, R. F., Calkins, H. W. and Marble, D. F.: Chapter 2: Essential parts of a geographic information system. In: *Computer Handling of Geographical Data,* Natural Resource Research Report No. 13. Paris: *The UNESCO Press.* pp. 15-19 (1976).

Waqar, Hussain Phulpoto: *Application of Geographic Information Systems(GIS) to Irrigation Projects,* M.Sc Engineering Thesis, AIT, Thailand (1997).

Authors' Address: **T. J. Deepak and M. S. M. Amin,** Department of Biological and Agricultural Engineering, University Putra Malaysia, Serdang 43300, Malaysia