Appendix F
Forestry

Remote-sensing techniques have been widely used by forestry companies and individual consultants for many years. The most frequently used type of remotely sensed data are black-and-white panchromatic aerial photos, usually having **a scale of 1:15,840** (i.e., **4** inches = 1 mile). Such photos show a tremendous amount of detail about the forest and other surface features; stereo pairs of photos can be used to obtain information about the species of trees present, number of trees per acre, area] extent of the forest stands, location and characteristics of existing or needed transportation networks, etc. Although a tremendous amount of highly useful information can be obtained from aerial photos, much of this information requires imagery having high levels of spatial detail—individual tree crowns, topographic characteristics of the terrain, etc. It is largely for this reason that many people have questioned the value of Landsat data for meeting information needs in forestry, since the ground resolution of each Landsat pixel is approximately **59 X 79** meters.

However, several different levels of detail are needed in characterizing or evaluating the forest resource. At the most detailed level, one must obtain actual measurements in the field from a sample of individual trees to estimate the merchantable timber volume per acre in individual stands of timber. On the other end of the scale, knowledge of the location and extent of forest stands is also important. It is this type of information for which Landsat data are of particular value, since the location and extent of forests can change dramatically over the course of a few years or even from one year to the next.

In other words, the average rate of growth of individual species of trees is known. Once the species composition of a specific stand has been determined, the changes in stand volume can be predicted reasonably well, barring unforeseen changes due to fire, insects, or disease. These unforeseen changes, from natural or human causes, require periodic assessment of the areal extent of forest lands; this can best be accomplished quickly and cost effectively by remote sensing. Traditionally, the forest industry has used aerial photography.

In recent years, as the quality of both aerial cameras and film has improved, and as the capability for obtaining photos from high-altitude aircraft has been developed, the use of relatively small-scale (e.g., 1:120,000) aerial photos has been of interest to forest industries because of the relative economy of such photography for many applications.

For example, in Maine, the Great Northern Timber Co. uses 1:120,000-scale color infrared photos for a wide variety of timber land and road network assessments, and for monitoring logging operations (i. e., the extent and location of clearcut **areas).** The company converts the information derived from these aerial photos into digital form and adds it to a data base which is part of a highly sophisticated Georeferenced Information System (GIS). The foresters at Great Northern are highly interested in the potential of Landsat data to supply much of the information they need, but they have yet not incorporated them into their procedures because of their concern about the continued availability of Landsat data in a standardized format, and the recent very large increases in the cost of the computer-compatible types (CCTs), If the price for digital Landsat data rises too high, they will continue to rely on aerial photography, where the cost of obtaining the necessary data and the source of data are known, predictable factors.

The Southern Timberlands Division of St. Regis Paper Co. (headquartered in Jacksonville, Fla.) has also developed a sophisticated GIS, which is tied into the corporate computer network. St. Regis foresters were interested in integrating the data from such a system into their forest management operations. Because some of the early research results appeared promising, St. Regis submitted a proposal to the National Aeronautics and Space Administration to evaluate the use of such data for meeting some of the information needs of the forest industry. St. Regis asked Purdue University to work with them on this project.

Researchers set up a three-phase evaluation of the Landsat data and digital-processing techniques. Phase I involved a detailed assessment of the benefits and limitations of using Landsat data to meet operational information needs of the Southern Timberlands Division. Specifically, the division wished to know the accuracy and reliability of identifying coniferous forest cover, the optimal times of year to obtain Landsat data, and the accuracy and reliability of acreage estimates. In addition, it had many questions concerning the procedures for incorporating such data into the existing resource management system, the cost and availability of hardware and software for utilizing Landsat data, personnel and training requirements, etc. They also wished to know the cost and timeliness as well as the continued availability of the Landsat data.

When dealing with a new technology such as this, a myriad of unknowns, both technical and financial,

must be examined before it becomes reasonably clear that the technology can meet operational needs for specific types of information. The results of Phase I indicated that Landsat data and computer analysis techniques could provide useful input to a Forest Resource Information System (FRIS)–a computer-based GIS; approval was given to proceed with Phase 11 and III.

In Phase II, a computer terminal in Jacksonville was connected to the main computer at the Laboratory for Applications of Remote Sensing (LARS), Purdue University, where appropriate data analysis software existed. The staff at LARS trained St. Regis personnel in analyzing Landsat data. After St. Regis obtained additional equipment to implement completely the St. Regis FRIS, the "umbilical cord" to Purdue was cut. During Phase III, St. Regis tested and made the entire system completely operational.

Integrating Landsat remote-sensing technology into FRIS required St. Regis to spend over $1,300,000 for hardware and to hire two data specialists (one analyst and one programmer). However, the company estimated that these costs would be recovered in approximately **8** 1/2 years through: 1) increased efficiency in forest mapping, and **2)** considerable improvement in efficiency of field operations. By using Landsat data, the company was able to identify areas where only minor changes in the area or condition of the forest could be better defined, and to assign less field work to them. This decreased the total amount of field-crew time required and enabled more effective use of the field crews in areas where significant changes were occurring.

The utilization of Landsat data in the FRIS was described in detail at a symposium held in Jacksonville in May 1981, to which key personnel from all of the forest industries in the country were invited. As an indication of the widespread interest in the possible use of Landsat data, all except one of the forest industry companies sent representatives (usually senior-level executives) to the symposium. Two different types of users can be defined: the larger forestry companies like St. Regis or Great Northern, who would develop their own capability to analyze and use Landsat data, and the smaller companies who would like to have access to the same type of information, but cannot afford such an operation themselves. The smaller companies would be interested in purchasing value-added services. Companies specializing in analysis of Landsat data as a service to forest industries might have considerable demand for their products.

To date, however, forestry companies other than St. Regis have made little progress in incorporating Landsat data into their information system. Value--added companies have not increased their business with forest companies significantly. The reasons for this may be varied and complex, but two factors predominate:

1. There is no commitment by the U.S. Government or any private group to *supply data* promptly on a continuous basis, and forest industries are not yet ready to modify their entire method of monitoring the resource base. *
2. Potential users of the data are worried about the cost of the primary data. As previously indicated, because of the number of decades required to grow a crop of trees to merchantable size and the fact that periodic inventories of the resource base are necessary, the resources that can be allocated to any one inventory are minimal. At **$200** per CCT, the cost of the price of digital data was very reasonable, even when the forested areas of interest involved only a small portion of the area covered by that particular frame of Landsat data. However, the announced price of **$4,400** per frame of Landsat 4 thematic mapper data {starting February 1985 **),** makes the cost of obtaining the data a major issue for forestry companies, especially when there seems to be no indication that such data costs will stabilize. **If the Landsat system is transferred, cost increases will remain a major concern.**

It seems clear that the forest industries are not about to commit themselves to use a data-collection system such as Landsat unless the long-term implications of such a commitment are clear, and that the cost, availability, and utility of the data can justify such a change in their current methods of obtaining needed information.

The forest industry will not begin to use satellite data on a regular basis until it is assured that they will meet forestry information needs. Unfortunately, many individual studies have shown the benefits and limitations of Landsat data, but most of these have been of a research or a one-time demonstration nature; very few involved industry-defined operational constraints. Therefore, there is still a major need for development, demonstration, and evaluation of the technology under *operational conditions.* For instance, in the St. Regis project, researchers found that wintertime Landsat data were superior to spring or summer data because the primary information need was for stands of coniferous rather than deciduous forest cover.

As the St. Regis project and other studies have shown, Landsat data for forestry purposes have con-

* Because of annual cycles of industry operations, the potential for obtaining Landsat data within a reasonable time after it is collected is of concern. The consistency of format is also of concern because of the costs of revising software and hardware whenever changes in the format of the data occur.

siderable potential. The St. Regis project used geometrically rectified Landsat data overlaid onto a landownership map. Areas of coniferous, deciduous, and other cover types were then identified and these results were compared with existing cover-type maps to locate areas where differences existed between the two data sets. Field crews then concentrated their efforts in these areas of discrepancy. Landsat data from a second date were overlaid onto the first data set, and used to determine the extent of logging and reforestation operations, and whether the field records agreed with the results obtained from the first Landsat data set. Areas in which no significant changes in forest cover occurred were also defined; this led to modifications of the statistical sampling strategy for field inventories.

Landsat data have been applied to selecting the optimum location for a paper pulpmill in relation to the potential timber supply and transportation network. Such procedures may also prove effective for locating potential sources of wood supply for existing mills and then arranging a mutually beneficial long-term forest management lease with the owner.

In summary, Landsat data have been or could be of benefit in monitoring field records and rapid updating of maps, improved efficiency of field operations, timber supply monitoring, and long-term planning. It must be emphasized, however, that the effective use of Landsat data by forest industries involves developing entirely new information management systems that integrate Landsat data with many other types of data obtained from a variety of sources.

The decision to use Landsat data therefore represents a very major change in the data-collection and information analysis techniques of a corporation. In spite of many potential uses of Landsat data, it is clear that such satellite data will not entirely replace aerial photography because the characteristics and information content of the two data types are quite different, each having unique advantages and significant limitations. The key to effective use of Landsat data involves their appropriate integration with other data. However, unless concerns over continued data availability (in a standardized format that does not change at frequent intervals), and the future cost and timeliness of the data are effectively addressed to the satisfaction of corporation executives, many potential users of Landsat data will continue to use other forms and sources of data for their information systems.