SPATIAL FOOD AND AGRICULTURAL DATA

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Contents

Summary

Spatial data is playing an increasingly important role in today's agriculture. New technology such as low-cost computers, remote sensing, and Global Positioning Systems (GPS) enable the growers to collect high resolution spatial data. GIS is an inseparable component in the process of assimilation and analysis of spatial data. Farmers and growers use spatial data to improve the production practices by making more informed decisions. Spatial information is also becoming crucial in the study of food supply chain management and food traceability systems. Part of spatial data collected by farmers can now be used by consumers using technologies such as RFID to provide them with detailed information about the product they purchase. Expert systems and decision support tools are among other areas of applications that can effectively utilize the spatial information. In the near future, it is expected that definite strategies will emerge in creation, upkeep and use of spatial data in almost all spheres of food and agriculture. The purpose of this chapter is to provide introductory information on how

spatial data is collected and used for agricultural and food applications.

1. Introduction

Since 1990, the concept of using spatial data for precision agriculture and food traceability has attracted the attention of the agricultural community. Spatial or “geo-referenced” data is any data that has information on geographical location attached to it. The Global Positioning System (GPS), which can very accurately locate a geographical position, has been the main driving force behind the development of spatial data in agriculture. This is a major breakthrough because it allows all known information about soil and plants to be localized to a sub-meter scale rather than over the entire field. The Global Positioning System (GPS) is a worldwide radio-navigation network formed from a constellation of 24 satellites and their ground stations. GPS receivers use these satellites as references to calculate their positions on the ground. Since each satellite sends information on its location, the receiver can measure the distance to the satellite. If four satellites are visible to the GPS receiver at any time, it measures its ground locations by triangulation. Triangulation is to calculate the location by way of intersection of three spheres whose radii are the distances of three satellites from the receiver. The fourth satellite is used to check on the precision of distance measurements. However the error in using this method is about 13 m. Differential GPS or "DGPS" yields measurements with more accuracy. It uses a stationary source of known location along with the satellites and makes the measurements more precisely (www.trimble.com/gps/index.htm)

The relevant soil and crop information at localized sites can be collected in real-time by sensors mounted on agricultural machinery as well by those locally installed in the field. GPS receivers coupled to rugged computers enabled the development of a new series of tools to collect these localized spatial data at the field level. The data thus derived can be stored in a digital format along with the geographical position information. The vast amount of spatial data collected could be used to make decisions on agricultural inputs, such as fertilizer, pesticides, seeds, and water at each localized site using a GIS software package. This led to the development of a new information-based management technique called precision agriculture, wherein the spatial data plays a pivotal role.

Precision agriculture is information-intense and mapping of different soil, crop, and environmental data within a field produces large quantities of spatial data. Data integration tools, expert systems, and decision support systems become necessary when dealing with the organization and analysis of this voluminous data (Sigrimis et al., 1999).

According to Stafford (2000), some problems associated with the acquisition and applications of this spatial data for precision agriculture are the lack of:

- rapid sensing systems that can acquire spatial data on the soil, crop and the environment,
- validated models for determining application rates based on the localized input data. Here, the application rate refers to the quantity of agricultural inputs such as seed, fertilizer and pesticides that are applied to the unit area

of the given site,
- techniques for more precise management of application rates and more accurate localization of the application site.

Although the economic benefits of implementing the concept of precision agriculture remain unproven, stricter environmental regulations could require its use to provide an alternative means for optimizing the use of agrochemicals.

Traceability of the food supply chain from soil to supermarket is another application of spatial data and has gained momentum due to legislation and consumer pressures (Zilberman & Millock, 1997). Information is an expensive resource and the means to fully utilize this information must be made readily available to the farmer and processor alike. The processor is one who processes, packs and markets the agricultural produce. These systems work to improve access to available spatial data, promote its reuse, and ensure the additional investment in spatial data collection and management. When farmers and producers can access spatial data on their resources in combination with the power of Geographic Information Systems (GIS), decision support tools, expert systems, and techniques for spatial analysis, optimal management of their production systems becomes feasible.

Moreover, spatial data regarding agriculture can enhance knowledge of farmland, identify opportunities for better land use, and determine the impact of policies and regulations of farm activities. For instance, it can assist regulation agencies to make better policies for crop production systems.

Farmers interested in expanding their businesses or switching to a new crop can use spatial data to examine data on soil, crop suitability, land use pattern and infrastructure. The spatial data can potentially be used as a basis for determining the value of farmland. Spatial data also assists in identifying market potentials, analyzing land reserves, tracking urban/rural conflicts, relating flood/fire hazards to farmland, tracking issues such as animal health and insurance and applying buffers to farmland.

Out of all these potential uses of spatial data for food and agriculture, precision agriculture has been the most relevant application. In this context, Geographical Information System (GIS) has been the pivotal element in the creation, analysis, modeling, and presentation of spatial data. Moreover, for a single food or agricultural product, the spatial data from production and processing can be traced along the supply chain for food safety or other reasons in a more efficient manner. This section describes the methods of acquiring yield, soil, and plant data in spatial terms and the strategies on how the agricultural inputs are managed using this data with the assistance of variable rate application techniques to maximize production. The basic concepts of GIS relevant to precision agriculture and how it helps to manage and make decisions around the spatial data are also briefly discussed. Issues relating to the application of spatial data to food traceability and safety have been highlighted in this section.

2. Precision Agriculture

Precision agriculture is an information-based management technique that utilizes scientific practices and technological tools to optimize agricultural production and management choices. This technology is also known as precision farming or site-specific crop management. A comprehensive approach to precision agriculture covers all facets of crop production such as tilling, planting, scouting, harvesting, input applications and post-harvest processing.

The primary goals of precision agriculture are to improve profitability, increase efficiency and improve environmental performance. Profitability may be improved by increasing yields, lowering input costs, enhancing crop quality and lowering production risk. Field efficiency can be improved by performing the right practice at the right time and place. Several ways to help lower risk are to evaluate time management practices such as time spent on planting, spraying or harvesting. These practices are time consuming and how much time is dedicated to each activity may be related to specific equipment size, cost of production, and efficiency of the farming operation. Precision agriculture helps prevent over-application of fertilizer or crop protection inputs, which can contaminate the soil and water resources. Applying the right amount of inputs at the right location and time provides environmental protection without compromising crop yield.

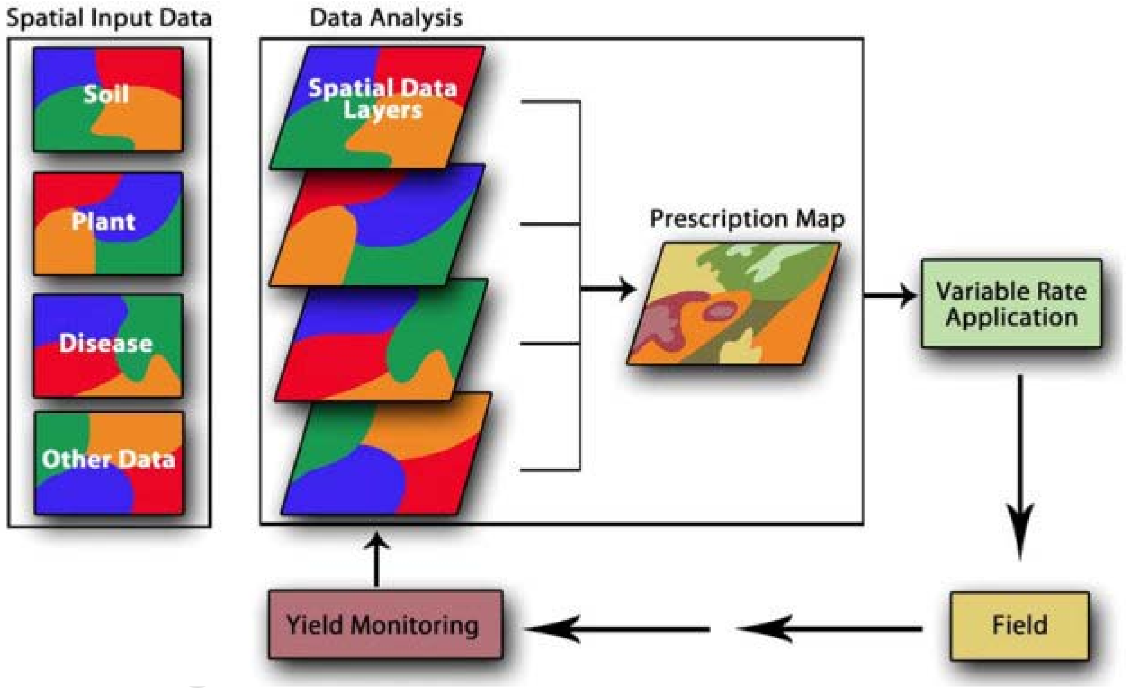

Figure 1: Flow of spatial data in a precision agriculture system

Figure 1 illustrates a typical precision agriculture system, wherein spatial data on characteristics of soil, plant, disease and other relevant factors deemed to influence the crop yield are the inputs. For instance, the soil's electrical conductivity, the plant's chlorophyll content, and previous seasons' disease incidence could be the input factors under consideration. Spatial data on each such input are converted to map layers. These layers and the yield map from the previous season are overlaid on each other to analyze and arrive at models relating the site-specific yield data and the inputs. This would provide prescription data on how and where crop inputs such as seeding rate and fertilizer rate could be changed to maximize the crop yield. This prescription would be fed to the on-board computers of appropriate variable rate equipment such as seeders and fertilizer applicators, which would implement these prescriptions in the field. While the crop is being harvested, yield monitors are used on the combine to acquire GPS-tagged yield data from the field. The spatial yield data is cycled back into the precision agriculture system to validate and refine the yield model for the next cropping season.

Information is perhaps the farmer's most valuable resource and management tool. Timely and accurate information is essential in all phases of production from planting to harvesting. To achieve success, farmers need site-specific information describing variability of important factors such as physical properties of soil, fertility levels, pest infestations, water availability and harvested crop yield in previous seasons. Inputs are given to the crop production environment at the right location on a precise need basis and involve modern technology such as Geographic Information Systems, Global Positioning Systems and automatic control systems.

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Biographical Sketches

Dr. Reza Ehsani was born in Iran. Ehsani obtained a Ph.D. degree in Biological and Agricultural Engineering from the University of California, Davis, USA in 2000, where he worked on precision agriculture applications for high value crops. Ehsani has also obtained a M.S. degree in 1992 and a B.S. degree in 1988 in Agricultural Engineering from Tehran University, Iran. He is an Assistant Professor of Agricultural and Biological Engineering at the University of Florida/IFAS Citrus Research and Education Center (CREC). He was an assistant professor and a precision agriculture specialist at the department of Food, Agricultural and Biological Engineering at the Ohio state University before joining the University of Florida. His current areas of research include developing and improving yield monitoring systems for citrus mechanical harvesters, applications of wireless sensor networks for citrus groves, application of GPS/GIS for grove management, and development of soil and plant sensors. He also works on the development of education materials on the application of GPS/GIS and sensor technology for citrus production, and organizes grower conferences on precision agriculture and mechanical harvesting for citrus. Dr. Ehsani is a member of the American Society of Agricultural and Biological Engineers.

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