INFORMATION REQUIREMENTS FOR AGRICULTURE: THE NEXT DECADE

Chris J. Johannsen
Director, LARS, Purdue University
Department of Agronomy
1150 Lilly Hall
West Lafayette, IN 47907
(317) 494-6305

Allan Falconer
Utah State University
Department of Geography
and Earth Resources
Logan, UT 84322-5240
(801) 797-1334

William Wigton
Agricultural Assessments International
2606 Ritchie Marlboro Road
Upper Marlboro, MD 20772
(301) 336-5229

Abstract

International agriculture needs improved capabilities for crop production monitoring and management data. Many countries, using an area frame sample, have begun to integrate GIS and remote sensing in their national crop inventory statistics programs and as the basis for famine early warning systems. The demand for accurate digital data has been heightened by the boom in precision farming which requires analysis of data collected at 1-5 meter spatial intervals. Manipulation and interaction of such data as digital soils maps, field boundary maps, drainage maps, yield monitor images, fertilizer, seed and chemical rate applications are primary to precision farming. Interest is building in the use of remotely sensed data to compare with yield image maps to assist in management decisions. The demand for digital data at all levels will increase dramatically as data are collected for local, regional and national statistics, the management of crop production, transportation to markets, crop insurance decisions, marketing commodity futures and delivery of data to farm consultants. Users in the United States will include county extension educators, crop consultants, ag industry agronomists, farm management groups among others. In a global context the users will include development agencies, national governments, agribusiness and the investment community as well as international organizations concerned with the environmental issues related to agriculture and land use.

INTRODUCTION

Agricultural statistics as reported by national and international groups and organizations are primarily acreage and yield estimates of individual crops. Remote sensing in conjunction with Geographic Information Systems (GIS) is a good technique for identifying crops and monitoring changes in crop conditions. Statistical sample frames can be constructed using remotely sensed data by delineating the areas used for crop production. Primary sample units (PSU) can be assigned after the density of crops are known with a sampling frame. These are proven approaches used by the National Agricultural Statistical Service (NASS) of the US Department of Agriculture. Similar approaches have been used by the Foreign Agricultural Service and non-government organizations (NGOs) for estimating crop area and yield in foreign countries.

Difficulty in obtaining data in a timely and cost effective mode has curtailed the agricultural uses of remote sensing by many groups. Another important factor is that agricultural remote sensing has been oversold in the past. People were told that you could detect diseases and insects and later learned that you could not. This is rapidly changing with many organizations launching satellites and seeking agricultural groups as customers. Another factor encouraging a "second look" at remote sensing is that people are becoming familiar with yield images collected by yield monitors on harvesting equipment. They now realize that one can not do anything to change the yield for that year when viewing a yield map. However, if they could obtain a "yield map" early in the growing season by remote sensing techniques, perhaps one could make changes in their cultural practices and economically increase yield. An example would be to apply nitrogen fertilizer through their irrigation water after seeing that the crop a reduction in chlorophyll.

Precision farming is a current buzz word among agricultural circles in the USA and in Europe. The term "precision farming" means carefully tailoring soil and crop management to fit the different conditions found in each field. Precision farming is sometimes called "prescription farming," "site-specific farming" or "variable rate technology" (Johannsen 1994, 1996a, 1996b and 1996c). It has caused a focus on the use of three technologies: remote sensing, geographic information systems (GIS) and global positioning systems (GPS).

All three technologies have been used extensively in space and by defense departments around the globe. We have literally taken "agriculture into the space age". Farmers have services available that involve satellites collecting data, transmitting locational information, or providing data from a variety of sources. These technologies can be used in any agricultural locations except where restricted by the government . Farmers can analyze the available satellite information themselves, hire a land or crop consultant or they can rely on companies to do this service for them for a fee.

Some farmers have already received benefits of satellite remote sensing data. Satellite images from Landsat and SPOT have been used to distinguish crop species and locate stress conditions (Lozano-Garcia et al. 1995). The cost of obtaining the images has been the biggest deterrent in regular use of such data. A typical farm manager of 2,500 acres is not going to spend $500 to $3,500 every 2 weeks to monitor conditions in his field. Resourceful agricultural industry dealers can however, purchase digital satellite data over their trade area and spread the cost among numerous customers. Trained personnel in the use of computer analysis systems, basics of remote sensing and spectral responses of crops & soils will be a limiting factor in rapid use of these technologies.

We predict that future satellite launches, such as the TRW Small Satellite, World View Imaging, Resource21, ORBIMAGE, GER, EarthWatch and Space Imaging, will be competing for the agricultural market and lowered prices will encourage farmers to participate. The remote sensing part of precision farming will need to be proven; it has been receiving its first test through the 1995 and 1996 growing season since companies like Resource21 are providing prototype data by aircraft. They are receiving repeat customers which is a good sign.

More recently farmers have gained access to site-specific technology through Global Positioning Systems (GPS). GPS makes use of a series of military satellites that identify the location of farm equipment within a meter of an actual site in the field (Parsons et.al. 1995). The value of knowing a precise location within inches is that 1) tillage adjustments can be made as one finds various conditions while traveling across the field, 2) locations of soil samples and the laboratory results can be compared to a specific soil type and to crop yields at the end of the season, 3) fertilizer and pesticides can be prescribed to fit soil properties (clay and organic matter content) and soil conditions (relief and drainage), and 4) one can monitor and record yield data as one goes across the field.

The real value for the farmer is that he can perform more timely tillage, adjust seeding rates, perform more accurate crop protection programs, and know the yield variation within a field. These benefits will enhance the overall cost effectiveness of his crop production (Johannsen 1996b).

TILLAGE

The ability to vary the depth of tillage related to soil conditions is very important to proper seedbed preparation, control of weeds and fuel consumption and therefore cost to the farmer. Most farmers are using conservation tillage which means leaving residues on the soil surface for erosion control. The use of GPS in making equipment adjustments as one goes across the different soil types would mean higher yields and safer production at lower cost. This part of precision farming is in its infancy.

The equipment companies have announced tillage equipment with GPS and selected controls tailored to precision farming at some of the recent conferences and there will be more to come.

SEEDING

Hybrid seeds perform best when placed at spacing that allow the plants to obtain such benefits as maximum sunlight and moisture. This is best accomplished by varying the seeding rate according to the soil conditions such as texture, organic matter and available soil moisture. One would plant fewer seeds in sandy soil as compared to silt loam soils because of less available moisture. The lower seed population usually has larger heads (ears) of harvested seeds providing for a maximum yield. Since soils vary even across an individual farm field, the ability to change seeding rates as one goes across the field allows the farmer to maximize this seeding rate according to the soil conditions. A computerized soil map of a specific field on a computer fitted on the tractor along with a GPS can tell farmers where they are in the field, allowing the opportunity to adjust this seeding rate as they go across their fields.

CROP PROTECTION

The application of chemicals and fertilizers in proper proportions are of environmental and economic concern to the farmers. Environmental regulations are calling for the discontinuance of certain pesticide applications within 100 feet of a stream or waterbody or well or within 60 feet of an intermittent stream in the USA. Constraints on applying ag chemicals are also mandated in some European Countries. Using a GPS along with a digital drainage map, the farmer is able to apply pesticides in a safer manner. In fact, the spraying equipment can be preprogrammed to automatically turn off when it reaches the distance limitation or zone of the drainage feature. Additionally, farmers can preprogram the rate of pesticide or fertilizer to be applied so that only the amount needed determined by the soil condition is applied varying this rate from one area of the field to another. This saves money and allows for safer use of these materials.

HARVESTING

The proof in the use of variable rate technology (adjusting seed, pesticide, fertilizer and tillage) as one goes across the field is in knowing the precise yields. Combines and other harvesting equipment can be equipped with weighing devices that are coupled to a GPS (Parsons et al. 1995). One literally measures yield on the go. With appropriate software, a yield map is produced showing the yield variation throughout the field. This allows farmers to inspect the precise location of the highest and the lowest yielding areas of the field and determine what caused the yield difference. It allows one to program cost and yield to determine the most profitable practices and rates that apply to each field location. In our opinion, the use of yield monitors is a excellent place to begin if one wants to get started in precision farming.

Yield data from the same field over 3^+ years would define the weak spots in the field and narrow down the probability of what is causing a low yield.

CONCLUSIONS

The information requirements are changing rapidly in agriculture because of the changes in technology. Improvements in spatial and spectral resolutions of remotely sensed data has started agriculturists to think of ways to use this additional information. The yield monitor images has started the demand for images during the crop growing season. This trend is actually starting new industries that are supplying equipment, software and consultation.

GPS has already made a big impact on providing precise data/information locations in precision farming. Where does GIS and remote sensing fit with this trend? Several companies are starting to market GIS record-keeping systems so farmers can record all of the field operations such as planting, spraying, cultivation and harvest (along with specific information such as type of equipment used, rates, weather information, time of day performed, etc.). Additionally the farmers are able to record observations through the growing season such as weed growth, unusual plant stress or coloring and growth conditions. Data collected by the GPS operations can be automatically recorded with the GIS program. Remotely sensed data can be analyzed and added to the GIS using soil maps, digital terrain and field operations information as ground truth.

This can be used to guide further field operations like spraying, fertilizing and irrigating plus it is part of the permanent record. Trends like precision farming will make a strong impact on the way growers manage their farm operations in the future. We will see a steady growth of the remote sensing, GIS and GPS technologies as a result of this method of acquiring agricultural information in the next decade.

Acknowledgments

Partial funding for the senior author for this effort obtained from Stennis Space Center, (NASA Grant NAG13-38).

References

Johannsen, C.J., (1994) "Precision Farming: Farming by the Inch," The Earth Observer, A Bimonthly EOS Publication, NASA, November/December, 1994, 6: 24-25.

Johannsen, C.J. (1996a) "Overview of Precision Farming," Information Ag Conference Proceedings, Champaign, IL, July, 1996, 53-54.

Johannsen, C.J. (1996b) "Farming by the Inch," The World & I, February, 1996, 148-155.

Johannsen, C.J. (1996c) "Satellite Technology: The World of Precision Farming is on the Horizon and Coming Soon to a Farm Near You," Agri-Alternatives, July-August, 1996, 5-6.

Lozano-Garcia, D.F., R.N. Fernandez, K. Gallo, C.J. Johannsen. (1995) "Monitoring the Droughts in Indiana, USA," International Journal of Remote Sensing, 16, (7): 1327-1340.

Parsons, S.D., D.R. Ess, C.J. Johannsen. (1995) "How GPS Works and Why DC is Needed," Precision Decisions '95 Conference Proceedings, Champaign, IL, November 27-28, 1995, 28-32.