VIEWING NOTES

The Role of Numerical Analysis in Forest Management

by Roger M. Hoffer

VIDEOTAPE SERIES

Introduction to Quantitative Analysis of Remote Sensing Data

Inquiries about the VIDEOTAPE SERIES may be directed to:

CONTINUING EDUCATION ADMINISTRATION
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PREFACE

Remote sensing helps provide up-to-date information critical to the management of earth resources on a regional, national, and international level. As data collection and communication techniques are refined, as computational and analysis technologies evolve, and as sophisticated output devices become more economical, remote sensing will play an ever larger role as a source of information. The videotape you are about to see is one in a group of educational programs developed at Purdue University to keep scientists and administrators abreast of this rapidly evolving technology.

Purdue University has long been a leader in the development of remote sensing technology through the Laboratory for Applications of Remote Sensing (LARS). For over fifteen-years, the interdisciplinary staff, from the schools of agriculture, engineering, and science, has been responsible for much of the development in remote sensing and has gained world-wide recognition through these accomplishments. Today, activities at the Laboratory include both fundamental research and applications research, with additional major emphasis on training people in the use of quantitative remote sensing systems and developing educational materials to foster understanding of the technology.

Several key aspects of remote sensing technology are addressed in these videotapes, which make up the series Introduction to Quantitative Analysis of Remote Sensing Data. The tapes focus on such topics as scene radiation, data collection and preprocessing, and data analysis -- from both theoretical and applications perspectives -- and each from the perspective of a single scientist who is recognized as an expert in the field. In this way, when you view each tape, you are able to share personally in the insights and judgements offered on this increasingly important technology.

Videotape presentations in the series include the following titles:

The Role of Numerical Analysis in Forest Management by Roger M. Hoffer, professor of forestry.
The Role of Pattern Recognition in Remote Sensing by Philip H. Swain, associate professor of electrical engineering.
The Remote Sensing Information System by David A. Landgrebe, professor of electrical engineering and associate dean of engineering.
Correction and Enhancement of Digital Image Data by Paul E. Anuta, research engineer.
Spectral Properties of Soils by Marion F. Baumgardner, professor of Agronomy.

Level and Prerequisites

The videotape series was prepared for graduate and advanced undergraduate students and professionals new to the field of remote sensing. Before viewing this tape, you should already have a basic understanding of remote sensing and its related terminology, such as can be gained through any of a number of introductory texts or through studying selected minicourses in the series Fundamentals of Remote Sensing (Purdue University, 1976, 1980).

Despite the mathematical and statistical nature of some aspects of the technology, the videotapes have been prepared with non-mathematical audiences in mind. Whenever possible mathematical relationships are illustrated graphically and described verbally. You may wish to consult the textbook Remote Sensing, the Quantitative Approach, edited by Philip H. Swain and Shirley M. Davis (McGraw-Hill Book Company, New York, 1978), for in-depth explanations of many of the concepts presented.

About the Author

Roger M. Hoffer is professor of forestry at Purdue University and program leader of ecosystems research programs at the Laboratory for Applications of Remote Sensing. He teaches three courses in remote sensing and has lectured, consulted, and participated in remote sensing activities in South America, Asia, and Europe. He was the 1978 recipient of the Alan Gordon Memorial Award from the American Society of Photogrammetry for his significant achievements in remote sensing, is a three-time recipient of ASP Presidential Awards for Meritorious Service and was elected as a "best teacher" in 1979 by the Purdue Student Association.

Professor Hoffer has served as principal investigator on Landsat, Skylab, and other major remote sensing projects and has authored over 100 scientific papers on remote sensing. His research has focused on the use and refinement of computer-aided analysis techniques for forestry applications and on the study of the spectral characteristics of earth surface features.

Acknowledgements

Others at Purdue University who contributed to this videotaped program were Mason C. Carter, head of the department of forestry and natural resources; Shirley M. Davis, senior education and training specialist; James D. Russell, associate professor of education; Neil Sydor, producer-director; Susan L. Ferringer and Kathleen Z. Barash, visual designers; and Sara Jane Coffman, instructional developer. Music by Richard K. Thomas. Viewing notes were prepared by James Tilton.

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Time: 27 minutes

The Role of Numerical Analysis in Forest Management

by Roger M. Hoffer

Synopsis

The forests of the world are an important resource that requires intelligent, effective management. Current, accurate information about many aspects of the forest is essential to meet various management objectives. Many types of information needed can be obtained through the analysis of digital data collected by satellite. Classification of multispectral data over forest areas, where the vegetation is complex, is best accomplished with the multi-cluster blocks approach, a way to develop training statistics that blends the supervised and non-supervised approaches.

In mountainous regions, the addition of digital topographic data to the spectral data may further improve the capability to map forest cover types using current satellite data. With digital techniques it is also convenient to analyze satellite data collected on different dates in order to make use of changes in the scene over time; this is an important source of information for many purposes, for example to aid in assessing damage caused by insect infestations.

The geographic data base--a concept that has evolved along with the computer technology--has the potential for providing "customized" information required to meet specific needs of forest managers. Remote sensing and quantitative analysis techniques will have an increasingly important role in forest management in the next decade.

Objectives

Upon completion of this videotape, you should be able to:

1. List five major benefits obtained from forest lands.

2. State three advantages of using Landsat data for obtaining forest management information.

3. Describe three different techniques for training a computer to perform classifications. State which training technique was found to be best for classifying Landsat data of forested areas.

4. Briefly describe three techniques for using topographic data in combination with Landsat data.

5. State an advantage for using Landsat data obtained over the same area on different dates.

6. Explain the concept of a standardized data base for resource management using Landsat data as a foundation.

-- TURN PAGE --

-- BEGIN VIEWING THE TAPE --

I. Information Requirements of Forest Management

The forests of the United States are one of the nation's most valuable resources. They provide

- timber for wood and wood industries,
- outdoor recreation,
- food and cover for wildlife,
- rangeland for grazing, and
- soil and water conservation.

> "Because of the demands that are placed on forests to meet so many consumer needs, it's vital that the forest resource be managed effectively and efficiently."

Such management requires reliable, current, and accurate information. Different levels of management need information at varying degrees of detail:

Level of Management	Information Requirement
National	Overall statistics in tabular form
Regional	Maps and tables showing the location of timber, growth patterns and logging operations
Local	Detailed forest maps over relatively small areas

> "[Trees are] a crop with a rotation of from 30 to 80 years.... The effects of proper management--or mismanagement--stretch over many decades." (from G. Robinson Barker, St. Regis Paper Company)

II. Primary Data Sources for Forest Management Information

A. Field Measurements
B. Aerial Photography
C. Landsat Satellite Data

Satellite data and computer analysis is used to augment aircraft data and field data.

> "...computers and satellites don't eliminate costly field work or large-scale photography, but they make it possible to use relatively expensive, ground-based data-gathering techniques more effectively."

Advantages of Landsat as a data collector include:

- fast data collection over large areas,
- repeat coverage of the same area, and
- digital format.

The digital form of Landsat data allows it to be overlaid with timber inventory and other land information and analyzed on a computer. This adds speed and flexibility to the handling of forest management information.

> "With the help of computers these data can then be organized and analyzed in such a way that the best management decisions can be made."

III. <u>Analysis of Landsat Forest Imagery</u>

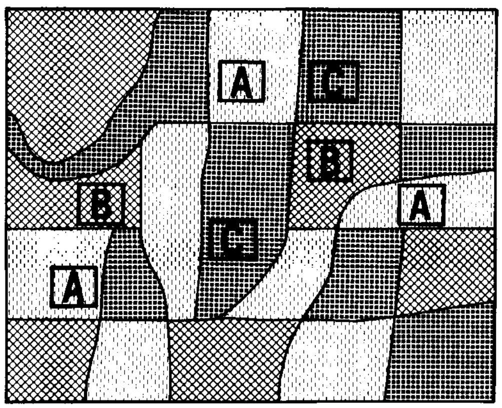
Computer-aided analysis usually consists of

- development of training statistics and
- computer classification of the entire data set.

A. Development of Training Statistics

Training statistics are generally developed using one of the following three methods:

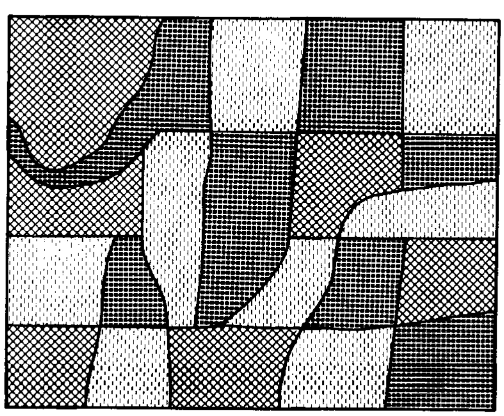
1. Supervised Technique



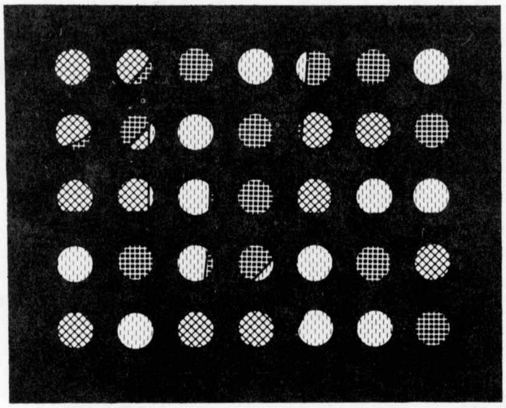
Training statistics are developed from areas of known cover type called "training fields". Ideally, the training fields should cover only a relatively small portion of the data set involved.

> "The supervised technique has been used quite effectively for agricultural mapping, but is of somewhat less value in forestry applications.... The primary reason for this is the difficulty in defining areas that represent <u>all</u> of the significant variations in spectral response for every cover type of interest."

2. Unsupervised (clustering) Technique



The entire data set is classified according to spectral characteristics of natural data clusters as defined by the computer. Field reference data and/or aerial photography is used to associate the naturally occurring spectral classes with ground features of interest.

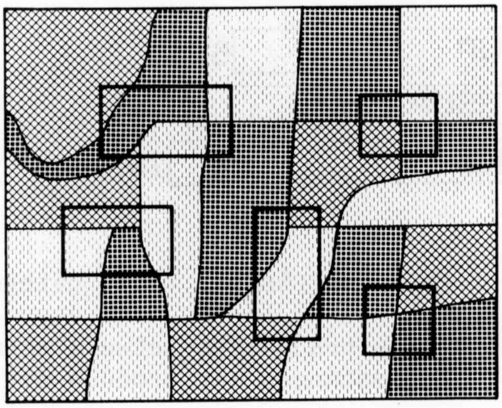


To reduce cost, a systematic sample of the data ponts can be used in the clustering process.

"We've found that the clustering technique effectively overcomes the primary limitation of the 'supervised' technique; but when we're working with large areas, the amount of computer time required by the iterative clustering sequence makes this technique very <u>expensive</u>."

3. Multi-Cluster Blocks Approach

The multi-cluster blocks technique is a combination of the supervised and non-supervised (clustering) techniques.



As in the supervised technique, several training areas are designated by the analyst. In the multi-cluster blocks technique, however, <u>each</u> training area contains <u>several</u> cover types and spectral classes.

As in the unsupervised technique, the training areas are clustered (classified according to spectral characteristics) and the spectral classes are associated with ground features of interest. In this way the natural spectral groupings present in the data are discovered.

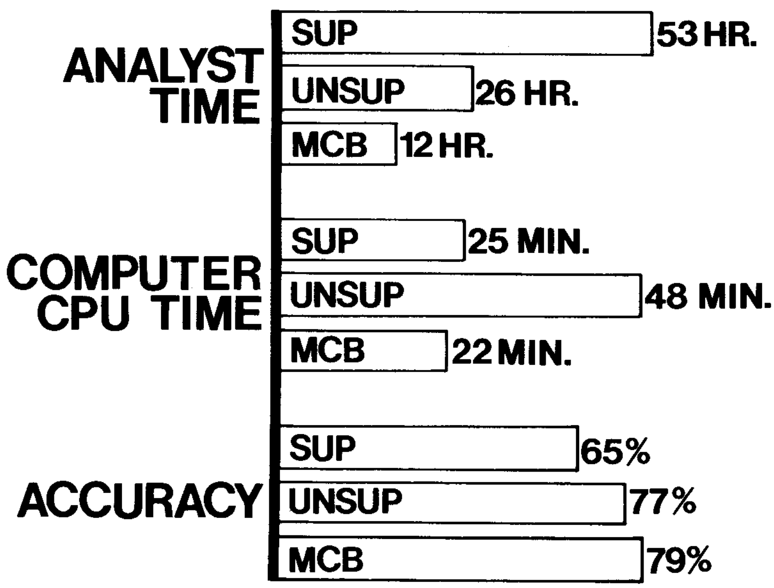
"In practice, less than one percent of the total area to be classified is used in this training phase.... This makes the multi-cluster blocks technique a very efficient procedure."

B. Comparison of Methods for Developing Training Statistics

The supervised, unsupervised and multi-cluster blocks (MCB) techniques were evaluated by comparing them in terms of

- analyst time,
- computer CPU time, and
- classification accuracy

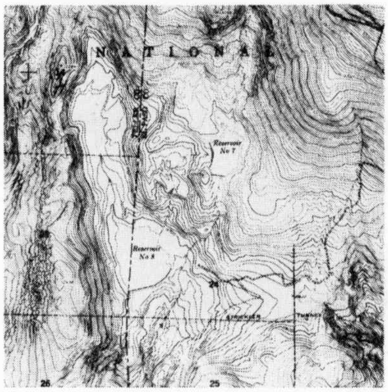
when used to analyze Landsat data of a heterogeneous forested area.



‖ "Multi-cluster blocks performed best in all three categories...."

Any analysis such as this involves trade-offs between accuracy required and costs. Different circumstances may produce different results.

IV. Using Topographic Data with Landsat Data

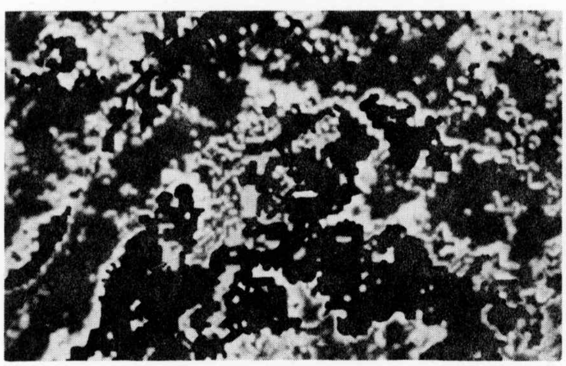


"When topographic data is available in digital format and overlaid pixel-by-pixel on Landsat data, analysts have a flexible and powerful management tool."

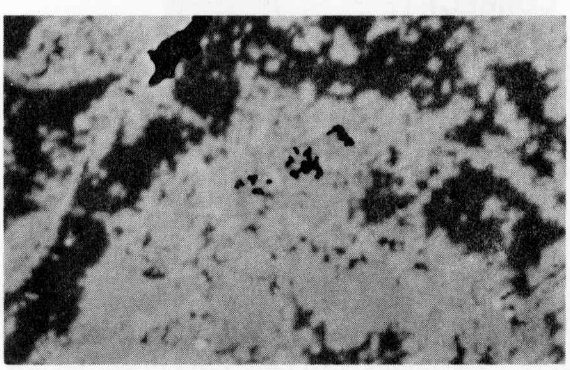
Three ways to use this combined data are:

A. Post-Classification

"...topographic data can be used <u>after</u> a classification of spectral data to refine broad classes."



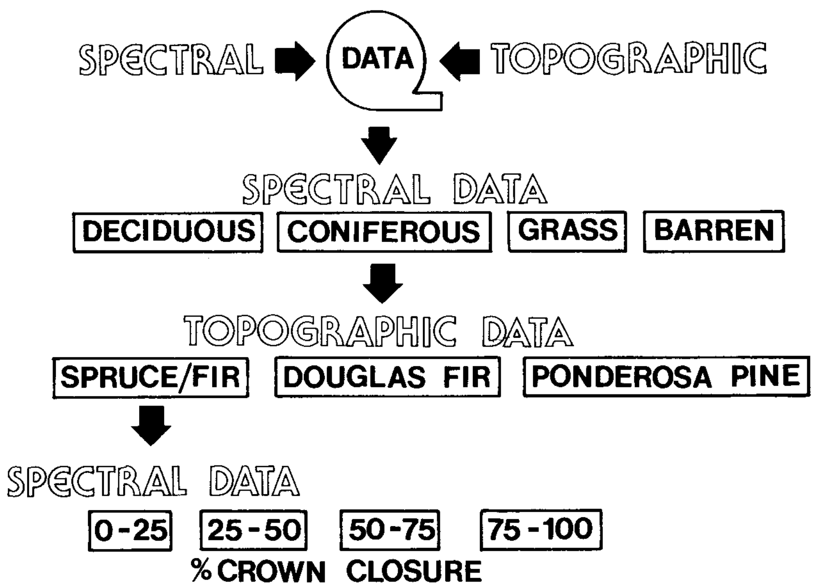
In the elk and deer winter range example, first a cover type classification was made based on Landsat data alone.



Then winter range areas were identified as those locations which were classified as an appropriate cover type and <u>also</u> had the appropriate elevation, slope and aspect, as indicated by the topographic data.

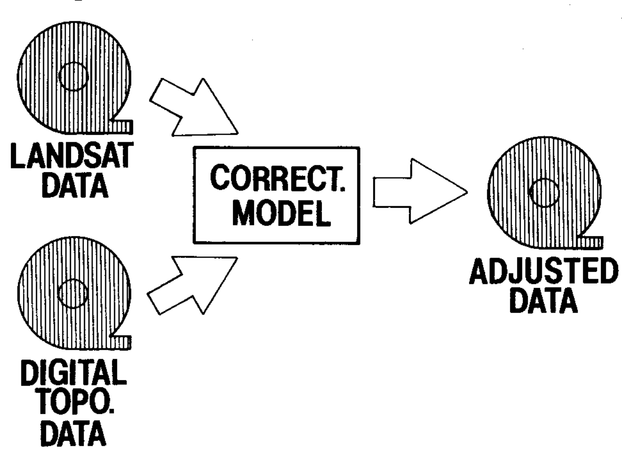
B. Layered Classification

Topographic data can be used in conjunction with Landsat data as a part of a sequential analysis procedure using a layered classification technique in order to produce cover type maps to a greater level of detail than can be achieved using Landsat data alone.



Major cover types are first classified using spectral data. Topographic data is then used to classify forest species according to elevation. Spectral data can then be used again, this time to separate individual species into various density classes.

C. Illumination Angle Adjustment

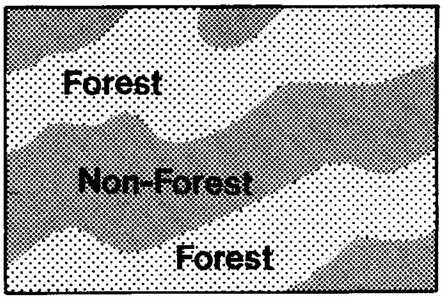


A model can be developed to adjust the Landsat data for variations in illumination by using topographic information and the position of the satellite relative to the sun. (Although often referred to as a correction, strictly speaking this is an adjustment rather than a correction.)

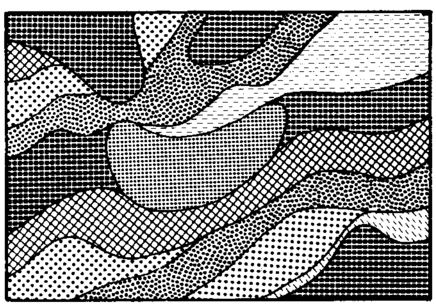
V. Multitemporal Landsat Data Sets

Landsat data collected on different days can be overlaid and analyzed together. Such multitemporal data sets can often yield information which cannot be obtained using single-date data.

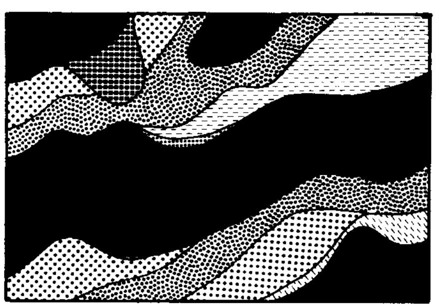
Example: Gypsy Moth defoliation (Courtesy of Darrel Williams, Goddard Space Flight Center)



Use a Landsat image from a previous year when there was no defoliation, and classify into forest versus non-forest.



Register this year's image which shows defoliation damage to the previous years' data base.

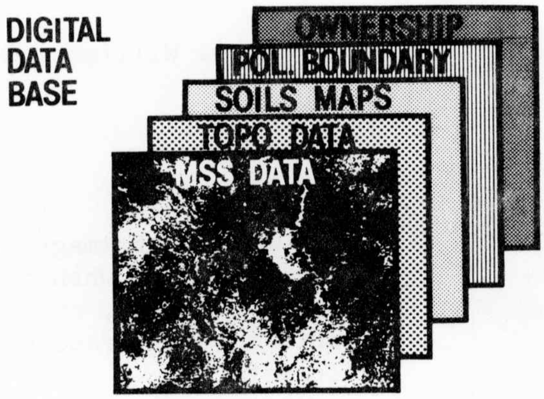


Apply the forest/non-forest mask and classify only the forested areas into the various defoliation categories.

This process eliminates 'errors of commission' where Gypsy Moth defoliation is erroneously indicated in non-forest areas.

The repetitive coverage of Landsat is what makes the use of multitemporal data so effective.

VI. Landsat MSS Data as Foundation for Standardized Data Bases



"Other characteristics of Landsat--its synoptic view and uniformity of image scale--also make it an effective foundation for standardized data bases. The possibility of combining satellite multispectral data with other kinds of data in a geographic data base provides tremendous potential for resource managers. In this way Landsat data from one or several dates can serve as a foundation for topographic data, land-ownership data, soils information, political boundaries, watershed boundaries, and many others."

VII. Summary

We've discussed

- the need of forest managers to have accurate and current information,
- digital Landsat data as a data source for forest management,
- techniques for developing training statistics for computer-aided classification of forested areas,
- how the addition of topographic data to digital Landsat data can improve classification accuracy
- how multi-temporal data can be used to extract information not otherwise obtainable, and
- how data bases are extremely flexible tools for handling information important to forest management.

"It seems apparent that in the years ahead, as new techniques are developed and tested, remote sensing and quantitative analysis techniques will play an increasingly important role in providing resource managers with the type of information which they require for effective resource management."

SELF-CHECK QUESTIONS

1. What are five major benefits obtained from forest lands?

2. Why is the digital format of Landsat data an advantage?

3. In determining which technique is best for a particular Landsat data analysis problem, what are three criteria that can be used in comparing possible techniques?

4. What is the key factor that allows Landsat data to serve as an effective foundation for standardized data bases? What are four types of data that could be correlated with Landsat data to form a data base for a particular area?

CHALLENGE QUESTIONS

1. How are training fields selected in the supervised technique for developing training statistics? How does the method for developing training statistics differ when using the unsupervised technique? What are the characteristics of the training areas selected when using the multi-cluster blocks technique?

2. Explain how topographic data can be used after computer classification of spectral data to further refine the classification.

3. How can multitemporal/multispectral data sets be used to prevent the classification of particular portions of a data set into an impossible class?

FURTHER READING

Hoffer, R.M. 1976. "Techniques and Applications for Computer-Aided Analysis of Multispectral Scanner Data." Invited Paper. Proceedings of the XVI World Congress of the International Union of Forest Research Organizations, Oslo, Norway, June 1976. Also available as LARS Information Note 062276, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47907.

Fleming, M.D. and R.M. Hoffer. 1979. "Machine Processing of Landsat MSS Data and DMA Topographic Data for Forest Cover Type Mapping." Proceedings of the 1979 Symposium on Machine Processing of Remote Sensed Data, Purdue University, West Lafayette, Indiana. pp. 337-390.

Hoffer, R.M. and P.H. Swain. 1980. "Computer Processing of Satellite Data for Assessing Agricultural, Forest, and Rangeland Resources." International Archives of Photogrammetry, Vol. XXIII, Part B7, Commission VII, published by the XIV International Congress for Photogrammetry, Hamburg, Germany, 1980. Also available as LARS Information Note 072580, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47907.

Hoffer, R.M. 1979. "Computer-Aided Analysis of Remote Sensor Data--Magic, Mystery, or Myth?" Invited paper. Proceedings of the International Conference on Remote Sensing in Natural Resources, University of Idaho, Moscow, Idaho. Also available as LARS Information Note 041381, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47907.

ANSWERS TO SELF-CHECK QUESTIONS

1. Five major benefits obtained from forest lands are timber for wood and wood industries, outdoor recreation, food and cover for wildlife, rangeland for grazing, and soil and water conservation.

2. The digital format of Landsat data allows it to be overlaid with other types of data and analyzed on a computer. Computer analysis adds speed and flexibility to the analysis procedure.

3. Three criteria that can be used in comparing possible Landsat data analysis techniques are analyst time, computer CPU time, and classification accuracy.

4. The key factor that allows Landsat data to serve as an effective foundation for standardized data bases is its digital format. Types of data that could be correlated with Landsat data to form a data base for a particular area include topographic data, land-ownership data, soils information, political boundaries and watershed boundaries.