Foreword

Interfacing Geographic Information Systems and Remote Sensing for Rural Land-Use Analysis

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INTRODUCTION

In a broad sense, as the rural land-use planning process developed in the United States, certain decisions have historically been made about data requirements that influence the role of geographic information systems (GIS) and remote sensing. The geographic information systems/remote sensing data specifications for rural land-use analysis have involved various parameters, but most significantly include functional categories, spatial resolution, and temporal resolution of data. The functional definition of the types and categories of information required, for example, has been a difficult, yet critical, task. The ideal situation is for diverse data requirements to be categorized in hierarchical classification systems which include local, regional, and national data requirements (Nellis, 1989).

While hardware and software for geographic information systems have improved exponentially in the United States, implementation of technology for management purposes has grown linearly (Johnston, 1987). Many rural land-use planners now recognize the potential value of and have access to GIS capabilities, but often find little direction for effectively manipulating their data. Through interfacing of GIS technology with remote sensing, different management scenarios can be processed allowing the manager to analyze many management alternatives before selecting the alternative that would be most suitable. Environmental analysis of the historic range of the condor within California, for example, provides one example of the use of geographic information systems/remote sensing for exploring rural land-use management options toward an overall condor recovery program (Star and Estes, 1990). This particular rural land-use problem (relative to condor habitat) involves combining condor observation data with selected environmental data sets, including Landsat TM derived land use and land cover with topography, to examine issues of map scale, resolution, classification, and accuracy.

As the more recent literature reflects, there are a wide range of potential applications of GIS/remote sensing technology for analyzing rural land-use systems (Figure 1). Various types of specialized scenarios can be derived from the range of general applications (Figure 2). The objective of this special issue of *Photogrammetric Engineering and Remote Sensing* is to provide examples of current GIS/remote sensing research efforts associated with rural land-use systems analysis.

GIS/REMOTE SENSING FOR RURAL LAND-USE ANALYSIS

This special issue focuses on four sub-themes within the framework of rural land-use analysis:

- sampling procedures for rural land-use analysis,
- agricultural land-use mapping and productivity,
- irrigation agriculture and water management, and
- dynamics of rural land use/land cover.

Sampling Procedures for Rural Land-Use Analysis

In the article, "Automated, Objective Procedure for Selecting Representative Field Sample Sites," by Warren, Johnson, Goran, and Diersing, a procedure utilizing geographic information system technology and *a priori* incorporation of ancillary data was developed to maximize the representativeness of field sample sites for use with satellite digital data. The study enhances the rural resource managers ability to accurately correlate spectral response patterns with conditions on the rural landscape. Within the Geographical Resources Analysis Support System (GRASS), a data layer representing spectral land-cover types of a salt desert ecosystem in Utah (derived from SPOT satellite data) is overlaid with ancillary data (soil survey information).

Agricultural Land-Use Mapping and Productivity

Another important sub-theme of rural land-use analysis is agricultural mapping and productivity. One example of this subtheme is research by Moran. In an article entitled "A Window-Based Technique for Combining Landsat Thematic Mapper Thermal Data with Higher-Resolution Multispectral Data over Agricultural Lands," Moran focuses on remote sensing of agricultural field surface temperature. Surface temperature

Rural land use/land cover	Land use surveys Land use change Land reclamation
Agricultural resources	Soil surveys Soil erosion Conservation tileage Crop acreage surveys Crop health Crop yield
Forest resources	Cover type surveys Insect and disease infectation Forest productivity
Rangeland resources	Biomass estimates Vegetation mapping
Water resources	Water supply and demand Watershed runoff and water quality Flood boundary mapping Agrohydrologic surveys Wetlands surveys

Fig. 1. Selected applications of GIS/remote sensing technology for rural land-use analysis.

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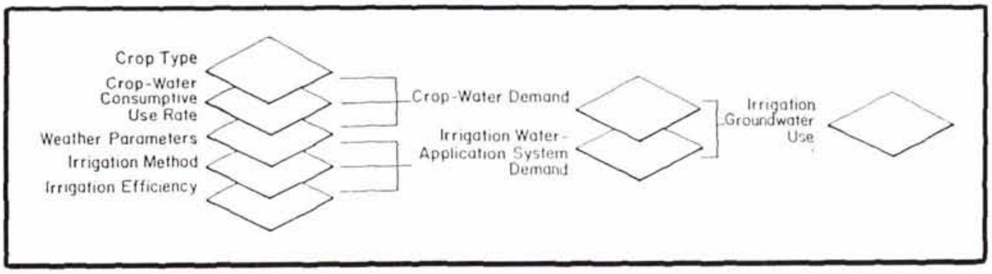

FIG. 2. A groundwater demand prediction model for western Kansas. The model incorporates both remote sensing and geographic information system technology (Nellis, 1989).

measurements are a major component when monitoring crop evapotranspiration, stress, yield, and soil moisture. Moran first describes the fundamental problems associated with the use of Landsat Thematic Mapper (TM) band 6 thermal data at 120- by 120-m spatial resolution for mapping surface temperature of agricultural fields in Arizona. She then demonstrates the use of two techniques which utilize Normalized Difference Vegetation Index (NDVI) information derived from 30- by 30-m TM bands 3 and 4 in conjunction with TM band 6 data, to build a new thermal channel at 30- by 30-m spatial resolution whose agricultural pixels are not contaminated by field boundaries or roads. An airborne infrared thermometer (IRT) provided detailed temperature transect information on the same dates as TM data. Correlation between the TM data and the IRT data revealed that both of the techniques provided superior surface temperature information when compared with the use of standard TM thermal band 6 data at 120- by 120-m resolution. Improvements in measuring the surface temperature of agricultural fields using TM data are significant for many agricultural applications.

Everitt, Lulla, Escobar, and Richardson have produced an excellent review paper of multispectral videographic remote sensing and GIS for rangeland management. The uses of this innovative technology in determining the extent of grazing, plant stresses, phytomass level, and soil salinity have been documented. An application of GIS and videographic data is discussed to illustrate the use of this approach in rangeland management. One of the interesting developments is the acquisition of 8-mm camcorder coverage of rangeland and other rural land-use areas from the Space Shuttle.

Further support to this sub-theme is offered by Marsh, Walsh, and Hutchinson in the paper, "Development of an Agricultural Land-Use GIS for Senegal Derived from Multispectral Video and Photographic Data." This article demonstrates the logistical advantages of utilizing a multispectral video system, coupled with the map generation capabilities of GIS, to accurately map rural land-use characteristics in Senegal. The research also provides insight as to the limitations of combining multiple video scenes into a single, geographically registered image.

IRRIGATION AGRICULTURE AND WATER MANAGEMENT

Interfacing GIS and remote sensing has contributed significantly to the rural land-use manager's ability to monitor the dynamics of irrigation agriculture. In the paper, "A Retrospective Analysis of GIS Performance: The Umatilla Basin Revisited," by Astroth, Trujillo, and Johnson, a unique reflection back at the success of a GIS project completed in 1982 is evaluated. The study assesses the validity of a GIS approach for predicting irrigation diffusion patterns in the Columbia River Basin. The original model included inputs of Landsat data, pumping plant locations, topography, soil surveys, and land ownership. From these data inputs, other spatial data were derived, such as slope, soil irrigability, land cover, crop types, crop-water requirements, and energy costs. A determination was made of the degree of areal correspondence between the 1979 irrigation development potential map generated by GIS analysis, and a 1987 map of center pivot irrigation. Of the new land areas developed, a high proportion occurred on land originally rated good to excellent potential for development. The results indicate that the assumptions and the predictive modeling capability of GIS were highly successful.

In another related paper, Morse, Zarriello, and Kramber focus on water rights adjudication using remote sensing/GIS technologies. The State of Idaho is undertaking the largest water right adjudication ever in the United States – that includes 140,000 water rights within a 72,000 square mile area. Morse *et al.*, of the Idaho Department of Water Resources, have developed an innovative use of remote sensing and the Public Land Survey System (PLSS) to facilitate the implementation of a large scale adjudication of water rights. Landsat MSS images are geometrically controlled and transformed to principal components. The transformed data are clustered and classified to derive information in six rural land-use classes. The classified Landsat data are overlaid with the PLSS digital files and the acreage of each land-cover class is computed. Classification accuracy is determined by using regression analysis of Landsat derived irrigated acreage against the acreage measured from USDA/ASCS aerial slides. The resulting products, the land-cover overlays at 1:24,000 scale, are used to adjudicate water resources.

DYNAMICS OF RURAL LAND USE/LAND COVER

Interfacing of GIS and remote sensing provides new and exciting capabilities for analyzing the dynamics of rural land-use change. Jakubauskas, Lulla, and Mansel used a geographic information system, for example, to conduct classification comparisons to assess the vegetation changes in a fire-altered landscape comprising pine forest. Pre-fire and post-fire maps were compared using a GIS, and a map of vegetation change was generated. This analysis has shown that post-classification comparison within the context of a geographic information system is a valuable procedure in landscape assessment using sets of data from diverse sensors.

In Turner's invited paper on changing patterns of land use/land cover in nine rural counties in Georgia, using the digitized aerial photography and landscape pattern analysis algorithms, shows the importance of historical databases. These databases could provide the information regarding past changes in the rural landscapes and the associated effects on ecological processes. Policy decisions would certainly benefit from such an insight. Turner found that coniferous forests increased in all nine counties and that agricultural land increased in coastal plain counties, but declined in the mountain and piedmont counties. Various spatial measures employed by Turner show that the Georgia landscape is less fragmented than it was in the 1930s. These findings would enable the land-use planner and environmental assessment specialist to devise appropriate future plans in achieving sustainable development goals for Georgia. Turner has aptly shown that the linkage of remote sensing and GIS technologies with rural landscape ecological research can provide a basis for assessing broad scale rural changes.

Baumann, in "Attempting to Detect and Record Brushland in the Northeastern United States Using MSS Data: Schoharie County, New York," examines a satellite based, land-cover information system approach for identifying and mapping a significant transitional land use. Brushland throughout the northeastern United States represents an early indicator of the rural land-use shift; from agriculture to rural residential. The derived approach offers insight to county and local government officials in planning and managing a county's future land use.

CONCLUSIONS

As appropriate rural land-use decisions become increasingly critical, the need for more information increases correspondingly. At the same time, the need for increased sophistication in storage and retrieval methods and use of data intensify. In this regard, remote sensing technology, in conjunction with geographic information systems, has served as a valuable approach to the rural resource manager.

The science of remote sensing has emerged and grown during the 1980s, with emphasis focusing on the development of improved statistics for rural planning, and more sophisticated models, particularly two- and three-dimensional models. Advancement in computer technology, associated with dramatic improvements in microcomputer storage capacity, is making possible the development of more sophisticated rural land-use models and the increasing availability of remote sensing and geographic information systems to the rural land-use planning community. This special issue builds upon these trends.

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