Remote Sensing Applied to Resource Management[1]

Henry M. Lachowski[2]

Abstract

Effective management of forest resources requires access to current and consistent geospatial information that can be shared by resource managers and the public. Geospatial information describing our land and natural resources comes from many sources and is most effective when stored in a geospatial database and used in a geographic information system (GIS). The information on the location and condition of current vegetation is one of the key elements in resource management. Remote sensing data, such as aerial photographs, satellite imagery, aerial video, and data collected by other remote devices, are primary sources for mapping vegetation. Comparison of images acquired several days or several years apart can assist in determining changes that occurred in that time period. The Forest Service, U.S. Department of Agriculture, has been using various remote sensing and associated technologies to map vegetation and monitor changes. Current needs include an increased training and awareness in use of this technology, as well as development of new applications, standards, and guidelines.

Introduction

Geospatial information about land and natural resources is essential to effective management of natural resources. Data from various remote sensing instruments make a substantial contribution to the geospatial information needed in the USDA Forest Service (FS). Remote sensing is a source of current and repeatable information on the location, quantity, and quality of land cover and other resource information, particularly vegetation. It allows change detection and monitoring of land cover and vegetation over time. Data from various remote sensing tools form an important source for various geographic information system (GIS) databases and subsequent analysis. Many types of data are already in digital form, and others can be digitized. Satellite imagery covers large areas and has the locational precision and spatial resolution to satisfy many natural resources mapping requirements. For many applications satellite imagery needs to be used in conjunction with a closer view provided by aerial photographs and airborne video images. The global positioning system (GPS) used in conjunction with satellite imagery helps managers determine changes in land cover over time.

This paper examines the ability to integrate remote sensing imagery in a GIS combined with ancillary data, including cartographic feature files (CFFs), digital elevation models (DEMs), digital orthophotoquads (DOQs), and other resource data layers to provide a solid geospatial data foundation for support of Forest Service management of natural resources.

Data Collection Through Remote Sensing

The USDA Forest Service uses data from a variety of remote sensing instruments, such as the advanced very high resolution radiometer (AVHRR), which uses data obtained through the U.S. Geological Survey (USGS) EROS Data Center (EDC), from the U.S. Department of Commerce, and from the National Oceanic and Atmospheric Administration (NOAA) weather satellites. It has relatively course spatial resolution of 1.1 by 1.1 km pixel size with five spectral bands. Broad area

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[2] Program Leader, Integration of Remote Sensing, Engineering Staff, USDA Forest Service, 2222 West 2300 South, Salt Lake City, UT 84119.

coverage is obtained with a swath width of 2,700 kilometers. Temporal resolution is excellent with repeat coverage over a given geographic area every 12 hours. Major applications for this data include: vegetation discrimination, vegetation biomass, snow/ice discrimination, vegetation/crop stress, and geothermal mapping. This imagery is currently used by the Forest Service in association with the USGS on development of a global vegetation data set and with the United Nations on verification for a global vegetation characterization data base.

Another remote sensing instrument is the Landsat Multispectral Scanner (MSS). MSS imagery has a spatial resolution of 80 m, spectral resolution in 4 bands, revisits the same geographic location every 16 days, and covers an area of 185 by 170 km per scene. The Landsat program gathered digital MSS data from 1972 through 1992. The result is a 20-year time span of data that can support evaluations of change in landscapes or land cover over a longer time period than any available earth observation system. MSS data is available through the EDC working in cooperation with the National Aeronautics and Space Administration (NASA) Landsat Pathfinder Program. Pathfinder efforts are focused on evaluation of global change by using available remote sensing technologies. The North American Landscape Characterization (NALC) Project, a component of the Landsat Pathfinder Program, is developing an archive of MSS data and production of three-date georeferenced data sets, called triplicates, acquired in 1970's, 1980's and early 1990's. The NALC images are geometrically rectified, georeferenced, and placed into a UTM map projection. Pixels are resampled into a 60 by 60 m size format for compatibility with the 30 by 30 m Landsat Thematic Mapper (TM) data resolution.

TM imagery has 30 m spatial resolution with seven spectral bands. The satellite covers the same geographic location every 16 days, each scene covering 185 by 170 km. The Landsat Program is the longest running program in the collection of multispectral, digital data of the earth's land surface from space. The temporal extent of the collection, the characteristics and quality of Landsat data, and the ability to collect new data directly comparable to that in the archive, make Landsat data a unique resource to address a broad range of issues in ecosystem management. An interagency consortium called the Multi-Resolution Land Characteristics Monitoring System (MRLC) has been established to purchase TM imagery to cover the United States (not including Alaska). This group has selected the appropriate scenes and developed image processing, georeferencing, terrain correction, clustering and classification strategies. This Federal consortium includes U.S. Environmental Protection Agency, EMAP; U.S. Fish and Wildlife Service, GAP Program; USGS EDC and National Water Quality Assessment Program; and NOAA Coast Watch Change Analysis Program. High resolution airborne video and digital cameras provide a powerful tool for ecosystem management. A camera can be mounted in a small airplane and imagery can be viewed as soon as the flight is complete (Bobbe 1995). Video imagery linked with GPS provided location information for each frame, allowing users to quickly locate specific areas on maps or images. Video images can be digitized and used with other GIS layers.

Use and Access to Remote Sensing Data

Applications of the various remote sensing sources vary widely among resource management agencies, depending on their specific requirements. Users of digital imagery range from novices, who simply use imagery as a backdrop for overlaying GIS information, to expert users, who do classification of landscapes for input into large area assessments or forest planning efforts. Thus, a wide range of user needs must be met in the form of technology transfer and training to fullfil the Forest Service's mission. Access to remote sensing data should rapidly increase for several reasons, among them, new cooperative agreements among agencies to share data acquisition costs, and improved information access on the information super highway. Currently, many potential users of remote sensing are either not aware of how to access the data or believe that the cost of acquiring the data is prohibitively high. Improved access to the data, both physically and financially, will likely increase the number of users.

New data procurements, such as the one recently made by the Forest Service, will provide AVHRR, Landsat Multispectral Scanner triplicates, and Landsat TM imagery, for all lands in the continental U.S. This low cost purchase will provide imagery except for Alaska at very low cost to the entire Forest Service at three different scales. Purchases such as these provide inexpensive and easy access to data and will surely spur interest in using digital imagery for applications such as Resources Planning Act (RPA) assessments and forest planning. Access to the internet now gives users the capability to preview satellite imagery acquired from several platforms including Landsat. This will allow users to assess the condition of the imagery (e.g., cloud cover) and will ensure that the user is confident in the quality of the imagery before purchasing. Because internet access will also provide an easy method for ordering and transferring digital imagery, the process of data acquisition that was recently time-consuming and inefficient at best will be streamlined. Several new satellite sensors are being developed and are scheduled to be launched within the next decade. Once these plans come to fruition, users of remote sensing data will have several new options. These sensors will allow for different perspectives of the landscape because of the differences in spectral, spatial, and temporal resolutions of the imagery they will provide.

Applications of Remote Sensing

With new GIS hardware and software available to the Forest Service, and existing GIS and image processing capabilities, the use of digital imagery for effective resource management will continue to increase. Virtually everyone in the Forest Service will have the capability to view and manipulate imagery in some way. The Forest Service's use of remote sensing has been shaped not only by technological advances, but by the changing needs for information (Lachowski 1995). Increasingly, the synoptic view that is offered by remote sensing has become more important as issues such as endangered species and cumulative effects have shaped management activities on Forest Service lands. The need for information on the type and condition of the vegetation is almost always critical to these issues and remote sensing plays an important role in collecting this information.

Mapping Vegetation and Land Cover Characteristics

The Forest Service has a wealth of experience with using digital imagery for projects ranging in scales from RPA assessments to forest and project plans. Perhaps the most common use of digital imagery in the agency is for mapping vegetation and land cover characteristics. For example, digital imagery from Landsat Thematic Mapper has been used to map vegetation and model old-growth forests in California (Warbington 1993), Washington, and Oregon (Congalton 1993, Tepley 1993). These successful, region-wide projects are examples of how satellite imagery can be useful at the forest level for mapping vegetation and land cover. In addition, numerous individual forests in every region have used digital satellite imagery to map vegetation characteristics (Evans 1992, Gonzales 1992). Applications of this information serve a variety of purposes ranging from multi-region and multi-agency planning (Columbia River Basin Assessment) to forest planning efforts (Warbington 1993), and project level applications such as wild and scenic river planning (Linderman 1995) and range allotment mapping and analysis (Martinez 1994). On a broad scale, the Forest Service has used digital satellite imagery, such as AVHRR data from NOAA weather satellites, to map forest land for the entire U.S. and Mexico. These maps are used for RPA assessments and are useful as a baseline analysis for forests at the national level. Currently, other studies are planned to assess the feasibility of linking this information with forest inventory and analysis (FIA) inventories.

Change Detection

In addition to mapping vegetation and land cover, Forest Service managers have recognized the usefulness of multi-date digital imagery in performing change detection for mapping insect and disease outbreaks as well as for updating management activities and forest plan monitoring (Maus 1992). Because each National Forest is mandated by law to monitor the effects of their management over time, the ability to perform change detection is potentially the most effective use of digital imagery from remote sensing. Performing change detection may also be the most underutilized application of digital imagery. This is particularly true as the span of digital imagery available for an area becomes ever wider and the costs of older data continue to plummet. Using digital imagery for performing change detection offers many advantages over traditional methods. The traditional approach for mapping change was to compare two maps, each interpreted independently. Often, false changes would result because of differences in classification schemes or mapping techniques. With advances in geocoding of digital imagery, image-to-image comparisons can be made where spectral values between two or more dates of imagery can be compared. These techniques can help eliminate problems associated with traditional map comparison methods. As awareness of these simple techniques for performing change detection increases and more resource managers have access to the necessary computer hardware and software, the demand for such analysis will certainly increase.

Ecological Unit Mapping

Current direction of the Forest Service requires that an ecological approach to resource management be used. To ensure ecosystem management is applied over various scales of landscapes, the National Hierarchy of Ecological Units was developed (Avers 1993). Within the National Hierarchy, various scales of units are being mapped and used for planning efforts at large scale (multi-region), medium scale (multi-forest), and small scale (multi-district). The boundaries of these units will be based on ecological influences, social/political considerations, and multi-agency needs. Currently, remote sensing is playing a major role in the delineation of these boundaries at all levels. Digital imagery from satellites is being heavily used for the smaller scale units (e.g., ecoregion, sections, and subsections). The larger scale units (e.g., land type associations, and landtype phases) are being mapped using combinations of aerial photographs and satellite imagery (Fallon 1994). Once ecological units are mapped, their characteristics can be monitored over time by using remote sensing techniques. Additional information can be added to ecological units for project level analysis that can also be derived from remote sensing.

Disaster Assessment, Forest Pest Management, and Other Areas

Recent fires in large ecosystems such as the Greater Yellowstone Area and the Payette National Forest have been mapped by using digital imagery from satellites. Other landmark disasters, such as the Mount St. Helens eruption and the Mississippi River flooding, have also been mapped from satellite imagery. Although the use of satellite imagery for such events is somewhat rare, it is often the only type of current information available or accessible. Satellite imagery will continue to fulfill a role in these assessments and will likely increase as access to and interest in digital imagery increases.

Current Needs

Training and Awareness on How to Use the Data

New users of remote sensing imagery will need to know opportunities and pitfalls of using the new technology. They will need to know when it is appropriate to use a particular type of imagery and when it may not be. With personnel reductions, fewer employees are likely to have graduated from recent university remote sensing programs; thus, more will need to be trained. Using remote sensing imagery will likely be a skill they acquire to compliment a wide range of other job responsibilities they will have. New and experienced users will need technical instruction in how to best use digital imagery for different scales of projects ranging from simple applications, such as using imagery as a backdrop for updating GIS layers to more complex applications like automated image analysis for vegetation mapping and change detection. Users of digital imagery will need to share ideas and techniques for using new types of digital imagery. This transfer of information among users will need to take place between all levels of the Forest Service, including Ranger Districts, National Forests, regions, research stations, and State and Private Forestry.

New Sensor Applications Testing and Guidelines

As new types of imagery become available they will need to be assessed for cost effectiveness as well as application suitability. Some new sensors will have hyperspectral bands with very narrow wavelengths. Others will have higher spatial resolution than current satellite sensors. Still others will acquire imagery at different times of the day such as early morning. However, increased access to remote sensing information may also increase potential for abuse of the technology. As applications are developed for new types of imagery, guidelines for using the imagery will need to be developed to inform prospective users of pitfalls and potentials. Pilot projects will need to be carried out to evaluate imagery for meeting various user requirements.

Data Standards and Methods

The Forest Service will need to provide standards and guidelines in the collection, design, use, and storage of remote sensing related data. These types of standards will allow for information sharing between districts, forests, and regions. Information sharing across administrative boundaries will be critical to the success of ecosystem management practices. Standardized naming conventions, file structures, and methodologies will promote information sharing and development of corporate database structures in the FS. These processes will simplify the use of geospatial data, including data acquired through remote sensing and make the application of these data sources to resource management easier and more efficient.

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