Introduction

The rapid development of spatial technologies in recent years has made available new tools and capabilities to Extension services and clientele for management of spatial data. In particular, the evolution of geographic information systems (GIS), the global positioning system (GPS), and remote sensing (RS) technologies has enabled the collection and analysis of field data in ways that were not possible before the advent of the computer.

How can potential users with little or no experience with GIS-GPS-RS technologies determine if they would be useful for their applications? How do potential users learn about these technologies? Once a need is established, what potential pitfalls or problems should the user know to avoid? This article describes some uses of GIS-GPS-RS in agricultural and resource management applications, provides a roadmap for becoming familiar with the technologies, and makes recommendations for implementation.

Spatial Technologies

Geographic Information Systems

GIS applications enable the storage, management, and analysis of large quantities of spatially distributed data. These data are associated with their respective geographic features. For example, water quality data would be associated with a sampling site, represented by a point. Data on crop yields might be associated with fields or experimental plots, represented on a map by polygons.

A GIS can manage different data types occupying the same geographic space. For example, a biological control agent and its prey may be distributed in different abundances across a variety of plant types in an experimental plot. Although predator, prey, and plants occupy the same geographic region, they can be mapped as distinct and separate features.

The ability to depict different, spatially coincident features is not unique to a GIS, as various computer aided drafting (CAD) applications can achieve the same result. The power of a GIS lies in its ability to analyze relationships between features and their associated data (Samson, 1995). This analytical ability results in the generation of new information, as patterns and spatial relationships are revealed.

The Global Positioning System

GPS technology has provided an indispensable tool for management of agricultural and natural resources. GPS is a satellite- and ground-based radio navigation and locational system that enables the user to determine very accurate locations on the surface of the Earth. Although GPS is a complex and sophisticated technology, user interfaces have evolved to become very accessible to the non-technical user. Simple and inexpensive GPS units are available with accuracies of 10 to 20 meters, and more sophisticated precision agriculture systems can obtain centimeter level accuracies.

Remote Sensing

Remote sensing technologies are used to gather information about the surface of the earth from a distant platform, usually a satellite or airborne sensor. Most remotely sensed data used for mapping and spatial analysis is collected as reflected electromagnetic radiation, which is processed into a digital image that can be overlaid with other spatial data.

Reflected radiation in the infrared part of the electromagnetic spectrum, which is invisible to the human eye, is of particular importance for vegetation studies. For example, chlorophyll strongly absorbs blue (0.48 mm) and red (0.68 mm) wavelength radiation and reflects near-infrared radiation (0.75 - 1.35 mm). Leaf vacuole water absorbs radiation in the infrared region from 1.35 - 2.5 mm (Samson, 2000). The spectral properties of vegetation in different parts of the spectrum can be interpreted to reveal information about the health and status of crops, rangelands, forests and other types of vegetation.

Applications

The uses of GIS, GPS, and RS technologies, either individually or in combination, span a broad range of applications and degrees of complexity. Simple applications might involve determining the location of sampling sites, plotting maps for use in the field, or examining the distribution of soil types in relation to yields and productivity. More complex applications take advantage of the analytical capabilities of GIS and RS software. These might include vegetation classification for predicting crop yield or environmental impacts, modeling of surface water drainage patterns, or tracking animal migration patterns.

Precision Agriculture

GIS-GPS-RS technologies are used in combination for precision farming and site-specific crop management. Precision farming techniques are employed to increase yield, reduce production costs, and minimize negative impacts to the environment (Zhang et al., 1999). Using GIS analytical capabilities, variable parameters that can affect agricultural production can be evaluated. These parameters include yield variability, physical parameters of the field, soil chemical and physical properties, crop variability (e.g., density, height, nutrient stress, water stress, chlorophyll content), anomalous factors (e.g., weed, insect, and disease infestation, wind damage), and variations in management practices (e.g., tillage practices, crop seeding rate, fertilizer and pesticide application, irrigation patterns and frequency) (Zhang, Wang, & Wang, 2002).

Site-specific data, such as soil characteristics, fertility and nutrient data, topographic and drainage characteristics, yield data, harvester-mounted yield sensor data, and remotely-sensed vegetation indices, are collected from different sources and stored and managed in a spatial database, either contained within the GIS or connected to the GIS from an external source. The analytical power of a GIS is applied to the data to identify patterns in the field (e.g., areas of greater or lesser yield; correlations between yield and topography or characteristics such as nutrient concentrations or drainage) (Zhang et al., 1999).

Once patterns and correlations are elucidated, management practices can be modified to optimize yield and production costs, and minimize environmental impacts caused by excessive applications of fertilizers and pesticides. Site-specific applications of fertilizers, pesticides and other applications can be implemented by dividing a field into smaller management zones that are more homogeneous in properties of interest than the field as a whole (Zhang et al., 2002).

Forest Management

Spatial technologies are well suited for applications to resource management issues. The ability to interface GIS with relational databases enables integration of large data sets and many variables to support management decisions (e.g., Arvanitis, Ramachandran, Brackett, Rasoul, & Du, 2000). One example is the Florida Agroforestry Decision Support System (FADSS) (Ellis, Nair, Linehan, Beck, & Blance, 2000). FADSS is a GIS application that integrates geographically linked data on climate and soil characteristics in the state of Florida with a database of over 500 trees and 50 tree attributes. FADSS enables landowners, farmers and extension agents to make management decisions based on site-specific and tree-specific information.

Habitat Analysis

The modeling capabilities of GIS can be combined with remotely sensed landscape imagery to evaluate the effects of management practices and to assist resource managers and public decision makers in making informed decisions. For example, a GIS-enabled program, VVF, was developed to assess the suitability of a landscape as a species habitat (Ortigosa, De Leo, & Gatto, 2000). VVF integrates user-selected environmental variables to produce habitat suitability maps, and enables the user to create habitat suitability models for a specified area. Another model, LEEMATH (Landscape Evaluation of Effects of Management Activities on Timber and Habitat), evaluates both economic and ecological effects of alternative management strategies on timber production and habitat quality (Li, Gartner, Mou, & Trettin, 2000).

Data Analysis and Display

The spatial visualization capabilities of GIS technology interfaced with a relational database provide an effective method for analyzing and displaying the impacts of Extension education and outreach projects. This application was demonstrated in the Florida Yards & Neighborhood (FY&N) program developed by the University of Florida Extension to teach homeowners and landowners how to reduce non-point source pollution and storm water runoff and protect the environment through landscape practices they exercise in their own yards.

Homeowners filled out surveys both before and after receiving training in landscaping methods. Responses to questions concerning landscape practices were rated as good, fair, or poor and statistical analysis was conducted on before and after scores for each landscape practice using a relational database interfaced with GIS software. Geospatial analysis of the extent of homeowner/landowner adoption of these best management practices taught by the program enabled assessment of impact by acreage and location, identification of areas needing greater emphasis, tracking of change, and the ability for policymakers to see impacts in map format