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Role of GPS and GIS in precision agriculture

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Abstract: Precision agriculture is an agricultural system that has the potential of dramatically changing agriculture in this 21st century. Precision agriculture lends itself to most agricultural applications and can be implemented at whatever levels are required. Precision agriculture is based on information technology, which enables the producer to collect information and data for better decision making. Precision agriculture is a pro-active approach that reduces some of the risk and variables common to agriculture. Geographic information system (GIS) which is emerged by calculating the present context allows us to produce a complex view about the land's characteristics. Thus, it provides making appropriate decisions in the field of agriculture. Research method in this study is a library method in which, the role of modern agricultural systems, including satellite data, geographic information systems and global positioning system are discussed. Also, the complete architecture of a typical agricultural information management system is introduced by examining the data structure and data types used in the agriculture section. Finally, the results of two case studies in Khuzestan are presented which can be considered as an implementation pattern of such information architecture. As a result, the data received from SSCM system (simultaneous control management of resources) is the main base for precision agriculture which requires special tools and methods. Tools such as GPS, GIS, and RS are used to determine variability and different factors and elements in a farm.

Key words: Precision agriculture; GIS; GPS; SSCM; New systems

1. Introduction

What is Precision Agriculture? Precision agriculture is relative new and lacks a recognized and useful definition. To better understand the need for an accurate definition of precision agriculture let's look at how precision agriculture is being considered. Precision agriculture is considered a concept, management strategy, and even a philosophy.

1.1. Concept

It is said, "Precision agriculture is a phrase that captures the imagination of many concerned with the production of food, feed, and fiber." The concept of precision agriculture offers the promise of increasing productivity while decreasing production cost and minimizing environmental impacts. Precision agriculture conjures up images of farmers overcoming the elements with computerized machinery that is precisely controlled via satellites and local sensors and using planning software that accurately predicts crop development. This image has been called the future of agriculture.

1.2. Management strategy

Most management strategies for precision agriculture match resource applications and agronomic practices with soil properties and crop requirements as they vary across a site. Sometimes referred to as site-specific or prescription application and generally includes:

- Soil sampling - the ability to determine the physical characteristics and the variability of the soil in the field.
- Variable rate application - the ability to precisely apply the required type and quantity of nutrient of chemical needed to specific areas of the field.
- Yield monitoring - the ability to accurately measure the yield and simultaneously record the location in the field.

Each of these components is necessary, but alone or together does not constitute precision agriculture.

1.3. Philosophy

Precision agriculture is the ability to manage land by the square meter instead of the square mile. Precision agriculture is changing the farmers and rancher's relationship with the land. "Through the ages agriculture production systems have benefited from the incorporation of technological advances primarily developed for other industries. The industrial age brought mechanization and synthesized fertilizers, the technological age offered genetic engineering and now the information age brings the potential for Precision Agriculture."

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1.4. What precision agriculture should be!

Precision agriculture is an information-based, decision-making agricultural System designed to improve the agricultural process by precisely managing each step to ensure maximum agricultural production and continued sustainability of the natural resources. Let's look at this definition more closely:

Information-based, decision-making system Farming and ranching have always been a gamble. There are so many variables, many of which the producer has no control over. Some of the variables can be reduced or eliminated when the producer has information, which enables them to make decisions, they were unable to before. Precision agricultural can provide the producer accurate and timely information for making decisions.

1.5. Designed to improve the agricultural process

Precision agriculture is technologically feasible as well as being economically and environmentally justifiable. Improving the agricultural process can maximizes financial return and increases the stewardship of land, water, and related natural resources.

1.6. Precisely managing each step to ensure maximum production

Most producers would admit that increasing yields is their number one goal. But increasing yields may have a negative effect on the financial return. Precision agriculture enables the producer to reduce production cost and increase the potential for greater yields.

1.7. Continue sustainability of natural resources

Production of food, feed, and fiber are dependent on the quantity and quality of soil, plant, water, and air. No matter what agricultural systems are used, without protecting the natural resources, yields will decrease until the point of no return. The concept that precision agriculture is a system, (Webster: interrelated, interacting, independent elements forming a complex whole), provides a more useful foundation for understanding precision agriculture.

An Agricultural System that can be used for:

- Land preparation
- Seeding
- Chemical application
- Fertilizer application
- Crop monitoring
- Nutrient auditing
- Soil & leaf testing
- Pest management
- Conservation practices; Operation & management
- Gross margin analysis

Today, environmental protection is considered more and more. This tendency can be seen in the agricultural field which is direct and indirect due to the emphasis on human health. Also, economy is also important.

Today, the use of chemical fertilizers and agricultural mechanization gradually has created imbalances in terms of natural resources (Jo´ ri, 1998). In the current situation, the sustainable agriculture through the creation of a comprehensive management system based agricultural information management systems is a priority considering the serious limitations in available resources and also, intervention of the complex factors in the production and precision agriculture have been achieved.

Before the industrial revolution, agriculture was limited to small areas and at that time, there was little information concerning the performance of production systems and their differences from each other. Moving towards mechanized agriculture was began by uniform cultivation of large lands in the second half of the twentieth century. But the advanced technology of the late twentieth century and early twenty-first century led agriculture to the exact layout of the agriculture along with the economies of scale associated with large operations (La´szlo, 1992).

Precision Agriculture is a method of agriculture that considers changes in the land and the technology of cultivation, nutrition and fertilizer, spraying, and etc. are used according to these changes. Also, they are used in local applications in a particular land. Global Positioning System (GPS) provides the possibility to attribute the spatial coordinates of the farm data. Also, it is possible to determine and record the correct position continuously. Considering that this technology in the field of agriculture has caused that more details already be available, therefore, it provides a larger database for users. Geographic information system (GIS) is essential to the storage and handling of data (Lee, 1997).

Using GIS technology allows us to analysis and process a large amount of data at high speeds and less time and remote sensing systems provide uniform measurements with high-speed for large areas in the digital form. Interpreted images and terrain data for many applications including the science of forest and conditions of agricultural crops, determining the area under cultivation, environmental assessments can be one of the most economical and efficient methods which used by managers and decision makers to adopt the obtained details.

Using the information from satellite images which are collected in GIS databases information and maps of land cover/land use could be achieved simultaneously in addition to saving time and money (Mandal, 2000).

Using this technology, the possibility to use an optimum or near optimum amount of chemical and nutrition fertilizers for each area of the land (1). As a result, we are able to save more money, in addition

to preventing the environmental pollution caused by the use of chemical fertilizers and so on (Mandal, 2000).

There are several systems on the market for this technology. Although currently their reliability of the users is hardly known, there is also this issue even among scholars of and other countries as well (Mandal, 2000).

2. Materials and methods

The research method in this paper is considered in a description form and library research type.

In this paper, the concepts of precision agriculture and the use of GPS and GIS in precision agriculture systems are discussed as new technologies in agricultural mechanization.

Also, the complete architecture of a typical agricultural information management system is introduced by examining the data structure and data types used in the agriculture section. Finally, the results of two case studies in Khuzestan are presented which can be considered as an implementation pattern of such information architecture.

3. Results and discussion

3.1. Introduction of the concepts used in precision agriculture

3.1.1. Site-Specific concept

It is a phrase that refers to the smallest level of a single element. For example, the mentioned materials can be used only in a part of a farm which was invaded by weeds instead of discussing the farm level with respect to the utilization of herbicides. "Site-specific" management manages spraying in a land which is invaded. Site, simply, is the smallest unit that a farmer can manage it with existing tools. This surface is usually about 100 square feet. Treating or curing any site is unique and it requires certain information which is done by soil test data and crop evaluation reports (12).

3.1.2. Information processing in precision agriculture

Precision agriculture is a cyclical process. Of course, the farmer can start farming based on "site-specific" information. Farmers generally require annual planning, data collection and analysis of information in order to complete the cycle of precision agriculture.

You should conduct a soil test before planting. Then, data analysis should be done in order to determine soil profile conditions, so that it can be called at any time and by any method.

In crop season, start the work by sowing different values of seeds depending on the data and utilize variable rate of fertilizer which are obtained from soil tests. Crop growth is performed for research on issues such as weeds, pests or diseases.

At harvest time, when the crop is harvested, the crop monitor which is embedded inside the combine provides the crop condition based on the geographic location and map of crop condition across the farm according to its geographical location.

3.2. Crop growth

When the crop grows, observations must be carefully conducted to record any problems and arose developments. Although, crop evaluation is not a new thing, today it can be imported into GIS and be related to the exact location of the problem through GPS data and data can be analyzed by comparing with other data in GIS.

Commonly, people who have adequate knowledge are able to determine many problems that have arisen in the farm and evaluate their crop. One of the modern means of assessing is a GPS receiver and a computer. With the advent of video mapping, each untrained person is able to record farm condition to be analyzed and reviewed by qualified personnel. Other methods are used to diagnose problems in a farm include remote sensing by spatial or other aerial equipment. Optimizing is essential to the availability of satellite data. But these data should be used as the source of the common agricultural information (11).

3.3. Application of variable amounts of chemicals

VRT (variable rate technology) and VRA (variable rate applications) are assigned for development and expansion of variable rate sprayer which is a very important tool in precision agriculture. In places where the treatments of a site-specific have become the alternative to the use of chemicals with a constant amount in the whole farm, sprayer that can distribute variable amounts of chemicals are essential. Such machines are programmable to deliver the correct amount of chemicals depending on farm conditions. This plan is conducted by crop growth data and crop condition and its analysis. This part of precision agriculture is responsible for lowering costs and reducing prejudicial to the environment by the automatic application of minimal amounts of chemicals (Leboeuf, 2000).

3.4. Crop monitoring

Crop monitoring may be the most fundamental part of precision agriculture. The traditional method of crop monitoring which is conducted by weighting the harvested crops provides a way that can be useful at the moment crop monitoring in precision agriculture. For example, in cereal harvest, modern monitoring uses sensors that are located on the combine to record the amount of the harvested crop along with harvest rate. These data are combined with GPS location of each data and provides the

possibility to prepare the crop maps in the GIS system. This map can be compared with the results obtained from farmers and crop consultants in relation to soil test data maps, chemicals application maps and other information and it can be used to manage site-specific program of the future year. When these maps are overlapped in the GIS system in the layer form and integrate with each other, it indicates the crop map of the relations between the amount of crop and farm condition variables in documented form (Mesterha, 2001) (Fig. 1).

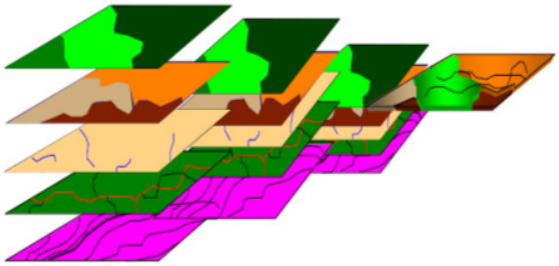

Fig. 1: Overlap of some different layers and create a new layer

4. Technologies in precision agriculture

4.1. Map

Map generation for crop and soil characteristics is the most and the first important step in precision agriculture. These maps provide the base of spatial variability control. Data collection was performed both before and during production and can be implemented by means of GPS coordinates (Mandal, 2000). Data collection technology generally includes network soil sampling, performance monitoring, satellite images and farm measurements. Assessment tools such as soil pipes are used to collect food condition and hydraulic conductivity of the soil and optical scanners are used to detect and identify weeds in organic materials (Mandal, 2000). Then, these data will be imported into computer systems and stored in a map. The generated maps are used to obtain information and operate it in strategic decision-making to control variability. Mapping can be done directly by the application of RS and GIS or initially it is prepared manually during the farm operation and then converted to digital form (Fig. 2) (Kuma, 2007).

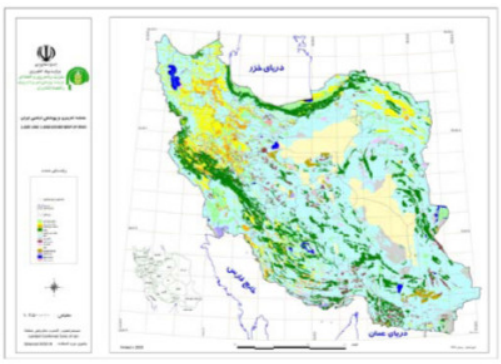

Fig. 2: Land use and vegetation map

4.2. Remote sensing

RS measures the visible and invisible features of a farm or a group of farms and also it converts point measurements of continuous spatial information. This technique monitors the dynamic conditions of the soil and the plant in glancing form. Visual observations are recorded through a digitization device which is geo-referenced and they are entered into the GIS database. Aerial photos and video camcorders also can be used in precision agriculture. Satellite images are a powerful tool for estimating the area under cultivation within a month with 95% accuracy and estimating performance during 10 days for the single crop cultivation area with 90% accuracy. Usually satellite images such as Landsat and Spot are used, because they can be used in precision agriculture (Mandal, 2000).

4.3. Geographic information systems

GIS is a useful tool for the assessment and management of agricultural resources. GIS plays an important role in the development of expert systems in different fields of agriculture as an essential technology for the decision support system (IDMAS[16]) (Mandal, 2000). Application of GIS generally includes various types of spatial and description data. Maps are in both raster and vector formats and descriptive data are preserved in the database format of SyBase™, Orascle™, Informix™, SQL server and so on. GIS can be used in three level of Wokstation GIS, Desktop GIS, and Enterprise GIS. General architecture of how to use the map data and remote sensing in GIS in precision agriculture operations is shown in (Fig. 3). Of course, specific techniques are used in each step of which are as follows (Mandal, 2000):

Classification of remote sensing images provided by different satellites or other platforms using supervised and unsupervised methods

Separation of different areas on the images to extract performance maps' polygons

Multivariate cluster analysis using fuzzy logic based on performance maps

Morphological filters or setting bounds for the interest variables

Spectral filters using Fourier series

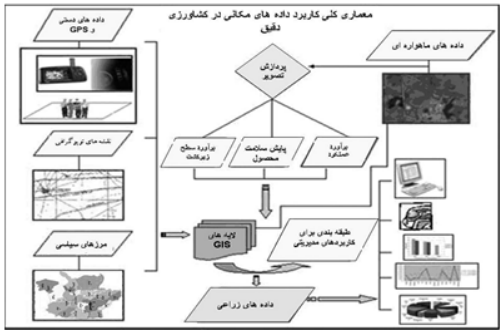

Fig. 3: General architecture of how to use the map data and remote sensing by GIS

Here, the results of two case studies are presented at different stages of preparing and processing images for extracting cultivation patterns and also spatial statistical models for estimating the area under crops are provided which are somewhat match the specified pattern.

The extracted map of TERRA satellite image is shown in Fig. 4 to extract the area under wheat cultivation for a part of Khuzestan in an image processing operation by supervised method.

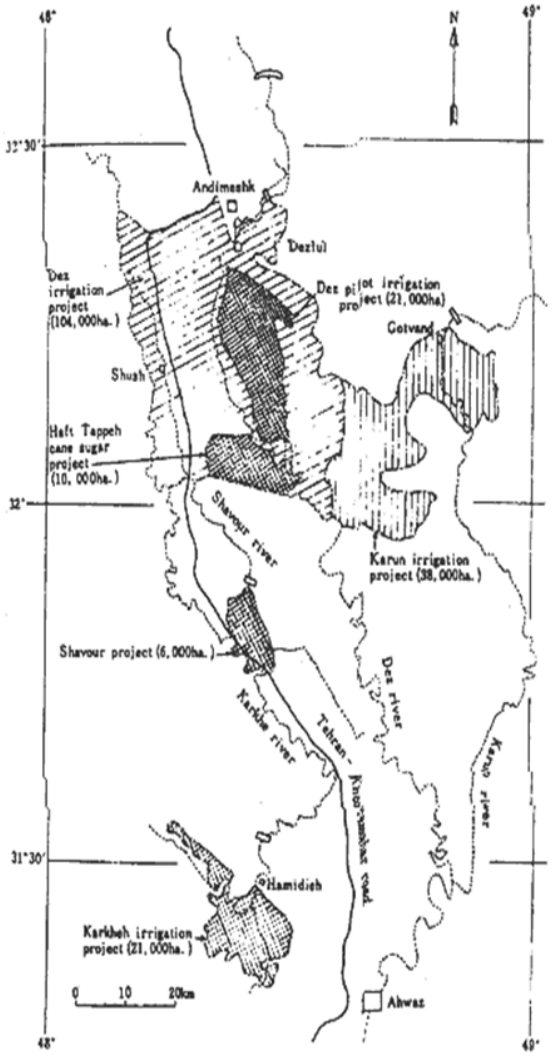

Fig. 4: Final map of the area under wheat cultivation for a part of Khuzestan

A regression analysis was done between the numerical values of the map cropping patterns and climate data in a part of this region (Mashhad city) based on the above algorithm and also estimates of wheat cropping pattern which is obtained from image processing operations of Fig. 4. The result of this analysis is the estimation map of wheat cultivation in this area that can be seen in Fig. 5. Such a map in fact can be used as the potential of wheat based on spatial variability of climatic parameters.

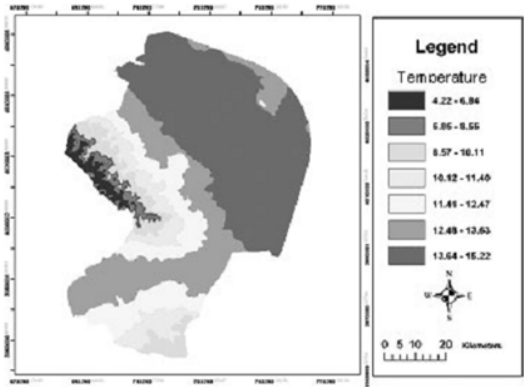

Fig. 5: Map of the area under wheat cultivation based on the spatial variability of climate factors of khozestan

5. Conclusion

Using data received from the SSCM System (Simultaneous Source Control Managers) is the main base for precision agriculture that requires special tools and methods. Tools such as GPS, GIS, and RS are used to determine variability and different factors in a farm.

Fast processing by GIS systems and increasing the accuracy of satellite images data with the help of data collected from location experimental data provide appropriate solutions. Pest and disaster control, crop estimation and evaluating the status of plant growth are provided at a very wide level by satellite data and reduce the adverse effects of plans on the environment and smooth the ways to achieve sustainable, environmental, and dynamic agriculture development.

References

Jo´ ri, J.I., Erbach, C.D., 1998. Annual International Meeting Sponsored by ASAE, Paper No. 981051.

Kuma, A., G.N., Ghosh, S.,Venniyoor. (2007), Application of Remote Sensing in Agriculture – Experiences, Food and Nutrition SecurityCommunity, New Delhi, 9 February

La´szlo´ , A., 1992. Automatiza´la´s a vegyszerkijuttata´sban (Automatisation in chemical application). Mezo¨gazdasa´gi Technika (Agricultural Technique) 33 (4), 33.

Leboeuf, J. (2000). Practical applications of remote sensing technology and industry perspective. Hort Tech. 10: 475-480

Lee, B.L., Y.C. Kim and M.E. Park, (1997), Interactive web interface for GIS applications in Agriculture, Korea Agricultural Information and Technology, Vol.6 No.1, pp136-139

Mandal,D., S. K., Ghosh. (2000), Precision farming – The emerging concept of agriculture for today and tomorrow, in the Nagarjuna Agricultural Research and Development Institute, current science, vol. 79, no. 12-25

Mesterha´zi, P.A´., Pecze, Zs., Neme´nyi, M., 2001. A precı´zio´s no¨ve´nyve´delmi elja´ra´sok mu¨szakite´rinformatikai felte´telrendszere (The engineering and GIS background of the precision farming technology). No¨ve´nyve´delem (Plant Protection) 37 (6), 273_/281.