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THE ECONOMIC VALUE OF REMOTE SENSING OF EARTH RESOURCES FROM SPACE: AN ERTS OVERVIEW AND THE VALUE OF CONTINUITY OF SERVICE

VOLUME IV

FORESTRY, WILDLIFE AND RANGELAND

Prepared for the
Office of the Administrator
National Aeronautics and Space ADministration
Under Contract NASW-2580

October 31, 1974

NOTE OF TRANSMITTAL

This resource management area report is prepared for the Office of the Administrator, National Aeronautics and Space Administration, under Article I.C.1 of Contract NASW-2580. It provides backup material to the Summary, Volume I, and the Source Document, Volume II, of this report. The interested reader is referred to these documents for a summary of data presented herein and in the other resource management areas.

The data presented in this volume are based upon the best information available at the time of preparation and within the resource of this study. This information inclu'es a survey of existing studies plus Federal budgets and statutes. Throughout the analysis, a conservative viewpoint has been maintained. Nonetheless, there are, of course, uncertainties associated with any projection of future economic benefits, and these data should be used only with this understanding.

ECON acknowledges the contributions of John Andrews and Peter Stevenson who authored this volume.

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ABSTRACT

Benefits attributable to an ERS system in the resource management area of extensive use of living resources are in excess of $92.2 million annually. These benefits derive largely from the potential improvements in accuracy, timeliness, and completeness of inventories and related statistical information. An ERS system can provide these benefits by supplying the initial stage of a three stage sampling procedure for estimating critical variables. The timber and forage resources of the United States both have economic value in the tens of billions of dollars, but the economic benefits of improved management of the forests and rangelands are not limited to efficiency in the production of these commercial resources. The benefits involve the other multiple-use values as well, including watershed, wildlife, and recreation.

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1.0 INTRODUCTION AND OVERVIEW: FORESTRY, WILDLIFE AND RANGELAND

The natural resources of this area are distinguished from those of the other areas of the study by their renewability and the fact that they are not intensively used in the United States. Thus, wildlife, including sport fish are included, while domestic animals and commercial fish are not. Timber and forage are included while farm crops and pasture are not. An important general characteristic of the resources of this area is that their values are interrelated -- hence, society's choice to limit intensive management for the dominant commercial products. For example, a timber stand provides harvestable growth of wood, while simultaneously providing soil stability (and new humus), wildlife food and shelter, water, various recreational opportunities, and in some cases livestock forage. The investments required to maintain this multiple-use productivity would not be justified by the timber growth value alone, so that intensive management for timber would be destructive. Because of these value interrelationships, the management of the resources of this area is largely under public influence or control. Following is a summary of the facts on resource ownership, location, and management policy which are background to this study.

1.1 Forest Areas and Ownership

About one third of the total land area of the United States is classified as forest, or 754 million acres out of a total of 2.3 billion acres.* Of this forest land, about 500 million acres is classified as commercial timberland, which means it is considered capable of producing crops of industrial wood and has not been withdrawn from this use. The remaining forest land, about 250 million acres, includes areas not capable of producing industrial wood because of low productivity, remoteness, or adverse topography, as well as areas that have been withdrawn from timber commercialization to preserve their value for recreation, water production, grazing, wildlife habitat, and scenery.

The commercial forest land is about 73 percent privately owned, with the remaining 27 percent under the

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* Statistical information in this section is taken from The Outlook for Timber in the United States, Forest Resource Report No. 20, U.S. Forest Service, October, 1973.

administration of federal, state, and local governments, including about 1 percent held in trust for Indians.

Noncommercial forest lands are about 25 percent in private ownership, 71 percent publicly owned, and 4 percent in trust for Indians. The interior of Alaska contains about 106 million acres of forest land, all classed as noncommercial. About one fifth of this forest land meets the productivity standards for commercial timberland, but is not included in that category primarily because of its geographic and economic remoteness. Almost all land in Alaska is still in public ownership.

Combining commercial and noncommercial forest land, the overall ownership breakdown is as follows: private ownership, 56 percent; public ownership, 42 percent; in trust for Indians, 2 percent.

In this report, the forests of the United States are studied as much as possible as one economic unit, independent of ownership. This viewpoint is appropriate for analysis of the impact of satellite information which is inherently aggregate and includes no reference to political or economic boundaries.

1.2 Rangeland Areas and Ownership

By rangeland* is meant land in large areas that supports grasses suitable for livestock grazing. It is distinguished from pasture in that it is a component of ranching operations, while pasture comes in comparatively small parcels and is a component of farming operations. Rangeland is managed primarily by the manipulation of the animals that graze on it, while pastures are usually managed much more intensively with the aid of cultural practices such as seeding, fertilization, cultivation and irrigation. About 30 percent of the rangeland in the United States is coextensive with forest land; that is, it supports both timber and grasses suitable for livestock grazing.

Although each of the conterminous 48 States contains a significant amount of rangeland, the Western States dominate, both in total rangeland area, and in proportion of the total land in range. Of the 1.9 billion acres total land in the

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* The term "forest-range" is often used as we use rangeland here. See for example The Nation's Range Resources, Forest Resource Report No. 19, Forest Service, USDA, December, 1972.

48 States, 1.2 billion is in range. The Federal Government maintains jurisdiction over 31 percent of the rangeland, or 373 million acres, while non-Federal owners control 69 percent, or 829 million acres.

1.3 Wetlands as Wildlife Habitat

The wildlife resource is managed through management of its habitat, and remotely sensed information that can contribute to wildlife management is usually information about wildlife habitat. The forests and rangelands provide habitat for much of the wildlife of the United States, but another category of land is important as well. Many species depend on wetlands for their survival. These include fish, waterfowl such as geese, ducks, and swans, and furbearers such as muskrats, mink, beaver, and otter. Wetlands are also important for marsh birds, deer, rabbits, pheasants, and grouse.

Coastal wetlands are the object of severe competition among various alternative land uses which affect their value as wildlife habitat.

1.4 The Private Sector and Forest Policy

The manufacture, distribution, and sale of timber products is entirely a private undertaking in the United States, as is almost all logging. Thus, regardless of who owns forest land and invests in its productivity and protection, the harvest of timber and conversion into useful products is carried on in a manner determined by the characteristics of the private logging and forest product manufacturing industries.

Similarly, the raising of livestock for meat, hides, and wool is a private business, and this grazing industry is the only means in existence of converting the forage resources of the nation's rangelands into economic value.

Forest recreation is partly a private business activity, particularly the intensive forms such as skiing and the provision of meals and lodging, but recreation is largely provided by public agencies.

The private owners of forest land are of many different types and use their properties for many different purposes. The Forest Service estimates that farmers own 26 percent of the commercial forest land, miscellaneous private owners hold another 33 percent, and forest industries hold 14 percent. Approximately 20,000 companies constitute this last class of ownership. Four million farmers and other individuals hold separate properties constituting the other 59 percent.

There are definite economies of scale in forest management, since most forestry operations can be done only with large equipment, skilled workers, and seasonal concentration of activity. Small forest properties cannot produce much net income for their owners. Thus the small properties are owned by people whose main source of income--and primary interest--lies elsewhere. Only a few of the nonindustrial properties are large enough to be important sources of income. Corporations sometimes hold forest land as an investment, but there cannot be very many of these large nonindustrial ownerships. On the average, the nonindustrial ownerships are much too small to be economic as independent timber growing ventures, but the owners are independent and have little motivation to be interested in the effect of their forest management practices on the rest of society.

The industrial owners, on the other hand, control larger properties and benefit from the economies of scale in forest management. The larger ones manage their forests rather intensively. They have a definite economic incentive to manage their lands. Since this incentive comes almost entirely from the demand for wood, however, their interests are concentrated on timber as their forest crop. Industrial owners respond more readily to the desires of society than the nonindustrial owners, partly in meeting the market demand for wood products, and partly in recognizing the potential threat of public control. As a result, the industrial ownership forms a reasonably effective institution for executing forest policies.

This characteristic is somewhat strengthened by the fact that most industrial owners are members of organizations providing coordination in executing policies affecting their own lands. For example, the Industrial Forestry Association and the Southern Forest Institute provide some services for their members and provide a mechanism through which groups of industrial owners can influence what individual companies do.

Besides the industrial forestry organizations, there are many other private institutions functioning in the areas of forest management and policy. The most common type of activity is educational. The American Forest Institute, the Forest Farmers Association Cooperative, and the National Wildlife Federation perform educational functions. Services such as organized trips into wilderness areas, management advice to forest owners, and trail maintenance for hikers are provided by various other private clubs and associations.

There is a group of professional societies including the Society of American Foresters, the American Society of Range Management, and the Wildlife Society. These exert a considerable influence on the way professional conservationists perform their duties.

Taken together, the organizations mentioned above play an important role in the development and execution of forest policies in the United States.

1.5 Federal Government Functions

The federal government has a dual role in forest and rangeland management and policy. Originally it was thought that the forest and rangelands should be operated by private enterprise just as are lands which are suitable for agriculture. However, some of the forests and grasslands were so seriously abused that it seemed imperative for the government to operate some of these lands as public enterprises in order to ensure future supplies of forest and range benefits. The public therefore came into the permanent land management business by reserving parts of the public domain and by acquiring other lands from private owners.

At the same time it was necessary for the public to take some action regarding the substantial part of the forest lands that remained in private ownership. Currently, these two aspects of public action overlap in many places, and some of the institutions serve both functions.

Current federal government policies regarding the forests and rangelands are grounded largely in the 1960 Multiple-Use Sustained-Yield Act, which states that "the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes." In defining multiple use, the Act includes the language: "The management of all the...resources of the national forests...in the combination that will best meet the needs of the American people,...that some land will be used for less than all of the resources;...and not necessarily the combination of uses that will give the greatest unit output." This Act was intended to give legislative sanction to long-standing programs and policies and to give a clear negative answer to the demands of the timber industry for first priority in forest resource use.

Following this legislation, the Wilderness Law of 1964 authorized the setting aside of over 9 million acres on the national forests as wilderness. The law provided that similar areas may be established as national parks and monuments and national wildlife refuges. Also in 1964, the Land and Water Conservation Fund Act provided for allocation of funds to federal agencies and the states for acquisition of outdoor recreation areas. The legislative recognition of wildlife values was enhanced by the passage in 1966 of the Rare and Endangered Species Act, declaring it a national policy to protect species of native fish and wildlife threatened with extinction and to protect their habitat.

In addition to the 1960 Multiple-Use Sustained-Yield Act, an older act provides direction to federal forestry policy. This is the McSweeney-McMary Act of 1928, with its amendments and supplements. This Act serves as the basis for the research side of the federal activity in forestry, including the Forest Survey.

The new Forest and Rangeland Environmental Management Act of 1974 recognizes the importance of efficient management of the forest and rangeland resources on a coordinated national basis, with emphasis on their finite and renewable nature. Section 3 of this Act expands the research responsibilities of the Forest Service, calling for a periodic "National Renewable Resource Assessment," and amending the McSweeney - McNary Act to cover all renewable resources of the forests and rangelands. In addition, the Act directs the preparation of a "Renewable Resource Program -- for protection, management, and development of the National Forest System," including an assessment of opportunities and needs for public and private investments and their anticipated benefits.

1.6 Summary of Results

Benefits to the resource management functions of this area are estimated to be in excess of $922 million. This figure is the present value at 10 percent of an annual benefit stream of $92.2 million. Of this annual benefit, $62.2 million is "hard;" while the remaining $30 million is a little less conclusively established. These quantified benefits accrue to the following resource management functions: Determine timber volume by type, location, and ownership; prepare rangeland inventories; manage timber harvest; manage livestock grazing; manage timber production investments; manage forage production investments; make multiple use allocation decisions. The exact scope of each of these functions is specified in Appendix A. Table 1 on page 1-8 presents the quantitative benefit estimates, broken down by resource management function, type of benefit, and conclusiveness. Substantial additional benefits exist, but numerical values have been calculated only as shown in Table 1. The major additional benefits identified in this study are in the following resource management activities: research; conservation; damage assessment and prevention; administrative, judicial, and legislative functions. A qualitative discussion of these benefits is included with the detailed treatment of each resource management function in Appendix A.

The benefits are estimated within a general conceptual framework that regards the forests, rangelands, and wildlife areas as capital assets, requiring specific investments to produce valuable output. With this viewpoint it is possible to calculate the economic value of the resources. As with other capital assets, this is done by discounting (capitalizing) the stream of net output values through time. Then the benefit of ERS information is calculated as the difference between the value of the asset in the presence of the information and the value of the asset in its absence.

Appendix D contains a calculation of the value of the timber and forage resources together with analysis of the cost of "error" in timber harvesting decisions. The following information from that appendix is essential for the understanding of the benefit calculations.

The commercial timber resource of the United States is worth about $50 billion based on its 1970 level of production. The livestock forage resource is worth about $30 billion on the same basis. Timber is managed for sustained yield; that is, harvesting policies are designed so that the annual cut is no more than can be continued indefinitely. This principle is economically sound for the owner of a capital asset that can generate annual returns competitive with other investment opportunities. In this study it is assumed that the United States economy provides ample investment opportunities returning 10 percent. Timber, considered independently of other forest resource values, does not return close to 10 percent per year. In fact, an upper bound for the economic return possible to a timber owner from the timber's growth is the ratio of the annual growth volume to the inventory volume.* This is true independent of timber prices, since they affect the liquidation value of the inventory in the same way as they affect the value of the annual production. The actual economic return is

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* 3 percent is typical under intensive management.

Table 1 Quantitative Benefit Estimates by RMF, Type, and Conclusiveness

RMF Number and Title	Equal Capability Hard	Increased Capability Hard	New Capability Hard	New Capability Soft
2.2.1 Determine Timber Volume by type, location, and ownership	0.8	0.4	*	
2.2.7 Prepare Rangeland Inventories	1.9	1.8	**	
2.4.1 Manage Timber Harvest	1.3	1.5	19.0	
2.4.2 Manage Livestock Grazing				15
2.4.3 Manage Timber Production Investments			5.5	
2.4.4 Manage Forage Production Investments				15
2.4.5 Make Multiple use allocation decisions			30.0	
TOTAL	4.0	3.7	54.5	30

* The benefit associated with this new capability is realized through RMFs 2.4.1, 2.4.3, 2.4.5.
** The benefit associated with this new capability is realized through RMFs 2.4.2, 2.4.4, 2.4.5.

less than the ratio of annual growth to inventory because investments must be made to maintain the growth. If timber is considered independently of other forest resource values, it is thus in the owner's economic interest to liquidate the timber and invest the proceeds at 10 percent or more.

The importance of this observation lies in its implications for the cost of mismanagement of the forest resources. Suppose a segment of the United States commercial timberland is currently being managed in a way that could be maintained indefinitely under current technology. Then, if because of inaccurate inventory information or analysis, 20 percent too much timber is cut in one year, an analysis based on timber values alone will assign a *benefit*, to this error. In fact, it is a *cost*, but it can be calculated only through consideration of non-timber values.

The value model of Appendix D provides a measure of the cost of overcutting, according to the formula.

$$\text{Cost} = L_o \left(1-\frac{\rho}{r}\right) \quad (e-\ln(1+e)),$$

Here, L_o is the "liquidation" value of the current (sustained yield) inventory--the market value of the stumpage. ρ is the ratio of annual growth to inventory, and varies according to climate, biological factors, and intensity of management. r is the discount rate. e is the error in inventory level as a fraction of the correct value L_o.

1.7 Function of Remote Sensing

Remote sensors provide information with several important general characteristics. First, remotely sensed information is essentially of the survey and inventory type -- that is, it relates to the question "How much of what is where?" rather than to the question "What will happen when a certain action is taken?" Second, it is typically synoptic. An item of remotely sensed data refers to a weighted average or aggregate of the property being sensed over a geographic area. In the case of ERTS-1, the area is at least an acre. In some uses of information, it is advantageous to be able to obtain averages or aggregates directly, rather than having to calculate them from point-specific data. A third general characteristic of remotely sensed information is that it seldom provides a direct measurement of the variables of interest. To make use of such information, it is necessary to understand how the measured information is correlated with the desired information. This means that the procedures for making these correlations are very important for making efficient use of remotely-sensed information, and for estimating its value. For example, in using remote sensing to detect insect activity in a forest, it is necessary to know whether insect activity causes changes in spectral reflectance characteristics or other properties susceptible to remote sensing.

In view of these considerations, it is to be expected that remotely-sensed information, and ERS information in particular, has greatest value as a *supplement* to information derived from other sources, rather than as a *substitute,* and that the realization of this value will depend on the development of new systems for coordinating the use of information from various sources.

In the case of the forests, inventories are accomplished through sampling procedures in which direct measurements from the ground play a part. The traditional use of remotely sensed data is to incorporate them into a multistage sampling procedure, with economic benefit achieved through reduction of the amount of ground work required. Aircraft photography has been used in this way. Until consideration was given to the new potentials of satellite information, the specifications on accuracy and timeliness of conventional procedures were usually considered appropriate. In the public sector such specifications have been essentially derived from budgets. If the specifications were appropriate, then the function of remote sensing through an ERS system would be in further reducing inventory costs and in helping to meet these specifications. However, with ERS data comes the possibility of considerably surpassing traditional specifications because of the comprehensiveness and frequency of aerial coverage. In fact, those variables that are measurable from the ERS distance can be obtained at as high a resolution level in time and space as is useful in describing a growing forest (possibly excepting fire and insect damage descriptors). Because of this, it may be possible to virtually eliminate the costs of errors in forest measurement, without increase in the costs of forest management procedures.

As an indication of the capability of ERTS-1 in observation of the forest resources, Figure 1 on page 1-11 contains a July, 1972 image of a forested area in Alaska, about 200 miles North of Fairbanks showing a forest fire in progress and several scars from previous fires of various ages. The image shown is a fake-image composite of MSS bands 4,5, and 7, represented as yellow, red, and aqua, respectively.

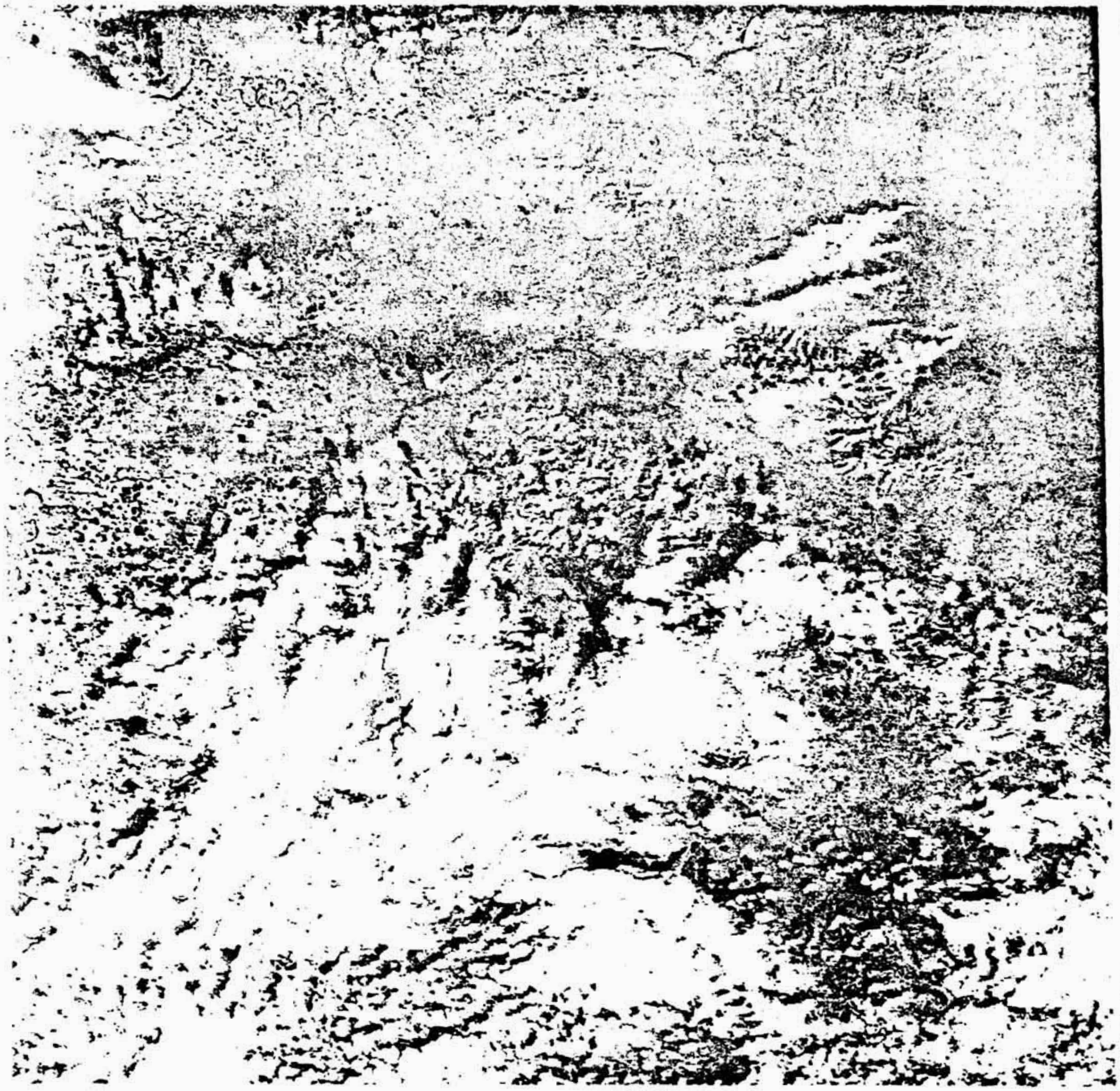

Figure 1 ERTS-1 Image of Area in Alaska
Showing Forest Fire

The active fire in the upper right is clearly shown as heavy black with smoke dissipating toward the left. Fire scars appear as black areas, modified by admixture of the spectral bands indicating the extent of regrowth. The vegetation types are visually distinguishable to some extent. The deeper red represents heavily wooded areas, while the red modified by yellow indicates vegetation of other types. Lakes and rivers are easily distinguished in dark shades of blue and in black. Clouds are shown as white, and their shadows are shown as black areas of corresponding size and shape.

All this is immediately evident from the visual display. For an experienced user of ERTS-1 data, a much more detailed interpretation is possible. Further, the technology for automatic data processing of the contents of the ERTS tapes is rapidly developing. This permits both visual displays with enhancement of key features and direct input of the data into management information systems.*

1.8 Cartography, Thematic Maps, and Visual Displays

As discussed in the resource value model of Appendix D, information of the survey and inventory type is a requirement for the production of economic value from the forests and rangelands. The informational products of this resource management activity are used both as aids in preparing more complex informational products such as statistical services and research results, and directly in the management of resources. The use of ERTS-1 data in preparing maps and visual displays has proceeded in two directions. In one direction, one attempts to mimic photography or direct visual observation, depending on a human interpreter to detect or even measure, phenomena of interest. When this is done, the potential for obtaining useful information is limited not only by the resolution of the ERTS data system, but also by the interpretation skills of the human interpreter. Equal capability and increased capability benefits can be calculated for such applications, but they tend to be small in comparison with the new capability benefits obtainable through more sophisticated use of the data. Further, a substantial part of these cost savings can be attributed to the production of the base topographic maps by the United States Geological Survey and this benefit is discussed under resource area number 5, Nonreplenishable Natural Resources (Volume VII of this study).

Until 1973, the various federal agencies with responsibilities in the preparation of maps and surveys prepared base maps independently. In that year, however, an OMB task force

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* For an example of an ERTS image of a rangeland area, see Figure 1.5 of Volume I of this report.

report on mapping, cartography, and surveying* proposed a more centralized federal mapping process to limit unnecessary duplication. Currently, except for the Soil Conservation Service, all civil federal agencies obtain basic topographic maps made by the Geological Survey.

New capability benefits are achievable through more or less sophisticated techniques of processing the digital data, resulting in displays which enhance the interpretation powers of the human users. Such procedures have been developed by various experimentors for the classification of vegetation by species and condition. For example, Baumgardner, Kristof, and Henderson at Purdue University have made effective use of ERTS-1 data in mapping soils and vegetation in Lynn County, Texas. Their techniques could be applied to other arid-semi-arid regions, such as cover one third of the world's land area. The benefits achievable through improved mapping methods producing more comprehensive or timely information are closely related to those of the associated statistical information and the management activities they support. Therefore, they are not quantified in this section, but are included in the calculations of later sections.

The legislation which implies most of the federal activity in mapping of extensive resources does not specify mapping directly, but mandates the preparation of inventories and other necessary management information. These laws are discussed in Appendix B.

Some detail on the particular resource management functions of this resource management activity and the current ERTS-1 experimental work is provided in Appendix A, Sections 2.1.1 through 2.1.4.

1.9 Statistical Services

Equal capability and increased capability benefits, totalling $4.9 million annually, are estimated within this activity for forest inventories and rangeland inventories. To facilitate presentation of the ERTS-1 capabilities and the capabilities of remote sensing techniques, the individual RMF's are defined to specify the collection or production of particular classes of data within the inventory process. For example, determination of timber volume and determination of forest area are separate RMF's, though both are products of the timber inventory process as usually conducted. For equal

* Office of Management and Budget, Federal Task Force on Mapping, Washington, D.C., 1973.

capability benefit estimation, it is not meaningful to separate these functions. Accordingly, the benefits calculated under RMF 2.2.1 (determine forest timber volume by type, location, and ownership) applies to the entire inventory process of the forest survey. Similarly, the benefits calculated under RMF 2.2.7 (prepare rangeland inventories) include any cost savings that could be associated with RMF's 2.2.8 (measure rangeland yield) and 2.2.10 (assess range forage conditions).

Statistical services are a necessary part of the process of producing usable output from the forests and rangelands. Inventory statistics such as those of RMF's 2.2.1, 2.2.2, 2.2.5, and 2.2.7, are a direct operating management requirement, while related statistics discussed under the other RMF's of this area are needed in the planning of operations and in setting policy. These information uses are within the classification of "inputs to the production function" as discussed in Appendix D. But, statistical services produced by all the RMF's of this area are also used in research activities -- activities directed at changing the "production function" itself.

Some statistical work is performed *only* for the purpose of direct management and planning activities. This work is discussed under the RMF category 2.4 (Allocation), and includes the "management planning" inventory and the "silvicultural examination program" conducted by the Division of Timber Management of the Forest Service.

The federal government is active in the area of statistical services covering the extensive use of living resources primarily through the Forest Service, the Soil Conservation Service, the Bureau of Land Management, and the Bureau of Indian Affairs. (The general resource management responsibilities of these agencies are treated in Appendix B).

By direction of McSweeney-McNary Act of 1928, the Forest Service is responsible for conducting a continuous survey of forest resources in the United States. This act (as amended) directs the Secretary of Agriculture to "make and keep current a survey and analysis of the present and prospective conditions of and requirements for the renewable resources of the forest and rangelands of the United States, its territories and possessions, and of the supplies of such renewable resources, including a determination of the present and potential productivity of the land, and of such other facts as may be necessary and useful in the determination of ways and means needed to balance the demand for and supply of these renewable resources, benefits and uses in meeting the needs of the people of the United States."

The survey authorized by the McSweeney-McNary Act is conducted by the Forest Survey Branch of the Forest Economics and Marketing Research Division of the Forest Service.

Adhering to the national emphasis of the act, the Forest Survey administrators also assist with and in many cases direct the surveys of the Bureau of Indian Affairs, the Bureau of Land Management, The Tennessee Valley Authority, state forestry agencies, and private industry.

The new Forest and Rangeland Environmental Management Act of 1974 directs the Forest Service to "prepare a National Renewable Resource Assessment . . . The Assessment shall be prepared not later than December 31, 1974, and shall be updated updated during 1979 and each tenth year thereafter, and shall include:

(1) an analysis of present and anticipated uses, demand for, and supply of these renewable resources, with consideration of the international resource situation, and an emphasis of pertinent supply and demand and price relationship trends;

(2) a general inventory of these present and potential renewable resources and opportunities for improving their yield of tangible and intangible goods and services together with estimates of investment costs and direct and indirect returns to the Federal Government;

(3) a description of Forest Service programs and responsibilities in research, cooperative programs, and management of the National Forest System, their interrelationships, and the relationship of these programs and responsibilities to public and private activities; and

(4) a discussion of important policy considerations, laws, regulations, and other factors expected to significantly influence and affect the use, ownership, and management of these lands."

Current forest inventory procedures used by the Forest Survey include two-stage sampling. The first stage consists of aerial photography of forest lands by state. Survey experts determine from the aerial photographs which specific areas are to be examined in detail. The second stage is performed by ground crews who survey the specific parcels of forest chosen by the stage-one process. Sample plots are established by the ground crews and measured as to area, volume, growth rates, species, and mortality rate. These sample plots are the statistical base used in computing the overall state-wide survey data. Beyond the sample plots, these crews also visit those areas that may be disturbed by insects, erosion, or fire, as indicated by the aerial observations.

Within the Forest Service, the Survey is conducted by the six regional experimental stations. The Division of Economics and Marketing publishes the results of this work including comprehensive information on the extent, condition, volume, and quality of timber resources. The 1974 appropriation for this survey amounted to $3.433 million while the 1975 estimate is $3.829 million. Though the Forest Survey hopes to reduce the interval between survey reports to five years, past surveys have been approximately ten years apart. "Thus, the first survey under the act was published in 1945; the second, known as the 'Timber Resources Review', in 1953; and the third entitled 'Timber Trends' in 1963."*

The most recent of these studies is called "The Timber Outlook for the United States, 1970."** These studies concentrate on four principal parameters: (1) forest area; (2) inventory volume; (3) growth; and (4) removals. These four parameters are broken down and discussed in various ways, and projections of all four are made for future levels. Timber supply projections are developed from these basic data and other assumptions on management procedures and consumption patterns.

Current work of the Forest Survey Branch includes the design of a unified data system to be used with interactive terminals. The data system will be kept current and expandable. The technical objectives of the Forest Survey are being more clearly related to the need to understand the resource output responses of alternative forest management practices.

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* Michael Frome, The Forest Service (New York: Praeger Publishers, 1971), p. 41.

** M. Sullivan, Personal telephone interview: August 8, 1974, at 11:00 A.M. Mr. Sullivan is a member of the Timber Management Bureau of the United States Forest Service.

In the area of rangeland statistics, the Forest Service has not had a continuous program. Early proposals included a 1960 recommendation by a committee of professional agricultural societies for a census of grazing lands and a 1961 report by the Secretaries of the Interior and Agriculture to Congress presenting the need to conduct appraisals of public range resources. These recommendations were not implemented. In 1974, however, the Forest-Range Task Force of the Forest Service produced the Forest Range Environmental Study (FRES).* The purpose of the FRES report was to "assemble information about all of the Nation's range and to develop a technology for its evaluation that would serve the planning needs of the Forest Service."** Under the Forest and Rangeland Environmental Management Act, work of this kind will be continued and integrated with forest resource information programs.

1.10 Calendars

Four resource management functions are identified within this activity, and ERTS-1 experiments have demonstrated capabilities which may make useful contributions to some of them. However, we have neither estimated quantitative benefits nor developed evidence of significant unquantified benefits.

Nevertheless, it is possible that the availability of comprehensive, consistently recorded and processed data over a long period will lead to improved understanding of cyclical phenomena, and associated benefits.

Summaries of ERTS-1 experiments relevant to this RMF category are included in Appendix A.

1.11 Allocation

The allocation activity includes the operating management decisions that are necessary for continuous production of output from the resources, as well as the more general decisions on where and to what extent management should be intensified for particular outputs. This activity does not include the protective management functions such as fire and insect control, the research functions, or policy decision making, all of which belong to other resource management activities.

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* Forest Range Task Force, The Nation's Range Resources Forest Resource Report No. 19, Washington: United States Government Printing Office, 1972.

** Ibid., p. 1.

The operating decisions for the timber and forage resources are of two kinds: (1) where and when to collect output; (2) where and when to make investments. The first RMF, number 2.4.1 (Manage Timber Harvest) covers the output collection for the timber resource. The second RMF, number 2.4.2 (Manage Livestock Grazing) covers output collection for the forage resource. The next two RMF's, 2.4.3 (Manage Timber Production Investments) and 2.4.4 (Manage Forage Production Investments) include such activities as planting trees and seeding rangelands, road building in the forests, and fence building and water hole development in the rangelands. Finally, RMF 2.4.5 (Make Multiple Use Allocation Decisions) is the implementation of the multiple-use policy. This requires national level allocation decisions as contrasted with the previous RMF's which cover more localized decision making.

New capability benefits within the allocation activity have been estimated for RMF 2.4.1 (Manage Timber Harvest), RMF 2.4.3 (Manage Timber Production Investments), and RMF 2.4.5 (Make Multiple-Use Allocation Decisions). These benefits total $54.5 million per year, and are based on new modeling of the forest resources on a national basis together with an analysis of the important ERS capability for inexpensively making inventory information point-specific (one point covers about one acre). In addition, results of the 1968 Frank and Heiss grazing land study have been examined, updated, and accepted with reservations, leading to a "soft" benefit of $15 million per year in RMF 2.4.4 (Manage Forage Production Investments). Similarly, the 1974 Rangeland Case Study of EarthSat provides the basis for a "soft" benefit of $15 million per year in RMF 2.4.2 (Manage Livestock Grazing).

The "hard" benefits of RMF 2.4.1 are stated somewhat conservatively, since they apply only to the National Forest System. The model which is used for this case could be applied to other commercial timberlands, leading to further benefits.

1.12 Conservation

The resource management functions of this activity are those concerned with protecting the resources from damage by human abuse, and with repairing past damage. This category is distinguished from 1.13 Damage Prevention and Assessment in that the agents causing the damage of concern in the function of that category are not associated with human use of the resources, and consequently, have a more random nature.

Quantitative benefit estimates have not been performed for this activity, but it appears that an ERS system might make valuable contributions through its monitoring capability, particularly by providing early and comprehensive evidence on long term trends such as rangeland deterioration or improvement.

It is not necessary that ERS images provide complete and conclusive evidence on the state of the variables of importance, but only that it provide guidance for more efficient use of ground-based and aircraft data collection techniques.

In other words, the concept in back of the potential benefits is multistage sampling, just as it is for the benefits calculated in the allocation activity.

1.13 Damage Prevention and Assessment

This resource management activity includes protection of the multiple-use resource values from fire, disease, insects, other animals, erosion, and pollution. Although the distinction is only approximate, the RMFs covered here differ from those of activity 1.12 Conservation in being protection against random damage agents, rather than against the more predictable results of human use patterns.

The Forest Service has been extremely active in prevention and assessment of fire damage to the forests and rangelands. Under the leadership of the Service, other government agencies and private industry have coordinated their efforts. Currently, annual expenditures for protection of the forest resources from fire (all organizations) is over $320 million.* This seems sufficient to restrain forest fire damage to the extent that current knowledge permits. This figure does not include research, however, which provides some hope of improving that knowledge.

We have not estimated numerical benefits for this or other applications of this resource management activity, but it would be surprising if ERS data could not be used to make deployment of the annual protection investment more efficient, perhaps by more effective monitoring of fire fuel conditions. Thus, an annual benefit in the tens of millions would be reasonable.

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* The Outlook for Timber in the United States, Forest Service, 1973, p. 37.

Insect and disease take a large toll of timber values, and associated forest values, as well, but the relatively low national expenditure on prevention and control of their damage ($12 million in 1970) is a symptom of the fact that not much is known about how to prevent or limit this damage. The critical information needed here is thus not of the survey type which can be augmented by an ERS system, but of the research results type, for which the usefulness of ERS data is less clear.

1.14 Unique Event Recognition and Early Warning

The unique event of most evident relevance to this resource area at the present time is the construction of the Alaskan Pipeline.

We have not made a quantitative estimate of the benefits which may accrue through wildlife habitat protection. Benefits may be present, however, since an ERS system is particularly efficient for generalized monitoring of remote locations.

1.15 Research

Research is necessarily a vital activity in the management of natural resources. Its relationship to the investments and returns which characterize the economics of natural resource use is outlined as part of the value model presentation in Appendix D. The product of research activities is information--information of a different kind than the survey and inventory information dealt with in the previous sections of this report. Survey and inventory information is a category of operating inputs, investments necessary for the process of producing economic value from the resources. Research information on the other hand is information about how to produce; its benefit is in making possible a greater output value for a given set of inputs. When research produces a benefit, it is likely to be large, since it can affect the productivity of the resource indefinitely.

In the case of the forests and rangelands, the Forest Service is explicitly given research responsibilities by legislation such as the McSweeney-McNary Act and the Forest and Rangeland Environmental Management Act. The 1974 budget of this agency includes $64 million for forestry research.

One of the most effective forms of research in the case of natural resources is the analysis of descriptive data on the ongoing operations, and this is a substantial part of the work of the Forest Survey division, whose $4 million annual budget is not included above.

The information needs of research activities are extremely varied, so that an accurate model for benefit estimation of ERS data is likely to be complicated. We have not developed one, but we can point out ways in which ERS data may contribute significantly.

One is through motivating and hastening the development of integrated data bases to coordinate management and policy on a national basis. Traditional data collection and processing has been uncoordinated because of differences among ownerships in objectives and in management resources. Since ERS data are inherently independent of ownership and available over a wide geographical range, they are most easily and efficiently used in information systems of the same broad scope.

Similarly, simulation models will probably be developed in a way influenced by ERS data, and may lead to benefits in the form of better management practices.

1.16 Administrative, Judicial, and Legislative

This resource management activity includes functions of broad impact such as resource use policy setting and budget legislation for the agencies responsible for implementing policy. Numerical benefits have not been estimated within this activity, but the qualitative discussion here and in Appendix A suggests that if the effort were made to construct appropriate models, significant benefits could be established.

The general functions of various institutions in forestry policy are described in Section 1.5.

At the level of congressional legislation, including federal budget determination, these institutions provide two kinds of influence on the process-- objective information (expert testimony) and the presentation of their stands or preferences. Congress integrates and acts on this information first through its committees and second through its final decision process.

Data and information about the natural resources and related economic questions influence this process at three stages.

First, the expert opinions and the preferences of the interest groups are formed under the influence of such information. Second, information is selected, edited, and presented to the committees specifically to influence their judgment. Finally, the committees process and select information for presentation to the assembled Houses.

In such a decision making process, a property of the information becomes very important that has not been emphasized in the analysis of the other resource management activities. That property is its credibility, or perceived accuracy. In the legislative process, as in any political process, the form of the information becomes significant, as well as its precision and timeliness. Photographs and satellite images have a universal credibility that may impact the legislative process more efficiently than other forms of presentation.

For example, "before and after" images graphically showing rangeland deterioration may hasten corrective action, while even accurate and reliable statements of experts concerning the number of acres and their condition classes may not.

APPENDIX A:

DETAILED EXAMINATION OF BENEFITS BY RMF

Table 2 beginning on page A-2 gives the names and numbers of all the RMF's defined for this study, together with benefits broken down by type for those RMF's for which they were calculated.

In the remainder of this appendix the benefit estimates are documented. For those RMF's in which benefits were not calculated, the discussion constitutes preliminary structure for estimation of benefits.

Table 2 . Magnitudes and Types of Net Annual Benefits by Resource Management Activity
Extensive Use of Living Resources: Forestry, Wildlife and Rangeland

Resource Management Function	Benefits, $ millions (1973)		
	Equal Capability	Increased Capability	New Capability
2.1 Cartography, Thematic Maps and Visual Displays			
2.1.1 Thematic mapping of forests and rangeland by vegetation type and characteristics			
2.1.2 Rangeland mapping			
2.1.3 Wildlife habitat mapping			
2.1.4 Soil mapping of forests and rangelands			
2.2 Statistical Services			
2.2.1 Determine forest timber volume by type, location and ownership	0.8	0.4	
2.2.2 Determine forest land areas			
2.2.3 Measure forest timber growth and removals by type and location			
2.2.4 Forecast forest timber supplies by type and location			
2.2.5 Determine commercial characteristics of forest timber by type and maturity			
2.2.6 Determine proportions of timber destruction due to various natural agents			
2.2.7 Prepare rangeland inventories	1.9	1.8	
2.2.8 Measure rangeland yield			
2.2.9 Forecast rangeland yield			

"Soft" benefits parenthesized

Table 2 Magnitudes and Types of Net Annual Benefits by Resource Management Activity
Extensive Use of Living Resources: Forestry, Wildlife and Rangeland

Resource Management Function	Benefits, $ millions (1973)		
	Equal Capability	Increased Capability	New Capability
2.2.10 Assess range forage conditions			
2.2.11 Forecast range forage conditions			
2.2.12 Assess wildlife habitats			
2.3 Calendars			
2.3.1 Establish green wave and brown wave calendars by forest or rangeland vegetation type			
2.3.2 Establish calendar for cyclical patterns of insect infestation in forests			
2.3.3 Determine schedule of grazing opportunities on rangelands			
2.3.4 Establish calendar of wildlife habitat changes			
2.4 Allocation			
2.4.1 Manage timber harvest	1.3	1.5	19
2.4.2 Manage livestock grazing			(15)
2.4.3 Manage timber production investments			5.5
2.4.4 Manage forage production investments			(15)
2.4.5 Make multiple-use allocation decisions			30
2.5 Conservation			
2.5.1 Design and monitor forest rehabilitation			

"Soft" benefits parenthesized

Table 2 Magnitudes and Types of Net Annual Benefits by Resource Management Activity
Extensive Use of Living Resources: Forestry, Wildlife and Rangeland

Resource Management Function	Benefits, $ millions (1973)		
	Equal Capability	Increased Capability	New Capability
2.5.2 Design and monitor rangeland rehabilitation			
2.5.3 Monitor and limit damage to wetlands			
2.5.4 Monitor and limit damage in the Giant Redwood and Sequoia forests			
2.6 Damage Prevention and Assessment			
2.6.1 Assess and reduce disease, weed, and animal damage to forests			
2.6.2 Assess and reduce disease, weed, insect, and animal damage to rangelands			
2.6.3 Assess and reduce erosion damage to forests and rangelands			
2.6.4 Assess and reduce fire damage to forests and rangelands			
2.6.5 Assess and reduce pollution damage to wildlife areas			
2.7 Unique Event Recognition and Early Warning			
2.7.1 Monitor impact of the Alaskan Pipeline on wildlife			
2.8 Research			
2.8.1 Research forest management practices			
2.8.2 Research forest and range fire control techniques			

"Soft" benefits parenthesized

Table 2 Magnitudes and Types of Net Annual Benefits by Resource Management Activity
Extensive Use of Living Resources: Forestry, Wildlife and Rangeland

Resource Management Function	Benefits, $ millions (1973)		
	Equal Capability	Increased Capability	New Capability
2.8.3 Research rangeland management practices			
2.8.4 Research methods of disease control and animal damage reduction in forests and rangelands			
2.8.5 Research ecological relationships relating to wildlife			
2.9 Administrative, Judicial and Legislative			
2.9.1 Design forestry legislation and monitor compliance			
2.9.2 Design rangeland legislation and monitor compliance			
2.9.3 Design legislation related to wildlife and monitor compliance			
TOTAL:			
Hard Benefits documented in ECON case Studies	4.0	3.7	54.5
Soft Benefits	-	-	(30.0)

"Soft" benefits parenthesized

RMF No. 2.1.1

THEMATIC MAPPING OF FORESTS AND RANGELANDS BY VEGETATION TYPE AND CHARACTERISTICS

Rationale for Benefits

Thematic maps are useful in the preparation of inventories, statistics, and projections to support efficient timber management and efficient management of livestock grazing activities.

Federal Government Activities and Responsibilities

Thematic maps of forest and rangeland vegetation are prepared primarily by two agencies of the Department of Agriculture: the Forest Service; the Soil Conservation Service.

In addition to its use of maps as an aid in preparing the published data of the Forest Survey, the Forest Service (Timber Management and Planning Division) maintains an extensive map atlas covering the National Forest System and functioning as an important component of its management information system. In this system, maps are used to portray a large variety of vegetation characteristics and soil characteristics, together with management plans and structures (such as fences and roads).

Rangeland vegetation types are mapped by the Forest Service as part of its inventory and analysis work and by the Soil Conservation Service as part of its soil survey responsibilities.

Functions of Remote Sensing

Remote sensing can make possible more extensive and timely maps of vegetation types, particularly in remote areas including Alaska and foreign countries. Cost savings are often possible for maps covering large areas. Accuracy can be considerably improved over ground-based procedures.

Economic and Technical Models for Estimating Benefits

Since mapping activities in this resource area are so closely interrelated with statistical services and other management functions, benefits attributable to mapping in itself are not estimated.

RMF No. 2.1.1

Current ERTS Activities

Accurate thematic mapping by satellite or aircraft is dependent on both the resolution of the imagery and the reliability of identification technique. An analysis of ERTS MSS data for Lynn County, Texas, suggests that the ERTS data can be used successfully to identify and map by vegetative species in rangeland areas.* Another study concentrating more on forest lands proved the ability of ERTS data to discriminate between Douglas Fir, Ponderosa Pine, Juniper and other softwoods.**

As to development of ERTS interpretation techniques, R. C. Heller has conducted studies on "image enhancement techniques" where ERTS data simulated true color images showing discrimination between vegetation types, bare soil and harvested crops.***

Estimate of ERTS Economic Capabilities

Annual Benefits:

Through later RMFs.

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* Baumgardner, Marion; Kustaf, Steven; Henderson, James; "Identification and Mapping of Soils, Vegetation, and Water Resources of Lynn County, Texas, by Computer Analysis of ERTS MSS Data", in, Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1, Volume II, (Greenbelt, Maryland: Goddard Space Flight Center; 1973), p. 18.

NOTE: The investigators of the above study may be found at Purdue University, West Lafayette, Indiana.

** Heller, R. C.; Aldrich, R. C., Weber, F. P.; Driscoll Driscoll, R. S.; Test ERTS Multispectral Imagery for Identification of Forest Rangeland, Non-Forest, Water Resources, and Forest Stress.

*** Heller, R. C.; Interpretation Techniques Development -- Image Enhancement Techniques.

RMF No. 2.1.2

RANGELAND MAPPING

Rationale for Benefits

Maps of rang land areas can be used as a graphical presentation of data on range condition (measured in four condition classes), location of ecosystems, range trends (long term deterioration or improvement), and forage productivity or livestock carrying capacity. Such maps are valuable in making forage condition assessments and forecasts, in wildlife management, in scheduling livestock grazing, in designing and executing soil conservation programs, in designing and executing range rehabilitation, in fire prevention and control, and in weed control.

Federal Government Activities and Responsibilities

The rangeland mapping function is subsumed under the term "rangeland inventory". The federal activities and responsibilities are therefore covered under RMF 2.2.7 (Prepare Rangeland Inventories).

Functions of Remote Sensing

This topic is discussed under RMF 2.2.7.

Economic and Technical Models for Estimating Benefits

Since mapping activities in this resource area are so closely interrelated with statistical services and other management functions, benefits attributable to mapping in itself are not estimated.

Current ERTS Activities

Useful rangeland maps show both vegetation type and overall land use of the mapped district. One method of measuring the helpfulness of remotely sensed data in rangeland mapping is to test the ability of the imagery to delineate major vegetation zones. The ERTS-1 Range Analysis Team* used

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* G. R. Heath and H. D. Parker, "Forest and Range Mapping in the Houston Area, with ERTS-1 Data,: from Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-I, (New Carrollton, Maryland: Goddard Space Flight Center, 1973), p. 169-170.

conventional and computer-aided processing techniques to investigate the accuracy with which two major vegetation zones on the Texas Gulf Coast could be distinguished using ERTS-1 data. The computer classification technique used by the study team involves the correlation of individual clusters of data with specific ground phenomena. These data clusters "were combined such that the boundary between the two vegetation zones were approximated in the output cluster map, which was color coded and filmed".** The study group found that the "similarity of the cluster map to the vegetation zone boundaries from the ground truth indicates that the groups of clusters constructed did provide a reasonable match with vegetation zones.***

Another study, conducted by J.V. Drew demonstrated the ability of ERTS MSS imagery to identify and delineate between the basic kinds of range sites. Range sites are identified by characteristic plant communities.****

Estimate of ERTS Economic Capabilities

Annual Benefits:

Through later RMFs.

** *Ibid*, p. 169-170

*** *Ibid*, p. 170

**** Paul M. Seevers, and James V. Drew, "Evaluation of ERTS-1 Imagery in Mapping and Managing Soil and Range Resources in the Sand Hills Region of Nebraska" from Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-I (New Carrollton, Maryland: Goddard Space Flight Center, 1973), p. 87-89.

RMF No. 2.1.3

WILDLIFE HABITAT MAPPING

Rationale for Benefits

Wildlife habitat surveys support estimates of wildlife populations and trends, essential for conservation programs. Particular categories of wildlife habitat other than the forests and rangelands in general are wilderness areas, wetlands, wild and scenic rivers, and tundra.

Federal Government Activities and Responsibilities

The Bureau of Sport Fisheries and Wildlife of the Department of the Interior inventories waterfowl populations, using aerial surveys. The bureau plans to make a national wetlands survey.

Functions of Remote Sensing

Since many wildlife areas are inaccessible or difficult to reach by other means, remote sensing is often the only practical approach to obtaining survey information.

Economic and Technical Models for Estimating Benefits

Since mapping activities in this resource area are so closely interrelated with statistical services and other management functions, benefits attributable to mapping in itself are not estimated.

Current ERTS Activities

Principal Investigator:

Anderson, Richard

Report:

Estuary and Wetlands Surveys - Chesapeake Bay by Anderson, Richard R.

Color additive and color composites were utilized to delineate tonal structure in wetlands. This tonal structure reflects species differences such as: salt marsh cordgrass, salt meadow cordgrass, and needlebrush. Saline and near-saline wetlands can be delineated from ERTS-1 images as the wetland-upland boundaries and land-water interfaces are clearly defined.

RMF No. 2.1.3

<u>Estimate of ERTS Economic Capabilities</u>

Annual Benefits:

Not Estimated.

RMF No. 2.1.4

SOIL MAPPING OF FORESTS AND RANGELANDS

Rationale for Benefits

Soil maps and surveys are valuable because of their utility as an aid in predicting the response of land to specific treatments or the absence of treatment. The treatments of primary importance are associated with the management of the forests and rangelands for yield and for soil conservation. Specifically, knowledge of the boundaries of major soil types as portrayed in soil maps can be combined with other information to predict timber and forage yields and how they depend on planning, thinning, seeding, and fertilization methods and schedules.

Federal Government Activities and Responsibilities

The Soil Conservation Service prepares soil maps as graphic presentation of its soil surveys. In preparing soil maps, cartographers obtain aerial photographs and make photomosaics to be annotated by soil scientists who conduct detailed field examination of the soil. The total budget for soil mapping (not only forests and rangelands) is $3.6 million per year. To date, soil surveys have been completed for less than 20 percent of the U.S. The Soil Conservation Service plans to update soil surveys on a 20 to 25 year cycle.

Non-Federal Activities

The Weyerhauser Corporation has soil-mapped both public and company owned forest access for the use of state governments and universities.

Functions of Remote Sensing

Remotely sensed information may make possible earlier completion of planned soil maps for most of the U.S., as well as soil mapping of important areas of other countries. In addition, cost savings may be possible in preparing the maps.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Quantitative benefit calculations for soil mapping are treated in the Agriculture study (Resource Management Area 1).

RMF No. 2.1.4

Current ERTS Activities

Principal Investigator:

Parks, W. L.

Report:

Soil Survey and Classification for Western Tennessee by Parks, W. L.

Comments:

The identification and delineation of a large soil association has been accomplished. Soil types have been identified through the use of aircraft imagery. However, a soil association map appears to be the best that space imagery alone will provide.

Estimate of ERTS Economic Capabilities

Annual Benefits:

None Estimated

See Volume III

RMF No. 2.2.1

DETERMINE FOREST TIMBER VOLUME BY TYPE, LOCATION, AND OWNERSHIP

Rationale for Benefits

This resource management function consists of the preparation of timber volume statistics for publication, and thus for use beyond a specific immediate management need. Volume determinations for more restricted purposes are included as part of RMF 2.4.1 (Manage Timber Harvest).

Traditionally, timber inventory procedures have emphasized the determination of volume, and volume data are important for some management activities. For example, in preparing a timber sale or a specific harvesting operation, the volume of the timber involved is an important item of data. However, in describing a stand of timber or a larger unit to be managed for sustained yield, the volume figures for the various types are by themselves of little significance. The sustainable yield is the single quantity of greatest interest for timber management, and this is closely related to current and projected growth rates. Thus, volume determinations produce benefits largely through their use in supporting other statistical and analytical work.

Federal Government Activities and Responsibilities

The general activities of the various federal agencies in timber inventory are described in Section 1.9. Here we treat more specifically the timber volume information obtained and published by the Forest Survey. The Outlook for Timber in the United States gives timber volumes broken down in various ways. Types are in terms of species, stand volume class, and diameter class, while location is given by state. Volume data are also broken down by ownership class.

As stated in Section 1.9, volume estimates are prepared through a double sampling procedure using sample plots selected from aerial photography, and field sampling to select specific trees for volume measurements. The volume measurements on individual trees are actually *estimates* calculated from diameter and length measurements, broken down according to the various commercial uses of parts of the trees. The volume per unit area of the timber stand is estimated photogrammetrically. In many timber stands, this volume per unit area figure is closely related to: (1) the average height of the dominant trees; (2) the proportion of the total ground area within the timber stand boundary that is obscured by the crowns of the trees. The essence of the technique is the correlation of these remotely sensed data with the volume more directly estimated by ground based procedures.

Functions of Remote Sensing

The function of remote sensing in the preparation of inventory information in general is discussed in Section 1.9. With respect to volume, remote sensing results in a decrease in emphasis given to that quantity as a primary descriptor of the timber resource. Volume is neither a variable directly recorded by remote sensors, nor is it one of the most useful primary variables to be studied for management purposes. The trend toward replacing the emphasis in volume with emphasis on growth is consistent with the availability of inventory techniques using aerial photography, but it is accentuated by the availability of three-stage sampling techniques in which the classification constituting the first stage can be done automatically from ERTS tapes.

Economic and Technical Models for Estimating Benefits

Although the primary benefits of satellite information in this area are of the new capability type, and best estimated as part of later RMFs including RMF 2.4.1 (Manage Forest Timber Production) and RMF 2.9.1 (Design Forestry Legislation and Monitor Compliance), cost savings would be achieved if current inventory objectives were maintained and ERS data were used to supplement data from other sources in meeting these objectives.

EarthSat has prepared cost models to estimate these cost savings as part of their Forestry Case Study. These models include formulae for determining the part of the Forest Survey's expenditures which can be attributed to field inventory, applied separately to the individual experiment stations to determine inventory costs per acre. The assumptions on ERS system costs are based on demonstrated (by Nichols)* ERTS-1 capabilities for inventory of the Qunicy Ranger Station of the Plumas National Forest, with the reasonable assumption that costs per acre of inventories prepared by the Nichols procedure would be uniform across the country.

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* See page A-17.

RMF No. 2.2.1

EarthSat's estimates for national Forest Survey cost savings based on these models are given under four sets of assumptions, formed by combining "high" and "low" estimates for both ERS system inventory costs and for current system costs. The lower estimate of ERS system costs, 1.71 cents per acre or $595,000 (annual) total, is based directly on Nichols' work. The higher estimate is produced by an arbitrary adjustment of the lower estimate to insure conservatism. We present here the consequence of the use of the lower estimate alone. The two estimation methods for Forest Survey inventory costs are both reasonable and give somewhat different results. We average the results of the two methods, obtaining annual costs of $1.4 million. This leads to a single rough estimate of cost savings of $800,000 per year. Assuming that benefits continue at this rate from 1965 to infinity, and discounting at 10 percent to 1965, the present value of the cost saving is $8 million.

Because of the slow progress of current Forest Survey inventory work, the likely use of any realized cost saving of this type would be increased inventory activity. Thus, an "increased capability" benefit based on the equal budget assumption is reasonable. Since the cost saving is about 57 percent, the total benefit is $\frac{-\ln(0.43)}{0.57} \times \$8$ million or $11.8 million.

The above benefit estimates are based on the assumption that demand for current Forest Survey information on timber volume will not be supplanted by demand for statistical products differing in accuracy, timeliness, comprehensiveness, or convenience of use. Although this is clearly an unrealistic assumption (partly because an ERS system can contribute to such changes in demand for statistical products, and partly because of trends of the type reflected in the Forest and Range Environmental Act), it does provide a "hard" estimate of a minimum for the realizable benefits of an ERS system through this RMF.

Current ERTS Activities

Current study on timber volume inventorying using ERTS imagery is being conducted by the following 4 investigators:

RMF No. 2.2.1

1. Dr. Emilio De Benito
   Escuela Technica Superior
   De Ingenieras De Montes
   Audad Universitaria
   Madrid, Spain
   Phone: 244-4807

   Title of Study: Timber Industry - Land Use in Huelua, Spain

2. Robert C. Heller
   Pacific S.W. Forest Range Station
   U.S. Department of Agriculture
   P.O. Box 245
   Berkeley, California 94701
   Phone: 415-486-3122

   Title of Study: Inventory of Forest and Rangeland Resources (including stress).

3. Phillip G. Langley
   Earth Satellite Corporation
   2150 Shattuck Avenue
   Berkeley, California 94704
   Phone: 415-845-5140

   Title of Study: Develop a Multi-Stage Forest Sampling Inventory System Using ERTS-A Imagery.

4. James Nichols
   Space Sciences Laboratory
   University of California
   Berkeley, California 94729
   Phone: 415-642-2351

The most impressive ERTS experiment relating to timber volume inventories is that of Nichols and others at Berkeley. Their procedure includes manual and automated analysis of ERTS-1 data, supporting aircraft data and ground data through multistage sampling techniques. The procedure was applied to the Quincy Ranger District of the Plumas National Forest in California. The procedure is able to match or surpass the accuracy of conventional inventory techniques, to provide more specific location information, and provide cost savings, in addition to saving considerable time.

The implication for Forest Survey Type inventories is that they may become less expensive, more accurate, and more timely. Since the important first-stage information is obtainable in remote areas as easily as in other areas, inventories may also be made more comprehensive.

An important feature of the procedure is the use of automatic classification of the timberland on ERTS data tapes into four timber volume classes at the first stage. The development of effective classification programs for that purpose has made possible a reduction in the amount of expensive and time-consuming ground work required.

Estimate of ERTS Economic Capabilities

The capabilities discussed above for improving timber volume inventories are associated with the properties of ERTS-1. Accordingly, the estimated benefits can be achieved with an ERTS-like system. The benefits might be increased somewhat if the spectral resolution were improved. This might improve the classification process of the first stage of the inventory, so that less field work would be required to provide the same overall accuracy. Further cost savings would result. Better spatial resolution is not necessary, since it would neither improve accuracy nor decrease costs.

Annual Benefits:

Equal Capability; $800,000

Increased Capability; $380,000

New Capability; through later RMFs.

RMF No. 2.2.2

DETERMINE FOREST LAND AREAS

Rationale for Benefits

Forest land areas vary with gains due primarily to reseeding of abandoned farm lands and losses due to a wide variety of changes in land use including urban development, cropland expansion and highways. Monitoring of these changes is important in timber management and planning, land use planning and administration, and in soil and water conservation.

Federal Government Activities and Responsibilities

Determination of forest land areas is performed by the Forest Service, the Bureau of Land Management, the Bureau of Indian Affairs, and the National Park Service. The Tennessee Valley Authority also determines forest land areas within the Tennessee River system.

Forest land area statistics are typically prepared from (1) calculations using the pertinent dimensions of aerial photography; and (2) ground surveys. Since forest land areas vary with reseeding, urban development, cropland expansion, and highway construction, the accuracy of these statistics is dependent on the output of timely aerial and ground studies.

Function of Remote Sensing

Remotely sensed data can lead to improved timeliness in monitoring changes in forest land areas and in cost savings for the monitoring process. The accuracy of forest area measurements with remote sensing as an aid is far superior to that of other procedures.

Economic and Technical Models for Estimating Benefits

Benefits for this RMF are included in the calculation under RMF 2.2.1, which actually applies to the whole forest inventory process.

Current ERTS Activities

The experiments discussed under RMF 2.2.1 also apply to this RMF. Heller has observed that simulated true color enhancement is effective for discrimination between vegetation types, bare soil and harvested crops. Detection of timber cutting areas is also easy on simulated true color.

RMF No. 2.2.2

Estimate of ERTS Economic Capabilities

Annual Benefits:

Through RMF 2.2.1.

RMF No. 2.2.3

MEASURE FOREST TIMBER GROWTH AND REMOVALS BY TYPE AND LOCATION

Rationale for Benefits

The descriptive variables of the greatest importance for management of the timber resource are growth and removals, since they determine the economic output. Two growth concepts are important--total growth and net growth. The latter takes account of damage and mortality. Statistics on growth and removals broken down in various ways are part of the output of the usual inventory processes. In-place mapping of growth is particularly valuable, since it contributes to efficient harvesting decisions.

Federal Government Activities and Responsibilities

The forest inventory work of the various federal agencies is described in Section 1.9 (Statistical Services). Conventional procedures for estimating growth and removals differ little among the various inventories. For growth, sample trees are marked and their growth rates are estimated by comparison of direct measurements made on different occasions. By the use of statistical sampling methods, these data are extrapolated to the level of interest.

Measurement of tree removals is usually done by ground checks of tree stumps after contract cutting, or by obtaining removal figures from private industry.

Function of Remote Sensing

Remote sensing can be applied to the problem of measuring growth in at least two ways. One is to concentrate on the accuracy of area measurements so that the extrapolation of ground-estimated tree growth to forest units can be more precise. Another is to develop multistage sampling procedures in which the initial stratification is by growth-related variables observable by the remote sensors.

With any estimation procedure, the frequent coverage of the same area obtainable with an ERS system and the capability of associating estimates with specific locations promise to considerably improve the economic value of the growth information and to reduce the cost of providing it on a timely basis.

RMF No. 2.2.3

With greater use of remote sensing, the variables chosen as primary descriptors of the forest may change. Net growth minus removals (change in inventory) may be more directly measured, and on an in-place basis, sc that the accuracy of estimates of this crucial variable will not be eroded by propagation of sampling errors in the other variables.

Economic and Technical Models for Estimating Benefits

See RMF 2.2.1, under which the whole inventory process is discussed.

Current ERTS Activities

See RMF 2.2.1 for discussion of experiments by Nichola and Langley.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Through RMF 2.2.1.

RMF No. 2.2.4

FORECAST FOREST TIMBER SUPPLIES BY TYPE AND LOCATION

Rationale for Benefits

Forecasts of timber supplies are important for long range planning of timber management activities, as well as for making multiple-use allocation decisions as discussed under RMF 2.4.5. In addition to their importance within this resource management area these data are important to land use planners, and economic planners in government and industry generally.

Federal Government Activities and Responsibilities

Over the past several decades, the Forest Service has periodically reviewed the timber supply and demand situation in the United States. The McSweeney-McNary Forest Research Act of 1928 provides the legislative underpinning for these activities.

In this act the Secretary of Agriculture is directed to cooperate with the other federal agencies, state forestry agencies, and private industry, in "....keeping current a comprehensive survey....of timber supplies, including a determination of the present and potential productivity of forest land...."* To assist the Forest Service in making this national forecast of timber supplies, the Bureau of Land Management, the Bureau of Indian Affairs, and the Tennessee Valley Authority make the results of their individual forest inventories available to the Forest Service.

Function of Remote Sensing

To the extent that remote sensing improves the quality of the information available to support supply forecasts, it benefits this RMF. Important improvements may occur in timeliness, comprehensiveness, and accuracy.

Economic and Technical Models for Estimating Benefits

Benefit models have not been developed for this activity.

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* U.S. Forest Service, The Outlook for Timber (Washington, D.C., Government Publication Office, 1973), p. 1.

RMF No. 2.2.4

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated

RMF No. 2.2.5

DETERMINE COMMERCIAL CHARACTERISTICS OF FOREST TIMBER BY TYPE AND MATURITY

Rationale for Benefits

This is one of the statistical products of standard inventories. It is valuable in assessment of the potential for supplying raw materials for the various forest products.

Federal Government Activities and Responsibilities

The Forest Service prepares these statistics as part of the Forest Survey, and in more detail in support of timber management activities for the forest lands under its administration.

Since the Forest Service provides the accepted methodology of forest inventorying for all the federal agencies, the Bureau of Land Management, the Bureau of Indian Affairs, and the Tennessee Valley Authority, follow the methods described in RMF No. 2.2.1.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Through RMF 2.2.1.

RMF No. 2.2.6

DETERMINE PROPORTIONS OF TIMBER DESTRUCTION DUE TO VARIOUS NATURAL AGENTS

Rationale for Benefits

This information is very valuable in conservation and in damage assessment and prevention activities. Only partial statistics in this area can currently be prepared, because of the difficulty in establishing causes of destruction.

Federal Government Activities and Responsibilities

The Forest Service, in cooperation with the Bureau of Land Management, the Bureau of Indian Affairs, and the Tennessee Valley Authority, determines the extent of timber damage by various natural agents. One purpose of the Forest Survey is to detect the existence and proportions of any forest disturbances. Once a disturbance has been found, ground crews are sent to the area to determine the cause. Among the various agents often causing disturbances, are pests, animal damage, and tree diseases.

Current ERTS Activities

According to EarthSat's Forestry Case Study, Kirby has reported recognition of burned over areas in Canada from color composite interpretation. Tueller* recognized burn scars in Nevada from ERTS data and characterized them by age category. Colwell has reported successful burn area detection and mapping and gross fire damage evaluation in California as well as fuel hazard recognition in frost-killed eucalyptus stands.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

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* See RMF 2.4.1

RMF No. 2.2.7

PREPARE RANGELAND INVENTORIES

Rationale for Benefits

Rangeland inventories are statistical products essential to the management decisions of rangeland operators. The FRES* system of range inventory classifies resource units by eco-system, ownership, productivity, and condition. Resource units are ecological units that are homogeneous at the national level. Classification of rangeland areas by resource units improves productivity estimates, projections, condition assessments, and tread assessments. This information supports grazing allocation decisions and rangeland improvement decisions.

Federal Government Activities and Responsibilities

The Forest Service and the Bureau of Land Management are the Federal agencies most active in this function. Their inventories have been conducted every three to ten years, and have been designed for use in administering grazing allotments and the other federal rangeland areas. In addition, the Soil Conservation Service inventories private rangelands when requested to do so by individual ranchers, and conducts the Conservation Needs Inventory.

With the expanded responsibilities assigned by the Forest and Rangeland Environmental Management Act of 1974, the Forest Service can be expected to increase its activity in rangeland inventorying, monitoring and analysis.

Functions of Remote Sensing

Remote sensing may provide cost savings in this function, but its more important contribution will probably be to significantly improve the timeliness and comprehensiveness of rangeland inventories. Inventory information is not currently collected frequently enought or at enough locations to fulfill its important *monitoring* function.

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* "Forest-Range Environmental Study", a program for the U.S. Forest Service, 1970-1972.

RMF. No. 2.2.7

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

The EarthSat Rangeland Case Study calculates cost savings benefits on an equal capability basis in the range of \$2.7 million to \$3.4 million. These figures represent present value of constant annual benefits of \$435,000 to \$548,000, assumed to continue from 1977 through 1986, and discounted to 1976.

The annual figures are calculated as a difference between conventional rangeland inventory costs (including aerial photography costs) and estimates of costs using ERS system information. For the benefit estimate, the costs of aerial photography should be subtracted from the cost savings. On this basis, the annual savings are between \$100,000 and \$210,000. The present value of this annual flow from 1977 to infinity, discounted to 1975, is \$913,000 to \$1.91 million. The upper value is still conservative, based on ERTS-1 experiments by G. Bentley. We use it as the single "best" estimate.

An additional "increased capability" benefit estimated on an equal budget basis is \$1.8 million. This is obtained as follows. The ERS system cost is \$.21 per square mile, while the cost of the current system is \$.94 per square mile. The saving is thus \$.73 per acre, or 77 percent. The increased capability benefit is therefore

$$\$1.9 \times \left[\frac{-\ln\ (1-.77)}{.77}\right] - 1 \ \text{million} = \$1.8 \ \text{million.}$$

These cost savings benefits are very small compared to possible benefits achieved through the use of improved range-land inventories in other statistical activities and in management activities such as scheduling of livestock grazing and purchases, management of forage production, conservation, research, and administration. The "new capability" benefits are best estimated through the analysis of these management activities.

Current ERTS Activities

The following scientists are currently investigating ERTS capability to perform rangeland inventories:

RMF No. 2.2.7

1. Gordon R. Bentley
   Bureau of Land Management
   Building #50
   Denver Federal Center
   Denver, Colorado 80225
   Phone: 303-234-2374

2. Dr. James V. Drew
   412 Administration Building
   University of Nebraska
   Lincoln, Nebraska 68508
   Phone: 402-472-2875

3. Robert C. Heller
   Pacific Forest and Range Station
   U.S. Department of Agriculture
   P.O. Box 245
   Berkeley, California 94701
   Phone: 415-486-3122

<u>Estimate of ERTS Economic Capabilities</u>

The above estimates based on EarthSat's study apply to an ERTS-like system:

Annual Benefits:

Equal Capability; $1,900,000

Increased Capability; $1,800,000

New Capability; Through later RMF's.

RMF No. 2.2.8

MEASURE RANGELAND YIELD

Rationale for Benefits

These statistics support range resources management and administration, as well as research directed at improving livestock productivity.

Federal Government Activities and Responsibilities

The Forest Service prepares their statistics on a national basis as part of programs like the Forest-Range Environmental Task Force.

Function of Remote Sensing

More accurate, timely, and comprehensive statistics could be prepared with the aid of additional data. Costs of preparation might be reduced.

Current ERTS Activities

Among the many variables to be considered in an accurate assessment of rangeland yield are the presence and size of ephemeral lakes within the perennial rangeland. A study of California's forage resource using ERTS-1 data found that the existence and magnitude of these lakes can be detected on a given date using MSS bands 6 and 7.*

The most important use of ERTS images for forecasting rangeland yield is in monitoring changes in forage plant condition and development. It was found in the study cited above that annual rangeland containing recently germinated forage species could be differentiated from rangeland where germination had not occured.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not estimated.

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* David M. Carneggie, Stephen D. DeGloria, "Monitoring California's Forage Resource Using ERTS-1 and Supporting Aircraft Data," from Symposium on Significant Results Obtained from the Earth Resources Technology Satellite, (New Carrollton, Maryland, 1973), p. 93.

RMF No. 2.2.9

FORECAST RANGELAND YIELD

Rationale for Benefits

These forecasts support efficient allocation decisions in rangeland management and livestock growing.

Federal Government Activities and Responsibilities

The Forest Service includes these forecasts in the analytical work of the Forest Survey and of special programs like FRES.

The Service has developed long-term prediction techniques based on repeated sampling from permanently established clusters.

Short-term forecasts are generally made on the basis of visual evidence in the field and from aircraft or helicopters. Several investigations have also developed prediction techniques based on weather data.

Function of Remote Sensing

Additional information can improve the accuracy, detail, and comprehensiveness of short-term and long-term rangeland yield forecasts.

Current ERTS Activities

Accurate assessment of rangeland seeding is accomplished by detecting the extent of germination for the area under study. A report on California's forage resource demonstrated the capability of ERTS data to differentiate classes of forage plant condition including germination.*

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

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* David M. Carneggie, Stephen D. DeGloria, "Monitoring California's Forage Resource Using ERTS-1 and Supporting Aircraft Data," from Symposium on Significant Results Obtained from the Earth Resources Technology Satellite, (New Carrollton, Maryland, 1973), p. 93.

RMF No. 2.2.10

ASSESS RANGE FORAGE CONDITIONS

Rationale for Benefits

Accuracy and timeliness of range forage condition assessments are extremely important to the range managers and livestock owners who use this information for allocation decisions.

Federal Government Activities and Responsibilities

Much of the statistical work of the agencies administrating rangelands belongs to this RMF. The bulk of this information is prepared by the Statistical Reporting Service of the U.S. Department of Agriculture, which collects data on crops and livestock products and distributes them in hundreds of reports each year. Monthly reports show reported range forage conditions in 17 states, and also includes comments on general range forage conditions for each state individually and for the Western range regions. These reports are based on mailed inquiries sent monthly to ranchers and farmers.

The rangeland inventories of the Forest Service and the Bureau of Land Management also provide information on forage conditions.

Function of Remote Sensing

Remotely sensed data could improve the economy of the assessment process and improve accuracy and timeliness.

Current ERTS Activities

Gordon Bentley of the Bureau of Land Management is conducting a study entitled, "To Advance Predict Ephemeral and Perennial Range Quantity and Quality During Normal Grazing Season." He may be reached at:

Bureau of Land Management
Building #50
Denver Federal Center
Denver, Colorado 80225
Phone: 303-234-2374

David Carneggie and Stephen DeGloria of the University of California at Berkeley have produced a report entitled, "Monitoring California's Forage Resource using ERTS-1 and Supporting Aircraft Data." They concluded that the most

RMF No. 2.2.10

important use of the ERTS imagery for evaluating rangelands lay in ERTS monitoring of changes in forage plant condition and development.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Through RMF 2.2.7.

RMF No. 2.2.11

FORECAST RANGE FORAGE CONDITIONS

Rationale for Benefits

These forecasts are extremely important in rangeland management, particularly in scheduling and alloting livestock to grazing areas.

Federal Government Activities and Responsibilities

The Forest Service and the Bureau of Land Management experts currently forecast range feed conditions through trend analysis at various levels of sophistication, from large surveys of sample lots to casual impressions of personnel.

Several range scientists have developed regression equations based on weather data to predict forage yield. Unfortunately these predictions are now based on weather data from widely scattered weather stations, making extrapolation difficult and subject to uncertainty. In addition, weather data are not always available from ground stations over many of the rangelands. This severly restricts the use of such predictive models.

Current ERTS Activities

ERTS data provides a permanent record of range conditions at a given date and for a given year. A comparison of ERTS images with aircraft data obtained in previous years reveals the difference in range condition between years. ERTS data acquired on a year-to-year basis can provide the first effective means for comparing changes in range condition from year to year for large rangeland areas.*

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

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* David M. Carneggie, Stephen D. DeGloria, "Monitoring California's Forage Resource Using ERTS-1 and Supporting Aircraft Data", from Symposium on Significant Results Obtained from the Earth Resources Technology Satellite, (New Carrollton, Maryland, 1973), p. 94.

RMF No. 2.2.12

ASSESS WILDLIFE HABITATS

Rationale for Benefits

Statistical information on wildlife habitats is currently scarce and difficult to obtain, though it is very valuable in estimating wildlife populations and in conservation and wildlife management activities, particularly in the wetland areas.

Federal Government Activities and Responsibilities

The Bureau of Sport Fisheries and Wildlife of the Department of the Interior has responsibility for monitoring wildlife habitats. It currently makes a semiannual survey of the prairie potholes to forecast waterfowl availability. A national inventory of wetlands is being planned, as authorized by the Fish and Wildlife Coordination Act. Previously wetlands inventories have been conducted at 20 year intervals. The Soil Conservation Service of the United States Department of Agriculture, conducts a national inventory of soil and water conservation needs as part of its Land Inventory and Monitoring Program.

Non-Federal Activities

The Connecticut Wetlands Protection Act directs the Department of Environmental Protection to inventory Connecticut's coastal wetlands. New York State has similar legislation.

Functions of Remote Sensing

Remote sensing promises to increase comprehensiveness of wildlife habitat inventories.

Current ERTS Activities

Carl E. Abegglen of the Bureau of Sport Fisheries and Wildlife is conducting a study entitled, "Evaluation of Space Acquired Data as a Tool for Management of Wildlife Habits in Alaska." Mr. Abegglen may be reached at:

Division of Wildlife
Bureau of Sport Fisheries and Wildlife
813 D Street
Anchorage, Alaska 99501
Phone: 907-265-2898

RMF No. 2.2.12

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.3.1

ESTABLISH GREEN WAVE AND BROWN WAVE CALENDARS BY FOREST OR RANGELAND VEGETATION TYPE

Rationale for Benefits

These phenological data are important for insect damage control activities in the forests, for fire damage prevention in forests and rangelands, and for preparing rangeland crop assessments and forecasts.

Federal Government Activities and Responsibilities

The Forest Service has basic responsibility for preparing and disseminating information of this type.

Function of Remote Sensing

Remotely sensed data could lead to cost savings in preparing calendars currently in use, as well as leading to the preparation of more comprehensive and reliable calendars.

Current ERTS Activities

Dr. B. E. Dethier
Department of Agronomy
Box 21, Emerson Hall
Cornell University
Ithaca, New York 14850
Phone: 607-256-3034

Dr. Dethier's study is entitled, "Phenology Satellite Experiment (Greenware NE-69)".

The recording of phenological calendars by ERTS-1 multispectral data is accomplished by detecting relative changes of spectral reflectance through time of forests, rangelands, and specified crops. In a phenological study of the Appalachian Corridor and the Mississippi Valley Corridor, researchers found that analysis of ground observation photography and ERTS-1 imagery indicated vegetation changes very well. Accordingly, the study group also concluded that specific phenological events such as crop maturity and leaf fall can be mapped for specific sites and entire regions.*

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* Bernard Dethier, Marshall Ashley, Byrar Blair and Richard Hopp, "Phenology Satellite Experiment" from Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1 (New Carrollton, Maryland, 1973), p. 157.

RMF No. 2.3.1

EarthSat reports that McMurty in Pennsylvania and Colwell in California have used multidate imagery showing phenological changes in vegetation to aid in vegetation type discrimination. McMurty has reported separation of softwoods from hardwoods using this technique.

Dr. Jay McKendrick
Institute of Agriculture Science
University of Alaska
Palmer, Alaska 99645
Phone: 907-745-3257

Dr. McKendrick's study is entitled, "Identification of Phenological Stages and Vegetation Types for Land Use Classification in Wilderness Area".

Dr. John W. Rouse
Remote Sensing Center
Texas A & M University
College Station, Texas 77843
Phone: 713-845-5422

Dr. Rouse is working on a study entitled, "Monitor Vernal Advancement and Retrogradation (Green Wave Effect) of Natural Vegetation in Great Plains Corridor".

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.3.2

ESTABLISH CALENDARS FOR CYCLICAL PATTERNS OF INSECT INFESTATION IN FORESTS

Rationale for Benefits

Such information would be useful in insect damage reduction and in research on insect damage.

Federal Government Activities and Responsibilities

The United States Forest Service has basic responsibility for preparing and disseminating information of this type.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.3.3

DETERMINE SCHEDULE OF GRAZING OPPORTUNITIES ON RANGELANDS

Rationale for Benefits

Timing of livestock grazing in rangelands is a critical area of range management.

The Forest Service and Bureau of Land Management currently make adjustments in schedules for access to their perennial ranges only at the permittees request. Information on the actual period of range readiness is seldom available.

Function of Remote Sensing

Remote sensing may make it possible to extrapolate the limited information effectively to improve accuracy of grazing opportunity calendars.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.3.4

ESTABLISH CALENDAR OF WILDLIFE HABITAT CHANGES

Rational for Benefits

Regular comprehensive inspection of wildlife areas can lead to information on general patterns that could not otherwise be obtained.

Federal Government Activities and Responsibilities

The Bureau of Sport Fisheries and Wildlife of the Department of the Interior has the basic responsibility for federal government work in this area.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.4.1

MANAGE TIMBER HARVEST

Rationale for Benefits

The demand for timber products has been increasing steadily in recent years, and further substantial increases are projected. More intensive and comprehensive management can increase supplies to meet this demand. The benefits of timber management are achieved through increased sustained yields of timber simultaneously with protection or enhancement of non-timber forest values such as water, wildlife, recreation, and forage. The importance of the management of the harvest of timber is primarily in assuring that desired timber yields are obtained with a minimum destruction of the vital non-timber values.

Federal Government Activities and Responsibilities

The Forest Service is the federal agency most active in management of timber production. The Bureau of Land Management, the Bureau of Indian Affairs, the Tennessee Valley Authority, and the Army Corps of Engineers, all perform some management activities relative to the timber lands they administer.

The Forest Service manages timber land in the National Forests, which account for about 18 percent* of the total U.S. commercial timberlands. The Service also encourages more efficient timber management on other public lands and on private lands through such measures as general forest protection from fire and other destructive agents, technical assistance and educational efforts, cost sharing of forestry practices, and controls on timber cutting practices. The Forest Service annual budget for National Forest management is about $230 million.**

Timber harvests in the National Forest System are managed through the conduct of timber sales. These are held by the rangers responsible for the management of the districts of the National Forests. Sales are awarded through auction bidding, beginning at a price established by the ranger on the basis of an appraisal. The planning and execution of timber

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* U.S. Forest Service, Outlook for Timber, (Government Printing Office, Washington, D.C., 1973), p. 11. FRR-20.

** Apper ix to the Budget of the Federal Government, Fiscal Year _975, p. 205.

sales is within guidelines, often including a quota, from the National Forest supervisor. The planning stage includes the location of mature timber to constitute the sale and an estimate of its volume for appraisal purposes.

The information needs of the U.S. Forest Service in timber management are met primarily by its Timber Management and Planning Division which conducts a "management planning" inventory to prepare long range management schedules and guidelines. The FY 1973 budget allocation for this inventory was $3.5 million.* Before making decisions on the extent and pattern of timber harvests, more detailed data are required. To meet this need, the Division conducts a silvicultural examination program designed especially to identify, map, measure, and prescribe treatment for each timber stand. The FY 1973 budget allocation for this activity was $3.1 million.** Of course these management information sources are supplemented by the statistical data of the Forest Survey Division, whose activities are outlined under the resource management activities of mapping (see 1.8) and statistical services (see 1.9).

The Bureau of Indian Affairs manages 16 million acres*** of Indian forest lands. Management of timber production on these lands is a mixture of public and private interests, with the major objective of producing income for the Indian owners.

The Bureau of Land Management administers 114 million acres of forest and woodland, 28 million acres of which is classified as commercial timber land.**** Though this Bureau is primarily a land managing agency with limited responsibilities in forestry, its policies affect valuable timber lands in Oregon, California and Alaska.

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* Mr. Sullivan, Personal Telephone Conversation of August 8, 1974 at 11:00 A.M. Mr. Sullivan is a member of the Timber Management Division. 202-447-7495.

** Ibid.

*** Albert C. Worrell, Principles of Forest Policy, (New York: McGraw-Hill Book Company, 1970), p. 184.

**** Ibid., p. 184.

RMF No. 2.4.1

The Tennessee Valley Authority is an independent federal agency which has played an important role in forest management within the Tennessee River system. Forest Management within the TVA is performed by the Division of Forestry Development.

Non-Federal Activities

Since most commercial forest land in the United States is privately owned, timber management is primarily a private activity. Some of the largest private timber holdings are as follows: Boise Cascade, 6.8 million acres; Champion International, 7.0 million acres; Chesapeake Corporation of Virginia, 322,000 acres; Crown Zellerback, 1.3 million acres; Great Northern Nekovsa, 2.7 million acres.

Private forest owners and managers make considerable use of the published data of the Forest Survey. These data are important for long range planning, capital allocation decisions, general evaluations of raw material sources, projections of forest resource supplies, and projections of markets and prices. More specific inventory data are also required in timber management, particularly in planning specific treatments such as planting, cutting, and thinning. Private companies currently obtain these data largely through inventory contracts with forestry consultants.

Function of Remote Sensing

Remote sensing through aircraft photography has improved timber management in past years by increasing the accuracy, timeliness, and comprehensiveness of timber inventories and related management information such as growth and condition statistics. ERS-derived information can be expected to improve timber management further in the same way.

In addition, ERS data may make possible the creation and efficient maintenance of large data bases describing the timber resource. The use of such data bases and the computerized models which they support may contribute to better coordination of timber management decisions on the national and regional levels. The new Forest and Rangeland Environmental Management Act of 1974 (Section 6a) specifically calls for coordination of resource use plans for units of the National Forest System and for coordination of planning among the federal agencies and state and local governments.

RMF No. 2.4.1

Unified and comprehensive inventory information in computerized data bases can considerably reduce the extra inventory work currently required for harvest management. For harvest purposes, volume and growth information must be location specific. Well designed multistage sampling procedures using ERS data tapes for initial classification can provide location-specific information comprehensively and frequently, so that much of the data collection currently required for harvest management may be eliminated. The combination of timeliness and comprehensiveness of remote sensing is the source of this advantage. As is indicated by the calculations of the next section, these properties can be transformed into precision of the statistical sampling process, making it possible to virtually eliminate the cost of sampling error.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Equal capability and increased capability benefits to timber management functions are based on cost savings in data collection and inventory preparation. We treat here the Timber Management and Planning Inventory of the Forest Service.

As part of the case study in forestry, EarthSat prepared cost models of the timber inventories of several federal agencies. Just as under RMF 2.2.1 (Determine Forest Timber Volume by Type, Location, and Ownership), we adapt the results of that study.* The upper and lower bounds EarthSat provides for the current costs of the inventory are based on two reasonable interpretations of accounting data. To produce a single "best" estimate, we average the two. The cost rate used to represent an ERS-aided inventory is 1.61 cents per acre as estimated by Nichols** for his experimental procedure. Total annual inventory costs in the National Forest System under current procedures are thus estimated as $950,000, while the ERS-aided cost estimate is $150,000. The differences of $800,000 represents an 84 percent saving.

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* Earth Satellite Corporation, Draft - Forestry Case Study Report, (Berkeley, California: Earth Satellite Corporation, 1974), pp. 180-189.

** For an account of Nichol's work, See RMF No. 2.2.1

RMF No. 2.4.1

The result of any cost saving in the Stage-I inventory process would most likely be increased inventory activity. An "increased capability" benefit based on the equal budget assumption is therefore reasonable. Since the cost saving is about 84 percent, the total benefit is $1.7 million per year for the National Forests. The increased capability benefit is the difference, $1.7 million minus $0.8 million or $0.9 million.

Since the information needs for timber management on industrial forest land are similar to those in the National Forest System, we extrapolate the above-calculated benefits on the basis of commercial timberland areas in industrial and National forest ownership.

Eighteen percent of the total United States commercial timberland is in the National Forest System, while 13 percent is in industrial ownership.* The factor for extrapolation is thus $\frac{13}{18}$, so the additional benefits are $0.6 million (equal capability) and $0.6 million (increased capability). The totals are $1.4 million per year in equal capability benefits, and $1.5 million per year in increased capability benefits.

The basic model we use for estimating new capability benefits to timber harvest management can be outlined as follows: Timber harvest rates cannot be set optimally because of uncertainties in yields. The accuracy of yield estimates is improvable through more timely or more precise inventory information, through more accurate prediction of timber losses, or through more location-specific information. More briefly, the concept is that more accurate information permits more nearly optimal harvest decisions.

In implementing this modeling concept, we use the general structure outlines in Appendix D, in which the national timber resource is described by a production function, and two general uses of information are characterised: information for direct management, a necessary input to the production process; and information for improving the production process. In this section, we are concerned with the first use of information. The particular quantity of greatest interest is net timber growth (growth minus mortality), and it

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* U.S. Forest Service, <u>Outlook for Timber</u>, (Washington, D.C.; Government Printing Office, 1970), p. 11 FRR-20.

is approximately true that efficient timber management involves setting harvest rates equal to net growth rates.

Consider a timber resource "unit" consisting of sub-units among which growth and mortality rates are understood to vary. Sub-units may be distinguished geographically, or by type, ownership, maturity, or by some combination of qualities. If growth estimates have a sampling error $\frac{\sigma}{\mu}$, whether obtained for the unit as a whole or by sub-unit, then it is advantageous to obtain them by sub-unit. Setting sub-unit harvest amounts equal to the net growth estimates, the manager obtains a standard error of $\frac{\sigma}{\mu} \frac{1}{\sqrt{n}}$ as a percent of the total net growth for the resource unit.

The model of the cost of error in inventory level given in Section 1.6, can be used to calculate the benefit associated with a procedure for estimating growth by sub-unit.

The cost of maintaining error e is $L\ (e - \ln)\ (1 + e)\ (1 - \frac{\rho}{r})$

where L is the inventory value, ρ is the annual timber yield (value of net output per dollar inventory), and r is the discount rate. Here e is given as a fraction of L. Over time, errors in harvest lead to errors in inventory of the same order so that e will average about $\frac{\sigma}{\mu}$. The procedure for estimating growth by sub-unit results in a reduction of e to $\frac{e}{\sqrt{n}}$, so the benefit is

$$L(1 - \frac{\rho}{r})\ [e - \ln\ (1 + e) - \frac{e}{\sqrt{n}} + \ln\ (1 + \frac{e}{\sqrt{n}})]$$
$$= L\ (1 - \frac{\rho}{r})\ [e\ (1-\frac{1}{\sqrt{n}}) + \ln\ (1 + \frac{e}{\sqrt{n}}) = \ln\ (1 + e)].$$

Conventional inventory procedures of the Timber Management and Planning Division produce growth estimates by ranger district. An ERS-aided inventory procedure producing growth estimates of the same precision by pixel would provide this benefit. Ranger districts vary in size up to 100,000 acres. Consider a district of 10,000 acres. Since a pixel covers about one acre, the value of n in the above equation would be 10,000. Assume (very optimistically that the current sampling error within a type-class about to be cut is 5 percent. Then the above benefit expression becomes

$$L\ (1 - \frac{\rho}{r})\ [.05\ (.99)\ + \ln\ (1.0005) - \ln\ (1.05)].$$

Considering the whole National Forest System, L is about \$57.6 billion and ρ is about 3 percent. Thus, the national benefit would be

$$\$40.32\ (.0495 + .0005 - .0488)\text{ billion}$$
$$= \$48.4\text{ million.}$$

More realistically, current sampling errors for growth rates may average more than 10 percent. In this case the benefit of obtaining the same precision by sub-units would be more than

$$\$40.32\ (.0996 + .0005 - .0953)\text{ billion}$$
$$= \$190\text{ million (present value)}$$

The above benefits are based on the assumption that with or without ERS data, harvest rates are set at the ranger district level to match local net growth rate estimates. To the extent that harvesting rates are not so carefully matched to net growth rates, the benefit estimate is conservative. This is because a mismatch of net growth and harvest means either the steady state operating level of inventory has not yet been reached or harvesting decisions are not being made efficiently. In either case the difference between resource value with ERS-supported growth estimates and ERS-less growth estimates will be greater than it is near the steady state optimum.

RMF No. 2.4.1

Current ERTS Activities

1. Dr. Paul T. Tueller
   Renewable Resources Center
   University of Nevada
   Reno, Nevada 89507
   Phone: 702-784-4934

2. G. Lorain
   Renewable Resources Center
   University of Nevada
   Reno, Nevada 89507
   Phone: 702-784-4934

3. Dr. George J. McMurty
   220 Electrical Engineering West
   Pennsylvania State University
   University Park
   Pennsylvania 16802
   Phone: 814-865-9763

Dr. Tueller is working on a study entitled, "Methods of Utilizing Multispectral Satellite Imagery for Wildland Resources Evaluation".

According to Astronautics and Aeronautics, "Tueller and Lorain have found it easy to classify burn scars as less than one year old, one-to-ten years old, or more than 10 years old. Such rapid delineation of burn scars can be of considerable value in forest and range management".*

Several ERTS-1 investigators have reported successful detection and/or mapping of recent forest clearcut areas for ERTS data. Dr. McMurty of Pennsylvania State University has reported recognition of clearcut areas as small as 20 acres by application of computer processing techniques in the Stone Valley Experimental Forest in Pennsylvania.

Dr. Colwell of the University of California at Berkeley has recognized cutover forest areas from color composite interpretation.

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* Enrico P. Mercanti, "ERTS-1 Teaching Us a New Way to See", Astronautics and Aeronautics, (New York), September 1973, pp. 46-47.

RMF No. 2.4.1

Estimate of ERTS Economic Capabilities

Equal capability and increased capability estimates as discussed in the last section apply to an ERTS-like system. Already published results by Jim Nichols establish the ability of ERTS to improve *volume* inventory procedures significantly. In view of the importance of *growth* estimates, however, his current work is directed at designing a sampling method to improve their accuracy. Necessarily, improvement of volume accuracies in such a process is accompanied by a decline in growth estimates accuracies, and vice versa. Firm evidence on the extent of accuracy improvements in growth estimates will have to await his results. However, measurable improvements are certainly possible, whether by the sophisticated procedure he is investigating or by some other. For instance, extremely accurate aerial measurements are well demonstrated by ERTS experiments. These could be used to support the calculation of growth rates based on volume differences recorded by coverage at different times. However, the ability of procedures like those of Nichols to provide estimates for areas much smaller than a ranger district has the same impact as improved statistical precision. Because of this, it seems safe to say that the improvements in harvest management possible by virtue of an ERS system are underestimated in the calculation of the last section and the technical capabilities of ERTS-1 would be sufficient for this application. Thus, the "new capability" benefit potential exceeds $190 million (present value).

There is little doubt that the potential benefits can actually be achieved, at least in the National Forest System. The Forest Service is actively pursuing technology of the kind required, and recognizes the importance of improved inventory procedures in optimizing harvest planning.

The economic potential exists for similar benefits throughout all the commercial forest land of the United States, but the divided ownership and uncoordinated management objectives of the various owners makes the realization of such benefits less certain.

Annual Benefits:

Equal Capability; $1,300,000

Increased Capability; $1,500,000

New Capability; $19,000,000

RMF No. 2.4.2

MANAGE LIVESTOCK GRAZING

Rationale for Benefits

Livestock grazing is the tool by which the forage resource is converted into economic value. Thus, from the rangeland manager's point of view, grazing schedules should be determined with the objectives of maintaining high forage yields while protecting other resource values of the ranging environment. However, from a broader economic viewpoint, there is more to it than that. Domestic livestock use the range resources only as a supplement to other nourishment, and only on a seasonal basis. There is not necessarily *any* economic benefit in their consumption of forage. Benefits occur only if the use of rangeland forage provides more food value or less costly food value than the best available competitor.

In distinguishing the RMF's for the purposes of the present study, the management of livestock grazing is considered to comprise the short term stocking decisions made by the livestock owner, and the benefits are achieved through his earnings. The formulation of policies and procedures for rangeland use, including the sale of permits, is considered to be part of RMF 2.4.4 (Manage Forage Production Investments).

Federal Government Activities and Responsibilities

The federal government is not active in this function.

Non-Federal Activities

The private livestock industry manages the grazing activities which result in economic output from the forage resource. Cattle ranchers are the major rangeland users, though sheep are also grazed to some extent. The forage is most efficiently used by calves from about 300 to 600 pounds. Cattle above this weight are usually fattened in feedlots.

The major information needs for the scheduling of livestock range use are assessments and forecasts of range forage conditions. Assessments are usually based on the growth of certain indicator plants, but forecasts are difficult, since the readiness of the range is dependent on many variables, including vegetation type, soil characteristics, previous usage levels, and climatic factors. Ranchers obtain forage condition assessments from their own observations, from the rangeland owners, and from published maps and statistics of the Department of Agriculture.

RMF No. 2.4.2

Functions of Remote Sensing

Remote sensing can lead to the provision of more timely, accurate, and comprehensive forage condition information for livestock owners, and potentially to more dependable methods of making predictions. These advantages are discussed under RMF's 2.2.10 (Assess Range Forage Conditions) and 2.2.11 (Forecast Range Forage Conditions).

Through the use of such improved information, critical decisions may be made more nearly optimal, particularly those on the purchases of cattle for stocking of the range and the timing of transfer to the feedlots.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

As part of the case study in Rangeland Applications, EarthSat modified the Halter-Dean* model to incorporate a description of a ranch's use of more timely forage condition information. The original model is a simulation of an integrated range-feedlot operation in the Sacramento Valley of California. It was published in 1965, and was supported by cattle price and other relevant data of the years 1954 through 1963.

The EarthSat Rangeland Case Study provides an estimate of benefits to the cattle industry through greater earnings as a result of improved cattle buying and range utilization decisions. The benefit estimate is $17 million to $28 million, representing the present value of additional earnings in the years 1977 to 1986, discounted at 10 percent to 1976.

These figures are derived by extrapolation to the national level of the results of the modification of the Halter-Dean model.

Unfortunately, the critical price data used in this calculation are those of the original paper, referring to the years 1954 to 1963. The *output* of the model was adjusted by use of the wholesale price index, but this gives no clue to

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* Halter, A. N. and G. W. Dean, 1965, "Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to a Large Scale Ranch," Journal of Farm Economics, 47:557-72.

the impact of current or projected beef or feed prices on the earnings change of interest.

EarthSat concludes that a cattle rancher could expect to improve his earnings per AUM by $.437 by fully exploiting ERS range forage condition data. In extrapolating this figure to the United States over the period 1977 to 1986, projections of beef demand are based on the FRES report of the Forest Service, and conservative assumptions are made on the extent of use of the improved information, both in terms of rate of innovation and portion of total United States grazing affected. The lower benefit estimate of $17 million (present value) corresponds to an assumption of slower innovation than the higher one of $28 million.

In spite of the use of old data, this modeling approach provides some guidance in estimating potential benefits of an ERS system to livestock grazing management. It is likely that the benefit as calculated by EarthSat is understated. If it is assumed that decision makers take advantage of opportunities to improve earnings, it is reasonable to estimate the present value on the basis of continuation of the annual national benefit from the first year to infinity. A detailed consideration of beef demand projections would not add useful information, since the magnitude of the current benefit is so uncertain. EarthSat's study gives the potential annual national benefit in the first year as $14.6 million. We accept this as a rough indication of the valid annual benefit, so that the present value to infinity would be about $150 million.

Current ERTS Activities

A study of California's forage resource demonstrated the capability of correct analysis of ERTS data to predict when grazing could commence and when it should be terminated at the end of the growth season. These management decisions could be aided by ERTS ability to differentiate between germinated and non-germinated rangeland.*

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* David M. Carneggie, Stephen D. DeGloria, "Monitoring California's Forage Resource Using ERTS-1 and Supporting Aircraft Data", from Symposium on Significant Results Obtained from the Earth Resources Technology Satellite, (New Carrollton, Maryland, 1973), p. 94.

RMF No. 2.4.2

Other ERTS-1 experiments which relate to this resource management function are discussed under Resource Management Activities 2.1 (Cartography, Thematic Maps, and Visual Displays) and 2.2 (Statistical Services).

Estimate of ERTS Economic Capabilities

The benefits quoted above in the discussion of the EarthSat study apply to a system with technical capabilities similar to those of ERTS-1. The treatment of the use of information is not detailed enough to relate the parameters of the system to the numerical benefit estimates, but it appears that more frequent coverage than provided by ERTS-1 could be valuable as could improved spectral resolution.

Annual Benefits:

Equal Capability; RMF 2.2.7

Increased Capability; RMF 2.2.7

New Capability; ($15,000,000)

RMF No. 2.4.3

MANAGE TIMBER PRODUCTION INVESTMENTS

Rationale for Benefits

The benefits of timber management in general are described under RMF 2.4.1 (Manage Timber Harvest). Here the subject is the input side of the production of forest values. The benefits of making good decisions on the timing, location, and extent of investments consist of greater productivity of timber and other forest values. Since the non-timber values are always considered in the analysis of proposed timber-oriented investments, it is important to recognize that the benefits of good decision making are realized partly through these values. In addition, some forest investments are made primarily to enhance environmental protection or to maintain recreation, wildlife, and aesthetic values, but these also affect timber productivity and are considered part of this RMF. The important investments for protection from fire, insects, and disease, however, are not considered part of this RMF, but are included under resource management activity 2.6 (Damage Prevention and Assessment). Research investments are treated under resource management activity 2.8 (Research).

Federal Government Activities and Responsibilities

The general forest management responsibilities of the federal agencies are described under RMF 2.4.1 (Manage Timber Harvest) and further in Appendix B.

Specific investment activities in reforestation, stand improvement, fertilization, and assistance to forest landowners are discussed here. Available data on investment expenditures cover the decade of the 1960's and are taken from The Outlook for Timber in the United States.* Since the benefit estimates for this RMF are based on consideration of the forest resource as an economic unit, non-federal investment activities are included in this summary.

Planting in the 1960's covered about 1.5 million acres per year, of which only part was on recently logged land. In some areas, particularly in the East, part of the planting effort was devoted to abandoned fields no longer used for agricultural purposes. On the National Forests and other ownerships in the West, most planting has been on recent cutovers.

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* FRR-20, USDA Forest Service, October, 1973.

For the entire decade, the areas planted comprised about 8 percent of the industrial portion of the commercial timberland, 3 percent of other private ownerships, and 2 percent each of National Forest and other public holdings. In total area planted per year, this works out to 222,000 acres of the National Forests, 140,000 acres under other public ownership, 545,000 acres of industrial forest land, and 570,000 acres of farm and miscellaneous ownership. Costs of planting averaged about $50 per acre in 1971, and total national planting investments in that year were about $85 million.

Timber stand improvement practices include deadening inferior hardwood and thinning of young stands. This practice has been concentrated in the South. Average costs have been near $18 per acre, and the total annual expenditure for all ownerships was about $25 million in 1970.

Fertilization has been used to a limited extent, and primarily by industrial owners. There is still much uncertainty concerning the potential biological productivity benefits it can provide, the environmental consequences, and the relative magnitudes of its costs and financial benefits.

Federal and State agencies have provided forest landowners and operators with technical assistance. In 1971, such programs totaled $24.1 million.

Another major investment class required for the production of timber output is road building and maintenance. Expenditures for roads on National Forests, for example, have included Forest Service costs of about $180 million per year and timber purchasers costs of $112 million per year.

The information requirements for decisions on the location and timing of planting and improvement investments include inventory statistics and analysis of the type published by the Forest Survey.

Non-Federal Activities

These are covered in the above discussion.

Function of Remote Sensing

By improving the accuracy, timeliness, and comprehensiveness of available information such as prepared by the Forest Survey, remote sensing can lead to more efficient logistics of those investments which are made on a location-specific basis. In fact, the *cost* of the sampling error associated with such information can be virtually eliminated.

Economic and Technical Models for Estimating Benefits

Under ideal conditions of information availability and use, managers can prepare investment plans in an optimal way. One way of summarizing the economic structure of such plans would be to prepare a map for each year and each class of investment, showing for each geographic unit the dollar amount required. More mathematically, the resulting atlas would be a set of functions, assigning investment rates to geographic locations.

In the absence of completely adequate inventory information and related analysis, investment plans are not optimal. Rather, plans are in "error" to an extent depending on the inaccuracy of the information available to the planner. In the steady state which is the goal of forest management, investment rates for planting and stand improvement are closely related to primary variables of the inventory process; planting rates should be approximately proportional to net growth rates (since harvest rates are) while stand improvement investments such as precommercial thinning are closely related to area and volume. Accordingly, investment rates will deviate from the optimum to an extent reflecting the sampling error of the inventory information. The most accurate way of determining the cost of this error is to determine the difference it produces in the value of the output of the production function. To avoid the necessity of estimating this response (though it is not difficult), we use the conservative approach of estimating the cost of the error in terms of "wasted" investment dollars.

Assume that to be assured of maintaining the steady state outputs, planting and thinning investments must be made to a greater extent than the optimal rate (location by location). If the inventory data has sampling error $\frac{\sigma}{\mu}$, then it is assumed that investment of the optimal amount plus this fraction are required to assure steady state outputs. If the sampling error is reduced through the use of ERS information from $\frac{\sigma_1}{\mu}$ to $\frac{\sigma_2}{\mu}$, then the associated benefit is on the order of I $\left(\frac{\sigma_1-\sigma_2}{\mu}\right)$ where I is the investment in planting and improvement.

RMF 2.4.3

Current ERTS Activities

The experimental work of Nichols and others at the Space Sciences Laboratory of the University of California at Berkeley discussed under RMF 2.2.1 (Determine Forest Timber Volume by Type, Location, and Ownership) shows that the current data products of the Forest Survey can be produced at lower cost and on an in-place basis. His current work is directed toward the design of inventory procedures for improved precision in net growth estimates. Application of such techniques to the Forest Survey should lead to improved management of timber production investments.

Estimate of ERTS Economic Capabilities

Considering the results of Nichols' experiments with ERTS-1 data tapes used in the first state of a multistage sampling procedure, it appears that an ERS system could provide a reduction in sampling error for the Forest Survey. If the reduction is from 10 percent to 5 percent (probably a conservative assumption), then according to the formula of Page A-57. the benefit is about 0.05 x I were I is the annual investment in planting and stand improvements. This investment is about $110 million per year, so the annual benefit is about $5.5 million.

Annual Benefits:

Equal Capability; RMF 2.2.1

Increased Capability; RMF 2.2.1

New Capability; $5,500,000

RMF No. 2.4.4

MANAGE FORAGE PRODUCTION INVESTMENTS

Rationale for Benefits

Although rangelands are managed primarily extensively, through management of the animals which graze on them, there are also management practices requiring investments in the land. Both kinds of management are included under this RMF. The Forest Service lists 18 management practices for which it has collected cost data specific to various ecosystems.* Several of these are fertilization, irrigation, drainage, brush control, seeding, water developments, and fences. The benefits of good management of such investments are increasing the net output of multiple-use values of timber, water, forage, wildlife, and recreation.

Federal Government Activities and Responsibilities

The Forest Service and the Bureau of Land Management are the Federal agencies most active in the management of grazing lands. The Forest Service has jurisdiction over 166 million areas of grazable land within the National Forest System. This has been divided into over 11,000 grazing allotments assigned to more than 20,000 operators. The basis for the administration of grazing privileges in the National Forest System is contained in the Organic Administration Act of 1897, the Granger-Thye Act of 1850, and Title III of the Bankhead-Jones Farm Tenant Act of 1937.

Grazing permits have a 10-year term with provision for renewal. A permit is validated each year by annual payment of a grazing fee. It specifies the number of animals to be grazed on the public lands along with the season of use. The Forest Service may make annual adjustments in the amount of grazing allowed in order to meet the sustained capacity of the range. These adjustments may be made either in number of animals allowed on the range or in the length of the grazing season.

The Bureau of Land Management administers grazing lands in units called grazing districts, roughly analogous to soil conservation districts. These lands are located in the Western states and range in size from 3 million acres to 9 million acres.

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* Duran, G., and Kaiser, H. F., Range Management Practices: Investment Costs, 1970, USDA Forest Service, Washington, D.C., 1972.

RMF No. 2.4.4

The legislative basis for the Bureau of Land Management's activity in administering grazing lands is the Taylor Grazing Act of 1934. This Act was a response to a Forest Service report on the condition of the Western range. It had as a major objective the correction of the long-term deterioration of these rangelands. In addition to administering 160 million acres in the grazing districts, the Bureau leases 18.5 million acres of other public lands for grazing purposes.

Some grazing land is also administered by the National Park Service, the Fish and Wildlife Service, and the Bureau of Indian Affairs.

As with timber production, management information needs in rangeland management include inventory information and analysis. All of the range-related statistical products of resource management activity 2.2 Statistical Services are important for range management (See Section 1.9).

Functions of Remote Sensing

Remote sensing may improve range productivity by improving the vital management information in several ways. Timeliness is one -- current information on range condition can result in more precise judgement on allowable grazing load, and in the case of ephemeral grasslands, very timely information is necessary for detecting readiness in time to use it. Comprehensiveness is another -- information is often lacking on large areas of valuable grazing land. Finally, accuracy is particularly critical since the costs of rangeland damage by overgrazing are high. Inventories based on multistage sampling beginning with ERTS data tapes can be considerably more accurate than those produced by other procedures.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

EarthSat's Rangeland Case Study provides estimates in this RMF based on "rangeland resource reallocation" and "rangeland productivity increase." However, the assumption on the contribution of ERS information to the potential benefits discussed is entirely arbitrary.

Further, these potential benefits are limited to those predicted by the Forest Service's FRES report as resulting from implementation of management strategies developed on the basis of already existing information.

RMF No. 2.4.4

A very rough, but conceptually sounder estimate is obtained from the Frank and Heiss study of 1968. This study concluded that a benefit of 0.5 percent of the value of the forage resources could be achieved through the proper use of ERS data. Appendix D of the present report contains a model of the value of the forage resource.

Current ERTS Activities

The relevant ERTS activities are discussed under the resource management activity 2.2: Statistical Services (See Section 1.9).

Estimate of ERTS Economic Capabilities

From Appendix D, the United States forage resource is worth on the order of $30 billion. The above estimate of 0.5 percent of this value gives $150 million as the present value of the benefits.

Annual Benefits:

Equal Capability; RMF 2.2.7

Increased Capability; RMF 2.2.7

New Capability; $15 million

RMF No. 2.4.5

MAKE MULTIPLE-USE ALLOCATION DECISIONS

Rationale for Benefits

The multiple-use concept of public lands management requires decisions on the extent of intensive management of forests and rangelands for crop production, as contrasted with reserving land for recreational use, wildlife protection, and watershed protection. This RMF is the making of such decisions, and its benefits are in the enhancement of these multiple-use values of the forests, rangelands, and wildlife areas.

Federal Government Activities and Responsibilities

The Multiple-use Sustained-Yield Act of 1960 (74 Stat. 215; 16 U.S.C. 528-531) provides the legislative basis for the principle of sustained production of crops with protection of other uses. The Act directed the Forest Service to manage the National Forests on this principle. The Multiple-use and Classification Act of 1964 authorized multiple-use management on public domain lands under the Bureau of Land Management. The Wilderness Act, also passed in 1964, provides for the preservation of a few million acres in the National Forests and Parks and Wildlife Refuges as a remnant of the original frontier wilderness.

The responsibilities of the Forest Service in multiple-use management have been expanded by the new Forest and Rangeland Environmental Management Act of 1974. This Act includes the declaration, "The Forest Service ... is responsible for essential programs and services which must be maintained on an integrated basis, including programs to aid private and State forest land managers through cooperative efforts to achieve resource management goals ... and through the management of the National Forest System." The Act also specifically includes the national grasslands as part of the National Forest System, and recreation, grazing, water, and timber among the resources to be managed.

The extent and nature of the lands under the administration of the Bureau of Land Management and the Forest Service are discussed in Sections 1.1 and 1.2. But it is important to realize that the influence of these agencies in multiple-use management extends to all United States forests and rangelands. There is obviously some important influence through the cooperative programs of the Forest Service and its publication of research and statistical work, but there is another vital effect, achieved through supply and demand relationships. For example, if the softwood timber harvest from national forests were increased, this would have an effect on the prices of forest products. Consequently, the most profitable management practices for privately owned forests would be altered, probably resulting in a buildup in their timber inventories. Similarly, if the publicly owned lands provide recreational opportunities at prices below their value, then the potential to supply such opportunities from private lands will not be developed. These are ways in which the management of the National Forests affects multiple-use management throughout the United States.

The information requirements for the execution of this RMF are provided primarily by the Forest Survey described in Section 1.9. Its primary purpose is to support decision making on this level and on the national policy level of the RMF's of resource management activity 2.9, (See Section 1.16) by providing analyses of resource supply and demand covering the forests and rangelands. These research and analysis functions of the Forest Survey are discussed under resource management activity 2.8 (See Section 1.15).

Function of Remote Sensing

Remote sensing impacts the execution of multiple-use policy through its effect on inventory data and associated analysis including the use of computerized data bases. Improvements in timeliness, precision, and comprehensiveness are relevant to this RMF for rangeland inventories, wildlife habitat surveys, and for forest inventories, particularly the Forest Survey.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Under conditions of "ideal" information the annual investment of $1.8 billion (see Appendix D) required to produce the multiple outputs of the forests, rangelands, and wildlife areas would be made optimally. That is, each class of investment would be made in an amount at each location determined by the productivity of the resource for each of the multiple-use outputs. An uncertainty in the productivi[illegible]s results in a waste of investment resources in a corresponding amount. For instance, if productivity estimates differ from true productivity with average error $\frac{\sigma_1}{\mu}$, and if the error could be reduced to $\frac{\sigma_2}{\mu}$, then the fraction $\frac{\sigma_1 - \sigma_2}{\mu}$ of the investment could be saved.

RMF No. 2.4.5

As discussed under RMF 2.4.3 (Manage Timber Production Investments), the sampling error of the data collected for the Forest Survey could probably be reduced from 10 percent to 5 percent through proper use of ERS data. Perhaps one third of this improvement, or $1\frac{2}{3}$ percent could be obtained in the average "error" in setting investment rates by location. The resulting annual benefit would be on the order of

$$\$ .0166 \times 1.8 \text{ billion} = \$30 \text{ million.}$$

Current ERTS Activities

ERTS scientists feel that vegetation maps should have great value in remote areas for watershed management, wildlife management, and land use planning.

J. H. Anderson of the University of Alaska made a photointerpretation of a color composite of MSS Bands 4, 5, and 7 of the Seward Peninsula, Alaska. It took only 10 man-hours to delineate seven vegetation types, whereas existing vegetation maps identify only four. It is hoped that these vegetation maps would be helpful in delineating areas to be managed for caribou, moose, and water fowl as well as areas which might be opened to homesteading or managed for trapping of fur-bearing animals. Other relevant ERTS Activities are discussed under the resource management activity 2.2 Statistical Services (See Section 1.9).

Estimate of ERTS Economic Capabilities

Annual Benefits:

Equal Capability; RMF 2.2.1

Increased Capability; RMF 2.2.1

New Capability; $30 million

RMF No. 2.5.1

DESIGN AND MONITOR FOREST REHABILITATION

Rationale for Benefits

One of the means available for meeting the long term demand for forest products, as well as contributing to soil and water conservation is to replant area. of deteriorated forest or convert areas from other used to forest land. Thus, forest rehabilitation is one way of expanding the potential production of all forest values. Monitoring is an important part of rehabilitation programs since success of growth is less certain than in seeding and planting programs for land in continuous forest use.

Federal Government Activities and Responsibilities

This is one of the important activities of the Forest Service, which conducts reforestation programs in the National Forest System as well as sharing costs of reforestation programs on State and private lands.

Function of Remote Sensing

Accuracy, timeliness, and comprehensiveness of the information provided by the Forest Survey are important in both the planning and the monitoring aspects of reforestation. Thus, by improving these qualities of the inventory information, remote sensing can benefit this RMF.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

This model outline under RMF 2.4.5 (Manage Timber Production Investments) could be extended to apply to this RMF as well, by replacing the steady state assumption with a dynamic structure. However, their extension has not been developed.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.5.2

DESIGN AND MONITOR RANGELAND REHABILITATION

Rationale for Benefits

The consequences of long periods of rangeland abuse in the West and Southwest includes the virtual destruction of the economic value of about 80 million acres. Fortunately, it has been possible to restore rangeland value, also over a long period of time. The benefits of such rehabilitation, by reseeding, other land investments, and grazing controls are in re-establishing an asset which can produce the multiple-use outputs on a sustained basis.

Federal Government Activities and Responsibilities

Determined federal efforts to restore depleted rangelands date from 1932, when the Forest Service made a survey reporting on the condition of the Western range, resulting in the passage of the Taylor Grazing Act. Only 80 million acres were included in the original provisions for protection, but in 1959 the acreage was increased to 160 million acres. The Bureau of Land Management has invested continuously in reseeding these rangelands.

Function of Remote Sensing

Information supporting sound decisions on rehabilitation investments is scarce. Remote sensing may contribute by making inventories more comprehensive and timely, and by providing dependable range trend indications, so that the success of rehabilitation programs can be evaluated, and the need for new efforts noticed before deterioriation is advanced.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

A model relating the precision of rangeland inventory and condition statistics to the "accuracy" of investment decision similar to the one used in forestry management applications would be helpful in estimating benefits to this RMF. Because of the large number of variables required to describe rangeland productivity and the need to consider the time dimension explicitly, the modeling effort would be considerable, and has not been undertaken for this study.

C-2

RMF No. 2.5.2

Current ERTS Activities

The pertinent current ERTS activities are discussed under the statistical RMF's (activity 2.2).

Estimate of ERTS Economic Capability

No quantitative estimates have been made, but because of the broad information scarcity, the capability of ERS-aided inventories to fill it, and the large economic value of the rangeland resource, it is possible that the benefit to this RMF is at least as large as those calculated for other RMFs. Lack of sufficient inventory information is the main reason that more effort is not put into rangeland restoration.

Annual Benefits:

Not Estimated

RMF No. 2.5.3

MONITOR AND LIMIT DAMAGE TO WETLANDS

Rationale for Benefits

Wetlands are important to the resources of this area because they provide a unique and fragile wildlife habitat. Wetlands are the subject of intense competition among various land uses. Accordingly, the preservation of their value as wildlife habitat requires monitoring of damage and possibly protective measures.

Federal Government Activities and Responsibilities

The Bureau of Sport Fisheries and Wildlife was established in the Department of the Interior on August 8, 1956, by the Fish and Wildlife Act of 1956. The Bureau is responsible for improving and maintaining wildlife resources by a variety of management activities including wildlife habitat preservation planning and monitoring.

In October, 1972, Congress enacted the Coastal Zone Management Act (Public Law 92-583). This act is designed to protect the coastal zone, including wetlands.

Function of Remote Sensing

Very limited information is available on the changes in wetland area and the kind of development and drainage occurring in these lands. But these are the kinds of data which satellite imagery most clearly and accurately reveals. Remote sensing by satellite can be expected to make a substantial contribution to this RMF.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

No models have been developed.

Current ERTS Activities

See RMF 2.1.3 (Wildlife Habitat Mapping).

Estimate of ERTS Economic Capability

Annual Benefits:

Not Estimated.

RMF No. 2.5.4

MONITOR AND LIMIT DAMAGE IN THE GIANT REDWOOD AND SEQUOIA FORESTS

Rationale for Benefits

These forests are unique and "nonrenewable" resources, whereas most forests are reasonably considered as "renewable resources". Monitoring and controlling damage to these forests reduces the likelihood of serious and irreversible destruction.

Federal Government Activities and Responsibilities

The National Park Service was established in the Department of the Interior on August 25, 1916 (39 Stat. 535; 16 U.S.C. 1). Among its objectives is the protection of the natural environment of the areas under its jurisdiction. The Service has the responsibility for administration of the Sequoia National Park.

Non-Federal Activities

The Giant Redwood Forest is under the administration of the State of California.

Function of Remote Sensing

Remote sensing probably provides the most cost-effective way of monitoring disturbances in these forests to the extent required to assure preservation of their value.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.6.1

ASSESS AND REDUCE DISEASE, WEED, INSECT, AND ANIMAL DAMAGE TO FORESTS

Rationale for Benefits

This activity preserves the value of the forests for timber production and other uses.

Federal Government Activities and Responsibilities

The U.S. Forest Service has the responsibility for protecting the national forest lands it administers from damage. The other federal agencies administering forest land have the same responsibilities on their lands. In addition, the Forest Service cooperates with State and local governments, agencies, and organizations, forest industries, and private landowners in the protection of 577 million acres of forested land. Expenditures for pest control have averaged about $12 million annually of which 7 percent is federally provided.*

Forest insect and disease damage is assessed annaully in surveys sponsored by 26 states and the Forest Service under the Forest Pest Control Act (61 Stat. 177; 16 U.S.C. 591-4). Data from these surveys are used to recommend suppression or control programs. Detection surveys combine use of aerial sketches, aerial photographs, ground inspection, and reports from concerned citizens.

When disease or insect activity has been established and located through detection surveys, evaluation surveys are conducted to evaluate damage. These are generally based on a statistical sampling design.

Function of Remote Sensing

Remote sensing has the potential to provide earlier evidence of beginning pest damage, particularly in remote areas.

Economic and Technical Models for Estimating Benefits

Models for benefit estimation will have to cope with two limitations in current management systems. One is that very

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* Data for period 1960-1970, The Outlook for Timber, U.S. Forest Service, 1973.

little is known about how to control pest damage, even when its location and extent is known. The extreme solution of destroying the contaminated region is feasible only when detection is extremely early. Second, means of pre-visual detection of insect and disease activity, though considered possible, have not yet been demonstrated.

Current ERTS Activities

Principal Investigator

Ralph C. Hall

Report:

Application of ERTS-1 Imagery and Under-flight Photograph in the Detection and Monitoring of Forest Insect Infestation in the Sierra Nevada Mountains of California.
Assessment of Disease Damage

Classification of the defoliated areas into light, medium, and heavy, damage has been accomplished. The investigators were able to differentiate the bark and beetle damaged areas principally on the basis of color differences.

Dr. Heller and others of the Pacific South West Forest and Range Station (Forest Service) have conducted an evaluation of ERTS-1 imagery to determine the minimum infestation size resulting from mountain pine beetle that is detectable from ERTS imagery. Their preliminary assessment of capabilities is that large infestations of heavy damage can be detected from ERTS-1 imagery. Unfortunately, this is of limited value to forest protection programs. Only early detection of pest out-breaks allows effective suppression.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.6.2

ASSESS AND REDUCE DISEASE, WEED, INSECT, AND ANIMAL DAMAGE TO RANGELANDS

Rationale for Benefits

This RMF preserves the value of the rangelands for livestock feeding, sheltering and feeding wildlife, and other uses, including watershed management.

Federal Government Activities and Responsibilities

The Forest Service has general responsibilities in this area, while the Bureau of Land Management is active in the protection of the lands it administers.

Function of Remote Sensing

Remote sensing has the potential to provide timely evidence of beginning damage, particularly in areas not regularly inspected by other means.

Estimate of ERTS Economic Capability

Annual Benefits:

Not Estimated.

RMF No. 2.6.3

ASSESS AND REDUCE EROSION DAMAGE TO FORESTS AND RANGELANDS

Rationale for Benefits

This RMF preserves the value of the forests and rangelands for timber production, forage production, wildlife shelter and feeding, recreational and other uses.

Federal Government Activities and Responsibilities

The Forest Service and the Bureau of Land Management perform this function to some extent as part of the operating management of the timber and forage resources.

In addition, the Soil Conservation Service of the Department of Agriculture, established under authority of the Soil Conservation Act of 1935 (49 Stat. 163; U.S.C. 290a-f), has responsibility for developing and carrying out a national soil and water conservation program in cooperation with landowners and operators and other land users and developers, with community planning agencies and regional resource groups, and with other agencies of government -- Federal, State, and Local. The service makes soil surveys to determine soil use potentials and conservation treatment needs. These are published with interpretations useful to cooperators, other Federal agencies, State and Local organizations.

Current ERTS Activities

Principal Investigator

Fryrear, D. W.

Reports:

Soil Survey and Classification and Soil Erosion by Fryrear, D. W.

Comments:

Principal Investigator reported two blowout areas, previously unknown to personnel at Big Spring Field Station, were located through use of ERTS MSS imagery.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.6.4

ASSESS AND REDUCE FIRE DAMAGE TO FORESTS AND RANGELANDS

Rationale for Benefits

This activity preserves the value of the forests for timber production and other uses.

Federal Government Activities and Responsibility

The Forest Service has the specific responsibility of cooperating with other forest owners and managers in the protection of the nation's forest and range environment from fire.

All 50 States have cooperative agreements for participation with the Forest Service in the Cooperative Forest Fire Control Program. The Forest Service provides coordination and financial assistance. This program includes Federal-State cooperation in producing and distributing tree seeds and seedlings for planting on State and private forest lands, and for windbreaks and shelterbelts.

Function of Remote Sensing

It appears that the contribution of remote sensing to this function may be in providing better deployment of *preventive* resources possible through comprehensive monitoring of fuel conditions.

Current ERTS Activities

ERTS imagery can provide the basis for determining the location and extent of rangelands where potential fire hazards exist either by virtue of early drying or by virtue of the presence of abundant forage which when drying creates the flash fuel for spreading fire to more valuable vegetation types.*

ERTS images of Big Delta, Alaska, taken August 21, 1972, shows that old forest fire burns are very well revealed in false color enhancement, not so much because northern

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* David M. Carneggie, Stephen D. DeGloria, "Monitoring California's Forage Resource Using ERTS-1 and Supporting Aircraft Data," from Symposium on Significant Results Obtained from the Earth Resources Technology Satellite, (New Carrollton, Maryland, 1973), p. 94.

ecology is slow to heal but in this case because a different type of vegetation, aspen and birch, grew to replace the original habitat of black spruce which esisted fifty years ago.

Rangeland recently burned (within six months), is detectable on ERTS imagery, MSS Band 4. Prompt and systematic determination of location and extent of burned grassland, therefore, is possible.

Estimate of ERTS Economic Capability

Annual Benefits:

Not Estimated.

RMF No. 2.6.5

ASSESS AND REDUCE POLLUTION DAMAGE TO WILDLIFE AREAS

Rationale for Benefits

This activity contributes to the objectives of preserving wildlife areas for various uses.

Federal Government Activities and Responsibilities

The Environmental Protection Agency, an independent agency of the Executive Branch created in 1970, endeavors to abate and control pollution systematically.

Function of Remote Sensing

Comparison of images of the same area in successive occasions may provide a fast way of detecting disturbances.

Estimate of ERTS Economic Capability

Annual Benefits:

Not Estimated.

RMF No. 2.7.1

MONITOR IMPACT OF THE ALASKAN PIPELINE ON WILDLIFE

Rationale for Benefits

By monitoring the impact of the Alaskan Pipeline on wildlife, determination of possible changes in feeding and migration would be accomplished. Changes in normal behavior of wildlife could lead to population thinning and ecological shifts within the wildlife balance. The benefit of information on such changes is in assuring the preservation of wildlife values.

Federal Government Activities and Responsibilities

The Bureau of Sport Fisheries and Wildlife of the Department of the Interior has the responsibility of wildlife stewardship. The Bureau's activities include studies of wildlife populations and ecological studies, and wilderness preservation planning.

Function of Remote Sensing

Regular inspection of periodic images of the critical areas may be an inexpensive way of detecting problems for more detailed investigation.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.8.1

RESEARCH FOREST MANAGEMENT PRACTICES

Rationale for Benefits

Research activities in forest management practices are performed for the purpose of discovering means of increasing timber growth and for extending timber supplies beyond present levels.

Federal Government Activities and Responsibilities

Primary Federal responsibility in research of management practices is given to the U.S. Forest Service. This research function of the Forest Service is authorized by the McSweeney-McNary Forest Research Act of 1928. Presently research is being conducted on genetics, spacing, thinning, harvesting and environmental aspects of Forest Management.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.8.2

RESEARCH FOREST AND RANGE FIRE CONTROL TECHNIQUES

Rationale for Benefits

Research in the area of fire control techniques is being conducted to improve both fire fighting and prevention methods. Improved fire control would result in increased timber yield and wildlife protection for the forests, and better forage conditions in the rangelands.

Federal Government Activities and Responsibilities

As is the case with the bulk of research in forestry, the U.S. Forest Service conducts research in fire control techniques. Currently the forest service is conducting tests in prescribed burning and closer timber use. The National Park service and the Forest Service are involved with rangeland fire-control research.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.8.3

RESEARCH RANGELAND MANAGEMENT PRACTICES

Rationale for Benefits

Improved rangeland management practices developed through research have resulted in the increased vigor and density oı existing and developing rangelands.

Federal Government Activities and Responsibilities

Rangeland management practices are researched by the U.S. Forest Service, the Agricultural Research Service, both of the Departments of Agriculture, and by the Bureau of Land Management of the Department of the Interior. One important activity is the development of improved grass types and the determination of better ways to match grass types with particular ecological characteristics of the range environment.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.8.4

RESEARCH METHODS OF DISEASE CONTROL AND ANIMAL DAMAGE REDUCTION IN FORESTS AND RANGELANDS

Rationale for Benefits

These research activities are performed for the purpose of improving timber yield, forage vigor, and reducing exploitive rangeland practices.

Federal Government Activities and Responsibilities

The U.S. Forest Service performs the major research efforts for the nation's forests. There has been increasing experience in recent years in the use of forest fertilizers to accelerate tree growth and improve resistance to disease. The Forest Service also reports studies on exploitive rangeland practices which lead to erosion.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.8.5

RESEARCH ECOLOGICAL RELATIONSHIPS RELATING TO WILDLIFE

Rationale for Benefits

Improved ecological balances brought about by research in this area will result in normalized wildlife population balances, better scenic qualities, recreation and food production for those dependent on this ecological system.

Federal Activities and Responsibilities

The Bureau of Sport Fisheries and Wildlife of the Department of the Interior is currently tagging and examining wildlife for purposes of improving the wildlife balance. Other Federal agencies including the EPA and the Forest Service are examining the effects of chemical fertilizer, air and water pollution.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF NO. 2.9.1

DESIGN FORESTRY LEGISLATION AND MONITOR COMPLIANCE

Rationale for Benefits

Forestry legislation has had the function of defining and strengthening the concepts of multiple use and sustained yield. Thus its overall objective is the enhancement of the value of the forest resources, and value has the meaning developed in Appendix D, the ability to produce sustained outputs of timber, forage, wildlife values, water, and recreational values. Legislation supports this objective by establishing policies for agencies such as the Forest Service, assigning and funding of some of their major tasks, and at the state and local level, by directly regulating private forest operations.

Federal Government Activities and Responsibilities

Federal Legislation has resulted in the definition and application of the sustained-yield and multiple-use concepts, as summarized in Chapter 1 and Appendices B and C.

Estimate of ERTS Economic Capabilities

Annual Benefit:

Not Estimated.

RMF No. 2.9.2

DESIGN RANGELAND LEGISLATION AND MONITOR COMPLIANCE

Rational for Benefits

Rangeland legislation has been necessary primarily to halt the abuse of the range resources which was caused by years of overgrazing. Its objectives have been to enhance and protect multiple-use values of the rangelands. Its major impact is through the budget setting process for the Forest Service and the Bureau of Land Management and in the direct assignment of some of their responsibilities.

Federal Government Activities and Responsibilities

Federal Legislation has resulted in the definition and application of the sustained-yield and multiple-use concepts, as summarized in Chapter 1 and Appendices B and C.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

RMF No. 2.9.3

DESIGN LEGISLATION RELATED TO WILDLIFE AND MONITOR COMPLIANCE

Rationale for Benefits

Wildlife related legislation has the benefit of assuring consideration of wildlife values in decision making affecting the forest and rangeland resources. In some cases, it is directed to the correction of a specific situation damaging to these values.

Federal Government Activities and Responsibilities

Federal Legislation has resulted in the definition and application of the sustained-yield and multiple-use concepts, as summarized in Chapter 1 and Appendices B and C.

Estimate of ERTS Economic Capabilities

Annual Benefits:

Not Estimated.

APPENDIX B:

SUMMARY OF APPLICABLE FEDERAL BUDGETS

The federal government is active in the management of the natural resources of this area through several agencies of the Department of the Interior, several of the Department of Agriculture, and the Tennsessee Valley Authority.

Table 3 on page B-2, summarizes the applicable budgets of these agencies. Their genral responsibilities are stated in this Appendix, while more detailed activities specific to the RMFs are discussed in Appendix A.

Department of the Interior

The Department of the Interior, created by an act of Congress in 1849 (9 Stat. 395; 43 U.S.C. 1451), is responsible for the administration of about 500 million acres of federal lands and 50 million acres of land held in trust (mostly Indian reservations). The Department is also charged with "the conservation, development, and utilization of fish and wildlife resources; the coordination of Federal and State recreation programs; the preservation and administration of the Nation's scenic and historic areas ..."* The following bureaus of the Department carry out these responsibilities with respect to the forests, rangelands, and wildlife areas: (1) Bureau of Land Management; (2) National Park Service; (3) Bureau of Indian Affairs.

- Bureau of Land Management

  The Bureau of Land Management was established in 1946 in accordance with the President's reorganization plan 3 (5 U.S.C. 133y-16). The Bureau classifies, manages, and disposes of public lands** and their related resources according to the

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* General Services Administration, United States Government Manual. (Washington: Government Publication Office, 1973).

** "Public land" is used by the BLM to mean land which has never left Federal ownership; also lands in Federal ownership which were obtained by the government in exchange for public lands or for timber on public lands.

Table 5 Federal Budget Summary--Resource Area 2: Extensive Use of Living Resources				
Department Agency Division Item	Federal Budget Request, ($, thousands)			Source
	Fiscal Year 1973	Fiscal Year 1974	Fiscal Year 1975	
Department of Agriculture				
Forest Service				
-Forest Research	55,548	63,577	63,946	Budget of the Federal Government, Fiscal year 1975 p.208
-Forest Land Management	309,091	280,805	292,579	Budget of the Federal Government, Fiscal year 1975 p.208
-State and Private Forestry Cooperation	391,944	372,309	386,095	Budget of the Federal Government Fiscal year 1975 p.208
Forest Economics and Research Division				
-Forest Survey	3,293	3,433	3,820	The Senate Appropriations (Interior) Fiscal Year 1973, pp.1742-1744. Also Federal Budget, Fiscal year 1975
Timber Management and Planning Division				
-Management Planning Inventory	3,544	3,649	3,820	House Appropriations (Interior) Fiscal year 1975, p.282 (GOUSC 581)
-Silvacultural Examination	3,100	2,532	NA*	Mr. Sullivan Personal Telephone Conversations of August 8 and 26. Mr. Sullivan is a member of the Timber Management Division. 202-447-7495
-Land Classification	461	787	825	House Appropriations (Interior) Fiscal year 1975, p.193
Department of the Interior				
Bureau of Land Management				
-Forestry	7,721	8,256	8,998	House Appropriations (Interior) Fiscal Year 1975, Pt.IV, p.541
-Range Management	7, 109	7,973	9,133	House Appropriations (Interior) Fiscal year 1975, Pt.II, p.485
-Recreation and Wildlife	5,733	6,606	9,513	House Appropriations (Interior) Fiscal year 1975, Pt. III, p.485
-Firefighting and Rehabilitation	22,804	6,400	5,400	House Appropriations (Interior) Fiscal year 1975, Pt. III, p.485
Bureau of Sports, Fisheries and Wildlife				
-Comprehensive Natural Resource Planning	NA*	2,563	3,613	House Appropriations (Interior) Fiscal year 1975, Pt.IV, p.541
Bureau of Indian Affairs Tribal Resource Development				
-Forestry and Agriculture	19,551	19,788	19,772	Federal Government Budget, Fiscal year 1975, p.581
Independent Agencies				
Tennessee Valley Authority				
-General Research Development	11,660	12,532	11,833	Federal Government Budget, Fiscal year 1975, p.948

* NA means not available.

principle of multiple use management. Public land resources managed by the Bureau include timber, minerals, wildlife habitat, livestock forage, public recreation values, and open space.*

- The National Park Service

The National Park Service was established in the Department of the Interior on August 25, 1916 (39 Stat. 535; 16 U.S.C. 1).** The National Park Service administers for the American people an extensive system of national parks, monuments, historic sites, and recreational areas. The stated function of this agency is to "administer the properties under its jurisdiction...to protect the natural environment of the areas, and to assist states, local governments, and citizen groups in the development of park areas.***

- The Bureau of Indian Affairs

The Bureau of Indian Affairs was created in the War Department in 1824, and transferred to the Interior Department in 1849. In 1921, Congress passed the Snyder Act, providing substantive law for appropriations and defining the scope of activities for the Bureau. A later bill, the Indian Reorganization Act of 1934, (48 Stat. 984; 25 U.S.C. 461 et. seq.) broadened the duties of the Bureau. The present responsibilities of the Bureau include working with the Indian peoples in "the development and implementation of programs for their economic advancement and for full utilization of their natural resources consistent with the principles of resources conservation.****

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* _Op. cit._, p. 274.

** _Op. cit._, p.270.

*** _Ibid._, p. 270.

**** _Op. cit._, p. 273.

The Department of Agriculture

The Department of Agriculture was created by an act of Congress on May 15, 1862 (12 Stat. 387; U.S.C. 511, 514, 516). The act directs the Department of Agriculture to "acquire, and to diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that work, and to procure, propagate, and distribute among the people new and valuable seeds and plants.* To accomplish this purpose, the Department functions in the areas of research, education, conservation, marketing, regulatory work, agricultural adjustment, surplus disposal, and rural development.**

Within the Department of Agriculture, the following bureaus have specific duties in the administration and protection of forests, rangelands, and wildlife areas: (1) Forest Service, (2) Soil Conservation Service, (3) Statistical Reporting Service, (4) Agricultural Research Service, (5) Agricultural Stabilization and Conservation Service, (6) Cooperative State Research Service, (7) Federal Extension Service. The first two have responsibilities broader than a single RMF area, and are therefore discussed in this section. The activities of the remaining five bureaus are treated in later sections.

- The Forest Service

  The federal forest reserves were established by the President from the public domain by the creative act of March 3, 1891. (26 Stat. 1103; 16 U.S.C. 471). In 1905 the Forest Service was created within the Department of Agriculture and the Federal Forest Reserves and their management was transferred from the Interior Department to the Forest Service. (33 Stat. 628; 16 U.S.C. 472).

* Wayne D. Rasmuisen and Gladys L. Baker, The Department of Agriculture (New York: Praeger Publishers, 1972) p. 243.

** General Services Administration, United States Government Manual (Washington: Government Publication Office, 1973), p. 94.

The forest Service carries the main federal responsibility for protecting and developing the forest resources of the country. Accordingly, the scope of its activities is extremely broad, and its organization is complex. The agency is organized along the lines of its three major areas of responsibility: national forest administration, state and private forestry cooperation, and research.*

Under the national forest administration, there are nine administrative regions each directed by a regional forester who is responsible to the Chief of the Forest Service. This regional forester has authority over the forest supervisors. Each forest supervisor administers one of the national forests. Each national forest is further divided into ranger districts which are the basic units of administration. The Forest Service manages 187 million acres in 41 states and Puerto Rico, consisting of 155 national forests and 19 national grasslands.

The Forest Service cooperates with the states and with private landowners in forest-fire control, forest-pest control, forest management, and flood prevention.

The research organization of the Forest Service is structurally independent of the other two parts of the agency's organization. Eight regional forest experiment stations conduct research on problems of local importance in their regions.**

- The Soil Conservation Service

The Soil Conservation Service was created by the Soil Conservation Act of 1935 (49 Stat. 163;

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* Albert C. Worrell, Principles of Forest Policy, (New York: McGraw-Hill Book Company, 1970), p. 182-183.

** Ibid., p. 183.

U.S.C. 590 a-f). The agency has the responsibility of developing and performing a national soil and water conservation program. The present programs of the S C.S. include (1) conservation operations, (2) river basin surveys and investigations, (3) watershed planning, (4) watershed and flood prevention operations, (5) Great Plains Conservation program, (6) Resource Conservation and Development Program.*

- <u>The Statistical Reporting Service</u>

  The Statistical Reporting Service (S.R.S.), h[illegible] two main statistical functions: (1) prepare cro[illegible]d livestock estimates, reports of production, [illegible]y, price and other matters, (2) set and maintain [illegible] quality of statistical work for all the agencies within the U.S.D.A.

<u>Tennessee Valley Authority</u>

The TVA is an Authority established by an act of Congress on May 18, 1933 (48 Stat. 58; 16 U.S.C. 831-831 dd). This Authority, a government owned corporation, is concerned with conducting a "unified program of resource conservation, development, and use, to advance the economic development of the Tennessee Valley region.** Among the other activities of the TVA including river control and hydroelectric power, are the research and development programs in forestry, fish, wildlife, and watershed protection in the Tennessee Valley tributory system.

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* General Services Administration, <u>United States Government Manual</u> (Washington: Government Publication Office, 1973), p. 118-119.

** Ibid., p. 556.

APPENDIX C:

SUMMARY OF APPLICABLE FEDERAL STATUTES

Table 4 on page C-2 lists the federal statutes pertinent to remote sensing of forest, rangelands, and wildlife area.

Table 4 Federal Statutes Pertinent To Remote Sensing of Forests, Rangelands and Wildlife

Name of Federal Statute	Classification: Date	Agency Affected	Comments
Endangered Species Act	1973	DI	Investigation and inventory of certain species
National Resource Lands Management Act (Still Pending)		BLM	Inventory of BLM Lands
Forest and Rangeland Environmental Management Act	1974	USDA - Forest Service	Coordination of management. Extends responsibilities of FS to coordinate management of forest and range resources on multiple-use basis. Ammonds-McSweeney-McNary Act to extend Forest Survey
Land and Water Conservation Fund Act	1964	DI	Acquisition of recreation areas
Wilderness Law	1964	DI	Setting aside land for wilderness

Table 4 Federal Statutes Pertinent To Remote Sensing of Forests, Rangelands and Wildlife

Name of Federal Statute	Classification		
	Date	Agency Affected	Comments
Multiple-Use Sustained-Yield Act	1960	USDA - Forest Service	Basis for major policies on resource use
Weeks Law	1911	USDA - Forest Service	
Clarke-McNary Act	1924	USDA - Forest Service	Acquisition, mapping, examination, inventorying
McSweeney-McNary Act	1928	USDA - Forest Service	Nationwide forest survey of productivity, demand for and supply of timber
Forest Resources Act	1967	USDA - Forest Service	
Forest Pest Control Act	1947	USDA - Forest Service	Surveys of forest lands to detect pests
Timber Development Organizations Act	1967	USDA - Forest Service	Management assistance to state and private
Agricultural Research Act	1935	USDA	Includes forest research
Soil Conservation Act	1935	USDA	Survey forest soil
Fish and Wildlife Act	1934 1950 1947 1949 1950 1956	Bureau of sport Fisheries and Wild-life DI	Inventory and protect wildlife
Taylor Grazing Act	1934	DI	Establishes procedure for private use of western public grazing lands. Protection and management of grazing districts

APPENDIX D:

THE RESOURCES AND THEIR VALUE

The many and various economic resources of the United States forests, rangelands, and wildlife areas can be grouped into several classes. One class covers timber and livestock forage as commercial products. Others are soil, water, wildlife, and recreation. The application of conventional techniques of economic theory is comparatively easy within the first class, while quantitative treatment of resources of the other classes is more difficult. Water is an important output of the forests, rangelands, and wetlands, but it is treated as a separate major resource category in this study (Resource Area 3; See Volume V).

Our quantitative evaluation of the timber and forage resources will be based on capitalization of their outputs through time. Thus, we are regarding the resources as capital assets, which produce economic outputs in response to specific inputs, and are valued on the basis of this continued production. This process is described by a production function.

For the timber resource, the inputs to the production function include tree planting, protection from fire and insect damage, and road building, among others. The outputs are primarily saw timber and pulpwood. As with other capital assets, the major investments are often made considerably before the corresponding returns are generated. The time interval between tree planting and harvest, for instance, may be well over 50 years. Nevertheless, management for sustained production may result in a "steady state" so that annual investments and returns remain constant over a long period. In this section, where our concern is with the general structure of the resource values and the way that information affects those values, we decribe the resources as if they were managed in the "steady state" fashion.

For the rangeland resource, the output of the production function is livestock forage, and the inputs are of many kinds. Several of them are reseeding, brush control, water hole development, and fence building.

Figure 2 (on page D-2) contains a diagram of the production functions for the timber and forage resources.

Natural resources, such as timber and forage, differ from many other capital assets in the following two ways. First, survey and inventory information is an absolute requirement for their production of output, and second, this information tends to be expensive. Concerning the need for such information--how much of what is where--it is clear that one cannot even harvest a tree unless one can find it, but to manage continued production, it is vital to know where next year's trees are growing as well as this year's. The required information is expensive primarily because the resources are spread out geographically and cannot be moved.

To correctly describe the general structure of timber and forage resource value, we must recognize that information of the survey and inventory type is one of the necessary inports to the production function, and a correct valuation must include consideration of its cost.

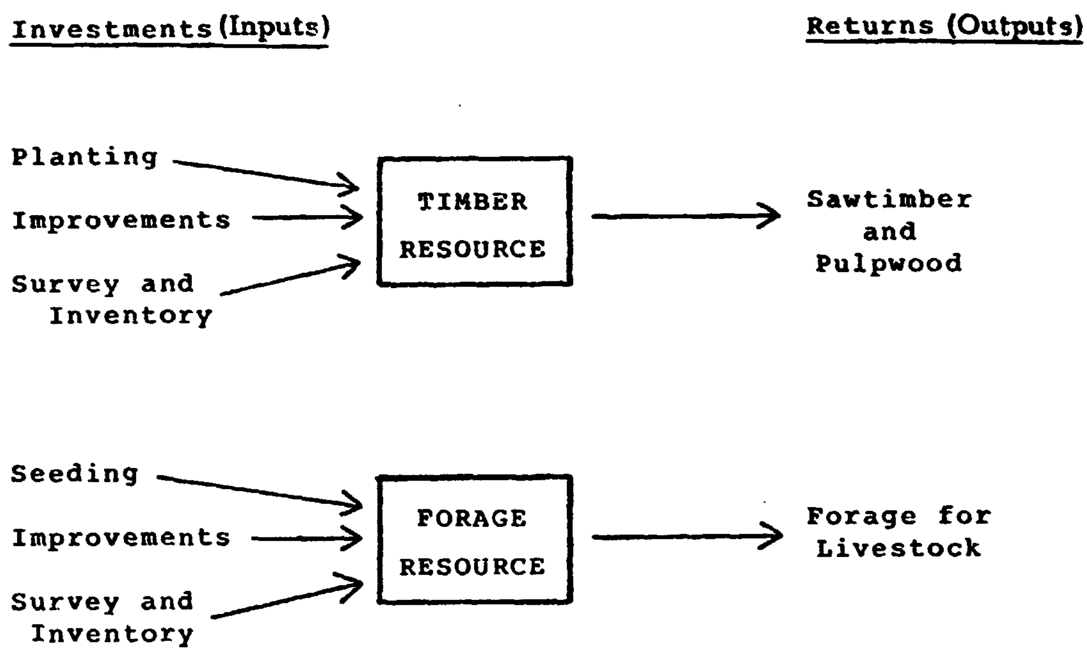

Figure 2 Production Functions for Timber and Forage

Survey and inventory information is an *input* to the production function, but does not in itself *change* the production function. Another kind of information *does* change the production function, making it possible to get more output for a given set of inputs. For example, information on where the forests grow best permits concentration of harvest and reforestation in that area, thus increasing the total production resulting from a given investment. Similarly, information on the relative efficiency of various practices can lead to improved management and thus a change in the production function. It is clear that in this kind of analysis, the concept of production function includes the state of knowledge of the manager of the resource and the institutional and other constraints on his behavior. That is, we are describing the manager's knowledge of how to produce and his ability to apply it, not necessarily the biological potential of the resource. Accordingly, in some cases the production function can be significantly changed simply by the communication of agricultural research results to a resource manager. However, the production function will not be changed by the existence of the research results unless they are communicated to a manager.

"Research information" is a good general name for the type of information that changes the production function. Investment in research information is an important aspect of the economics of forest and rangeland protection and use. We have noted that information of the survey and inventory type is not research information, but we must also note that it is a very valuable input in generating such information. For example, statistics on annual forest growth by region or on rangeland trend by region can be derived from inventory information obtained at different times, and analysis of these statistics may lead to significant changes in management plans. This analysis is essentially a research activity since it may improve efficiency of production, but it is based on statistics which are produced from survey and inventory information. The two uses of survey and inventory information (as input to the production function, and as input to the research process) are diagrammed in Figure 3 (page D-4).

The appropriate level of investment in survey and inventory information is an important and difficult question. With enterprises not involving natural resources, it is often feasible and economical to obtain essentially complete information on the location and relevant characteristics of the productive assets. With the forests and rangelands, "complete" information is prohibitively expensive, if possible at all. However, considerable information of this type is absolutely essential for sustained yield and protection of the resource. In this situation it is clearly important that the decision on the level of investment in information and the means of obtaining it be given careful study.

The description of the timber and forage resources by production functions, with the assumption of "steady state" management leads to rough numerical valuation of these resources. To calculate it, we subtract the present value of the investments from the present value of the returns.

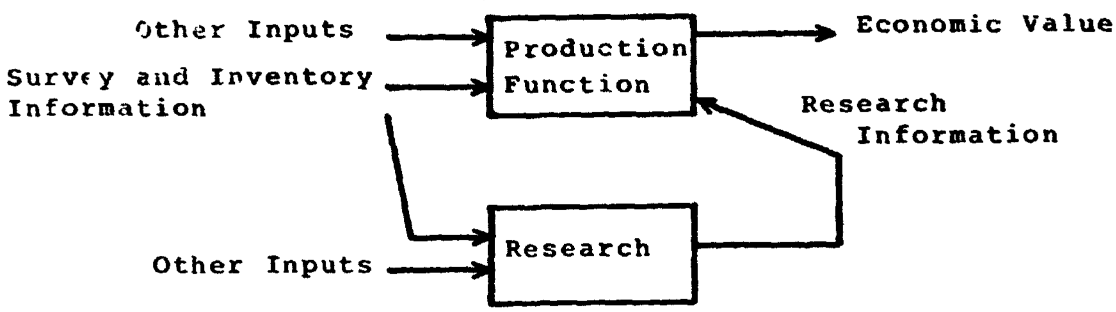

Figure 3 Information Types. Research Information Changes the Production Function

Timber and Forage Valuation

Current annual harvests of timber in the United States are about \$7.5 billion cubic feet of saw timber and \$5.6 billion cubic feet of pulpwood.* Prices for saw timber average near \$60 per thousand board feet while pulpwood prices are about \$3 per cord.** Thus, the current annual timber output has a value of about

$$7.5 \text{ billion cu.ft.} \times \$60/\text{thous.bd.ft.} \times 12 \text{ bd.ft./cu.ft.}$$
$$+ 5.6 \text{ billion cu.ft.} \times \$3/\text{cord} \times \frac{12 \text{ cord}}{500 \text{ cu.ft.}}$$
$$= \$5.8 \text{ billion.}$$

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* 1970 data from The Outlook for Timber

** Summer, 1974

Estimated costs of forest protection, planting, and improvements total near $0.8 billion per year, broken down by investment class in Table 5 on page D-6.

The total annual costs of United States forest survey and inventory information is near $40 million.

Thus, the net annual output of the forests is about $5.8 billion - $0.9 billion or $4.9 billion. The present value (at 10 percent) of a cash flow to infinity comprised of $4.9 billion per year is $49 billion. Accordingly, we can say that the economic value of the United States timber resource as a productive asset is on the order of $50 billion. Of course, we could replace the steady-state assumption with projections of the data used to derive this figure into the future, and this would lead to a different value--probably much larger. But the calculation as given serves to establish perspective and show the general structure of value for the timber resource.

It is interesting to compare the $50 billion figure with the "value" calculated by multiplying timber prices by inventory volumes. Total United States commercial timber volume is about 715 billion cubic feet consisting of 651 billion cubic feet of saw timber and 64 billion cubic feet suitable for pulp. At $60 per thousand board feet for saw timber and $3 per cord of pulpwood, the inventory value is about $475 billion. The wide discrepancy between the forest valuation based on current production and that based on price of inventory is an indication that values other than timber are implicitly recognized, and that greater timber outputs under current management procedures would impair these values. Non-timber outputs of the commercial timberlands can be included in the steady state model. In fact, the Multiple-use Sustained-Yield Act and more recent legislation define a policy for use of the National Forest System which calls for operation producing steady state outputs of benefits, specifically including esthetics, public access, wildlife habitat, and recreational and wilderness use.

In the description of the forests by a production function, we can add an output called "non-timber value". Let T be the annual net value of the timber output (calculated above as $4.9 billion), and let N be the annual additional value output of the non-timber classification. Let L be the timber "liquidation" value (price times inventory volume, calculated above as $475 billion). By the steady state assumption, the quantities L, T, and N are related in a sustainable way. That is, the resource is able to continue to produce benefits T and N from the "capital" L. We further assume that

Table 5 Annual Investments for Production of Timber Output

Investment Class	Amount, $ Millions (1970)
Forest Fire Protection	320
Insect and Disease Control	12
Tree Planting	85
Timber Stand Improvement	25
Road Construction and Maintenance	400
Totals	842

Source: U.S. Forest Service, Outlook for Timber in the United States (Washington, D.C.: Government Printing Office, 1973) Chapter II.

the particular steady state which exists is optimal. That is, the sum of the present value of the flows to infinity of T and N would not be increased by changing the size L of the capital asset through additional cutting or through additional forestation. When considering these hypothetical additional activities, we regard them as one-time alterations, leaving the system in a new steady state. The point is that the alternative steady states are not more desirable than the existing one. In all this discussion, we are assuming the production function is not changed. If it were, then we would expect a new level of L would be optimal. Looking at the way in which T and N are affected by small perturbations in L (due to one-time cutting, forestation, or abstention from steady state ha~vest), we can make a useful quantitative statement of the assumption of optimality. If V_t and V_n are the present values of the streams of timber and non-timber outputs respectively, the statement is

$$\frac{\partial}{\partial L}\left(V_T + V_N\right) = 0. \tag{1}$$

So that L can be used as a variable without confusion, L_o denotes the current (optimal) value of L.

$\left.\frac{\partial V_T}{\partial L}\right|_{L_o}$ is easily evaluated. An additional cutting of value h produces a cash flow of h in the current year and a depletion of the growing stock by the same amount. The yield in later years becomes $\frac{T}{L_o}(L_o - h)$ instead of T. The annual loss is thus $\frac{Th}{L_o}$, and the change in V_T is

$$h - \frac{hV_T(L_o)}{L_o}.$$

Thus

$$\left.\frac{\partial V_T}{\partial L}\right|_{L_o} = -\left[1 - \frac{V_T(L_o)}{L_o}\right].$$

Considering now the impact on the non-timber values of reducing L, it must be recognized that society has demonstrated a clearly nonlinear value function for such values. When L was very large, timber usage was permitted to dominate, resulting in partial liquidation of the resource (decrease in L). Liquidation beyong L_o is so strongly opposed that the current steady state operation is maintained. This general behavior is most simply described by a non-timber value model which assigns diminishing marginal value to these outputs as L increases. We use the formula

$$V_N = A + B \ln L \tag{3}$$

where A and B are constants to be determined. A is not important for the implications of the model since one deals only with differences in V_N associated with variations in L. However, it can be set at a convenient conventional value. Using the convention that when $L = L_o$ (all units of the non-timber value are priced at the marginal value corresponding to $L = L_o$), one obtains

$$V_N (L_o) = \frac{\partial V_N}{\partial L} L_o = B \frac{L_o}{L_o} = B$$

so that

$$A = B (1 - \ln L_o).$$

The description of the steady state (Equation (1)) is used to find B. Differentiating (3) gives

$$\frac{\partial V_N}{\partial L} = \frac{B}{L}.$$

Substituting this in (1),

$$\frac{\partial V_T}{\partial L} + \frac{B}{L} = 0.$$

At $L = L_o$, this becomes (using (2))

$$\frac{B}{L_o} - 1 + \frac{V_T(L_o)}{L_o} = 0,$$

so that $B = L_o - V_T(L_o)$.

Now the value fraction of Equation (3) becomes

$$V_N(L) = A + (L_o - V_T(L_o)) \ln L$$

$$= (L_o - V_T(L_o))(1 - \ln L_o + \log L)$$

$$= (L_o - V_T(L_o))(1 - \ln \frac{L}{L_o}).$$

Particularly interesting is the change in V_N corresponding to "errors" in L. Since the steady state optimal level is L_o, a value other than L_o is an "error." Since it is convenient to work with percentages, this error is denoted by

$$e = \frac{L - L_o}{L_o}.$$

The change in the non-timber values due to the error e is

$$V_N(L) - V_N(L_o) = (L_o - V_T(L_o))(1 + \ln (1 + e)) - (L_o - V_T(L_o))$$

$$= (L_o - V_T(L_o)) \ln (1 + e).$$

$$= L_o(1 - \frac{V_T(L_o)}{L}) \ln (1 + e).$$

The change in the timber values is

$$-(1 - \frac{V_T(L_o)}{L_o})(L - L_o) = -(1 - \frac{V_T(L_o)}{L_o}) eL_o.$$

The net change is the sum of these, or

$$L_o (1 - \frac{V_T(L_o)}{L_o})(\ln (1 + e) - e)).$$

It is convenient to write $V_T(L_o)$ in terms of the steady state annual output which determines it. If r is the discount rate (we use 10 percent), $V_T(L_o) = \frac{T}{r}$, so the net change can be written

$$L_o \ (1 - \frac{T}{rL_o}) \ (\ln \ (1 + e) - e). \quad *$$

$\frac{T}{L_o}$ is just the annual production rate of timber value. Denoting this rate by ρ, the net value change becomes

$$L_o \ (1 - \frac{\rho}{r}) \ (\ln \ (1 + e) - e). \quad **$$

Since $L_o = V_T(L_o) + V_N(L_o)$, the product of the second two factors can be regarded as the fractional change in commercial timberland value due to a harvesting error e, where the value includes timber and the non-timber values. The quantity $(1 - \frac{\rho}{r})$ is related to the biological productivity of the timberland and to the intensity of timber management.

The quantity ρ, the ratio of annual yield to inventory volume, is typically much less than 10 percent. This is true even under the most intensive management currently practiced, and even on the most productive lands. This fact about timber production is very significant. It implies that timber values alone do not justify the sustained-yield concept, and this would be true even if timber prices increased substantially (because such an increase does not affect the ratio). The optimal cutting policy based on timber values alone is to liquidate the inventory, investing the proceeds in other activities which can yield 10 percent or more per year. The history of conflict between the logging industry and the defenders of the forests for various non-timber uses bears out the truth of this statement.

The quantity $(1 - \frac{\rho}{r})$ is equal to $\frac{V_N(L_o)}{L_o}$, the non-timber fraction of the total commercial timberland value. Of course it is at its greatest where ρ is small.

* ln = natural log
** ln = natural log

Currently the annual production of livestock forage on the United States rangelands is about 215 million AUM (animal unit months -- the amount of forage consumed by one cow in one month). This forage is not itself a traded commodity; it is converted into economic value only through the livestock whose growth it supports. An estimate of the value of an AUM of forage is provided, however, by the price of the equivalent nutrient value in the nearest substitutable commodity, which is hay. Hay prices are about $35 per ton, and a ton of hay provides feed value equivalent to $\frac{82}{45}$ AUM. Thus, the value of forage is about $19 per AUM, and the current national forage output is worth about 215 x $19 million or a little over $4 billion. The investments in the land required to produce this output include fencing, seeding, fertilization, irrigation, weed control, and insect and disease control, among others. Total annual land investments average about $860 million. Rangeland survey and inventory costs have been estimated as $270,000 per year.* Since this figure is based primarily on data on aerial photography expenditures collected by Frank and Heiss** in 1968, current costs are probably closer to $420,000 per year. Combining these information costs with the investments in the land, we obtain total annual costs of $1.3 billion for producing the United States forage output.

The net annual output of the forage resource is thus about $4.0 billion minus $1.3 billion or $2.7 billion. Capitalizing this annual flow at 10 percent annual interest, we obtain a resource value on the order of $30 billion. As with the timber resource, a different figure would be obtained if the inputs and outputs were projected according to trends in demands and policies, but this rough estimate serves to establish perspective.

The above valuation of the forests and rangeland as producers of commercial products shows that they are enormously valuable. Of course it is possible to estimate additional economic values associated with recreation and wildlife. In the cases where commercially useful timberland has been withdrawn for other uses, it is clear that the implied value is at least as great as it would be under timber use. Similarly, where residential or industrial use of wetlands is prevented to maintain wildlife and water values, at least an equivalent value is implicitly attributed to these resources.

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* EarthSat Rangeland Case Study.

** Heiss, K. P., Frank, C. R.; Management of Grazing Lands by Earth Resources Observation Satellite, Princeton, N.J., 1968. (Mathematica Report).