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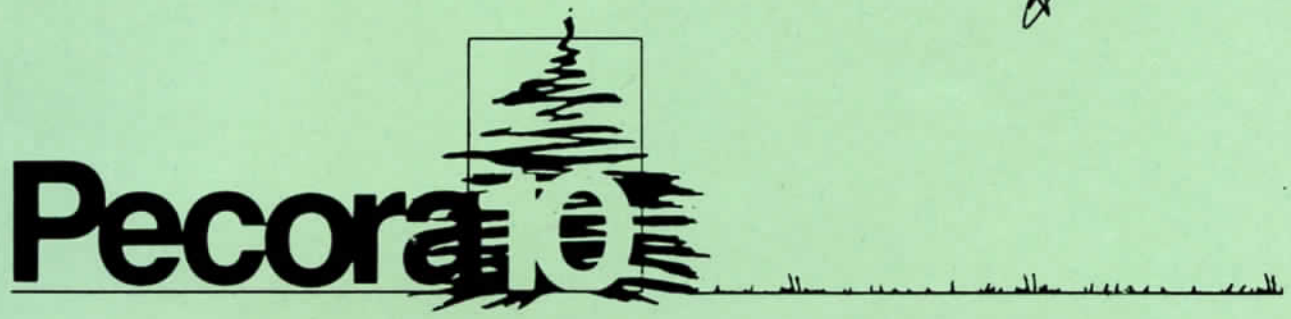


# Remote Sensing in Forest and Range Resource Management

# ABSTRACTS

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1. Evolution of Remote Sensing in Range Management, Speculations on its Future, by C. E. Poulton, Consultant, Natural Resources Assessment and Management.

2. Status of Remote Sensing in Forestry, by R. C. Heller, Professor Emeritus, University of Idaho.

3. New Horizons in Remote Sensing for Forest and Range Resource Management, by D. T. Lauer, U.S. Geological Survey.

# EVOLUTION OF REMOTE SENSING IN RANGE MANAGEMENT, SPECULATIONS ON ITS FUTURE

By Charles E. Poulton

## ABSTRACT

The author has been privileged to work on range resource analysis from the days when the examiner prepared his own map while walking the landscape through the development and application of space-age technology to rangeland assessment. From this background the development of remote sensing as a tool in rangeland resources assessment and monitoring is summarized. Revealing examples of old and new range survey maps and data are presented and interpreted. The levels of application of remote sensing technology by agencies and companies responsible for rangeland resources management in the United States is evaluated. Case studies that exemplify these applications are presented. Three examples of applications in the developing nations are summarized. Throughout the presentation, emphasis is on remote sensing, not on the ground evaluation methods for range assessment. Treatment of the latter is limited essentially to requirements for verification of the results of image analysis and interpretation. The potential of remote sensing as a tool in ecological assessment and monitoring of rangeland resources is evaluated from the author's experience. Some suggestions are made about requirements and opportunities for its expanded and successful use in future years.

# STATUS OF REMOTE SENSING IN FORESTRY

By R. C. Heller

## ABSTRACT

Foresters used remote sensing before the term "remote sensing" existed. For years, aerial surveys were conducted by aerial observation supplemented with oblique photography. Early on, foresters saw the advantage of vertical aerial photography for forest land assessment. Today, photo interpretation of color, color infrared and black and white aerial photographs remains the principal source of information for management foresters worldwide. Innovations used by forest damage assessment specialists include large scale, small scale and panoramic photography.

Satellite data has been slow in gaining acceptance by foresters working both on public and private forest lands. However, one promising development by private industry is the incorporation of Landsat reflectance data into a geographic information system(GIS). Thematic mapper data shows great promise for forest applications, but its adaption is slowed by high cost and slow acquisition of data.

Except in tropical forests where cloud cover is a constant problem, imaging radar is not being used by foresters for management purposes.

Except for some developmental work for identification of buried gravel deposits, the primary use of airborne thermal scanners is as a night-time mapping device of large forest fires.

# NEW HORIZONS IN REMOTE SENSING FOR FOREST AND RANGE RESOURCE MANAGEMENT

By Donald T. Lauer

## ABSTRACT

Forest and range resource scientists were among the first to recognize the potential of aircraft and satellite remote sensing for management of timber, forage, water, and wildlife resources. Today, data from a variety of sensor systems are being put to practical use for inventorying, evaluating, monitoring, and assessing forest and range resources. In the future, improved sensor systems providing new kinds of data will be available. Likewise, new types of data handling and processing systems can be anticipated.

Among the new or anticipated aircraft and satellite systems are the U.S. Geological Survey (USGS) acquired Side-Looking Airborne Radar (SLAR), the Landsat thematic mapper (TM), the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR), the French Systéme Probatoire d'Observation de la Terre (SPOT), the German Shuttle Pallet Satellite (SPAS)-Modular Optoelectronic Multispectral Scanner (MOMS), the European Space Agency (ESA) Spacelab Metric Camera and Earth Resources Satellite (ERS-1), the National Aeronautics and Space Administration (NASA) Large Format Camera (LFC) and Shuttle Imaging Radar (SIR-A, -B, and -C), the Russian Meteor satellite BIK-E and "Fragment" experiments and MKF-6M and KATE-140 camera systems, the Japanese Marine Observation Satellite (MOS-1) and Earth Resources Satellite (JERS-1), the Canadian Radarsat, the Indian Resources Satellite (IRS), and systems proposed or planned by China, Brazil, Indonesia, and others.

Improved data handling and processing systems will evolve to complement future sensor system development. As data from new systems provide increased spatial resolution and additional spectral bands, improvements must be made in the speed and efficiency of computer processing systems--as being demonstrated by the massively parallel processor currently under development at NASA's Goddard Space Flight Center. However, forest and range resource managers are often located at remote field offices and must work with a wide variety of spatially referenced data. They will seek stand-alone data processing and analysis systems that can handle both image (raster) and cartographic (vector) data, that use off-the-shelf hardware components and transportable and expandable software, and that are relatively low in cost.

Application examples show uses of 1-kilometer-resolution AVHRR data for separating broad vegetation classes at the regional level, 80-meter multispectral scanner (MSS) data for vegetation-type classification at a generalized level for planning purposes, 30-meter TM data for mapping and assessing resources at the range allotment or management unit level, and 10-meter SPOT-simulator data for mapping at the suballotment level.

## SESSION 1: INTEGRATED RESOURCE INVENTORY

MODERATOR: M. GOLDBLATT

1. The Potential Impact of Thematic Mapper, SPOT and Microprocessor Technology on Forest Type Mapping Under Lake States Conditions, by T. M. Lillesand, P. F. Hopkins, M. P. Buchheim, and A. L. Maclean, University of Wisconsin-Madison.

2. An Operational Interagency GIS: The Glacier National Park/Flathead National Forest Project, by D. B. Wherry, J. A. Hart, Washington State University. C. H. Key, Glacier National Park. S. A. Bain, Flathead National Forest.

3. Leaf-Off, Remotely-Sensed Data as a Source of Forest Resource Information, by W. D. Hudson and D. P. Lusch, Michigan State University.

4. The Evaluation of Thematic Mapper Data for Range Management Applications in Western Canada, by K. P. B. Thomson, Canada Centre for Remote Sensing. C. Gosselin, Intera Technologies Ltd. B. W. Adams, Alberta Energy and Natural Resources. I. Sutherland, Alberta Remote Sensing Center.

5. Multispectral Video Applications in Natural Resource Inventories, by D. E. Meisner, University of Minnesota.

# THE POTENTIAL IMPACT OF THEMATIC MAPPER, SPOT AND MICROPROCESSOR TECHNOLOGY ON FOREST TYPE MAPPING UNDER LAKE STATES CONDITIONS

by

Dr. Thomas M. Lillesand
Paul F. Hopkins
Martin P. Buchheim
Ann L. Maclean

## ABSTRACT

The relative coarse spatial, spectral and radiometric resolution of the Landsat Multispectral Scanner (MSS) has severely limited the practical application of MSS data to forest type mapping and condition assessment under Lake States' conditions. At the same time, forest managers at all levels continue to face the reality of having to "do more with less" in terms of the information collection processes which support their management activities. Accordingly, many of these managers are currently interested in determining how Thematic Mapper (TM) technology might contribute to their data needs in the present, and what level of information SPOT technology will likely afford them in the future.

Based on the analysis of actual TM data on the one hand, and simulated SPOT data on the other, this paper attempts to set forth what can (and cannot) be done with these respective sensing technologies in terms of type mapping under Lake States' conditions. Study sites in northern and east-central Wisconsin have been used to evaluate the accuracy and specificity with which forest types can be discriminated using each type of data. The sites were chosen to represent the diverse mix of cover types typical of the region and extensive reference data were collected to verify all image classification results. This paper discusses the comparative results obtained using each data source, and employing both visual image interpretation and "automated" classification procedures.

The paper concludes with discussion of the use of TM and SPOT data for base mapping and revision, and the potential impact microprocessing technology will have on analyzing TM and SPOT data at local levels of forest management. Briefly described is the Wisconsin image-based experimental mapping program and the design of IBM XT and AT clusters being tested to support image processing and geographic data handling functions.

# AN OPERATIONAL INTERAGENCY GIS: THE GLACIER NATIONAL PARK/FLATHEAD NATIONAL FOREST PROJECT

By David B. Wherry, Judy A. Hart, Carl H. Key, and Stan A. Bain

## ABSTRACT

Interagency agreement between Glacier National Park (GNP) and Flathead National Forest (FNF) has allowed these neighboring federal agencies in Montana to share the costs and benefits of a regional, Landsat-based, Geographic Information System (GIS) project. Benefits of the interagency approach have included cost sharing of personnel and materials, agglomerated project resources, increased Park-Forest dialog, a superior Landsat classification and covertype legend, and more widely dispersed exposure for a successful GIS program.

Landsat 3 categorized landcover imagery and digital terrain elevation, slope, and aspect data were prepared for pilot project areas by Park and Forest personnel in a 1983-84 cooperative database effort. With distinct administrative mandates, ancillary data planes addressing agency mapping requirements for management, inventory, and research were constructed independently by Park and Forest project teams. The pilot GIS database (17 data layers) was tested for FNF's Hungry Horse Ranger District. Information supporting forest resource inventory and management practices was modeled and extracted from the database. Similar inventory and research modeling tasks were tested in GNP. When evaluated by Park and Forest managers, speed and accuracy of GIS processing and product generation met all acceptability criteria.

Establishing in-house GIS expertise and maintaining in-agency project management were identified as vital success factors in creating an operational GNP/FNF GIS program. Park and Forest personnel were educated in GIS techniques and system use through the Digital Image Analysis Laboratory (DIAL) training programs at Washington State University Computing Service Center (WSUCSC). GIS processing is being accomplished with WSUCSC's VICAR/IBIS image processing system at the DIAL facility. GNP and FNF project teams access computing resources through a WSUCSC telecommunications network. By contracting for computing services at WSUCSC, GNP and FNF gained freedom from many of the personnel support costs associated with image processing/GIS hardware and software acquisition, installation, and maintenance, while gaining training, supported hardware/software access, project assistence and consulting, and an immediate start-up time after project approval. GIS databases are now being constructed for all six FNF ranger districts (25-70 data planes each) and GNP in its entirety (16-17 data layers). Continuous support of GNP/FNF GIS development by DIAL staff in early stages of the pilot project has been reduced to infrequent telephone consulting contact as Park and Forest personnel gain experience. Self sufficiency of GIS project teams is expected by the end of the database construction and testing phase in 1986-87.

# LEAF-OFF, REMOTELY-SENSED DATA AS A SOURCE OF FOREST RESOURCE INFORMATION

By William D. Hudson and David P. Lusch

ABSTRACT

Forest resource data sources have traditionally relied, almost exclusively, upon aerial photography and other remotely-sensed data acquired during the growing season. The use of leaf-on aerial photography is a logical choice whenever differences amoung hardwood species are required. The availability of leaf-off, high-altitude, color infrared (CIR) aerial photography, as well as multi-temporal Landsat data for most of the country make these two important additional sources of forest resource information. Recent investigations at MSU have demonstrated the utility of these leaf-off, remotely-sensed data.

The use of leaf-off aerial photography for compiling topographic maps, identifying landforms and delineating soil boundaries is well developed. Lesser attention has been paid to the characteristics of vegetation which are obtainable during leafless conditions. The examples cited illustrate the unique capabilities of leaf-off CIR aerial photography to provide information on coniferous understories, hardwood-conifer mixtures, and certain broad hardwood associations.

The acquisition of multi-spectral, multi-temporal (including leaf-off) data from the Landsat series of satellites has provided a voluminous source of potential forest resource data. Like aerial photography, many forestry applications have relied on analyses of Landsat scenes acquired during the growing season. Several successful applications of Landsat data are discussed to indicate the potential for using leaf-off satellite data. A study to evaluate the accuracy and costs of mapping small-area forest lands compared two image dates; mapping accuracy was highest using a winter false-color composite compared to a fall scene. Utilizing a computer-enhanced, false-color composite acquired in the spring (April), coniferous forest types were visually interpreted with overall classification accuracies ranging from 73 to 85 percent. Digital classification of a winter, snow-covered scene utilized a spectral response curve model to efficiently identify individual species, with mapping accuracies of 66 to 81 percent, and provided a measure of stocking as well.

# THE EVALUATION OF THEMATIC MAPPER DATA FOR RANGE MANAGEMENT APPLICATIONS IN WESTERN CANADA

By K.P.B. Thomson, C. Gosselin, B. W. Adams, and I. Sutherland

## ABSTRACT

A project to evaluate Thematic Mapper data for range management applications was started by the Canada Centre for Remote Sensing (CCRS) in 1984. The experiment is a joint effort between CCRS and the Alberta Department of Energy and Natural Resources and the Alberta Remote Sensing Center.

Ground and satellite data were collected in a rough fescue prairie area in Alberta at four dates during the grazing season. Ground data included the percentage of green and brown vegetation and bare soil and the weight of grass, litter and forbes at selected range sites. A set of photographs was also taken at each site during the date of the passage of LANDSAT 5.

The Thematic Mapper data for each date were subjected to a sun angle correction and a set of digitally stretched images were made for various band combinations.

Correlation between the Thematic Mapper spectral data and ground parameters show the variation in the spectral data as a function of time for selected sites. The reflectance in TM 5 and TM 7 increases as the amount of litter increases. TM 4, the near infrared band, shows a corresponding decrease as the brown biomass increases.

Digitally stretched images of TM 2, TM 3, TM 4 and TM 3, TM 4, TM 7 (or TM 5) band combinations also show clear differences between low litter early green sites and high litter late green sites.

The paper also compares the standard LANDSAT (MSS) Rangeland Enhancements and Thematic Mapper image enhancements for mixed grass prairie areas. These standard MSS enhancements were previously developed by CCRS and are now used operationally by Canadian range management agencies. The information on range use, derived from the spectral data, in the mixed grass prairie appears to be similar for both the TM and MSS enhancements. However, the high spatial resolution of Thematic Mapper provides the range manager with more detailed and precise information on legal boundaries, water sources, well sites and saline areas.

# MULTISPECTRAL VIDEO APPLICATIONS IN NATURAL RESOURCE INVENTORIES

By Douglas E. Meisner

## ABSTRACT

Airborne video offers numerous advantages to the remote sensing user: instant turnaround provides timely data; the availability of a live image during acquisition simplifies the operation; and the low media cost ($10 for two hours of data) allows large areas to be covered inexpensively.

Video also has the advantage of relatively low resolution. This limitation requires reliance on spectral patterns during interpretation, rather than on spatial patterns such as shape and texture. To that end, interpretability is enhanced by the use of multispectral imagery.

This paper will describe the use of the Biovision camera, a three channel multispectral camera imaging in green, red, and near infrared channels. The three images are electronically encoded to generate a color infrared image. A standard NTSC color composite signal is provided, making the unit compatible with off the shelf video recorders and monitors.

Several applications of the system in resource inventory will be discussed. Video tape examples of some of these will be displayed.

In addition, several alternatives for interpretation of the data will be described. These include a color video digitizer board capable of transferring the data to an ERDAS-PC image analysis/geographic information system; standalone use of the PC/digitizer board; manual interpretation using the still-frame function of a standard video cassette recorder or a digital frame store unit; transfer of manually interpreted data to a map base using a Bausch and Lomb Zoom Transfer Scope; and available options for obtaining low cost hard copy for field use.

## SESSION 2: LAND USE/LAND COVER MAPPING

MODERATOR: W. MILLER

1. Interim Program for Land Cover Mapping in Alaska Utilizing Landsat Digital Data, by M. Shasby, Technicolor Government Services, Inc. L. Gaydos, K. Fitzpatrick-Lins, D. Carneggie, D. Lauer, U.S. Geological Survey. S. Benjamin, V. Ambrosia, Technicolor Government Services, Inc.

2. Mapping Rangeland Vegetation Using Landsat MSS Digital Data for Resource Management Planning, by W. R. Rush, Bureau of Land Management. S. M. Howard, Idaho Dept. of Water Resources. W. D. Harrison, Soil Conservation Service.

3. The Use of Landsat "Rangeland Enhancements" to Monitor Public Rangelands in Southern Alberta, by S. G. Klumph and B. W. Adams, Alberta Energy and Natural Resources.

4. Current Forest Mapping Techniques in Southeast Asia, by L. Fox III, Humboldt State University.

5. Tropical Deforestation and the Implications of Microcomputer-Based Image Processing Technology: Case Study Indonesia, by S. C. Ahearn, R. W. Kiefer, and T. M. Lillesand, University of Wisconsin-Madison.

# INTERIM PROGRAM FOR LAND COVER MAPPING IN ALASKA UTILIZING LANDSAT DIGITAL DATA

By Mark Shasby, Leonard Gaydos, Katherine Fitzpatrick-Lins, David Carneggie, Donald Lauer, Susan Benjamin and Vincent Ambrosia

## ABSTRACT

The enactment of the Alaska National Interest Lands Conservation Act (ANILCA) in 1980 has imposed mandates on all major land management agencies in Alaska to prepare comprehensive resource and managment plans to assess wildlife habitat, oil and gas exploration and development, wild and scenic rivers, land disposals, timber production, and archeological and cultural resources. To meet these objectives, the U.S. Geological Survey (USGS) has embarked on a program to classify land cover for the entire State of Alaska using Landsat digital data. The USGS, in cooperation with other agencies, has already completed 115 million acres of Landsat-derived land use/land cover classification for the State of Alaska. With this work as a substantial foundation, the USGS has prepared a comprehensive plan for classifying the remaining areas of Alaska. The development of this program will lead to a complete interim land use/land cover classification system for Alaska and allow the dissemination of map products, statistics, and acreage summaries for all areas of Alaska at 1:250,000 scale. It also allows for the dissemination of Landsat digital data for those areas.

The 5-year plan incorporates a three-phase approach. Phase I will utilize existing land cover data bases in Alaska including the Landsat classifications of the National Petroleum Reserve of Alaska (NPRA), and the Arctic Coastal Plain, the Kenai, Togiak, Tetlin, and Yukon Flats National Wildlife Refuges, the Bristol Bay Subregion, the Nulato Hills, and the Tanana River Basin. Phase II involves additional work on ongoing projects to produce maps corresponding to the interim classification standards as well as specified maps desired by cooperating agencies. The area encompassed by these projects is approximately 55 million acres. Phase III describes a strategy for completion of the interim mapping program in Alaska with potential interagecy cooperation. When completed, 153 Alaska 1:250,000-scale quadrangles will be published that show land use/land cover from digital Landsat classifications and statistical summaries of land cover for all townships. Computer-compatible tapes also will be produced.

An interagency working group has already met and established an Alaska classification system composed of 17 land use/land cover types modified from Anderson and others (1976) Level II and Viereck and Dyrness (1982) for the unique ecoregions which are found in Alaska. Plans have also been made to produce six 1:250,000-scale quads to test the feasibility of the mapping effort.

The completion of the interim mapping program promises three important results: (1) complete mapping of Alaska land use/land cover at 1:250,000-scale from Landsat digital data analysis, (2) a comprehensive vegetation classification similar to Anderson Level II and Viereck and Dyrness for the unique Alaska region, and (3) the successful large-scale cooperation of local, regional, State, and Federal agencies in completing one of the largest land management and resource mapping plans undertaken in the United States.

# MAPPING RANGELAND VEGETATION USING LANDSAT MSS DIGITAL DATA FOR RESOURCE MANAGEMENT PLANNING

By William R. Rush, Stephen M. Howard and William D. Harrison

## ABSTRACT

The objective of this project was to produce usable map products depicting present rangeland vegetative communities based on Landsat MSS digital analysis and appropriate ancillary data. These products will provide the Bureau of Land Management, Cascade Resource Area (CRA) staff with a base inventory for the CRA Resource Management Plan and Environmental Impact Statement (RMP/EIS). They will also provide the Soil Conservation Service (SCS) with an inventory of private rangeland within BLM grazing allotments.

Of particular interest is the ability of Landsat spectral data to distinguish non-native homogeneous stands of Taeniatherum caputmedusae (medusahead grass) and Bromus tectorum (cheatgrass brome) from native plant communities. This project will establish baseline information for monitoring the changes in distribution of these two species.

The project area was stratified to separate soils derived from igneous and sedimentary parent materials and to delete agricultural lands. Image masks of grazing allotments and BLM administered lands were generated. Training segments were identified using National High Altitude Aerial Photography (NHAP). Each training segment of 50x50 pixels was clustered into 10 to 12 spectral classes. The spectral classes in each segment were then ground checked and labeled according to the following:

1. Physiography
2. Elevation
3. Slope %
4. Parent Material
5. Stratum
6. Aspect
7. Species Composition %
8. Range Site
9. Range Condition
10. Surface Stones %
11. Bare Soil %
12. Rock Outcrop %

A master statistics file of 57 spectral classes representing 15 vegetation cover types was compiled, and the study area was classified using a maximum likelihood decision rule. The image masks of grazing allotment boundaries and BLM lands were applied to the classified data to generate vegetation cover information about each grazing allotment.

Output Products included the following:

1. Tabular reports by grazing allotment showing acres of vegetation cover types within BLM and Non-BLM lands.
2. Color-coded maps of the Resource Area at 1:100,000 scale showing vegetation cover types.
3. Symbol map overlays for the 7.5 minute topographic maps of the project area at 1:24,000 depicting vegetation cover types.

The project represents a cooperative effort by three agencies to generate uniform vegetation cover data at least cost. The data will be integrated into a cooperative Geographic Information System (GIS).

# THE USE OF LANDSAT "RANGELAND ENHANCEMENTS" TO MONITOR PUBLIC RANGELANDS IN SOUTHERN ALBERTA

By S. G. Klumph and B. W. Adams

## ABSTRACT

A special enhancement technique has been developed jointly by federal and provincial agencies to produce satellite imagery which can be used to monitor range use in the mixed prairie range areas.

Public Lands Division of Alberta Energy and Natural Resources is responsible for the administration and management of three million acres of public rangeland in Southern Alberta. "Digital stretch" image enhancements are now routinely used by field staff in the monitoring of range resources on these lands.

The Alberta Centre for Remote Sensing uses a computerized image analysis system to generate colour negatives of spring and fall Landsat scenes, from which colour prints are in turn produced. A range officer will use the satellite images in conjunction with field checks to identify and map patterns of range use, and to plan corrective management if necessary. The images are also used to delineate and monitor burn areas, as well as native range converted to tame pasture or irrigation. The images have proved useful for locating potential watering developments, relocating salt licks and cross fences. Other practical applications and their benefits, as well as limitations of the images are discussed.

# CURRENT FOREST MAPPING TECHNIQUES IN SOUTHEAST ASIA

By Lawrence Fox III

## ABSTRACT

Remote sensing procedures such as satellite image interpretation, digital analysis of satellite data and interpretation of aerial photographs have been used to various degrees for forest mapping in Southeast Asia since 1950. Aerial photographs were the primary tool employed until the launch of Landsat in 1972. Since the establishment of a consistent Landsat, MSS data base in the late 1970's, visual interpretation of single band, MSS imagery has been the most commonly employed technique for forest mapping with satellite data. Landsat imagery has not been routinely available from the United States because of persistent failure of satellite tape recorders and, of course, the shear magnitude of imagery broadcast on a worldwide scale. Local receiving stations in India and Thailand, for example, have greatly increased the availability of data.

Just as the U.S. receiving stations have shown a steady improvement in their ability to process high quality photographic images, so have the foreign stations. Since 1980, foreign stations in Asia have been able to produce high quality black-and-white imagery. Color composites are still a problem, however, because of film writer limitations.

The traditional strategy for forest mapping is based on medium scale aerial photography with Landsat imagery used only on an experimental basis. Bangladesh, China, India, Iran, Indonesia, Malaysia, and Nepal take this approach. An interesting departure from the traditional strategy is under way in Sri Lanka where Landsat imagery is used for cartographic control as a base map, and vegetation is interpreted and mapped with aerial photography

The more innovative approach to mapping is based on visual interpretati of Landsat imagery as the operational method for country wide analysis with digital processing in the research and development stages. The countries of Pakistan, Thailand, and Vietnam use this approach.

# TROPICAL DEFORESTATION AND THE IMPLICATIONS OF MICROCOMPUTER-BASED IMAGE PROCESSING TECHNOLOGY: CASE STUDY INDONESIA

By Sean C. Ahearn, Ralph W. Kiefer, and Thomas M. Lillesand

## ABSTRACT

The monitoring of tropical deforestation is one of the most important natural resource issues of the century. Until recently the data necessary for this monitoring have been scarce or nonexistant. With the development of Landsat MSS receiving stations in Thailand, Indonesia, China, Australia, and Brazil, the data gap is beginning to close. The ability of these stations to receive Thematic Mapper and SPOT data in the future will provide an even higher level of detail over the tropical countries.

In the past, the question as to who would do the monitoring was confined to a limited number of centralized facilities with large computers and extensive support equipment for image analysis. With the advent of microcomputer technology this is no longer true.

A case in point is the Institut Pertanian Bogor (IPB) Remote Sensing Laboratory in Bogor, Indonesia. The laboratory is the result of a cooperative project between the IPB and the University of Wisconsin-Madison, supported by the United States Agency for International Development.

The lab is an IBM-PC/XT microcomputer-based image processing system that is capable of reading and analyzing Landsat MSS 1600 bpi tapes. The hardware consists of four IBM-PC/XT microcomputers networked to a 160 MB disk drive, an 800/1600 BPI tape drive, and a Gould DeAnza high resolution graphics terminal. The software includes a wide range of digital image processing programs for geometric rectification, image enhancement, and image classification, as well as a basic geographic information system capability.

With the change from expensive, difficult to maintain minicomputers, to affordable, relatively resilient microcomputer-based image processing systems, the ability to tackle deforestation problems will be present at the national or regional level. This places the analysis of imagery in the hand of the people who know their country best and in turn will generate a greater within country commitment to policy promulgation and implementation in the area of deforestation.

## SESSION 3: GEOGRAPHIC INFORMATION SYSTEMS APPLICATIONS

MODERATOR: D. HUNTER

1. Updating Range Surveys Using a Geographic Information System, by J. C. Eidenshink, Technicolor Government Services, Inc. D. Sjasstad, Bureau of Indian Affairs.

2. Cost-Efficiencies of Surface Cover Mapping for Geographic Information System Applications, by S. C. Williamson, U.S. Fish and Wildlife Service. I. E. Lindauer, P. DePlazes, University of Northern Colorado.

3. Developing a Resource Management Data Base for the Okanogan National Forest from Multispectral Imagery and the Use of GIS, by G. O. Klock, G. O. Klock and Associates. P. Gum, U.S. Forest Service. L. E. Jordan, ERDAS, Inc.

4. Geographic Information System and Remote Sensing Applications in Rural Alaska Subsistence Use Protection, by K. G. Meyer, Colorado State University.

# UPDATING RANGE SURVEYS USING A GEOGRAPHIC INFORMATION SYSTEM

By Jeffery C. Eidenshink and Dave Sjasstad

## ABSTRACT

A spatial data base for the Fort Berthold Indian Reservation in North Dakota was developed to demonstrate the use of a geographic information system for natural resource management. Key components of the digital data base are detailed soil survey data, range site data, and range survey data. The range site data were derived by aggregating soil mapping units based on interpretations provided in the Soil Conservation Service's published soil surveys. Range survey data (stocking rates and condition class) are derived from field surveys. In order to utilize the range site data, it was necessary to determine the stocking rate and condition class for each of the 1,100 range sites on the reservation.

To correlate the field survey data to the soil-survey-based range sites, a 1:24,000-scale map which included range site boundaries was produced for each township within the reservation. Each range site polygon was assigned a unique label so polygons of the same class could be discriminated. Uniquely labeled management units were also included on the maps in order to allow discrimination of the potential differences in stocking rates due to grazing management practices.

A tabular listing, which included the label given to each unique range site polygon, the range site class, and the acreage of the range site within a management unit, was provided with each map to cross reference and identify all range sites within a management unit.

The 1:24,000-scale maps and the tabular data were compared to maps of the transect information obtained by field surveys to derive the stocking rate and condition class for each range site within a management unit. The resultant data base components were a map of range sites within management units and an associated tabular file containing, among other data, attribute information on stocking rate and condition class.

This geographic information system was used to implement a revision of stocking rates based on a 1984 report issued by the Soil Conservation Service for the State of North Dakota. The report recommended approximately a 25-percent decrease in the stocking rate. The stocking rates were adjusted within the tabular file for each range site on the reservation in less than two days.

The capabilities of geographic information systems allow complex manipulation of tabular and map data necessary for revising and updating range management information in a timely and efficient manner.

# COST-EFFICIENCIES OF SURFACE COVER MAPPING FOR GEOGRAPHIC INFORMATION SYSTEM APPLICATIONS

By Samuel C. Williamson, Ivo E. Lindauer, and Patricia DePlazes

## ABSTRACT

A standard test methodology is needed for selecting the most efficient and effective remote sensing technique for a geographic information system application (Aronoff, 1982). The approach should compare remote sensing techniques with the objective of maximizing mapping accuracy while minimizing cost per unit area, subject to constraints on minimum acceptable accuracy and maximum acceptable cost per unit area. Any map accuracy assessment requires a knowledge of error-producing factors, as well as mapping methods, procedures, applications, and technological limitations. An assessment of surface cover map accuracy should include a statement about the type of accuracy assessment, identification of the relevant error-causing variables, an examination of the types of site-specific mapping errors, a description of the classification system, and a description of the physical representation of the minimum mapping unit.

This study quantitatively assessed the accuracy of rangeland vegetation cover maps produced by three remote sensing techniques: machine classified Landsat (MCL) multispectral scanner (MSS) digital data, color composite Landsat (CCL) MSS images, and medium scale color infrared (MSCIR) aerial photography. Information from the three techniques was compared to ground reference data gathered in the fall of 1983 in the Piceance Creek watershed of northwest Colorado.

Assessments of site-specific mapping errors were made using a stratified random sampling design and analyses based on error matrices. Several comparisons were made to compensate for differences among the vegetation classification systems used with each remote sensing technique. Using the preferred classification system (without overlap of cover types) CCL accuracy was 27%, MCL accuracy was 26%, and MSCIR accuracy was 58%. The heterogeneous mixture in the upland shrub surface cover type was difficult to map accurately, particularly with Landsat imagery. Color composite Landsat had the lowest total mapping costs at .062 cents/acre, followed by MCL at 4.1 cents/acre, and MSCIR at 8.2 cents/acre. Based on an accuracy:cost ratio analysis, the most cost-efficient procedure for mapping large expanses of rangelands would use a combination of medium scale color infrared aerial photography for heterogeneous or high interest areas, and CCL for homogeneous and low interest areas, where lower accuracy is acceptable. A highly cost-efficient proposal for mapping rangelands would probably involve some use of medium scale (1:58,000) color infrared aerial photography from the National High Altitude Photography Program.

# DEVELOPING A RESOURCE MANAGEMENT DATA BASE FOR THE OKANOGAN NATIONAL FOREST FROM MULTISPECTRAL IMAGERY AND THE USE OF GIS

G.O. Klock, P. Gum, and L.E. Jordan, III

## ABSTRACT

The vegetation and overstory crown closure for approximately three million acres of the Okanogan National Forest and nearby forest and range lands have been classified by use of Landsat multispectral imagery and Defense Mapping Agency topographic information to form a data base for fire fuels management. Through the use of supervised maximum likelihood classification, 139 vegetation mapping classes ranging from pure old-growth conifers stands, to mixed conifers, rockland, and various range species have been identified across these lands in North Central Washington. Ecologic models were developed and used in conjunction with the vegetation mapping. Four levels of crown closure have also been classified from imagery on these same lands. Accuracy of the classification in terms of the correct specie and conifer size class identification exeeds 80 percent across the project area. The crown closure mapping exceeds a level of 90 percent correct. Location of the individual 0.6 acre or 50m pixel units was verified at +50 meters.

The data base includes vegetation specie, conifer size class, crown closure, average elevation, aspect, and slope class with summary statistics by GEOLOC units. Although this data base was prepared for fire management, it is also available for use in other resource management activities. An additional ten layers of management data is now being prepared for use by the Okanogan National Forest through inputs of digitization, elevation data, and the MSS data previously used. These layers include land ownership, wildlife habitat, soils, current and potential productivity, and transportation networks.

Information in this data base is available for display on the Okanogan National Forest's ERDAS IBM PC-XT Image Processing/ Geographic Information System (GIS). Individual files of the various data layers (vegetation, crown closure, aspect, etc.) can be displayed for interpretation, overlayed to make composite data layers, or output to scaled geo-referenced color maps for field use. Most maps are produced at the 1:24,000 scale so that they may be used at the same scale as the aerial resource photos. These tools provide the resource manager an opportunity to develop inexpensive current color maps for many activities such as planning and project monitoring programs. The data base remains dynamic through updating of digitized information and use of reclassification.

# GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING APPLICATIONS IN RURAL ALASKA SUBSISTENCE USE PROTECTION

By Kevin G. Meyer

## ABSTRACT

Geographic information systems and remote sensing have the potential to make major contributions to the protection of subsistence use in rural Alaska. The protection of rural Alaskan subsistence use emerged as an important management issue for federal land managers with the passage of the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). Provisions of Title 8 of the Act, Subsistence Management and Use, require that traditional subsistence use by rural residents of the State, both Native and non-Native, receive preferential consideration in land use planning and environmental review.

The Bureau of Land Management, in its interpretation of ANILCA Section 810, has developed specific guidelines to protect the "supply side" components of subsistence use. These components are identified as: 1) wildlife and plant species utilized in subsistence; 2) the habitat of those species; 3) traditional access to subsistence resources; and 4) protection from significant increases in competitive use by non-subsistence users.

The framework for an operational subsistence use protection management program has been developed by the author which incorporates geographic information system capabilities as a base for data management. The program utilizes remote sensing and the USDI Fish and Wildlife Service's Habitat Evaluation Procedures for data input and analysis. Major components of the management system include: 1) documentation of traditional subsistence use; 2) evaluation of subsistence resources within subsistence use study areas; 3) conflict identification and impact analysis; and 4) administrative decision making and documentation.

The management system is designed for systematic review of potential restrictions to subsistence use from proposed land use activities. It provides a base for impact assessment and significance determinations to meet ANILCA Section 810 compliance requirements. In addition to the Section 810 protection program, the management system can provide the framework for a general subsistence resource management program. In this application, subsistence use demands can be projected, resource shortfalls identified, and management programs developed to insure long term subsistence opportunities.

## SESSION 4: CHANGE DETECTION AND MONITORING

MODERATOR: J. MERCHANT

1. A Perspective on Using Remote Sensing for Detecting and Monitoring Change in Renewable Resources, by L. F. Werth and F. T. Batson, Bureau of Land Management.

2. Change Detection in Rangeland Environments Using Landsat MSS Data -- A Quantitative Approach, by D. C. Johnston and R. H. Haas, Technicolor Government Services, Inc.

3. Assessing Dynamic Forage Conditions in Individual Range Pastures Using Thematic Mapper Imagery and an IBM Personal Computer, by L. D. Miller, Y. K. Yang, T. Cheng, M. Unverferth, and K. Wills, University of Nebraska.

4. Evaluation of a Layered Approach for Classifying Multitemporal Landsat MSS Data, by D. F. Lozano-Garcia and R. M. Hoffer, Purdue University.

5. Comparative Evaluation of Digital Change Detection Methods in Forestland and Rangeland Environments Using Landsat Multispectral Scanner Data, by G. S. Burns, NASA/National Space Technology Laboratories.

# A PERSPECTIVE ON USING REMOTE SENSING FOR DETECTING AND MONITORING CHANGE IN RENEWABLE RESOURCES

By Lee F. Werth and Fred T. Batson

## ABSTRACT

Reduced dollars and manpower will require increased efficiency for change detection and monitoring of public land resources. The vast acreages administered by public agencies for range, wildlife, recreation, forestry, watershed, and minerals activities mandate increased emphasis on remote sensing in combination with ground surveys to monitor resource status and change. The type of remote sensing system required will depend on the level of detail desired and the resource extent. For example, satellite systems may be adequate for monitoring gross changes over large areas. However, large scale aerial photography may be more appropriate for site specific monitoring of key plant communities within livestock grazing allotments.

In some cases, remote sensing may provide the types of quantitative data required by resource managers. In others, remote sensing and change detection will only "flag" areas requiring further investigation. Remote sensing will never replace field monitoring, but it can make the on-the-ground efforts more efficient.

The key questions determining the utility of a remote sensing monitoring system are: 1) are the changes indicated real (valid) and 2) what relevance do they have to resource management decisions? Resource managers must be assured that an indicated change is valid and is not based on phenologic differences, atmospheric effects, misregistration or other anomalies not related to vegetative responses. At first glance, remotely sensed changes indicated by factors such as "greenness," albedo, or biomass may seem to have definite relevance to resource management requirements. However, resource managers may see little utility in these kinds of data because they do not yet translate into terms that they may be familiar with. Not all types of change are of equal importance to a resource manager. He or she may need to know whether an apparent change relates to a high value livestock or wildlife forage, but would not be concerned if the change occurred with a relatively unimportant species.

To effectively use remote sensing technology, there is need for closer communication and understanding between resource managers and remote sensing specialists. Each must make further attempts to understand the other's requirements and capabilities. This is especially important since the types of data provided via remote sensing systems cannot duplicate some of the traditional field gathered data that resource management personnel are comfortable dealing with. However, remotely sensed data may provide an important supplement to resource monitoring efforts and permit on-the-ground managers to increase the efficiency of their total monitoring programs.

# CHANGE DETECTION IN RANGELAND ENVIRONMENTS USING LANDSAT MSS DATA -- A QUANTITATIVE APPROACH

By David C. Johnston and Robert H. Haas

## ABSTRACT

During a range forage utilization study on the Crow Creek Indian Reservation in central South Dakota using Landsat multispectral scanner (MSS) imagery, the opportunity arose to examine range condition trends. A procedure was developed to compare changes in spectral reflectance over time for polygon areas defined by resource type within management units. A *t*-test was used to evaluate changes in brightness and greenness within polygons between September 27, 1978, and September 18, 1983. Brightness was measured using the first principal component images for both dates, and greenness was measured using the second principal component images for both dates. Examination of the brightness data showed that the assumptions required for a valid *t*-test were met. The greenness data violated the assumption of independence between the two dates, which meant that greenness change could not be considered.

The *t*-values calculated from each polygon were coded into three groups: (1) those indicating significant brightness decrease, (2) those indicating significant brightness increase, and (3) those indicating no significant change. These results were formatted into an image, which is a preliminary attempt at producing a range condition trend map.

# ASSESSING DYNAMIC FORAGE CONDITIONS IN INDIVIDUAL RANCH PASTURES USING THEMATIC MAPPER IMAGERY AND AN IBM PERSONAL COMPUTER

L. D. Miller, Y. K. Yang, T. Cheng, M. Unverferth, and K. Wills

## ABSTRACT

Frequent, timely assessment of changes in the mean and spatial distribution of green canopy biomass density or green forage within each of his pastures can provide the ranch manager with valuable, quantitative information for his livestock management decisions. Thematic Mapper (TM) images are of sufficient ground resolution to provide a detailed map of the spatial distribution of the green forage within each pasture. Transformation of selected spectral bands of the TM image into appropriate, calibrated green forage maps can readily be completed using one of the established vegetation indices such as the Transformed Vegetation Index (TVI). Ground sampling by clipping test plots at reference positions within pastures provides a basis for calibrating these green forage maps in tons per acre. The mean, variance, and distribution of the green forage can then be estimated for each irregular pasture specified.

Practical application of these general procedures for improved management of individual pastures requires that appropriate image analysis techniques be available to the rancher. These techniques must be usable on his personal microcomputer and interfaced to the computer ranch management decision models he currently utilizes. A microcomputer image processing system has been constructed which meets these criteria and can perform all the necessary image analysis functions.

The IBM PC is readily available to ranchers. It is being used for maintaining livestock records, cash flow analysis, determining feed mixes, and many other related functions. Extending its application into image processing requires the addition of a new display subsystem for portraying the Thematic Mapper images in an appropriate size, format, and color balance to support the recognition of individual pastures, ground sample locations, fence boundaries, etc. The TM imagery is easily accessed on standard five inch floppy disks or from eight inch disks with the addition on an inexpensive eight inch disk drive.

TM image maps can be displayed in high quality natural color or color infrared on the auxiliary display screen and a cursor used to draw a complex polygon corresponding to the fenced boundary of each pasture. Each of these pasture boundaries can be saved on disk and superimposed upon each successive, new image map(s) acquired for the ranch. The transformation of the appropriate spectral bands for each of the TM's quarter acre picture elements or cells within a specified pasture can be performed to estimate its relative level of green forage. Corresponding ground calibration measurements, if available, can be used to establish the relationship between this transformation and tons of green forage per acre for each cell. These relative or calibrated green forage levels can then be displayed as image maps using colors to code their ranges and all other areas suppressed except the selected pasture(s). This estimate of green forage for each quarter acre cell can also be summed over the irregular pasture area and a tabular output prepared which illustrates and compares conditions in each pasture, such as the total, mean, and variance of the green forage; the confidence limits of their calibration; and even a graphic histogram of their distribution.

# EVALUATION OF A LAYERED APPROACH FOR CLASSIFYING MULTITEMPORAL LANDSAT MSS DATA

By D. Fabian Lozano-Garcia and Roger M. Hoffer

## ABSTRACT

Considerable interest has been generated in recent years concerning the destruction of forests in many countries of the world. There has been speculation concerning a possible relationship between the increased level of carbon dioxide in the earth's atmosphere and deforestation. Landsat multispectral scanner data provides a unique opportunity to study the earth's surface and the extent and condition of various cover types, including forest cover. Many different computer-aided analysis techniques have been developed to classify Landsat multispectral scanner (MSS) data. However, most of these techniques are designed to utilize a single data set. To determine changes in the extent or condition of the forest canopy that may occur over time requires overlaying multiple data sets and a different approach to the analysis of such a multi-temporal data set.

This research examines the effectiveness of the Layered Classifier as a possible technique for analyzing multi-temporal Landsat data. The test site was near the Monroe Reservoir in the Hoosier National Forest. Landsat satellite data, obtained on four dates throughout the year were digitally registered and analyzed. The results show that the Layered Classification technique enabled more accurate classification results to be obtained, and at far less cost (in terms of computer time needed) than were obtained by simply combining the data from two dates and applying a standard maximum likelihood classification algorithm. These results provide significant insights into effective techniques for using satellite data to monitor changes in forest canopy conditions or the areal extent of forest cover.

# COMPARATIVE EVALUATION OF DIGITAL CHANGE DETECTION METHODS IN FORESTLAND AND RANGELAND ENVIRONMENTS USING LANDSAT MULTISPECTRAL SCANNER DATA

By Gregory S. Burns

## ABSTRACT

Two digital procedures were used to develop land cover change maps from multidate Landsat coverages for three test areas. One method employed a post classification comparison of land cover categories produced independently from all bands for each date. The second method involved using the same numerical data processing routines, but processed visible and infrared band pairs from both dates simultaneously to classify ground areas with similar change characteristics between dates. In order to provide a standard for comparison, land cover change maps were produced from aerial photography for each test area that was both spatially and temporally coincident with each multidate set of Landsat overpasses. These results from all data sources were geographically co-registered in a multichannel data base for each test area so that equivalent ground areas could be compared.

These comparisons revealed that the results produced by both techniques agreed with over 95% of the photo-identified change locations within the 30' by 60' Louisiana control area. These deforested areas accounted for 10.2% of the 2032 square mile area, while the two digital techniques produced 13% and 11.9% measures. In the southwest Kansas test area 19% of the rangeland in the 15' by 30' area was mapped as changed using the aerial photography. The two digital techniques indicated changes of 21.4% and 16.8% of that 471 square mile area with performance showing a 93% and 95% agreement between data sources. The Arizona control area was limited to the extent of two non-adjacent flightlines for the first date that total 458 square miles and which partially cover fifteen 7.5' USGS quadrangles. Within this area three major change categories were found covering less than 2.5% of the area. Performances of the digital methods ranged from 90% to 98% depending on the type of change.

## SESSION 5: VEGETATION DAMAGE ASSESSMENT

MODERATOR: P. MURTHA

1. Large-Scale Color-IR Photographs for Incipient Bark Beetle Attack Detection, by P. A. Murtha, University of British Columbia.

2. The Use of Landsat MSS Digital Data to Detect Mortality of Lodgepole Pine Caused by the Mountain Pine Beetle, by J. A. Brockhaus, H. M. Cheshire, and S. Khorram, North Carolina State University.

3. Surveying Spruce Budworm Defoliation with an Airborne Pushbroom Scanner, by F. J. Ahern, Canada Centre for Remote Sensing. W. J. Bennett, Intera Technologies, Ltd. E. G. Kettela, Maritime Forest Research Centre.

4. Digital Airborne and Satellite Data for Evaluating Spruce Budworm Damage in Quebec, by J. Beaubien, Laurentian Forest Research Centre. P. Laframboise, Centre quebecois de l'Energie et des Ressources.

5. Use of Color Infrared Aerial Photography for Assessing Red Spruce Mortality and Decline, by M. J. Weiss, L. R. McCreery, and W. M. Ciesla, Forest Pest Management, USDA/Forest Service.

# LARGE-SCALE COLOR-IR PHOTOGRAPHS FOR INCIPIENT BARK BEETLE ATTACK DETECTION

By Peter A. Murtha

## ABSTRACT

Recent studies of bark beetle attacked conifers have suggested subtle hints which may be used in the interpretation of bark beetle "green" attack. Recognition of the green attack phase depends on the interpretation of a variegated magenta pattern. The effects are discussed and demonstrated for current or green attack classes for both spruce beetle attack on Engelmann spruce and mountain pine beetle attack on lodgepole pine.

# THE USE OF LANDSAT MSS DIGITAL DATA TO DETECT MORTALITY OF LODGEPOLE PINE CAUSED BY THE MOUNTAIN PINE BEETLE

By John A. Brockhaus, Heather M. Cheshire, and Siamak Khorram

## ABSTRACT

Airphoto interpretation has been used to assess the degree of mortality in lodgepole pine stands caused by the mountain pine beetle. These studies have proven to be successful in monitoring and mapping mortality for localized areas but may not be an appropriate technique when attempting to monitor large regional areas. Digital multispectral remote sensing data, such as that provided by the Landsat satellites, may provide the opportunity for monitoring and mapping the degree and extent of mortality caused by the mountain pine beetle in an economic and timely manner. In 1981 the United States Forest Service (Methods Applications Group) funded a pilot project to determine the utility of Landsat MSS digital data for monitoring and mapping the intensity and spatial extent of lodgepole pine mortality caused by the mountain pine beetle.

Portions of the Ashton and Park Island Ranger Districts within the Targhee National Forest, located in eastern Idaho, were selected as test sites for this project. Thirty lodgepole pine stands representing a range of mountain pine beetle infestation conditions were selected as field plots to be used in analyzing the Landsat MSS data. Data collected at each plot included: (1) area of the plot in acres; (2) live timber volume in board feet; (3) dead timber volume in board feet; (4) number of live trees; and, (5) number of dead trees. Analysis of the field data resulted in the development of three mortality classes based upon percent dead volume: (1) 0-34.5%; (2) 35-66.5%; and, (3) 67-100%. Plot boundaries were transferred to United States Geological Survey 1:24000 orthophoto maps which were then used to determine the UTM coordinates of the center of each plot. Calibration equations were developed relating MSS image x,y coordinates to UTM easting and northing coordinates; these equations were used to accurately determine the location of plot centers within the MSS data.

Average plot reflectance values in each MSS waveband were obtained for each plot and used to develop spectral signatures for the three previously defined mortality classes. Spectral signatures were also developed for other land use/land cover types occurring within the study site, such as water, grass, hardwoods, brush, and bare soil. These signatures were applied to the MSS data through a table look up, minimum distance multispectral classifier which classified each pixel within the study area into one of the cover types specified.

Results of this classification process seem to correspond well to ground conditions described by USFS personnel. Analysis of classification of the 30 field test plots indicated that 25 of the 30 plots (85%) were correctly classified into their original mortality class. Budget limitations of this project prevented the collection of an independent verification data set; therefore, it is very difficult to accurately assess the reliability of this procedure. It is strongly recommended that a verification data set be collected before this technique is attempted again.

# SURVEYING SPRUCE BUDWORM DEFOLIATION WITH AN AIRBORNE PUSHBROOM SCANNER

By F. J. Ahern, W. J. Bennett, and E. G. Kettela

## ABSTRACT

Insect damage is one of the most serious causes of forest depletion and growth loss in Canada. Informed forest management requires yearly information on insect damage to plan countermeasures and to revise predictions of future wood supply. LANDSAT MSS data have not generally been satisfactory for insect damage assessment. In 1983 the Canada Centre for Remote Sensing carried out an assessment of the ability of airborne multispectral scanners (mechanical and pushbroom) to detect current year damage to softwood stands by spruce budworm larvae.

Data were acquired on July 12, 1983 with a mechanical scanner of approximately 25 m resolution and 16 km swath width and an electro-optical ("pushbroom") scanner of approximately 7 m resolution and 5 km swath width. Independent verification photography was acquired with a 240 mm mapping camera in the same aircraft with the multispectral scanners, and with 35 mm and 70 mm cameras in separate aircraft.

It was possible to detect and identify areas of spruce budworm defoliation very easily on natural colour images made from the pushbroom scanner data, but similar images made from the lower resolution mechanical scanner data did not show areas of defoliation. Additional processing and the use of other bands of the mechanical scanner, including a band in the shortwave infrared (SWIR) region, were also unable to produce images showing areas of defoliation unambiguously. The primary reason for the different results was traced to the difference in spectral bands between the two sensors, with the improved radiometric resolution of the pushbroom scanner playing a contributing role.

A system which could provide operational insect image surveys based on data from an airborne pushbroom scanner is described. Further work toward such a system is in progress at the Canada Centre for Remote Sensing.

# DIGITAL AIRBORNE AND SATELLITE DATA FOR EVALUATIONG SPRUCE BUDWORM DAMAGE IN QUEBEC

By Jean Beaubien and Pierre Laframboise

## ABSTRACT

Since 1970, northeastern North America has experienced a spruce budworm (Choristoneura fumiferana (Clem.)) outbreak that has an important influence on the management of fir/spruce forests in Quebec. There is a great need for information on the amount and location of budworm damage for the planification of stand management or spraying strategies. The current methods used to estimate the extent of damage over large areas rely on aerial visual surveys and various types of ground surveys. Recent remote sensing tools may have the potential of providing a more rapid and accurate assessment.

Studies indicate that Landsat MSS, high altitude CIR aerial photography, and even medium scale photography have low capabilities for detecting levels of spruce budworm damage. A study was initiated to determine the potential of higher spatial and/or spectral resolution digital data for detecting, mapping, and quantifying cumulative defoliation needed mainly for spray protection programs.

A Deadalus 1260 and a MEIS II (Multi-Detector Electro-Optical Imaging Scanner) collected multispectral digital data over an area with different levels of defoliation. Ground resolutions are 20 and 10 m, and 5.6 and 2.8 m respectively. There was one flight in November 1983 and another in August 1984. Future SPOT multispectral and panchromatic imagery was simulated from these airborne data. A Landsat TM scene of May 18, 1984 was also acquired.

The effectiveness of various enhancement techniques, including principal component analysis, for discriminating damage levels is being investigated. The study is also to determine the optimum spectral band combinations from these sets of data for enhancing or digitally classifying levels of defoliation. The capabilities and limitations of airborne and satellite (Landsat TM and SPOT) digital data is being analyzed and will be discussed, considering the time of the year of data acquisition. From the state of our present studies, the data gathered in autumn, when deciduous trees are defoliated, have more potential.

# USE OF COLOR INFRARED AERIAL PHOTOGRAPHY FOR ASSESSING RED SPRUCE MORTALITY AND DECLINE

By Melvyn J. Weiss, Lew R. McCreery, and William M. Ciesla

## ABSTRACT

The presence of elevated levels of red spruce decline and mortality in high mountain regions of the Northeastern United States has recently received considerable publicity.

In 1984 a survey was conducted over portions of New York, New Hampshire, and Vermont by the Durham Field Office, Forest Pest Management, Northeastern Area, USDA Forest Service. The purpose of this survey was to provide data on the distribution and magnitude of red spruce decline and mortality in these states.

The survey method consisted of a combination of 1:8000 scale CIR aerial photos and ground surveys. Data was obtained for four survey regions. Two were in New York: the Adirondack Mountains and the Tug Hill Plateau. The remaining two units comprised Vermont and New Hampshire. Primary sample units consisted of randomly selected 8000 acre blocks which were stratified into vegetation classes. Vegetation classes with a spruce-fir component were stratified into 3 mortality classes based on the proportion of conifer mortality. A series of 2-1/2 acre photo sample plots were established within these strata and counts of dead trees were made. A subsample of photo sample plots were ground cruised.

The survey provided estimates of the area and proportion of forest area with a spruce and fir component in each of 3 mortality classes. Estimates of the number of trees and volume loss for each vegetation type and mortality class were also obtained.

## SESSION 6: MAPPING SOIL AND WATER RESOURCES

MODERATOR: E. HORVATH

1. Landsat Imagery: A Tool for Monitoring Snowmelt and Predicting Runoff Patterns for Mountain Watersheds, by R. W. Marrs, University of Wyoming.

2. Microwave Remote Sensing of Snowcover in Forested and Non-Forested Areas, by D. K. Hall, A. T. C. Chang, and J. L. Foster, NASA/Goddard Space Flight Center.

3. Photogrammetric Input to a Geographic Information System for Modeling Soil Erosion, by R. Welch, T. R. Jordan, University of Georgia. A. W. Thomas, U.S. Department of Agriculture.

4. The Relationship Between Soils Data and Forest Clearing and Forest Regrowth Trends in Costa Rica, by R. E. Pelletier and S. A. Sader, NASA/National Space Technology Laboratories.

5. Mapping Soil and Soil Degradation Using Remote Sensing Techniques, by H. S. Iyer, M. L. Manchanda, and J. Prasad, Indian Institute of Remote Sensing.

# LANDSAT IMAGERY: A TOOL FOR MONITORING SNOWMELT AND PREDICTING RUNOFF PATTERNS FOR MOUNTAIN WATERSHEDS

Ronald W. Marrs

## ABSTRACT

A project was undertaken in 1983 to gather a statewide data base and implement analysis techniques that would employ Landsat imagery as a supplement to more traditional techniques of snowpack monitoring and water management in Wyoming. Snowpack has been traditionally monitored by selected, on-site recording stations and periodic sampling for water content. These measurements can be used to forecast runoff if variables, such as rate and timing of spring warm-up and uptake of moisture by soils and vegetation, can be taken into account. Such techniques have been proven effective, but are subject to limitations with regard to accuracy and practicality. LANDSAT data can be used to effectively augment these measurements and improve water forecasts.

The method used is to interpret snowcover area from a sequence of LANDSAT images selected from coverage obtained during several snowmelt seasons. Snowcover measurements are obtained by electronic planimeter using a video-analogue image analyzer. The snowcover measurements are plotted against measured streamflow summed over the melt season. As cumulative runoff increases, snowcover decreases each year. The empirical relationship derived from the correlation of these data is evaluated and compared to similar curves for other snowmelt seasons to derive a composite relationship that represents the "typical" pattern of snowmelt vs. runoff for each watershed. This typical curve can then be used to forecast volume and timing of runoff during the spring snowmelt using the current LANDSAT imagery to assess the condition of the snow pack in a given watershed. As each successive image is returned from the satellite, the forecast can be modified to accommodate any variations from the normal snowmelt pattern.

The video image analyzer is essential to this research because it provides an efficient method for snowpack estimation. Streamflow measurements are essential for the derivation of the snowpack/runoff relationship, but are no longer required for forecasting after a representative data set has been gathered and reliable predictor curves have been defined.

During 1983 and 1984 the data base was developed for those Wyoming watersheds in which snowpack is a significant contributor to the annual runoff. Snowcover measurements were then made for each watershed using imagery representing different periods during the snowmelt season. Plots of snowcover vs. runoff were then constructed for each area for each snowmelt season (lack of adequate streamflow data or cloud free LANDSAT coverage precluded evaluation of some basins some years). However, because Landsat has been operational for thirteen years, useful data were found for each area for several seasons.

Measurements of snowpack were made for all Wyoming drainages in which snowpack is a major contributor to spring runoff. Composite curves were compiled for those areas where adequate data were available for several seasons. Both the individual and composite curves are useful for predicting the expected runoff from the most recent satellite images. Dates for beginning, peak, and end of spring snowmelt can be predicted.

# MICROWAVE REMOTE SENSING OF SNOWCOVER IN FORESTED AND NON-FORESTED AREAS

By D. K. Hall, A. T. C. Chang and J. L. Foster

## ABSTRACT

The presence of even a thin layer of snow exerts a major influence on the local and regional energy balance because of its high albedo. Snow depth is important for climate studies and energy balance studies because deeper snow can take longer to melt than shallow snow and thus the highly reflective surface is present for a longer amount of time. The extent and depth of the world's snow cover is highly variable. Using satellite-derived passive microwave data, snow can be detected and measured through clouds and during darkness. Measurement of snow depth is feasible in non-forested areas. Previous studies have shown that brightness temperatures ($T_B$) ($T_B = \varepsilon T_S$ where $\varepsilon$ is emissivity and $T_S$ is surface temperature) derived from passive microwave aircraft and satellite sensors are significantly inversely correlated to snow depth in homogeneous prairie areas. Since much of the Earth is covered by forests, it is necessary to be able to measure the amount and distribution of snow in forested as well as non-forested areas. As vegetation and forest cover become more dense, the correlation between $T_B$ and snow depth becomes poorer because the forest cover increases the emissivity and the $T_B$. Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) and Nimbus-5 and -6 Electrically Scanning Microwave Radiometer (ESMR) data of five separate snow-covered regions are discussed to illustrate this problem. The regions are: 1) the North Slope of Alaska and 2) the Canadian High Plains, both of which are homogeneous areas characterized by low vegetation, 3) the State of Indiana with cropland and deciduous and coniferous mixed forest cover, 4) northern Minnesota with predominately coniferous forests, and 5) a densely forested (mixed hardwood and deciduous) area in the lower peninsula of Michigan. The vegetation and forest characteristics are found to vary widely among the regions and are described in terms of their relationship to microwave $T_B$. The best coefficient of correlation, R, value was found in the Canadian High Plains area where R = -.93 and the poorest was found in the heavily forested lower peninsula of Michigan where R = 0.0. Physically-based models can be used to calculate the influence of vegetation on the $T_B$/snow depth relationship.

# PHOTOGRAMMETRIC INPUT TO A GEOGRAPHIC INFORMATION SYSTEM FOR MODELING SOIL EROSION

By R. Welch, T. R. Jordan and A. W. Thomas

## ABSTRACT

Ephemeral gully erosion is a significant problem in the agricultural areas of the Southeastern United States. Photogrammetric techniques for monitoring erosion from ephemeral gullies in agricultural fields are currently being developed by the University of Georgia Laboratory for Remote Sensing and Mapping Science (LRMS) working in conjunction with the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) at Watkinsville, Georgia, and the USDA-Soil Conservation Service (SCS). Seven test sites have been established in north Georgia and aerial photographs recorded at critical times throughout the year. Large scale contour maps are being produced for dates corresponding to tillage, planting, and harvest operations. Maps from different dates are registered to one another, the areas of change digitized, and the volume of soil lost between dates computed. A detailed soil survey is also performed to determine the variety and distribution of soil types present in the fields. The photogrammetrically derived data are integrated with information on soils, rainfall, tillage and planting practices to create a data base which can be accessed by Geographic Information System (GIS) software and used to model soil erosion. It is anticipated that these efforts will lead to a quantification of the effects of ephemeral gully erosion on the agricultural lands of the Southeast.

# THE RELATIONSHIP BETWEEN SOILS DATA AND FOREST CLEARING AND FOREST REGROWTH TRENDS IN COSTA RICA

By Ramona E. Pelletier and Steven A. Sader

## ABSTRACT

Trends indicate that rates of deforestation in tropical regions have greatly increased in recent years having a substantial impact on local resources as well as global processes. Costa Rica, as an example indicative of many areas in tropical and subtropical regions, is originally assumed to have been nearly all forested while less than one third of the area is in primary forest today. Techniques utilizing remotely sensed data can provide for a means by which present and past forest conditions can be assessed. However, future estimates must also include input from the variety of biophysical factors which influence the propensity with which forested land may be subject to clearing and subsequent regrowth. This paper will discuss the relationships between soil type and trends in deforestation and the potential for land use abandonment and forest regrowth. The effect of clearing trends on critical erosion areas will also be examined. Finally, relationships between a variety of biophysical factors and soil type will also be discussed to indicate how soil data, when not available in these regions, may be compensated for by the existing biophysical data.

The larger study, regarding deforestation trends, was conducted in the San Jose 1:20000 quadrangle area of Costa Rica, while intensive studies on forest regrowth trends were conducted in the Sarapique near the La Selva Biological Preserve and in the proximity of the Rio Macho Forest Reserve. These regions exhibit a great diversity in climate and landforms in a relatively small area and have available several thematic maps of biophysical information. A geographically referenced data base was created for the quad containing the original thirty- nine class soil data set and six regrouped classifications based on U.S. soil taxonomy; forested condition from five dates between 1940 and 1983; and biophysical data from maps of geomorphology, geology, slope and Holdridge-derived life zones. For the intensive study sites, comparisons of land cover patterns from three dates of Landsat MSS data were included.

To investigate the relationship between soil type and deforestation each soil group classification was overlaid with each date of classified forest condition and correlated. The correlations demonstrated that certain soil types were quite likely to experience deforestation, other soil types experienced very little, and many showed only moderate correlations. This latter occurrence indicates that other biophysical factors have a greater influence on the propensity towards deforestation than does soil type in those cases. Similar relationships could be drawn between soil type and the likelihood that an area would be abandoned and returned to forest regeneration. Relationships established between soil type and other biophysical data sets were helpful but not definitive in compensating for soils data where none exists.

# MAPPING SOIL AND SOIL DEGRADATION USING REMOTE SENSING TECHNIQUES

By H. S. Iyer, M. L. Manchanda and J. Prasad

## ABSTRACT

Aerial photographs and Landsat imagery have been used in different parts of NW and Central India to map soil and soil degradation. To select a suitable date and bands of Landsat imagery, the salt affected areas were delineated visually for a part of Haryana for all the four bands (band 4, 5, 6 and 7) in combination with FCC at 1:250,000 scale and for all the six dates available (Sept. 22; October 10; November 15 and December 03, 1972; Feb. 13 and March 3, 1973). From the study the results can be given as:

Season: March = February > November = Sept. = October > Dec.
Bands : Band 5 = FCC = Band 4 > Band 6 > Band 7.

If band with date is combined then Band 5 in month of March provided the maximum information and Band 7 of the same month gives the least informaiton. In overall perspective FCC was found to be better for soil and soil degradation mapping. Landsat imagery was also enlarged from 1:1 M to 1:250,000 and 1:120,000 scales. Enlargement to 1:250,000 scale provided extra delineation of units and more informations. However, further enlargements to 1:120,000 scale did not yield extra information.

Landsat interpretation units delineated at 1:120,000 were also compared with mapping units delineated at 1:50,000 scale using air photos of 1:25,000 scale. The approach for interpretation of Landsat imagery and air photos was the same upto sub-land types; thereafter a different approach had to be adopted for further sub-dividing these units. A good coincidence of boundaries was found between the two upto sub-land type. Soils were mapped upto sub-group level using Landsat imagery whereas sub-groups were divided upto family when mapped using aerial photos.

To study soil degradation, areas in NW India and Central India were taken and studied using Landsat imagery and aerial photographs. Soil salinity was mapped in three categories, such as slightly, moderately and strongly salt affected areas, on aerial photographs as well as Landsat imagery. The areal extent as measured on both these products was also not significantly different. Waterlogging, canal seepage areas and depressions were mapped separately from aerial photos whereas these had to be merged together while mapping through Landsat imagery. The area delineated on Landsat imagery was considerably less than the actual, as delineated through air photos and confirmed on the ground. It was mainly due to season, as the data belonged to January when most of the flood prone areas have become dry after monsoon. Ravines were delineated as shallow, moderately deep and deep using aerial photos, while all three classes were merged into one while interpreting Landsat imagery. Some of the non-ravinous areas, adjoining ravines were also misinterpreted as ravines using Landsat data.

However, keeping in view time and cost which is about one fourth as compared to using aerial photos, Landsat imagery is good in mapping soils at scale 1:250,000 or smaller upto sub-group level of soil classification. Salt affected soils can be mapped accurately and ravines can be mapped within reasonable accuracy. To identify and map waterlogged areas accurately, Landsat imagery of proper season is required.

## SESSION 7: FIRE FUEL MAPPING

MODERATOR: W. BONNER

1. Vegetation and Fire Fuel Models Mapping of North Cascades National Park, by R. R. Root, S. C. F. Stitt, M. O. Nyquist, G. S. Waggoner, and J. K. Agee, National Park Service.

2. Operational Fire Fuels Mapping with NOAA-AVHRR Data, by R. A. McKinley, E. Chine, Technicolor Government Services, Inc. L. Werth, Bureau of Land Management.

3. Comparison of Fire Fuel Maps Produced Using MSS and AVHRR Data, by W. A. Miller, U.S. Geological Survey. D. C. Johnston, Technicolor Government Services, Inc.

4. The Use of Wildland Fire Fuel Maps Produced with NOAA AVHRR Scanner Data, by L. Werth, Bureau of Land Management. R. A. McKinley, E. Chine, Technicolor Government Services, Inc.

5. Fire Management's Use of Landsat Derived Resource Data Bases, by P. W. Gum, U.S. Forest Service.

# VEGETATION AND FIRE FUEL MODELS MAPPING OF NORTH CASCADES NATIONAL PARK

By Ralph R. Root, Susan C. F. Stitt, Maurice O. Nyquist,
Gary S. Waggoner, and James K. Agee

## ABSTRACT

A digital data base was created for North Cascades National Park and immediate surroundings using geographic information system (GIS) techniques. Landsat 2 and 3 multispectral scanner (MSS) data, Defense Mapping Agency (DMA) digital terrain models, and a manually digitized map of local precipitation zones were the data sources used. The purpose of the project was to derive vegetation/landcover and fire fuel models classifications. A late July, 1979 Landsat 3 scene covered most of the park, and a late June, 1978 Landsat 2 scene provided data for a small section in the southeastern corner of the study area.

The 1979 MSS data was processed through a series of Earth Resources Laboratory Application Software (ELAS) programs to produce "unsupervised" homogenous training statistics which in turn were used for a maximum likelihood classification over the entire data set within the study area. The resulting 38 spectral classes were lumped into 9 broad cover type classes. The scene was georeferenced to the Universal Transverse Mercator (UTM) grid projection, and output with a 50 meter cell size. The June, 1978 Landsat 2 scene was similarly processed, using signature extension techniques, and was merged to the July, 1979 data.

DMA digital topographic data were processed into elevation, slope, and aspect models using ELAS program modules, and resampled to register with the Landsat data. Precipitation zones and park boundary lines were manually digitized and subsequently converted to ELAS data raster format. These data were registerd with both the Landsat data and topographic models, creating a 5-layer data base.

Using another ELAS software module to extract unique combinations of the general Landsat cover type map, slope, elevation, aspect, and precipitation zones, a 22-class vegetation map (e.g., Douglas fir closed canopy, Douglas fir open canopy, silver fir closed canopy, silver fir open canopy, etc.), was produced. Field checking at 820 plots on the ground showed this map to have an overall accuracy of 84%.

This final, more detailed map, which was the first comprehensive vegetation map for the park, was then used as a basis for producing "best fit" National Fire Danger Rating System (NFDRS) models, and best fit Northern Forest Fire Lab (NFFL) models. A total of 10 NFDRS models and 7 NFFL models were assigned to appropriate combinations of vegetation classes, also creating the first comprehensive fire fuel models maps of the park.

As fuels information is analyzed from 425 ground plots, using computerized fuel modeling techniques in the U.S. Forest Service BEHAVE software, new custom fire fuel models will eventually be developed and incorporated after they are sufficiently verified by field testing.

# OPERATIONAL FIRE FUELS MAPPING WITH NOAA-AVHRR DATA

By Randy A. McKinley, Edward Chine, and Lee Werth

## ABSTRACT

The Bureau of Land Management is currently developing a general fire fuels data base for the eleven western contiguous states, excluding Washington. This project is in support of the Boise Interageny Fire Center's (BIFC) effort to develop the Initial Attack Management System (IAMS). An operational technique has been developed which utilizes NOAA-AVHRR remotely sensed data to produce vegetation cover information suitable for aggregation to broad scale fire fuel classes. This technique utilizes pre-processing steps which include raw data evaluation and manipulation, multi-scene registration, and multi-date data base development. To transform base data into useful vegetation information, digital image processing procedures including ratioing (ie.normalized difference calculation), principle components analysis, clustering, and classification are employed. This paper expands strictly upon the above technical procedures and alerts prospective users to inherent limitations of similar data sets.

# COMPARISON OF FIRE FUEL MAPS PRODUCED USING MSS AND AVHRR DATA

By Wayne A. Miller and David C. Johnston

## ABSTRACT

The Bureau of Land Management (BLM) has a national fire program that uses an Initial Attack Management System (IAMS) located at the Boise Interagency Fire Center in Idaho to provide real-time information to fire management officers. IAMS is a geobased information system that uses data from three different sources registered to a one-minute latitude/longitude grid. The three data sources are (1) an automatic lightning detection system, (2) a remote automatic weather station, and (3) a fire fuel digital data base. Currently, information relating to fire fuels, a component of the fire fuel digital data base, is obtained through the manual interpretation of Landsat multispectral scanner (MSS) images (1:250,000 scale). Because this approach is labor intensive, BLM has been interested in determining if digital image analysis of Advanced Very High Resolution Radiometer (AVHRR) data can provide similar results for less cost. Therefore, a study was initiated between BLM and the National Mapping Division's Earth Resources Observation Systems (EROS) Data Center to determine the accuracy and cost effectiveness of using MSS or AVHRR data to develop fire fuel information in support of the IAMS program.

Fire fuel information for Malheur County in eastern Oregon had been previously derived using both MSS and AVHRR data. Using stratified random sampling techniques, 165 samples were independently selected from each information source and field checked. The accuracy of the two sources of information was similar (approximately 90 percent overall), and for an area the size of Malheur County (6.4 million acres), the costs were about the same ($12,000 or 0.19 cents per acre). But the cost per acre was substantially lower where digital analysis of AVHRR data were used to derive fire fuel information for a 42-million-acre area in eastern Oregon. It only cost $16,000 or approximately 0.04 cents per acre.

Based upon the results of this study, the BLM has decided to use digital analysis of AVHRR data to support their operational fire fuel mapping program.

# THE USE OF WILDLAND FIRE FUEL MAPS PRODUCED WITH NOAA AVHRR SCANNER DATA

by Lee Werth, Randy McKinley, and Ed Chine

## ABSTRACT

In the near future, BLM fire managers will initiate operational use of the Initial Attack Management System (IAMS). The system is designed to assist local fire management personnel make accurate and rapid dispatch decisions. The components of IAMS are Automatic Lightning Detection System (ALDS), Remote Automatic Weather System (RAWS), terrain data, and fire fuels data. The Service Center (Denver) in conjunction with the Boise Interagency Fire Center and BLM Washington Office are working closely with the BLM State and District Offices to map fire fuels and produce terrain data layers for the IAMS data base. Fire managers will access IAMS via microcomputers at local offices.

By 1988, fire fuel maps will be generated for BLM Districts within 10 western States. Because of time and dollar restrictions and monitoring potential, AVHRR data was chosen to prepare the fire fuels maps. The fire fuel classes represent aggregations of vegetation types that have similar fire behavior characteristics. Since ALDS is only accurate to within 1 mile, the IAMS data base and subsequently the fire fuel classes, will be represented by 1 minute latitude and longitude or 664 acre cells (varies depending on latitude) using 1:250,000 USGS base maps. Besides the digital data retrievable locally via microcomputer for initial attack, the Districts will have 1:250,000 Versatec hard copy maps that can be used for wildfire and prescribed fire planning.

AVHRR spectral data had to be stratified with elevation data to separate some fuel classes that were important to the California and Nevada fire community. Some fuel classes that could not be separated with the combination of AVHRR and terrain data had to be digitized from existing maps and then imbedded into the classification. Districts are reporting overall accuracies of 70-80% but the real evaluation will take place during the 1985 fire season when IAMS becomes operational. It may prove necessary to modify the AVHRR fuel map as problem areas are identified and/or greater levels of detail are required in key areas.

# FIRE MANAGEMENT'S USE OF LANDSAT DERIVED RESOURCE DATA BASES

By Philip W. Gum

## ABSTRACT

The utilization of fire effects as the driving force for developing fire management direction in the Okanogan National Forest's Land Management Plan created a need for resource information and decision supporting tools which had not previously existed. A determination of the data/answers needed to make the most correct decision created the problem of acquiring natural resource data bases which were species specific, highly accurate and at a cost which could be afforded. After reviewing "in hand" data bases and decision supporting tools it was decided to acquire new data bases utilizing Landsat imagery and ancillary information for species specific vegetation, forest crown closure, slope, aspect, and elevation mapping at a .6 acre resolution and at a classification accuracy greater than 80 percent.

All data layers, mapping, etc., would be tied to and compatible with Geolock mapping system which utilizes latitude and longitude, ortho photos, and USGS 7.5 minute quads. Each USGS 7.5 minute quad is gridded into 400 Geolock cells which at 54 degrees N. Latitude constitute approximately 82 acres each. This mapping system enables users to take advantage of electronic location devices such as Loran C to increase speed and accuracy in initially locating fire incidents.

Although vegetation by species and diameter class, crown closure, and terrain by slope, aspect and elevation were originally mapped and data base integrity maintained at a .6 acre resolution, we required the information to be summarized by Geolock cell for use in our fire management computerized dispatch system (GRIP). The Geolock cells become the geographical data base size for collecting and storing the necessary data to accurately, within model limitations, calculate fire behavior and therefore fire effects of any given fire.

Down dead woody material was not either estimated nor were correlations with plant associations/vegetative types made using Landsat since this information was derived from other processes. However, fuel models based on brush and grass fuels are readily mapped provided tree crown closure is not complete.

Information from automatic lighting detection system (ALDS), fire weather utilizing remote automated fire weather stations (RAWS), wildland fuel models, land management objectives, current and potential productivity mapping, inherent value at risk assessments, priority guides, fire weather seasonal predictive guides, slope, aspect, elevation, crown closure, and vegetation by species and size class are all combined by interactive computer programs utilizing DG MV8000 to display to decision makers desired information. Information is to be displayed for both the 2 minute Initial Attack decision as well as alternative fire strategy analysis.

## SESSION 8: MAPPING AND MONITORING WILDLIFE HABITAT

MODERATOR: B. SCHRUMPF

1. Landsat-Facilitated Vegetation Classification of the Kenai National Wildlife Refuge and Adjacent Areas, Alaska, by S. S. Talbot, U.S. Fish and Wildlife Service. M. B. Shasby, Technicolor Government Services, Inc. T. N. Bailey, Kenai National Wildlife Refuge.

2. Elk Habitat Evaluation Using Distance-Transformed Landsat Data, by R. Murray, Oregon State University. D. A. Leckenby, Oregon Dept. of Fish and Wildlife.

3. Stream/Riparian Area Inventory and Monitoring Using Large Scale Color Infrared Airphotos, by P. Cuplin and F. Batson, Bureau of Land Management.

4. Operational Methods and Emerging Technologies for the Assessment and Monitoring of Wildlife Habitat in Developing Countries, by B. D. Treadwell, Wildlife and Remote Sensing Consultant. S. Berwick, International Institute for Environment and Development. P. L. Warren, Arizona Remote Sensing Center.

5. Mapping the Green Leaf Area Index of Rangeland with Airborne Multispectral Scanner Data, by P. J. Curran and H. D. Williamson, University of Sheffield, United Kingdom.

# LANDSAT-FACILITATED VEGETATION CLASSIFICATION OF THE KENAI NATIONAL WILDLIFE REFUGE AND ADJACENT AREAS, ALASKA

By Stephen S. Talbot, Mark B. Shasby and Theodore N. Bailey

## ABSTRACT

A Landsat-assisted vegetation map was prepared for Kenai National Wildlife Refuge (1.97 million acres). The refuge lies within the middle boreal subzone of south central Alaska. Seven major classes and sixteen subclasses were recognized: forest (closed needleleaf, needleleaf woodland, mixed), deciduous scrub (lowland and montane, subalpine), dwarf scrub (dwarf scrub tundra, lichen tundra, dwarf scrub and lichen tundra, dwarf scrub peatland, string bog/wetlands), herb (graminoid meadows and marshes), scarcely vegetated areas, water (clear, moderately turbid, highly turbid), and glaciers.

The methodology employed a modified cluster-block technique. Sample areas were described based on a combination of helicopter-ground survey, aerial photo interpretation, and digital Landsat data. Major steps in the Landsat analysis involved: preprocessing (geometric correction), spectral class labeling of sample areas, derivation of statistical parameters for spectral classes, preliminary classification of the entire study area using a maximum-likelihood algorithm, and final classification through ancillary information such as digital elevation data.

The vegetation map (scale 1:250,000) was a pioneering effort since there were no intermediate-scale maps of the area. Representative of distinctive regional patterns, the map was suitable for use in comprehensive conservation planning and wildlife management.

# ELK HABITAT EVALUATION USING DISTANCE-TRANSFORMED LANDSAT DATA

By RJay Murray and Donavin A. Leckenby

## ABSTRACT

Landsat Multispectral (MSS) data that have been transformed into distance-from-edge classes is the basic information source used in an operational system developed for Rocky Mountain Elk habitat evaluation. The Environmental Remote Sensing Applications Laboratory (ERSAL) and the Oregon Department of Fish and Wildlife have developed the computer-based system, accessible via remote terminals, which is used by field biologists to: delineate areal MSS data blocks, distance-transform the related classification data, and print hard-copy maps and summaries. Data resulting from the computer-assisted processing were used to calculate a Habitat Effectiveness Index (HEI) for different management plans, especially for alternate cutting patterns within areas of active timber harvesting. Distance-transformed data has general utility and can be used in many applications that have a distinct spatial component.

Examples based on timber sales affecting the primary elk habitat components--forage, thermal cover, hiding cover--are used to illustrate the procedures. The intensity of habitat component use by elk has been documented previously in comprehensive field observations. Picture elements of forage and cover habitat components were grouped into less-than-optimal, optimal, and exceeds-optimal classes defined by their distance from a habitat edge. HEI's for each management alternative were then computed from the transformed data. Repeated calculations for several management alternatives enabled modeling the cumulative effects of several sales on habitat conditions throughout an elk management unit.

The occurrence and balance of habitat components was readily evident to laypersons and experts alike. Those groups evaluated the areal data, coded and displayed by distance classes, to decide which management action would maintain or enhance cover and forage for elk. This format clearly depicted relevant information for groups participating in public reveiws of management plans for logging sales. Automated handling of habitat and distance data helped biologists provide managers with detailed HEI analyses at appropriate times during the decision process.

Obtaining accurate minimum distances from a combination of edges is not a trivial computational task. Pre-computed distance tables, indexed by row-column increments within a maximum distance disk, are used for accurate and computationally efficient transformations. Program modules are available for the following operations: extracting areas from a central file, re-assigning class symbols, changing symbols for a "patch" within a delineated region, distance-transforming classification data, and generating 7.5 minute quadrangle-matching line printer maps (1:24,000 scale). A common, raster-format file structure is used in all program modules. As a result, data entry and program execution for each module are standardized.

# STREAM/RIPARIAN AREA INVENTORY AND MONITORING USING LARGE SCALE COLOR INFRARED AIRPHOTOS

By Paul Cuplin and Fred Batson

ABSTRACT

There is an increasing level of interest in inventory and monitoring of critical stream/riparian environments. The Bureau of Land Management has investigated the use of remote sensing procedures to increase the efficiency of traditional ground-based methodologies.

Ground data collection combined with photo interpretation of large scale color infrared airphotos at a scale of 1:2,000 in 9- x 9-inch format provides inventory and monitoring capability for riparian areas on arid land streams/riparian areas.

Variables that can be photo interpreted from large scale color infrared airphotos and used to detect change in riparian areas are stream width, flood plain width, stream channel stability, stream bank stability, stream shade, ground cover trees, shrubs, herbaceous vegetation, bare soil, riparian area and width, density and structure of large trees and shrubs.

# OPERATIONAL METHODS AND EMERGING TECHNOLOGIES FOR THE ASSESSMENT AND MONITORING OF WILDLIFE HABITAT IN DEVELOPING COUNTRIES

By B. Dean Treadwell, Steven Berwick, and Peter L. Warren

## ABSTRACT

Remote sensing has a proven applicability for providing a wide variety of information required for wildlife habitat assessment and monitoring. Habitat types as defined by physiography, substrate and plant cover, spatial distribution, and degree of interspersion, forage quality, and changes over time have all been successfully addressed by remote sensing methods. Regional information needs, for example the distribution of riparian forests, are perhaps the easiest to accommodate, but more specific data, such as the current distribution of water points and available forage are more useful for actual management. Certain information needs, such as the activity areas of poachers as evidenced by trails through tall grass, require virtually instant availability of the overflight record.

Successful implementation of remote sensing technology in many developing countries can be limited by various constraints including the timely processing of films, the necessary refrigeration of color infrared film, the availability of suitable aircraft, the timely acquisition of permits and other logistical requirements, and the level of counterpart expertise. Monitoring programs require that all aspects of the technology, including the equipment, the means for processing and analysis, and the trained counterparts, remain in the country and operational. Recurrent costs must also be provided.

Small format (35 and 70 mm) aerial photography offers a versatile and economical system which can provide either complete coverage of moderate size areas, or sub-sample coverage for regional applications or monitoring programs. Dual camera configurations can be adapted to most aircraft to provide multi-scale and/or multi-emulsion photography. The equipment is sturdy and reliable, easy to operate and inexpensive enough to be left in-country for program continuation.

New developments in solid state video camera technology have produced a potentially valuable tool for habitat assessment. These low-cost, rugged, self-contained systems can record data in several spectral bands including near- and mid-infrared and offer instant availability of the overflight record. With computer interface capabilities and the availability of micro-computers, a complete acquisition/analysis system can be assembled at a reasonable cost.

The ultra-light aircraft is an inexpensive platform for remote sensing systems. Although ultra-lights are neither suitable for every situation, the minimal operational costs of these aircraft enable frequent and repetitive overflights and a limited portability via trailering if required. The successful application of remote sensing technology for wildlife habitat assessment and monitoring requires a thoughtful marriage of the most appropriate methods, recurrent funding requirements, and the thorough logistical planning designed to surmount the inherent constraints encountered in many developing countries.

# MAPPING THE GREEN LEAF AREA INDEX OF RANGELAND WITH AIRBORNE MULTISPECTRAL SCANNER DATA

By Paul J Curran and H Dawn Williamson

## ABSTRACT

Remotely sensed data have been used to discriminate between vegetated areas but a more testing application of remotely sensed data is the estimation of vegetation amount within these areas. In this experiment, airborne multispectral scanner data, collected in June 1984 were used to estimate the green leaf area index (GLAI) of 60 km² of rangeland. The initial methodology involved: (i) radiometric and atmospheric correction, (ii) production of a vegetation index, (iii) calculation of the relationship between a vegetation index and GLAI, (iv) production of an image of GLAI by inversion of (iii) and (v) accuracy assessment. The initial accuracy of GLAI estimation was ± 0.75 GLAI for an area and 17-40% at the 95% confidence level for a six class classification.

A number of changes in the experimental methodology were evaluated by their effect upon the accuracy of GLAI estimation. In order of increasing importance these changes were: suppression of environmental effects in the remotely sensed data, processing on a per-field rather than a per-pixel basis, improvements in the method for calculating the calibration relationship between the remotely sensed data and GLAI and allowance for error in the ground data. By utilising these findings in a refined methodology the accuracy of GLAI estimation increased to ± 0.15 GLAI for an area and 67-87% at the 95% confidence level for a five class classification.

The refined methodology was then applied to an airborne MSS data set collected for 100 km² of the same rangeland in August 1984. The accuracy of GLAI estimation was similar at ± 0.22 GLAI for an area and 55-92% at the 95% confidence level for a five class classification.

## SESSION 9: GLOBAL RESOURCE ASSESSMENT

MODERATOR: G. THORLEY

1. Monitoring the Earth--Too Many Players?, by G. A. Thorley, U.S. Geological Survey.

2. The Relationship of Global Green Leaf Biomass to Atmospheric $CO_2$ Concentrations, by C. J. Tucker, NASA/Goddard Space Flight Center. I. Y. Fung, NASA/Goddard Institute for Space Studies. C. D. Keeling, Scripps Institution of Oceanography. R. H. Gammon, NOAA.

3. Quantity and Areal Distribution of Soil Organic Carbon as Related to Vegetation Cover Classes Derived from Landsat Data, by P. J. Zinke, E. Katibah, H. Jenny, and A. Stangenberger, University of California-Berkeley.

4. Monitoring Tropical Forests from Satellite and Aircraft Platforms: Some Limitations and New Approaches, by S. A. Sader, A. T. Joyce, and R. B. Waide, NASA/National Space Technology Laboratories.

5. An Ecoregion-Continuum Approach to Global Vegetative Biomass Estimation, by T. L. Logan, Jet Propulsion Laboratory.

6. Predicting Change in Basic Ecosystem Processes from Properties of the Vegetative Canopy, by R. H. Waring, Oregon State University.

# MONITORING THE EARTH--TOO MANY PLAYERS?

By Gene A. Thorley

## ABSTRACT

Remote sensing from satellites provides a unique tool to measure the parameters of the Earth on a worldwide scale. These measurements assist in improving our understanding of such complex Earth systems as the atmosphere, biosphere, lithosphere, and hydrosphere. Modeling the Earth as an integrated system through the use of satellite measurements may lead to new scientific insights and fundamental knowledge heretofore not possible due to the limitations of regional and in situ measurement capabilities.

A number of organizations are currently engaged in, or proposing to embark on, worldwide measurement/monitoring programs. Program objectives vary in type and complexity, including a form of technical library (the Global Environment Monitoring System of the United Nations Environment Program), and an ambitious experiment to validate algorithms to derive land surface climatological parameters (International Satellite Land Surface Climatology Project).

Modeling and understanding the Earth as an integrated system is an immense undertaking and will require at least as many measurements as currently acquired. Improved coordination is required among the diverse national and international measurement/monitoring programs to ensure that sensors, launch dates, orbits, and supporting research are complementary to the maximum extent possible. Development of a long-term program of Earth system monitoring/modeling, such as the International Global Change Program proposed by the International Council of Scientific Unions, could provide the necessary focus and structure for effective international coordination and cooperation.

# THE RELATIONSHIP OF GLOBAL GREEN LEAF BIOMASS TO ATMOSPHERIC $CO_2$ CONCENTRATIONS

By C. J. Tucker, I. Y. Fung, C. D. Keeling, and R. H. Gammon

## ABSTRACT

Advanced very high resolution radiometer data from the National Oceanic and Atmospheric Administration's polar orbiting meteorological satellite have been obtained globally for a 19-month period, processed to produce a green leaf biomass spectral vegetation index for the entire terrestrial surface by month, zonally aggregated by latitude, and compared to atmospheric $CO_2$ concentrations from observing stations. A strong inverse association was found between the monthly Pt. Barrow $CO_2$ concentrations and the vegetation index measurements from 50°N - 80°N, between the monthly Mauna Loa $CO_2$ concentrations and the vegetation index measurements from 10°N - 30°N, 10°N - 80°N, and the global total, and between the globally averaged $CO_2$ concentrations and the globally averaged vegetation index. No relationships between atmospheric $CO_2$ concentrations for the South Pole station and the vegetation index measurements from any latitude zone or combinations of zones were found.

# QUANTITY AND AREAL DISTRIBUTION OF SOIL ORGANIC CARBON AS RELATED TO VEGETATION COVER CLASSES DERIVED FROM LANDSAT DATA

By Paul J. Zinke, Edward Katibah, Hans Jenny, and Allan Stangenberger

## ABSTRACT

The amount of soil organic carbon storage is an important element in the determination of the global carbon balance involving atmospheric carbon dioxide. Remote sensing offers the means of making a global assessment of terrestrial organic carbon storage in biomass and in associated soils.

The results presented in this paper are from an investigation designed to examine the applicability of a remote sensing aided system for estimating the quantity and areal distribution of soil organic storage in a test site including the central Sierra Nevada of California. The study site was chosen because it contained sufficient remote sensing, soils, vegetation, and associated data. A non-remote sensing aided approach was compared with a remote sensing aided technique for soil organic carbon estimation.

The study area was a full Landsat data scene extending diagonally between Fresno and Mono Lake, California. The landscape was stratified based upon soil-related variables of constant geologic parent material (granite), and vegetation as major cover classes.

The remote sensing data for the area was sampled by censoring out all non-granite areas based upon existing geologic maps. Nineteen sample blocks of 15,000 pixel size were then chosen on appropriate Landsat Multispectral Scanner digital data for classification into the vegetation classes using 7 to 5 ratio values known to encompass the six major cover classes.

Available meter depth soil carbon storage data based upon numerous soil pit samples and analyses were distributed to their respective cover classes and cumulative probability distributions of organic carbon storage and appropriate central tendencies calculated for each cover class.

Total carbon storage calculated for the study area by non-remote sensing aided estimate was $.18 \times 10^{12}$ kilograms (.18 gigatons) with a confidence interval of 11.25%; while using the remote sensing stratification the estimate was $.12 \times 10^{12}$ kilograms (.12 gigatons) with a confidence interval of 3.54% (+ -). We conclude that in areas where there are adequate ground data the remote sensing data classification allows a more sensitive estimate of total soil organic carbon.

# MONITORING TROPICAL FORESTS FROM SATELLITE AND AIRCRAFT PLATFORMS: SOME LIMITATIONS AND NEW APPROACHES

By Steven A. Sader, Armond T. Joyce, and Robert B. Waide

## ABSTRACT

Tropical forests have great importance with respect to the global energy balance, climate, geochemical cycle and various beneficial resources they provide to mankind. Remotely sensed data and appropriate sampling techniques within a geographic data base may offer the best opportunity to inventory and monitor tropical (frost-free) environments. The complexity of mixed tropical forest has little parrallel with the coniferous forests of North America where much of the previous remote sensing applications have been demonstrated. Frequent cloud cover, inaccessible terrain, data acquisition problems, and closed, diverse forest canopies with high leaf area indices create difficult challenges for remote sensing studies in tropical regions.

Estimates of tropical deforestation rates differ by more than 100% with no quantifiable basis to determine the accuracy of the most frequently quoted estimates. Recent investigations in Costa Rica have shown that forest clearing rates and trends can be linked to biophysical characteristics of forest landscapes and proximity to road networks. Quantitative information on these relationships and data from other countries will form the basis for predictive modeling of changes in the forest environment in tropical regions.

Previous investigations of tropical forest species identification and forest inventory using Landsat MSS have met with limited success. Until recently, there has not been any significant research in tropical forest regions using scanners with spectral and spatial resolution equivalent to Landsat TM. Studies in Puerto Rico with aircraft acquired TMS have shown spectral differences related to forest successional stages and mountain life zone communities. Stratification of forest environments using ecological and terrain data enhance the identification of some tropical forest communities.

In consideration of the persistent cloud cover over tropical regions, different polarizations of aircraft L-band, synthetic aperature radar (SAR) data and coregistered TM and SAR data sets were analyzed to determine the relationship between SAR backscatter and forest structure parameters - crown closure, physiognomy, relative height and area. A laser profiler was capable of penetrating a dense tropical wet forest canopy in Costa Rica. Measurements were compared to tree height measurements collected along the profiler track. Canopy height and terrain profile can be measured accurately with laser profilers or radar altimeters which provide an important variable (canopy height) needed in the estimation of above ground biomass.

Results of these remote sensing investigations that address biomass estimation and estimation of "deforestation event probabilities" will be integrated into a multistage forest inventory and monitoring design. Remote sensing techniques and geographic information systems are viewed by the international research community as technology with great potential to contribute new information and scientific understanding of critical global environmental issues.

# AN ECOREGION-CONTINUUM APPROACH TO GLOBAL VEGETATIVE BIOMASS ESTIMATION

Thomas L. Logan

## ABSTRACT

The global estimation of vegetative biomass involves a complex spatial problem that may be broken into smaller components for intensive analysis and comprehension of fundamental relationships. Considering the large differences in canopy expression (and biomass quantities) between forest and monocultural environments, the use of a regional approach to biomass estimation appears reasonable. This paper draws upon the results of monocultural (and near monocultural) biomass estimation research in the literature, and a research project in which the biomass of a coniferous forest was accurately estimated from satellite imagery, to propose the hypothesis that different biomass/spectral relationships exist for each vegetative ecoregion. It is further proposed that the biomass/spectral relationships are actually a continuum across the various vegetative environments.

In 1983, research was completed that developed a look-up table procedure for accurately estimating the total standing biomass (carbon) of a coniferous forest from NOAA-6 AVHRR spectral imagery. The look-up table is derived from a graph which bears resemblance to a two-dimensional 'Rooster's Tail,' with well defined crescentic layers of biomass plotted against AVHRR channels 1 (RED) and 2 (NIR). The approach differs from conventional regression techniques by providing a simple mathematical mechanism for compensating for the non-linearities in biomass/spectral relationships.

Numerous researchers have established linear and near-linear regression relationships for agricultural and grassland environments. However, as the vegetative environment becomes heterogeneous (mixed species, increasing trees, progressing toward forestation), the biomass/spectral relationships become progressively more non-linear, reducing the reliability of regression techniques. This has led to observation that different biomass/spectral relationships exist for each vegetative environment (or ecoregion). It is hypothesized that the biomass/spectral relationships are actually a continuum across the various vegetative environments with the 'Rooster's Tail' being condensed for agricultural environments, and 'fanning' out as heterogenity increases. This occurs much like the natural environment which is a continuum from monocultural to heterogeneous forested conditions. If reliable biomass/spectral trends can be established across the progression of ecoregions, then approximate biomass (and carbon) quantities (and change) can be easily predicted on a global scale using the table look-up technique.

# PREDICTING CHANGE IN BASIC ECOSYSTEM PROCESSES FROM PROPERTIES OF THE VEGETATIVE CANOPY

By R.H. Waring

## ABSTRACT

Certain characteristics of vegetative canopies are indicative of such ecosystem processes as photosynthesis, transpiration, respiration, and decomposition. These processes depart from normal long before changes in the composition of vegetation occur; they are, therefore, harbingers of change. A new generation of satellite-borne sensors gives promise of adequately discriminating spectral reflectance in key wave-lengths to evaluate canopy properties from space. Moreover, certain types of measurements provide clues to whether changes in the water balance, nutrient availability, temperature, or air qualilty are likely causes of alterations in basic ecosystem processes.

Seasonal or annual changes in canopy photosynthesis are mirrored by changes in the amount of solar radiation absorbed in the 400-700 nm band. In general, an improvement in the environment allows fuller canopies to develop and their display to be extended in time. A reduction in canopy and in duration of display follows adverse changes in environment.

Plant respiration rates depend on the amount of living tissue present and seasonal changes in temperature. The amount and height of vegetative canopy is correlated closely with living biomass and may be estimated with microwave or laser sensors. Temperature is a climatic variable measurable from satellites carrying appropriate thermal sensors.

Transpiration is a function of a number of climatic variables (wind, humidity, temperature, and solar radiation load) and two vegetative properties: the amount of active canopy and its departure in temperature from that of the air. The latter measurement indirectly relates to the extent that stomata are open. All of these variables can be remotely sensed.

Decomposition depends on the amount and quality of organic litter produced annually and surface temperature and moisture conditions. The amount of canopy shed can be estimated by seasonal extremes in photosynthetic activity. Quality can be biochemically defined from the ratio of lignin to protein nitrogen; the higher the ratio, the slower the rate of decomposition. An imaging spectrometer with resolution of 10nm over the range from 400 -2400 nm holds promise for discriminating spectral characteristics unique for both lignin and protein nitrogen.

Change in the lignin/protein nitrogen ratio not only affects decomposition but also indicates changes in the palatability of plants to animals and susceptibility to many diseases. It reflects alterations in the ratio of photosynthesis to nutrient uptake. As the ratio increases, a proportionally larger amount of photosynthate is allocated to roots rather than to foliage.

In addition to the processes described, remote sensing may also provide insight into causes for alterations attributed to moisture stress (sensed in the infrared spectrum) and heavy metal toxicity (noted by a shift in the near infrared toward the blue end of the spectrum).

By focusing on the the basic processes operating in all ecosystems it should be possible to diagnose subtle changes and better predict the effects of drought, fertilization, climate warming, and air pollution on vegetation and the associated changes in animals populations, soil formation, atmospheric chemistry, and hydrology.

## SESSION 10: NEW AND EMERGING TECHNOLOGY -- DATA ACQUISITION

MODERATOR: W. BARNES

1. An Airborne Imaging System for Measuring Bi-Directional Reflectance, by W. L. Barnes, F. G. Huegel, and J. R. Irons, NASA/Goddard Space Flight Center.

2. High Spectral Resolution Remote Sensing with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), by G. Vane, Jet Propulsion Laboratory.

3. Research Optical Sensor, by C. F. Schueler, Hughes Santa Barbara Research Center.

4. MODIS: A Moderate-Resolution Imaging System for the Space Station Polar-Orbiting Platform, by W. L. Barnes, NASA/Goddard Space Flight Center.

5. Imaging Spectrometry: What the Future Holds, by A. F. H. Goetz, Jet Propulsion Laboratory.

# AN AIRBORNE IMAGING SYSTEM FOR MEASURING BI-DIRECTIONAL REFLECTANCE

By W. L. Barnes, F. C. Huegel, and J. R. Irons

## ABSTRACT

An airborne system to image the bi-directional reflectance of plant canopies in 32 spectral bands between 0.4 and 0.8 micrometers has been developed and tested at Goddard Space Flight Center. The system consists of the Advanced Solid-state Array Spectroradiometer (ASAS), a 32-channel imaging spectrometer, and a semi-automated pointing system that allows the ASAS to be pointed 45° fore or aft of nadir. The system has been flown on an SC-7 Skyvan at an altitude of 3.0 kilometers. At this altitude the ASAS has a nadir spatial resolution of 2.6 meter and a swath of 1.3 kilometer. The pointing system allows the acquisition of 150 lines of data at 10° fore-aft pointing increments. Thus, ten angular views of 32 spectral channels each can be acquired in a single pass.

Initial experiments will be to quantify atmospheric effects on multiple angle measurements of bi-directional reflectance and to examine the bi-directional reflectance of forest canopies.

# HIGH SPECTRAL RESOLUTION REMOTE SENSING WITH THE AIRBORNE VISIBLE/INFRARED IMAGING SPECTROMETER (AVIRIS)

By Gregg Vane

## ABSTRACT

The value of high spectral resolution remote sensing has been thoroughly demonstrated in the recent past through the use of several airborne and spaceborne spectroradiometers and a prototype infrared imaging spectrometer which has been developed at the Jet Propulsion Laboratory. Imaging spectrometry is defined as the simultaneous acquisition of images in many narrow contiguous spectral bands. This approach to imaging allows a complete reflectance spectrum to be reconstructed for each picture element (pixel) in the scene. If the surface materials in the scene have unique spectral signatures, the information in the reconstructed spectrum will allow these materials to be directly and uniquely identified on a pixel-by-pixel basis. Many naturally occurring surface materials have diagnostic absorption features that are 20 to 40 nm in width at the half power points; it is for these types of materials that imaging spectrometry has proven especially effective. Examples of the successful application of imaging spectrometry to geological and botanical remote sensing will be presented from data acquired with the prototype instrument mentioned above.

A second-generation sensor is now under construction at JPL which will image the 0.4 to 2.4 um region in 224 contiguous 10 nm spectral bands. This instrument, which is called the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), will be an operational NASA facility instrument to be flown on the NASA U-2 and ER-2 when it is completed in 1987. From an operating altitude of 20 km, AVIRIS will have a ground pixel size of 20 m and swath width of 11 km, giving images that are 550 pixels across. Data will be encoded to 10 bits to take advantage of the high radiometric performance of the instrument. Signal-to-noise ratios of about 200 to 1 and 100 to 1 are expected in the visible and short wavelength infrared respectively. The foreoptics of AVIRIS consist of a modified Kennedy scanner with a three-sided mirror designed to scan a field of view of 33 degrees. Light collected by the foreoptics is split between four spectrometers which are optically connected to the foreoptics with light fibers. At the focus of each spectrometer is a line array of detectors. The spectrometer for the visible portion of the spectrum uses a 32 element silicon line array while each of the three spectrometers for the near and short wavelength infrared uses a 64 element line array of indium antimonide.

A key element of the AVIRIS system is the data handling facility also under construction at JPL which is based on a VAX 11-780 minicomputer. This facility will provide the archiving and retrieval of all AVIRIS data. The facility has been sized to permit the complete pre-processing of a given data set within two weeks of acquisition. Pre-processing consists first of converting the raw data recorded aboard the U-2 on a high density tape to a computer compatible 6250 bpi tape (CCT) which is the archival medium. The archival CCT will contain the raw image data and the engineering, calibration and aircraft motion data acquired with the image data. Retrieval processing, which will be done only on those portions of the raw data requested by experimenters, will consist of radiometric correction to the raw data using the appropriate calibration data, and geometric corrections based on knowledge of aircraft motion.

AVIRIS experimenters will be chosen by NASA through the "dear colleague" letter process. The first letter will be released in Spring 1986. For details, contact Dr. Robert E. Murphy, Earth Science and Applications Division, NASA.

# RESEARCH OPTICAL SENSOR

By Carl F. Schueler

## ABSTRACT

Advances in Landsat sensor technology at Santa Barbara Research Center (SBRC) have been sponsored by the National Aeronautics and Space Administration's Goddard Space Flight Center (GSFC). The most recent development in this area is a concept known as the Research Optical Sensor (ROS). ROS is intended for land resource research, and must provide excellent spatial, spectral, and radiometric resolution, plus ground programmable data acquisition flexibility so that the sensor can be tailored on-orbit to specific research requirements. Fundamental imaging requirements that ROS must satisfy include a ground resolution of 10 meters in the visible and near infrared (VNIR) and 20 meters in the short-wave infrared (SWIR), many spectral bands covering the VNIR and SWIR at a spectral resolution of 20 nanometers, and enhanced pointing capability for bidirectional reflectance distribution function (BRDF) measurement as well as for stereo and cross-track imaging. A variety of sensor concepts were initially examined to arrive at a flexible MLA design for land resource scientists.

# MODIS: A MODERATE-RESOLUTION IMAGING SYSTEM FOR THE SPACE STATION POLAR-ORBITING PLATFORM

By W. L. Barnes

## ABSTRACT

The Space Station being developed by NASA includes in its baseline configuration both polar and equatorial unmanned platforms. The Earth Observing System (EOS), a proposed sensor compliment for the polar platform, includes the Moderate-resolution Imaging System (MODIS) as part of its initial orbital configuration. MODIS is designed to generate a 10-year data base for a wide variety of remote sensing research problems in the areas of ocean, atmosphere and land science. The system consists of 52-spectral channels viewing a 1500 kilometer swath in the wavelength region from 0.4 to 12.0 micrometers. The ten thermal channels will image the Earth daily with a spatial resolution of 1.0 kilometer, while the channels measuring reflected solar radiance will survey the Earth once every 2 days with a spatial resolution of 500 meters (12 channels) or 1.0 kilometer (30 channels). MODIS will consist of two sensor packages designated MODIS-T (tilt) and MODIS-N (nadir). In order to avoid specular reflectance from the ocean surface, MODIS-T, which will include 17 spectral channels in the visible and near infrared (<1.0 micrometer) region, can be tilted to view fore and aft 20° while scanning $\pm$ 45° crosstrack. MODIS-N will view nadir and also scan $\pm$ 45° crosstrack with a total of 35 spectral channels.

Preliminary sensitivity studies have indicated that a whisk-broom scanner with an imaging spectrometer aft optics system is feasible for MODIS-T while a whisk-broom scanner with 71 individual filter/ detector modules in the focal plane will meet the MODIS-N requirements.

# IMAGING SPECTROMETRY: WHAT THE FUTURE HOLDS

Alexander F. H. Goetz

## ABSTRACT

Imaging spectrometry for Earth remote sensing has developed over the last few years to satisfy the need for more precise remote sensing information than can be gathered by broad-band multispectral scanners. The goal is to create images in which each picture element represents a composite spectrum of all the materials within an instanteous-field-of-view. That is equivalent to a laboratory spectrum both in spectral as well as radiometric resolution. If these criteria are met then all the information theoretically available about the surface composition will be acquired by the sensor.

Research during the last five years, both in the field and in the laboratory, has revealed the potential of high-spectral resolution remote sensing for studies of rocks, soils, vegetation and water, all the components of the Earth's surface. Technological developments in the area of infrared area array detectors, optics and data systems have made it possible to build imaging spectrometer sensors that cover the wavelength region of reflected sunlight from 0.4 to 2.5μm.

An imaging spectrometry program being implemented at the Jet Propulsion Laboratory and contains four sensor elements. At present the Airborne Imaging Spectrometer (AIS) is the only sensor collecting data. It acquires images in 128 bands simultaneously in the wavelength region 1.2 to 2.4μm. In late 1986 the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), now under construction, will be operational. This instrument, to be flown on the NASA ERS-2, will cover a swath 11 km wide and collect image data in 224 spectral bands between 0.4 and 2.4μm simultaneously. The next step, presently in the planning stage, is the Shuttle Imaging Spectrometer Experiment (SISEX) which will acquire data on a global basis in 128 spectral bands over a 12 km swath. A follow-on to SISEX, called the High-Resolution Imaging Spectrometer (HIRIS), is envisioned for the space platform expected to be launched in the mid 1990's. HIRIS would acquire data similar to SISEX, but over a swath 50 or more kilometers in width.

Technology is now available to develop imaging spectrometer sensors as well as to handle and analyze the vast quantities of data that will be produced. The stage is set for a new era in remote sensing in which a much larger number of questions can be addressed with remote sensing since the full information content of the reflected signal can be acquired and utilized.

The research described in this summary was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

SESSION 11: NEW AND EMERGING TECHNOLOGY -- DATA PROCESSING

MODERATOR: M. DEVIRIAN

1. The Massively Parallel Processor - Programming and Applications, by H. K. Ramapriyan, J. P. Strong, and J. C. Tilton, NASA/Goddard Space Flight Center.

2. Concurrent Processing Technology for Land Remote Sensing, by J. E. Solomon and M. Lee, Jet Propulsion Laboratory.

3. Employing Geographic Reasoning in Ecoregion Mapping, by J. W. Merchant, University of Kansas.

4. Analysis of Image Processing Algorithms for Classifying the Forests of Northern Minnesota, by S. R. Yool, J. L. Star, J. E. Estes, and D. B. Botkin, University of California-Santa Barbara.

5. Interpretation of Forest Cover on Microwave and Optical Satellite Imagery, by P. W. Mueller, R. M. Hoffer, and D. F. Lozano-Garcia, Purdue University.

# THE MASSIVELY PARALLEL PROCESSOR - PROGRAMMING AND APPLICATIONS

BY H. K. Ramapriyan, J. P. Strong and J. C. Tilton

## ABSTRACT

The Massively Parallel Processor (MPP) is a unique computer capable of orders of magnitude higher computational speeds than conventional computers.

The MPP was conceptualized at the Goddard Space Flight Center (GSFC) in 1977 and developed, under contract, by the Goodyear Aerospace Corporation (GAC). It was delivered to GSFC in May 1983. Since then, GSFC has been active in integrating it with a VAX-11/780 host computer and developing systems and applications software.

The MPP is a Single Instruction Multiple Data (SIMD) computer consisting of 16,384 relatively simple processing elements (PE's) configured as a 128 x 128 array. Each PE has a 1024-bit local memory and is capable of arithmetic and logical operations in a bit-serial fashion. Also, each PE is connected to its four nearest neighbors (N, E, S, W) thus permitting shifting an entire bit-plane of data by one step in the array in one cycle (100 nsec). This arrangement makes the MPP ideally suited for image processing where point or local neighborhood operations can take advantage of the parallelism. As an example, the MPP can perform eight bit additions at the rate of over 6 billion per second.

Various tools are available to facilitate programming the MPP. The best speeds possible are achieved using the MPP's assembly lanaguage (MCL). However, the speed gains provided by the MPP are considerable even when it is programmed in the high order language currently available on the MPP: Parallel Pascal (PP).

Several image processing algorithms are being programmed for the MPP. These include general image and matrix manipulation subroutines which can be incorporated into larger programs, and computationally intensive techniques which typically take over 1/2 hour of CPU time on conventional computers for moderate image sizes (512 x 512, 4 to 7 bands). Some of the remote sensing applications programs being implemented are: Thematic Mapper Geometric Correction, Synthetic Aperture Radar (SAR) Signal Processing, Automatic Matching of Stereo-Pairs of SAR images to generate digital elevation data (as a part of the Shuttle Imaging Radar-B - SIR-B - experiment), general geometric correction including accounting for elevation, Textural Feature Extraction, Iterative Clustering (ISODATA and CLASSY), Per-Point Maximum Likelihod Classification, Contextual Classification and Connected Component Labeling. The paper will provide details of the timings and sample outputs from these programs.

Typically, it is found that programs which are severely compute-bound on other computers become I/O bound on the MPP. This situation will prevail until the conventional peripheral devices feeding the MPP are upgraded.

# CONCURRENT PROCESSING TECHNOLOGY FOR LAND REMOTE SENSING

By Jerry E. Solomon and Meemong Lee

## ABSTRACT

As the available data for land remote sensing becomes increasingly larger and more complex, e.g., thematic mapper, imaging spectrometer, and synthetic aperture radar imagery, the need for cost effective powerful computational resources becomes greater. Many scientists find their ability to utilize these new types of data severely limited by locally available computer facilities since most do not have easy access to super-computer class machines. Help appears to be on the way in the form of high performance/cost ratio machines built around the concepts of concurrent processing utilizing low-cost microprocessors as the basic building blocks. The field is a rapidly expanding one with a great diversity in the architectures being proposed and built. The purpose of this paper is to present a short overview of the current state of the field and an in-depth look at a specific concurrent processor implementation. A detailed discussion is presented of results obtained using the California Institute of Technology (Caltech) nearest neighbor concurrent processor (NNCP), sometimes referred to as the "hypercube", for image processing and analysis problems. Efficient utilization of concurrent processor machines requires a very different approach to algorithm design and implementation than in the case of serial machines. The machine architecture is described and a discussion of the implications of this architecture for image processing algorithm developed is given. Finally, the potential for constructing a super-computer "workstation" is described in light of the experience gained from the NNCP machine.

# EMPLOYING GEOGRAPHIC REASONING IN ECOREGION MAPPING

By James W. Merchant

## ABSTRACT

Algorithms currently used to classify multispectral scanner (MSS) data are founded, almost exclusively, upon spectral pattern recognition techniques. Spectrally-based classification algorithms have been found to be effective in distinguishing many types of "land cover" (e.g., grass, coniferous forest, water). They have been less successfully employed to identify and map landscape regions (e.g., ecoregions, land use regions) which, although of vital interest to wildland resource managers, cannot be demarcated on the basis of spectral characteristics alone. Such regions are characterized not only by land cover composition, but by the distinctive manner in which cover types are distributed and arranged.

Visual image interpreters routinely employ spatial cues evident in a scene to aid in data classification and mapping. Such cues may include parcel size, parcel shape, pattern, texture, context and associations of cover types. Visual image interpretation also, almost always, requires a systematic, logical approach to data analysis and employs deductive reasoning and inference.

The principal objective of this research is to explore the manner in which thematic mapping efforts based upon Landsat digital data might be improved by more rigorous application of "geographic reasoning" and "spatial logic." "Geographic reasoning" is defined as the systematic application of geographic knowledge and understandings in analysis of data acquired via remote sensing for the purpose of accomplishing a specific set of objectives. A strategy for employing such reasoning in classification of Landsat Thematic Mapper data is proposed. The strategy is founded upon "spatial logic," logic that seeks to emulate important aspects of visual image interpretation. Spatial logic is developed as the image analyst transforms observations, understandings and geographic knowledge of the landscape into decision rules which can be applied in data analysis to segment that landscape into regions of interest.

An experiment designed to test the proposed strategy is summarized. Thematic Mapper data are initially stratified into water, vegetated and non-vegetated pixels. A region-growing algorithm is then used to define "fields" of similar land cover composition. Fields are characterized by size and neighborhood attributes. Hierarchical clustering is employed to test the hypothesis that the diversity, field sizes and spatial interspersion of land cover types are useful discriminants of ecological regions. The hypothesis is shown valid. The significance of the results is discussed. It is suggested that artificial intelligence concepts and techniques will facilitate development of complex data analysis strategies which employ spatial logic.

# ANALYSIS OF IMAGE PROCESSING ALGORITHMS FOR CLASSIFYING THE FORESTS OF NORTHERN MINNESOTA

By S. R. Yool, J. L. Star, J. E. Estes, and D. B. Botkin

## ABSTRACT

It is important to test the limits of space-based sensor data and associated processing algorithms to understand their potential for the production of world forest maps of verified accuracy. Such maps are needed to evaluate concerns that massive forest clearing will result in new carbon dioxide emissions to the atmosphere, promoting global warming and related environmental effects. Landsat data from a forest test site in northeastern Minnesota is used to evaluate waveband ratios, staistical filters and principal components algorithms for large-area forest classification. These algorithms were used with Landsat data to produce spectral variables. Performances of the spectral variables were ranked based on their accuracy in classifying vegetation at the Minnesota test site. Analysis of performance indicates that no single spectral variable is best overall for forest classification, but performance appears to depend on the vegetation class and the spectral variable used. Differences in performance appear to be related to variations in background reflectance, surface illumination and spatial pattern by class. These results underscore the complexity of the relations between the land cover regime, remotely-sensed data, and the algorithms used to process these data.

# INTERPRETATION OF FOREST COVER ON MICROWAVE AND OPTICAL SATELLITE IMAGERY

By P. W. Mueller, R. M. Hoffer, and D. F. Lozano-Garcia

## ABSTRACT

Since 1972, when the Landsat-1 satellite first obtained Multispectral Scanner (MSS) data of the earth's surface, numerous studies have demonstrated the effectiveness of computer-aided analysis of such optical satellite data for mapping forest and other broad cover types. In 1982, a new generation optical scanner—the Thematic Mapper (TM)—was launched, thereby providing multispectral data with greater spectral dimensionality, finer spectral resolution, and finer spatial resolution. The potential usefulness of satellite synthetic aperture (SAR) radar was demonstrated by imagery obtained by the Seasat SAR and Shuttle Imaging Radar-A (SIR-A) sensors, in 1978 and 1981 respectively. In October 1984, the Shuttle Imaging Radar-B sensor (SIR-B) was operated from the cargo bay of the Space Shuttle orbiter Challenger. The SIR-B sensor operated at a 23.5 cm (L-band) wavelength with a HH polarization as did Seasat and SIR-A, but had the additional capabilities of variable look-angles and onboard digital recording.

Both SIR-B and TM data were acquired for a predominantly forested area of northeastern Florida. On October 9, 10, and 11, 1984, three different sets of radar data were acquired, each at a different look-angle—28°, 45°, and 58°. The TM data utilized in the study was acquired on October 12, 1984.

This study investigated the information content of the various TM bands and the three SIR-B look-angle data sets. Digital techniques were used to produce enhanced imagery which was studied to determine the utility and importance of the various bands and look-angles as they pertain to forest resources. The results indicate that both the optical and microwave portions of the electromagnetic spectrum provide a variety of information about the forest and other cover types present.

Major forest cover types within both deciduous and coniferous forest categories can be distinguished on the SAR data due to the different radar returns at the different look-angles, as well as on the TM data, particularly the near and middle infrared wavelengths, due to differences in spectral response. Edge effects from forest stands are very distinctive on the SAR data due to the side look-angle of this instrument system, but are not evident on the TM data. There was also an obvious difference between flooded and non-flooded forest stands on the SAR data. These and other features of this interesting set of TM and SAR data will be presented and discussed in this paper.