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Abstract

In the Phase II Ecosystem Management Research Program in the Ouachita and Ozark National Forests, an interdisciplinary group of scientists are evaluating the effects and trade-offs of partial cutting methods in a replicated stand level study. Information from approximately 2,000 plots is being collected by more than fifty researchers during this five-year project with plans to continue data collection long term. To evaluate the effects of different management strategies and their interactions with forest resources, data must be brought into a common format and made available to all researchers. To this end, a data support system was developed which utilizes Geographic Information System (GIS), Global Positioning Systems (GPS) and remote sensing technologies. Aerial photography, along with digitized layers of stand and greenbelt boundaries, roads and streams, and GPSed silvicultural plot locations form a framework to which data from diverse research areas can be linked. Researchers can not only share information resources, but can graphically visualize and query both spatial and attribute data to reflect forest ecosystem changes under various management strategies. The methodology used to develop and configure this large, relational database into an easily accessible form usable in an interactive GIS program could be transferable to other areas of natural resource management.

Introduction

Ecosystem Management Research Project.--Changing attitudes toward national forests have increased demands to manage forests in a socially acceptable and ecologically sustainable manner. In response, research was initiated in the Ouachita and Ozark National Forests to investigate alternatives to clearcutting in pine and pine-hardwood stands (Mersmann et al., 1994). This research is based on the need and desire to manage national forest lands using silvicultural practices consistent with sustainable ecosystem management. The Ecosystem Management Research Program in the Ouachita and Ozark National Forests is composed of three phases. The first phase established demonstration stands that provided early evidence of the operational feasibility of selecting for various densities, compositions, and structures of pine/hardwood overstories. The second phase takes a statistical approach to study alternative silviculture treatments at the stand level and is the focus of the data support system described in this paper. The third phase is a large-scale landscape-level study designed to test the operational implementation of ecosystem management at the watershed level (Baker, 1994a).

Phase II, a replicated stand-level study, was installed in mature, shortleaf pine (*Pinus echinata* Mill.)-hardwood stands in the Ouachita and Ozark National Forests during the summer of 1993. A series of permanent and temporary sample plots was established to test and evaluate a range of partial cutting methods (seed-tree, shelterwood, single-tree and group selection) and vegetation management treatments (site preparation and release). The objectives of the study are to evaluate (1) the biologic and economic feasibility of using partial cutting methods and long-term retention of pine-hardwood overstories to establish and maintain mixed pine-hardwood stands that reflect indigenous vegetation and historical stand structure on south-facing slopes of the Ouachita Mountains and (2) the effects and trade-offs of the partial cutting methods on various commodity and non-commodity resources and values (Baker, 1994a). Thirteen treatments include both even-aged and uneven-aged reproduction cutting methods with longterm retention of various densities, compositions, and structures of overstory pines and hardwoods. Two controls, an unmanaged control and a clearcut control, are also included as part of the 13 treatments. Four levels of vegetation management are also being investigated. The effects of harvesting vegetation management treatments will be evaluated in terms of multiple resources and noncommodity values, including: plant and animal communities, arthropod and microbial communities, soils, water, cultural resources, scenic quality, recreational opportunities, and harvesting and management costs. Information from approximately 2,000 plots is being collected by more than fifty researchers during this five-year project with plans to continue data collection long term.

Data Support System.--A tremendous amount of data has been collected by Phase II researchers up to this point. At a 1993 symposium, researchers reported on pretreatment conditions and preliminary findings of the Ecosystem Management Research in the Ouachita Mountains (Baker, 1994b). Papers were narrowly focused on topics such as: herbaceous plant diversity, small mammal communities, breeding birds, arthropod biodiversity, water chemistry, scenic quality, and harvest management costs. Each research team has begun to accumulate a significant amount of information on the various components of the project. Because ecosystem management is a holistic, integrated approach to managing resources, decisions are based on complex interactions of biotic and abiotic factors across the landscape (Lachowski et al., 1994). In order for Phase II researchers to evaluate treatment effects on the ecosystem as a whole and understand their spatial relationships, they must have access to information collected by other teams for each specific location and treatment. All variables must be weighed and referenced to one another before a broader focus on the ecosystem can be achieved. This GIS database support system provides an easily accessible interface through which researchers can make ecosystem level evaluations.

Materials and Methods

Database Design.--The first step in developing a data support system for the Ouachita/Ozark National Forest Ecosystem Management Research effort was to determine common denominators which applied to the data of every research team. Research topics include silviculture, biodiversity, wildlife, water quality, soils, cultural resources, visual quality, recreation, arthropod and microbial communities, as well as logging and management economics. It was also necessary to determine what types of data were being collected and devise methods to store, view, integrate and evaluate many different data formats. Data formats included tabular records, tables, charts, analyses, color slides, color and black and white photographs, stand maps, and plot diagrams. Although each research team devised data collecting methods appropriate to its needs, all data could be tied to specific real world locations where treatments had been installed at stand, plot and subplot levels.

A conceptual design was developed to integrate both spatial and tabular data from 52 stands and more than two thousand plots. Because all data can be tied to specific treatment locations, Geographic Information System (GIS) software provides a logical means to integrate research efforts. Global Positioning Systems (GPS) data serve as a coordinate framework to bring the real world data into a computer world analysis. This spatial model has evolved into a data support system which allows integration of all phases of the research.

Developing a Spatial Reference System.--Determining a coordinate reference for each treatment location was the first step in the development of this data support system. Stands were located on USGS quadrangle maps based on hand-drawn stand maps provided by Ouachita/Ozark National Forest Service personnel. The roads and streams on the quad maps were digitized in the area of each stand using PC ARC/INFO* GIS. Digitizing is the process of manually capturing spatial data and recording x, y coordinates into map features. Quad maps were then scanned into tiff images. Maps were rectified and registered using the road and stream cover in Workstation ARC/INFO* GIS. Image rectification corrects distorted image data to create a more faithful representation. Image registration serves to transform the rows and columns of a scanned image into real world x, y coordinates. These processes use georeferencing information from the digitized cover to correctly register the scanned image in geographic space (Lillesand and Kiefer, 1994). The registered quad maps were then brought into ArcView* GIS, and UTM coordinates were determined for the center of each stand. Stand locations in northwestern Arkansas and eastern Oklahoma are shown in Fig. 1.

Using coordinates for the center of each stand to guide the pilot, fall color stereo aerial photography was obtained at a scale of 1:7,200. The center aerial photo for each stand was scanned into a tiff image, registered, and used as a base map for other stand data. Registration was accomplished by first converting the tiff images to ER Mapper* files using Image Alchemy*. Then Image Alchemy and customized programs were used to convert the registered raster quad map files to ER Mapper registered images. The quad maps were used to register and rectify the aerial photos as raster images using ER Mapper. This complex procedure was necessitated by the paucity of roads and streams in the area of many stands, making it impossible to register the aerial photographs using the vector road and stream coverages. In addition, GPS coordinates were collected and differentially corrected to assist with the rectification of photos and to pinpoint various wildlife and silviculture subplots. Differential correction is a process which corrects GPS error, some of which is intentional degradation of the satellite performance by the U.S. Department of Defense. It greatly increases accuracy and is accomplished by developing a correction factor for data from a receiver placed on a known control point and then using this factor to correct rover receiver data collected during the same time frame (Oderwald and Boucher, 1997).

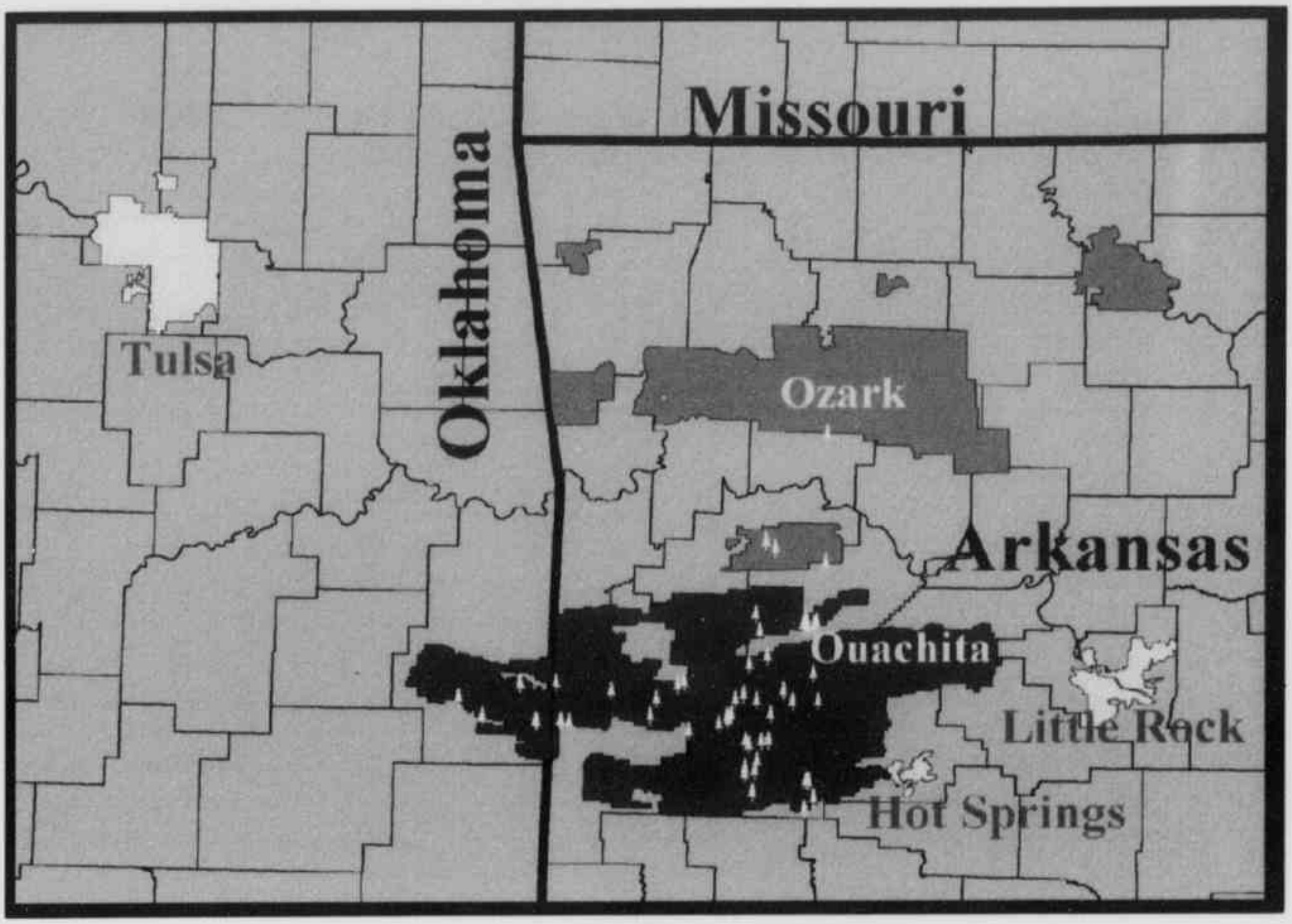

Fig. 1. Location of 52 Phase II stands in northwestern Arkansas and eastern Oklahoma.

Using the scanned and registered center aerial photo as a base layer for each stand, stand boundaries and greenbelts were delineated using "heads-up" digitizing in workstation ArcInfo. "Heads-up" is a digitizing method that captures spatial data by tracing over an image on the computer monitor. The stereo photography was utilized to insure the accuracy of boundary lines. Stand and greenbelt areas were calculated in acres and hectares using ArcView and then saved as attributes of each stand. GPSed silvicultural plot locations where imported into ArcView and overlayed on the aerial photo along with stand and greenbelt boundaries for each of the 52 Phase II stands (Fig. 2).

Developing a GIS Database.--Data submission, metadata, and data correction forms were designed and distributed to all researchers involved in the project. Compartment and stand numbers were selected to serve as primary database keys in the relational database model and link records to a central treatment database which contains coordinate information for each stand. Data distribution policies and procedures were established.

Because of the diversity of data types, from digital records to visual images, it was necessary to choose a software package that could easily display a wide range of data sources. ArcView GIS serves this purpose. Many types of data can be integrated and manipulated as various themes and projects. The ArcView interface can also be modified using Avenue* scripts so that researchers who have little experience with GIS software can easily interact with many layers of data. Avenue is an ArcView companion package that provides a programming language for customization and development of the ArcView interface. DBASE* was chosen as the relational database package because of its compatibility with ArcView and with most of the database and spreadsheet formats in which data are submitted.

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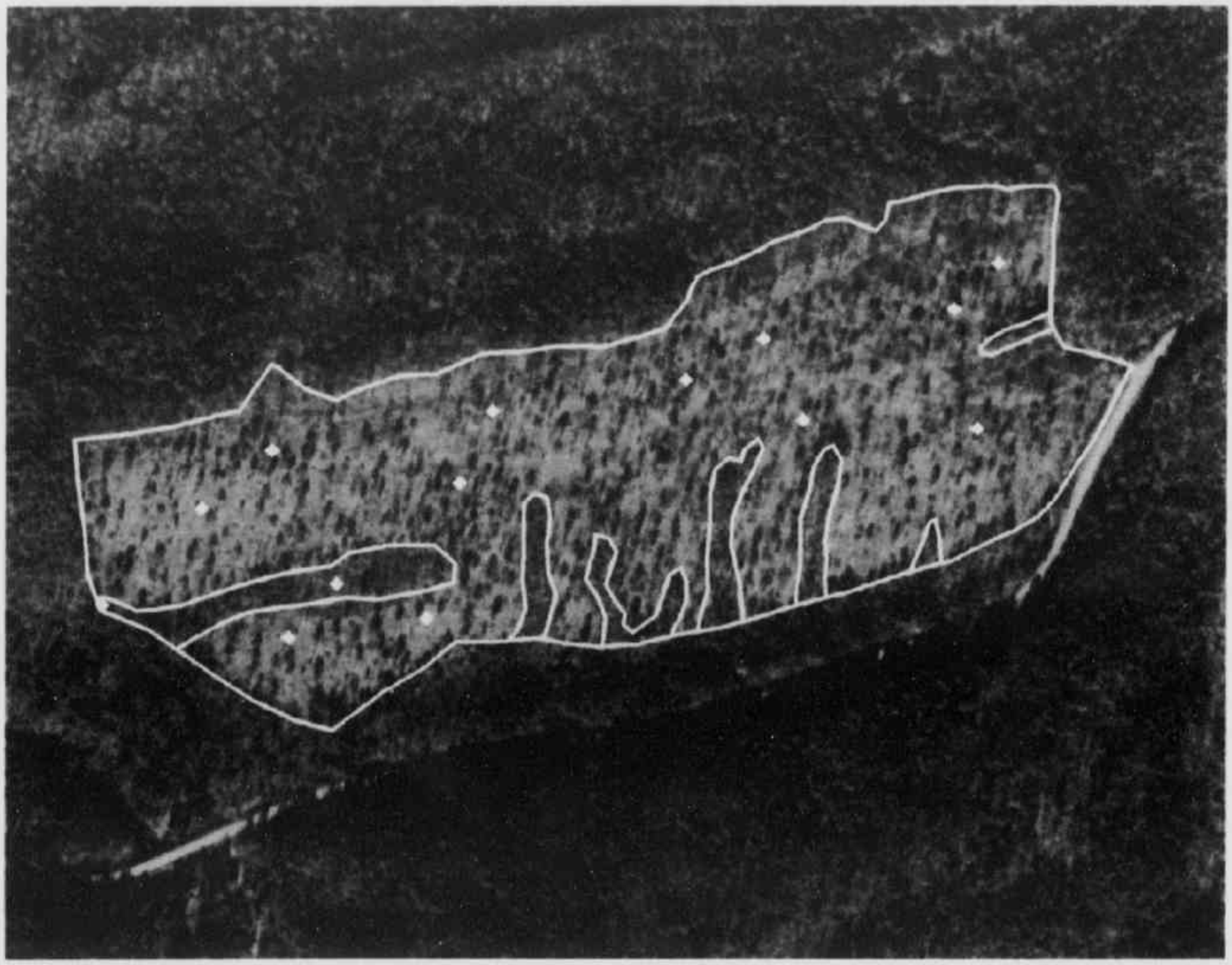

Fig. 2. Registered aerial photo of Stand 1036-17, pine/hardwood seed tree treatment, on the Oden Ranger District in the Ouachita National Forest, Yell County, Arkansas, with overlaying stand and greenbelt boundaries, and silvicultural plot locations.

Digital records from each research team member were brought into dBASE as separate files and linked by treatment, compartment, and stand number. Color slides, black and white photographs, and plot diagrams were converted to tiff images and "hot-linked" to the appropriate stands and/or plots using ArcView. Links between images and related theme features can be created so that clicking on a feature will display the linked image in a separate window. Stand maps and aerial photos were imported as image data and displayed as themes in ArcView projects. Tables, charts and analyses were also linked to stand data in ArcView. The linkage of spatial and attribute data in a GIS allows researchers to display, manipulate, query and analyze any data that can be referenced to a specific location.

Avenue scripts will be written to modify the ArcView interface for easier manipulation of research topics within the study. Icons will be incorporated into the Arc View button bar which correspond to specific data sets, such as wildlife, silviculture, visual quality, management economics, etc.

Data have been organized in an easily accessible manner. Both images and tabular data are stored on optical CD-ROM disks in a format that is accessible to many computer platforms. Aerial photographs and printed ArcView layouts of stand and quad maps have been organized in notebooks for quick reference during the development of the project. Data and documentation submitted by researchers are arranged in a separate notebook.

A data dictionary accompanied the development of the database. The dictionary contains brief descriptions of projects and themes developed in ArcView and item definitions and coding descriptions for each variable represented in a theme. It also includes detailed variable definitions supplied by the researcher for each data file submitted.

Developing Researcher Access.--Several data access options are proposed. Access approval procedures were formulated by team members. Access on site in the Spatial Analysis Laboratory (SAL) in the School of Forest Resources will be the most direct route. Electronic access may be obtained over a high-speed modem or an internet connection to the World Wide Web (WWW). With an internet connection and any web browser that supports Java, remote PC clients will be able to access a PC in the SAL on which ArcView Internet Map Server is installed. This software is an extension to ArcView 3.0 and allows thousands of gigabytes of geographic information to be deployed and accessed via the Internet.

Discussion

Initiation of this data support system involved the development of a conceptual design which allows all research areas of the Phase II Ecosystem Management Project to be integrated into a spatial model. Remote sensing provided a base layer of photographs to which individual observations, statistics, tables, graphics, photographs, maps, etc. are linked based on common spatial coordinates. GIS provides access to all information layers and facilitates the evaluation of complex interactions using spatial statistics. When this database support system is fully developed, researchers will be able to investigate relationships between their data and that of others by overlaying themes and preforming spatial analysis procedures. Only by combining what we know about ecosystem components and ecosystem processes can we arrive at a more complete understanding of how ecosystems work and how they respond to disturbance (Larsen et al., 1997).

An ArcView/Avenue interface is being developed to allow easy access to the various components of each database topic. Electronic access will provide support and integration of all research activities. Researchers can not only share information resources, but can graphically visualize many facets of the forest ecosystem and its changes under various management strategies by investigating the spatial interrelationships. Researchers can also produce map products that clearly illustrate the effects and trade-offs of partial cutting methods on various commodity and noncommodity resources and values. The methodology used to develop and configure this very large, relational database into an easily accessible form usable in an interactive GIS environment should be transferable to many other areas of natural resource management.

* Use of registered trade names is solely for the reader's information and does not imply endorsement of the product.

Literature Cited

Baker, J.B. 1994a. An overview of Stand-Level Ecosystem Management Research in the Ouachita/Ozark National Forests. IN: Baker, J. comp. Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings. October 26-27, 1993; Hot Springs, AR. Gen. Tech. Rep. SO-112. New Orleans, LA: USDA, Forest Service, Southern Forest Experiment Station. p. 18-28.

Baker, J.B. comp. 1994b. Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings. October 26-27, 1993; Hot Springs, AR. Gen. Tech. Rep. SO-112. New Orleans, LA: US Dept. of Agriculture, Forest Service, Southern Forest Experiment Station. 259 pp.

Oderwald, R.G. and **B.A. Boucher.** 1997. Where in the world and what? An introduction to global positioning systems. Kendall/Hunt Publishing Co., Dubuque, Iowa. 64 pp.

Lachowski, H.M., T. Wirth, P. Maus and **P. Avers.** 1994. Remote sensing and GIS: their role in ecosystem management. J. Forestry 92(8): 39-40.

Larsen, D.D., R. Shifley, F.R. Thompson III, B.L. Brookshire, D.D. Dey, E.W. Kurzejeski and **K .England.** 1997. 10 guidelines for ecosystem researchers: lessons from Missouri. J. Forestry 95(4): 4-9.

Lillesand, T.M. and **R.W. Kiefer.** 1994. Remote sensing and image interpretation. John Wiley and Sons, Inc., New York. 750 pp.

Mersmann, T.J., J.B. Baker, J.M. Guldin and **W.F. Pell.** 1994. Implementing Ecosystem Management Research: Bringing Researchers, Managers, and Citizens Together. IN: Baker, J. comp. Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings. October 26-27, 1993; Hot Springs, AR. Gen. Tech. Rep. SO-112. New Orleans, LA: USDA, Forest Service, Southern Forest Experiment Station. p. 10-17.

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