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The utilization of ERIS-1 data in 18 developing countries has been reviewed and evaluated, This overall assessment is supported by more detailed economic evaluations in four selected countries: Bolivia, Thailand, Kenya and Botswana. Two quantitative economic evaluations were conducted, one on the benefits to be derived from improved rice-crop forecasting in Thailand and the other on benefits stemming from improved range-carrying-capacity estimations in Kenya. Additional qualitative evaluations were made of potential improvements in mineral exploration (principally in Bolivia and Botswana), water resources management (mainly in the Mekong Basin and the Okavango Delta), and cartographic mapping. While organizational and technical progress varies widely, it seems clear that substantial benefits can accrue to these countries in cartographic mapping, mineral exploration, water resources management, range mangement, crop forecasting, and rural/regional development. These benefits can be accrued at acceptably low cost levels, provided that appropriately timed and scaled technical assistance (including training in ERTS-data interpretation and application to managment-decision processes) is provided to the individuals and institutions involved with ERTS-data utilization in each country.

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AN ECONOMIC EVALUATION OF THE UTILITY OF ERTS DATA FOR DEVELOPING COUNTRIES

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AUGUST 1974

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The colorful ERTS image of northern IRAN on the facing page was taken on June 2, 1973. Tehran, the capitol, can be seen in the lower right-hand quadrant of the image. It is located at the edge of a long desert basin near the base of the Elburz Mountains.

Information can be extracted from ERTS imagery by automated or manual photointerpretation techniques. These techniques rely on recognition of features based on shape, context, and color. Changes in dynamic features can be observed through repetitive observations.

In this false-color image, vegetation appears red, snow and clouds white, water dark blue, and bare terrain a wide range of gray-like tones. These tones are associated with soil and rock types, their distribution and terrain slope.

The ERTS image has sufficient geometric fidelity to meet map-accuracy standards at scales of 1:500,000. The image itself is a photomap, and maps can be made directly from it.

NOTICES

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16. Abstract

The utilization of ERTS-1 data in 18 developing countries has been reviewed and evaluated. This overall assessment is supported by more detailed economic evaluations in four selected countries: Bolivia, Thailand, Kenya and Botswana. Two quantitative economic evaluations were conducted, one on the benefits to be derived from improved rice-crop forecasting in Thailand and the other on benefits stemming from improved range-carrying-capacity estimations in Kenya. Additional qualitative evaluations were made of potential improvements in mineral exploration (principally in Bolivia and Botswana), water resources management (mainly in the Mekong Basin and the Okavango Delta), and cartographic mapping. While organizational and technical progress varies widely, it seems clear that substantial benefits can accrue to these countries in cartographic mapping, mineral exploration, water resources management, range management, crop forecasting, and rural/regional development. These benefits can be accrued at acceptably low cost levels, provided that appropriately timed and scaled technical assistance (including training in ERTS-data interpretation and application to management-decision processes) is provided to the individuals and institutions involved with ERTS-data utilization in each country.

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PREFACE

This report presents the results of a one man-year study conducted by ERIM in association with System Planning Corporation and Mathematica, Incorporated. The study was designed to determine whether or not ERTS-data utilization by developing countries had significant benefit/cost potential.

A project such as this could not be conducted without considerable assistance and advice from many people associated with agencies having activities and projects in developing countries. These contacts are too numerous to mention here, but the authors are indebted to them. Special thanks are due to the ERTS Principal Investigators of the four countries which were visited as well as to the AID missions for arranging the meetings and providing other help as needed. Special assistance was also provided by the IAGS mission in Bolivia.

This report was prepared through the efforts of a number of professional staff members of the three participating organizations. We would particularly like to acknowledge the following specific contributions:

W. L. Smith prepared Appendix A, "ERTS Data Use as an Aid to Mineral Exploration in Developing Countries."

Dr. S. Jakubiak wrote Appendix B, "ERTS Data as an Aid to Rice Crop Prediction: Thailand."

B. W. MacDonald wrote Appendix C, "ERTS Data as an Aid to Improved Range Management: Kenya."

P. Drake prepared Appendix D, "Mapping Applications of ERTS," and Appendix E, "Hydrologic Applications of ERTS."

Finally, this study would have never been conducted without the visionary support of our sponsors in AID. We appreciate the guidance and counseling of Mr. John Fry in formulating the goals and objectives of the study and Mr. Merrill Conitz for his assistance and guidance in the conduct of the program.

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1
INTRODUCTION

1.1 BACKGROUND

The purpose of this study has been to investigate for the Agency for International Development (AID) the potential economic and social benefits that may accrue to developing countries (DCs) from the utilization of imagery obtained by NASA's Earth Resources Technology Satellite (ERTS). ERTS, the first satellite dedicated to earth-resources experimentation, was launched in July, 1972. Carrying a multispectral scanner, return-beam vidicom cameras, and a data-collection system, the satellite provides periodic imagery of the United States and certain foreign countries. The foreign recipients of the imagery were selected on the basis that they designate a principal investigator (if necessary, coinvestigators) and provide NASA with progress reports on their ERTS applications.

Eighteen developing countries are presently receiving ERTS imagery from NASA. To ultimately yield economic benefits, this imagery must be transformed into information in a format which is useful for decision making by those who are responsible for the allocation of scarce resources. Managers normally are required to make decisions under conditions of less-than-perfect knowledge, and information is sought to facilitate the decision process. A typical chain of events leading from the statement of broad national objectives to actual project management is illustrated in Figure 1.

At the highest levels of planning, consideration is given to national goals and the "state of the world," and a national plan is

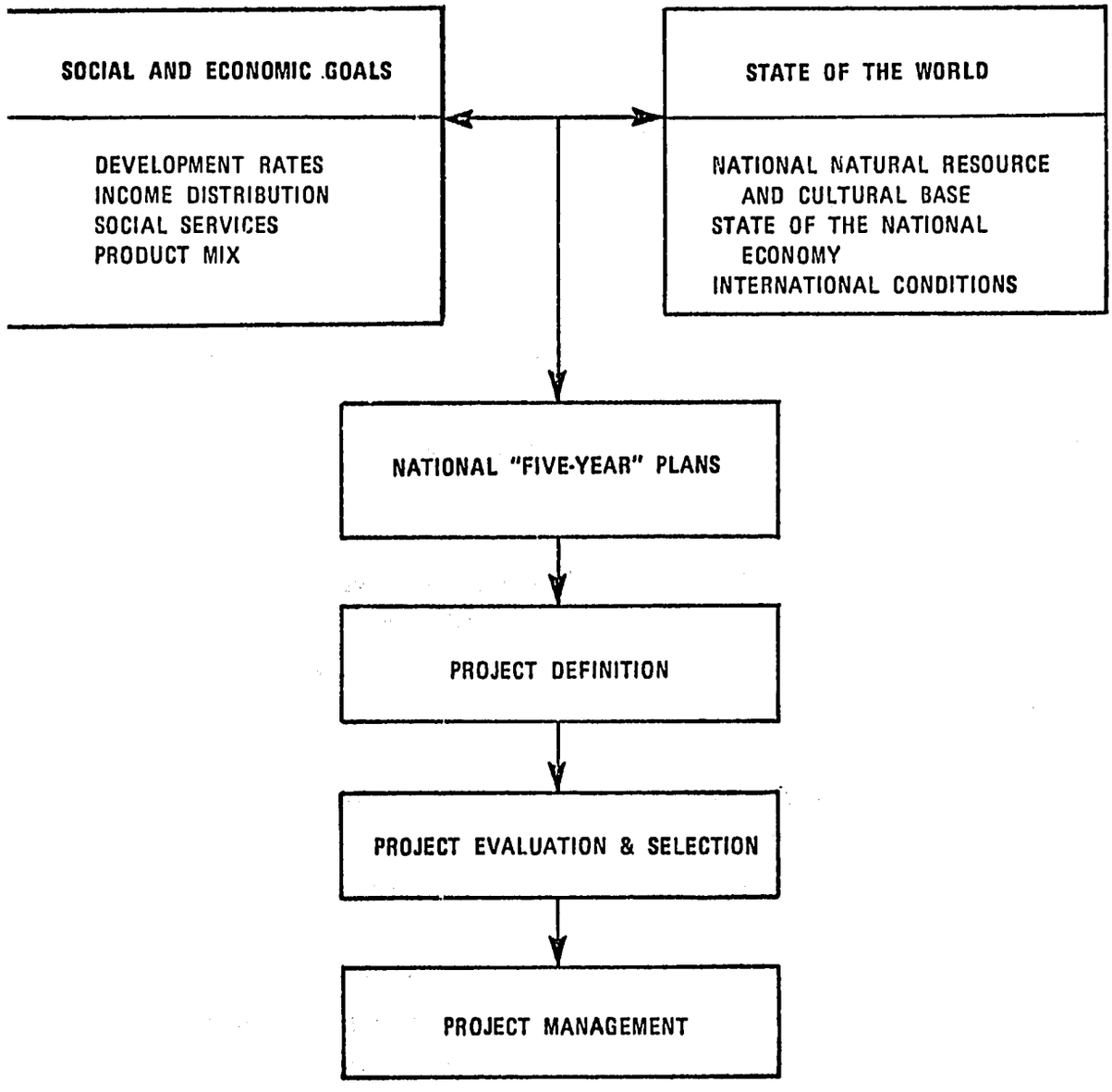

FIGURE 1. AN OUTLINE OF THE PLANNING PROCESS

formulated as a reconciliation of these. Given the existing patterns of social and economic behavior, the national resource base, international considerations, and the political and economic feasibility of change via new technology, investment, and social and economic reorganization, the plan seeks to maximize public welfare.

Some minimum knowledge of the national physical and cultural base is required. This includes the identification and distribution of natural resources, geology, hydrology, and land use. The traditional method by which this information is acquired is from cartographic and thematic maps. However, the production of these maps is costly and time consuming, but without them or some substitute a realistic national plan is difficult to achieve.

Given an overall plan or direction, the next step in the planning process is to devise a set of projects that are supportive of the goals. Some of these projects are complementary and some are alternatives; the choice depends upon their ranking or evaluation with respect to their economic benefits and costs.

Project definition, evaluation, and management all require economic and national resource information — indeed, the very choice of projects may depend upon the cost and availability of information for purposes of control.

From the viewpoint of the decision makers, information has economic value only insofar as it facilitates "better" decisions (broadly defined as those choices among alternatives for which there is a greater expected present value). By evaluating projects in terms of present values we recognize that time is a major dimension in economics, and it is the time distribution of all costs and benefits (and the proper discount rate) which is relevant to the analysis.

The economic value of ERTS imagery depends upon its technical and temporal attributes and the nature of the economy, as well as the

cultural context into which it is introduced. To the extent that ERTS imagery provides information equivalent to that acquired by conventional methods, but at lower cost, or permits "better" decisions (in terms of higher expected present value) than would be possible in its absence, the imagery has economic value. This study has been addressed to assessing the relative benefits and costs of the utilization of ERTS imagery by developing countries.

1.2 THE TECHNOLOGY OF REMOTE SENSING

Before discussing the proposed cost-benefit evaluation per se, it is perhaps useful to describe briefly the ERTS-based remote sensing technology which provides the new forms of resource information which appear to be of potential benefit to developing countries.

1.2.1 REMOTE SENSING FROM ERTS-1

The Earth Resources Technology Satellite (ERTS-1) provides repetitive, synoptic coverage of the earth every eighteen days in four spectral bands. These data are available as 100 x 100 nautical mile (10,000 square nautical mile) images in the single spectral bands or in any combination of them or as color composites. This imagery can be used to locate specific features and to produce a wide variety of thematic maps. Automated processing of digital-data tapes is also possible for specific applications investigations.

ERTS's near polar sun-synchronous orbit enables the satellite to cross the equator at approximately 9:30 am local time on the north-to-south leg of each orbit. Shadows cast upon the ground at this time of day provide the greatest assistance in interpretation of surface features.

ERTS passes over any location on the earth's surface once every 18 days, at the same time of day and with the same lighting. The

advantage of this repetitive coverage is its great potential for monitoring time-dependent changes in surface features.

Several technical advantages result from the high altitude of an ERTS-satellite platform. ERTS imagery is orthophotographic,* which is especially useful for cartography. Because of the high altitude and resulting small scale of imaging, only 500 images are required for complete coverage of the U.S. (Mapping with high-altitude aircraft requires 500,000 images.) The high altitude platform of ERTS provides a synoptic field of view, which is useful to many disciplines because it provides instant generalization. As a result, some hitherto unknown large-scale features have been discovered. These advantages offered by ERTS allow series of photomap products to be produced in a fraction of the time required by conventional methods and at a cost which permits frequent new editions. (For a more detailed discussion of these advantages, see Appendices D and E.)

The principal operating sensor on board the satellite is a multispectral scanner which measures optical energy simultaneously in four spectral bands; the data is stored by a tape recorder for non-U.S. coverage and transmitted to three data reception stations within the U.S.** These four wavelength bands cover the visible to near-infrared portion of the electromagnetic spectrum. The bands have been designated as Nos. 4, 5, 6 and 7. Band 4 ranges from 0.5 to 0.6μm, the "green" spectral region. In this band, water is relatively transparent, enhancing features within the water such as sediments, shallows, and bottom topography. Because of atmospheric scattering, this band is often of

* Each point on the image appears to have been photographed from directly above. Thus distortion resulting from tilt and relief are minimal. This makes the image particularly useful for cartography.

** A data reception is also operational in Canada and one is being installed this year in Brazil.

limited use. In Band 5, 0.6 to 0.7μm (the visible "red" band), the sensor "sees" through the atmosphere readily. This band is particularly suited for land-use mapping where regional population patterns need to be observed against background vegetation. There is good contrast between cultural structures, vegetation patterns and soils, making it suitable for the study of desert regions. Bands 6 (0.7 to 0.8μm) and 7 (0.8 to 1.1μm) are in the near-infrared part of the electromagnetic spectrum. In both, vegetation appears bright and water appears black. In the 0.7 to 0.8μm band, the earliest detection of vegetation stress is possible inasmuch as vegetation brightness depends on its health. The longer wavelength band (0.8 to 1.1μm) is of particular interest in agriculture and hydrology for purposes of soil-moisture assessment and water-resources management.

ERTS carries a data-collection system which relays telemetered information from about 100 collection stations located in remote regions of North America. The stations collect data on water quality, rainfall, snow depth, seismic activity, etc. which is transmitted from all sensors every three minutes. A message is relayed from each remote site at least once every 12 hours.

1.2.2 APPLICATIONS OF ERTS IMAGERY

ERTS capabilities which are pertinent to the problems of developing countires include those related basically to earth-resources planning and management.

> Regional studies of land use and population distribution; mapping for utilities and communications systems and engineering projects; and assessment of available essential resource potential for the future.

- Mapping of agricultural, forest, and soil resources, fisheries, rangelands, physiographic units, water bodies and parameters affecting water quality, mineral resources, and favorable geological indicators for purposes of investment, national planning, and export growth.
- Public health considerations, including determination of the patterns, interrelationships, and transmission modes of epidemics by remote sensing the effects of disease vectors of plant, animal, and human epidemics.

The accomplishments of remote sensing to date in pertinent applications and the potential ERTS applications to practical national development planning are briefly summarized below.

Agriculture and Land Use

Accomplishments to date include thematic mapping with emphasis on the capability of monitoring seasonal changes. Objectives have included the identification of vegetation soil and water features; the detection of stress, drought, and fire; the assessment of crop, timber, and rangeland vigor; and the development of information for land-use planning. Discrimination of natural and cultural patterns has also been accomplished.

Significant results in this area obtained from ERTS-1 and reported on at the March 1973 ERTS symposium* include:

- Identification of large masses of citrus fruit and rice fields in eastern Spain
- Engineering analysis of ERTS data for Southeast Asian agriculture
- Interregional analysis of natural vegetation analogues

* The symposium on Significant Results Obtained from ERTS-1, sponsored by NASA, was held March 5-9, 1973. The symposium provided an open forum for users of ERTS data to present the significant accomplishments of their investigations. Representatives of federal, state, and local organizations presented their views on how ERTS data are being used and will be used for solving operational resource-management problems.

- Interpretation of ERTS multispectral scanner images of a savannah area in eastern Colombia
- Land-use studies in the northern Coadrella Valley, California
- Application of ERTS remote sensing to resource management and development in Sahelien Africa (Republic of Mali)

Potential ERTS-data applications include:

- Assessment of soil types and moisture
- Planning of transportation routes for food products (railroad, highway, river), irrigation projects, commercial logging, firebreaks, and communications lines
- Definition of agricultural land-use potential for livestock, plantations, grain crops — as related to population distribution
- Determination of vegetation boundaries and areas subject to flooding
- Assessment of effects of infestation, erosion, overgrazing, overcropping, and changes in fresh-brackish water boundaries
- Surveys for land use management.

Water Resources, Coastal Problems, Fisheries

Accomplishments to date include the monitoring of such fresh-water features as lakes, river basins, estuaries, and snowpacks. Such information is prerequisite to the management and conservation of water for irrigation and for municipal and industrial uses. Remote-sensor data has been applied to coastal and marine-resource studies at various levels, including identifying pollutants, mapping biologically rich areas, monitoring estuarine processes, and developing knowledge of basic oceanographic phenomena and predicting routes of fish migration.

Significant results in these areas obtained to date from ERTS-1 and reported on at the March 1973 ERTS symposium include:

Interpretations of the hydrology of closed basins and deserts of South America

- Detection of major river-bed changes in the River Ebro (Spain)
- Use of multispectral imagery to water-resources development planning in the lower Mekong Basin
- Biomass assessment in the upwelling areas along the northwest coast of Africa
- ERTS imagery as an aid to fisheries management in the northern Gulf of California
- Use of ERTS imagery in the study of suspended sediment and aquatic fronts
- Correlation of ERTS multispectral imagery with suspended matter and chlorophyll in the lower Chesapeake Bay

Potential ERTS applications include:

- Interpretation of sea color and location of shoals
- Identification of biologically rich areas in coastal regions and location of fishing grounds
- Observation of erosion, sediment transport and dispersion or deposition
- Definition of watersheds and drainage patterns and location of potential hydroelectric power sites
- Determination of soil moisture, wetland characteristics, estuarine and shoreline features, and saline incursion

Mineral and Land Resources

In the area of mineral and land resources, accomplishments to date have been at the level of identification and mapping, plus some initial study on resource inventories, determination of spectral properties of surface materials, and locating features which could serve as indicators of geological structure and guides to possible mineralization. Major successes include the detection of fracture patterns and the use of

multispectral imagery as the basis for mapping outcrops and distinguishing various soil and lithologic varieties.

Significant results in the area of geology obtained from ERTS-1 and reported on at the March 1973 ERTS symposium include:

- Use of ERTS-1 data for geological mapping over southern Morocco
- Study of morphology, provenance, and the movement of desert-sand seas in Africa, Asia, and Australia
- Use of ERTS imagery in the search for prophyry-copper deposits in Pakistani Baluchistan
- ERTS image contribution to understanding geologic structures related to the Managua earthquake of 1972
- Use of ERTS imagery as an aid in the definition of the geotectonic domains of the southern-African crystalline shield
- Relationship of ERTS-detected geologic structure to ore and mineral-fuel deposits in the northern coast ranges of California

Potential applications of ERTS data include:

- Surveys of mineral belts for possible indicators of ore deposits
- Maps of structure, lithology, and surface materials in areas poorly explored at present
- Identification of areas of potential geologic hazards
- Monitoring of coastal geology, deltas, wetlands, channels, erosion, and flooding
- Location of sites for industrial and engineering projects, power sources, ground stability, essential resources, and geomorphological constraints

1.3 APPROACH

The overall approach of our study is summarized in Figure 2. As indicated, there were five principal phases: (1) information collection and selection of case-study countries, (2) visit preparation, (3) visits, (4) benefit-cost evaluations for specific case-study applications and associated analyses, and (5) overall evaluation and reporting. The total effort represented about one man-year.

In selecting countries for visits, the objective was to strike a balance among geographical area, level and rate of economic development, functional applications of the ERTS principal investigators, and a judgment of the potential economic significance of imagery utilization in each country. Based upon the information sources indicated in Figure 2, Bolivia, Thailand, Kenya and Botswana were selected, and the choice was approved by AID.

In preparing for the visits, available socio-economic data were studied and meetings were held with AID, as well as with international organizations and embassies of the host countries. An attempt was made to anticipate which applications of ERTS imagery were potentially most beneficial, and to prepare briefing materials for the countries that reflected this initial effort. In retrospect, by showing the people in each country exactly how the information we requested fitted into the study, we were able to engender a large measure of interest and cooperation.

The visits took place over a three-month period and represented the largest part of the study effort. Approximately one week was spent in each country. The team consisted of the persons responsible for the study: Donald S. Lowe, principal investigator and a physical scientist, Dr. Robert A. Summers, co-principal investigator and a systems engineer, and Dr. Edward J. Greenblat, an economist. This combination of backgrounds proved valuable for collecting data and

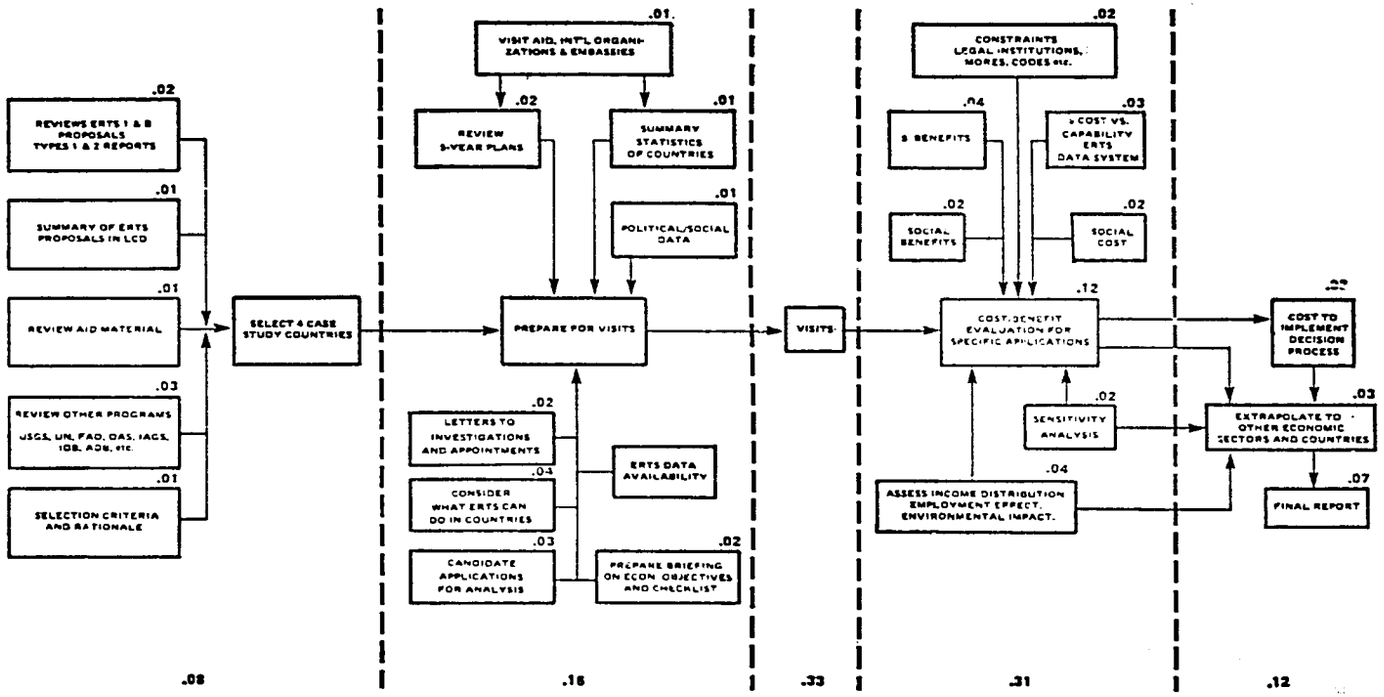

FIGURE 2. OVERVIEW OF STUDY APPROACH

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eliciting effective responses to questions in the host countries.

During each visit there was extensive contact with the local ERTS principal investigator (or his designated representative) and AID representatives. Typically those interviewed included the ERTS principal investigator and coinvestigators, government officials responsible for planning and financing, U.S. Embassy and AID officers, members of international agencies and bilateral assistance groups, and representatives of the private sector. Every attempt was made to obtain independent opinions from those who were not directly involved with the ERTS experiment. Trip reports have been prepared and are included in this report as Appendix G.

The main purpose of each visit was to trace the course of the ERTS imagery from ERTS experimentation to actual use for decision making. This involved an assessment of the process illustrated in Figure 3. As we have already observed, ERTS imagery will have no economic value unless its attributes are actually used by the technical and managerial communities of the public and private sectors.

The visits were made to assess the state of the information-generation process for the sample countries. In this light, a major task of each visit was the identification of some case studies for benefit-cost analyses of specific ERTS applications. These would provide the references for the evaluation, although we realized that the case studies could provide, at best, only partial indicators of the benefits and costs of ERTS utilization.

The case studies selected were rice-crop forecasting in Thailand, rangeland management in Kenya, watershed management in Botswana and the Mekong, and overall studies of the potential from utilization of the imagery for minerals exploration and mapping applications. The first two studies in Thailand and Kenya were quantitative in nature and have been carried out for a range of significant parameters. The

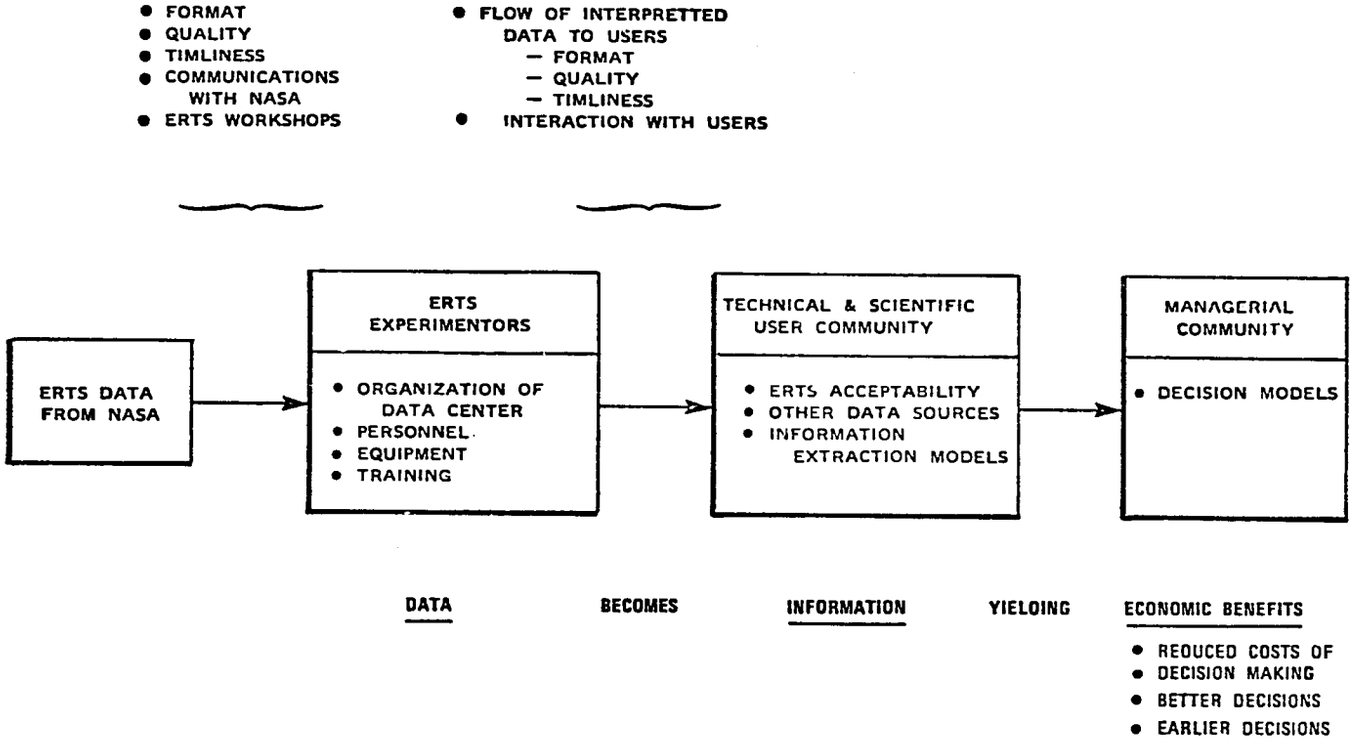

FIGURE 3. A PROCESS OF ERTS DATA UTILIZATION

last three studies are qualitative. These case studies are documented in Appendices A through E, and summarized in Chapter IV.

In the case study of rice-crop forecasts, it is expected that the interpreted imagery could be used for more accurate estimation of total acreage, patterns, and intensity of cultivation. From this information more precise estimation of the allocation of total rice acreage among the three types of cultivation would be possible. Furthermore, a more accurate production and unit identification and description would permit more efficient statistical stratification for on-site sampling, and hence, a more accurate crop prediction. The model that was employed for this analysis postulates that economic welfare losses occur as a result of inaccurate crop forecasts and that these losses can be reduced with more accurate forecasts.

In the case study of rangeland management, economic benefits from ERTS imagery are attributed to more efficient allocation of the biomass for grazing domestic and wild animals. In Kenya, one of the case-study countries, cattle and wildlife are the major source of local income. Commercial interests raise cattle as a "cash crop;" an indigenous subculture, the Masai and other nomadic tribes, raise cattle as "a way of life" but do not for the most part enter into the market economy. Wildlife, which is the major attraction for tourism (which competes with coffee as the number one foreign-exchange earner) in Kenya, also requires large amounts of rangeland. It is likely that the ERTS imagery, which can quantitatively map the vegetative biomass, could be very useful for the development and implementation of a rangeland-management model that would maximize returns from the cattle and tourism industries while setting aside sufficient land for the Masai. This is an example of the social and economic benefits which may accrue from effective utilization of the imagery.

Economic benefits from ERTS applications in minerals exploration are expected from three sources: reduced costs, increased likelihood of discovery, and earlier realization of the net income from mining (as a result of reduced exploration time). ERTS imagery can be used to produce low-cost regional geological base maps which are a necessary input to minerals exploration. It is also expected that information extracted from the imagery can substitute for higher-priced information provided by conventional methods. It is to be emphasized that this may not be the same information - which makes a cost-effectiveness comparison difficult - and that the information may require a new approach to minerals exploration, but the result is likely to be lower-cost discoveries. Because of the technical attributes of ERTS imagery, information can be extracted which cannot be acquired by conventional methods. This information, combined with what is already known, will increase the efficiency of exploration by raising the likelihood that a given amount of funds will result in a find.

If the information extracted from the imagery serves as a substitute for conventionally acquired information and in doing so reduces the time as well as the cost of exploration, then additional economic benefits will be realized. This is based upon the fact that the economic value of the net revenue from mining operations depends upon when (in time) the revenue is received. Assuming that the reduction of the exploration period will reduce the time lag for accruing net income, then ERTS imagery will yield benefits as a result of this early acquired information.

Other activities for which case studies have been prepared are the use of ERTS imagery in cartographic mapping and watershed management. Economic benefits which may accrue from these applications are due to the same properties of the imagery which have been discussed in terms of the other case studies.

1.4 ORGANIZATION OF THE REPORT

Appendix F presents a review and summary tables of the ERTS-1 programs in 18 developing countries. To acquaint the reader with the scope and status of the ERTS-1 projects, Section 2 presents a condensation of this review, an evaluation, and a discussion of the procedure for selecting the four case-study countries.

A major part of the study was devoted to visiting the four case-study countries to collect first-hand data on the ERTS experiments and on the acceptance and utilization of ERTS-derived information by planners and decision makers. A summary of observations resulting from these visits is given in Section 3. Detailed trip reports on various contacts and discussions are given in Appendix G.

Section 4 outlines how benefits can be derived and calculated from information obtained from ERTS data. Five application areas are singled out as having a high potential for benefit to developing countries. Two of these applications have been quantitatively treated in this study: improved rice-yield forecasting and grazing-land management. The remaining three applications were treated qualitatively: mineral exploration, mapping, and water-resource management. Summaries of these five analyses appear in Sections 4.2.1 through 4.2.5. The complete analyses are found in Appendices A through E.

The main body of the report ends with Section 5, "Summary, Conclusions, and Recommendations." The report would not be complete without some discussion of the costs involved in extracting information from ERTS data. In Appendix H we have attempted to lay out these costs in order of increasing capability for extracting information from ERTS.

2

SUMMARY OF ERTS PROJECTS AND SELECTION OF CASE-STUDY COUNTRIES

The initial task in this study was to summarize and assess the status of ERTS-1 programs in 18 developing countries plus FAO and the Mekong Secretariat. Then, in order to gain some insight into the potential magnitude of benefits from ERTS-data utilization by developing countries in general, the programs and results of four countries now using ERTS data were analyzed in some detail. These analyses required data-gathering visits to the selected countries. Selection of the four case-study countries required careful consideration to minimize biasing of the findings. This section of the report first summarizes the status of the ERTS-1 programs in 18 participating developing countries and then describes the selection criteria and outlines the activity and rationale behind the selection of the four case-study countries: Bolivia, Thailand, Kenya and Botswana.

Prior to the study we determined that the selection process would be limited to countries having ongoing ERTS-1 studies. Among these countries, four would be selected in a manner to obtain representation and balance among parameters such as geographical location, level of national economic development, type of economy, potential economic significance of the ERTS program, the resource areas to which ERTS would be applied, and the level of technical capability for extracting information from ERTS. Selection on these bases required a review and summary of the ERTS programs and some understanding of the candidate countries and their development plans.

2.1 REVIEW AND SUMMARY OF ERTS INVESTIGATIONS

ERTS-1 was launched successfully in July, 1972. Prior to launch NASA negotiated 375 contracts with investigators who proposed studies for ERTS-data utilization in various earth-resource applications. NASA provided ERTS data to foreign investigators in return for reports

documenting their data utilization.

The ERTS proposals and status reports* from the 18 developing countries having ERTS experiments were obtained from NASA along with those of the Mekong Secretariat and FAO. Table 1 lists these experiments. These ERTS programs are briefly summarized below and presented in detail in Appendix F. It should be pointed out that we considered only ERTS projects being conducted by residents of the developing countries. There are a number of ERTS investigators in developed countries whose studies involve developing countries, but these have not been evaluated.

Throughout the study we have attempted to keep abreast of the progress of the ERTS-1 projects. Thus, Appendix F and the summaries below give the current status of the ERTS projects as obtained from published reports and discussions with persons intimately familiar with the programs.

MEKONG SECRETARIAT

The ERTS proposal outlines the application of ERTS data to resources management of the lower Mekong Basin for the purpose of planning and investigating water-resources development projects. Specific objectives include monitoring agricultural practices, gathering agricultural statistics, forecasting floods for the basin, assessing flood damage, and understanding regional hydrology.

Some progress has been reported to NASA. Three important uses for ERTS imagery in the Makong Basin are (1) flood and drought management, (2) watershed management, and (3) soil mapping. Specific benefits include identification of forest cover and other terrain and vegetational units. Color composites have enabled recognizing forest deterioration, measuring the magnitude of inundation of agricultural lands, identifying drainage problems related to the construction of gravity canals in the low-lands, and detecting the effect of flood regulation by tributary dams. Planning

*Information from the status reports covers those reports received and released by NASA 20 May 1974.

TABLE 1. SUMMARY OF ERTS EXPERIMENTS

COUNTRY	PRINCIPAL INVESTIGATOR	PROPOSAL NO.	PROPOSAL DESCRIPTION	NUMBER OF REPORTS RECEIVED BY NASA OFFICIAL/(UNOFFICIAL)	RESOURCE AREAS ADDRESSED * (TOTAL FOR NATION)
ARGENTINA	Dominguez, O.	528	Agricultural-livestock studies	0 (1)	RALE
	Garuti, Hamberto H.	529	Crop classification, water-resource management, coastal processes, pattern recognition.	0	
BOLIVIA	Brockmann, Carlos	571	Mapping and evaluation of basic resources, particularly mining, agriculture, and land use.	3 (6)	GCALW
BRAZIL	de Mendonca, Fernando	326-01	Resource utilization in agriculture.	3	
	Amaral, Gilberto O.	326-02	Geological and mineral-resource survey.	3	
	Gama, Emmanuel de Almeida	326-03	Bathymetric studies of east coast.	3	AFRGCOW
	de Azevedo, Luis Henrique	370	Survey of natural resources and environment in Amazon Basin	0	
	Velloso, Marcos Henrique	525	Inventory of coffee plantations.	0	
CHILE	Saa, Rene	372	Land-use classification and monitoring	0	AFH
COLOMBIA	Koopmans, Bastiaan	305	Thematic mapping	2	CWLAR
	Fletcher, Gonzales Alvaro	624	Monitoring and prediction of floods	1	
ECUADOR	Moreno, Nestos Vega	371	Agricultural, geological, and hydrological mapping for land-management planning.	0	CAGWL
GUATEMALA	Garcia, Luis	369	Updating of resource and land-use data	1 (3)	CLARWG
PERU	Pomalaza, Jose C.	302	Investigation of hydrological cycle in Sante River Basin.	0	W
VENEZUELA	Corao, Manuel J.	117	Land-use analysis, analysis of urban growth	2	GARWU
	Romero, Adolfo C.	120	Survey of natural resources in remote areas.	2	
BANGLADESH	Hossian Anwar	564	Evaluating land and water resources, developing flood control.	0	AFWDC
KOREA	Lee, Joung Hwan	570	Investigating geologic and structural features.	0	GW

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TABLE 1. SUMMARY OF ERTS EXPERIMENTS (CONCLUDED)

COUNTRY	PRINCIPAL INVESTIGATOR	PROPOSAL NO.	PROPOSAL DESCRIPTION	NUMBER OF REPORTS RECEIVED BY NASA OFFICIAL/(UNOFFICIAL)	RESOURCE AREAS ADDRESSED* (TOTAL FOR NATION)
FAO	Fischnich, O.E.	603	Integrated resource surveys.	0	ACEFLRW
PHILIPPINES	Busuego, Fernando	612	Land-use studies, improving base maps. tectonic studies.	1	COAF
THAILAND	Sabhasri, Sanga	620	Planning, development, and management of resources.	2	AFOCWGL
BOTSWANA	Hepworth, J.V.	643	Resource evaluation and development planning on national scale-geological mapping, hydrological study, cartography	3	GWARC
KENYA	Omino, J.H.O.	658	Agricultural, range, and hydrological surveys	1 (2)	ARW
LESOTHO	Nixon, Peter	681	Agricultural and mineral-resource development.	2	GA
MALI	Konate, Mamadu	626	Improvement of natural-resource data base for input to agricultural, hydrological, and geological development.	1	AWG
MEKONG SECRETARIAT	Van der Oord	605	Resource management of Lower Mekong Basin for planning and investigating water-resources development projects.	3	W
INDONESIA	Katili, John A.	004-1	Topographic and geologic mapping, land-use classification.	1	GLCW
		004-2	Investigation of Barito River Basin and Island of Bali	1	

* Abreviations of resource areas:

A - Agriculture
C - Cartography
E - Ecoiogy
F - Forestry
G - Geology
L - Land Use
O - Oceanography
R - Range
U - Urban Growth
W - Water

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for tanks (smaller dams) can be improved with ERTS data. Three computer programs have been developed for the preliminary analysis of data from system-corrected, ERTS-1, computer-compatible tapes. Plans for systematic mapping program have been developed.

The Mekong Group feels that the ERTS imagery is the best input they have had and anticipate that ERTS could provide substantial improvements to the broader problems of establishing projects and their objectives. Some investigators feel that the entire program has been reshaped by ERTS imagery. The images have changed and sharpened the whole concept of the basin and the emphasis of the program. The Secretariat has submitted a proposal for ERTS-B.*

KOREA

The Koreans proposed to investigate geologic and structural features, including the interpretation of lithologic and structural units and the delineation of zones for mineral exploration. At present the Mineral and Geological Institute is the sole organization participating in the study. However, the government is promoting an interdepartmental project involving the ministries of agriculture, construction, and transportation. More training and equipment are necessary. No reports have been received.

PHILIPPINES

ERTS data was to be evaluated for use in tectonic studies, for the preparation of photomaps and the improvement of base maps, in land utilization studies, for coastal and seashore marine studies, and in agricultural and forestry industries. One initial report was received by NASA.

BANGLADESH

No reports have been received from Bangladesh's principal investigator. Basic land and water resources were to be evaluated and

*ERTS-B, the next satellite in NASA's earth-resources experimental program, is to be launched early in 1975.

interpreted using ERTS imagery for hydrology, soils, agriculture, and topography. They proposed to develop flood-control protection projects and to evaluate agricultural potential for long-range planning. Instrumentation for interpreting ERTS imagery is limited.

INDONESIA

Indonesia proposed to perform topographic and geologic mapping, land-use classification and monitoring, construction of land-use maps, disaster assessment, and orthophoto mapping. The correlation between satellite, aircraft, and ground-truth data would be investigated.

Work has commenced on a photomap of the country (1:1,000,000 scale), a reconnaissance land-use map, and a map showing geomorphic and geologic features. Some attempts at interpreting land use from multispectral scanner images have been unsuccessful. The imagery has been useful for identifying lineaments. Cloud coverage has been a large obstacle in ERTS interpretation.

Bakosurtonal, the government mapping agency, and Lapan, the space and science agency, are the two active agencies in remote sensing. Future plans for remote sensing include a major outlay to establish an ERTS receiving station. Presently Indonesia has an aircraft-based multispectral-scanner system for resource surveys of Bali and other areas. Although the Indonesians have not yet had a lot of practical experience, their preparation and training have been good.

THAILAND

The utility and economy of ERTS data were to be assessed for input to the planning, development and management of resources. Specific objectives included yield prediction, land-use classification and monitoring, forest land use and inventory, oceanographic studies including pollution monitoring, preparation of land use maps of the entire Kingdom (1:1,000,000 scale), and hydrologic and geologic studies.

Crop-region boundaries are clearly defined on ERTS imagery. Newly identified features include an alluvial fan and the shape and size of

flood plans in the central region. Broad classifications have been made of the forests. A country-wide forestry map based on ground checking, aircraft photos, and ERTS imaging was made in one year's time. Eight generic classes were used. Formerly, it took about 10 years to map 25% of the country. Forest and non-forest areas have been distinguished and mapped at a scale of 1:250,000. Contours of depth, sediment boundaries, and effluents of polluted water have been detected. The imagery has proved to be useful for resource mapping. Several unknown circular geologic features have been detected. Geological boundaries on the imagery indicate the need to revise current maps. While it takes 11 years to produce a new geologic map by conventional techniques, it takes about three months using ERTS data. The ERTS-based map would be less detailed but would show more lineaments, along which most major mineral deposits historically have been found. Land-use mapping is performed with ERTS data. It is anticipated that ERTS could help in production estimates in general and especially with rice. A rice-forecasting model, using ERTS, has been developed.

Thai scientists and technicians were familiarized with ERTS-imagery processing and interpretation during a six-week training course in early 1973. This experience was quite valuable. A mosaic of all Thailand was assembled using black-and-white ERTS multispectral scanner data. Substantial progress has been made in the fields of agriculture, geology, geography, forestry, and land use. Lectures on ERTS have been given at many secondary schools. The Thai five-year development plan includes the establishment of an ERTS receiving station. An ERTS-B proposal has been submitted.

MALI

The natural resource data base in Mali is incomplete, and it was hoped that ERTS could ameliorate this situation. The hydrological regime is not well understood. Specific objectives included a survey of grasslands, an assessment of seasonal changes in soil moisture, and an

investigation of the geographical distribution of underground water resources and geological studies.

LESOTHO

Lesotho proposed to assess the value of ERTS imagery in accelerating agricultural and mineral-resource development. ERTS imagery was to provide input for a land-use survey, crop mapping and monitoring, range management, and soil conservation.

A "quick-look" survey of ERTS imagery has been reported. Features were identified relating to problems of land use, crop production, range management, soil conservation, and hydrology. Major interpretative work has not yet been completed. Though results of the first look are encouraging, additional effort is needed for progress toward utilization. An ERTS-B proposal has been received.

KENYA

Kenya proposed to examine the feasibility of conducting agricultural and hydrological surveys using ERTS data. Specific objectives included vegetation mapping and monitoring, range inventories, soil studies, livestock and game studies, and hydrological studies.

Interpretation of ERTS imagery has enabled the identification of vegetation and plantation crops, specific forest types, some soil types, and various hydrologic and physiographic features. A Duth-sponsored soil survey has been undertaken using ERTS data. Considerable ERTS analysis is being done by Chevron and other oil companies. ERTS has facilitated making regional geological maps and has enabled, through more local observations, the extension of interpretations into unknown areas. Lake shorelines have been revised and basement-system metasediments have been differentiated. Interpretative work is proceeding slowly to exploit the full information-content of the imagery. Deficiencies in the project, other than organizational, stem from the lack of expertise, equipment, and repetitive coverage. Thus far, the studies have not progressed much beyond identifying features and

performing simple map corrections.

Kenya has expressed a desire to develop a program that will effectively utilize remote-sensing techniques and imagery. Some individuals anticipate that ERTS will contribute to more effective range management by improving the estimates of animal-carrying capacity and, hence, livestock and wildlife distribution. There is concern about the continued availability of ERTS imagery. If continued availability is assumed, some investigators recommend that applications to non-renewable resources be de-emphasized and that more emphasis be placed on renewable resource management. Primary application areas of interest are land use, soil erosion and denudation of land, water use, and geological applications. Kenya has inquired about the possibility of converting a spacecraft telemetry station on San Marcos to an ERTS receiving station in conjunction with Italy. An ERTS-B proposal has been submitted.

BOTSWANA

The Botswana project proposed to assess the value of satellite imagery for resource evaluation and development planning on a national scale. The proposed investigation includes geological mapping as part of a large on-going program, which includes hydrological study of a critical swamp area, vegetation mapping, game concentrations, identification of ecologically degraded areas, and construction and revision of maps of large uncharted areas.

Upon first looking at ERTS imagery, several investigators were concerned with the limited spatial resolution. The geologists, who were not as concerned with resolution, were the most enthusiastic about the capability of ERTS imagery. However, further research has convinced more investigators of the capability of ERTS. Important lithological patterns have been discovered. A pre-existing drainage system of the Okavango Swamp has been detected. River areas infested with water weed have been delineated. Brush fires were identified, roads and railways

distinguished, and reservoir silt deposits detected. Broad vegetation types have been mapped, phenological events detected, and wildfires detected and mapped. ERTS imagery at a 1:250,000 scale has been sold to hunters for safaris to be used as self-defining maps. However, a concern has been expressed about the quality, availability, and regularity of ERTS imagery, all of which have posed some problems.

Though Botswana has limited facilities and personnel, it is undertaking a serious and fruitful effort. They have submitted an ERTS-B proposal. Work is just getting underway on Bot-2, a UNDP program designed to determine the ecological effects of taking water from the land-locked delta at the Okavango. The program will utilize ERTS data.

CHILE

Chile proposed to employ ERTS imagery to identify and monitor land use, agricultural changes, and water availability for agricultural practices. No reports have been received and no progress is evident.

BOLIVIA

The ERTS program in Bolivia is very active and well organized. Significant progress has been reported. User participation is high. Because of deficient terrain, poor transportation, and inadequate funding, Bolivia's natural-resource data base was deficient. ERTS offers great hope in that it facilitates the preparation of accurate maps for minerals, petroleum exploration, forestry, hydrology, identification of areas of agricultural concentration, and assessment of potential land use. The principal interests of the ERTS program in Bolivia are cartography, agriculture, petroleum exploration, and hard-rock geology.

ERTS imagery has been useful in the field of geology for defining obscured structures and lineaments, differentiating the extent of volcanic formation, and correlating regional fracture zones with volcanism. The imagery was used to assist in the preparation of a structural map of the Central Altiplano at a scale of 1:500,000. Comparisons or over-view analysis of large areas have been facilitated

with ERTS. With ERTS a classification has been developed for mapping volcanic features, lithology, soil moisture, and geologic structure.

A space photomap of the Sucre Region has been prepared at a scale of 1:250,000. The map is preliminary, the first of several such maps which will comprise the first physical map of Bolivia. The application of multispectral scanner imagery to geologic mapping has resulted in the preparation of regional geological maps, studies relative to mining, geomorphological maps, studies relative to petroleum exploration, volcanological maps, and maps of hydrological basins. In agriculture, ERTS images are employed to study land classification and forest mapping.

Eleven thematic maps have been made from an ERTS image of the central sector of western Oruro Province. This thorough natural-resource inventory includes maps, overlays, and detailed interpretations of drainage, hydrology, volcanism, structured geology, physiography, geological mapping, and soil types. As a result of this study, the ERTS-Bolivia Project is processing 9.5 times 9.5 positive transparencies of all Bolivia using Diazo-color techniques on Bands 4, 6, and 7.

The provincial government of Potosi has entered into a contract with GEOBOL to utilize ERTS data for a natural-resource inventory of the province and adjacent areas. Twelve ERTS frames will be used. Ten different types of thematic maps are being considered. The Bolivian ERTS Program estimates approximately a 300-to-1 cost differential between the ERTS-based inventory and that obtained by conventional means. The Provincial Government of La Paz is interested in a similar study. There is a desire to obtain a complete natural-resource inventory of Bolivia. This could be done with ERTS imagery in about 1.5 years, with aircraft coverage and ground checks in 6 years, and without aircraft or ERTS in 25 years (estimate). A 1:1,000,000-scale soil map of the entire nation is expected to be available in about two years as a result of utilizing ERTS and aerial-photography support. Vegetation classification for all Bolivia is underway and should be available in the latter part of the

year at a 1:1,000,000 scale.

Oil-exploration geologists have used ERTS and are enthusiastic about it. Representatives from Total feel they have received more information from a single ERTS frame than from all previous sources of data. The Bolivian Atomic Energy Commission is interested in ERTS for uranium exploration.

The primary needs for ERTS data utilization in Bolivia are (1) trained personnel and (2) equipment to take full advantage of the available information. In Bolivia an effective program at the initial level of capability has been assembled at minimal costs. An ERTS-B proposal has been submitted.

VENEZUELA

The ERTS proposal outlined plans for the development of techniques to investigate and estimate natural resources in remote areas, including geologic structure, landform analysis, lithology, vegetation communities, and grazing lands. Land-use analysis and detailed analysis of urban growth in selected cities would be performed.

Laboratory work has been done for the development of techniques for surveying natural resources. An evaluation of natural resources has been completed for selected areas and thematic maps have been prepared depicting land use, regional structures, hydrology, geology, geomorphology, and coastal pollution. A methodical study has been completed on altitude determination of cloud cover over selected areas. Multispectral-scanner, false-color products have been made. No progress has been reported for the second project.

ECUADOR

The project proposed to undertake broad agricultural, geological, and hydrological mapping which would yield inputs for land management planning. No reports have been received by NASA.

PERU

Peru proposed to evaluate ERTS imagery for an examination of the

hydrological cycle in the Sahte River basin. Specific objectives centered on measurements of snowpack, estimates of the hydrologic potential of lakes, and classification of vegetation as related to ground water. No reports have been submitted to NASA.

GUATEMALA

The Guatemalans proposed to assess the utility of ERTS imagery for updating resource and land-use data. Specific objectives centered on variables in the areas of hydrology, soils, vegetation, and agriculture.

Interpretation of ERTS imagery has enabled the delineation of tectonic structures and the extrapolation of geology to unmapped areas. The cartographic accuracy is reported to be good, resulting in the anticipation of employing ERTS data to update resource maps. Previously mapped vegetation and soil features have been detected. Reports state that the study's progress has been limited by the quality of the imagery. An ERTS-B proposal has been submitted.

COLOMBIA

Proposed uses of ERTS included automatic analysis of multispectral scanner data for thematic mapping, soils, vegetation, land use, surface hydrology, cattle-grazing densities, and grass burns. Comparative studies would examine the benefits of ERTS imagery with conventional air photos and aircraft multispectral scanner images. Automatic mapping techniques were to be developed. ERTS was used to monitor and predict floods and to develop a land-use classification system for flooded areas. The user community considers the program to be in an experimental phase and is not yet substantially involved. An ERTS-B proposal has been submitted.

BRAZIL

Much work has been done in Brazil and the reported progress is impressive. Overlays of the different spectral bands of scenes in the Amazon Region have been prepared. Vegetation, drainage systems, and hydrographic basins have been mapped. Areas of erosion, agricultural

activities, and potential agricultural areas have been identified. The imagery has indicated that bathymetric surveys are possible. Lithology has been identified on a 1:1 million-scale image. ERTS images have been employed to position drainage systems and relief more accurately. Soil resource studies have been conducted. Information on forestry activities has been provided which will be useful in view of the legal regulation in respect to reforestration. Some states are using ERTS data for agricultural statistics and crop forecasts. Steps are being taken to use ERTS in the Ministry of Transport, mainly in the design and construction of the new Perimetral Road.

Imagery is being used as the basis for exploration of barren lands. The use of MSS channels 5 and 7 have enabled the production of elaborate thematic relief charts emphasizing crests, mountain ranges, and table lands. Physiographic diagrams prepared from ERTS images have been applied with favorable results to nautical cartography in coastal zones of difficult access. New morphological charts have been prepared and existing charts have been corrected. Soil maps are being prepared at a 1:250,000 scale through the use of MSS channel 5.

The Brazilian ERTS Data Reception Station at Cuiaba has successfully yielded imagery which appears to be of better quality than that received from NASA. Data was processed at NASA since the facility at Cachoeira Paulista is not yet operational. By the beginning of 1974, $6 million had been spent on hardware for the ERTS program. The running costs of the two stations is in the order of $2 million a year.

The number of users had increased to over 250 by mid-1973, more than twice as many as were identified at the beginning of the year. The goal is to reach over a thousand users by the end of 1974. A measure of the user's interest is the financial support of INPE given by the following collaborating agencies: Ministry of Mines and Energy - $650,000 per year; Ministry of Interior - $370,000; and Ministry of Agriculture - $400,000. The private sector is beginning to get involved. An ERTS-B proposal has been submitted.

ARGENTINA

The Argentines proposed to conduct a natural-resource study, primarily on geology and mining. The primary purpose was to put geological and structural data found in ERTS imagery on conventional 1:50,000-scale maps and to investigate whether or not these structures are related to mineral deposits. The utility of ERTS for agricultural-livestock studies was to be examined. Specific objectives included map-drainage networks, land use and ecological units, soils, and recommendations for management of humid pampas. Crop classification, water-resource management of coastal processes, and models of pattern recognition were to be undertaken.

An informal report indicates that extensive work is underway in the agricultural areas, including the wet pampas. ERTS has enabled crop classification and water-resource management. Models of pattern recognition are being developed. Imagery and computer-compatible tapes (CCT) are being employed for digital classification, and algorithms have been developed. Data-extraction results are being examined and compared for ERTS imagery and CCT.

The Dominguez project has reported only a quick look. No interpretive work has been done. The Garuti project appears to be making good progress, and a formal report to NASA is planned for May.

FAO

FAO proposed to use ERTS for conducting integrated resource surveys in selected areas of Sudan, Philippines, and Colombia. These investigations cover agriculture, geology, forestry, land use, range resources, and hydrology. No reports have been received by NASA. An ERTS-B proposal has been submitted.

2.2 EDUCATION AND TRAINING

AID's Office of Science and Technology has sponsored several international training programs. Some of these, organized by geographic area, are described below. The importance of training to the success of ERTS

investigations cannot be overstated.

ASIA

Several AID training programs have been held in Asia. In early 1973, a Remote Sensing Training Course was jointly sponsored by AID and the Royal Thai government in Thailand. The purpose was to train Thai scientists and resource managers to evaluate and utilize modern remote-sensing techniques, particularly those associated with ERTS and Skylab. The specific disciplines covered included agriculture, forestry, land use (geography/demography/cartography), geology, and hydrology. In all 71 people attended, including 58 Thais and 4 from the Mekong Committee.

The Asian Seminar and Workship on Remote Sensing, sponsored by AID's Office of Science and Technology was held in the Philippines in May, 1973. The aim of the program was to introduce remote-sensing technology to developing countries and to focus specifically on the application of ERTS data to national problems and programs. Fifty-one attendees participated, representing nine countries and one regional organization in Southeast Asia (26 registered participants, 23 registered observers, and 2 unregistered observers). Workshops were held in geology-hydrology, oceanography-fisheries, cartography-land use, and agriculture-forestry. Korea sent 2 representatives, Thailand 2, Indonesia 1, and the Philippines 37.

AFRICA

In April, 1973, a seminar, sponsored by AID's Office of Science and Technology was conducted in Bamako, Mali, for French-speaking countries as part of an international training program. It was very similar to the Asian Seminar. In April, 1974, the East African Seminar and Workshop on Remote Sensing of Resources and Environment, sponsored by AID for three weeks, was held in Nairobi, Kenya, for English-speaking nations. A selected group of 30 African resource and environmental specialists were given instruction in the techniques of extracting resource and environmental data from ERTS and other remotely sensed

imagery. Lectures and laboratory sessions were planned according to the participants' interests and needs.

SOUTH AMERICA

Since 1953, a cartographic school has been sponsored by the Defense Mapping Agency/Inter-American Geodetic Survey (DMA/IAGS). As of 1973, 3,500 attendees had participated in the classes. Over 17 different courses are offered. In 1973, a nine-week course, sponsored by AID's Office of Science and Technology was held in Panama on Remote Sensing Orientation and Applications. Seven weeks of classes were held, one devoted to field exercises and one allocated for a seminar. Since 1953 the following countries have sent the noted numbers of trainees to the school: Argentina, 5; Bolivia, 233; Brazil, 360; Chile, 71; Colombia, 457; Ecuador, 306; Guatemala, 188; and Venezuela, 239.

2.3 OTHER DATA SOURCES

To obtain a better understanding of the 18 candidate countries, pertinent material such as State Department Background Notes, AID reports, and Mineral Trade Notes were reviewed and abstracted. The literature review was followed up by consultation with agency personnel who had direct contact and experience with the nations and their programs. Some of the agencies consulted were AID (African, Asian, and Latin American Bureaus), USGS (foreign geology and training offices), International Bank for Reconstruction and Development, NASA (International Affairs Office and Goddard Space Flight Center), Earth Satellite Corporation, OAD, International Monetary Fund, and U.S. Bureau of Mines.

2.4 SELECTION OF CASE-STUDY COUNTRIES

The data on the 18 developing countries conducting ERTS experiments were collated and analyzed to select four countries for detailed analysis. From the findings on these four countries, we hoped to generalize on the benefits of ERTS-data utilization by all developing countries. Such extrapolation would be possible or plausible only if the selected countries were representative of the others or if key parameters

associated with various aspects of development were bracketed by the case study countries. No unique set of countries could be selected. Rather, care was taken to assure that balanced representation was achieved among these major parameters:

- Geographic location
- Level of economic development
- Type of discipline and functional applications proposed
- Economic significance of applications

Other considerations included facilities for data interpretation and processing, probability of success in current ERTS experiments, government commitment, technical interest and enthusiasm, and probability of obtaining the required data.

The four countries selected were Bolivia, Thailand, Kenya and Botswana. Pertinent data on these countries and their ERTS programs are given in Tables 2 and 3. From inspection of Table 2, one can see that the character of the selected countries varies considerably. The population density and per-capita income varies over a wide range; the economies range from mining, through agriculture, to tourism; ERTS-data extraction capability varies from well-trained indigenous personnel considering the use of computers to expatriate personnel equipped only with light tables; and the geography varies from lowland, humid subtropical characteristics, through desert, to cool, high plateaus. Table 3 shows that the total number of engineers and scientists in these countries ranges from 180 to 10,925.

Since much could be learned from the non-case study countries, letters were sent to the remaining 14 ERTS investigators asking their views on various aspects of their ERTS program and potential benefits. A copy of this questionnaire-letter appears in Appendix I. Responses have been received from Brazil, Colombia, Chile, Korea, Philippines and Venezuela. The data from these responses have been incorporated into our summary of the status of these ERTS projects (see Section 2.1).

TABLE 2. DATA ON FOUR AID CASE-STUDY COUNTRIES

BOLIVIA	
Status:	A middle-group developing country, low population density Population, 4.1 million GNP, $970 million Per capita CNP, $234
Geography:	Cordellera, Altiplano, jungle, pampas
Population:	Latin American and Indian
Economy:	Well-developed mining industry Developing ranching Rural villages
Resource areas*addressed by ERTS study:	G C A L W
ERTS staffing:	PI and co-PIs are indigenous
BOTSWANA	
Status	A lower-group developing country, low population density Population, 0.63 million GNP, $66 million Per Capita GNP, $105
Geography:	Deserts, swampland
Population:	African and European towns, rural villages
Economy:	Good prospects for mining industry Poor agricultural villages
Resource areas* addressed by ERTS study:	G W A R C
ERTS staffing:	PI and co-PIs are expatriates
KENYA	
Status:	A middle-group developing country, low population density Population, 12 million GNP, $1725 million Per capita GNP, $144
Geography	Veldt, rift valleys, coastal belt
Population:	European and African in modern cities Rural villages Migrating cultures
Economy:	Agricultural, stock, commercial
Resource areas* addressed by ERTS study:	A R W
ERTS staffing:	PI and some PIs are indigenous, project manager and most co-PIs are expatriates
THAILAND	
Status:	An upper group developing country high population density Population, 40 million GNP, $7,260 million Per capita GNP, $183
Geography:	Long coastline, deltas, river valleys, forested mountains
Population/ Economy	Agricultural villages, overpopulated cities with manufacturing and commerce, tin mining, fishing, forestry
Resource areas* addressed by ERTS study:	A F O C W G L
ERTS staffing:	PI and co-PIs are indigenous — have had ERTS training course.

*Abbreviations of resource areas:

A - Agricultural	L - Land use
C - Cartography	O - Oceanography
F - Forestry	R - Range
G - Geology	W - Water

TABLE 3. LABOR FORCE IN SCIENCE AND TECHNOLOGY [1]

COUNTRY	YEAR	TOTAL STOCK		NUMBER ENGAGED IN RESEARCH AND EXPERIMENTAL DEVELOPMENT	
		Scientists And Engineers	Technicians	Scientists And Engineers	Technicians
BOTSWANA	1967	180	606	10	6
KENYA	1970	3,000*	8,900	569**	1,034**
BOLIVIA	1967	10,925	12,825	400**	800***
THAILAND	1969	5,583	N.A.****	N.A.****	N.A.****

* Of which 70% are foreigners

** Data are in full-time equivalent.

*** Including auxiliary personnel.

**** Not available.

3

SUMMARIES AND OBSERVATIONS IN CASE-STUDY COUNTRIES

The visits to case-study countries, which involved stays of five to seven days in each, were arranged chiefly through the principal investigators. These visits included in-depth discussions with approximately 25 to 35 persons ranging from scientists, engineers, and technicians to permanent secretaries and deputy cabinet ministers. On-sight observations were made of the ways in which the ERTS data were being utilized, both in terms of information extraction and application of information to the decision process.

It was probably fortuitous that the first visit was to Bolivia where, on a very limited budget, a very active and relatively productive program is underway under the guidance of the principal investigator, Dr. Carlos Brockmann. Dr. Brockmann has approximately six professionals on loan from several user agencies -- Dr. Brockmann himself is on loan from YPFB, the national oil company. He is heading an ERTS program office located within the Geological Survey of Bolivia (GEOBOL). In Bolivia the user participation seems particularly good in that resource scientists from user agencies are participating directly and are in residence in the ERTS program within GEOBOL. In addition, there are two presidential directives which support the ERTS program and specifically direct participation by user agencies. This is an advantage which few other nations can point to with the same degree of clarity. A particularly interesting example of activity within Bolivia has been the production of a complete natural-resource inventory of one particular frame. In this case, approximately 10 thematic maps have been made for this area. In addition, a number of cartographic corrections have been utilized by the IAGS in conjunction with the Institute of Military Geography. Several specific examples of cartographic corrections have been assembled and put into a summary report. It is worth noting that

the Bolivian ERTS program is on the threshold of computer analysis. A professional is being trained at Purdue/LARS, and computer-compatible tapes have been obtained and preparations made for their analysis. The ERTS program in GEOBOL serves as a data center for the entire ERTS program. This provides an effective centralized location for ERTS data, which is made readily available to all users. In summary, the program is well organized and is getting a great deal of return out of a minimal investment. Bolivia has submitted a proposal in the amount of $150,000 to the UNDP for the development of the ERTS program. As of the completion of this final report, we have been informed that this UNDP proposal has been accepted for funding. Additional funding is also being provided by AID. This is very encouraging and should help move the Bolivian program along rapidly.

The potential ERTS-applications areas include: mineral exploration, land utilization, cartography, and geological mapping. An expanding oil exploration now going on highlights the utilization in that area. ERTS data could be of considerable use in cartography for IAGS. Minerals have always been a principal hard-currency earner for Bolivia and it is felt that mineral exploration is a fruitful area for ERTS applications. The question of resettlement is an interesting possibility and requires a careful assessment of the potential of the Altiplano and the lowlands of the country. In its present state, the Altiplano (which has been the traditional center of Bolivian civilization) has difficulty supporting its population. Application of this new source of data may facilitate more efficient land utilization.

The program in Thailand, now headed by Dr. Sanga Sabhasri (Secretary-General, National Research Council of Thailand) has some unique features of its own. These include a considerable reservoir of highly skilled people and a well-developed governmental infrastructure for attacking resource problems. Much work is going on in the making of thematic maps. Both analog and digital work are being done on change detection. There

is some user participation and interest, and computer analysis has been initiated. There are many highly trained and skilled personnel available; however, their activities are somewhat circumscribed by the traditional vertical organization and limits on internal horizontal communications. The structure of the USOM-supported program within Thailand is aimed at improving these communications. For example, the Applied Scientific Research Corporation of Thailand (ASRCT) operates the ERTS Data Center for all Thailand; this tends to have a unifying influence which should begin to improve horizontal communications. The ERTS Coordinator at USOM, Mr. Joseph Morgan, continues to have a very beneficial influence on the entire program.

Potential ERTS-applications areas in Thailand include rice-crop forecasting, geological exploration (including minerals and petroleum), water-resource management, and land-use planning. Rice-crop forecasting has been selected for a case study in this effort since it has already established a decision mechanism, namely the granting of export licenses and the export tax which can be utilized in estimating benefits. Also, a relatively modest improvement in crop-forecasting accuracy may accrue considerable benefits -- right now crop-forecasting errors seem to be significantly higher than those in the United States. The emerging and expanding activity in minerals and petroleum is also of interest, as is the general question of land-use planning and resettlement programs. A very significant activity is water resource management, considering that much of central Thailand is a flood plain. The Mekong Secretariat, which is conducting such a program, is attempting to employ ERTS data in the activity. Much of the current activity is focused on the planning for the large Pa Mong dam.

The African countries represent a somewhat different cultural and political environment within which to examine resource-management decision processes. In particular, it is essential to recognize the relatively short duration of independence of these countries and the

related cultural and political constraints. In Kenya and Botswana, for example, the process of transferring technological expertise from expatriates to indigenous professionals is far from complete. For Kenya the Principal Investigator is Mr. J. Omino, Permanent Secretary, Ministry of Natural Resources. Mr. A.B. Cahusac serves as ERTS Program Coordinator for Mr. Omino. Some limited thematic mapping is going on and some user interest is emerging. However, there seems to be a limited capacity for internal communications. And some organizational improvement, as well as training, will be required in order to realize much of the potential benefits of ERTS-data utilization. Subsequent to our visit, the Survey of Kenya has been given responsibility for the establishment of an ERTS Data Center, which should improve the situation significantly. Some of the potential ERTS-application areas include: grazing and wildlife management, land use, agriculture, water resources, and mineral exploration -- including an emerging petroleum exploration effort. The area selected for the current ERTS-based case study is grazing and wildlife management. This appears to be particularly attractive as a case-study area in view of the fairly well-demonstrated ERTS-supported capability for estimation of biomass and range-carrying capacity. In Kenya, this should be directly applicable to the significant current national problem of allocating grazing and wildlife areas; this must be accomplished with a suitable balance between preservation of traditional cattle raising and the possible enhancement of the tourist industry. The latter now rivals coffee as the largest hard-currency earner for Kenya.

Botswana, which until its independence in 1966 was known as the Bechuanaland Protectorate, has some very promising potential for ERTS-data utilization, which may come as a surprise to an observer on first examining this country and its national needs. The ERTS-1 Principal Investigator is Dr. J. Hepworth, Chief, Geological Survey Department. Some work is being done on thematic maps and cartographic uses. There

is some user participation. Internal communication, while limited, is improving and some consideration is being given to the establishment of an ERTS-data center. There are numerous advantages to the program in Botswana, which include a rather enlightened national view toward planning and the utilization of many different sources of talent. In addition, there is strong indication of a large mineral potential which has hardly been touched. There is also a tremendous fresh-water resource in the Okavanga Delta. It appears that Botswana is on the verge of a significant minerals boom. New sources of diamonds, gold, and copper have been found, and there is room for constructive speculation as to what may be available in what is known as the Kalahari Desert. In addition, a recently initiated UNDP-sponsored study (BOT-2) of the Okavango Delta should be very helpful in determining the best uses of this fresh-water resource for national purposes. The use of ERTS data for improved understanding and management of water resources, with the Okavanga Delta as well as the Mekong as example, is the basis of a non-qualitative case study in the present report. As in Kenya, much of the technological expertise is still in the hands of expatriates, which may present problems in effectively transferring the technology into the national fabric on a long-term basis. The problems of grazing and wildlife management and the potential conflicts between the two are also of interest, particularly in view of the fact that national parks and preserves constitute 17% of the land area of Botswana (the largest percentage of any country). Tourism is growing and is likely to become much more significant in the national economy. A considerable boost in the efficiency of the ERTS program is anticipated when the transition to ERTS-B is accomplished, at which time the principal investigator and most of the users will be co-located in Gaborone.

4

GENERAL EVALUATION OF THE POTENTIAL OF UTILIZING ERTS DATA IN DEVELOPING COUNTRIES

4.1 METHODOLOGY AND CONSIDERATIONS RELEVANT TO DEVELOPING COUNTRIES

In this chapter, we present the methodology used to analyze the contributions of satellite remote sensing to national welfare and, in particular, the relevance of ERTS data to developing countries. The second portion of this chapter presents a brief summary of the individual case studies performed as part of this research; more detailed discussions of these cases are presented as appendices to this report.

4.1.1 METHODOLOGY

Any new investment, whether public or private, must be justified in terms of its returns per unit of outlay. At a minimum, total returns must be greater than total outlays (both discounted). A maximization of net benefits requires that marginal benefits equal marginal costs (i.e., that project size be determined by the incremental costs and benefits). Within a national context, or the context of any diversified investing group, various projects must be compared and the project with the greatest rate of return selected.

Theoretically, in a developed country with a free captial market, all projects with a positive rate of return will be undertaken either by private enterprises or, if benefits are not received directly by the investor, by the government. In a developing country, capital markets are not free; rather, interest rates are constrained and the allocation of funds is restricted. Cost-benefit analyses are required to determine not only the "profitability" of the individual project but also its merit relative to other projects competing for limited funds.

In this study, we look only at the individual project's "profitability" (i.e., the ability of satellite-based information system to yield benefits greater than the incremental costs involved). This

information, in turn, can provide input into the overall national-investment decisions and/or project-level decisions of developing countries.

There are several approaches within a cost-benefit analysis which can be relevant in the study of satellite-based information systems: equal budget/unequal benefits, equal capability/unequal budget, and unequal budget/unequal capability. These are as their names imply: same total expenditure on information but benefits are increased because the quality and/or quantity is greater; quality and quantity of information remain constant but the new system affords cost savings; both quality/quantity of information and expenditure have been affected, presumably with a greater return per unit of expenditure.

Graphically, the output of any information system (or any other productive technology) can be viewed as a function of expenditure with diminishing returns, as pictured by curve S in Figure 4 below. (We assume that the relationship is continuous although, in fact, it may not be.) The curve drawn represents the most efficient expenditure-capability relationships possible (i.e., for any given budget, the maximum capability is that shown by the point on the curve). The curve is called the efficiency frontier. Any point to the right of the curve is inefficient, that is it requires outlays in excess of the minimum necessary to yield that capability.

The choice of a specific information system, a point on the efficiency frontier, is governed by the value of the benefits yielded at each capability level and by any capital constraints existing in that country. If the yield function, or function of benefits associated with each capability level, is that represented by curve AA, then any point on the efficiency curve between a and b is an economically justified system. If the yield function is that represented by curve BB, there is no information system which yields benefits greater than costs. If there is a budget constraint upon information-system costs, such as that

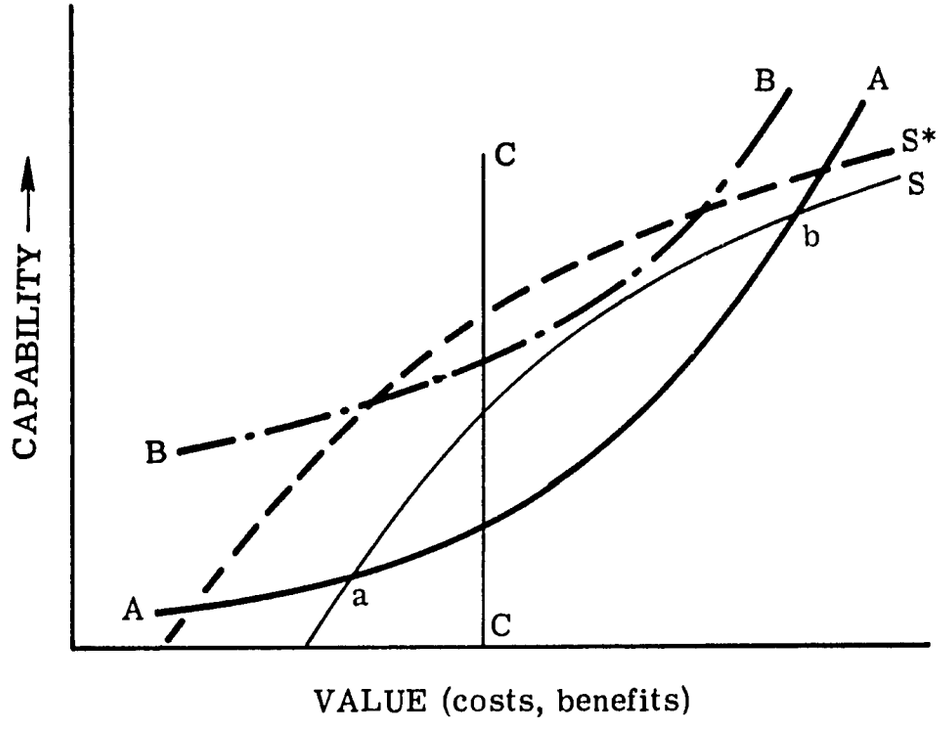

FIGURE 4. ILLUSTRATIVE COST AND BENEFIT CURVES AS A FUNCTION OF CAPABILITY

represented by the vertical line CC, then only systems on the efficiency frontier to the left of CC can be selected -- these systems may or may not be economically justified, depending on the shape and position of the yield curve in that portion of the graph.

Generalizing in broad fashion, one might say that the United States is characterized, at least potentially, by a yield curve similar to AA -- thus information systems have been instituted to supply data of a wide variety to many sectors of the economy. Developing countries, on the other hand, often have information systems of a much narrower scope, either because a capital constraint such as CC exists or because, in many areas, the costs are greater than the expected (discounted) yields.* This can be attributable to a different value placed upon information, a different rate of time discount, higher costs for information systems, etc.

The effect of the increased efficiency in information gathering allowed by satellite-based systems is to move the efficiency frontier to the left (e.g., to the curve S*). That is to say, the new systems using satellite imagery can achieve a given capability level at reduced costs. Whether the next effect is expanded capability with constant outlay or constant capability with reduced outlay, or some point in between, is a function of the position of the yield curve and the country's overall capital constraints and investment analysis.

For example, Figure 5 indicates the net effect of a new or improved information system when the yield curve is that characterized by AA. With the initial information system, characterized by cost curve S, any point between a and b constituted a system in which total (discounted)

*That is to say, the yield curve is similar to BB in its relationship to the cost curve or efficiency frontier. This is not intended to imply that benefits are less than in developed countries, but only that the cost curve is always to the right of the yield curve, whatever the reason -- lower benefits or higher costs for a given capability.

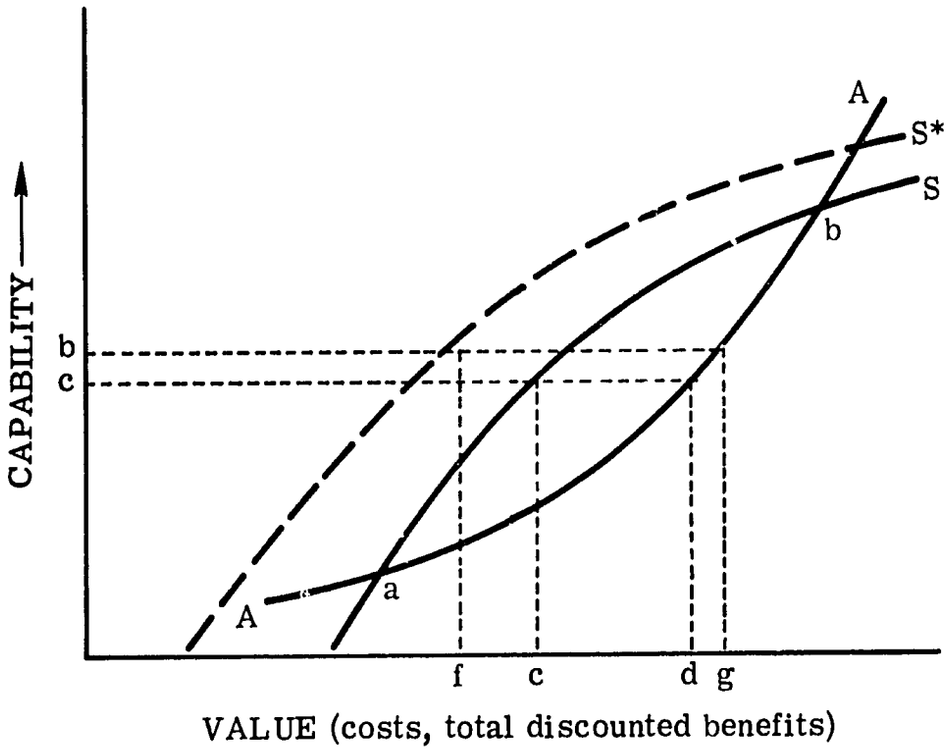

FIGURE 5. TOTAL DISCOUNTED COSTS AND BENEFITS AS A FUNCTION OF CAPABILITY

benefits were greater than total (discounted) costs. A system with capability e would be considered the most "profitable" since marginal costs equal marginal benefits at that point (i.e., the slope of the cost curve equals that of the yield curve), yielding benefits of data cost c. With improved technology, and a shift in the system cost curve to S*, the new optimal system would be that with capability h, at a cost f, and benefits g. Benefits would have increased by dg and costs reduced by fc.

In Figure 6, the situation is more akin to that which might be expected in a number of instances in developing countries (for at least some portions of an information gathering system). With a yield curve of BB and a cost curve of S, the information system under consideration would not be economically justifiable. However, the introduction of new technology and the consequent shifting of the cost curve to S* reduce costs sufficiently so that an information system is justified. The optimal system would be that with capability d, yielding benefits e, at a cost f. Improved technology, therefore, would allow the institution of an information system not previously justifiable. If there is a budgetary constraint of CC, then the system would be restricted to one with a capability of b and concomitant benefits of a. In other situations (other countries or other information systems in the same country), an information system might have been established when costs were higher (i.e., curve S) but expanded in capability when new technology allowed greater capability for the same outlay.

4.1.2 ERTS-DATA USES IN DEVELOPING COUNTRIES

The range of possible information systems is indicated by the breadth of ERTS-data collection and application in the United States. In less developed countries many of the same types of data, such as agricultural acreage, are collected. Since they are based on smaller samples and less extensive coverage, however, they are less accurate.

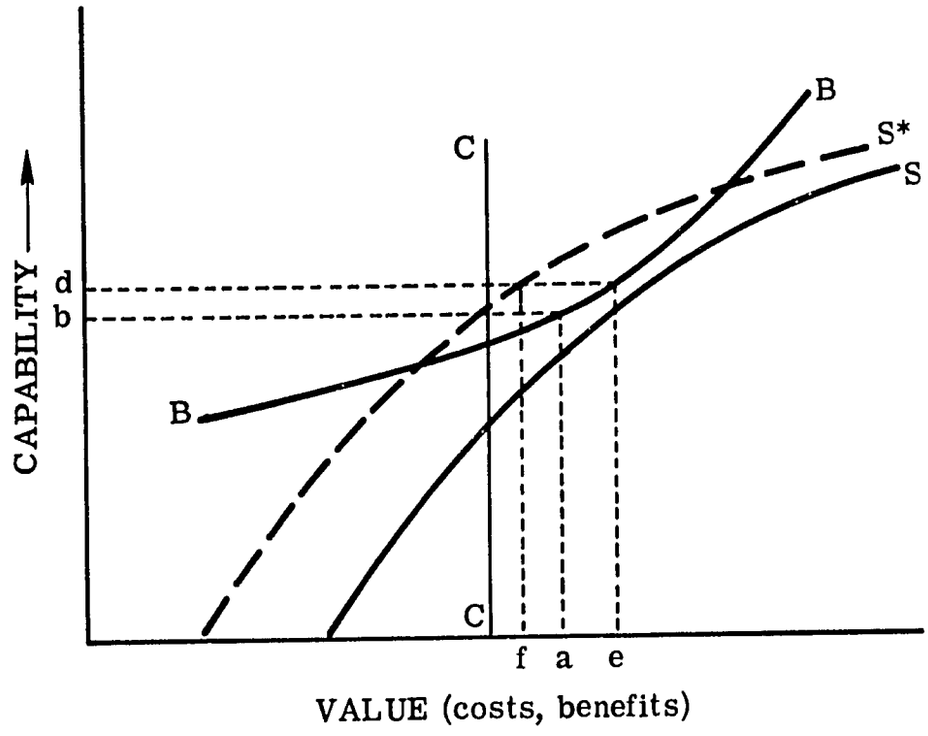

FIGURE 6. EXAMPLE OF AN UNECONOMICAL COST/BENEFIT INFORMATION SYSTEM

Thus, an ERTS data-based capability not sufficiently accurate to provide incremental benefits in the United States may be cost-beneficial in certain developing countries. Moreover, some types of information may not be collected at all, or only on a sporadic basis, in developing countries.

The benefits of ERTS to these countries basically would be in increased accuracy of the types of data already collected and in increased coverage and forms of data. For example, ERTS would permit systematic mapping of geological features rather than the ad-hoc exploration now characteristic in many instances. Current acreage and land-use estimates in developing countries often are based on subjective estimates (e.g., summation of farmer's own subjective estimates of hectares in each type of crop). ERTS would permit in many, but not all cases, objective measurements of total hectares cultivated by crop. ERTS, as part of a general information system, can be used on a recurring or non-recurring basis. Several examples of each are described below.

4.1.2.1 Non-recurring Uses of Satellite Imagery

Non-recurring uses of ERTS would be those in which satellite imagery is used to map features considered to be permanent or changing only gradually. The most obvious are ERTS-based maps of soil type; and geological features.* Clearly, these maps could be updated periodically as new equipment is developed which yields images of higher information content or as these features themselves change slowly over time (or as the result of a natural event such as an earthquake), but images would

*Included in these "non-recurring cases would be a "one-time" seasonal (quarterly) coverage over a single one-year period in order to facilitate proper characterization of these features. An example would be vegetative indications of geological features.

not be needed quarterly or even annually.*

Land-use maps, which would require more frequent updating than many other types, would serve several functions. The data collected would result in a series of maps showing land by use at any given point in time and its change over time. Data on vacant land at a given point in time would indicate total land available for agricultural and recreational uses, perhaps forming the basis for national policies on land use and preservation. Information on forests might aid in the creation or maintenance of sensible policies for the lumber industry. Information collected over time would indicate direction and speed of urban growth (although changes in density would have to be gauged with census sampling). Data on residential location at a given point in time could serve as the first tier in census-sampling designs.

In turn, data from land-use maps would aid in the rational planning of national transportation systems and their expansion. Basic networks could be structured on the basis of the likely flow of people and materials between urban areas, from major producing or raw materials areas to processing areas, etc. Information on land-use changes over time would indicate areas in which expansion of transportation systems may be necessary.

Transportation planning would be aided by ERTS images showing physical land structure and terrain. These data would indicate the

* In truth, there are "degrees" of non-recurring. Annual or quarterly data on crop acreage would clearly be classed as a recurring use of ERTS, but land-use mapping falls into a gray area. Land-use patterns do not change as rapidly as agricultural-cropping or crop-disease patterns. But land-use maps require more frequent updating than many other types of maps such as those charting natural physical characteristics. Since trends in land-use would be discernable and sudden (unpredictable) reversals unlikely on less than a quarterly basis, for purposes of the present analyses we class land-use mapping as a basically non-recurring use of ERTS to distinguish it from those information areas, such as crop-disease monitoring and water management, which may require hourly, weekly, monthly ERTS data.

transportation routes between destinations most suitable for each mode considered (railroad, road, river or ocean, air). Using these data in cost-effectiveness analyses, one could select the mode and route with the least-cost connection between any pair of destinations, modified by knowledge of the modes to be used in adjacent connecting areas. In concept, ERTS data on land-use patterns and trends and on land terrain and structure would permit planners to construct a transportation model which would consider traffic volume and mode-route costs. The subsequent transportation-system design and long-term expansion plan would be more efficient than one built ad hoc based on limited information gathered sporadically.

In this instance, ERTS is more important to developing countries than to developed ones such as the United States because in the latter much more land-use and geological information already exists and transportation systems are for the most part already constructed. Although developing countries could, of course, obtain much of the same information with conventional censuses, land surveys, and the like, the costs (and time delay) may be prohibitive. Thus, in essence, ERTS provides a new information capability.

ERTS can also be used to produce soil-survey maps which indicate soil type, soil moisture, soil permeability, and water availability. These would allow more rational policies in agricultural planning (e.g., to encourage crops in regions particularly suited to those crops and thus have intranational specialization suited to regional environments rather than ad hoc specialization fit for the self sufficiency of each area or unit. In developed countries such as the U.S., the farmers themselves are more commercially oriented, generally aware of soil characteristics and potential, and informed about prices and products. The market mechanism itself can ensure a more efficient crop structure. In developing countries, on the other hand, farmers are generally less aware of new developments, more loath to deviate from

traditional patterns and assume risk, and less aware of soil type and crop compatability. It then falls to the governments of developing countries to investigate crop suitability for particular areas and formulate policies to maximize total output. The Thai government, for instance, has already announced its intention to construct soil-type maps as the basis for policies in agricultural rationalization.

Perhaps one of the most spectacular uses of ERTS is geological mapping as the first stage in mineralogical exploration. Not only can features be seen with ERTS which are not readily visible from aerial photographs, but substantially greater coverage can be obtained. Whereas limited funds restrict current exploration in developing countries to areas already suspected of containing mineral deposits, ERTS would allow systematic mapping of the whole of a country to determine those areas which, initially, appear promising in terms of mineral deposits. These areas, in whole or in part, would then be investigated further and classified by subsequent rounds of testing.

Again, the benefits of ERTS to already developed countries are probably in the form of cost savings since exploration is likely to be undertaken in any case on a fairly systematic basis. But the benefits to developing countries are probably in the form of increased present value of earnings from mineral exploitation. Because of budget and skilled labor constraints often present in these nations, first-stage surveying may be spotty at present. ERTS would allow complete first-stage (satellite) surveying, and this greater coverage would yield a

higher probability of discovery in the present period.* Since discovery and mining operations would be brought forward in time, the discounted total income from mineral exploitation (and processing) would be greater. Not all areas considered likely prospects will be developed commercially if there are capital constraints on investment funds. And not all sites discovered to contain minerals will prove to be commercially profitable at current world prices. But the use of ERTS for comprehensive first-stage surveys will yield a greatly expanded basis from which to select areas for further exploration and commercial development. The effect of ERTS will be either a net increase in mining activity in the present period or, at the very least, a more complete roster of mineral-bearing sites from which to select the most lucrative for development as resources permit.

Furthermore, in addition to the direct income effects of mineral discovery and exploitation, the use of satellite imagery for mineral exploration may indirectly accelerate economic development in developing countries through its impact on trade. These nations are generally short of foreign exchange, and constraints are often placed on the importation of industrial inputs as well as consumer goods. Mineral recovery and processing can be an important source of foreign exchange,

* We assume that, eventually, all mineral deposits would be discovered. However, if the scope of exploration in the present period is restricted by budgetary constraints and not all areas are surveyed, then some potentially profitable mineral deposits are likely to be overlooked and not discovered until some later period, perhaps much later if they are distant from currently known deposits. A complete first-stage survey of geological structures is likely to yield some interesting sites which might otherwise be overlooked. Hence, we feel that more complete first-stage surveys allowed by ERTS will bring the discovery of some deposits forward in time. Although the productivity of any sites so discovered is no different than if they had been undiscovered until a later date, the discounted present value of production is greater by the very nature of the discounting process which penalizes income postponement (assuming constant prices).

either directly through export of products or indirectly through import substitution for mineral products currently supplied by foreign producers. Thus, accelerated discovery and commercial development of mineral deposits could speed economic development through expanded net-import capacity in the current period.

4.1.2.2 Regularly Recurring Uses of ERTS Imagery

In general, we have classified as recurring all those uses of satellite imagery which require data either annually or more frequently. Overall, recurring uses are those which map the results of irregular phenomena such as weather and those dependent on short-term human decisions such as crop types. In less developed countries, the greater proportion of recurring uses of ERTS are likely to be those relating to agriculture and water-resource management.

As was true for non-recurring uses of ERTS, the information gained from recurring uses of ERTS can, at least in principle, for the most part be obtained by other means such as aerial surveys, on-site surveys (complete enumeration or sample surveys), etc. The United States and other developed countries have extensive information systems already in existence and accuracy is generally high. Thus, the impact of ERTS would be primarily in cost-saving and secondarily in improved accuracy. On the other hand, developing countries have less-developed or non-existent systems for reporting agricultural, weather, and water-supply data. Hence, it is expected that the impact of ERTS will be primarily in terms of increased accuracy, which entails a direct effect on the magnitude of benefits from information.

In agriculture, ERTS can be used to indicate total acreage cultivated in a given year and the allocation of that acreage among crops. Crop forecasting can be greatly improved since there are currently only subjective estimates of cultivated area by crop and classification by type. In other words, more accurate acreage estimates from ERTS, first

of all, would yield data on total area under cultivation by crop and method, and second would allow more accurate sampling for on-site unit-yield surveys. The sampling weights would be more accurate overall and sample sites selected would be more representative of the class they represent. If it is firmly established that crop disease can be detected by satellite (together with aircraft-based observations) before it is visually obvious, then counter-measures can be introduced sooner and the disease brought under control at an earlier stage.* Drought effects can similarly be detected, thus indicating to national authorities the need for possible changes in regional irrigation schedules.

Earlier detection of disease and water stress (drought) would impact on the volume of total production since remedial measures could be instituted to reduce losses. More accurate prediction of crop output, on the other hand, would not affect total production, but it would affect consumer welfare directly through the flow of produce to market from inventories and indirectly through government trade policies. More accurate crop predictions would result in a steadier rate of consumption of agricultural produce since pre-harvest consumption rates, affected by forecasts through price responses, would be in line with true production and not based on erroneous crop and price expectations. Steadier rates of consumption yield a higher level of consumer welfare even if total annual consumption is the same.**

* This presumes that the cost of treatment is not prohibitive and that supplies of chemical sprays, sprayers, etc. are available when needed. This is not always the case. In Thailand, for example, detection of orange-leaf virus on rice is apparently of limited remedial value since the periodic sprayings involved are too expensive for the average rice farmer to sustain. However, early detection might aid in containing the virus if, for example, destruction of infested crops inhibits the spread of the virus.

**See Section 4.2.3 below and Appendix B for a more detailed discussion.

Furthermore, with more accurate information on crop output, the government could more accurately chart trade policy. Food import needs would be known with greater accuracy and further in advance, precluding the kind of tragedy stemming from the last severe Indian drought, which was not adequately gauged in advance. With more accurate data on food exports and imports, a government could issue import licenses in line with expected foreign-exchange earnings from the outset of the period without periodic and somewhat erratic changes in the number of licenses granted.

A steadier flow of imports can mean greater welfare for consumers of imported goods and/or a steadier flow of capital and materials for the industrial sector. The latter can be critical in a less developed country, which is characteristically dependent upon imported goods for capital equipment and raw or semi-processed inputs to industry. Erratic import flows require either that scarce capital be used to build large inventories and storage facilities for imported goods (to ensure a steady supply to industry) or that industry periodically work at less than full capacity for want of necessary inputs or parts. Both situations involve an inefficient use of resources which could be alleviated by steadier import flows.

Another potentially important use of ERTS in less developed countries (and developed countries as well) is for range management. With ERTS, it is relatively easy and inexpensive to monitor grazing lands and estimate animal-carrying capacity. Based on this information, herd size can be adjusted to prevailing conditions or, alternatively, supplementary food supplies brought in during periods of short natural supply. In essence, a larger herd could be sustained <u>in good health</u> on a smaller land mass. Of course, aircraft could in principle be used to gather similar information, but the costs are so much greater that it would significantly reduce, if not eliminate, the profitability of grazing-land management. And, too, the necessary investment in airplanes would

be difficult given the overall capital constraints and foreign-exchange shortages. An example of ERTS use in grazing-land management with regard to Kenya is presented below in this chapter and in more detail in Appendix C.

More recurring uses of ERTS can be mentioned only briefly here. ERTS can be used to estimate timber stands and thus prevent overcutting in the lumber industry. It can also be used to gauge the rate of soil erosion and river/harbor silting over time as the basis for judging the effectiveness of remedial measures which may have been undertaken. The aspect of environmental monitoring was performed in Kenya. It was found that agricultural practice along the Tana River in Kenya cause silting and pollution which affect the ocean beaches near the river's mouth. This phenomenon obviously has an adverse impact upon the tourist industry. Water flow and its variation within a given time period (year) can be estimated using ERTS, thus aiding in engineering planning of major hydrological structures. Again, each of these uses of ERTS could, in principle, be satisfied by major aerial and/or ground-information systems. But, since the costs would be high in terms of money and skilled manpower, they would not be instituted in developing countries, which are characteristically short of resources. Thus, introduction of ERTS and its low-cost provision of a broad array of data constitutes a net increase in survey capability, yielding a variety of positive benefits.

4.1.2.3 Other Considerations

The areas in which ERTS data might impact on trade policy and foreign exchange earnings have been mentioned in several places. However, income distribution effects so far has not been discussed. That ERTS will contribute to economic development or total consumer welfare does not guarantee that income distribution will be improved or even that the poorer sectors of society will directly benefit from the use of ERTS. In truth, it is difficult if not impossible to make a broad

statement about the income distribution effects of ERTS since it is critically dependent upon the use of ERTS data and the group in control of that activity.

For example, if ERTS is used to detect crop disease and remedial actions can be instituted (perhaps with government subsidies), then individual farmers will benefit. To the degree that small farmers share in the disease prevention or containment programs, income distribution is improved or at least not made worse than it was previously. However, if only large farmers (latifundia, plantations, etc.) have the resources to undertake remedial actions, then clearly they will be better off as a result of the new information — — small farmers will benefit only to the extent that these actions inhibit the spread of the disease to their farms.

The use of ERTS for crop prediction has similarly ambiguous effects on income distribution. Overall, steadier distribution of produce results in greater consumer welfare, but it also results in a greater total expenditure on food over the period. Thus, there is some income redistribution in favor of inventory holders who commercially distribute the various crops. Some of these inventory holders, however, are small farmers themselves. Furthermore, the increased outlays associated with steadier produce flows may come primarily from richer families who previously purchased a full year's supplies in periods of low prices and made minimal purchases in times of high prices. With prices steadier, these families would no longer be able to reap such gains. Poorer families, on the other hand, unable to stock up on basic foods in low-price periods and therefore forced to restrict other purchases in order to buy food in high-price periods, will be able to maintain (since prices would vary less) a more even allocation of funds between food and nonfood items. With such a consumer-market structure, it is the poorer families, then, who would gain most from ERTS-based forecasts of greater accuracy, which help ensure less erratic produce supply and price patterns.

The distribution of benefits from mineral discoveries spurred by ERTS depends very much on the ownership of the mines, government receipts of royalties from private owners, conditions on capital repatriation by foreign owners, and the volume of local employment generated by the projects. Mining projects can be foreign enclaves with little benefit to the host country. But governments are much more aware of this danger now and, in fact, can use ERTS data (which is not private) to monitor operations of private companies and ensure a greater domestic benefit from mining operations in general.

In short, most cases would have to be analyzed within the context of a particular country and with knowledge of the groups involved in exploitation of the ERTS information. The next section of this chapter summarizes the case studies, which are more specific with regard to ERTS uses in particular areas, analyzed for this report.

4.2 SUMMARIES OF CASE-STUDY AREAS

Five areas were selected for more detailed analysis in this study: mineral exploration, grazing-land management in Kenya, rice-crop prediction in Thailand, water-resource management, and cartographic applications. The attached appendices contain specific descriptions of these analyses as well as discussions of other ERTS-related information areas. Here we present only brief summaries and discussions of these five analyses and conclusions.

4.2.1 ERTS-DATA USE AS AN AID TO MINERAL EXPLORATION IN DEVELOPING COUNTRIES

Mineral-resource revenues are important to the economies of several developing countries, particularly those where terrain or climate limit extensive agriculture. The extractive industries are often major sources of employment and important foreign-exchange earners. Oil, ores, and concentrates may be particularly profitable from the standpoint of hard-currency exchange. In many other developing countries, the minerals

sector could well become economically significant if there were better knowledge of regional geology, concerted efforts in systematic minerals search, and resource-management ability to make the critical decisions and take the actions required in exploration and development. Much of the information needed by management for planning and decision making may be derived from the interpretation of ERTS data.

The discovery of new economic deposits will depend largely on providing exploration geologists with better information on geologic structure, stratigraphic sequence, geomorphic units, and various secondary vegetational or hydrologic clues to obscured structure or lithology. Aircraft and ground surveys are often costly long-term efforts, but ERTS data in many instances may reduce large areas of ground to a number of select locations for further exploration, thereby minimizing the aircraft and ground coverage required. Such use of ERTS, which is a good investment of scarce capital funds, could permit resource agencies to have an earlier and more knowledgable position when dealing with foreign development or exploitation of concessions. The ERTS program provides high-quality multispectral imagery, and because of repetition coverage every 18 days it is usually possible to obtain cloud-free images of geological features and surface characteristics each season. Relatively small geological features may be identified in addition to those so subtly expressed that they may only be discernible as lineaments or domes over one or more images.

The case-study countries provide examples of widely different economic activity related to the minerals industries and a decided difference in the approach of the national geological agencies to making use of ERTS technology. For example, in Bolivia, where the minerals industry is of paramount importance, a notable effort has been undertaken, including the first thorough inventory of national resources made from a single ERTS frame and an experimental regional map (at a 1:250,000 scale) based on ERTS imagery. A photomap of all Bolivia has been

scheduled. The geologist-investigators have located previously obscured structures in the petroleum region and previously unknown lineaments in the tin- and copper-producing areas. In addition, they have correlated volcanic formations with regional fracture zones. Geologic maps and cross sections have been revised and a large number of salars have been properly relocated on geologic maps. Like most developing countries, Bolivia is in need of a broad systematic exploration program for further development of economic mineral reserves to assist planning at many levels. Although computer analysis of tapes and the use of interactive image-enhancement equipment (e.g., a color additive viewer) are generally desirable for obtaining the maximum benefits of ERTS products, Bolivia's successful results so far have been obtained through the use of light tables, manual plotting equipment, and low-cost techniques for enhancing ERTS imagery (color composites with diazochrome). Of particular note are the overlays which have been prepared from several ERTS frames showing the structural geology and lithology associated with known mineralization.

Botswana, with extremely limited water resources and poor geological information, appears to be on the verge of a minerals boom and has rapidly directed efforts toward the maximum exploitation of the geological applications of ERTS. Botswana's geologists are more than capable of identifying the geological-information content of ERTS data pertinent to mapping and surface indicators of structure. As in most of the developing countries, training will be required only in the use of specialized equipment for enhancing different spectral-band products and for relating data in terms of management requirements. Initial studies have confirmed the suggested faulting in the Okavango swamps and have defined further lineations. A major Northeast-Southwest trend has been defined in the Makgadikadi region parallel to the trend of the Ghanzi Ridge to the west. The Archean greenstone belts in northeast Botswana and southwest Rhodesia have been shown to be co-extensive. ERTS imagery suggests that copper- and coal-bearing formations may extend

under the Kalahari desert. Studies are being undertaken to obtain information on the regional structure of the tectono-metamorphic complex of eastern Botswana which could control sites of mineralization. ERTS images are also being examined for information concerning the regional geologic structure of the extension of the Bushveld Basin formations into southeast Botswana. In view of increasing activity in diamonds at Orapa, copper-nickel at Selebi-Pikwe, and intensive exploration in central and eastern Botswana, ERTS technology has ar ived just in time to assist the survey efforts in geological and reconnaissance mapping.

Thailand, a factor in tin mining, has not yet emphasized the potentialities of ERTS to economic geology; however, a worthy methodical mapping program is in progress. Much of the existing geological data on Thailand is out of date, but ERTS could span this gap by providing products orders of magnitude better for determining the broader structures, and with resolution adequate for reconnaissance. Thailand has produced a photomap of the entire country from selected ERTS images and has prepared a geological sketch map at a 1:1,000,000 scale from overlay tracings of the multispectral-scanner mosaic which shows faults, fractures, photolinears of as yet unknown significance, domes, folds, basins, old river channels, and igneous intrusive features. Thailand has been found to have distinctively fractured tectonic provinces which may correlate with mineralogenic provinces. This will be of primary value in indicating areas for further exploration.

In many developing countries a relatively few qualified geologists have been responsible for the entire national effort in minerals development. In Kenya, one such expatriate geologist essentially has been responsible for the investigation into the potentialities of ERTS data. Although Kenya has located only meager mineral resources, there is considerable foreign commercial activity underway in exploring for petroleum reserves. Therefore, the use of ERTS data could be of great current national value in negotiations and implementation programs. Lack of

equipment, deficiencies stemming from limited interpretive capability, and a historical lack of emphasis upon mineral resources have hampered Kenya's ERTS-effort in geology. In spite of the activity by major petroleum companies, the ERTS studies have not addressed this potentially important resource. Specific accomplishments include the revision of the shorelines of Lake Rudolf, identification of changes in the Oma delta since it was last mapped (15 years earlier), and differentiation of certain basement-system metasediments.

Although exploration cost savings are impossible to predict with any accuracy, it is possible to identify those sectors of exploration which will be affected by ERTS data. For example, it has been established that some 17 percent of U.S. oil-exploration costs and some 25 percent of U.S. and Canadian mining-exploration costs are attributable to geological search. It has also been shown that a comparison of thematic and geologic mapping using ERTS products to mapping using conventional aircraft methods indicates efficiency-cost ratios of 1:7 to 1:20 and higher, depending on the type of structure or deposits involved.

The ability to update existing maps or to acquire new high-quality photobase maps from ERTS images with a minimum of expense and field work is in itself a major step for many developing countries. However, the greater benefits will not accrue from exploration-cost savings but through analysis of the data and the taking of timely actions based on the information-content of the imagery. Insofar as ultimate benefits are concerned, it is again impossible to foresee the value of the discoveries, if any, which might accrue. Although the efficiency ratios cannot be reasonably extrapolated to unknown geological problems, it may be noted that in the United States the cost of geological search for oil is about 3 percent of oil-production values, and the cost of geological search by U.S. and Canadian mining industries is equivalent to 4 to 5 percent of mining-industry production values. This does not predict a return on investment, but it does illustrate the possible orders of

magnitude between the inexpensive application of ERTS data and possible large or accelerated benefits.

4.2.2 GRAZING-LAND MANAGEMENT IN KENYA

In modern Kenya, where coffee and tourism vie for first place as foreign-exchange earners, a significant minority of the population still bases its physical and cultural existence upon a nomadic pastoral existence. In centuries past, the populations of cattle and nomadic people were subject to natural ecological checks and balances. Competition with wildlife for forage existed, but it did not present a major problem since the human population was relatively small and veterinary services for cattle were non-existent. As health services for both man and beast became available and as the former colonial rulers began to obstruct natural nomadic migration with political boundaries, the stability of the ecosystem was upset. A population surge of humans led to a surge in heads of cattle, with the result that competition with wildlife for forage resources has become a serious natural problem. As has been true in cases of common grazing grounds throughout the world, the land has been overgrazed resulting in less forage for all competing uses. This shortage of forage resources reduces not only numbers of cattle but also numbers of wildlife, perhaps the mainstay of the tourist industry, which is now Kenya's largest foreign-exchange earner.

ERTS offers many potential benefits to Kenya in resolving or ameliorating the basic cattle-versus-wildlife conflict through improved grazing-land management. Benefits are also anticipated in the areas of water resources and geology. Of course, these benefits do not come free. It has been one purpose of this case study, therefore, to estimate both the benefits and the costs that an operational ERTS-data utilization system might offer to Kenya. Because of the limited nature of the study, attention was paid primarily to the potential of ERTS in grazing-land management. This application is a particularly important one for Kenya, since it embodies important segments of the Kenyan

economy and directly impinges on perhaps the most critical economic issue that Kenya currently confronts, the conflict between wildlife and cattle for scarce forage resources.

Three primary sources of economic benefits from ERTS applications to grazing-land management were identified:

- Cost savings to the forthcoming Kenya/Canadian International Development Agency (CIDA) aircraft monitoring and survey program
- Additional net foreign-exchange earnings from tourism resulting from enhanced game-management practices
- Additional earnings from the cattle and dairy industry stemming from an effective increase in range-carrying capacity.

4.2.2.1 Kenya/CIDA Cost Savings

A program to monitor and survey resources by aircraft will begin in Kenya under Canadian sponsorship in 1975. Kenya will assume financial responsibility in 1979. Expected direct program savings in vegetation monitoring from ERTS are K£ 32,000 per year. Assuming a 20% discount rate, this yields a present value (1979-96) of K£ 91,000 (see Table C-3, Appendix C).

4.2.2.2 Tourism Benefits

By greatly enhancing Kenya's capabilities in grazing and wildlife management, ERTS is expected to increase the effective carrying capacity of the game preserves and parks and their surrounding ecosystems. Since wildlife is the chief attraction of Kenya to tourists, the greater numbers and/or vigor of wildlife is expected to increase tourist amenity and thereby enhance foreign-exchange earnings from tourism. Thus, the benefit is the difference between net earnings from tourism with and without ERTS.

Estimation of this benefit requires the proper description of several important parameters (see discussion in Appendix C) and must be

adjusted to reflect problems of cloud cover and the contributions that the Kenya/CIDA program would make to tourism independent of ERTS. For conservative parameter choices (e.g., historic tourist-expenditure growth rate of 11% — — see Table C-11, Appendix C), the present value of benefits is estimated at K£ 1,900,000 at a 20% discount rate (1977-96).

4.2.2.3 Cattle and Dairy Benefits

By enhancing existing rangeland-management capabilities, ERTS should help increase the effective carrying capacity of the rangelands and thus provide greater revenues through augmented meat and milk production. The same parametric variation of increased carrying capacity used in the tourist-benefits estimation is used here:

Benefits = Earnings with ERTS - Earnings without ERTS

These benefits are also adjusted to account for cloud cover and the Kenya/CIDA aircraft program. For conservative parameter selections (see Table C-15, Appendix C), benefits in this sector are estimated at K£ 760,000 at a 20% discount rate (1977-96).

4.2.2.4 Conclusions

A grazing-land management system based on ERTS appears to offer appreciable economic benefits to Kenya. In addition to providing resource information that should ease the conflict between cattle and wildlife for scarce forage resources, it appears that substantial contributions can be made to the tourist and commercial-ranching sectors. Cost savings in aircraft surveys also seem possible. Assuming a net 5% increase in carrying capacity, a 5% tourist expenditure/carrying-capacity sensitivity, and historical growth rates in tourist expenditures (11%) and in commercial ranching income (10%), ERTS application in Kenya is estimated to have the following present values of future benefits at a 20% discount rate (1977-96):

Discount Rate		Time Horizon 1986	1996
0%	a	0.9	2.0
	b	11.6	98.6
	c	6.4	20.6
	T	18.9	121.2
10%	a	0.4	0.6
	b	4.9	19.7
	c	2.9	5.5
	T	8.2	25.8
20%	a	0.2	0.3
	b	2.2	5.5
	c	1.6	2.2
	T	4.0	8.0

where a = A/C Survey Cost Savings in millions of dollars

b = Tourist Industry Benefits in millions of dollars

c = Ranching Industry Benefits in millions of dollars

T = Total Benefits in millions of dollars

At the lower discount rate of 10%, the total figure becomes $26 million for a 1996 time horizon.

A further clarification of economic benefits will require more information on likely percentage increases in rangeland carrying capacity and tourist-revenue sensitivity to these increases.

The impact on employment of ERTS-data utilization in Kenya appears to be relatively small in both the tourism and cattle-raising sectors.

4.2.3 RICE-CROP PREDICTION IN THAILAND

Once having selected Thailand for analysis of benefits from satellite imagery, it was only logical to focus on the uses of remote sensing in agriculture. Agriculture contributes approximately 30 percent of the Thai GNP and is a primary source of foreign-exchange earnings as well. Within agriculture, rice is the most important single crop, accounting for half of all income from crops (using 1963 prices) and essentially 10 percent of the GNP. Moreover, about 20 percent of the

rice produced is exported (in 1972); these exports contribute nearly 20 percent of all Thai foreign exchange (in 1972).

This study concentrated on the use of satellite imagery for improved accuracy in prediction of rice production. Appendix B presents the background and detailed calculations of our estimates of the benefits which might accrue to Thai nationals and foreign customers from the use of satellite imagery to improve rice-crop forecasting.* Although the evidence gathered is incomplete, it would appear that current predictions of output vary widely with respect to accuracy and, furthermore, do not converge to actual production figures as the forecast period becomes shorter. In fact, when two succeeding forecasts are given, it would appear that one is an overestimate and one an underestimate, thus bracketing the true production tonnage.

Experiments done in the United States indicate that the use of satellite imagery may improve the accuracy of crop forecasts through improved acreage estimations. We would expect that satellite imagery would be used in Thailand first to estimate total acreage sown to rice and second to estimate acreage damaged and thus not likely to be harvested. Since the yields differ for the two major types of rice grown in Thailand, floating and transplant rice, it is important to note that satellite imagery can be used to estimate the acreage in each type separately.** With more accurate estimates of the acreage sown and damaged in each of the two types and of current yields (either obtained on-

* Throughout this discussion, it is assumed that all interested parties had and have equal access to the same forecast data both before and after the introduction of satellite-based systems.

**In brief, the process would require first that all rice-growing areas be delineated and then that the floating be distinguished from the transplant rice by identification of field shapes. Transplant rice is grown in paddies with regular and well-defined dikes or walls; floating rice is grown in naturally flooded areas without regularly shaped walls. Transplant rice has a yield approximately double that of floating rice.

site through yield sampling or statistically with the use of a weather-yield model), more accurate forecasts of total output could be obtained.

A simple demand model was used to estimate the benefits which might be associated with an improved forecasting accuracy. The model assumes that rates of inventory depletion and hence consumption are closely linked to forecasts of production and that erroneous forecasts cause depletion rates to vary about the rate appropriate to true production levels — — this is a critical assumption which is not universally accepted. The basic tenet of the model is that a steady rate of inventory depletion or supply (of rice) to consumers yields a greater consumer welfare than an erratic supply which is alternately above and below that rate of inventory depletion commensurate with production. The more erroneous the forecast, the greater is assumed to be the deviation about "justified" depletion rates since depletion prior to harvest is adjusted to forecasts and after harvests to true production. Additionally, the model assumes that the post-harvest period involves not only an adjustment to true production but also an adjustment to compensate for the pre-harvest errors in rates of depletion.

The model as originally presented by Hayami and Peterson[2] dealt with an economy closed to trade. In Thailand, however, a great proportion of rice output is exported; thus the model had to be adapted to the Thai case. The benefits to foreign consumers are the same as those welfare benefits described by Hayami and Peterson: increased consumer welfare resulting from a more even flow of total supply as forecasts of the available total supply deviate to a lesser degree about true value. However, to the degree that the errors in Thai forecasting offset errors in forecasting the rest of the supply, improved Thai accuracy results just in larger total errors for the foreign submarket area analyzed. In other words, if Thai forecasts err in the opposite direction from the forecasts of the rest of the supply to the area, improved forecasting in

Thailand and, hence, a steadier rate of export supply* can actually result in negative benefits or disbenefits associated with a satellite system. In all likelihood, errors would be of the same sign in some years and opposite sign in others; thus the net effect would be positive benefits over time. The magnitudes cannot be calculated precisely, however, without more precise assumptions as to value and direction of forecast errors for the two components of supply (Thai and all other) in the foreign markets.

The magnitude of benefits accruing to Thai consumers depends upon the degree to which the Thai government can ensure a steady flow of rice domestically in spite of variations in foreign prices and production forecasts. If the Thai government were able to guarantee a steady domestic supply at some given (predetermined) rate, then any fluctuations in supply resulting from forecasts would be totally absorbed by the export market. But data indicates that the supply varies domestically as well as internationally; thus it seems reasonable to assume that to the degree that forecasts affect rates of inventory depletion, the rate of domestic supply is influenced.

The assumptions of the model and the equations used are presented in Appendix B. The critical assumptions are those relating to the rate of inventory depletion (i.e., that inventory holders believe crop forecasts and immediately adjust inventory depletion rates to accord with

* The impact of Thai forecast errors on exports is through government use of forecasts to control exports. Logically, an underestimate of production would lead to the government's granting fewer export licenses than might otherwise be granted, with a subsequent compensatory "dumping" of rice exports after true production is known. (The effect of the rice premium would be similar if the rice premium, export tax, were changed each time foreign prices were altered. We feel that the primary determinant of exports is probably the availability of export licenses rather than the free-market response to the level of export premium on rice.)

them and that they compensate in full during the post-harvest period for any errors made in depletion rates in the pre-harvest period). Implicit in these is the assumption that demand for Thai rice is strong (i.e., that there is no glut).

Given the assumptions used in the analysis, welfare benefits accruing to both foreign and domestic consumers of Thai rice are (1) proportional to the equilibrium price of rice (associated with the true production quantity), (2) positively related to the reduction in forecast error, and (3) inversely related to the price elasticity of demand for rice and the proportion of the year during which the rate of inventory depletion or supply deviates from the rate appropriate to true production.* The greater the proportion of supply fluctuation absorbed by the export market, the less the benefits received domestically.** In essence, a "pool" of total welfare benefits is divided between the foreign and domestic markets, although these total benefits are partially a function of the allocation of supply variations between the two markets.

* It should be noted that neither Hayami and Peterson nor the Earth Satellite Corporation took time periods into account in calculating benefits. Because of this, they confuse quantities actually sold in a given time period (which is a portion of a year) with annualized rates of sale. As such, their estimates of benefits are a multiple of the true figures. See Appendix B for a more detailed discussion.

** A caveat must be inserted here. The above discussion is in terms of welfare benefits accruing directly to consumers of Thai rice. Welfare benefits received by domestic rice consumers are less if there is a lesser initial (pre-satellite system) fluctuation in supply about normative supply absorbed by the domestic market. However, there is a domestic counterpart to the benefits received by foreign consumers which has not been explored in this study because of data limitations. More explicitly, if import policy is determined in part by expectations of export earnings, then more accurate predictions and a steadier flow of foreign-exchange earnings may result in a steadier flow of imports which would yield welfare benefits to consumers of imported goods. It may also impact on Thai domestic productivity if imports of raw and intermediate materials are affected.

Calculations were performed for several assumed values of forecast error, both before and after implementation of a satellite-based information system, as well as for several values for price elasticity of demand and allocation of supply variation or deviation between the two markets. The estimates of benefits similarly ranged widely, from several hundred thousand dollars (U.S.) annually to tens of millions. The full sets of estimates are presented in Appendix B.

Table 4, a condensation of data found in Appendix B, indicates welfare benefits to be expected for several of the parameter values assumed. The total benefits accruing to Thai domestic consumers could range from $1.2 million to 48.6 million (U.S.) annually. The greater the proportion of variation absorbed by the export market, the fewer the domestic welfare benefits to be expected. Table 5 shows present values of benefits only, based on a 1977-1996 time horizon and a 20% social rate of discount.

In general, it is clear that the annual welfare benefits attributable to improved forecast accuracy (which is manifested in reduced variation in rates of rice supply about true production-based rates of supply) could be substantial. Although foreign benefits are expected, if the Thais are to pay for the information system, then the nationally received benefits alone must pay for the costs. Thailand is surely not interested in financing a system which can be justified only in terms of benefits received externally. Given our calculations, the satellite-based information system can probably be justified on the basis of domestic (internal) welfare benefits alone.

On the other hand, there is an additional factor to be considered from the Thai national point of view. Assuming a basically inelastic foreign demand for Thai rice, a steadier rate of rice export could result in greater Thai foreign-exchange earnings depending on forecast error signs and rates. (See Appendix B for a more detailed discussion.) However, this is not a net gain in global welfare but, rather, a

TABLE 4. ANNUAL BENEFITS TO THAI CONSUMERS FROM IMPROVED RICE-PRODUCTION FORECASTS ($ U.S. MILLIONS)

FORECASTING ERRORS FOR THAI RICE		PROPORTION OF VARIATION (DEVIATION) IN SUPPLY ABSORBED BY EXPORT MARKET (V)			
		V = 0.20		V = 0.50	
		PRICE ELASTICITY OF DEMAND (α)		PRICE ELASTICITY OF DEMAND (α)	
		α = 0.1	α = 0.5	α = 0.1	α = 0.5
Current	Improved				
0.15	0.05	44	9	17	3
	0.02	49	10	19	3
0.10	0.05	32	3	6	1
	0.02	41	4	8	2

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TABLE 5. PRESENT VALUE OF ERTS BENEFITS TO THAI CONSUMERS FROM IMPROVED RICE-CROP PREDICTION*
($ U.S. MILLIONS)

FORECASTING ERRORS FOR THAI RICE		PROPORTION OF VARIATION (DEVIATION) IN SUPPLY ABSORBED BY EXPORT MARKET (V)			
		V = 0.20		V = 0.50	
		PRICE ELASTICITY OF DEMAND (α)		PRICE ELASTICITY OF DEMAND (α)	
		α = 0.1	α = 0.5	α = 0.1	α = 0.5
Current	Improved				
0.15	0.05	124	25	43	10
	0.02	137	27	53	11
0.10	0.05	91	9	18	4
	0.02	116	12	23	5

*FOR THE PERIOD 1977-1996; DISCOUNT RATE OF 20%

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transfer of foreign assets from net-importing to net-exporting countries

4.2.4 WATER MANAGEMENT (MEKONG, OKAVANGO)

Predicting, managing, and understanding water resources at appropriate time and space scales is the hydrologist's basic goal. Enough water of sufficient quality should be provided at lowest costs to places when it is needed and economically justifiable. The detrimental effects of man-made or natural events (such as water pollution or floods) upon the hydrological cycle must be studied and controlled.

As is true in most systems, proper interpretations among individual components of the hydrological environment are more important than understanding each component separately. Characteristics which must be correlated include surficial deposits, geological landforms, regional physiographic settings, local topography and hydrology, and vegetative and land-use features. ERTS imagery can be employed for useful interpretations of many of these elements as well as for synoptic observation of complete watersheds. ERTS can provide interpretable data on extent, distribution and length of river channels, location, size and shape of lakes that act as water reservoirs and evaporation sources, type and extent of vegetation, and geologic features that govern the occurrence, movement, and storage of ground water.

ERTS MSS bands 6 and 7 provide the maximum image contrast between water-land boundaries. Band 4 allows discrimination of bottom features in water a few meters or tens of meters deep. The ERTS Data Collection System (DCS) facilitates the determination of water levels. Combined DCS and tape data should provide water-volume estimates as a key output of information-gathering systems.

ERTS imagery has been employed in a vast array of hydrological applications. Many of these applications center on problems that are similar to those in developing countries and should be viewed as exemplary models. An excellent example is the strikingly successful

application of ERTS to the mapping of flood-inundated areas in the United States. Areas, including high-water patterns, have been successfully mapped seven to twelve days after the event because of the persistence of inundation-related reflectance changes on terrain features. Graphic comparisons between low flow and the areal extent of flood inundation facilates rapid assessments of the areas of flood damage. The regional effectiveness of flood-control structures may be assessed. General areas where significant changes in the course of the river may require dredging and other construction may be determined.

Such techniques could be and are being successfully applied to water-resources planning in the Lower Mekong Basin. The Committee for Coordination of Investigations of the Lower Mekong Basin is concerned with promoting, coordinating, supervising, and controlling the planning and investigation of water-resources development projects in the Lower Mekong Basin. Because the present data base in incomplete, ERTS could be used effectively as an information-gathering system. W.J. Van Liere of the Committee states that the whole project has been reshaped by the influence of ERTS data, which presents a better picture of how flooding and drainage occur in the basin. The repetitive coverage of ERTS has prompted insights into the transformation of changing features such as the extent of flooding, moisture retention in various soil types, and sedimentation of the reservoirs and floodplains. ERTS has improved the understanding of the patterns of natural flooding, as well as natural drainage, through the rainy season. As a result, the dynamic properties of drainage basins can be better described. Thus, ERTS has provided new and invaluable tools for flood-control analysis for the Mekong Committee's flood-forecasting program and for the design of agricultural policies in the flood zone.

An accurate, timely, quantitative water-resources data base for Botswana, a nation plagued by insufficient water, is of high importance. The Okavango River is the only perenially flowing river in the nation.

Several developmental prospects stem from diverting water from the Okavango River and Delta. However, the government is vitally concerned with assessing the ecological balance of the Delta areas in hope of obviating any deleterious effects should water be diverted from the basin. ERTS data has been a source of input for some studies in the area. ERTS data will be an important input to the recently initiated UNDP-sponsored BOT-2 project to define the water resources of the Okavango. The enhanced dynamic change-detection capability of ERTS would be a valuable tool with which to monitor the effects of any developmental changes upon the Delta area. A more extensive gauging network is needed for the Okavango -- data from this network could be utilized in a newly developed mathematical forecasting model. The DCS system could facilitate expanding and improving this gauging network. The Department of Geological Survey plans to produce accurate and detailed maps of all the underground water resources of the nation. ERTS has been used to interpret ground-water data in both the United States and Mali.

In both these cases, where flooding is a phenomenon with far-reaching consequences, the economic value of ERTS imagery and data should be high. Both the Mekong Committee and Botswana have submitted ERTS-B proposals which testify to their interest in the hydrologic applications of ERTS.

4.2.5 CARTOGRAPHIC APPLICATIONS

The discipline of cartography is concerned with the collection and analysis of data and measurements of various patterns of the earth. These data are graphically represented on such a reduced scale that the patterns can be made clearly visible. Until a whole nation is sufficiently mapped, continual waste occurs because special surveys are made for special purposes and scarce resources are inefficiently allocated.

Five phases have been identified in geographic data handling: data specification, data acquisition, data-storage retrieval and manipulation, data dissemination, and data applications. ERTS, as a data-gathering system, greatly reduces the effort which must be expended in these phases. The acquisition phase is eliminated when lesser developed countries receive the data. Because of the synoptic nature of ERTS and its wide field of view, the third stage is greatly simplified. Each ERTS frame contains a vast amount of information that by conventional means could be provided only with many frames at larger scales. In addition, the interdisciplinary nature of ERTS data could promote cooperation across disciplines which could enhance data dissemination and data applications.

There are four levels of survey sequence, ranging from low to high detail: exploratory, reconnaissance, semi-detailed, and detailed. The level at which the survey will be carried out is dependent on the amount of both existing information and required information. There should be attempts to make the surveys integrated and multidisciplinary. This serves a twofold purpose: economy in data collection and analysis resulting from investigating several items at one time, and promotion of a holistic view of the natural environment. However, one finds that low-detailed surveys tend to be more integrated in nature than high-detailed surveys, which are often designed to meet specialized requirements. Thus, in lesser developed nations (where economic resources are limited), ERTS can be used as a tool with which to conduct exploratory and reconnaissance surveys. A well-planned, efficiently constructed geographical-data base is critically important to a developing nation. In a lesser developed nation, where limited resources must be carefully proportioned among vying programs, an unwise allocation could adversely impact the economy to a much greater degree than in a developed nation, where the diversified economy would more easily absorb the loss.

The use of imagery from ERTS might effectively reduce the budget required to develop a geographic-data base. ERTS imagery offers certain

unique advantages over conventional methods for collecting geographical data. Numerous applications of the imagery in the field of cartography are being studied. Imagery can be electronically transmitted without serious distortion. Cartographic products from ERTS may be obtained in near real time, within two weeks after image acquisition by ERTS. ERTS imagery is orthophotographic. ERTS repetitive capability permits the monitoring of dynamic changes. ERTS imagery is ideal for small-scale mapping because of orthographic projection and uniform illumination throughout the scene which yields meaningful color and tone gradients. Each ERTS frame covers a large ground area allowing a synoptic view which provides instant generalization. The advantages offered by ERTS allow series of photomap products to be produced in a fraction of the time required by conventional methods, and at a cost which permits frequent new editions.

In terms of mapping, ERTS has exceeded expectations. Image quality products (MSS-bulk) have been produced up to at least the 1:250,000 scale. Mapping with the ERTS MSS is geometrically limited by National Mapping Accuracy Standards (NMAS) to a scale of 1:1,000,000 or perhaps 1:500,000. Geometric accuracy may be improved, without degrading image quality, by applying corrections based on ground control. Investigations have shown that ERTS imagery can be used for cartographic photobase products at scales of 1:500,000 and smaller. The imagery is useful for assessing the need for revision of features on large-scale maps (1:24,000), as well as for detecting change and positioning gross features on medium- and small-scale maps (1:250,000 or 1:1,000,000).

Lesser developed nations are rapidly becoming aware of the importance of mapping for planned development and economic growth. Botswana, for example, embarked on a national mapping program. In terms of cost, a national mapping program at a scale of 1:50,000 would be expensive and wasteful. Over three quarters of the required map sheets would cover areas that are relatively barren or not intensively used. ERTS

could provide a low-cost substitute for these maps. Botswana's ERTS-B proposal reflects an increased awareness of the cartographic value of ERTS. An elemental photomap of undeveloped areas at a scale of 1:250,000 will be produced for use in their current program of mineral exploration.

Much of Bolivia remains unmapped and uncovered by aerial photography, as is the case in many of her Latin American neighbors. The Bolivians have concluded that precision ERTS images can be used in producing a small-scale cartographic map of the whole country. The imagery could be used for making much needed land-use maps of the nation. Without ERTS, this task would take eight to ten years, with ERTS two years. A complete natural-resource inventory of Bolivia could be completed in one and one-half years with ERTS, six years with ERTS aircraft and ground checks, and twenty-five years without ERTS. ERTS could be used as an auxiliary tool for choosing corridors as the Bolivians expand their transportation system. Such a project is currently underway in Alaska — — ERTS is being used to help select a utility corridor.

Because many lesser developed nations are still in the project stage of development, an improved data base can lead to better formulated policies and decision. The multidisciplinary nature of ERTS allows many disciplines and functions to be served in unison and can promote cooperation and communication among various branches of government. ERTS can be used cost-effectively for accelerating national mapping programs. It can also serve as a vehicle for strengthening communications between the technical community and government officials who are responsible for agriculture, hydrology, energy, natural resources, transportation, health, and land-use planning.

5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 SUMMARY

The utilization of ERTS data in 18 developing countries has been reviewed and evaluated. This overall assessment is supported by more detailed economic evaluations in four selected countries. While organizational and technical progress varies widely, it seems clear that substantial benefits can accrue to these countries in crop forecasting, range management, mineral exploration, water-resources management, cartographic mapping, and rural/regional development. The accrual of these benefits can be achieved, at acceptably low costs, provided that appropriately timed and scaled technical assistance (including training in ERTS-data interpretation and application to management decision processes) is provided to the individuals and institutions involved with ERTS-data utilization in each country.

While the ERTS system is one of the more sophisticated current technological developments, ERTS-data utilization does not necessarily require high technology or expensive equipment. To be sure, sophisticated processing of ERTS data can yield information not obtainable with simple interpretive techniques. But to a developing country which has no large, organized, geographical-resource data base and which probably has significant relatively inaccessible regions, ERTS can provide this information for at least an order of magnitude lower cost compared to conventional techniques. This is not to say, however, that ERTS data can be utilized by developing countries without some investment on their part. In some ways, ERTS imagery can be considered to have evolved from panchromatic aerial photography. ERTS imagery is multi-band, covers a large area, has a uniform sun/view-angle relationship, and is a near orthoprojection (photo map). To take full advantage of ERTS data, the

resource-trained user must have some orientation in aerial photointerpretation and should have training in the differences between ERTS scanner imagery and conventional aerial photography.

The agricultural sector is of paramount importance in most developing nations. For those which produce a significant portion of their own crop needs, timely information on their anticipated crop yields can provide economic and social benefits to their own consumers. Since estimates of "foreign" benefits and foreign-exchange earnings are much more sensitive to assumptions and parametric values, positive benefits to the country concerned are less certain.

In the case study of rice-crop forecasts for Thailand, the interpreted imagery could be used for more accurate estimation of total acreage, patterns, and intensity of cultivation. From this information, more precise estimation of the allocation of total rice acreage among the three principal types of cultivation would be possible. Furthermore, a more accurate production-unit identification and description would permit more efficient statistical stratification for on-site sampling, and hence, more accurate crop prediction. The model that was employed for this analysis postulates that consumer welfare losses occur as a result of inaccurate crop forecasts and that these losses can be reduced with more accurate forecasts. For reasonably conservative ranges of parameters, the annual benefits to Thai consumers were found to vary from about $1 million annually up to $49 million. Since the lower number is based on a relatively high-price elasticity for an essential food staple, it seems reasonable to suggest that annual benefits on the order of tens of millions may be anticipated. In terms of total present value of benefits over a 20 year period, at a 20% discount rate, an amount on the order of $100 million seems plausible. It may also be argued that these consumer welfare benefits accrue most effectively to lower-income groups who cannot take advantage of prevalent price fluctuations by stocking up on commodities when prices are low.

Rangeland is also a key resource in most developing countries. In the case study of rangeland management for Kenya, economic benefits from ERTS data are attributed to more accurate estimation of biomass and animal-carrying capacity which permits more efficient allocation of the biomass for grazing of domestic and wild animals. The result is an increase in the effective carrying capacity of those rangelands. Cattle and wildlife are the major source of local income. Cattle are raised as a "cash crop" by commercial interests and as "a way of life" by indigenous subcultures such as the Masai and other nomadic tribes, who for the most part do not enter into the market economy. Wildlife, which is the major attraction for tourism (which competes with coffee as the number one foreign-exchange earner) in Kenya, also requires large amounts of rangeland. It is likely that ERTS imagery could be very useful for the development and implementation of a rangeland-management model that would maximize returns from the cattle and tourism industries while setting aside sufficient land for such groups as the Masai. For this grazing-land-management analysis and historical industry growth rates, the total present value of benefits (20 years, 20% discount rate) was estimated to be about $8 million. It is interesting to note that if a 10% social discount rate is used, the benefit figure becomes about $26 million. A conservative approach would probably suggest the use of the higher discount rate and, hence, the lower benefit figure.

Economic benefits from ERTS applications in minerals exploration are expected from three sources: (1) reduced costs, (2) increased likelihood of discovery, and (3) earlier realization of the net income from mining (as a result of reduced exploration time). Using ERTS-1 imagery, it is possible to produce low-cost regional geological base maps which are a necessary input to minerals exploration. It is also expected that information extracted from the imagery can substitute for higher-priced information provided by conventional methods. It is to be emphasized that this may not be the same information - which makes a cost effective-

ness comparison difficult - and that the information may facilitate a modified approach to minerals exploration, but the result is likely to be lower-cost discoveries. Because of the technical attributes of ERTS imagery, information also can be extracted which simply cannot be acquired by conventional methods. This information, combined with what is already known, will increase the efficiency of exploration by raising the likelihood that a given amount of funds will result in a find.

If the information extracted from ERTS data serves as a substitute for conventionally acquired information, and in doing so reduces the time as well as the cost of exploration, then additional economic benefits will be realized. This derives from the fact that the economic value of the net revenue from mining operations depends upon when (in time) it is received; and if it is a correct assumption that reducing the exploration period will reduce the time lag for accruing net income, then ERTS imagery will yield benefits because of this attribute.

For mineral exploration, therefore, the principal advantages of ERTS-data utilization appear to be in earlier, more complete, and less costly regional geological mapping which impacts the earlier phases of mineral exploration. Examples, particularly in Bolivia and Botswana, have been reviewed. In Bolivia, for example, significant new geological, geomorphological, and tectonic mapping have been accomplished from ERTS imagery using simple manual techniques (e.g., light tables and diazochrome color composites).[3]

In Brazil, a comparison of ERTS-1 and side-looking radar (SLAR) imagery for small-scale geological mapping and mineral exploration in the Amazon region indicates the superiority of ERTS-1 imagery. The ERTS imagery provides a similar amount of structural information as SLAR, but it contains a larger amount of lithological (rock type) information. In addition the acquisition and processing of ERTS imagery is less costly by a factor of over 30:1.[4]

Obtaining and ensuring sufficient water both for agriculture and human consumption are problems common to many developing nations. Two significant examples of ERTS-data potential for water-resource management in Botswana (Okavango Delta) and Thailand (Mekong Basin) have been reviewed. In both cases, capabilities for the synoptic, repetitive delineation of water-land boundaries, vegetation, and sedimentation are of key importance. In Botswana, repetitive ERTS imagery of the Okavango Delta could provide a major input to the ongoing, UNDP-sponsored, BOT-2 study. The ERTS data would serve as input into a newly developed mathematical forecasting model for the Okavango. The results of this analysis could have major impact on national decisions in the agricultural, ranching, and mining sectors. The Mekong Secretariat staff feels that ERTS data, by providing a better overall picture of drainage and flooding in the Mekong Basin, has reshaped the whole project approach. The selection, prioritization, and location of tanks (small dams), as well as direct planning for the large Pa Mong dam, would result in significant benefits.

Cartographic applications have been reviewed principally in Bolivia and Botswana. ERTS imagery is expected to make significant contributions to the national mapping programs in these two countries, particularly because they contain extensive regions of difficult and inaccesible terrain. In Bolivia, ERTS imagery has already been utilized to revise the 1973 edition of the national map (1:1,000,000) and provide a complete natural-resource inventory for one particular frame. It has been estimated that a complete natural-resource inventory of Bolivia could be completed in 1-1/2 years with ERTS - in 6 to 25 years without ERTS. Cost-savings ratios on the order of 100:1 have been estimated in the Bolivian ERTS program. National mapping standards can readily be met up to a 1:500,000 scale. Useful map-line products can be made up to 1:250,000. In Botswana, for example, the interior of relatively crudely mapped and ERTS data is planned for utilization in a 1:250,000-mapping

program for the undeveloped areas, some of which might have significant mineral potential. The expense of doing this without ERTS data is considered prohibitive by the Botswana Government. In Brazil, ERTS imagery has provided map revisions for the Amazon Basin.

While not specifically examined in this scope-limited study, the applications described above lead logically to the information base necessary for effective rural and regional development. Maps of soils, vegetation, drainage, and geological structure, as well as delineation of transient and permanent water bodies, provide essential information for actual and potential land-use determination. Desirable transportation corridors can be located. Demographic inferences have also been made by some investigators.[5] ERTS-type data provides a rapid and economical means for obtaining this essential type of planning data, particularly for unknown or inaccessible regions.[3]

Another significant aspect of ERTS-data utilization is that it provides decision makers with an overall synoptic view of large sub-national areas in essentially non-technical terms. The imagery provides nearly self-defining visual demonstrations of the effects of drought, flooding, fires, overgrazing, and desertification. The imagery also in Niger dramatically demonstrates the vast difference between the effects of planned (and fenced) ranching and the effects of overgrazing resulting from unplanned, nomadic grazing.[6] This type of self-defining visual demonstration, which is readily understood by non-technical personnel, can serve to strengthen the communication links between the technological community and decision-making government officials. This can be of particular significance in developing nations with modest or fragile scientific and governmental infrastructures.

5.2 CONCLUSIONS

Based on a limited sample of countries and case studies, several general conclusions become evident - it should be emphasized that many of these conclusions could apply to all countries using ERTS data.

(1) A potential exists for significant economic benefits from ERTS-data utilization by developing nations. In some few cases benefits are already being realized, although these are relatively minor at this time. The actual magnitude of the potential benefits depends, of course, upon the economic and social circumstances in each country. While the case studies have indicated potential benefits from certain applications, these benefits should not be simply projected or imputed to similar applications in other user countries. These case studies are essentially illustrative in nature.

(2) Significant amounts of information may be extracted from ERTS imagery by using relatively low-cost interpretive techniques. This does not necessarily imply that the more advanced techniques may not be justified on the basis of benefit/cost criteria.

(3) A basic ERTS program would be a highly cost-effective means for obtaining the resource information needed to achieve the benefit potential. A basic ERTS program would require an ERTS-data center for storage, retrieval, and distribution of ERTS data, light tables with magnifiers, a diazochrome color-composite capability, and resource sceintists trained in ERTS-data interpretation (see Appendix H). An investment beyond this minimum capability must be evaluated on the merits of each country's needs and potential benefits from ERTS-data utilization.

(4) For a country with more than one application area for ERTS data, a centralized ERTS-data center, preferably with government backing, is desirable. There is, of course, a trade-off between centralization to achieve the greatest impact with scarce resources and decentralization to ensure effective participation by mission-oriented agencies. Generally, in the early stages of ERTS-data utilization in countries with limited organizational

infrastructure in resource management, a centralized center appears crucial; as the national resource-management infrastructure matures, more decentralization is advantageous.

(5) Information obtained from ERTS data has no economic value unless it is used to make earlier or improved decision . Thus, it is important that ERTS projects be conducted in support of, and with the cooperation of, mission-oriented user agencies. The early involvement of users and decision makers in the program will greatly facilitate effective exploitation of ERTS data.

(6) A major issue for all participating developing nations (and prospective participants) is the existing uncertainty relative to the continuing flow of ERTS-type data. This is a key planning issue as well for the international and bilaterial assistance agencies which may wish to support efforts in developing countries to provide for ERTS reception, processing, and information extraction. Now that an ERTS-B mission has been approved, how long can its tape recorders be expected to function? Will there be an ERTS-C? Will the U.S. convert to an operational system and, if so, will its data characteristics be compatible with pre-existing ERTS-compatible facilities? A U.S.-government policy decision is needed so that longer-range plans can be made for ERTS data utilization in developing countries.

(7) NASA's Earth Resources Survey Program, through its support for U.S. investigators, is basically oriented to U.S. domestic applications. While NASA did undertake significant and commendable steps before the launch of ERTS-1 to encourage inter-

national participation in its earth-resources survey program,* such participation needs continued support by the U.S. so that the potential of ERTS technology as a powerful tool in solving global resource problems can be realized.

(8) While timeliness of data, as well as quality, is important for all dynamic processes, it is especially crucial in countries where ground-truth data-collection capabilities are quite limited.

(9) There is strong evidence of the importance of workshops for the dissemination of interpretation techniques and advice on the purchase of equipment. This training format should be extended to considerations of utilizing the new information in the management-decision process. Training in ERTS-data utilization will continue to be important, at least for the foreseeable future. Although four on-site case studies provide only a limited statistical base from which to draw conclusions, the beneficial impact of training is beyond question. The confidence and conviction of investigators trained in various AID-sponsored workshops was quite evident.

(10) As in any program, success can be significantly affected by program leadership and attitude of government policy makers. To obtain maximum benefit from the adoption of a new technological development such as ERTS, aggressive, dynamic leadership and support are needed effectively to introduce new information into national decision processes.

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* In 1968 the U.S. (through NASA) entered into bilateral agreements with Mexico and Brazil to initiate joint remote-sensing programs. NASA provided a six-month training program to 30 scientists. Following this, NASA negotiated some 100 foreign ERTS investigations in 37 countries, cooperated with Canada and Brazil on direct reception of ERTS data by these countries, and conducted (in 1971) a two-week International Workshop on Earth Resource Survey Systems, which had 175 foreign attendees representing 39 countries and international organizations.

(11) It appears likely, perhaps contrary to some conventional wisdom, that benefits may accrue earlier to certain developing nations than to developed ones. In many cases, the limited data base plus the absence of an elaborate resource-management infrastructure committed to dependence on conventional information sources could result in early quantum jumps in resources-management capability. Of course, this assumes adequate training and other appropriate technical assistance. In most developed nations, on the other hand, significant improvements over existing resource management must depend on the development and implementation of sophisticated resource models as well as the re-orientation of established bureaucracies.

5.3 RECOMMENDATIONS

In view of these conclusions, we recommend the following:

(1) The U.S. government should give more consideration and support to the special requirements of developing nations for utilization of ERTS technology to solve important development problems. More technical assistance should be provided to developing nations to facilitate improvements in their ERTS programs. This assistance can encompass bilateral or multi-lateral modes. Worthy projects using ERTS data should be encouraged and supported whenever feasible within AID development-assistance programs.

(2) The early achievement of economic benefits by developing nations should be facilitated by in-depth pilot projects for ERTS-data utilization which go beyond information extraction into the management-decision process. These pilot projects would be most effective if (a) they were directed toward national problems identified by knowledgable people within each country, (b) indigenous nationals actively participated in them, and

(c) they were supported by appropriate training programs and other suitable technical assistance.

(3) Regional cooperative programs for the acquisition, processing, and utilization of ERTS data should be encouraged. Since many resource problems are regional rather than national in scope, a regional program can be more effective. In addition, regional reception and processing facilities can reduce dependence on spacecraft tape recorders in a most cost-effective manner.

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Final Report

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VOLUME II: Appendices

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Appendix A
ERTS DATA USE AS AN AID TO MINERAL EXPLORATION IN DEVELOPING COUNTRIES

A.1 GENERAL

The extractive industries, including ores, industrial minerals and petroleum, are major sources of employment and important foreign exchange earners in many developing countries. The minerals industries are of potential economic significance in several others as well. Whether minerals exist or can be exploited is contingent upon better knowledge of regional geology, efforts in systematic exploration, and the ability of resources management to make the critical decisions and take such actions as are required in exploration, development and exploitation. Much of the information required by management for planning and decision making may be derived from the interpretation of ERTS data.

Mineral deposits may have a variety of surficial indicators or guides.[16] These are known to economic geologists and many such indicators may be identified on ERTS products. Most deposits of economic minerals are located by conventional aerial and field methods of exploration depending heavily on the study of topographic and geologic maps. Most mineral discoveries by geologic methods have resulted specifically from detailed investigation of structural conditions, and these had geological maps as their basis. In poorly mapped areas, ERTS images will provide a basis for better structural and lithologic mapping. Identifying new mineral deposits, particularly obscured mineralization, will rely heavily on the skilled interpretation of the structural and lithologic details interpreted from the ERTS images. Mineral deposits are usually relatively small targets, located at depth or at least obscured by vegetation or soils. Among the indicators which may aid in exploration are those which are based on the symmetry or geometry of geological

features, regional trends and apparent anomalies. Other guides include relevant structural, lithologic or stratigraphic sequences, secondary hydrological clues or interpretable vegetation changes. Even in the least developed areas it is unlikely that sizable undiscovered ore deposits still outcrop at the surface. The role of ERTS will be to provide data to geologists which may be used to identify the more subtle clues for mineral exploration in those locations where deposits exist at depth or where sedimentation or structural movements have concealed them. The unique role of ERTS products will not be the pinpointing of possible locations for exploration but will be educational. It will contribute to better understanding of regional ore genesis and better knowledge as to the possible extent of petroleum-bearing formations and structures.

Inasmuch as the developing countries are for the most part inadequately mapped, either topographically or geologically, the use of ERTS imagery in preparing base maps will be of primary value. The multispectral scanner system (MSS) on ERTS-1 has the broad wavelength capability, radiometric accuracy and registration required to provide excellent mapping fidelity and to permit the analysis of pertinent thematic signatures. Geological surface features less than 300 feet in size may be detected and the different spectral bands provide more lithologic and structural information than may be obtained from conventional aerial photography lay-downs. The foremost benefit of ERTS imagery use in poorly mapped regions is the synoptic view which permits the geologist to think on a broader conceptual scale as to the relationship of known mineralization or petroleum occurrences to a wider physical and environmental format. The ERTS system also provides computer-compatible tapes with which cartographers and geologists may undertake signature analysis by computer and identify and tabulate specific information on surficial geological phenomena, structure details and variations in

lithology. Spectral information is recorded as unique combinations of densities and methods may be employed to isolate, extract or enhance the image of a specific thematic content while preserving the geometry and resolution of the thematic image. The degree of sophistication which different developing countries are employing in methods for initial interpretation ranges from the inexpensive use of light tables and the production of diazo color transparencies to computerized processing, depending upon the national requirement, budget, or upon the degree of enthusiasm which the investigators successfully generate to obtain adequate appropriations.

Regardless of the equipment available, the geological information content of ERTS imagery is only derived after study by skilled geologists, preferably geologists familiar with the regional mineralization patterns and experienced in interpreting aerial photography. The proper data products need to be selected for interpretation, and the investigator would be adequately familiar with the data processing procedure to be able to identify technical errors in transmission. Skills required for interpreting multispectral products generally need to be acquired--e.g., through workshops or short courses--along with practical minimum facilities for visual inspection and the production of color transparencies for image enhancement. Low-cost manual techniques are available for enhancing imagery and preparing it in a format usable by economic geologists. With this minimum requirement and an aggressive program by the investigator, ERTS imagery may provide a basis for new structural diagrams, updated maps of remote areas, and provide much essential information for mineral resource management decisions.

A.2 THE IMPORTANCE OF ERTS GEOLOGICAL DATA FOR MINERAL VENTURES IN DEVELOPING COUNTRIES

Minerals and petroleum revenues can be an important part of the economy in developing countries, particularly those where forests,

swampland, mountains or deserts limit extensive agriculture. Petroleum and mineral operations can be a significant source of national wealth and domestic industry; and oil, ores or concentrates are profitable from the standpoint of hard currency exchange. The development of a profitable minerals sector of an economy is initially dependent upon successful mineral exploration and the development of resources. In areas where exploration by modern methods has been deficient, a broad methodical search is desirable to obtain essential information as to the location and size of any sedimentary basins, the patterns of geological structure, the delineation of mineralized regions, and the identification of potential areas for closer investigation. These are prerequisites for an effective, operative, developing mineral economy.

The discovery of new economic deposits will depend largely on providing exploration geologists with better information on the following: lineaments, fault lines, fold axes, stratigraphic sequence, igneous petrology, geomorphic units, the loci of fossil river channels or detrital deposits with prospects for placer operations, differing soil types, or secondary vegetational or hydrologic clues to obscured structure. Government agencies in developing countries have need for preinvestment surveys, and these may be assisted by ERTS products, particularly where requirements cover large or essentially inaccessible areas. Conventional aircraft and ground surveys are often costly long-term efforts, but the insertion of ERTS data in many instances can localize and hence minimize aircraft and ground coverage. This use of ERTS would be a good investment of scarce capital funds and could permit resource agencies to have an earlier and more knowledgable position when considering national ventures or when dealing with foreign development or exploitation of concessions.

If a geological reconnaissance is needed in a developed country where there are detailed maps available from government or private sources, aerial surveys may be put into service rapidly. The managements of government agencies or exploration companies have established

procedures for sequencing exploration and the rapid analyses of findings, and funds may be quickly available. In regard to exploration-company ventures overseas, an exploration geologist responsible for a major petroleum venture in Africa by a large U. S. company was interviewed. He used ERTS data and sophisticated interpretation methods. When asked about the economy of using ERTS data, he explained it was not the economy that was the primary factor but the time element and the great information content of ERTS products not otherwise obtainable. His need was the imagery and his great advantage was a staff of skilled geologists and technicians who were able to extract thematic information expertly and quickly. No developing nation and few developed nations have geological staff, facilities or funding comparable to the major minerals and petroleum companies. Often a relatively few qualified geologists are responsible for an entire national effort in mineral resource development. In the case-study countries considered below, one or more farsighted geologists have been responsible for convincing his agency of the potentialities of ERTS data for the national interest, and for carrying the weight of the investigation.

Because existing geological data in the developing countries is inadequate or incorrect, it is difficult for planning agencies to make decisions concerning funding exploration and the development of mineral resources. Although geological data is expensive to obtain by conventional methods, much of the initial exploration costs may be significantly reduced by the interpretation of ERTS data for identifying various indicators of the possible loci of mineralization and localizing likely areas for exploration. On the other hand, ERTS data use requires certain handling and skilled geological interpretation before it becomes of value to planners. Assuming the developing country has geologists experienced in interpreting aerial photography and that the minimum equipment and facilities for enhancing ERTS data are within the agency budget, the geological information derived will certainly prove advantageous for

exploration decisions as well as for other government functions. In those countries where the geological agency does not have such capabilities, the solution is either training or reliance upon foreign development or research efforts. Clearly, training in such circumstances is the desirable route for national interests.

The development of a capability in the geological interpretation of ERTS data depends largely on the involvement of the users through increased experience. In the developing countries the geological staffs are more than capable of identifying information pertinent to mapping and the surface expressions of structure. Training is only required in the use of specialized equipment for interpreting spectral band products and relating the data to resource management. In a specific sense this concept is consistent with that presented by AID at the CENTO Seminar in Ankara. [13]

A.3 THE APPLICATIONS OF ERTS DATA TO MINERAL EXPLORATION IN DEVELOPING COUNTRIES

The ERTS program was undertaken with the objective of providing high-resolution multispectral imagery of the earth's surface plus computer-compatible tapes. Employing a multispectral scanner (MSS) as the primary sensor, the satellite provides 10,000-square-nautical-mile synoptic images in four separate spectral bands or in any combination of black and white, as color composites, prints or transparencies at 1:1,000,000 scale. These can be enlarged to 1:250,000 scale without loss of geological content. Inasmuch as there is repeat coverage each 18 days at 9-10 AM local time, it is usually possible to obtain some cloud-free imagery of geological features and surface characteristics at different seasons. Relatively small geological features may be identified along with others so large or subtly expressed that they are only discernible as subsidence, domes, lineaments or other patterns over one or more images.

ERTS images may be studied as separate black and white images, as color composites, false color enhancements, or ratio imagery. The technique, although still largely experimental, has the potential of offering the user a means of determining from laboratory data what a number of surface materials will look like in a particular ratio image. Future potential applications of this technique to geologic mapping and exploration include the possibility of producing reconnaissance maps indicating concentrations of surface materials relevant to prospecting. Such reconnaissance techniques could be useful for reducing vast areas of ground to a number of prime locations. [18].

Whereas many of these techniques may be too complex or costly, the individual black and white single band images and transparencies often have abundant geological content. Band 5 (0.6 - 0.7 micrometers) greatly enhances geologic structure, and is particularly useful in desert and semi-arid regions. Band 7 (0.8 - 1.1 micrometers) is best for defining lineaments and structures associated with water. Water is black and vegetation is bright in the near-infrared bands. A composite of bands 5 and 7 has proven best for geologic mapping and differentiating rock types.

Cost-effectiveness is not easy to assess inasmuch as some features identified on ERTS imagery would be impossible to define by any other means. Some linear features which have been identified do not show at all on high-altitude aerial multispectral images, let alone conventional aerial photographs. As for the direct application of ERTS data for reconnaissance mapping and for localizing possible sites for oil or mineral exploration, the applications recognized to date and summarized at the Symposia on Significant Results Obtained from ERTS-1 include the following Observations: [5, 11, 14, 15]

A.3.1 RECONNAISSANCE MAPPING

- Better small scale maps can be produced from ERTS imagery for areas where poor or out-of-date maps exist

- Preliminary maps of remote regions or those with difficult terrain may be made quickly at a sizable cost savings.
- 1:250,000 scale maps are easily produced and are of good quality. Thematic maps may be produced by computer processing. Maps as large as 1:24,000 scale can be computer produced with better than expected quality.
- Photographic processes permit adjustment of products to specific scales.
- Stratigraphy, igneous contacts and definition of unit boundaries are often easily definable.
- Previously unknown structure, land forms, lineaments, etc, may be added to existing maps.

A.3.2 STRUCTURE

- Structural features and lineaments, clearly defined on black and white transparencies, are often too vague to be identified by other means.
- Surface expressions of major faults and folds, lithologic sequences and some rock type boundaries show clearly on ERTS images.
- Circular and elliptical structures which sometimes may have associated mineral deposits are exceptionally well seen due to the synoptic and illumination properties of ERTS images.
- Fracture patterns presumably controlled by subjacent structure have been noted. These may be related to crustal dynamics and regional mineralization.
- The geometry of metamorphism and intrusions may be assessed.

A.3.3 ISOLATION OF MINERALIZED AREAS

- Some mineral deposits occur along faults and fractures and at their intersections. Mining districts have been plotted against ERTS-identified lineaments and in some instances deposits which

were not known to be associated with known structural controls appear to fall close to these features.

- Some oil bearing structures were seen to be astride newly discovered lineaments. Surface expressions of previously unknown salt domes have been identified.
- A phenomenon described as "haziness" has been studied on ERTS products of some petroleum-bearing regions which have been suggested to be coincident with producing formations.
- Better definition of structure and surface expressions of intrusion known to be ore-bearing will increase probabilities of locating new deposits.
- The use of color additive processes provides products which appear to be helpful in identifying differences in lithology, surface deposits, alternation zones, and colored surface features sometimes related to mineralization.

Short and Lowman [15], considering the cost-effectiveness of using ERTS data in mineral exploration, state "The outlook is especially promising for certain parts of the world where ERTS images represent the first detailed surface coverage of regions that have never been surveyed or mapped beyond a reconnaissance level. This applies particularly to inaccessible high mountain areas, broad deserts, tundra and steppes, and polar regions as well as sections of underdeveloped or low population countries."

The ability to update out-of-date maps or to acquire new, good quality photo base maps from ERTS imagery with a minimum of expense and field work is in itself a major step for many developing countries. Regarding geologic maps, only a minor part of the US and most other developed countries is covered by quadrangle maps showing geologic structure or surface geology adequate for engineering use, soil or ground water studies, placement of dams, or for exploration for minerals. In the developing countries most of the intensive geologic mapping has been local, restricted to areas

of active extractive industry. Whereas the observation techniques available before ERTS required a piece by piece approach to mapping, ERTS data will now make it possible to undertake broad programs and geologic mapping at practical scales for reconnaissance and exploration, particularly in areas of difficult access.

A.4 CASE STUDY COUNTRY EFFORTS

In order to assess whether an improved natural resource information system justifies the necessary costs of training and equipment, four case study countries were selected, visited and analyzed. Bolivia, Botswana, Thailand and Kenya provide examples of wide geographic differences, different levels of economic activity related to the minerals industries, differing levels of overall economic development, and clear differences in the approach of the national geological agencies to make use of the new technology. Bolivia's minerals industry is of paramount economic importance and a notable ERTS effort is being undertaken. Botswana, with extremely limited agency resources and poor geological information to date, is possibly on the verge of a minerals boom and has rapidly directed efforts toward the maximum exploitation of the geological uses of ERTS products. Thailand, although a factor in tin mining, has not emphasized the potentialities of ERTS to economic geology, however, a worthy methodical mapping program is in progress. Despite the accelerating interest in possible petroleum reserves in Kenya, the national effort reported in the Final Report to NASA showed no effort in mineral resources. Aside from differentiating some basement system metasediments, Kenya's efforts have not progressed beyond identifying surface features and simple map corrections. No success was reported regarding the identification of structure. Kenya assessed its poor showing as due to a lack of equipment and interpretive know-how.

Itemized objectives and program progress are detailed in the following sections for each case-study country.

A.4.1 BOLIVIA

Mining is a significant part of the Bolivian economy providing over 80 percent of export income. However, the future growth of the mining sector is dependent upon large scale systematic exploration. Tin is the primary mineral production followed by nonferrous metals and some precious metals production. There is a copper belt in the western part of the country and a need for more information on the geological structure of that region. Petroleum is an important and rapidly expanding part of the economy, requiring further detailed geological knowledge of the sedimentary basins.

The objectives of the Bolivian investigation of the use of ERTS data for the mineral resource sector are listed by Dr. Carlos Brockmann, Principal Investigator, in the national ERTS proposal as

- Development of small-scale photomaps to assist in overall cartographic updating in Bolivia
- Development of overlays to the small-scale photomaps and to individual ERTS frames depicting significant structural/morphological features of the geology of Bolivia
- Confirmation of satellite remotely sensed data as an integral part of the regional resource evaluation and management program in the mineral and agricultural sectors of the Bolivian economy
- Establishment of a Bolivian center for resource management which can maximize the benefits to be derived from remotely sensed data from satellites and aircraft

The proposed areas of geological investigation include LaPaz, Oruro, Santa Cruz, and locations on the Altiplano. The study objectives included extensive use of existing ground truth, aircraft surveys, the cooperation of several military and civil government agencies, acquisition of equipment (listed elsewhere in this report), a training program, photomap preparation capability, and digital tape analysis of multispectral data and the preparation of thematic maps and overlays at preferred scales.

Dr. Brockmann has conducted a worthy effort of which the results are evident. A photomap of all Bolivia at 1:1,000,000 scale has been programed and an experimental map of the Sucre region at 1:250,000 scale has been prepared. The investigators have been able to define obscured structures in petroleum regions, previously unknown lineaments in mineralized areas, to differentiate the extent of volcanic formations and correlate these with regional fracture zones, and to locate properly a large number of salars on current maps. The structural section of the Eastern Cordellera is being revised. Overlays have been prepared for several ERTS frames showing lithology, structure, and associated known mineralization. Both RBV and MSS imagery has been employed in geological mapping. Studies have been undertaken using negatives, positives, mosaics and false color composites for soils, lithology, soil moisture and structure.

With purpose of extracting the maximum possible information from ERTS color composite prints for mapping natural resources, eleven thematic maps have been made from ERTS image 1010-14035, a scene of the central sector of the Antiplano. A band 6 image of this frame is shown in Figure A-1. The image includes most of western Oruro Province, the main feature being the Salar de Coipasa. Maps, overlays and detailed interpretations were prepared for drainage, hydrology, volcanism, structural geology, physiography, surface lithology and soil types. Figure A-2 shows four of these maps at a reduced scale. This effort constitutes the first thorough natural resource inventory made from a single frame. The investigators compared these results with similar interpretations made of the same area using black and white products obtained from band 7 of the MSS. Comparison indicated the color composite prints contained some 50% more data than the black and white prints at 1:1,000,000 scale for most thematic products. ERTS-Bolivia is consequently proceeding to process 9.5 x 9.5 inch positive transparencies of all the country using Diazo color techniques on bands 4, 5 and 7.

A.4.2 BOTSWANA

At the present time there is only sketchy knowledge of the geology of much of Botswana. Most of the interior consists of the Kalahari desert and the northwest is dominated by the Okavango swamps. The British Directorate of Overseas Surveys thoroughly mapped the hydrology of the swamp area at 1:50,000 in 1970, however, little is known of the geology and the possible relationship of the region to the East African rift system. Several large foreign mining interests are actively developing new major mineral discoveries in the central and eastern parts of Botswana. In fact, Botswana may be in the initial stages of major mining development. An exceptionally rich diamond mine is being constructed by DeBeers at Orapa, copper-nickel deposits are being developed at Selebi-Pikwe by a consortium of foreign investors including American Metals-Climax. Major exploration programs are underway and prospects look good for still further developments in copper, nickel, gold and diamonds. Adequate coal has been located in Botswana, but the Orapa diamond mine is obtaining its essential water supply from the variable outflow of the Okavango swamp. Principal Investigator Dr. J. V. Hepworth, in the hope that ERTS data would assist current geological survey efforts, proposed the following geological objectives:

The ERTS imagery would be critically examined for information concerning

- The geological structure and nature of the Kalahari basin and the implications of the SW-NE trending Ghanzi Ridge and other sub-parallel lineaments
- The regional geologic structure of the extension of the Bushveld Basin structure into southeast Botswana
- The regional trends in the tectono-metamorphic complex of Eastern Botswana which would control hitherto unknown sites of mineralization

- The large-scale photogeological contrasts between the Rhodesian craton and the Limpopo MobileBelt in Eastern Botswana so contributing to the analysis of this geotectonic junction
- Complete photomap of Botswana to update existing maps

Although the facilities and equipment of several government agencies are at the disposal of the Department, the main approach for analysis of ERTS images was to use visual photo interpretation methods. A zoom transferscope recently obtained by Botswana was not considered to be of particular use due to its limited field of view.

On receipt of the first ERTS-1 imagery, 6 out of 8 of the investigators in the geological investigation concluded that ERTS images show no more detail than ordinary aerial print layouts at a scale of 1:40,000, even when using MSS band 7. One investigator believed conventional photography reduced to 1:100,000 scale would contain more geological information and that interpretation of an unknown area by ERTS imagery would be extremely difficult. On the other
cerned more with information content than with resolution were favorable to the use of ERTS images, one noting that "the central zone of the Limpopo Mobile Belt can be traced right across the area, and the edge of the Karroo System can be defined." Another noted that one ERTS scene comprises an area comparable to coverage by nine print laydowns at 1:125,000, "This means that large areas can be viewed and that large-scale structures, changes in structure, and relations between structures can be more easily appreciated."

From such a reception the investigation has progressed to fulfill many of the objectives. The imagery has confirmed the suggested faulting in the Okavango swamps and has revealed further lineaments. A major NE-SW trend has been defined in the Makgadikadi region parallel to the trend of the Ghanzi Ridge to the west. The Archean greenstone belts in

NE Botswana and SW Rhodesia have been shown to be co-extensive and to cover a wider area than was formerly believed. A central region is now believed to have been "granitized." Knowledge of these lithological patterns is important to current mineral exploration planning.

Several previously undetected features have been added to maps. Mislocated and misinterpreted features have been corrected. The use of color composites made an important contribution to the studies. For example, it was noted that the recently completed Shashi reservoir is gradually filling with silt, this being the source of water being fed by pipeline to the Selebi-Pikwe copper mining region. It was also established that the hazy character criticized on earlier imagery was due to dust in the lower atmosphere raised during the dry winter season. A remnant of an older drainage system to the southwest of the Okavango swamps has been defined which indicates a seismic instability in the region, suggesting that a minor tilt of the earth's surface changed the direction of river flow. This is significant both to the possibility of active major faulting and to the hydrologic problems related to envisioning new water supply routes to eastern Botswana mining areas.

Although essentially limited to using light tables for data analysis, Botswana's effort is beginning to show promise and the objectives are beginning to be addressed. Coordination of the Botswana program to date has been difficult inasmuch as there has been no full-time professional attending the problem. This is unfortunate in view of the major minerals activities going on by exploration and mining interests. An imaginative ERTS-B proposal by B. H. Wilson has the objective of producing elemental photomaps of Botswana at 1:250,000 scale. This would be of interest to current exploration programs for mineral development. ERTS-1 imagery suggests that coal and copper bearing formations may extend under the Kalahari desert. This would be investigated further.

A.4.3 THAILAND

Thailand's minerals industry has recently shown marked increases

in the production of barite, fluorspar and tungsten. Tin production remains high, although the prices have continued to drop. Thailands' new 5-year plan prepared by the National Economic Development Board did not stress mining, the economy being primarily agricultural. The national proposal prepared by Dr. Pradisth Cheosakul (since succeeded by Dr. Sanga Sabhasri) included the following objectives related to geology:

- a national photomap at 1:1,000,000 scale
- a basic lithologic map, 1:250,000 scale, discriminating rock types (the Palezoic units are most complex and much of these are located in poorly accessible mountain regions)
- Structural map, 1:250,000 scale, showing structural lineations, mineralized zones and petroleum geology
- Ground water map, for detecting old river channels with possibilities of locating ground water storage, economic placer minerals and construction gravels

The Department of Mineral Resources has an operational photo interpretation facility, trained personnel, aircraft, photograph coverage of the proposed exploration areas, diazochrome capability, all essential interpretation equipment, computer time and a high level of photogrammetric competence.

Thailand has produced a photomap of the entire country from 49 selected ERTS band 7 images. A useful geology sketch map has been prepared at 1:1,000,000 scale from overlay tracings of the MSS mosaic showing faults, fractures, photolineaments of as yet unknown significance, domes, folds, basins, old river channels and features related to igneous intrusions. Thailand is shown as having distinctively fractured tectonic provinces which may be correlative with mineralogenic provinces. This should be of great value in indicating areas for mineral exploration. Other work on individual positive transparencies included detection of geomorphic features, land forms, soils, river patterns, lineaments, domes, faults, lithology, old river channels and structure. Thailand is well

into its program of mapping, if showing little progress to date in interpretation or in the area of economic geology. The Thailand effort would appear to be more academic in objective than other case study nations.

A.4.4 KENYA

Kenya has meager mineral resources and is only a small producer of precious metals, copper and berryllium. Nonmetals include cement, hydrous sodium-calcium carbonate, gypsum, salt and building materials. A new zinc operation is under development and a large fluorspar deposit is being developed in the Rift Valley. There is considerable foreign activity underway in petroleum exploration. The national ERTS proposal prepared by Dr. J. Ojal (since succeeded by Dr. J. Omino) emphasized agriculture, range management and water resources. The Geological Survey of Kenya has facilities for photog aphic, photogrammetric and cartographic operations. Light tables and Diazo equipment are available. The geological objectives of the national effort were not detailed in the proposal. Our visit confirmed that geologic activity was low, if not nonexistent, except for petroleum exploration by the private sector.

In the Final Report on the Kenya effort it was noted that there were deficiencies stemming from poor interpretive capability and lack of equipment. The studies did not address mineral resources. The investigation did not progress far beyond making map corrections and the identifications of known features. Specific accomplishments include the revision of the shorelines of Lake Rudolf, identification of changes in the Oma delta since last mapped 15 years earlier, and differentiation of certain basement system metasediments.

A.5 MINERALS EXPLORATION MODELS

In 1948 Professor Hugh McKinstry admonished his geology students at Harvard "If the broader structure of the district has not already been

deciphered, it will be well to do enough work of a reconnaissance nature to determine the general character of the rocks and their mutual relationships. A view of the region from the air is well worth the hire of a plane for an hour or two; it gives a comprehensive idea of the topography which can be obtained in no other way, and it often discloses broad geological features which would otherwise appear only after a protracted campaign of mapping."[10] At that time, as now, aerial photographs were the best possible base for mapping surface geology, but their optimum application to geological exploration was limited to a relatively few far-sighted geologists.

A generation later proper aerial coverage is incomplete in many of the underdeveloped countries and its application to geological exploration is often not fully exploited. Now ERTS imagery can bridge this gap by providing synoptic images orders of magnitude better for determining the broader structure, and with a resolution adequate for initial reconnaissance and for defining those areas where aerial coverage most likely should be undertaken. ERTS products also have unique applications to geologic mapping and aid in problems of assessing regional mineralization patterns. In the case of Bolivia, ERTS usage has permitted that country to attain geological information that would have taken years to acquire by conventional means at a major national expenditure. Botswana, faced with sudden major mineral activity and with inadequate geological mapping for much of the country, plans to obtain the maximum benefits from the interpretation of ERTS images.

Most developing countries need a broad systematic exploration program for possible economic mineral reserves. The exploration sequence is generally integral with national-level decision making by the country's planning office, the resource management agencies, and at the operational level in its geological survey or mining bureau. These decisions often follow this order:

A. Determine national economic or industrial need.
   Consideration of mineral economy prospects.
   Consideration of market.

B. Whether to undertake reconnaissance

C. Whether to mount general exploration program

D. Whether to undertake ground survey

E. Whether to test drill

F. Whether to develop resource

In a conventional exploration sequence, parallel decisions by geologists may include any or all of the following, depending in detail of course on whether the deposits involved are metal ores, petroleum, coal, industrial minerals, placer deposits, etc., and how situated:

1. Selection of favorable region
2. Assessment of possibilities after review of sundry maps, samples, etc.
3. Reconnaissance
4. General exploration program, aerial methods, interpretation
5. Detailed geologic mapping, sampling, geochemistry, selection of area to drill
6. Test drilling, geophysical surveys on ground
7. Systematic drilling, core sampling, evaluations
8. Systematic subsurface exploration, surveying, outlining ore, assessing reserves
9. Development of property for production

In the underdeveloped areas in particular, where relevant ERTS derived information is inserted into the geological decision-making sequence, the planning and resource management level decisions will be facilitated and accruing benefits would include the saving of exploration time and costs and a possible accelerated rate of discovery. The following models relate to that decision making, presuming an area deficient in available geological data identifies the management decision points in reference to the exploration route: (Fig. A-4) Conventional

Exploration Sequence in Undeveloped Area, and (Fig. A-3) Exploration Sequence in Undeveloped Area Employing ERTS Data. [3, 16, 20]

In those countries where geological information is deficient, ERTS data can play a significant role in providing the regional information essential to initial decisions concerning the type of agency efforts required to investigate the nature and extent of resources. In many of the 5-year plan type countries studies, the governments have relied upon information from private, often foreign-owned, petroleum or mining companies. No matter how detailed, such information is of necessity often limited by the product interest. The decision to undertake a broad mineral resource inventory or even a specific-mineral exploration program depends first on national economic or industrial needs, and secondly on the probability that the preinvestment investigation will prove to be practical and will identify various options for appraisal. Although ERTS images provide a great amount of geological information, they should not be used as a basis for exploration decisions except when carefully analyzed and interpreted in terms of exploration objectives by skilled investigators. Whereas knowledgable employment of ERTS data can greatly reduce the areas for exploration and may pinpoint regions where exploration is most apt to be rewarding, inept interpretation of ERTS data may steer costly efforts off on an entirely wrong track. Investigators may also knowingly or unknowingly use ERTS data to promote preconceived concepts.

Exploration procedures which are employed in surface and subsurface methods include a large number of electronic, seismic and other techniques. Geophysical and geochemical prospecting methods for petroleum and ores are largely responsible for the continuing discoveries which have kept development of these resources abreast of the industrial demands of the better developed nations. This level of exploration is not replaced by ERTS data; however, ERTS data may be an important aid in selecting the areas for study.

Of the several steps in conventional exploration, ERTS will have the most impact on decisions related to initial reconnaissance, geologic mapping and the extent of aerial coverage required. Improvement in any of these aspects should greatly increase the cost-effectiveness of exploration. Direct discovery of ores is not an anticipated result of the use of ERTS data; however, if any such discoveries do accrue they will most likely be in the remote, poorly mapped areas of the developing countries.

A.6 MINIMUM PRACTICAL REQUIREMENTS

Computer analysis of tapes and the use of a color-additive viewer are desirable for obtaining the maximum benefits from ERTS products, but this degree of sophistication is by no means essential. The most successful results obtained by investigators in the developing countries which have been studied have been the result of using light tables, manual plotting equipment, and low-cost techniques for enhancing ERTS imagery. National programs have been undertaken at low budgets by skilled geologists with experience in aerial photographic interpretation or photogrammetry. Know-how has been the all important factor.

The various "workshops" have been of exceptional value to investigators and their staffs. In some of the developing countries there is a great need for training personnel in ERTS technology, in the use of data products and in using the newly developed enhancement methods. This need, however, is far less among geologists than among users from other disciplines inasmuch as the study of maps, land forms, etc., is an essential part of their thinking. As the information gained from the interpretation of ERTS data becomes usable in economic planning, it will be important that other elements of the national economy become informed better as to ERTS' potentialities, including economists, conservationists, the domestic extractive industries and bankers, as well as personnel in government planning, budgeting and resource offices.

The use of a Diazo machine is an example of a low-cost technique for enhancing ERTS imagery and preparing it for natural resource interpertation as a product compatible with current information systems. A procedure developed at the New York State College of Agriculture [4] employs photographic techniques and standardization of 70 mm NASA film chips. A subtractive color process is used producing 1:3,300,000 images to scales up to 1:66,000. Diazo transparencies are produced in magenta, cyan and yellow for each MSS band. The investigator states data retrieval is possible from a great number of Diazo color combinations. Map transfer is easily done at 1:250,000 scale and enlargements are feasible up to 1:10,000 with overhead projectors. The approximate cost of preparing photographically enhanced enlarged negatives and positives and the Diazo materials is some 1¢ per square mile. The specific cost of making a land use classification map of twelve categories at a 1:250,000 scale is some $1.00 per square mile. This requires no expensive hardware. Subjective interpretation is such that it may be readily taught to non-technical users. The wide range in color selection allows adaptation for a wide range of applications.

A memorandum distributed by the Agricultural Extension Service, University of California[19] discusses the development of a low-cost rapid method of producing color enhancements from 70 mm or 9.5 inch bulk black and white positives. A Diazo machine is used to make positives in the green, red and IR bands. These are taped to a transparency mount and registered to make a simulated false color IR image which may then be projected or photographed to make slides. With proper density settings, it is possible to see about ten shades of gray scale for red and blue positives and seven or eight for yellow positives. Red positives were used for the red bands, blue for the IR, yellow for the green band. The enhancements are faithful reproductions of the regional imagery, and because it is a contact process, better detail is retained than in a process requiring projection. Enhancements can be made within a few minutes on

stock costing a few cents a sheet. Depending on subject matter, different color combinations would be selected.

Methods such as the above are well within any national budget. Light tables, manual plotting equipment, and a Diazo-type process would appear to constitute the minimum requirement for interpreting ERTS products.

At the 1970 AID Symposium on the Utility of Remote Sensing as an Aid to Developing Countries, Washington, D.C., it was noted that there would be a need to develop an indigenous analytical capability in a developing country so that practical problems could be addressed. It was noted that training and technical assistance in ERTS systems and techniques is our first order of business in the developing countries.[17] Data alone are of little value to the minerals sector of a developing country. Only in the hands of skilled geologists trained in the use of ERTS data do the products become information for aiding management decisions.

Training through "workshops" and various short courses has been made available to the geologist investigators. These have emphasized analysis of imagery and interpretation, the manipulation and enhancement techniques, information extraction, and the insertion of ERTS data into decision-oriented models. It is unlikely that competent geologists/investigators will have to be hand-led or provided a "cook book" for using ERTS data. It will only be necessary to provide training in the use of new techniques and to make the investigator aware of developing applications. The ultimate value of training will be agency capabilities in extracting information (e.g., through models) pertinent to the requirements of technical and policy management levels. Because there is no authoritative textbook on geological remote sensing, and few technical papers on the subject are available in languages other than English, regional workshops provide the best means of training geologists in techniques and applications.

A.7 ESTIMATED EXPLORATION COST SAVINGS

Exploration cost savings are difficult to forecast for the developing countries, let alone quantify in terms of the specific steps in the exploration sequence. All previous attempts to calculate cost savings or the future benefits to be derived from the use of remote sensing data in mineral exploration have been met with amusement or outrage, including the findings of the National Academy of Sciences/National Research Council Geology Panel, 1969 Summer Study on Space Applications of the Useful Applications of Earth-Oriented Satellites [7].

At the above meeting various approaches were tried to estimate the benefits which might accrue from a postulated program. Basing the inquiry on current annual exploration cost data, it was conservatively estimated exploration cost for U.S. oil was $2.05-billion of which $345-million were attributable to geology and geophysics. Mining industry exploration costs were most difficult to obtain, but were estimated at some $200-million for the U.S. and Canada, of which some $50-million related to geology and geophysics. This provides a basis for assuming which exploration costs would be affected: about 17% of oil exploration costs, and about 25% of mining industry exploration costs. These figures are surely too conservative for exploration in undeveloped areas where there is a deficiency of geological data available and where mounting an exploration would be more costly. The following cost savings discussion applies mostly to these 17% to 25% sectors of total exploration costs.

The impact of ERTS data would be largely on initial reconnaissance, aiding geologic mapping, and in reducing the extent of aerial coverage required. The specific cost savings would differ considerably from country to country depending upon the amount of geological information available, whether mineral activity is already a significant factor in the economy, and the nature and occurrence of the minerals of interest. Although cost-effectiveness studies are not yet available on mapping and

geological reconnaissance in the developing countries, relevant time and cost data have been compiled by several U.S. investigators, some involving remote areas with a lack of geological data. These are pertinent and a reasonable base for extrapolation.

In terms of geological reconnaissance and the production of photo-base metric maps from ERTS imagery, the value to developing countries is beyond estimate if considered in regard to the accelerated discovery of economic deposits. In terms of geological exploration costs alone it is possible to make assessments, assuming the ERTS images to be superior to any existing maps. In summing up the applications of ERTS to land use and mapping, Lindgren and Simpson[7] show the use of ERTS imagery to be cheaper by more than an order of magnitude over similar mapping by use of medium-altitude aerial photography as a base. They estimate that preparing a 10 to 12 category thematic map of an area the size of Iowa or Illinois by medium-altitude aerial photography would cost $1-million. The preparation of a base map and thematic overlays for geological use would be of similar cost. For a similar mapping from high altitude aerial photography, roughly assuming the cost of mapping would be proportional to the scale of the map, the same job would cost only 20% as much, or about $200,000. Extrapolation to the use of ERTS imagery would put the mapping at about $80,000, or 1/12 the cost of a conventional job.

Insofar as time saving is concerned, Miller and Belon[12] report the preparation of a resource survey of a 13,000 square mile area of a remote section of the Brooks Range of Alaska. Using color and black and white prints of the essentially inaccessible area, a multidisciplinary team with a minimum of orientation spent some 25 man-hours to make a survey, including maps of gross geologic features, previously unknown structures, tectonic zones pertinent to economic minerals, vegetation types, watershed drainage, and potential land use.

Lauer and Krumpe[6] present a detailed cost-effectiveness study related to using ERTS products for a wildland resources inventory of the

Feather River watershed in northern California as compared to a conventional black and white aerial photography coverage which took 3 years and was completed before ERTS, and in comparison to a CIR highflight coverage. The ERTS and highflight products were both superior to the conventional coverage but the ERTS study was clearly superior showing much better delineation density. Their itemized analysis showed favorable cost ratios of 1:20 for ERTS compared to conventional coverage, and 1:9 for ERTS compared to highflight coverage.

In terms of geological mapping of structures, Dr. R. Parker of the University of Wyoming had mapped the major fracture systems of the Wind River Mountains for 5 years by pack mules, completing less than 15% of the range. He completed the remaining 85% or more of the map with comparable accuracy in 3 hours time after he received the ERTS imagery of the range[15]. A lineament map of a 34,000 square kilometer area of the Canadian Shield was produced in 45 minutes because infrared imagery clearly delineated water-filled fractures[14]. In such an area of dense vegetational cover, similar to some of the developing countries, this degree of structural detail is most difficult to obtain either by aerial or surface methods.

In comments on the applications of ERTS to the Department of Interior programs, DeNoyer[2] noted in effect that although efficiency factors of 6 to 20 and higher had been reported at the second ERTS symposium, the real benefits come from the analysis of the data and taking timely actions based on the efficiently obtained information.

Some 17% to 25% of total exploration costs are conservatively estimated to be affected by the use of ERTS data. It is estimated that aerial geophysical coverage (hence costs) would be affected somewhat similarly to aerial photography due to the reduction of the area of study. The efficiency ratio for geological search and mapping is estimated to range up to 1:20 or more, depending upon the type of deposit or structure involved, the availability of geological data, and the amount of ground which would be reduced by the study of ERTS images.

Insofar as ultimate benefits are concerned, it is of course impossible to estimate the kind, number or value of discoveries, if any, which might accrue from the use of ERTS data. The best approach to such a question is probably the assumption that although total reserves would not be increased by the use of satellite data, there would be an accelerated rate of discovery of existing deposits. The NAS/NRC study[9] suggested, e.g., that a possible 5 percent of ultimate reserves might be brought into accelerated production over a 20-year period following the then postulated GEROS program. On the other hand, the same study noted that in the U.S. the cost of geological search for oil is about 3 percent of oil production values, and the cost of geological search by the U.S. and Canadian mining industries is equivalent to 4 to 5 percent of mining industry production values. This does not predict a return on investment but illustrates the possible orders of magnitude between the relatively inexpensive application of ERTS data and possible large or accelerated benefits.

FIGURE A-1. ERTS IMAGE (BAND 6) OF COIPASA REGION, BOLIVIA.*

*"Aplicación y Evaluación de Imágenes ERTS de "composición de color" al Inventario de Recursos Naturales", GEOBOL, Programa del Satelite de Recursos Naturales ERTS-Bolivia, C. Brockmann and A. Fernandez C.

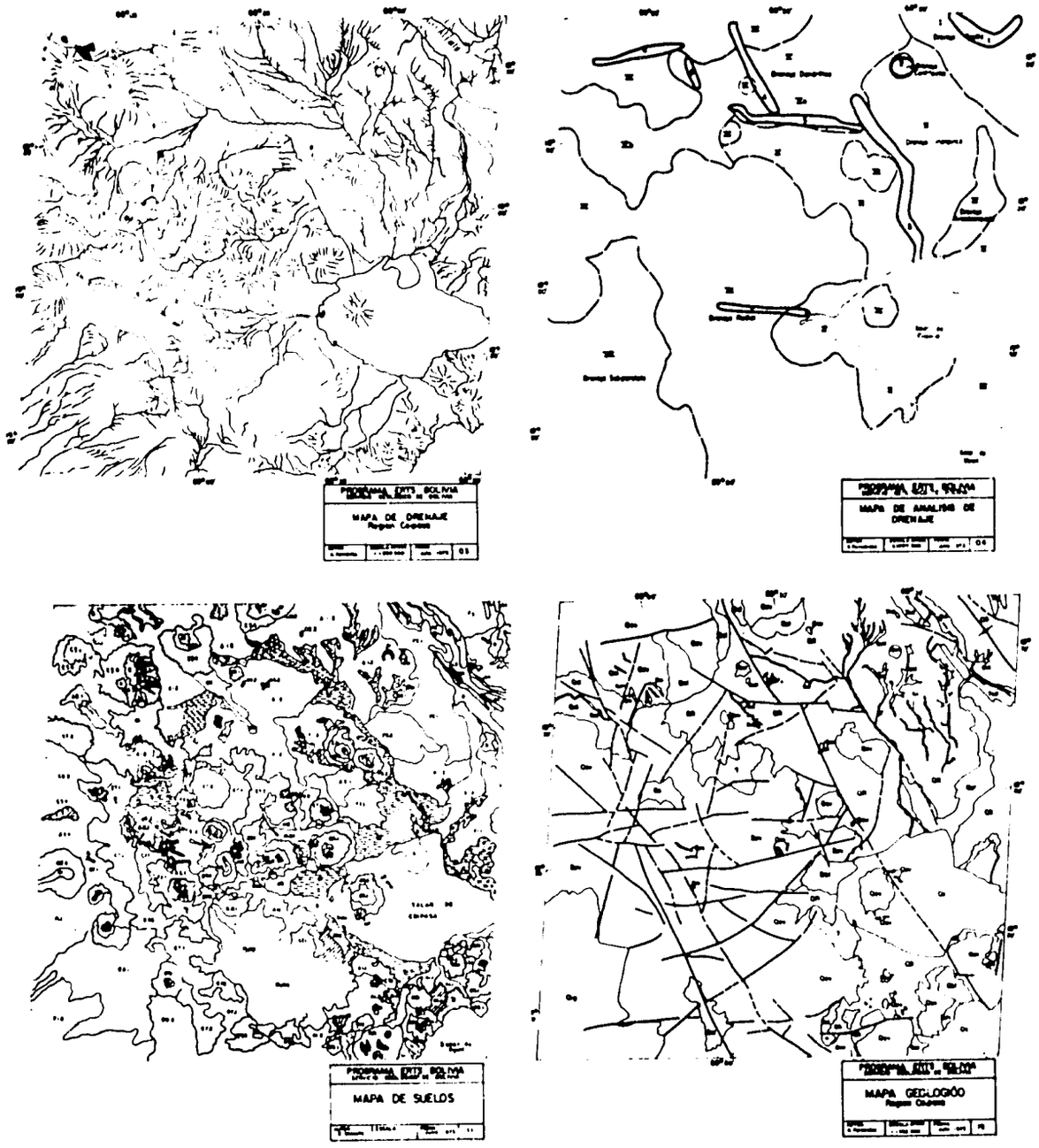

FIGURE A-2. FOUR THEMATIC MAPS MADE FROM ERTS IMAGERY OF COIPASA REGION, BOLIVIA *

*"Aplicación y Evaluación de Imágenes ERTS de "composición de color" al Inventario de Recursos Naturales," GEOBOL, Programa del Satelite de Recursos Naturales ERTS-Bolivia, C. Brockmann and A. Fernandez C.

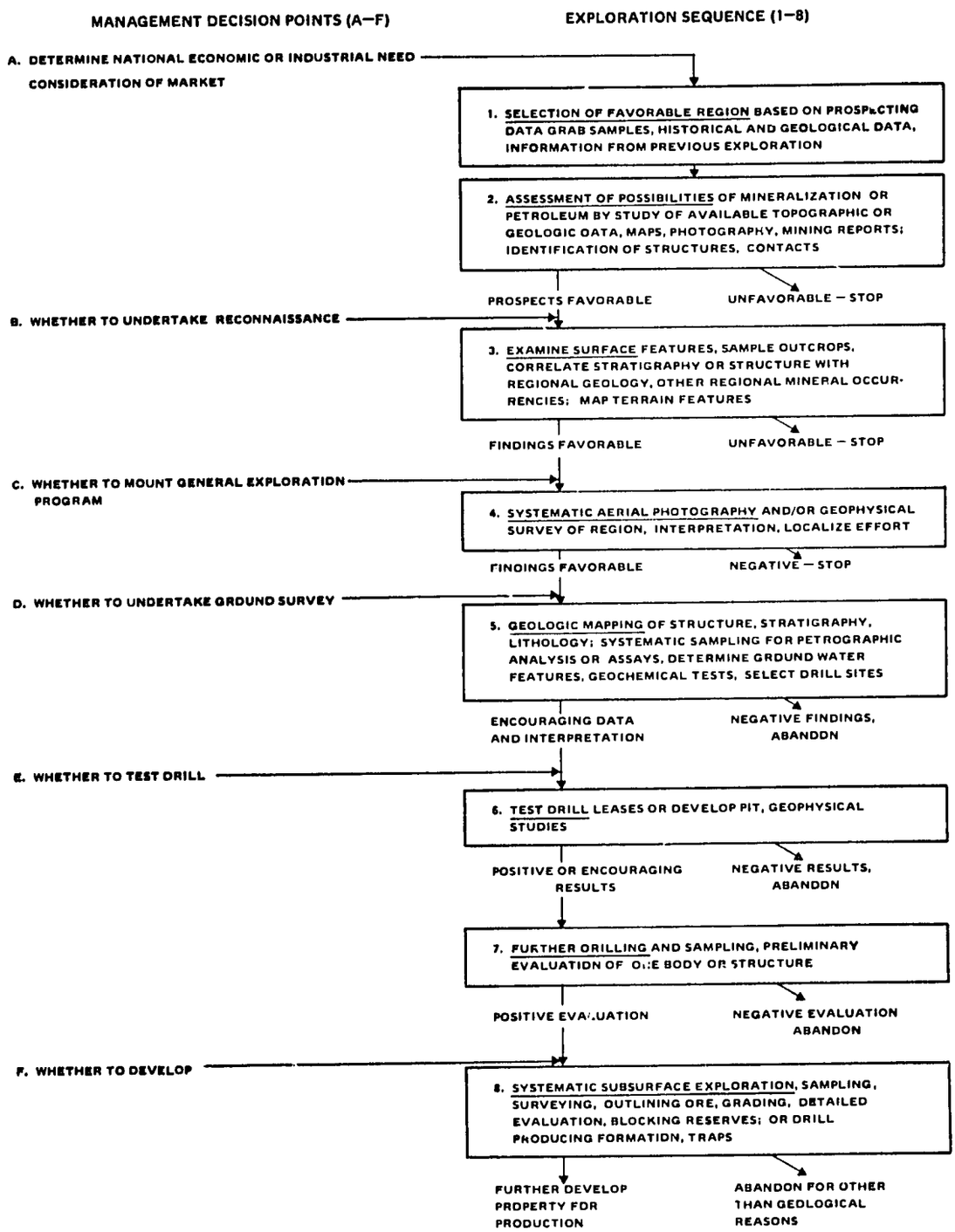

FIGURE A-3 CONVENTIONAL EXPLORATION SEQUENCE IN UNDEVELOPED AREA (PRESUMING A DEFICIENCY OF GEOLOGIC DATA AVAILABLE)

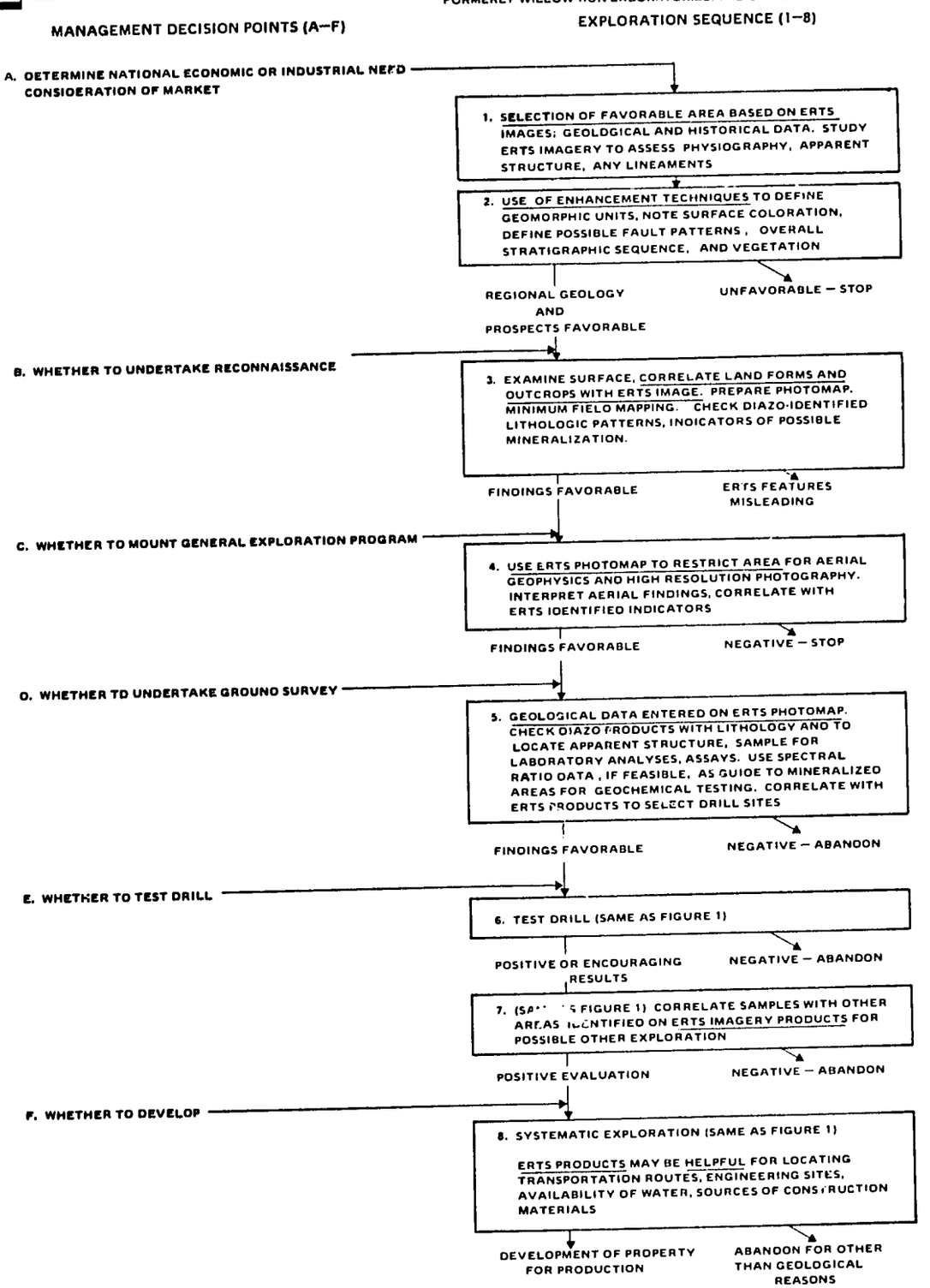

FIGURE A-4 EXPLORATION SEQUENCE IN UNDEVELOPED AREA EMPLOYING ERTS DATA (PRESUMING A DEFICIENCY OF GEOLOGIC DATA AVAILABLE)

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Appendix B
ERTS DATA AS AN AID TO RICE CROP PREDICTION IN THAILAND

B.1 BACKGROUND TO ESTIMATION OF BENEFITS

B.1.1 INTRODUCTION

A number of possible applications of satellite imagery have been discussed in the main body of this report. Among them was the use of such imagery for data collection on acreage and probable production in agriculture. The benefits from improved crop forecasts in the United States, discussed in such studies as that by the Earth Satellite Corporation, can differ radically from the benefits expected from the same satellite-based information systems in less developed countries. The rationale is simple: the current magnitude of prediction error is likely to be greater in less developed countries such as Thailand than in countries such as the United States which have sophisticated information gathering systems. Therefore, the institution of a satellite-based system would be associated with a greater improvement in data accuracy in a less developed country. At the same time, given the difference in current budget allocation for data collection in the two types of countries, the cost increment or decrement for a satellite-bases system as compared with the current system would also differ significantly.

The benefits of a satellite-based system in the United States may be primarily in terms of cost savings, with the degree of reporting accuracy unchanged or only marginally improved. However, it is highly unlikely that the current reporting system for agriculture in any developing country is as precise as could be achieved with a basic satellite-based system. Thus, the structure of cost-benefit analysis is different for the two types of situations. In analyzing the benefits

of satellite-based information systems for agricultural reporting in the United States, the approach might be one of equal budget - unequal capability analysis but is more likely to be one which emphasizes unequal budget - equal capability (cost savings); or unequal budget - equal capability (improved capability, with budget either greater or lesser, depending on the magnitude of current expenditures). The first and third approaches (improved capability) are much more likely to be applicable in the case of less developed countries.

In this particular case study on the use of satellite-based information systems for rice crop forecasting in Thailand, we assume that the system would result in improved accuracy of predictions. This appendix presents an estimate of the magnitude of benefits which might be associated with the institution of a satellite-based system of agricultural data collection. In this preliminary study, we cannot specify the exact structure of the data collection system except to say that satellite imagery would be used as the first tier in a multi-tiered data collection system which, in all likelihood, would involve at least some on-site sampling of crop yields. Because we cannot specify the exact survey structure (e.g., percentage of acreage selected for on-site yield sampling), and because the satellite-associated costs would be allocated among several uses or data-sectors, we cannot assign costs to a satellite-based rice forecasting system at this time.

This appendix is composed of three sections. The remainder of section 1 presents general background information on rice production and exports on Thailand to give the reader an idea of the magnitudes involved;* section 2 describes the model used to estimate benefits of

* Benefits estimated in this analysis are for future periods but based upon historical production and export magnitudes as an indication of magnitudes to be expected in the immediate future. Clearly, benefits estimates are to be interpreted as indications of approximate magnitude and not as precise data.

improved information systems; and section 3 presents the empirical results of our estimation of the benefits likely to be associated with introduction of a satellite-based information system for rice crop prediction in Thailand.

B.1.2 THE IMPORTANCE OF RICE PRODUCTION TO THE THAI ECONOMY

The selection of Thailand for analysis of benefits from satellite imagery was outlined previously. Give the selection of Thailand for this study, and given the importance of agriculture in Thai GMP (close to 30 percent of GNP), it was only natural that applications of satellite imagery in agriculture be chosen as one of the Thai case study areas. Furthermore, rice was the most logical crop upon which to focus in this preliminary analysis since it is a basic food item as well as a substantial proportion of all GNP; it is also a major export product.

Roughly speaking, rice production constitutes one half of all crop production in Thailand. Rice production accounted for 38.7 percent of all agriculture in 1963 and 50.1 percent of crops in the same year, using 1963 prices. The rice percentage of output, evaluated in 1963 prices, has slipped slightly below 50 percent in recent years as the rate of increase of rice production (tons) appears to be below that of crops in general (particularly tobacco, kenaf and jute).[1] Nonetheless, production has continued to increase rather than decrease and is still a substantial component of national output. Table B-1 presents data on annual production of rice and total value of GNP. Using an approximate price for paddy of 1,000 Baht per metric ton,* one can see that the wholesale value of rice output constitutes approximately ten percent of total GNP.

* In 1970, the average annual wholesale price in Bangkok Metropolis was 1,157 Baht per metric ton for No. 1 paddy, 1,011 for No. 2, and 969 for No. 3 paddy. Prices in the period 1966-70 were somewhat higher.

Table B-1 also presents data on the area cultivated and harvested over a period of years. Although total holding area appears to increase gradually and steadily over time, area cultivated has increased much more erratically. Area harvested is determined not only by the total area cultivated but also by area damaged and thus is subject to annual variations from two sources. Anticipating a later section in this appendix, it is worth noting that the variations in area harvested have been as great as 15 percent (1968/69 to 1969/70). That is to say, assuming these data are relatively indicative of the true hectarage, it is not really possible to predict area harvested by merely extrapolating from the previous year. Thus, periodic surveys of area under cultivation and damaged areas could greatly aid in crop forecasting.

Rice is important not only as a domestic food staple but also as an export product. Table B-2 indicates the proportion of rice export earnings in total export income. In 1972, for example, earnings from the exportation of rice comprised almost twenty percent of total earnings from exports that year. In turn, exported rice constituted more than twenty percent of total production harvested in the preceding crop year (1971).

B.1.3 THAI EXPORT MARKET FOR RICE

The majority of Thai rice exported is destined for other Asian areas, notably Hongkong, Singapore, Indonesia, India, and Malaysia with the Philippines importing a substantial quantity in 1971 and 1972 and only marginal quantities during the period 1963-1970. The data are presented in Table B-3. Table B-3 also indicates the importance of Thai rice to the importing countries, both as a percentage of total rice imports and as a percentage of total rice supplies available. (Rice supplies available are defined as total rice imports plus domestic production of the preceding year.) Thai rice is a substantial proportion of imports, and thus total supply, for Hongkong, Singapore,

and Saudi Arabia. In recent years, Senegal has become an importer of Thai rice and these imports constitute about a quarter of total supply. Although India, Malaysia, and Indonesia are important customers for Thai rice, the proportion of Thai rice in their total supplies is relatively low since domestic production is quite large in these countries.

The Thai government does not permit the free export of rice from Thailand but, rather, influences the flow with the use of two policy tools. The incentive to export is controlled through the use of an export tax or premium on rice which absorbs a great deal of the difference between export prices and domestic wholesale prices. In theory, the government could control the flow of exports through the rice premium alone if the tax were continually adjusted in response to changes in export prices, thus insulating the domestic market from variations in foreign supply as manifest in export price variations. In fact, it is difficult to fine tune this policy instrument and the government uses a second tool to control exports, i.e., a system of physical allocation achieved through export licensing, which is intended to ensure domestic sufficiency in rice. With adequate information on domestic production, export licenses can be used to guarantee a targeted supply domestically by granting licenses only for the excess over domestic needs. The rice premium then becomes a source of government income, absorbing the "windfall gains" which might otherwise accrue to exporters. Of course, if the premium is set too high in a given context, exports could be unduly discouraged.

It is likely that the government's policies for control of exports have not served to completely insulate domestic markets from foreign demand and guarantee a fixed domestic supply. If so, we cannot view exports as the residual or "run-off" after domestic needs are satisfied; variation in rate of supply probably occurs in domestic markets as well as export markets. Assuming that foreign demand for Thai rice is

greater than Thai supply at reasonable prices (i.e., a situation of relative rice shortage) and that Thailand can, in fact, export all rice in excess of domestic needs, then it is possible for forecasts to affect the rate of rice exports via the granting of export licenses.

Furthermore, if the volume of export licenses granted is influenced by forecasts of supply, and forecasts are erroneous, we can assume that there will occur fluctuations in rate of supply as export licenses are adjusted to true production. Additionally, if the export constraints do not completely insulate the domestic market from supply variations, i.e., if the Government is unable or unwilling to ensure a steady or fixed rate of supply domestically, then part of the fluctuations in dispersal must be felt in the domestic market. To the degeee that more accurate forecasts of production help to reduce the amplitudes of intra- and inter-year fluctuations in dispersal, then domestic consumers will benefit as well as foreign consumers from improved forecasting accuracy.

It is unclear whether Thailand's exports of rice are limited only by the Government's desire to limit exports. A paper by Richard Taylor,[5] describing past and current export trends for Thai rice, would imply that the market for Thai rice has deteriorated in some areas and that increased exports would require a Thai marketing effort to gain new footholds. On the other hand, the recent surge in world rice prices and Thai rice export price indicates initiation of a period in which demand outpaces supply. Given the increasing spread between export price and (historical) domestic wholesale price, it seems logical to assume that Thai exports could easily be expanded so long as the rice premiums are not excessive.

In this paper, in estimating the benefits which might be expected from improved forecasting, we assume that Thai rice exports will continue at approximately the same levels as prevailed in early 1970's. We further assume that the only constraints on exports are the

Government's imposed constraints and not a lack of world demand for rice. Thus, we assume that variation in Thai export supplies is due to Thai domestic policies and not to variations in international demand. To the degree that historical exports were less than possible because of a rice glut, then to that degree we have underestimated future benefits since benefits are proportional to value of transactions and export potential is now greater than previously.

B.1.4 RICE CROP FORECASTS IN THAILAND

The accuracy of crop predictions is important in Thailand because both the rate of domestic dispersal and the volume of export licenses granted can vary according to predictions. If predictions are accurate, then alterations in dispersal and export rates in response to predictions are considered as adjustments to altered market situations. But if predictions are not relatively accurate, then fluctuations in dispersal and export rate constitute over or under adjustment and involve unnecessary variations in rates of supply.

Table B-4 indicates roughly the degree of accuracy in rice crop predictions in Thailand. Unfortunately, the periodic predictions transmitted by the U.S. agricultural attaches in Thailand to the U.S. Foreign Agricultural Service offices in Washington are no longer permanently recorded. Thus Table B-4 is based upon predictions which were published at irregular intervals in a U.S. Department of Agriculture publication, Rice Market News. Although the agricultural attaches made (make) predictions on a regular basis, at fixed intervals, Rice Market News seems to publish only selected predictions. Thus, for example, there are several predictions of the 1969 crop but only one prediction presented for the 1970 crop.

In general, the forecast errors (as a percentage of the actual production) are in the range 5-10 percent, with two predictions exceeding a ten percent margin and three below five percent (excluding

the predictions for 1972 which were given as a range from 9.8 percent below harvest to 2.5 percent above it). It is very possible that the errors are in fact greater if we allow that the true production tonnage might not be known with accuracy. On the other hand, it is also possible that inventory depletion rates are based upon unofficial forecasts which are more accurate than the ones presented in this paper. It should be noted that, in those years in which several forecasts were presented, the forecasts do not converge to the true production figure as the forecast period shortens; the forecasts bracket the actual (reported) production figure.

The sources of forecast error can be several: inaccurate estimates of acreage cultivated and damaged areas, imprecise data on allocation of rice acreage among rice strains and cultivation methods associated with different average yields, erroneous yield forecasts for the several varieties of rice. The introduction of remote sensing into a general agricultural information system cannot improve the accuracy of specific yield forecasts, i.e., yield for each variety and environmental/cultivation situation. However, such imagery could greatly improve the accuracy of data on total area cultivated and area damaged, hence total area to be harvested.

Furthermore, it is felt that use of satellite imagery would allow a more accurate estimation of the acreage in each of the two major types of cultivation: floating and transplant rice. Floating rice is a fast growing strain used in areas in which controlled irrigation is not possible (flood plains, etc.). Transplant rice is sprouted in "nurseries" and then transplanted to fields after the monsoon; it is a less rapidly growing variety and is grown under conditions of controlled irrigation. The yields of the two varieties are quite different; the historical average yields for floating and transplant are 0.30 and 0.60 ton rai respectively. Thus an inaccurate

"allocation" of area among the two strains could easily result in large forecast errors for total production. Although the total area sown in each type may be predictable from year to year, since it is a function of land terrain and ease of irrigation control,* the area damaged is not so easily predicted since it varies geographically as well as by land (physical) type.** Thus the area harvested of each type may be a different proportion of that sown. Satellite imagery could therefore contribute to greater accuracy in prediction both by noting the total area sown to each type of rice and by noting the distribution of damaged area between the types.

Such acreage data could then be used as a sampling frame for selection of specific locations for on-site yield measurement. Alternately, on-site yield sampling could be greatly contracted if data existed for a weather-yield model. In the latter case, information on date and extent of monsoon rain would be used to estimate yield of each rice variety in several locations. Given data on yield, yield estimates would be multiplied by the appropriate acreage obtained from the satellite imagery to produce crop forecasts.

The use of satellite imagery to calculate acreage in floating and transplant rice can be described briefly. Band 5 and 6 images

* Approximately one third of the central plain is planted in floating rice, thus floating rice would constitute approximately twenty percent of total acreage, according to officials at U.S. Department of Agriculture, Foreign Agricultural Service, Grain Division.

** Cultivated areas which are not harvested are basically those areas which received insufficient water after the monsoon. The irrigation system is a "filter-down" system, thus the abandoned areas would be those fields at the periphery of the irrigated area. There is no reason this should be constant proportion of sown area in all parts of the country.

can be used to distinguish wet from dry areas. Thus, after the monsoon the areas in which rice might be growing can be delineated as those areas which are flooded. On band 4 images, water is not distinguished but rice imprints can be read. Thus, combining bands 4 and either 5 or 6, the flooded rice areas can be noted. All rice areas not flooded are planted in broadcast rice, a third type, which is a very small percentage of the total in Thailand (probably less than three percent). Within the flooded rice areas, all those fields with a regular shape and bounded by regular dikes and walls are fields of transplant rice; all those flooded rice areas of completely irregular shape, without walls to contain the water, are in floating rice.

The potential accuracy of crop forecast systems using satellite imagery has already been demonstrated in the United States. In a study of wheat production in Kansas, ERTS was used to estimate acreage in March and, using a weather model, to forecast production in June 1973. U.S. Department of Agriculture published their prediction in August, which differed from that of the ERTS study group by three percent. When final crop production figures were released in early 1974, they were within one percent of the ERTS-based prediction. Thus the ERTS data was used to obtain a more accurate prediction two months before the U.S.D.A. forecast.[7] Although it might be objected that wheat fields in Kansas are much larger than rice paddies in Thailand, it is not necessary to distinguish individual plots unless crops are intermixed in a geographic region. Although the area of any single Thai field or plot is quite small, there is little or no intermixing of crops in the rice-growing areas thus the areas would appear as extended rice fields, analogous to the large wheat fields in Kansas. The identification of a broad composite of individual rice fields would be quite adequate for acreage estimation and crop prediction.

B.2 ESTIMATION OF BENEFITS OF IMPROVED THAI RICE CROP FORECASTS

In the preceding section, we noted that there is probably room for improvement in rice crop forecasts in Thailand and that we believe that satellite imagery can contribute to improved forecasts through more accurate estimates of acreage sown by crop and area damaged. It remains to be proven, however, that this improvement in accuracy can be justified economically in terms of public welfare. In this section, we will first describe the assumptions and the model used to estimate welfare benefits of improved forecast accuracy and second we will present estimations of the benefits which could accrue to Thailand and to her rice customers. Basic to this analysis is the assumption that forecasts affect rates of product supply both domestically and internationally and, too, the assumption that (improved) satellite-based forecasts will be quietly disseminated.

B.2.1 THE BASIC MODEL FOR ESTIMATION OF BENEFITS

The basic model for estimation of benefits of improved information systems is that presented by Hayami and Peterson[8] for use in estimating benefits from improved crop forecasts in the United States. The model is based upon the assumption that the rate of product dispersal or inventory depletion (within a year) depends upon crop forecasts. Crop forecast errors result in deviations about the rate of inventory depletion which would prevail if production were known in truth. Such deviations about "normative" depletion rates, essentially a boom-bust type of fluctuation rather than a steady depletion rate, result in a loss in consumer welfare. The loss in consumer welfare is proportional to the magnitude of the forecast error squared, and inversely related to the price elasticity of demand.

The model is presented graphically in Figure B-1. The sloped

line D is the demand curve for the product in question, relating price (measured along the vertical axis) to quantity demanded by consumers (measured along the horizontal axis). The vertical line labeled S, intersecting the horizontal axis at quantity Q, is the supply curve associated with a total production of Q. The supply curve is vertical because total supply, in any one year, is fixed at the level of output and does not vary according to market price. Associated with this supply is a price P, the equilibrium price which exactly clears the market. Assume that, prior to the harvest, a forecast is made which predicts production of Q'. Anticipating a price of P' at harvest time when supply is expected to be at a level of Q', inventory holders reduce their rate of dispersal to the market in the current period, awaiting the better price of P'. By withholding from the market, they in fact force the current price up to the level P' in the present period. The rate of dispersal is reduced to Q'.

When the harvest comes in, and supply is seen to be Q, price begins to fall. Not only is supply greater due to the unanticipated increment in production of Q'Q, but also inventory holders have an excess of inventories which they feel obliged to sell in the post-harvest period. The excess in inventories is equal to the excess withheld from the market in the preharvest period, i.e., Q'Q. Thus, in the post-harvest period, inventory depletion is at a rate of Q" -- actual production of Q plus the excess in inventories (the distance Q'Q equals the distance QQ"). Rather than a steady rate of depletion at a rate throughout the year, the rate of inventory depletion first dropped to Q' and then jumped to Q". This results in a lost of consumer welfare.

Consumer welfare is calculated as the area under the demand curve up to the point of quantity supplied, i.e., the integral of the demand curve evaluated at the appropriate supply quantity.

Conceptually, it is the sum of the prices which would be paid for each individual unit of produce, each purchaser paying the maximum he is willing to pay. The "first" purchaser would pay some very high price for the first unit of produce; the "second" purchaser would pay a slightly lower price for the second unit; each purchaser being one point on the demand curve.

If inventory depletion were at a steady rate both before and after harvest, then consumer welfare would be accrued at a rate equal to the area under the curve up to Q in both periods. But, with erroneous forecasts, welfare is accrued at a rate equal to the area under the curve only up to Q' in the preharvest period, a loss in welfare of the area bounded by aghc. In the post harvest period, the rate of inventory depletion is greater and welfare is greater than would have been with a depletion rate of Q; welfare is accrued at a rate which is greater by the area chjf. This post harvest increase in welfare, vis-a-vis the situation of steady dispersal, is not enough to make up for the preharvest loss in welfare.* The difference is equivalent to the shaded area bounded by bcde,** assuming a straight-line demand curve.

* Hayami and Peterson contend that their model is symmetrical, that the loss in welfare is the same whether the preharvest depletion rate is Q' and the post-harvest is Q", or whether the preharvest depletion rate is Q" with a post-harvest cutback to Q' as inventories are built back up. This presumes that there exists <u>some</u> carry-over stock which allows a step-up in the preharvest rate of inventory depletion.

** A positive value equivalent to chjf plus a negative value equivalent to the area aghc yields a negative value bdce. The areas dghe and chjf are equal and thus cancel one another. Assuming a straight line demand curve, the area of the triangle abc is equal to that of cef, and they cancel. That leaves a negative value equivalent to the area bdce.

Note that we refer to Q', Q, and Q" as rates of dispersal or inventory depletion. These are annualized rates, and not total quantities. Thus, if dispersal were at a rate Q for a full year, the amount dispersed would be Q. Hayami and Peterson do not make the distinction but, rather imply that the quantity Q' is dispersed in the preharvest period and the quantity Q" in the post-harvest period, thus a total dispersal of Q' plus Q", equal to 2(Q) or double the annual production of Q'. The calibrations on the horizontal axis, therefore, represent annualized quantities divided by the number of periods in a dispersal year. Welfare loss due to erroneous prediction, the area bcde, is the price deviation about P multiplied by quantity deviation about Q where Q is total production divided by the number of periods.

The equation for calculation of welfare loss due to erroneous forecasting and post-harvest adjustment can be derived easily. The distance Q'Q is the forecast error multiplied by production, divided by the number of periods. The vertical distance PP" is a function of price elasticity of demand. Thus, using the equation for price elasticity of demand (α),

$$PP'' = \Delta P = (\Delta Q/Q)\ (P/\alpha) \quad \text{where } \Delta \text{ denotes an increment or deviation} \tag{1}$$

Multiplying by the horizontal distance Q'Q or ΔQ, welfare loss G is derived:

$$G = (\Delta Q)^2\ P/Q\alpha. \tag{2}$$

The deviation in Q (i.e., ΔQ), is a function of the forecast error, ε. Q itself is some proportion of production, equal to R/T where R is total (rice) output and T is the number of dispersal periods in a year. Thus $\Delta Q = \Delta R/T$. And $\Delta R = \varepsilon R$. Substituting in Equation (2)

yields the equation for calculation of welfare loss attributable to forecast errors:

$$G = \varepsilon^2 P R/T\alpha \tag{3}$$

where G = loss in consumer welfare

ε = forecast error as a proportion of true production

P = price which would prevail if the rate of dispersal were in accord with true production quantities

R = actual production

T = number of dispersal time periods in a year (minimum is 2 - one preharvest and one post-harvest period)

α = price elasticity of demand.

The benefits of an improved forecasting system are very simple: the reduction in welfare loss associated with the better system, i.e., benefits = $G_1 - G_2$ or

$$B = (PR/T\alpha) \quad (\varepsilon_1^2 - \varepsilon_2^2) \tag{4}$$

where B = benefits associated with an improved forecasting system

ε_1 = forecasting error of old system

ε_2 = forecasting error of new system

There are a number of assumptions associated with this model, both explicit and implicit. The model assumes that inventory holders fully believe the forecasts and act accordingly in adjusting their rates of inventory depletion. It assumes that they make no allowances for forecast error or risk, that reaction to forecasts is immediate, and that household consumption is in line with inventory depletion rates. In sum, the model assumes that household consumption of the product in question is varied in exact accordance with the crop forecasts prior

to the harvest and that any error in the forecasts is reflected in over or under consumption prior to the harvest and compensatory under or over consumption after the harvest.

Furthermore, the model also assumes that inventory holders do not realize (or at least, their actions do not reflect knowledge of) the effects of their collection post-harvest dumping. Thus, they do not moderate their preharvest withholding policies to avoid having greatly excessive post-harvest inventories. (In a perfectly competitive market, each inventory holder would assume that his individual policies do not affect the overall market price, although collectively their policies do determine price.) Additionally, the model assumes that there is no carry-over of excess inventory beyond the immediate post-harvest period, i.e., that the excess inventories accumulated in the preharvest period must be disposed of in the next period, as must all of current production. Clearly, too, the model assumes that price alone determines demand and ignores the effects of fluctuations in income, etc.

B.2.2 APPLICATION OF THE MODEL TO THE THAI CASE

The model as it stands is a somewhat naive but useful tool for the evaluation of welfare benefits from improved forecasting. To adopt the model to the Thai case, we must explicitly consider the impact of a sizable export market. Fluctuations in the rates of inventory dispersal, i.e., the distance Q'Q, are not confined to the domestic market alone. Clearly, crop forecasts and forecast error will affect the rate of export. The impact on the domestic consumers depends on the degree to which domestic inventory holders, both commercial distributors and private households, vary consumption or inventory depletion in response to market factors.*

* Throughout the analysis, it is assumed that all interested parties (domestic and foreign) have equal access to the same forecast data, both before and after the introduction of satellite-based information systems.

In Thailand, the Government has attempted to steady the rate of domestic inventory depletion by insulating the domestic market from foreign market fluctuations (using rice premiums and export licensing). Nonetheless, the domestic market would be affected by erroneous crop forecasts since the volume of export licenses granted depends on crop forecasts, the Government cutting back in years when production is expected to be below normal, etc. An underestimate of current production would lead to a volume of export licenses lower than might be tolerated in fact. To compensate for the preharvest undersupply, the volume of export licenses might then be stepped up in the period immediately following the harvest, thus resulting in an export cycle analogous to the inventory depletion cycle described by Hayami and Peterson.* Improved forecasting would thus yield welfare benefits to foreign consumers by evening out the rate of consumption of Thai rice in foreign markets, analogous to the Hayami-Peterson description of welfare benefits received domestically in the United States. In addition, a more accurate crop forecasting system and thus a more even flow of exports could yield welfare benefits to Thai domestic consumers of imports. To the degree that the granting of import licenses is dependent upon expected exports and varies as expected exports vary, then the more even flow of exports allowed by improved crop forecasting could be reflected in a more even flow of imports and hence increased (Thai) consumer welfare.

* Implicit in this model is the assumption that exports are supplied at a fairly steady rate throughout the year except for variations about the norm due to forecast and production variation. In fact, exports probably follow a peak-trough pattern. However, dispersal of Thai rice in foreign retail markets is probably at a more even rate and benefits are based on consumer welfare, not importer welfare.

The calculation of the welfare benefits which would accrue to Thailand's rice customers as the result of an improved rice forecasting system is quite analogous to the basic Hayami-Peterson approach. In this case, the demand curve would be that of the Thai's foreign customers and the supply curve would be composed of their domestic production plus total rice imports into these countries. Variation in supply, or the Q'Q of the Hayami-Peterson graph, is attributable to fluctuations in all three components of supply to the market area: production, Thai exports to the area, and imports from non-Thai sources. The supply deviation, Q'Q or Q, can be stated as a function of its components; using annualized quantities:

$$\Delta S_M/T = (\Delta S_o + \Delta S_x) / T = [(S_o)\ \varepsilon_o + (S_x)\ \varepsilon_x] / T \qquad (5)$$

where S_M = total supply available to the market area

S_o = supply from non-Thai sources (own production plus imports from countries other than Thailand)

S_x = imports of Thai rice to the market area

ε_o and ε_x = the errors or proportional deviations about "normative non-Thai and Thai components of supply, assumed to equal forecast errors associated with these quantities.

T = number of periods in a year.

In turn, the quantity $S_x\ \varepsilon_x$ is a function of the fluctuation in total Thai supplies or rates of inventory depletion (assumed to be equal to production times the forecast error), the proportion of this fluctuation transmitted to the export market, and the proportion of Thai rice exports going to the particular submarket area under analysis. Thus, if the welfare benefits of improved forecasting are to be estimated for a portion of the Thai export market, the quantity $S_x\ \varepsilon_x$

is equivalent to:

$$S_x \varepsilon_x = R \varepsilon_r V M \tag{6}$$

where R = total rice production

ε_r = forecast error for Thai rice

V = proportion of variation about true production transmitted to the export market as fluctuations in rate of export

The equation for estimation of benefits accruing to the consumers of the export submarket area as a result of improved rice crop forecasting is analogous to Equation(4)above but now contains quantity variables designated by product source and their respective error terms. Recalling the need to divide quantities by T, number of peirods in a year, the equation for estimation of welfare benefits accruing to foreign consumers of Thai rice is given as:

$$G = (P/T\alpha(S_o + S_x))[(S_o\varepsilon_o + R\varepsilon_r VM)^2 - (S_o\varepsilon_o^* + R\varepsilon_r^* VM)^2] \tag{7}$$

where the subscript (o) now indicates values relevant to the export market area being considered, an asterisk (*) indicates the error rates prevailing under an improved forecasting system for rice, and, as before:

where G = welfare benefits resulting from an improved crop forecasting system

P = price per unit of produce (rice) which would prevail if depletion rates were in accordance with true production quantities

T = number of time periods in a year

α = price elasticity of demand.

The benefits accruing to Thai rice consumers as a result of improved forecasting depend, first, on the relationship between forecasts and supply fluctuations and, second, on the proportion of overall fluctuation transmitted to the domestic rice market. As we have indicated above, we do not believe that the domestic market is supplied at a constant annual or even quarterly rate. The domestic market is composed of two segments in essence: those consumers who purchase their rice and grow none of their own, and those consumers who are also producers. The former are presumably supplied by inventory holders in the urban areas who adjust their rates of inventory depletion or sale to the market in accordance with market prices. In turn, we assume that these market prices are governed, at least in part, by forecasts of production and actual production quantities. We further assume that own-consumption by producers is similarly affected by market prices and hence, indirectly, by forecasts. Producers can respond to relative prices by varying their rate of consumption out of stocks and also their rate of supply to the market, hence the rice remaining for their own consumption, or by trading one quality of rice for another. Individual, nonproducer, households can also maintain private inventories and vary consumption in response to market conditions.*

For this analysis, we assume that the total deviation of inventory depletion rates or rice supply about "normative" depletion rate, is

* That is to say, although individual households might buy substantial supplies at a given time, particularly when prices are low, they may respond to forecasts of poor production, manifest in higher current prices, by reducing their current rate of consumption out of stock in anticipation of leaner times ahead. Their actions are exactly those of consumers who are faced in actuality with higher prices attributable to forecasts of poor harvests, i.e., reduced consumption in the current period in response to higher prices which, in turn, are due to anticipated future supply (relative) shortages.

equal to the forecast error, $R\ \varepsilon_r$. This fluctuation is a result of policies by major or wholesale inventory holders and micro or producer units plus, also, consuming households which vary their rate of consumption from stocks. The total deviation of inventory depletion of supply rates about "normative" is absorbed in toto by the export and domestic markets. Inventory holders withhold a certain quantity of rice, anticipating higher prices at harvest time, and this shortfall is distributed between the two markets. If the full shortfall is not taken out of exports, then there must be some withholding of rice from domestic consumption. Thus, an improved forecasting system reducing the deviation of inventory depletion rates about the "normative" rate or rate justified by the true production level, will yield benefits domestically as well as internationally.

The equation for the calculation of benefits accruing to Thai nationals is essentially equation (4) modified to reflect the fact that some variation in inventory depletion rates is transmitted to the export market:

$$W = [P/T\alpha\ (R - S_x)]\ \ [R\ \varepsilon_r\ (1 - W))^2\ -\ (R\ \varepsilon_r^*\ \ (1 - V))^2]$$

$$= [P\ R^2\ (1 - V)^2\ /\ T\alpha\ (R - S_x)]\ \ [\varepsilon_r^{\ 2} - \varepsilon_r^{*2}] \qquad (8)$$

where W = welfare benefits accruing to Thai consumers and the other variables are as defined above.

B.2.3 EMPIRICAL ESTIMATION OF BENEFITS

The welfare benefits resulting from an improved crop forecasting system, presumably based on the use of satellite imagery, were estimated for both Thai consumers and their foreign customers in a selected market area using the equations presented in the preceding

section. The assumptions of the model have already been stated above. The values of the parameters V and α, as well as the forecast errors themselves, cannot be known with certainty. Thus a sensitivity analysis was performed, calculating benefits at several logical (assumed) values of these parameters.

The price elasticity of demand for rice was assumed to be in the range 0.1 to 0.5; benefits were calculated at three possible values -- 0.1, 0.3, and 0.5. This was considered a reasonable range given the price elasticities calculated for basis food products in the United States by several investigators, i.e., a range of .02 - .15 for wheat, a range of .02 - .69 for potatoes, and a range .04 - .32 for rice.* The value of T, number of inventory dispersal periods in a year, was assumed to be three: one period during which inventory depletion is at a rate in line with true production, and two periods bracketing the harvest during which the depletion rates deviated above and below the justified rate.** Benefits are inversely proportional to T and α and it is an easy matter to modify the benefits estimates if different values of T and α are considered more realistic.

For the purposes of calculation, the foreign market area selected for analysis of benefits was composed of Hongkong, India, Indonesia, West Malaysia, Singapore, Saudi Arabia, and Senegal. These countries account for approximately half of Thai rice exports. Table B-5a presents total rice supplies, domestic and foreign, available in these countries as well as Thai exports to these countries in 1969 and 1970. Given the values presented for these years, benefits

* See Table B-5c for the investigators associated with each of these values.

** This would be in line with the situation in which the relevant forecast is published in August-September, after the monsoon is well past, harvesting takes place at the end of the year, and true output is known at the beginning of the following year.

calculations were done assuming that total supplies from non-Thai sources were 80 million metric tons. It was also assumed that an additional 750 thousand tons were imported from Thailand.

The value of P, price per metric ton, was assumed to be $100. This is the approximate export price prevailing in 1971-72.* Prices have increased considerably in the period since then and, if these higher prices are sustained without a significant decline in consumption, benefits should be estimated as some multiple of those presented in this paper since benefits are proportional to price. Furthermore, the retail price paid in these markets is presumably greater than $100 by the retail margin and any taxes added onto the Thai export price. Thus, to the degree that $100 is an underestimate of consumer price, benefits as calculated are an underestimate of the actual welfare benefits which would accrue.

The estimations of benefits which would accrue to customers in the principal submarket area defined (i.e., non-Thai cusomters) are presented in Tables B-6a and B-6b. Calculations are based on the assumption that the forecast error associated with non-Thai rice supplies to the market area is unaffected by the satellite-based information system, presumed to be used only in Thailand. In other words, it was assumed that $\varepsilon_o = \varepsilon_o^*$. Clearly, total welfare benefits would be greatly changed if the forecast error associated with S_o were simultaneously reduced.

Welfare benefits to consumers in foreign markets are based upon the change in fluctuations in <u>total</u> supply available to them, attributable to forecast errors. In the model used, fluctuations in total supply are synonymous with errors in forecasting total supply to the area. This latter is, in turn, a weighted average of the error in forecasting Thai production (ε_r) and the error in forecasting the

* See Table B-5b for data on export prices.

supply from all other sources (ε_o). The error in forecasting Thai supply can add to the total error or can counter (mitigate) the effect of errors made elsewhere. If the Thai and non-Thai forecasts err in the same direction, then any diminution in Thai forecast errors will serve to reduce the overall error in supply forecasting for the sub-market area. On the other hand, if the Thai forecasts err in the direction opposite that of the non-Thai forecasts, reduction in Thai errors can actually increase total error, thus exacerbating the forecast-based fluctuations in rate of supply. It can be seen from Equation (7) that it does not matter if we assume ε_o is negative and both ε_r and ε_r^* positive, or the reverse, since the weighted sums are squared. But it does matter if weighted errors are added or differenced within the parentheses prior to squaring.

Thus, in truth, a satellite-based information system may actually result in negative benefits because a mitigating or counterbalancing factor is taken away (i.e., the weighted sum of errors is greater). Benefits will always be positive so long as ε_o, ε_r, and ε_r^* are all of the same sign. Benefits may be negative, though not necessarily so, if the sign of ε_o is opposite that of ε_r and ε_r^* (the latter two assumed to be of the same sign).*

Table B-6a presents benefits when forecasts err in the same direction; Table B-6b presents benefits when Thai forecasts err in the opposite direction from forecasts of the non-Thai supply to the area. In other words, Table B-7a presents the range of benefits which might occur when the total margin of error is reduced since Thai contribution

* It can be shown algebraically that benefits will be negative if Thai and non-Thai errors are of opposite signs <u>and</u> the following relationship holds true:

$$(R)\ (M)\ /S_o \text{ less than } (2\varepsilon_o)/V(\varepsilon_r + \varepsilon_r^*)$$

Essentially, this inequality holds true when Thai supplies less than a majority of rice consumed in the area.

to the total error is reduced. Table B-6b, however, presents the disbenefits yielded when the error offset previously associated with Thai forecasts is reduced and thus total forecast error for the area is increased.

For both tables, welfare benefits were calculated at two assumed (and likely) absolute values of ε_o: $\varepsilon_o = 0.15$ and $\varepsilon_o = 0.10$. In Table B-6b these values are prefaced with a minus sign to remind the reader that they are of the opposite sign from ε_r and ε_r^*. Benefits were also calculated for several values of ε_r, initial forecast error for Thai rice, and ε_r^*, forecast error of improved satellite-based system. The absolute values assumed for ε_r were 0.15, 0.10, and 0.05, the last being considered an optimistic view of the current situation. Absolute forecast errors with a satellite-based information system were variously assumed as 0.05, 0.03, and 0.02. Thus, sixteen different scenarios were postulated with regard to absolute forecast error rates. These are listed down the left-hand side of the tables.

Estimations of benefits and disbenefits were also done for three different values of V, the proportion of variation in inventory depletion absorbed by the export market. As limits to the quantity of benefits expected from improved forecasting, benefits were calculated for V = 1.00, i.e., for all fluctuations transmitted to the export market resulting in wide deviation about normative or "justified" export rates, and for V = 0.20, i.e., the proportion of variation absorbed by exports only slightly greater than the proportion of exports in Thai output (exports of 1.5 million tons and production of 8.5 tons, milled basis). The benefits and disbenefits based upon V = 1.00 are considered overestimations since, as we have already indicated, the domestic market is not fully insulated from changes in rates of inventory depletion. Implicit in this whole process is

the assumption that exports are really a residual after supply of domestic needs, although government control of that residual is not always perfect hence there are fluctuations in domestic consumption as well as international exports. In other words, this analysis of benefits is relevant only to a period in which there is buoyant demand for Thai rice and Thailand can export all the rice it deems advisable at prices considered adequate. The current period fits this description, although historical periods do not.

Dealing first with the data in Table B-6a, i.e., positive benefits yielded, we note the magnitudes which might be expected. The most pessimistic view of benefits, estimated for a change in forecast error from only 0.05 to 0.03 and a distribution of fluctuations between domestic and export markets proportional to distribution of sales, ranges from $226,000 to $1,130,000* annually depending on the price elasticity assumed. These are annual benefits accruing to customers in half of the Thai rice export market from a slight improvement in rice forecast accuracy in Thailand alone. Recall that Thai rice imports to this market area constitute somewhat less than one percent of the total supply. The benefits jump to the range $5,552,000 to $27,760,000 if we assume that half of variation in depletion is absorbed by the export market and initial errors are 0.15 for both the market area and Thailand, the Thai forecast error being reduced to 0.02 with a satellite-based system. It is not improbable that the forecast error be changed by this amount with the institution of a satellite-based system accurately reporting acreage cultivated and damaged acreage for floating and transplant rice separately. It is also possible that half of the variation in the rate of inventory depletion is transmitted to the export market.

* U.S. dollars

On the other hand, in reality it is unlikely that the deviations in inventory depletion rates about "normative" depletion are equal to the forecast error multiplied by production ($R\ \varepsilon_r$). In other words, it is not likely that inventory holders completely believe in the forecasts and make no allowances for error and risk. More likely, the amplitudes of the fluctuations are less than $R\ \varepsilon_r$. Thus, one would guess, the annual benefits which would be associated with an improved forecasting system are somewhat less than the figures presented, assuming a price of $100 per metric ton. (Any increase in price, assuming consumption unchanged, would increase benefits above those presented here.) Nonetheless, the value of benefits is not trivial, even for a price elasticity as high as 0.5.

The smaller the proportion of variation in inventory depletion absorbed by the export market, the lower the benefits which would accrue to Thai foreign cusomters from an improved forecasting system. On the other hand, the smaller the proportion of variation absorbed by exports, the larger the fluctuations in domestic supply and hence the institution of a satellite-based information system for forecasting.

The total net benefits accruing to foreign nationals in the Thai export market area are a sum of the benefits and disbenefits which would be yielded by an institution of a satellite-based information system in Thailand.

The analogous disbenefits presented in Table B-6b are almost mirror images of the positive benefits in Table B-6a for the same combinations of parameters but always slightly smaller in absolute magnitude.* Thus, if the number of years in which forecasts err in the same direction equal (or outnumber) the number of years in which forecasts err in opposite directions, the sum of benefits will be positive over time. The more that Thai and rest-of-supply forecasts

* It can be shown algebraically that this will always be true.

tend to err in the same direction (due to similar climatological factors affecting both sets of forecasts), then the more there will be periods of (positive) benefits rather than disbenefits and the greater will be the value of benefits summed over time.

The proper calculation of net benefits would be based on present value of a stream of benefits and disbenefits, presented for a scenario in which error rates were postulated for each of a series of years, discounted, and then summed. For example, the scenario and benefits values shown in Table B-7 might be one of those hypothesized. In this case, the present value of benefits and disbenefits over a five year period would be in excess of $11 million. A series of such scenarios would be developed (using historical error rates or perhaps a random selection of combinations of pre- and post-satellite error rates) and a distribution of values for present value benefits would be found. There was neither time nor sufficient funds to generate such data for this study.

From the Thai national point of view, the welfare benefits received by Thai consumers presumably are of greater consequence. Table B-8 presents the welfare benefits which would accrue to Thai domestic (rice) consumers as the result of an improved forecasting system, based on the same assumptions used above to calculate benefits to foreign consumers. There is one very important distinction, however, between benefits received by foreign consumers and those received by Thai consumers: benefits to Thai consumers are always positive. This is because only one forecast error is involved; there are no offsetting errors in total forecast error. Implicitly, we have assumed that the Thai domestic market is fairly well insulated from supply conditions in the rest of the world. We have assumed that the amount of rice available to Thai consumers is a function of Thai needs (as determined by the government) subject to

fluctuations due to government export policies based on forecasts and not related to world rice forecasts/supplies (manifest in world prices). That Indian forecasts indicate a good year presumably does not really affect the volume of rice available to Thai's.

As a limit, benefits were calculated assuming that 100 percent of variation in inventory depletion is absorbed domestically, though this is unlikely. Excluding this case, the annual benefits accruing to Thai consumers would be not lower than $705,000 annually (initial forecast error of 0.05 and satellite-based system error of 0.03, 80 percent of fluctuations absorbed domestically, and elasticity of 0.5). The benefits could be as great as $48,660,000 annually if the domestic market absorbs its proportional share of total variation in inventory depletion (i.e., V = 0.20).

If we assume that the domestic market absorbs less than its proportional share of variation in inventory depletion, i.e., V > 0.20, benefits domestically would be less (but benefits to foreigners greater). Assuming that V = 0.5, i.e., variation is evenly split between the two markets even though exports are less than half of total dispersal, then benefits received domestically would range from a very minimum of $275,000 to a maximum likely value of $19,010,000 annually. These are the benefits expected from one use of the satellite-system; the same capital equipment could be used for other sectors as well.

Another, and separate, consideration in the estimation of benefits received by Thailand is the effect on foreign exchange earnings of a change in forecast errors. Referring to the basic diagram of the model presented in Fig. B-1, Thai foreign exchange earnings under the current system would be analogous to the area (P')(Q') + (P")(Q") in the two periods. Under a system of steady distribution of exports, the exchange earnings would be 2 (P) (Q). Fluctuations in rates of export

supply results in a net loss in foreign exchange earnings equal to 2 (ΔP) (ΔQ). In a market such as that presented in Figure B-1, a simple closed domestic market, this would constitute a loss in seller surplus and an equal increase in consumer surplus. An improvement in forecasting would therefore involve a transfer of revenue or "surplus" from consumers to sellers. In an international market, this would involve a transfer of foreign exchange from importing countries to exporting countries such as Thailand. In the situation described for Thailand, with fluctuations in supply deriving from domestic fluctuations as well as variations in the rate of Thai exports, the calculation of net exchange losses due to forecast errors is somewhat more complex algebraically. Nonetheless, the conclusion is the same: a reduction in forecasting errors and a concomitant reduction in supply variation could result in greater foreign exchange earnings for Thailand. Of course, this is not a net increase in world benefits. This is a "zero-sum" game in which Thailand's gains are losses to the importing areas of an equivalent amount, i.e. a transfer of foreign exchange assets from purchasers to sellers.

The magnitude of the foreign exchange transfer can be indicated algebraically. The loss in foreign exchange earnings to Thailand due to forecast error is 2 (ΔP) (ΔS_x)/T. The following substitutions are made in this basic equation:

$$\Delta S_x = V\ R\ \varepsilon_r$$

$$\Delta P = \Delta Q P/Q\alpha = P(S_o\ \varepsilon_o + V\ R\ \varepsilon_r)/(S_o + S_x)\alpha$$

since $$Q = (1/T)\ (S_o + S_x)$$

$$\Delta Q = (1/T)\ (S_o\ \varepsilon_o + V\ R\ \varepsilon_r)$$

The loss in foreign exchange earnings vis-a-vis a zero-error forecasting system is then

$$E = (2\ P/\alpha T)\ (V\ R\ \varepsilon_r)\ (S_o\ \varepsilon_o + V\ R\ \varepsilon_r)/(S_o + S_x) \tag{9}$$

and the net increment in foreign exchange earnings or transfer which would accrue to Thailand with an improved forecasting system would be equal to $E - E^*$, where E^* is the (lower) loss in exchange under the improved system (calculated for ε_r^*).

Assume the following values for the several parameters:

P = \$100

V = 0.20

R = 8.5 million tons, milled

S_o = 150 million

S_x = 1.5 million (total exports to all market areas)

T = 3

$\varepsilon_o = \varepsilon_r = 0.10$

$\varepsilon_r^* = 0.03$

$\alpha = 0.5$

In this particular example, we are assuming that all forecasts err in the same direction. Given this assumption, the increase in foreign exchange earnings realized by the Thai's in such a year as hypothesized could be as much as \$1.59 million (an increase in export earnings from rice of about one percent). On the other hand, analogous to the calculation of welfare benefits to foreign rice consumers, this calculation also is sensitive to the sigr of the error terms. For the same parameters as above but with $\varepsilon_o = -0.10$ (and ε_r and ε_r^* still positive), the foreign exchange losses would be given as nearly \$1.55 million. The

loss is somewhat less than the "analogous" gain, thus an equal distribution of years between the "positive" and "negative" situations would yield a net positive foreign exchange gain over time (of approximately $50,000 per year given these magnitudes). A predominance of years in which all forecasts err in the same direction would, of course, yield a greater positive increase in Thai foreign exchange earnings from rice.

There is an analogous transfer of purchasing power in the domestic market as well when forecast-based fluctuations are tempered by a more accurate report system. Here, the transfer is from domestic consumers to domestic suppliers. Thus, although total consumer welfare is increased with a more regular supply, consumers do have to pay for this increased welfare with greater total outlays for rice. In other words, although total welfare is increased with a steadier rate of inventory depletion, consumer surplus is decreased (by an amount equal to $(\Delta P)Q$ in the case of a straight line demand curve).

B.2.4 CONCLUSIONS

The estimations of benefits presented above were based upon a simple model, dependent upon several simplifying assumptions. Clearly, the evaluation of benefits should be modified to take into account the realities of the Thai situation. However, more data is needed on the crop forecast data actually used by inventory holders and the effects of forecasts on inventory depletion rates within the year. The model assumes that inventory holders completely believe the erroneous forecasts and that they act immediately to adjust inventory depletion rates. In all likelihood, there are several forecasts made prior to harvest and inventory holders adjust depletion rates with each one. Furthermore, it is likely that inventory holders allow for error in the forecasts and risk of midjudgment. Nonetheless, the model provides a useful point from which to begin an estimation of benefits.

The basic premise of the model used is that the benefits attributable to improved accuracy in Thai rice crop forecasting are the result of more even dispersal of rice from Thai inventories. Consumers in both the domestic and export markets would benefit from reduced fluctuations in the rate of rice inventory dispersal; these benefits are measured in terms of the increase in consumer welfare realized. An additional effect of improved crop forecasting would be a net transfer of foreign exchange assets to exporting countries.

Within the model, the benefits to both foreign and domestic consumers of rice are dependent upon a number of parameters such as price elasticity of demand, price and quantity of rice involved, number of periods in a year in which rate of dispersal deviates from that rate which accords with true production, forecast error before and after institution of a satellite-based information system, and proportion of supply variation borne by the foreign and domestic markets respectively. Welfare benefits to foreign consumers are positively related to price and proportion of variation borne by the export market and inversely related to price elasticity of demand and the number of time periods in a year. These benefits can be negative when forecasts of Thai and "other" supplies err in opposite directions.

Whatever their magnitude, benefits to foreign consumers of Thai rice are not likely to be considered justification for Thai expenditure on a satellite-based reporting system.* Expenditure of Thai

* An exception to this generalization should be noted. To the degree that Thai import policy is influenced by export flows and, hence, fluctuations in exports due to forecasting errors, Thai domestic consumers may benefit from a more regular flow of exports or, at least, a more accurate prediction of annual export earnings. If more accurate predictions of exports allow a more regular flow of imports, then a concomitant gain in consumer welfare for Thai consumers of imported goods is to be expected. Due to data limitations, this aspect of benefits could not be explored in this initial study.

national funds on a satellite-based system presumably must be justified in terms of benefits received domestically, i.e., internalized benefits. Our calculations would indicate that, so long as the Thai domestic market for rice is not completely insulated from foreign price and supply variations and so long as export licenses are dependent upon estimations of Thai production, there are benefits to be reaped by Thai (domestic) consumers from an improved forecasting system. These welfare benefits could amount to as much as $ U.S. 48 million annually. Even the minimum expected, $ U.S. 275 thousand per annum, is likely to be greater than the rice-associated increment in expenditure required by the institution of a satellite-based information system.

In addition to welfare benefits received by Thai consumers, Thailand could reap foreign exchange benefits from the more even flow of exports allowed by improved forecast accuracy. In terms of Thai self-interest, foreign exchange benefits could justify the implementation of a satellite-based reporting system.

However, this increase in Thai exchange earnings would not represent a net increase in world welfare or purchasing power but, rather a transfer of foreign exchange assets from improting countries to Thailand. Thus, from the point of view of a world-oriented authority, the foreign exchange effects of improved information systems would not be a suitable rationale of the satellite system. A world-oriented view would require that the <u>welfare</u> benefits justify the satellite-based reporting systems. Our preliminary analysis would indicate that these welfare benefits can be substantial and sufficient to more than cover the increment in costs involved.

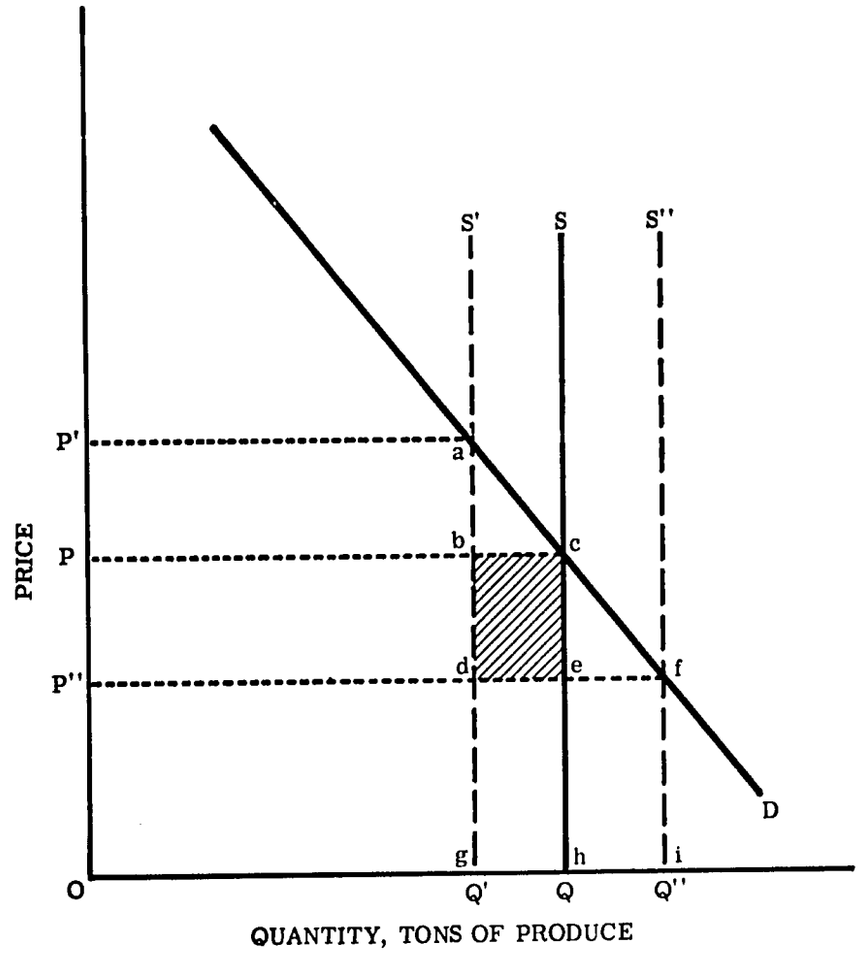

FIGURE B-1 INVENTORY ADJUSTMENT MODEL FOR EVALUATION OF BENEFITS FROM IMPROVED INFORMATION SYSTEMS

TABLE B-1. THAI GNP AND RICE PRODUCTION

Year*	Thai GNP,[1] billions Baht		Rice Producing Area, millions rai[1] (one rai = 0.4 acre)			Rice Production, 1,000 metric tons paddy		
	Current Prices	Constant (1962) Prices	Holding Area	Area Cultivated	Area Harvested	Source A [1]	Source B [2]	Source C [3]
1967	108.3	96.2	49.0	40.0	35.0	9,594	11,198	9,600
1968	116.8	104.4	50.5	44.7	39.1	10,772	12,410	10,770
1969	128.6	112.2	51.4	47.7	45.3	13,346	13,410	13,410
1970	135.9	119.7	52.3	48.8	44.6	13,401	13,500	13,570
1971	144.6	127.1	53.7	50.0	47.0	14,201	13,400	13,740
1972	n.a.	n.a.	54.8	44.6	41.0	11,669**	12,200	n.a.

* Year is that in which crop season begins, i.e. 1967 rice is harvested end of 1967 and beginning of 1968.

** Preliminary

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TABLE B-2. THAI RICE EXPORTS

Year	Total Export Earnings,[1] millions of Baht	Rice Exports[1]			Average Unit Export Price of Rice** Baht per metric ton
		Quantity, 1000 metric tons		Value, millions of Baht	
		Milled Rice Basis	Paddy* Basis		
1967	14 166	1 482	2 280	4 653	3 140
1968	13 679	1 068	1 643	3 775	3 535
1969	14 722	1 023	1 574	2 945	2 879
1970	14 772	1 063	1 636	2 516	2 367
1971	17 281	1 576	2 415	2 909	1 846
1972	22 491	2 112	3 250	4 437	2 101

* Assumes milled weight is 65 percent of paddy weight.

** Value of rice exports divided by tons of rice exports, milled basis.

TABLE B-3. THAI RICE EXPORTS TO PRINCIPAL CUSTOMERS

Year	Total Thai Rice Exports 1,000 Metric Tons	Imports of Thai Rice by Principal Customers																							
		Hongkong			Singapore			Malaysia			India			Indonesia			Philippines			Saudi Arabia			Senegal		
		1,000 Metric Tons	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [4]	1,000 Metric Tons [1]	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [4]	1,000 Metric Tons [1]	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [4]	1,000 Metric Tons [1]	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [4]	1,000 Metric Tons [1]	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [4]	1,000 Metric Tons [1]	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [4]	1,000 Metric Tons [1]	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [4]	1,000 Metric Tons [4]	Thai Rice as % of: Total Rice Imports*** [4]	Thai Rice as % of: Total Available Rice Supply**** [1]
1967	1,462	214	53.9	53.9	119	52.0	52.0	204	58.2*	11.0*	184	45.1	0.4	177	52.4	1.2	100	32.7	2.2	62	39.4	39.4	---	----	----
1968	1,068	132	41.7	41.7	131	42.4	42.4	191	65.0*	11.7*	208	58.0	0.4	45	6.9	0.2	**	--	---	72	46.9	46.9	---	----	----
1969	1,023	174	48.2	48.2	134	47.3	47.3	151	38.7*	8.8*	114	21.7	0.2	81	13.6	0.5	**	--	---	66	n.a.	n.a.	66	54.6	35.9
1970	1,063	196	57.8	57.8	139	59.2	59.2	128	61.0*	7.4*	34	13.0	0.1	144	17.5	0.8	**	--	---	121	56.9	56.9	71	53.0	26.4
1971	1,576	210	n.a.	n.a.	202	n.a.	n.a.	118	n.a.	n.a.	78	n.a.	n.a.	105	n.a.	n.a.	213	n.a.	n.a.	95	n.a.	n.a.	n.a.	n.a.	n.a.
1972	2,112	245	n.a.	n.a.	342	n.a.	n.a.	113	n.a.	n.a.	107	n.a.	n.a.	164	n.a.	n.a.	310	n.a.	n.a.	27	n.a.	n.a.	n.a.	n.a.	n.a.

*Percentages based on data for West Malaysia only.

**Less than 125 metric tons.

***Based on country import data in U.S. Department of Agriculture, Foreign Agricultural Service, Review of World Rice Markets and Major Suppliers, August 1972. If the data on Thai rice exports to a given country differed between Bank of Thailand and Review of World Rice, the latter figure was used to calculate Thai rice as a percentage of total rice imports since that was the source of total import data.

****Total available supply defined as total imports plus domestic production of the preceding year. Data on production from Review of World Rice, op. cit. Since Hongkong, Singapore, and Saudi Arabia are completely dependent upon imported rice, the percentage of imports represented by Thai rice is the percentage of Thai rice in total available supply.

TABLE B-4. FORECASTS AND FORECAST ERRORS FOR THAI RICE PRODUCTION

Year	Production Forecasts,[6] Million Metric Tons Paddy	Early Production Estimates,[6] Million Metric Tons Paddy	Final Production Estimates,[6] Million Metric Tons Paddy	Forecast Error as Percent of Final Production Estimate
1966	10.5 (*)		13.5	-22.3
1967	12.0 (*) 10.5 (9-12-67	11.4 (2-27-68)	11.2	+ 7.1 - 6.3
1968	14.0 (8-27-68) 12.0 (10-29-68)		12.4	+12.9 - 3.2
1969	12.4 (7-15-69) 14.0 (9-9-69 14.0 (12-2-69)	13.4 (2-25-70)	13.4	- 7.5 + 4.5 + 4.5
1970	14.0 (6-9-70)	13.5 (12-8-70)	13.5	
1971	13.4 (11-23-71)	14.0 (4-4-72)	13.4	0
1972	11.0 - 12.5 (10-31-72)		12.2	- 9.8 to + 2.5

U.S. Department of Agriculture, Agricultural Marketing Service, Grain Division, Rice Market News, various issues. Date of publication used is given in parentheses; (*) indicates forecast was mentioned in a later publication as "the previous forecast" but without a date of (prior) publication noted.

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TABLE B-5. BACKGROUND DATA FOR CALCULATION OF WELFARE BENEFITS OF IMPROVED FORECASTING

B-5.a. Total Rice Supplies in Principal Market Area, 1000 Metric Tons

Country	Domestic Production		Total Imports		Imports of Thai Rice[4]	
	1968	1969	1969	1970	1969	1970
Hongkong	--	--	359	339	173	192
India	54,642	60,706	516	254	112	33
Indonesia	16,231	17,530	604	800	82	140
Malaysia, West	1,279	1,422	225	195	132	119
Singapore	--	--	281	233	133	138
Saudi Arabia	--	--	121	181	35	103
Senegal	65	135	119	134	66	71
Total	77,217	79,793	2,225	2,136	733	796

N.B. Import figures for Thai rice may differ slightly from those in Table B-3. Data on rice imports from Thailand in Table B-3 are from Bank of Thailand Monthly Bulletin which has more recent years included. The above data are from U.S. Department of Agriculture, Foreign Agricultural Service, Review of World Rice Markets and Major Suppliers, (August 1972) which also contained data on production and total imports. For the sake of consistency, all data were taken from this single source for this table.

TABLE B-5. BACKGROUND DATA FOR CALCULATION OF WELFARE BENEFITS OF IMPROVED FORECASTING (CONTINUED)

B-5.b. Average Monthly Prices of Thai Rice, Baht per Metric Ton[1]

Period	Export Price, Unit Value Derived From Trade Statistics	Domestic Wholesale Price of Rice, Bangkok Metropolis	
		5% Broken	25% Broken
1971			
January	2231	1559	1362
February	2025	1342	1202
March	1990	1345	1130
April	1852	1350	1133
May	1796	1580	1418
June	1863	1645	1492
July	1715	1670	1513
August	1845	1700	1540
September	1775	1784	1598
October	1675	1739	1542
November	1710	1668	1508
December	1999	1554	1343
Average	1846	1578	1398
1972			
January	1895	1515	1415
February	1858	1476	1375
March	1856	1508	1407
April	1867	1481	1384
May	1857	1554	1464
June	1907	1613	1515
July	1896	1637	1538
August	2035	2055	1939
September	2275	2035	1884
October	2379	2176	2042
November	2698	2340	2144
December	2736	2471	2254
Average	2101	1822	1697

TABLE B-5. BACKGROUND DATA FOR CALCULATION OF WELFARE BENEFITS OF IMPROVED FORECASTING (CONTINUED)

TABLE B-5.b. Average Monthly Prices of Thai Rice, Baht per Metric Ton[1] (Continued)

Period	Export Price, Unit Value Derived From Trade Statistics	Domestic Wholesale Price of Rice, Bangkok Metropolis	
		5% Broken	25% Broken
1973			
January	3088	2360	2137
February	2914	2603	2343
March	2937	2699	2247

According to data from the American Embassy, Bangkok (agricultural attaché), export prices tripled by January 1974 and Thai wholesale prices had gone up by 50% over January 1973.

Note: During this period, the Exchange Rate was approximately 20 BHT/$U.S.

TABLE B-5.c. Domestic Price Elasticities of Demand Calculated for Several Food Products in the U.S.A.[9]

	Products		
	Wheat	Potatoes	Rice
G. E. Brandow	.02	.02a	.04
		.11b	
Henry Schultz	.03	.69	
Jim Matthews	.15		.10
P.S. George and G. A. King		.31a	
		.15b	.32
Grant and Moore			.16
Elasticities Selected For Study By Earth-Satellite Corp.	.10	.20	.16

Notes: a - retail
b - farm level

TABLE B-6.a ANNUAL WELFARE BENEFITS ACCRUING TO CONSUMERS IN PRINCIPAL MARKET AREAS, ASSUMING FORECAST ERRORS ARE IN SAME DIRECTION[a], THOUSAND $ U.S.

Assumed Forecasting Errors			Proportion of Variation in Dispersal Absorbed by Export Market, V								
ε_o Foreign Market Area	ε_r Thailand Currently	ε_r^* Thailand, With Satellite Based System	100 Percent			50 Percent			20 Percent		
			Price Elasticity, α			Price Elasticity, α			Price Elasticity, α		
			.1	.3	.5	.1	.3	.5	.1	.3	.5
ε_o=.15	ε_r = .15	ε_r^* = .05	43,590	14,530	8,718	21,480	7,160	4,296	8,470	2,823	1,694
		.03	52,140	17,380	10,428	25,670	8,557	5,134	10,170	3,390	2,034
		.02	56,440	18,813	11,288	27,760	9,253	5,552	11,060	3,687	2,212
	ε_r = .10	ε_r^* = .05	21,560	7,187	4,312	10,740	3,580	2,148	4,180	1,393	836
		.03	30,110	10,037	6,072	14,930	4,977	2,986	5,870	1,957	1,174
		.02	34,440	11,467	6,880	17,020	5,673	3,404	6,770	2,257	1,354
	ε_r = .05	ε_r^* = .03	8,540	2,847	1,708	4,190	1,397	838	1,690	563	338
		.02	12,840	4,280	2,568	6,280	2,093	1,256	2,580	860	516
ε_o=.10	ε_r = .15	ε_r^* = .05	29,560	9,853	5,912	14,440	4,813	2,888	5,670	1,890	1,134
		.03	35,300	11,767	7,060	17,250	5,750	3,450	6,800	2,267	1,360
		.02	38,180	12,727	7,636	18,640	6,213	3,728	7,400	2,467	1,480
	ε_r = .10	ε_r^* = .05	14,560	4,853	2,912	7,210	2,403	1,442	2,790	930	558
		.03	20,300	6,767	4,060	10,010	3,337	2,002	3,920	1,307	784
		.02	23,170	7,723	4,634	11,240	3,747	2,248	4,520	1,507	904
	ε_r = .05	ε_r^* = .03	5,730	1,910	1,146	2,800	933	560	1,130	377	226
		.02	8,610	2,870	1,722	4,200	1,400	840	1,730	577	346

[a] Assumptions:

1. Table 6.a is based on the assumption that forecast errors (ε_o, ε_r, ε_r^*) all have the same sign, i.e., err in the same direction in any given year.
2. Thai Rice exports to principal market area, S_x, are .75 million tons; this is half of assumed rice exports. Countries in area include Hong Kong, India, Indonesia, West Malaysia, Singapore, Saudi Arabia, and Senegal.
3. Total rice availability in principal market area exclusive of imports from Thailand, S_o, is 80 million tons annually.
4. There are three distinct selling periods in a year, T=3, of which rice is dispersed at "normative" rate in one.
5. Thai Rice production is 8.5 tons (milled).
6. Price is $100 (U.S.) per metric ton. N.B. - Benefits are proportional to price. Price used here was export price F.O.B. Bangkok in 1971-72 period. In truth, benefits should be calculated at retail prices, thus benefits should be some multiple of the figures given here, depending on the mark-up. Furthermore, prices have begun to climb at the wholesale level in the last year, export prices having nearly tripled from January 1973 to January 1974.

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TABLE B-6.b ANNUAL WELFARE BENEFITS ACCRUING TO CONSUMERS IN PRINCIPAL MARKET AREAS, ASSUMING THAI FORECAST ERRS IN OPPOSITE DIRECTION FROM FORECAST FOR REST OF SUPPLY,[b] THOUSANDS $ U.S.

Assumed Forecasting Errors			Proportion of Variation in Dispersal by Export Market, V								
			100 Percent			50 Percent			20 Percent		
			Price Elasticity, α			Price Elasticity, α			Price Flasticity, α		
ε_o Foreign Market Area	ε_r Thailand Currently	ε_r^* Thailand, With Satellite Based System	.1	.3	.5	.1	.3	.5	.1	.3	.5
ε_o=.15	ε_r = .15	ε_r^* = .05	-40,615	-13,538	- 8,123	-20,677	-6,892	-4,135	- 8,363	-2,788	-1,673
		.03	-48,917	-16,306	- 9,783	-24,859	-8,286	-4,972	-10,043	-3,348	-2,009
		.02	-53,090	-17,697	-10,618	-26,956	-8,985	-5,391	-10,886	-3,629	-2,177
	ε_r = .10	ε_r^* = .05	-20,491	- 6,830	- 4,098	-10,386	-3,462	-2,077	- 4,190	-1,397	- 838
		.03	-28,793	- 9,598	- 5,759	-14,568	-4 856	-2,914	- 5,870	-1,957	-1,174
		.02	-32,967	-10,989	- 6,593	-16,665	-5,555	-3,333	- 6,712	-2,237	-1,342
	ε_r = .05	ε_r^* = .03	- 8,301	- 2,767	- 1,660	- 4,182	-1,394	- 836	- 1,680	- 560	- 336
			-12,475	- 4,158	- 2,495	- 6,279	-2,093	-1,256	- 2,522	- 841	- 504
ε_o=.10	ε_r = .15	ε_r^* = .05	-26,590	- 8,860	- 5,316	-13,661	-4,554	-2,732	- 5,556	-1,852	-1,111
		.03	-32,074	-10,691	- 6,415	-16,440	-5,480	-3,288	- 6,873	-2,291	-1,374
		.02	-34,844	-11,615	- 6,969	-17,834	-5,945	-3,567	- 7,232	-2,411	-1,446
	ε_r = .10	ε_r^* = .05	-13,476	- 4,492	- 2,695	- 6,876	-2,292	-1,375	- 2,786	- 929	- 557
		.03	-18,971	- 6,324	- 3,794	- 9,655	-3,218	-1,931	- 4,103	-1,368	- 821
		.02	-21,741	- 7,247	- 4,348	-11,049	-3,683	-2,210	- 4,462	-1,487	- 446
	ε_r = .05	ε_r^* = .03	- 5,495	- 1,831	- 1,099	- 2,778	- 926	- 556	- 1,317	- 439	- 263
		.02	- 8,264	- 2,755	- 1,653	- 4,172	-1,391	- 835	- 1,676	- 559	- 335

[b] **Assumption:**

1. Contrary to Table 6.a, Table 6.b is based on the assumption that Thai forecasts err in the opposite direction from forecasts of the rest of rice supplied to the foreign submarket, i.e., that the sign ε_r and ε_r are alike but ε_o is of the opposite sign.
2. Thai Rice exports to principal market area, S_x, are .75 million tons; this is half of assumed rice exports. Countries in area include Hong Kong, India, Indonesia, West Malaysia, Singapore, Saudi Arabia, and Senegal.
3. Total Rice availability in principal market area exclusive of imports from Thailand, S_o, is 80 million tons annually.
4. There are three distinct selling periods in a year, T=3, of which rice is dispersed at "normalative" rate in one.
5. Thai Rice production is 8.5 tons (milled).
6. Price is $100 (U.S.) per metric ton. N.B. - Benefits are proportional to price. Price used here was export price F.O.B. Bankok in 1971-72 period. In truth, benefits should be calculated at retail prices, thus benefits should be some multiple of the figures given here, depending on the mark-up. Furthermore, prices have begun to climb at the wholesale level in the last year, export prices having nearly tripled from January 1973 to January 1974.

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TABLE 7. PRESENT VALUE OF BENEFITS FOR AN HYPOTHESIZED COMBINATION OF PARAMETERS AND ERROR RATES

Year	Forecast Errors			Undiscounted Benefits[a] $1000	Discounted Benefits[a,b] $1000
	$\varepsilon_o = \varepsilon_o^*$	ε_r	ε_r^*		
t=1	+.10	+.15	+.03	+5,750	+5,486
2	-.10	+.10	+.05	-2,292	-1,987
3	-.15	-.10	-.02	+5,673	+4,470
4	+.15	+.15	_.05	+7,160	+5,134
5	-.10	+.10	+.03	-3,218	-2,098
					+11,005 Total

Notes:

[a]Assumes V = .5, α = .3

[b]Discounted at 10 percent

TABLE B-8. ANNUAL WELFARE BENEFITS TO THAI CONSUMERS,[a] THOUSANDS $U.S.

Assumed Forecasting Errors For Thai Rice Crop		PROPORTION OF VARIATION IN DISPERSAL ABSORBED BY DOMESTIC MARKET, (I-V)								
		50 Percent			80 Percent			100 Percent		
E_r Current Error	E_r^*, Error With Satellite Based System	Price Elasticity, α			Price Elasticity, α			Price Elasticity, α		
		.1	.3	.5	.1	.3	.5	.1	.3	.5
E_r=.15	E_r^* = .05	17,200	5,734	3,440	44,040	14,679	8,808	68,810	22,937	13,762
	.03	18,580	6,193	3,716	47,560	15,854	9,512	74,315	24,771	14,863
	.02	19,010	6,336	3,802	48,660	16,221	9,732	76,035	25,345	15,207
E_r=.10	E_r^* = .05	6,450	2,150	1,290	32.250	5,505	3,303	25,805	8,601	5,161
	.03	7,825	2,609	1,565	39,125	6,679	4,007	31,310	10,436	6,262
	.02	8,255	2,752	1,651	41,275	7,046	4,228	33,030	11,010	6,606
E_r=.05	E_r^* = .03	1,375	459	275	6,875	1,174	705	5,505	1,835	1,101
	.02	1,805	602	361	9,025	1,541	925	7,225	2,408	1,445

[a]Assumptions:

1. Thai rice production is 8.5 tons milled of which 1.5 million is exported
2. There are three distinct selling periods in a year, T=3
3. Price is $100 (U.S.) per metric ton (N.B. - benefits are proportional to price). Wholesale prices ranged between $60 and $120 per metric ton in 1972, depending on quality grade and month. We assume an average wholesale price of $80 and a retail mark-up of 25% for illustrative purposes, thus a price of $100.

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Appendix C

ERTS DATA AS AN AID TO IMPROVED RANGE MANAGEMENT IN KENYA

C.1 INTRODUCTION

Kenya has set for herself a continuing objective of growing economic strength as the substance of the larger goal of social justice for every Kenyan citizen.[1] In common with many developing countries, Kenya has a variety of natural resources that she is seeking to marshal as effectively as possible to encourage economic development. Chief among these are agricultural, range, wildlife, water, and coastal resources. The Earth Resources Technology Satellite (ERTS) appears capable of providing the data inputs required for the production of adequate baseline and periodically updated resource information.

Because of time and man-hour limitations, the scope of this study was narrowed by choosing to concentrate on grazing land management in Kenya. This application was selected because of its major economic significance to the Kenyan economy, both for cattle ranching and tourism, and because it deals with a resource management function, grazing land management, to which ERTS has an appreciable application capability. This case study will seek to assess the economic ERTS-based grazing land management on parts of the Kenyan economy.

C.2 ERTS APPLICATIONS IN KENYA

The capabilities of ERTS in assisting in grazing land management, minerals exploration, environmental protection, soil surveys, and most other natural resource areas are relevant to Kenyan economic development. Based on our discussions both in the United States and Kenya and reports of the Kenya ERTS Principal Investigator, Mr. J. H. O. Omino, Permanent Secretary of the Ministry of Natural Resources, specific potential and current applications of ERTS imagery have been identified. Some of these applications are discussed below.

The Dutch have been sponsoring a soil survey in Kenya and have been depending upon ERTS data for their effort.[2] Kenya is planning a population census for 1976-77 and cartographic work will be needed beforehand;[3] ERTS could contribute in this effort. Analysis of land use patterns is another application to which ERTS could contribute in Kenya; conventional approaches currently used are too expensive to permit the development of a complete land use map for the country.[4] Data on soil moisture, water availability, weather prediction, dam locations, ground water, and crop forecasting are needed to help in Kenya's settlement plans,[5] all of which ERTS can at least partially provide. The Forestry Department has a continuing responsibility for timber inventory, which currently is conducted by air and ground. The air coverage currently cost a shilling per hectare, and a total of K£ 2000 per year is spent on the inventory process. ERTS could provide a savings here.

Soil erosion, land use, geology and dynamic monitoring of river systems are of particular interest to officials in the Ministry of Finance and Planning;[6] ERTS should be able to go a long way toward meeting these information needs. The location of groundwater resources, particularly urgent in the semiarid and arid areas of Kenya, is expected by Kenya's ERTS investigators to "facilitate much of the water resources survey work that will be carried out" in connection with Kenya's national master plan for water resources.[7]

As cited earlier in the introduction to the report, a compelling reason for developing countries to develop their own capabilities to analyze ERTS imagery is to familiarize themselves with the nature and extent of their natural and mineral resources so that they will not be placed at a disadvantage when negotiating with large private corporations that are eagerly gearing up to interpret LDC ERTS imagery. At least one large mineral resource (oil) company has been making

extensive use of ERTS imagery of Kenya and has found it very useful, particularly in facilitating the extension of interpretations based on more local observations by ground or aircraft into unknown areas. Analysis of the imagery is taking place both in Kenya and at company headquarters. Rapid interpretation of imagery would give an advantage to one company over another or over a government.

Kenyan range experts have already analyzed some ERTS-1 imagery. They emphasize the importance of vegetative change monitoring to grazing land management, particularly grass growth/precipitation effects. They have found that vegetative changes show up well in color composite imagery and are enthusiastic about the potential of ERTS data for habitat monitoring. Their greatest concern is the assurance of continuing data and foreknowledge of where the ERTS coverage will be.[8] A particularly important capability ERTS can provide is the ability to monitor range conditions many miles away from the roads. Most data gathering on range conditions is currently done on the ground.

Significant vegetative classification capability from ERTS imagery has already been demonstrated in Kenya by Dr. E. E. Zamierowski of the University of Nairobi. He reports:

"From the [ERTS] colour composites the following vegetation classes could be distinguished

a. grassland
b. bamboo thicket
c. podocarpus forest
d. podocarpus - cedar forest
e. cultivation clearings
f. intensive cultivation
g. acacia woodland (this was less easy to relate to the map than the more dense forest and grassland types)

h. combretum savannah

i. burned fields

j. conifer plantations

k. tea plantations

"The area of podocarpus forest recognized on the eastern side of the Cheranganis was seen to be much reduced from that shown on the map, indicating the potential for up-dating information from older mapping. Where the vegetation becomes sparse, as in the arid parts of the Rift Valley, it is difficult to distinguish types shown on the map-probably due to the greater reflectivity of the ground surface in comparison to the vegetation. Broad-leaved savannah types were also difficult to recognize on the enlargements."[9]

Dr. W. G. Sombroek, the Project Manager of the Kenya Soil Survey Project, reports significant application capability of ERTS for soil mapping:

"The project has started to use the ERTS-1 imagery as a tool for the mapping of soil resources at exploratory level on scales at 1:500,000 - 1:1,000,000 for the country as a whole. Particularly for the arid and semiarid parts of the country (2/3 of the total surface of Kenya) the imagery is proving to be of invaluable help. Due to their limited or non-existing rain-fed production potential, these areas have been studied very little in the field, with ordinary techniques of soil survey. Broad soil mapping in these areas is however much wanted, not only for pure scientific purposes but also because of plans for both irrigation development and range management development. In these areas, covered for a good part with unconsolidated quaternary sediments, the soils show in general a very clear-cut relationship with broad physiographic units, like sheetwash plains river terraces, floodplains etc. Therefore relatively few field observations and sampling are sufficient for mapping if the mentioned

physiographic units can be accurately delineated. This can be partly done from existing geological maps and aerial photographs, but the ERTS-imagery is not only a much quicker and cheaper tool; it is also more reliable and refined. This is because each physiography - soil unit has its own pattern of soil infiltration rate, drainage condition, soil moisture storage capacity, effective rooting depth and salinity - alkalinity often a reflection of quaternary climatic change. Moisture always being in the minimum, these differences in green foliage are reflected very strikingly on the false - colour ERTS images. At the same time the over-all occurrence of green matter is so restricted that differences in the appearance of the bare soil surface show up equally well.

"The images are also an excellent tool for teaching and training in physiographic aspects of soil survey and land evaluation in general."[10]

Dr. Charles Pase, Habitat Ecologist for the FAO/Kenya Wildlife Management Project, reports:

"Our major interest in the ERTS-1 imagery for Kajiado District, Central Province, Kenya lies in mapping areas of extensive drought, and areas of varying plant growth stages. "Phenology" or growth stage of range vegetation appears to be highly correlated with distribution of certain free-range game animals, notably wildebeest and zebra.

"Sequences of false-colour ERTS-1 imagery will be compared with animal distribution data from our District-wide reconnaissance flights which are planned for 3-4 times per year during the Wildlife Management Project. We feel that ERTS imagery will significantly aid in interpreting the game animal distribution data obtained by these large-scale census flights.

"Unfortunately the area in question was only scanned once and that too under heavy cloud cover. Repetitive coverage would have been extremely beneficial."[11]

Mr. Simon Taiti, a biologist and Head of the Research Division in the Game Department of the Ministry of Tourism and Wildlife, reports on the "Interpretability of ERTS-1 False Colour Imagery for Detailed Vegetation Mapping with Reference to the South Western (MARA) Area of Kenya (E - 1048 - 0712 - 9th Sept. 1972) 1:1,000,000":

"Having mapped the vegetation of the Masai Mara Game Reserve in the Narok District by physiogomic criteria determined on the ground in 1971-72, and using aerial photographs to determine changes in the vegetation, I have attempted to analyse visually and interpret the ERTS-1 false colour imagery in a test of consistency of registration of the known data.

"To key and decode the signatures of the false colour images I am using a 'Robbialas Paints Colour Card'. The scene includes Narok District (entire), Mau Forest (southern half), Lake Naivasha, southern end of Aberdares ranges, Suswa, Nguruman Escarpment, Magadi and Ngong-Nairobi areas.

"The Masai Game Reserve is roughly 600 square miles and within this scene, with prior knowledge of what to look for, I am able to depict about 35% of the type-units of vegetation, and the terrain fairly well.

"The Table C-1 below shows the codes for signatures and success of registration of the scale of one frame (approx. 7.5" x 7.5" for 13,000 miles):

"At present scale of 1:1,000,000 approximately 35% of detailed data is discernible. An enlargement of x3 to x5 may bring about 90% success."[12]

The full utilization of the advanced data capabilities of ERTS in these and other applications represents a significant economic opportunity to the Kenyan government. Before such applications are undertaken, full and careful consideration must also be given to the costs that these applications will also entail. Because the scope

of applications and their benefits and costs are so broad, this study has confined itself to an examination of the benefits from one particular application, that of grazing land management. This discipline was selected because of the direct and indirect significance of Kenya's grazing lands on her economy through ranching and tourism, and because it impinges upon a major economic issue confronting Kenya's economic planners, the conflict between cattle and wildlife for limited range resources. From the results of ERTS experiments to date, there is a reasonably strong basis for believing that improvements in biomass carrying capacity of rangelands are possible through an enhanced grazing land management capability based on ERTS.

C-3 HYPOTHETICAL ERTS OPERATIONAL SYSTEM

The accrual of benefits to the Kenyan economy will not take place automatically. Particular kinds of information must be extracted from the imagery, analyzed, and often compared with previous imagery. Based on the information extracted, resource management decisions must then be made and specific management actions developed and disseminated to the users in the wildlife and ranching areas. In certain instances on-site assistance may be required in implementing the operating level resource management actions. A viable and functioning administrative organization for this interpretation - analysis - decision - dissemination - implementation process should tend to produce economic benefits at the higher end of the spectrum presented in the later economic analysis; a poorly functioning organization should lead to the type of benefits at the lower end of the spectrum.

As stated earlier, economic benefits from improved grazing land management capabilities will accrue primarily through the effective increase in the biomass carrying capacity of Kenya's rangelands.

This can come about through ERTS's capabilities to

-monitor gross growth/precipitation effects

-measuring vegetative vigor and growth stage

-real-time river monitoring

-monitor wildlife migration patterns (particularly useful in conjunction with biotelemetry)[13]

-locate grass fires

-locate remote villages

These sorts of application capabilities should lead to short- and long-term management decisions such as outlined in Table C-2.

C.3.1 OPERATIONAL MANAGEMENT SYSTEM

An operational system in Kenya might have the following structure:

-an imagery interpretation team, consisting of a range ecologist, a hydrologist, and a geologist, and possibly others

-a resource executive management team, consisting of the above, plus an individual from the Ministry of Finance and Planning, Agriculture, Natural Resources, Tourism and Wildlife.

-local resource management agents in various locations throughout the country with easy access to field resource managers.

This management approach provides for the interpretation of the imagery, the formulation of resource management policy and specific actions, and the dissemination of the information and actions to the users. While setting up working interpretation and resource management teams will involve some difficulty, the major problems will probably not occur at this end of the information chain. The key link that will require attention and nurturing to insure its effectiveness will be the interface between the local resource agent and the user. Trust and belief in the soundness of the management decisions will develop only with time. Important both for the user and the central

resource managers will be a feedback mechanism to transmit questions, information, and results back from the user to the central managers and even the imagery interpreters. An ERTS management system will undoubtedly be characterized by a dynamic learning process for all sectors of the management system; this process should be encouraged.

C.3.2 INCREASES IN RANGE PRODUCTIVITY

All of the interpretation and management measures outlined before will act to improve the effective carrying capacity of grazing lands. What is a reasonable estimate for ERTS-based range productivity increases? As might be expected, there is no hard and fast number. There appears to be little doubt, however, that the institution of an ERTS-based system in Kenya, or anywhere, will lead to <u>some</u> improvement in grazing land management. Estimates for the United States have shown substantial variation.

Seevers and Drew[14] have reported that improved range management could provide a twenty percent increase in animal productivity in the Nebrasks Sand Hills region. Experiments done by Gerald W. Dean and others using simulation and programming models and reported by Frank have indicated that increased ability to predict grazing land forage production would increase the average farm return from 2-12%. Frank also states that 1970 technology applications could improve range efficiencies by 70-100%.[15] Heiss has estimated total agricultural productivity improvement from an ERTS-type of capability at 0.5% for the United States.[16] One remote sensing specialist in grazing land management has estimated thirty to fifty percent improvement[17] in range efficiency. The USDI Cost-Benefit Analysis Study has used a parametric approach in their case study on range land management, varying productivity improvement attributable to ERTS between 0.5% and 2% in steps of 0.5%.[18]

Table C-3 summarizes the productivity increase estimates that have been found to date. A firm lower bound appears to be 0.5%, while 10% to 20% appears to represent an approximate upper bound. It should be pointed out that these estimates are for the U.S. only, where an existing rangeland management system of some sophistication is already operational. In Kenya, the percentage increase in productivity must be calculated from a much lower range management basis, indicating that higher percentage increases for the application of the same technology should be possible. At the same time, the management information and dissemination systems necessary for the most effective utilization of ERTS data are probably better developed in the U.S. than in Kenya. This would tend to reduce the likely range of productivity increases available to Kenya from ERTS.

Until more definitive results come in from the ERTS experiments, particularly those overseas, no hard and fast estimate can be made. To cover both the optimistic and pessimistic factors described above, this study will use a high-low-middle approach with three productivity values: 20%, 1%, and 5%. Other values can and should be substituted into the analysis as new information becomes available.

C.2 ECONOMIC MODEL OF BIOMASS CARRYING CAPACITY ESTIMATION CAPABILITY

The timely availability of data on the carrying capacity and vegetative conditions of grazing lands is a desirable capability that has economic value to any human society. The nature and extent of that value depends upon the existing and projected conditions of the society's economy. The economic benefits conferrable by the ERTS data arise from:

1) Cost savings over an esisting survey system, if any.

2) The economic value of the effective increase in land carrying capacity net of the increase produced by an existing survey system.

The first effect can be properly assessed by determining the magnitude of the net reduction in program costs of ERTS surveillance over an existing system. The only competing surveillance and monitoring system identified is the aircraft monitoring system proposed by the Canadian International Development Agency (CIDA), which will be described below.

The second effect is far less amenable to straightforward benefit estimation. The approach that this study follows is to attribute benefits to ERTS based on percentage increases in projected earnings. For tourism, improved carrying capacity will permit greater numbers and increased vigor of wildlife which should increase tourist amenity and, the assumption is made, the growth rate of tourist-days and expenditures spent in Kenya. For the cattle industry, increased carrying capacity should translate into a direct percentage increase in industry earnings if a perfectly competitive market is assumed. No quantitative attempt is made to estimate ERTS impact on traditional nomadic ranching or wildlife ranching, since economic data on the former are lacking and the latter is still an experimental industry in East and South Africa, although it shows much promise. For these two cases, a brief qualitative assessment is made. For all the industries, growth is also dependent upon infrastructure development, such as roads, water, etc.; adequate levels of infrastructure are assumed.

C.4.1 COST SAVINGS

One potential source of economic benefits to Kenya from ERTS is the substitution of ERTS imagery for an existing surveillance, monitoring, or mapping program. If the cost to Kenya of using ERTS

imagery is less than the existing method of data collection, and the quality of the data are comparable, then cost savings from ERTS are a valid economic benefit. Any additional capability provided by ERTS must also be priced and counted as a benefit as well.

No on-going Kenyan program for which ERTS would provide a suitable substitute has been identified. There is, however, an aircraft surveillance program that is in the advanced planning stage for which ERTS could provide acceptable substitute data. This program is to be initiated in 1975 on behalf of Kenya by the Canadian International Development Agency (CIDA) as part of a larger coordinated international assistance effort, including the World Bank, the United States Agency for International Development, and others. Kenya has expressed substantial interest in the contributions that ERTS could make to this program. A plan for implementing ERTS-B data has been submitted by GOK's Ministry of Natural Resources to NASA,[19] and the concept appears to have backing within the Ministry of Finance and Planning.[20] The objectives of the aircraft surveillance program are:

- to provide baseline and non-variant data on cattle, livestock, and wildlife numbers and distribution
- to collect variant data on vegetation and other environmental parameters, land use, and human, livestock, and wildlife populations
- to analyze and process the baseline data to develop a comprehensive land use inventory
- to make predictions on significant changes in animal densities and develop predictive models
- to indicate requirements and priorities for further research on herds, wildlife, and ecosystems

The program envisages an initial survey of the entire country followed by tri-annual coverage of about half the country. An official

connected with the CIDA program has estimated that the ability of ERTS to monitor vegetative conditions would reduce the aircraft requirements of the program by 25%.[21]

As currently conceived, the program will involve three specially-modified Cessna 185 aircraft and crews of three pilots and nine trained observers. Fixed program costs such as airplane cost, hangar costs, fuel positioning costs, etc., will be ignored. The cost savings will be assumed to arise entirely from savings in aircraft operations and maintenance (O&M) costs and personnel salaries. O&M costs are projected by Canada at C$78,900 per aircraft per year, or C$236,700 per year for the fleet of three. At current exchange rates this is equivalent to K£ 82,000 per year.

No direct line item for personnel costs appears in current CIDA program estimates, requiring another approach to be adopted. In January of 1971, the East African Wildlife Society devoted K£ 1882 to pay seven months' salary for an aircraft pilot.[22] For a full twelve months this comes to K£ 3100. Assuming a 50% overhead factor produces an annual program cost of K£ 4700. Assuming that the nine other specialized personnel earn the same salary as the pilots results in costs of K£ 56,000 per year in 1971. Since that time the Nairobi Middle Index of Consumer Prices has increased by about 30%,[23] introducing this factor into personnel costs gives a total personnel cost of K£ 73,000 per year. Thus, total O&M and personnel costs for the CIDA program can be estimated at K£ 155,000 per year. A 25% reduction in these costs gives an annual gross benefit attributable to ERTS of K£ 39,000.

One modifying factor to consider is cloud cover and weather. Both affect aircraft operations, and cloud cover affects satellite performance. The average cloud cover of the 227 ERTS images through 3/25/74 is 34%. A histogram of cloud cover incidence is presented in

Figure C-1. The data in this figure are for Kenya as a whole and do not reflect cloud cover variability in individual areas within Kenya. It is still of value to note that almost half the imagery has 20% or less cloud cover, and two-thirds of the imagery has 40% or less cloud cover. To reflect the reduced economic value of ERTS imagery due to cloud cover, relative to aircraft, we shall use the average cloud cover percentage of 34%. However, since cloud cover and the storms that often accompany clouds will impede aircraft coverage as well, we shall divide the 34% figure by two, resulting in ERTS data being worth 83% that of aircraft. Multiplying our K£ 39,000 benefit figure by this percentage gives K£ 32,000.

Under existing plans, the CIDA program is to begin in 1975. For two years the program will be conducted by the Canadians, after which time they will begin to phase out and Kenyans will take over. By 1979 the program is expected to be completely Kenyan financed and conducted. Thus the K£ 32,000 savings will be assumed to begin in 1979 and continue into the foreseeable future.

C.4.2 ECONOMIC BENEFITS

The economic value of ERTS to the Kenya/CIDA surveillance and monitoring program is direct program cost savings in the form of reduced aircraft requirements. The annual benefits from this are estimated at K£ 32,000 in 1979. The 1974 present values for each of these three contributions at discount rates of 0, 10, 20, and 25 percent and for 1986 and 1996 planning horizons are seen in Table C-4.

C.5 BENEFITS TO TOURISM

The effect of an increase in carrying capacity on the growth of tourism in Kenya is a particularly difficult one to assess. There is no doubt that one of the prime attractions of Kenya to tourists is its

almost unique assortment of large mammals. As a World Bank appraisal has put it, "the rapidly growing tourist industry of Kenya is largely based on the abundance and diversity of the wildlife."[24] Kenya's eight national parks and four county council game reserves are the focal points of tourist activity.

The question is one of establishing the relationship between tourist expenditures and increases in park and preserve range carrying capacities. An increased carrying capacity would permit either larger numbers of animals, healthier and heavier animals, or both. The resulting increase in tourist amenity should lead to greater tourist expenditures, both from tourists who would visit Kenya anyway and from the incremental tourists drawn to Kenya by the greater amenity offered.

What we would like to know is the approximate range of (Δ tourist expenditures) / (Δcarrying capacity). A more useful form of this is $\frac{\Delta \log TE}{\Delta \log CC}$, or, in more understandable terms, the percentage increase in annual tourist expenditures for a given percentage increase in biomass carrying capacity. Two ways to attempt to find a direct measure of this relationship would be: 1) intensive tourist surveys; 2) a multivariate regression using tourist, wildlife census, and other relevant time series data. Tourist surveys by their very nature would be hard-pressed to provide a quantitative measure of tourist expenditure sensitivity to carrying capacity, although some important qualitative relationships can be found in this way. An attempt to set up a multivariate regression was made, but the inconsistencies, inaccuracies, and general unavailability of data on wildlife censuses discouraged our pursuing this approach any further.

The government of Kenya did conduct a tourist survey from September 1968 to August 1969 at Nairobi Airport.[25] This survey showed that the decision to travel to Kenya was mostly influenced by friends (39%) and other factors (22%) which were assumed to be personal in nature.

Presumably people would encourage their friends based on what activities they enjoyed while in Kenya. Of eighteen activities specified, the highest ranking was "game watching" at 73.4%. Second was "eating and drinking" at 70.2%, closely followed by "photography game" at 69.6%. These results further support the thesis that wildlife are very important to tourist amenity, and it must be assumed that additional wildlife would increase this amenity level.

Lacking a firm quantitative estimate for tourist expenditure sensitivity, we shall adopt a conservative parametric estimation approach. We believe that a credible range for this parameter is

$$0.01 \leq \frac{\text{\% change in tourist expenditures}}{\text{\% change in biomass carrying capacity}} \leq 0.10$$

This says that a doubling of biomass carrying capacity will produce anywhere from a 1% to a 10% increase in tourist expenditures.

We introduce here two factors that will tend to reduce the net economic value of ERTS imagery to tourism. The first factor, (1-KC), accounts for the benefits that would accrue to tourism through the mechanisms described earlier from the Kenya/CIDA aircraft survey program. This factor is estimated at 0.75, reflecting the aircraft program's lower annual coverage frequency (3 versus 20 for ERTS) and reduced extent of coverage (half versus all of Kenya). Assuming that each incremental frequency is worth a fraction less than one of the previous frequency increment, a KC factor value of 0.75 suggests that the factor value fraction is about 0.80, which seems reasonable.

The other factor introduced is that for cloud cover, (1-CE) which was discussed earlier. For 34.4% mean cloud cover, we assumed that half the cloud cover would affect aircraft operations as well, introducing a cloud cover factor of 17%, or 0.83.

Thus, the net impact of ERTS on tourist expenditures in Kenya is estimated to be

$$R = (1-KC)\ (1-CF)\ \frac{\Delta\ \%\ TE}{\Delta\ \%\ CC}\ (\Delta\ \%\ CC)$$

TF = tourist expenditures
CC = carrying capacity

R is a factor that is added to the projected growth rate of tourist expenditures rather than used as a direct multiplicative factor. This is because of the feedback mechanism which we postulated earlier, whereby tourist visits are motivated at least in part by friends who have been there. Thus, if ERTS-based range management leads to additional tourist visits, then these extra visits will in turn create additional visits, which lead in turn to more visits, ad infinitum. Thus, we suggest that if the non-ERTS annual growth rate of tourist expenditures is r%, the annual growth rate with ERTS will be r + R%.

The importance of increased carrying capacity to continued and expanded tourist expenditure growth is further underscored by the twin impacts of poaching and park and preserve capacity constraints. In recent months, poaching activity against elephants, according to Africana magazine, has amounted to "almost a free-for-all attack" encouraged by unprecedented world prices for ivory. The ability to more effectively manage more elephants and other game represents one measure that can help to lessen the long-term impact of poaching on Kenya's wildlife population. Definitive resolution of the poaching problem will require more direct measures such as tighter international control of ivory markets.

The problem of park capacity is a very uncertain one, though it is certain to be important before too many years pass. For approximately static park sizes, the growth in numbers of tourists has meant an ever-increasing density of tourists and an ever-increasing human impact in the parks and preserves. Wheel tracks have been found to affect local drainage patterns by diverting the slow wash of rain water, sometimes

causing serious gullying and erosion. In certain areas tourists have been found to cause ostriches to desert their nests every year by driving their cars too close to the sitting birds.[26] Especially for Nairobi Park, and increasingly for others, restrictions on off-road vehicle activity and the natural limits of human intrusion into park ecosystems may dampen Kenyan tourist expenditure growth in the future. An increase in the wildlife biomass of the parks, preserves, and surrounding areas will tend to offset this possible declining tourist amenity.

C.5.1 PROJECTIONS OF TOURIST DEMAND

Estimates of ERTS impact on Kenya's tourist industry depend upon the industry's anticipated future expansion. Past tourist industry data are presented in Table C-5. Data on numbers of visitors, while helpful, is not as useful as data on duration of stay and tourist expenditure. Kenya has observed that tourist expenditures tend to grow less rapidly than the growth in visitor days because there is a tendency for expenditure to fall with increased length of visit.[27]

Table C-6 projects the three tourist measures out to 1996 using a high-low-middle approach. While Kenya's tourist business has experienced rapid growth in the past ten years, it seems unlikely that this growth rate will continue unabated over the next twenty years. For this reason, the 20% growth rates in visitors and visitor days have been used as the upper limits in the projections. 10.9% visitor expenditure growth, the 1971-1972 increase, is already below the growth of the previous two years. Data through the first three quarters of 1973 show a decline in tourist and business visitors of 14% over the comparable 1972 period, although most of the loss was concentrated in the first quarter. The worldwide oil shortage may also have reduced visits to Kenya.[28] 11% was not chosen as the high-growth figure since it is expected that expenditures per visitor-day will soon level out.

The second Kenyan Development Plan[29] thought in 1969 that annual tourist growth would likely be somewhat below 15%, while total tourist expenditure would grow by 15%. As often happens in forecasting, the opposite has taken place.

C.5.2 TOURIST INDUSTRY PROFITABILITY

Although Kenya earns a substantial amount from tourist expenditures, not all of this is economic gain. Tourist expenditure figures do not indicate the net contribution of tourism to the Kenyan economy. To determine this net value, the alternative use value of the resources applied to tourism must be deducted.

Some tourist expenditures leak from the economy through tourist industry import requirements and profit repatriation. The Development Plan estimates this leakage at 25%,[30] and Mitchell puts this figure at 22%.[31] The further breakdown of tourist expenditures is seen in Table VII, taken from Mitchell. His explanation of the rows of the table are:

Row 3, profits and depreciation remaining in Kenya, cannot be dealt with until the time stream of receipts less cost of tourism is considered.

Row 4, tax on overseas investment income, is all gain on the not unreasonable assumption that these investors would not have invested in, and earned profits from, non-tourism activities in Kenya.

Row 5 (a), renumeration of low-skill labour, is comprised one-half of opportunity cost, and one-half net gain. The estimate of gain is probably conservative. Without giving full justification, suffice it to note that the minimum wage earned in most tourist activities is around £10 per month, and many persons earn much more than this due to union agreements. On the other hand, agriculture, which is the major alternative for unskilled workers, yields incomes of £3-4 per month.

Row 5 (b), renumeration of high-skill labour, is assumed to consist entirely of opportunity cost. That is, it is assumed that skilled workers in tourism would find alternative employment at the same salaries (or emigrate) in the absence of tourism. Note that insofar as all expatriates employed in tourism are classified as high-skill workers, none of the net current value accruing to labour goes to expatriates.

Row 6, rent, is assumed to consist of opportunity cost. This assumption is undoubtedly conservative.

Row 7, net indirect taxes, is pure gain. Net indirect taxes consist of import and excise duties, license and park entry fees paid directly or indirectly by tourists (e.g., excise on petrol), less the cost of all government agencies attributable to tourists (including a share of the expenses of running the airport, the immigration department, road maintenance, National Parks and Game Reserves, and an imputed rent for land used by Government in these activities). This item is tantamount to a sales tax charged to tourists, after deducting all costs to Government of serving them. It is pure gain, since the resources devoted to tourism would not earn a net export tax (after deduction of cost of Government services provided) of over 3% in any presently known non-tourist export activity.

Rows 9 and 11, efficiency gain and tariff valuation adjustment, are explained in detail in Mitchell.[31] Suffice it to note that insofar as the official rate of exchange (K£ 1 - US$ 2.80) undervalues foreign exchange, and since all earnings from tourism are foreign exchange earnings (if evasion is ignored), some adjustment should be made to take account of this fact. These rows indicate that the undervaluation in the case of Kenya may come to 10-19% of the value of tourist receipts, when considering net current value alone.

Row 12, total net current value, simply totals the previously identified gains. These amount to between one quarter and one third of tourists' expenditures.

Table C-7 indicates a high level of profitability for tourism. At a 20% opportunity cost of money, the net economic gain from tourist revenues becomes 38-20 = 18% + 25% to 31%, that is, 43% to 49%. At zero discount rate, this range jumps to 68-69%.

A 1971 International Finance Corporation analysis[32] estimating 1977 tourist project economics shows approximately the same conditions for the Kenyan tourist industry. Foreign exchange leakage was put at 24.6%. Applying Mitchell's estimates of labor opportunity costs and foreign exchange undervaluation gives a figure for tourist economic benefit of 64-68% of tourist expenditures.

With increasing competition among East African countries for tourists and currency realignments, these figures may overstate the profitability of tourism in future years. Therefore a figure of 60% will be assumed. This figure is applied to the projected tourist expenditure figures in Table C-8.

C.5.3 ESTIMATION OF BENEFITS TO TOURIST ERROR

Using the approach described previously, we can now calculate the benefits of an ERTS-management system on the tourist sector. The results are seen in Tables C-9 - C-14 for parametric values of tourist expenditure growth (TEG), TE/carrying capacity sensitivity, discount rate, time horizon, and effective increase in carrying capacity. Choosing an 11% TEG, 5% TE/CC sensitivity, 20% discount rate, 1986 time horizon and 5% increase in carrying capacity as conservatively representative values, we find that ERTS has a present value to the tourist sector alone of K£ 770,000, or over $2,000,000. At 10% discount rate this jumps to K£ 1,700,000.

C.6 GRAZING LIVESTOCK

Livestock are of chief importance to Kenya through their support of those people that are not active participants in the monetary economy. Nonetheless, livestock account for an appreciable share of Kenya's marketed agricultural output. By improving the grazing land management process, through accurate real-time assessments of range biomass carrying capacity, ERTS should be able to make a significant contribution to this sector of the Kenyon economy.

Table C-15 shows data on marketed livestock production revenues from 1967 through 1972. The average growth rate over this five year period was used to project out over the next twenty-five years, except that where this rate exceeded 10%, as for sheep, goat, and lamb slaughter and dairy products, the rate was reduced to 10%.

The net economic contribution of ERTS is not the increase in cattle revenues that greater productivity permits. Presumably greater productivity will also entail additional costs, although average total costs will probably decrease. A lower bound on the value of this increased productivity should be the extra revenues multiplied by the net percentage profitability of cattle operations. Unfortunately, such economic data were not available. However, data on the profitability of the agricultural sector as a whole are available.

In 1971, earnings from agriculture and forestry were K£ 17,720,900.[33] Gross farm revenue in 1971 was K£ 86,695,000.[34] This is a gross profit margin of 20.4%. According to an agricultural survey in one province of Kenya,[35] gross profitability of large farms was 21.8% in 1967/8, 21.2% in 1968/9, 22.6% in 1969/70, and 25.0% in 1970/1. Deducting interest charges for capital gives net returns of 12.1%, 10.7%, 12.6%, and 17.0% during those same years. Surprisingly, the same survey showed that, for the four years studied, returns on capital were never higher than 9.9%. This suggests that there is ample room for productivity improvement in farming.

To arrive at a figure for net profit margin, we shall take the average of the 1967-1971 Trans Nyoia net figures, since the gross figures seem to agree with the 1971 all-Kenya data. This produces a profit margin figure of 13.2%, or 13% for our purposes.

From this information, then, we shall calculate benefits to the cattle sector in the following way:

Benefits = Benefits with ERTS - Benefits without ERTS

$$\text{Benefits} = \sum_{j=1}^{4} \left[\left(E_{oj} + \delta E_{oj}\right)\left(1 + S_j\right)^t - E_o\left(1 + S\right)^t / \left(1 + r\right)^t \right]$$

$$= \sum_{j=1}^{4} \delta E_{oj}\left(1 + S_j\right)^t / \left(1 + r\right)^t$$

WHERE

E_{oj} = earnings from j^{th} cattle sector without ERTS, equal to 0.13 times gross revenues

δ = net percentage contribution of ERTS to earnings through increased carrying capacity, equal to the product of carrying capacity improvement, cloud cover factor and the Kenya/CIDA factor.

S = growth rate of earnings in cattle sector j

r = discount rate

t = year

j = 1 cattle and calves for slaughter

j = 2 sheep, goats, and lamb for slaughter

j = 3 hides and skins

j = 4 dairy products

Using this approach and our assumptions on carrying capacity improvement, growth rates, discount rates, and time horizons, we compute benefits seen in Table C-16. The benefit estimates range from K£ 85,000 to K£ 28,000,000 depending on the assumptions made. Using the relatively conservative assumptions of a 5% carrying capacity improvement, a 1986 time horizon, and a 20% discount rate, this model predicts the present value of cattle benefits to be K£ 560,000.

C.7 CATTLE VS WILDLIFE: THE CONFLICT IN KENYA

A significant minority of the Kenya population bases its physical and cultural existence upon a nomadic pastoral life. In centuries past the populations of cattle and tribespeople were subject to natural ecological checks and balances. Competition with wildlife for forage existed but did not present a major problem since the human population was relatively small and veterinary services for cattle were non-existent. With the advent of health services for both man and beast, and with colonial rulers beginning to obstruct natural nomadic migration with political boundaries, the stability of the ecosystem was upset. A population surge of humans led to a surge in head of cattle, with the result that competition with wildlife for forage resources has become a serious problem. As has been true throughout the world in cases of common grazing grounds, the lands have been overgrazed with the result there is less for all competing uses. This shortage of forage resources not only reduces numbers of cattle, but it reduces numbers of wildlife as well, perhaps the mainstay of the tourist industry, now Kenya's largest foreign exchange earner.

The conflict in Kenya between cattle and wildlife goes beyond the arena of the ecosystem and reaches into the very sinews of tribal society. To the Nilo-Hamitic tribespeople (the Turkana, the Kalenjiu, and the Masai) cattle are the mainstay of their tribal economy and are

central to their way of life. Milk is essential to their diet, and cattle blood is also important.

Cattle meat is eaten only on ceremonial occasions.[36] In addition to their dietary significance, cattle are of great importance as a measure of individual wealth. As part of this measure of wealth, numbers of cattle are considered more important than their vigor and weight.[37] Thus any new approach to improve the carrying capacity of Kenya's range lands, with or without satellite data assistance, will encounter this sociological constraint.

Cattle also represent a very important source of employment for the Masai. The warriors, or moran, Masai males of ages variously between 14 and 27, "have no duties apart from defending their people and cattle against wild animals and enemies and on suitable occasions taking the offensive."[38] At this period in their lives the males begin their acquisition of cattle, much as young males in other societies begin to seek their fortunes at this age.

In the past, the problem of range overgrazing has handled by the simple expedients of invasion of neighboring lands and warfare. But the limitations of Nasai expansion brought by the colonial government played midwife to a new class of problems to Kenya, those of and concomitant erosion, floods, and eventual starvation to the Masai. Under such ecological pressure, the Masai have begun to change their nomadic pastoral ways and are forming settled, enclosed ranches.[39] Certain Turkana tribespeople are returning to the role of hunter-gatherer after centuries as herdsmen.[40]

There are reports that government efforts to persuade the Masai to modify some of their customs, such as the use of the morans only for protecting herds are being accepted. Land adjudication, instead of communal land holdings, leading to group ranching also appears to be making some headway.[41]

An additional incentive for land adjudication and ranching by the Masai is coming from their desire to stake their rights to the land by legal means.[42] Continuing land adjudication should make ERTS impact on these people more likely, nomadism decreases, but it also will exacerbate the conflict with wildlife for forage, since the sense of land ownership will be greater.

The success of an improvement in the management of cattle and wildlife resources depends upon the extent to which the labor force, both Masai and others, co-operates with the new system. Since the Masai economy has essentially no use for most wildlife, excepting possibly the eland and water buffalo, any new program that relies strongly on wildlife herd sizes for its success must naturally have an incentive to modify their way of life. Indeed, the Masai currently have strond disincentives for preserving wildlife. Rhinoceros is poached for its horn, which is sold to Asian traders and sold in the Orient as an aphrodisiac.[43] Wildlife also poses some threat to Masai lives and livelihood, as is emphasized by a Masai warden:

> "...we have to share out land with wild and dangerous animals. We have to learn to give way to the elephant, the rhinoceros, the lion, etc., and this has not been our way of life. Many of us have lost children, others have lost relatives and stock to these animals which belong to the Government. The Government has value for these animals but they are of no value to us any more. The only value of these animals which we knew about is that they used to be the source of our traditionally important trophies, such as kudu horns used for war signals, lion manes worn as a sign of gallantry by the morans (young warriors), buffalo hides for shields, elephant tusks for ornaments worn by the morans, etc. The use of these things in our daily life is quickly becoming a thing of the past. This value of wildlife being gone, we know of no

other value whatever and yet our cattle are being killed and our people either being killed or injured by these animals. We are fined or imprisoned when we kill these animals for food even in times of extreme famine despite the fact that we share our land with them. The presence of these animals in our district means loss of lives and stock every year and nothing else."[44]

The competition between traditional cattle ranching and wildlife becomes even more severe during the dry season and particularly during a drought, such as Kenya is currently experiencing. With parks and preserves containing much of the available dry season water resources, conflicts between herdsmen and wildlife at the park perimeters and often within the boundaries of the parks and preserves themselves become very serious. By providing high frequency range condition information, which can in turn be fed into predictive models to give even more useful information, ERTS could provide the basics for quick reaction resource management decisions that can save both cattle and wildlife.

In certain respects, wildlife are more ecologically "efficient" in a given grazing area than domesticated cattle. Many species can feed without competing in the same area. The browsers, such as the rhino, giraffe, and gerenuk, consume leaves and shrubs, while the zebra, topi, and wildebeests are grazers. The buffalo, elephant, and most antelope eat both. Even the grazers specialize, with zebras eating standing hay, wildebeests and kongonis half-grown grass, and gazelles the newest grass.[45] Zebra also utilize a greater portion of grass stem, particularly during the dry season. The topi will eat rank meadow grass that most other antelope avoid. Then there are the carnivores that feed on these animals. Wildlife generally are better able to conserve water than cattle, in addition to breeding earlier and not requiring fencing, shelter, tsetse control, or veterinary

service. Cattle, by contrast, waste coarse grasses used by wildlife and do not support other carnivores, except occasionally man. Thus, if problems of refrigeration facilities and others can be overcome, game ranching may become more feasible than it is today, providing an additional benefit for land devoted to wildlife.[46]

This biological superiority of wildlife to cattle is seen by the fact that antelopes start to breed sooner than domestic stock and breed more rapidly. An eland matures in three years while a cow takes four. Hartebeeste, wildebeeste, and topi put on weight about 50% faster than a cow. while an eland is 100% faster. A gazelle puts on weight twice as fast as a goat and three times as as fast as a sheep.[47]

The feasibility of game ranching is being more widely discussed in recent years, partly because of the growing conflict between game and cattle for forage resources and partly because of the potential for greater economic gain. Field and Blankenship[48] have reported on the general feasibility of game ranching on three ranches, with recommendations ranging in one, mixed game and cattle in another, and a pure wildlife preserve for the third. If wildlife ranching develops into a significant commercial enterprise over the next decade or two, ERTS-based range management should have a favorable impact on it in much the same way as it will on commercial cattle ranching.

C.8 TOURISM IMPACT OF ERTS ON EMPLOYMENT IN KENYA

According to Mitchell,[49] the production and distribution of goods and services demanded by tourists in Kenya in 1966/67 required the employment of an estimated 11,150 people, or approximately 1.1 persons per K£ 1,000 of tourist expenditures. This includes businesses dealing directly with tourists, related government agencies, employees engaged in the production of curios and other items purchased by tourists from retailers, agricultural employment, and others.

Mitchell assumed that the ratio of jobs to tourist expenditures would fall with rising labor costs and capital-oriented technological improvements. He assumed a six percent annual increase in labor productivity. This may be accurate in the short run but probably overstates long run opportunities for labor substitution in tourism. Both 6% and 1% labor productivity increases have been assumed. The results are shown in Table C-17. For all but the most optimistic cases, the employment impact is relatively small.

C.9 IMPACT OF ERTS ON RANCHING IN KENYA

A crude estimate of the employment effects of ERTS on the modern ranching sector was made by examining gross farm revenue and agricultural employment statistics. In 1971 and 1972 Kenyan gross farm revenues were K£ 86,695,000 and K£ 106,181,000 respectively, for the modern sector.[50] Thus, employment per K£ 1,000,000 was 2435 in 1971 and 2122 in 1972, the dip reflecting increased prices obtained by farmers in 1972. It is assumed that these figures are relevant to cattle ranching.

Using the smaller of these two figures and assuming 1% and 6% labor productivities, we can estimate the impact of ERTS on employment in the modern cattle ranching sector. The results are seen in Table C-18. Again, the impact is appreciable but relatively small.

C.10 CONCLUSIONS

A grazing land management system based on ERTS appears to offer appreciable economic benefits to Kenya. In addition to providing resource information that should ease the conflict between traditional cattle grazing and wildlife for scarce forage resources, there appear to be substantial contributions that can be made to the tourist and commercial ranching sectors. Aircraft surveillance cost savings also seem possible. Assuming a net 5% increase in carrying capacity, a 5%

tourist expenditures and commercial ranching income, ERTS application in Kenya has a present value of future benefits at 20% discount rate of

Kenya/CIDA Cost Savings	K£ 91,000
Tourism	K£ 1,900,000
Ranching	K£ 760,000
	K£ 2,800,000

At current exchange rates, this is equal to $8,100,000. At the lower discount rate of 10%, this figure climbs to K£ 8,900,000, or $26,000,000.

A further clarification of economic benefits will require more information on likely range land carrying capacity percentage increases and tourist revenue sensitivity to these increases.

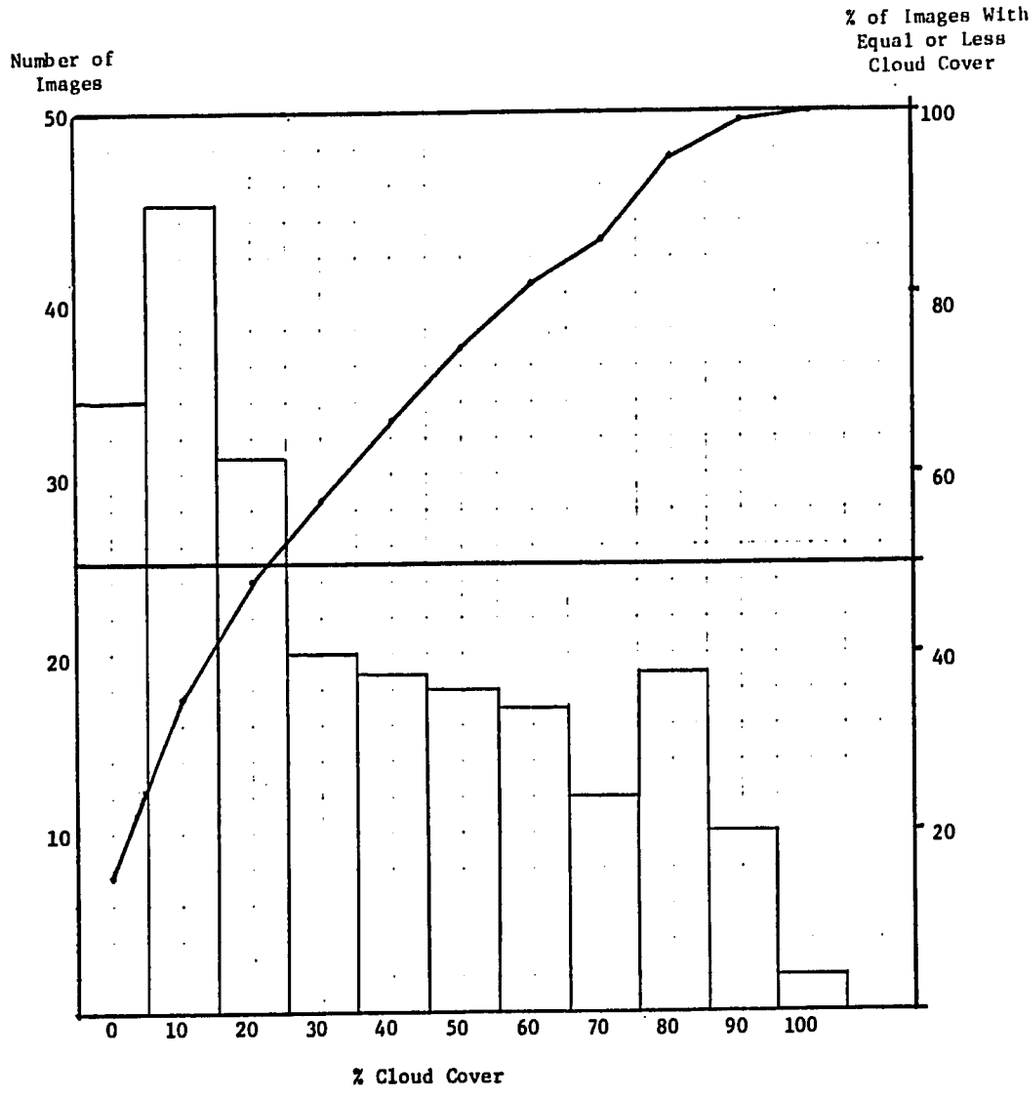

FIGURE C-1. CLOUD COVER DISTRIBUTION OF KENYAN ERTS IMAGERY

TABLE C-1. SUCCESS OF DISCERNING PHYSIOGNOMIC VEGETATION TYPES OF ERTS-1 IMAGERY

	TYPE	SIGNATURE (ROBBIALAC) CODE	SUCCESS OF REGISTRATION DISCERNIBLE:	UNDESCERNIBLE
1.	Mid-altitude Riparian Warburgia-Diospyros Forest	poppy	1	0
2.	Croton di chogamus riverine and hill top bushland	cappuchino	1	0
3.	Themeda grassland	silk grey	1	0
4.	Setaria - Themeda	whisper grey	1	0
5.	Lannea - commiphora Dischrostachys woodland	?	0	1
6.	Acacia hockii woodland	?	0	1
7.	Acacia drepanolobium woodland	?	0	1
8.	Acacia gerrardii woodland	?	0	1
9.	Acacia xanthophloea woodland forest	coralline	Inconsiderable	
10.	Balanites aegyptiaca woodland	sunburst	0	1
11.	Euclea divinorum vegetation	?	0	1
12.	Rhus - cordia termite mound thickets	?	0	1
TOTAL			4	7
SUCCESS			36%	64%

NOTE: Within the Masai Mara Game Reserve, registration is also good in

(a) Drainage pattern; (the Mara Talok, Sand River, Jager tiek, and Okeju Robkai rivers are all discernible)

(b) Terrain, as interpreted in association with signatures of vegetation characteristic to each type of topography.

TABLE C-2. GRAZING LAND MANAGEMENT DECISIONS AFFECTED BY ERTS BASED INFORMATION

RANCHING	WILDLIFE
1. Purchase of livestock	1. Modifying restrictions on tourist accessibility to wildlife
2. Moving cattle to lands with higher carrying - capacity	2. Modifying anti-poaching enforcement
3. Breeding of livestock	3. Modifying sale of game hunting permits and other cropping measures
4. Funding or termination of range improvement expenditures	4. Modifying game preserve boundaries reflecting changed ecological conditions

TABLE C-3. ESTIMATES OF INCREASE IN RANGE PRODUCTIVITY ARISING FROM ERTS-BASED IMPROVEMENTS IN GRAZING LAND MANAGEMENT

SOURCE	DATE	ESTIMATE	LOCATION	COMMENTS
DEAN	1965	2 - 12%	U.S.	
FRANK	1969	70 - 100%	U.S.	represents all technical improvements
HEISS	1969	0.5	U.S.	admittedly conservative estimate
SEEVERS AND DREWS	1973	20%	NEBRASKA	ERTS responsible for a significant part of increased productivity
COLWELL	1974	30 - 50%	U.S.	assumes well-developed management information and dissemination system
EARTH SATELLITE CORP.	1974	0.5 - 2%	U.S.	conservative parametric approach

TABLE C-4. ESTIMATED ECONOMIC BENEFITS (in thousands of K£) of ERTS TO KENYA/CIDA MONITORING AND SURVEILLANCE PROGRAM

TIME HORIZON	Discount Rate			
	0%	10%	20%	25%
1986	312	142	72	53
1996	702	218	91	63

TABLE C-5. RECENT PERFORMANCE OF KENYAN TOURIST INDUSTRY[27]

YEAR	NO. OF HOLIDAY AND BUSINESS VISITORS (THOUSANDS)	NO. OF HOLIDAY AND BUSINESS DAYS SPENT (THOUSANDS)	FOREIGN EXCHANGE EARNINGS FROM TOURISM, K£ x 10^6
1968	182.8	2249	17.3
1969	200.9	2131	16.7
1970	260.2	2712	18.5
1971	351.3	3654	23.9
1972	387.1	4696	26.5
Compound Annual Growth	20.6%	20.2%	11.2%

TABLE C-6a. PROJECTIONS OF HOLIDAY AND BUSINESS VISITORS TO KENYA, 1972-1996 (THOUSANDS)

YEAR	5%	10%	20%
1972	387.1	387.1	387.1
1973	406.5	425.8	464.5
1974	426.8	468.4	557.4
1975	448.1	515.2	668.9
1976	470.5	566.8	802.7
1977	494.0	623.4	963.2
1978	518.8	685.8	1,156
1979	544.7	754.3	1,387
1980	571.9	829.8	1,664
1981	600.5	912.8	1,997
1982	630.5	1,004	2,397
1983	662.1	1,104	2,876
1984	695.2	1,215	3,451
1985	729.9	1,336	4,142
1986	766.4	1,470	4,970
1987	804.8	1,617	5,964
1988	845.0	1,779	7,157
1989	887.2	1,957	8,588
1990	931.6	2,152	10,306
1991	978.2	2,367	12,367
1992	1,027.1	2,604	14,840
1993	1,078.4	2,865	17,809
1994	1,132.4	3,151	21,320
1995	1,189.0	3,466	25,644
1996	1,248.4	3,813	30,773

TABLE C-6b. PROJECTIONS OF HOLIDAY AND BUSINESS DAYS SPENT IN KENYA, 1972-1996 (THOUSANDS)

YEAR	5%	10%	20%
1972	4,696	4,696	4,696
1973	4,931	5,166	5,635
1974	5,177	5,682	6,762
1975	5,436	6,250	8,115
1976	5,708	6,875	9,738
1977	5,993	7,563	11,685
1978	6,293	8,319	14,022
1979	6,608	9,151	16,827
1980	6,938	10,066	24,230
1981	7,285	11,073	24,230
1982	7,649	12,180	29,076
1983	8,032	13,398	34,892
1984	8,433	14,738	41,870
1985	8,855	16,212	50,244
1986	9,298	17,833	60,293
1987	9,763	19,616	72,351
1988	10,251	21,578	86,822
1989	10,763	23,736	104,186
1990	11,301	26,109	125,023
1991	11,867	28,720	150,028
1992	12,460	31,592	180,033
1993	13,083	34,752	216,040
1994	13,737	38,226	259,048
1995	14,424	42,049	311,098
1996	15,145	46,254	373,317

TABLE C-6c. PROJECTED TOURIST EXPENDITURE IN KENYA, 1972-1996
(MILLIONS OF KENYAN K£)

YEAR	5%	11%	15%
1972	26.5	26.5	26.5
1973	27.8	29.4	30.5
1974	29.2	32.7	35.0
1975	30.7	36.2	40.3
1976	32.2	40.2	46.3
1977	33.8	44.7	58.3
1978	35.5	49.6	61.3
1979	37.3	55.0	70.5
1980	39.2	61.1	81.1
1981	41.1	67.8	93.2
1982	43.2	75.2	107.2
1983	45.3	83.5	123.3
1984	47.6	92.7	141.8
1985	50.0	102.9	163.0
1986	52.5	114.2	187.5
1987	55.1	126.8	215.6
1988	57.8	140.7	248.0
1989	60.7	156.2	285.2
1990	63.8	173.4	327.9
1991	67.0	192.5	337.1
1992	70.3	213.7	433.7
1993	73.8	237.2	498.8
1994	77.5	263.2	573.6
1995	81.4	292.2	659.6
1996	85.5	324.3	758.5
TOTAL	1,118.4	2,866.9	5,460.3

TABLE C-7. OPPORTUNITY COST AND NET CURRENT VALUE OF KENYA TOURISM IN 1966/7

COST ITEMS (1)	PERCENTAGE OF TOURIST EXPENDITURES TOTAL (2)	OPPORTUNITY COST (3)	NET GAIN (2) (3) (4)
1. Foreign exchange outflow	22	22	0
2. GNP (market prices)	78	-	-
of which			
3. Profits and interest remaining in Kenya and depreciation	38	(not applicable)	
4. Tax on overseas investment income	1+	0	1+
5. Remuneration of:			
a) low skill labour	13	5 - 7	8 - 6
b) high skill labour	18	18-	0+
6. Rent			
a) private activities	4	4-	0+
b) game parks & airports	1	1	0
7. Net indirect taxes	3+	0	3+
8. Subtotal (3+4+5+6)	78	a) 28 - 30	10 - 12+
Earnings gain		b) 38 %	not applicable
9. Efficiency gain (1/3 x 1/3 x 66)			11 %
10. Subtotal (8 + 9)			21 - 23 %
11. Tariff valuation adjustment (19 % to 35 % of row 10)			4 - 8 %
12. Total Net Current Value			25 % - 31 %

TABLE C-8. PROJECTED ECONOMIC BENEFITS TO KENYA FROM TOURIST EXPENDITURES (millions of K£)

Year	5% growth	11% growth	15% growth
1972	15.9	15.9	15.9
1973	16.7	17.5	19.1
1974	17.5	19.7	22.9
1975	18.4	21.7	27.5
1976	19.3	23.3	33.0
1977	20.3	25.6	39.6
1978	21.3	28.2	47.5
1979	22.4	31.0	57.0
1980	23.5	34.1	68.4
1981	24.7	37.5	82.0
1982	25.9	41.2	98.4
1983	27.2	45.4	118
1984	28.6	49.9	142
1985	30.0	54.9	170
1986	31.5	60.4	204
1987	33.1	66.4	245
1988	34.7	73.1	294
1989	36.4	80.4	353
1990	38.3	88.4	423
1991	40.2	97.2	508
1992	42.2	107	610
1993	44.3	118	731
1994	46.5	129	878
1995	48.8	142	1053
1996	51.3	157	1264

TABLE C-9. BENEFITS TO TOURIST SECTOR FROM 1% ERTS-BASED IMPROVEMENT IN GRAZING LANDS BIOMASS CARRYING CAPACITY

1986 HORIZON FIGURES in THOUSANDS of 1974 K£

Discount Rate	0%	10%	20%	25%	$\frac{\Delta \ln TE}{\Delta \ln CC}$
tourist expenditure growth					
	54	24	12	9	.01
0%	270	120	59	43	.05
	550	240	120	86	.10
	89	38	18	13	.01
5%	450	190	91	66	.05
	900	380	180	130	.10
	160	66	31	22	.01
11%	800	330	153	110	.05
	1,600	660	310	220	.10
	230	94	43	30	.01
15%	1,200	470	210	150	.05
	2,300	940	430	300	.10

TABLE C-10. BENEFITS TO TOURIST SECTOR FROM 1% ERTS-BASED IMPROVEMENT IN GRAZING LANDS BIOMASS CARRYING CAPACITY

1996 HORIZON FIGURES in THOUSANDS of 1974 K£

Discount Rate	0%	10%	20%	25%	$\frac{\Delta \ln TE}{\Delta \ln CC}$
tourist expenditure growth					
	210	52	18	12	.01
0%	1,000	260	92	60	.05
	2,100	530	180	120	.10
	480	110	34	21	.01
5%	2,400	542	170	110	.05
	4,800	1,100	340	210	.10
	1,300	270	73	43	.01
11%	6,600	1,300	370	210	.05
	13,000	2,700	740	430	.10
	2,600	490	130	71	.01
15%	13,000	2,500	630	350	.05
	26,000	4,900	1,300	710	.10

TABLE C-11. BENEFITS TO TOURIST SECTOR FROM 5% ERTS-BASED IMPROVEMENT IN GRAZING LANDS BIOMASS CARRYING CAPACITY

1986 HORIZON FIGURES in THOUSANDS of 1974 K£

Discount Rate	0%	10%	20%	25%	$\frac{\Delta \ln TE}{\Delta \ln CC}$
tourist expenditure growth					
	270	120	59	43	.01
0%	1,400	560	300	220	.05
	2,800	1,200	590	430	.10
	450	190	91	66	.01
5%	2,200	950	460	330	.05
	4,500	1,900	920	660	.10
	800	330	150	110	.01
11%	4,000	1,700	770	550	.05
	8,100	3,300	1,500	1,100	.10
	1,200	470	210	150	.01
15%	5,900	2,400	1,100	760	.05
	12,000	4,800	2,200	1,500	.10

TABLE C-12. BENEFITS TO TOURIST SECTOR FROM 5% ERTS-BASED IMPROVEMENT IN GRAZING LANDS BIOMASS CARRYING CAPACITY

1996 HORIZON FIGURES in THOUSANDS of 1974 K£

Discount Rate	0%	10%	20%	25%	$\frac{\Delta \ln TE}{\Delta \ln CC}$
tourist expenditure growth					
	1,000	260	92	60	.01
0%	5,300	1,300	460	300	.05
	11,000	2,700	930	610	.10
	2,400	540	170	110	.01
5%	12,000	2,700	850	530	.05
	25,000	5,600	1,700	1,100	.10
	6,600	1,300	370	210	.01
11%	34,000	6,800	1,900	1,100	.05
	69,000	14,000	3,800	2,200	.10
	13,000	2,400	630	350	.01
15%	66,000	12,000	3,200	1,800	.05
	130,000	25,000	6,400	3,600	.10

TABLE C-13. BENEFITS TO TOURIST SECTOR FROM 20% ERTS-BASED IMPROVEMENT IN GRAZING LANDS BIOMASS CARRYING CAPACITY

1986 HORIZON FIGURES in THOUSANDS of 1974 K£

Discount Rate	0%	10%	20%	25%	$\frac{\Delta \ln TE}{\Delta \ln CC}$
tourist expenditure growth					
	1,100	480	240	170	.01
0%	5,600	2,400	1,200	880	.05
	12,000	5,000	2,500	1,800	.10
	1,800	760	370	260	.01
5%	9,200	3,900	1,900	1,300	.05
	19,000	8,000	3,800	2,700	.10
	3,200	1,300	610	440	.01
11%	16,000	6,700	3,100	2,200	.05
	34,000	14,000	6,400	4,500	.10
15%	4,700	1,900	860	610	.01
	24,000	9,700	4,400	3,100	.05
	49,000	20,000	9,000	6,300	.10

TABLE C-14. BENEFITS TO TOURIST SECTOR FROM 20% ERTS-BASED IMPROVEMENT IN GRAZING LANDS BIOMASS CARRYING CAPACITY

1996 HORIZON FIGURES in THOUSANDS of 1974 K£

Discount Rate	0%	10%	20%	25%	$\frac{\Delta \ln TE}{\Delta \ln CC}$
tourist expenditure growth					
	4,200	1,100	370	240	.01
0%	22,000	5,500	1,900	1,200	.05
	47,000	12,000	4,000	2,600	.10
	9,800	2,200	680	420	.01
5%	51,000	11,000	3,500	2,200	.05
	110,000	24,000	7,400	4,500	.10
	27,000	5,400	1,500	860	.01
11%	140,000	28,000	7,700	4,500	.05
	300,000	60,000	16,000	9,400	.10
	53,000	9,900	2,500	1,400	.01
15%	280,000	52,000	13,000	7,400	.05
	590,000	110,000	28,000	16,000	.10

TABLE C-15. GROSS FARM REVENUE FROM MARKETED GRAZING LIVESTOCK, 1967 - 1996

Year	Cattle and Calves for Slaughter	Sheeps, Goats & Lambs for Slaughter	Hides & Skins	Dairy Products
1967	11,325	404	630	6,380
1968	11,669	440	657	7,126
1969	12,218	453	675	6,100
1970	13,324	475	604	6,806
1971	13,330	733	841	9,300
1972	16,510	811	967	11,650
1973	17,798	892	1,053	12,815
1974	19,186	981	1.147	14,096
1975	20,683	1,079	1,249	15,506
1976	22,296	1,187	1,360	17,057
1977	24,035	1,306	1,481	18,762
1978	25,910	1,437	1,613	20,639
1979	27,930	1,580	1,756	22,703
1980	30,109	1,736	1,913	24,973
1981	32,458	1,912	2.083	27,470
1982	34,989	2,104	2,268	30,217
1983	37,718	2,314	2,470	33,239
1984	40,660	2,545	2,690	36,563
1985	43,831	2,800	2,929	40,219
1986	47,251	3,080	3,190	44,241
1987	50,936	3,388	3,474	48,665
1988	54,909	3,727	3,783	53,531
1989	59,192	4,099	4,120	58,885
1990	63,809	4,509	4,487	64,773
1991	68,787	4,960	4,886	71,250
1992	74,152	5,456	5,321	78,375
1993	79,936	6,002	5,794	86,213
1994	86,171	6,602	6,310	94,834
1995	92,892	7,262	6,872	104,318
1996	100,138	7,988	7,483	114,749

TABLE C-16. BENEFITS TO CATTLE SECTOR FROM ERTS-BASED IMPROVEMENT IN GRAZING LANDS BIOMASS CARRYING CAPACITY

FIGURES in THOUSANDS of 1974 K£

	scount Rate	0%	10%	20%	25%
carrying capacity					
1986	1%	430	210	110	85
	5%	2,200	1,000	560	430
	20%	8,600	4,100	2,200	1,700
1996	1%	1,400	390	150	110
	.5%	7,100	1,900	760	530
	20%	28,000	7,700	3,100	2,100

TABLE C-17. IMPACT OF ERTS ON EMPLOYMENT IN THE TOURIST SECTOR

Horizon = 1996 (a) $\frac{\Delta\% \text{ TE}}{\Delta\% \text{ CC}} = 0.05$

1% PRODUCTIVITY INCREASE

Δ% CC	r	Jobs in 1985	Jobs in 1995	Total Job Years
1	11	190	1,000	7,600
1	15	290	2,200	15,000
5	11	960	5,200	38,000
5	15	1,500	11,000	75,000
20	11	3,900	22,000	160,000
20	15	6,000	48,000	310,000

(b)

6% PRODUCTIVITY INCREASE

1	11	130	430	3,800
1	15	200	940	7,200
5	11	650	2,200	19,000
5	15	990	4,800	36,000
20	11	2,700	9,400	81,000
20	15	4,100	20,000	150,000

TE = Tourist expenditures

CC = Carrying capacity

r = Tourist expenditure annual growth rate

TABLE C-18. IMPACT OF ERTS ON EMPLOYMENT IN THE RANCHING SECTOR

Horizon = 1996

(a)

1% PRODUCTIVITY INCREASE

Δ% CC	Jobs in 1985	Jobs in 1995	Total Job Years
1	800	1,700	20,000
5	4,000	8,300	98,000
20	16,000	33,000	390,000

(b)

6% PRODUCTIVITY INCREASE

1	450	570	9,400
5	2,200	2,900	47,000
20	9,000	11,000	190,000

Δ% CC = Carrying capacity percentage increase

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Appendix D

WATER MANAGEMENT APPLICATIONS

D.1 HYDROLOGIC APPLICATION OF ERTS

Predicting, managing and understanding water resources, at appropriate time and space scales, is the hydrologist's basic goal. Enough water of sufficient quality should be provided to places when it is economically justifiable, when needed, at lowest cost. The detrimental effects of man-made or natural events, such as water pollution or floods upon the hydrological cycle must be studied and controlled.

As is true in most systems, proper interpretations among individual components of the hydrologic environment are more important than the understanding of each component separately. Characteristics which must be correlated include surficial deposits, geological landforms, regional physiographic settings, local topography and hydrology, vegetative and land use features. ERTS imagery can be employed for useful interpretations of many of these elements as well as synoptic observation of complete watersheds.

One important requirement for water resources development is synoptic measurement of terrain characteristics. The importance of the requirement is heightened in areas where little previous knowledge of water conditions is available. Such is the case in many lesser developed nations. ERTS imagery is an appropriate tool for water resource development and can provide interpretable data on extent, distribution and length of river channels; location, size and shape of lakes that act as water reservoirs and evaporation sources; type and extent of vegetation; and geologic features that govern the occurrence, movement and storage of ground water.

Several features of spaceborne imagery enhance its utility for applications in hydrology. The imagery yields a better scientific understanding of the hydrologic cycle (particularly on regional,

continental and planetary scales) in terms of mass budgets, better definitions of surface water bodies (including dynamic changes), improving input data to mathematical models of the hydrologic system, assessing atmosphere water quantities, assessing certain terms in evaporation (evapotranspiration) equations and gaining better understanding of snow and ice-covered areas. With these data, the design, planning and management of various water resource projects may be improved. These capabilities place many important hydrologic objectives within present sensing capabilities. General reconnaissance, monitoring and surveying of dynamic hydrologic features and phenomena over sizable areas may be implemented on a routine basis at lower costs. Open surface water bodies as small as several acres in size may be mapped. Estuarine and coastal hydrologic features (including submarine features) may be surveyed. The monitoring of dynamic water circulation patterns, including the identification of sediment-laden waters, offshore waste dumping sites and plumes of outfall sewers, is possible. Flooded areas can be mapped on regional scales. Figure D-1 shows the extent of the Mississippi River before and during the flooding of 1973. Water turbidity characteristics in larger reservoirs, lakes and at the mouths of rivers may be detected.

D.2 SPECIFIC HYDROLOGICAL APPLICATIONS OF ERTS

Table D-1 presents the hydrologic applications of ERTS imagery made evident by studies to date. ERTS MSS bands 6 and 7 provide the maximum image contrast between water-land boundaries. A well-defined contrast between water masses containing different amounts of suspended material is provided by band 6, while band 4 allows discrimination of bottom features in water a few meters or tens of meter's deep. ERTS' repetitive coverage of the same area at frequent time intervals, at a low additional cost, enhances dynamic change detection in features. The synoptic coverage allows the analysis of water bodies and of entire surrounding watersheds to which lakes, reservoirs, and river systems

may be intimately linked. The following watershed parameters may be obtained: drainage patterns, land use and changes in land use, vegetation type, moisture distribution, plant water uses and changes in surface storage. Water surface area of lakes and reservoirs can be measured over thousands of square miles. The appearance or disappearance of peripheral features may be used to infer water levels. The ERTS Data Collection System (DCS) facilitates the determination of water levels. Combined DCS and tape data should provide water volume estimates as a key output of information gathering systems. Lineations and fractures which have previously been correlated with wells and springs of large capacity are delineated by ERTS.

Perhaps one of the most striking hydrological applications of ERTS is the mapping of flood-inundated areas, many of which have been mapped at scales of 1:250,000 and larger. Areas have been successfully mapped seven to twelve days after the event, through the use of infrared maps. Graphic comparisons between low flow and the areal extent of flood-inundation facilitates rapid assessments of the areas of flood damage. The regional effectiveness of flood control structures may be assessed. General areas where significant changes in the course of the river may require dredging and other construction may be determined.

D.3 ERTS APPLICATIONS IN DEVELOPING COUNTRIES

Mekong Basin Analysis

In 1957, the Committee for Coordination of Investigations of the Lower Mekong Basin was formed "to promote, coordinate, supervise and control the planning and investigation of water resources development projects in the Lower Mekong Basin."[1] The Committee is composed of the four member states of Thailand, Laos, the Republic of Vietnam and the Khmer Republic. They are assisted in their work by 25 cooperating countries and by 16 United Nations agencies. The Committee's attention focuses on the Lower Basin encompassing 606,000 square kilometers. Flooding of the Mekong is an annual phenomenon, and sometimes leaves

flood waters at a depth of three meters. In the dry season, when the water level falls in the Mekong, saline water penetrates inland. Farming life for the missions of inhabitants in the Delta is dictated by the vagaries of the annual floods, greatly affecting two vital parts of their diet: rice and fishing.

Many development possibilities have been examined for the Delta and the possible impacts of such possibilities are great. To suggest one, if flood protection, drainage and irrigation were provided, the entire cropping system would be changed. The Committee has developed many techniques to appraise the situation. A computer model of flood flows analyzes the effect of any major change in the hydrologic situation. Experts are appraising agricultural production in the Delta and fisheries research is in progress. Still much is virtually unknown and the data base required for effective planning must be greatly expanded. The exact source of the Mekong, believed to be about 4,500 kilometers long, is unknown. The twelfth longest river in the world, the river discharges 475,000 cubic meters of water into the sea each year.

Progress on the Mekong Development Project has been impeded by the almost total lack of any previously assembled, reliable data about the river. For many years, the emphasis has been on data gathering. The projects devoted to this task are too numerous to be specifically mentioned (see Table D-2). As a result several tributaries have been controlled and put to work. Educational programs for farmers are being conducted. Power plants are producing energy, promoting the modernization of some of the cities in the region. However, much remains to be done. "Valuable as these forerunners are in the areas in which they have sprung up, and effective as they are in meeting today's needs, their impact is small compared with the benefits that mainstream projects will confer on the whole region in time to come. The Mekong is a mighty and capricious river, and its basin is a vast human and physical system. The Mekong Committee recognizes that many decades of patient and careful investigation must be coupled with a steady

determination to make project construction keep pace with their countries needs, if the Committee's aims are to be achieved."[1]

ERTS imagery has and is being successfully applied to water resources planning in the lower Mekong Basin. W. J. Van Liere, of the Committee, feels that the whole project has been reshaped by the influence of ERTS data. He maintains that ERTS imagery presents a better picture of how flooding and draining occur in the basin, and should be used to determine the location of lesser dams (tanks). Current plans call for one hundred and fifty of these tanks at an average cost of approximately $0.5 million each. ERTS data have shown that water storage for the planned Pa Mong dam must be increased over that currently planned. Van Liere identified the following readily interpretable outputs from ERTS: flood management and control; forestry and watershed management; and soil productivity and mapping.

Data in formerly inaccessible areas has been made available by ERTS. Ground surveys have been refined using the imagery, mainly with respect to land forms and soils of existing and planned irrigation parameters. New data have been provided regarding the mechanism of flooding and drainage of the delta; siltation of the great lake and mapping of acidity and possibly salinity in the lower delta; and sedimentation and fisheries in the Mekong Delta estuarine areas.

The repetitive coverage of ERTS has prompted insights to the transformation of changing features such as the extent of flooding and moisture retention in various soil types. Hydrological data on sedimentation of reservoirs and floodplains have been gathered by ERTS in the Mekong area. Images of the contour of a reservoir area affected by sedimentation resulted in the identification of the extensive arms of two existing new tributary reservoirs which are heavily sedimented. There had been no field observations of this situation. The Mekong Secretariat is conducting investigations to determine if the siltation in the arms is beyond the broad design forecasts, as well as to locate the excessive watershed erosion or other causes of the siltation.

The flood plain and inundated areas in the entire Mekong Delta have been delineated easily. Through gage heights, the gradient of the Mekong River in this reach has been measured. It is therefore possible to follow the patterns of natural flooding, as well as natural drainage, through the rainy season. Thus, ERTS has provided new and invaluable tools for flood control analysis for the Mekong Committee flood forecasting program, and for the design of agricultural policies in the flood zones.

D.4 OKAVANGO DELTA ANALYSIS

A problem of paramount priority in Botswana is the scarcity of water which limits the country's development in all economic sectors. The effects of this scarcity are felt not only in limited food production but in shortages of water for household uses and on general public health. Industrial users are an additional strain on the limited water resources.

Rainfall is scant and unreliable. Though thousands of boreholes have been drilled, they cannot satisfy present needs nor can they hope to offer long-term resolution to the problems. The Okavango River is the only perennially flowing river in Botswana. The river originates in Angola where it has a catchment area of 205,000 km and enters Botswana in the extreme northwest from the Caprivi Strip. Effective utilization of this river basin's resources offers Botswana its greatest hope for assuaging its dire need for water. Upon entering Botswana, the Okavango spreads out over a delta of some 16,000 square kilometers, resulting in the evaporation of about 75% of its inflow. Half of the area is permanently flooded, the remainder floods seasonally. Maximum flooding of the Okavango begins in March and April at the inlet. Not till September and October do the floods reach the far end of the delta.

Several developmental prospects stem from diverting waters from the Okavango. One vital concern, however, is to carefully assess the ecological balance of the delta areas in hopes of obviating any

deleterious effects should water be diverted from the basin. Present demands on the Okavango are small: domestic use and stock watering in Ngamiland, cultivation of Lake Ngami and use by cattle, fisherman, farmers and wildlife, and the maintenance of a large and varied wildlife population throughout the Delta. Water is needed for the vital economic sectors of mining and agricultural development. The agricultural prospects of the Okavango itself are being examined, as well as the replenishment of Lake Ngami to open up new fishing grounds.

ERTS data has been a source of input for some studies in the delta region. Mr. Williamson, who is conducting a vegetation analysis in the Okavango feels that ERTS is excellent for identifying ecosystems and their boundaries. Results of studies of ERTS-1 images have indicated that flood patterns vary from year to year. The Department of Water Affairs hopes to continue monitoring the flood patterns of the delta, under an ERTS-2 proposal, in order to apply this information to land use development.

A four-year project sponsored by the UNDP, "Surveys and Training for the Investigation of Water Resources and Agricultural Production," (Bot. 1) was completed in the spring of 1972. Bot. 1 provided preliminary information on the water resources of the Delta and on some of the agricultural and sociological characteristics of the area. An ongoing program of routine collection of hydrological data has been established. A follow-up two-month project, "Reconnaissance Study of the Need for, and Costs of Transfer of Water from the Okavango Area to Other Parts of Botswana" sponsored by Sweden, investigated the economic and technical feasibility of water transfer.

To make use of and expand upon the data gathered in these two projects, a new two and one-half year project has begun, "The Investigation of the Okavango Delta as a Primary Water Resource for Botswana," (Bot. 2). The sponsoring agency is the FAO. This project would "identify and design possible means of establishing control over the movement of water through the Delta, and provide a preliminary

prediction of the effects on the environment of such control, in order to recommend the most suitable method of exploitation of water resources commensurate with conservation of the overall complex of resources making up the Okavango Delta." In addition, related programs on groundwater, irrigation, and wetland ecology are presently being undertaken.

ERTS could provide some useful supplementary data to these projects. The enhanced dynamic change detection capability of ERTS would be particularly valuable within these parameters. Measurements of the advance of flood waters in dry river beds and in flooded areas can be observed by ERTS, either directly when the surface water extent is large enough to be imaged or through inference from vegetation changes. Repetitive ERTS imagery could provide a basic framework by which the various disciplines in Bot. 2, as well as in other projects, could organize their study and ground work plans to optimize the selection of ground sites for detailed measurements and observations.

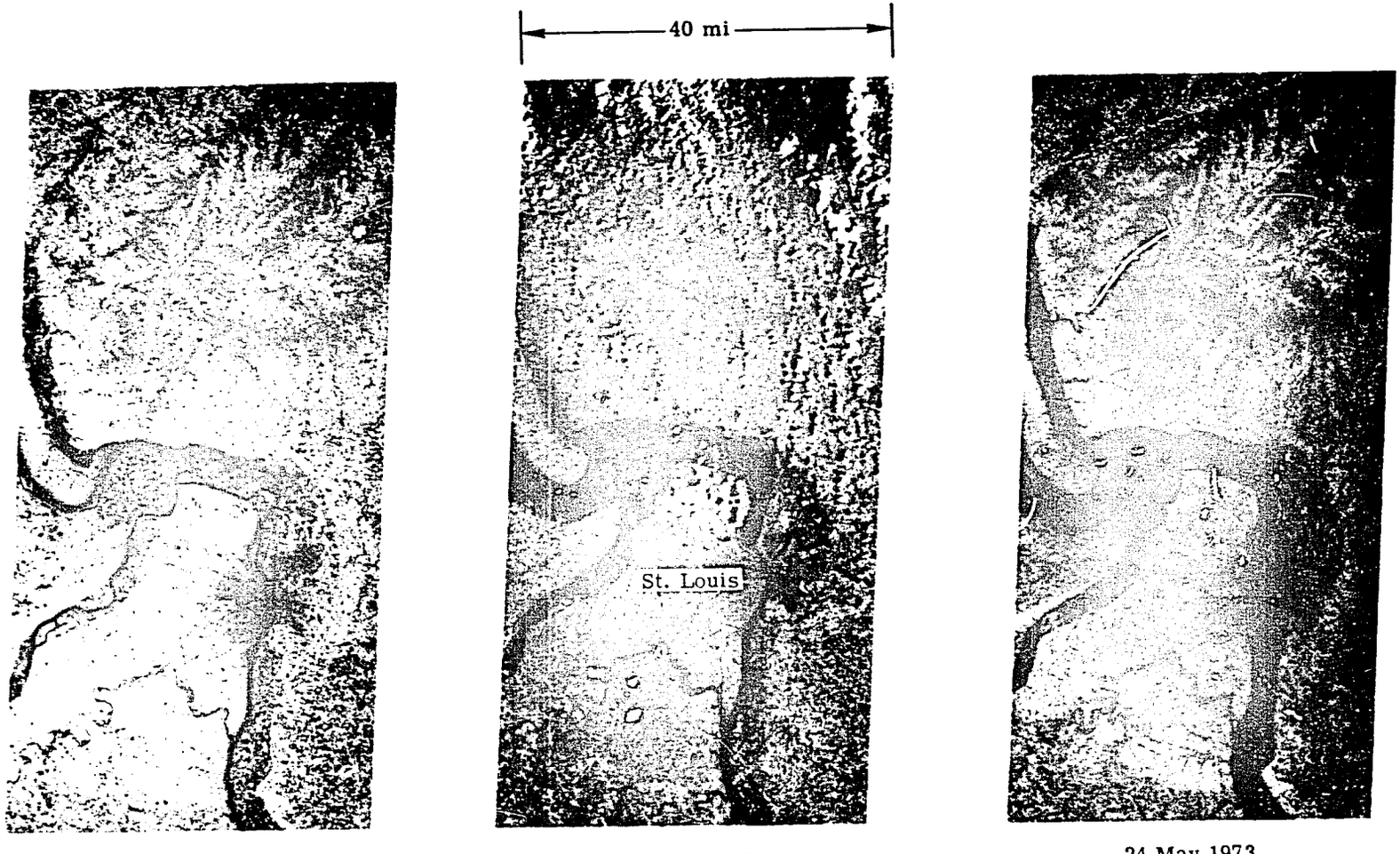
Surface water data are limited, and sampling errors due to limited observation can result in inefficient watershed management. A more extensive gauging network is needed for the Okavango, the data from which could be plugged into a newly developed mathematical forecasting model. Presently, there are 22 recording gaps and three staff gauges in eastern Botswana and 31 staff gauges and three recording gauges in the Okavango. The DCS system could facilitate an expansion and improvement of this gauge network. Currently an engineering study is being conducted, aimed at determining routes and costs for possible future transport of water from the Okavango to eastern Botswana. ERTS would provide a useful basis for the initial preliminary investigations, facilitating the selection of areas for further detailed study.

In addition, groundwater is another aspect of water resources on which there are insufficient quantitative data available. This lack of data, in all fields of water resources, means that caution must be used in any tentative assessment of groundwater resources. In addition, the growing population, rising standard of living, improved farming methods,

expansion of village water supplies and development of the mining sector, all are aggravating and increasing the demand of water.

Thus, the importance of an accurate, timely quantitative water resources base for Botswana is high. The Department of Geological Survey plans on producing accurate and detailed maps of all the underground water resources of the nation. ERTS has been used to interpret such data in other parts of the world (USA and Mali, for example). Another important factor in this application is the importance of hydrologic information to land use planning, especially in regards to the grazing of cattle. Over-grazing can cause irreparable damage. ERTS could be used to effectively monitor the dynamics of this problem.

The ERTS-2 proposals submitted by Botswana testify to the interest in the hydrologic applications of ERTS. The Department of Water Affairs wishes to continue monitoring of the flood patterns of the Delta in order to apply this information to land use development. Results of studies of ERTS-1 imagery have indicated that flood patterns vary from year to year. In an arid country where flooding is the main source of water, such information should have large economic value. The Department of Land Surveys has indicated that existing maps of the swamp and desert regions possess large discrepancies and so look to ERTS as a source of data for compiling small-scale maps of the entire nation.



2 October 1972 | 31 March 1973 | 24 May 1973

FIGURE D-1. BAND 7 ERTS IMAGERY SHOWING MISSISSIPPI RIVER BEFORE, DURING AND AFTER FLOODING. All-time-high flood crest occurred 28 April 1973. (Courtesy of M. Deutsch, USGS)

TABLE D-1. HYDROLOGIC APPLICATIONS OF ERTS IMAGERY

General

1. Mapping of salars or salt-encrusted playas which represent water discharges from closed drainage basin.
2. Mapping of drainage divides particularly around closed basins in dry regions.
3. Mapping of geological structural data, related to the origin and hydrologic closure of basins.
4. Revision of geologic maps to show hydrologically important differences in surficial deposits.
5. Revision of hydrologic features on topographic maps.
6. Monitoring seasonal changes in flood waters to evaluate areal and seasonal changes in weather.
7. Mapping of mountain snowpack.
8. Relation of permanent drainage basin characteristics to seasonal snow cover and flood water as an aid in estimating water resources of basins lacking meteorological or stream-gauging stations.

Specific

1. Flood mapping of the Mississippi River. Operational use of the data is foreseen in planning remedial measures during and after an emergency.
2. Observation of seasonal changes in the number and distribution of prairie ponds and lakes in North Dakota.
3. Monitoring seasonal change in the presence of water in range reservoirs in Northern California and in other western states as part of a continual reassessment of the condition of grazing lands and the availability of water for cattle.
4. Observation of intermittent-flooding playa lakes in the Texas high plains to assess ground water recharge in the area.
5. Routine mapping of water pollutants.

TABLE D-1. HYDROLOGIC APPLICATIONS OF ERTS IMAGERY (Continued)

6. Synoptic monitoring of effluent patterns at the mouths of rivers and along the coast of Northern California, relating seasonal change to water quality of coastal waters, erosion rates within the basin of parent rivers, dispersal of pollutants offshore and the distribution of sediment along the coast. Important to understanding the dynamics of coastal processes and to observe the effect of logging and other land use changes on the environment.

7. Mapping surface of water storage volume in water conservation areas of Southern Florida.

8. Mapping surface water permitting the operational use of ERTS imagery and digital data to locate water bodies as part of a National program for the inspection of dams.

9. Mapping shorelines of rivers and coasts and monitoring sediment transport. This allows accurate monitoring and prediction of the evolution of shorelines, yielding information for planning river and coastal control structures.

10. Monitoring sediment in reservoirs to indicate water quality and sediment deposition rates.

11. Used in conjunction with aerial photography in Sahelien Africa to analyze the relationship between amount of rain and amount of growth in grasses.

12. Delineated a patch of range in Mali, fenced off by the French, regulated and controlled for ten years, resulting in good grass growth.

TABLE D-2. SUMMARY OF
MEKONG COMMITTEE INVESTIGATION PROGRAMME: 1972[1]

Engineering Studies

Hydrology
Pa Mong project studies
Stung Treng project reconnaissance
Delta development planning
Tonle Sap feasibility study
Mainstream project desk studies
Flood forecasting
Basin systems analysis
Delta mathematical model
Sedimentology
Satellite data collection
Engineering for pioneer agricultural projects
Geological site investigations
Flood protection dikes
Tributary project inventory

Economic & Social Studies

Farmer education, Laos
Adaptation to irrigation, Thailand
Economic projections
Cost-benefit analyses
Resettlement studies & plans
Urban planning
Statistical yearbook
Legal analyses
Power market surveys
Electro-processing industry studies
Manpower planning
Mineral industries studies

Agriculture

Experimental Farms: Eak Mat
Battambang
Prek Thnot
Kalasin
Vientiane Plain

Pioneer agricultural project preparatory studies
Agricultural yearbook
Livestock improvement
Fisheries development

Navigation Improvement

Hydrography
Channel marking
Rockblasting
Boat building training
Improvement of ferry ramps and river ports
Bank protection
Transport studies

Ecology

Aquatic plant growth studies
Archaeology
Resettlement plans and studies
Groundwater quality research
Fisheries research and development
Wildlife studies
Watershed management
Vector-borne disease control
Water-borne disease research

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Appendix E
CARTOGRAPHIC APPLICATIONS OF ERTS

E.1 MAPPING

The discipline of cartography is concerned with the collection and analysis of data and measurements of various patterns of the earth. These data are graphically represented on such a reduced scale that the elements of this pattern can be made clearly visible.[1] The value of such information to a nation state is often not discussed, as its import is readily apparent. To our knowledge no study has been made relating level of economic development against percentage or scale of territory mapped. Listing the many possible applications of cartography would seem inappropriate to this study. Anything that man can observe, tangible or otherwise, can be mapped in its two or three dimensional distribution.

Yet the subject cannot be totally by-passed. Until a whole nation is sufficiently mapped, continual waste will occur in making special surveys for special purposes and scarce resources will be inefficiently allocated. Without complete coverage, it would be impossible to devise effective schemes of communication, to make grants of lands to settlers, to agree upon boundaries, etc. The general administration of a nation or any geographically defined subdivision requires maps to function. Such activities as defense, communication, education, and land taxation all require maps. Base maps are required by a host of development specialists for a myriad of purposes.

Many cartographers have noted the intrinsic value of cartographic products. "In developing countries maps are first and foremost a tool of development, and this must be the primary consideration in dealing with the mapping of these countries."[2] Thackwell confirms this role with his statement, ".... I do not doubt that the more good maps which are available to the public in any country, the better the change that the country has to progress and develop as a nation."[3]

The development of a geographic data base is a long, involved process, which involves both dynamic and static measurements. Five phases have been identified in geographic data handling.[4] The initial phase of data specification defines the set of data and data formats which comprise the input to programs and projects. Data acquisition, the second phase, is concerned with making and recording observations on the measure and reports on the status of the features. The third stage deals with data storage, retrieval and manipulation. Data dissemination, the fourth phase, involves the delivery of data to users. The fifth phase covers the actual data applications by the users. ERTS, as a data gathering system, greatly reduces the effort which must be expended in these phases. The acquisition phase is eliminated by lesser-developed countries receiving the data. Because of the synoptic nature of ERTS and its wide field of view, the third stage is greatly simplified. Each ERTS frame contains a vast amount of information that could only be provided, by conventional means, with many frames at larger scales. In addition, the interdisciplinarian nature of ERTS data could promote cooperation across disciplines which could enhance data dissemination and data applications.

Data needs for resource development problems may be categorized into three broad categories. 1) Institutional policies and programs for resource management, including technical and financial assistance related to resource use, must be formulated. When little previous data is available and when such programs don't exist, reconnaissance level surveys are needed. 2) Resource development potentials and problems must be identified and evaluated in order to define specific areas for pre-investment studies. Reconnaissance level surveys are also required for this stage. 3) The next level involves the design, planning and justification for investment in resource development for the specific areas previously delineated. Survey work is required at the prefeasibility or feasibility level.

There are four levels of survey sequence: exploratory, reconnaissance, semi-detailed and detailed. The levels range from low to high detail and are generally associated with the following characteristics: decreasing size of area surveyed at one time, increasing scale at which results are mapped and presented, increasing scale of remote sensing imagery used as source information, decreasing reliance on such imagery, increasing amount of field work and increasing density of sample observations on the ground.[4] The level at which the survey will be carried out is dependent on the amount of existing information and on the amount of information required. Attempts should be made to make the surveys integrated and multidisciplinary. This serves a twofold purpose: economy in data collection and analysis resulting from investigating several items at one time; and promotion of a holistic view of the natural environment. However, one finds that low-detailed surveys tend to be more integrated in nature than high-detailed surveys, which are often designed to meet specialized requirements.

Exploratory surveys are general wide-area inventories using broad classifications. They may be initial examinations of the potentials for economic development. Reconnaissance level surveys operate on a somewhat less generalized level to confirm the existence of commercial opportunities which may have been identified in the previous stage. Areas which warrant further study are identified and broad categories may be identified. More intensive investigations of selected areas are performed in semi-detailed intensive surveys in order to arrive at preliminary capability studies, perform cost-benefit analysis, etc. A maximum level of detail is sought in detailed surveys to establish concrete plans of development and to assist in management problems.

In relating these considerations to developing nations, two factors arise which make such nations special cases in resource survey planning. Existent, coherent data bases are much less common. Appropriate data acquisition planning is economically

more critical. Decision making criteria should be lucid and well-defined in order to obviate lasting damaging effects. In a lesser developed nation, where limited resources must be carefully proportioned among vying programs, an unwise allocation could adversely impact the economy to a much greater degree than in a developed nation where the diversified economy would absorb the loss. Thus, the importance of a well-planned, efficiently constructed geographic data base to a developing nation is critical.

E.2 ERTS FEATURES AND LIMITATIONS ON MAPPING

The process of establishing this base is complicated and requires a substantial commitment of monetary and human resources. In a lesser developed nation, often greatly deficient in this area, the allocation of limited resources is a crucial problem. The use of imagery from the Earth Resources Technology Satellite might effectively reduce the budgets required to develop such a data base. ERTS imagery offers certain unique advantages over conventional methods for collecting geographical data. Numerous applications of the imagery in the field of cartography have and are being studied.

ERTS offers many technical advantages for cartography over conventional aircraft systems and other satellite film systems with different configurations. Imagery can be electronically transmitted without serious distortion. Cartographic products from ERTS can be obtained in near real time, within two weeks after image acquisition by ERTS. This is a marked time improvement over the average five and one-half years required by the United States Geological Survey to produce published, multicolor quadrangle maps, which when finally issued are based on four year old data.[5]

No aerial photosystem nor film-return space system can equal the near-orthogonal imagery which ERTS produces.[6] The field of view of

ERTS MSS, which extends only 5.76° from nominal vertical, simplifies small-scale planimetric mapping and revision. The most important cartographic application centers on the monitoring of dynamic changes. Maintaining current, updated planimetry is a major mapping problem which ERTS may help to alleviate. "An image map consisting of little more than an image precisely referenced to the figure of the Earth is probably the most effective method of portraying up-to-date planimetry."[6] Though ERTS limits the compilation of topographic maps, the limitation is easily outweighed by the benefits which accrue from monitoring. Topographic mapping is a static process. Once an area is mapped topographically it requires little revision.

ERTS imaging is ideal for small scale mapping for two reasons: 1) orthographic projection, and 2) uniform illumination throughout the scene which yields meaningful color and tone gradients. Figure A1 illustrates these two features. The view angle is identical for the features at the edge of the frame as well as at the center. One may view the center of the volcanos at the perimeter of the image which would not be possible in an oblique view. The uniform illumination in Figure A1 allows the viewer to correlate surface material with tonal variations over the 100 x 100 mile area. ERTS provides objectivity in generalization of macro-forms of the surface of the earth. Previously small-scale (1:500,000 - 1:5 mill.) maps were produced with the subjective intervention of a cartographer, and compiled by a process of generalization which by its very character was subjective. Satellites, with their synoptic field of view, have remedied this situation.

The spectral image of a given ERTS scene, because of the system's radiometric fidelity, is more meaningful than that from a film camera. ERTS four waveband images can be combined to provide an optimized response for selected objects (of sufficient size) or scenes. Film cameras are limited to recording up to three bands on one film. This

separate band capability of ERTS is particularly valuable for areas that have unusual radiometric responses or that are imaged under unusual illumination conditions (e.g., polar regions).

The MSS band 7 has demonstrated unique capabilities. Under certain conditions it has effectively penetrated thin clouds and contrails. It defines water-land interfaces with high precision. It has yielded superior definition of vegetation patterns, of natural features of the earth's physiographic structure, and in some cases it is the best band for defining cultural features.

Various advantages of space imagery affect the capability to provide thematic information. Each frame covers a large ground area allowing a synoptic view which provides instant generalization. The difficulties of tedious mosaicing are obviated. This has led to the discovery of some hitherto unknown large-scale features so regional in scope that they could be obtained in no other way. The advantages offered by ERTS allow series of photomap products to be produced in a fraction of time required by conventional methods, and at a cost which permits frequent new editions. The progression of map preparation from foot traverse to preparation from aerial photographs reduced the number of ground points necessary for accurate control. Compilation from ERTS is another step forward with a much greater reduction in the number of required ground points. Another advantage of ERTS wide field of view is the reduction in storage requirements for a given geographic area. The sun angle is constant for each pass, producing for the first time qualitative color and tone, eliminating the problems of shading encountered in conventional imagery. The high-speed coverage yields simultaneous photography, promoting a high degree of data standardization. Change detection and measurements of seasonal fluctuations are facilitated by ERTS' short interval repeatability.

It is important to note that space imagery does have several major limitations: low resolution, low stereo capability, and the

inability to effectively and consistently penetrate cloud cover.

E.3 ERTS MAPPING ACCOMPLISHMENTS

From the mapping viewpoint ERTS has exceeded expectations.[7] Image-quality products (MSS-bulk) have been produced up to at least the 1:250,000 scale. Mapping with ERTS MSS is geometrically limited by NMAS to a scale of 1:1,000,000 or perhaps to 1:500,000. Geometric accuracy may be improved, without degrading image quality, by applying corrections based on ground control. Investigations have shown that ERTS imagery can be used for cartographic photobase products at scales of 1,500,000 and smaller.[7] Photographic products at scales at least as large as 1:250,000 can be used to complement existing line maps. The imagery is useful for assessing the need for revision of features on large scale maps (1:24,000) as well as detecting change and positioning gross features on medium and small scale maps (1:250,000 or 1:1,000,000). While these photomaps will not replace conventional line maps, they do provide an invaluable complement because of the additional information depicted.

The cartographic usability of the imagery has been demonstrated for the following: 1) compiling map areas of the world difficult to map by conventional means; 2) compiling maps for land use and changes in land use at a scale of 1:250,000; 3) compiling plainmetric maps to NMAS at scales of 1:250,000 and 1:1,000,000; 4) revising maps as large as 1:100,000 when controls are available; 5) producing orthophotomaps at scales up to 1:250,000.[8]

In Virginia ERTS-1 imagery has been employed operationally to predict the extent of needed revision of 1:24,000 scale maps. In Antarctica the imagery has been used operationally in compiling 1:1,000,000 scale photoimage mosaics along all of the coastal areas as well as for revisions of polar maps at scales as large as 1:250,000.

Land use inventory and mapping have been carried out with ERTS imagery for the states of Rhode Island, Massachusetts, and Connecticut. Land use in the state of Rhode Island was classified in forty hours of interpretation and towns containing as few as 7,000 persons were clearly distinguished and mapped.[9] Dr. Robert B. Simpson of Dartmouth College estimates that a land use map may be produced for an area the size of Missouri at a cost of approximately $75,000. A similar map produced from conventional aerial photography would cost about one million dollars. The Joint Federal-State Land Use Planning Commission of Alaska is making use of the imagery for inventory information of the state. The imagery has been used for identifying and preserving land suited for agriculture; forest location and management including assessment of damage by fire and infestations; pipeline and highway location; mapping and monitoring urban growth into open agricultural and recreational areas; and identifying critical areas for further studies. Particular emphasis has been placed on vegetative, hydrological and geological analysis of the proposed trans-Alaskan transportation corridor and lands. The corridor could include a secondary highway, railroad, and 48" pipeline for oil. Thirty man hours were devoted to preparing a regional resource survey of a remote and undeveloped region of Alaska. The survey was performed by a multidisciplinary team whose output included maps of three predominant types of vegetation, ten watershed drainages, and geologic features related to economic minerals.

E.4 USE OF ERTS MAPS IN DEVELOPING COUNTRIES

The lesser developed nations are rapidly becoming aware of the importance of mapping for planned development and economic growth. Interest was obvious at the UN Economic Commission for Africa's Cartographic Conference for Africa in November, 1972. The values

of these services were noted for inventory and exploration of forest and grass resources, animal resources, mineral resources, water and energy resources, development of national and multinational infrastructure, crop estimation, control of plant and animal diseases, regional physical planning, all activities essential to economic development. The UN Working Group on Remote Sensing of the Earth by Satellites expressed their enthusiasm for ERTS in the statement, "Production through space images of accurate cartographic maps of a country at a scale of 1:250,000 is an unprecedented method of rapidly updating existing thematic maps as well as for obtaining fundamental cartographic information about poorly or incompletely mapped regions." They concluded that "... as an item of priority, in view of the already demonstrated positive and real possibilities of remote sensing from space in the area of cartography, suitable measures should be taken to acquaint Member states, and especially developing countries, of such possibilities which might greatly enhance their means for natural resource planning on a national basis."[10]

Each of the four case study nations in this project have geographic data needs which ERTS could assuage. In 1970 Botswana embarked on a national mapping program. Requirements for complete coverage call for eight hundred and fifty maps at a scale of 1:50,000. These maps are standard international medium scale maps, compiled from aerial photographs. Currently fifty-five sheets have been published and forty-nine photomaps are available. A 1:1,000,000 scale, single sheet six color map, covering the entire nation, was originally published in 1970. In response to the popularity of and high demand for the map it was revised and reprinted in 1971. ERTS would be an effective and inexpensive tool with which the map could be accurately and often updated. Table E-1 gives the current map coverage of Botswana; that which has been completed and areas which still must be mapped.

In addition to the work documented by the chart, large scale township mapping has been done. The following five land resource maps are newer additions:

Central and Southern States Land Soils and Vegetation Sites 1:1,500,000;

Northern States Land, Vegetation 1:500,000

Central and Southern States Land Vegetation Map 1, 1:500,000;

Central and Southern States Land Vegetation Map 2, 1:500,000; and

Central and Southern States Land Vegetation Map 3, 1:500,000.

From a cost point of view, a national mapping program at a scale of 1:50,000 would be wasteful. Six hundred and fifty of the required eight hundred and fifty-eight map sheets would cover areas that are relatively barren or are not intensely utilized. At estimated costs of $12K per map with topographic contouring and $6K per map without it this cost is prohibitive to a country whose current budget for mapping is $210K/year, supplemented by $300K from Great Britain which produce all their 1:50,000 maps. Two years ago, Lands and Surveys proposed mapping the country at a scale of 1:500,000. This proposal, with an estimated cost of $2.7M was turned down by the government as being too costly. This is not surprising in view of the fact that the entire national budget for 1973 was $13M. In this situation, it is clear that ERTS can provide a low cost substitute for these maps. It has been argued that photomaps have limited value in that the user must be a photointerpreter and the image characteristics would change with season. A counter argument to this would be that maps made from aerial photography would be biased by the season, in which case the interpreter making the map must use multi-seasonal photography or his delineations are based on judgements which can introduce error. At least a photomap would have a date indicating the time it was taken. Current plans are underway in the Lands and Surveys Office

to make experimental color photomaps with ERTS using overlays for roads and names of cities and villages. Botswana's ERTS-2 proposals reflect an increased awareness of the cartographic value of ERTS. They propose to produce an elemental photomap of undeveloped areas at a scale of 1:250,000, which they plan to use in their current program of mineral exploration.

Figure E-1 is a 100 mi. x 100 mi. section of an aeronautical navigation chart, made in 1943 at 1:1 million scale, and Figure E-2 is an ERTS frame covering the same area. The ERTS frame tick marks are not precise representations of latitude and longitude but in general they are accurate to within a few minutes. On examination, the map and ERTS-image show clearly the high degree of inaccuracy in the overlay as well as the utility of ERTS for improving positional accuracy.

Bolivia has formulated a plan for mapping the entire country. In 1969 only twelve percent of the nation had been mapped at a scale of 1:50,000 or 1:100,000. In 1973, one hundred and one map sheets were produced at a cost of $7,425 per sheet. However, much of the nation still remains unmapped as well as uncovered by aerial photography. In this sense, Bolivia is representative of most of her South American neighbors as shown in Table E-2. Recently Bolivia completed a new preliminary map of the Republic at 1:1,000,000. ERTS imagery was used to correct location of rivers, lakes and ponds in areas uncovered by aerial photography. The project concluded that precision ERTS images can be used in producing a small scale cartographic map of all of Bolivia. In addition, the imagery could be used for making much needed land use maps of the entire country. Without ERTS, this task would take eight to ten years, with ERTS two years. A complete natural resource inventory of Bolivia could be completed in one and one-half years with ERTS; six years with ERTS, aircraft, and ground-checks; and twenty-five years without ERTS.

One of the principal constraints to the development of mining in Bolivia is the inadequate level of surveying and exploration currently performed. Once the mineral resources are discovered and mined, the presently deficient transportation system will not promote efficient marketing. ERTS can ameliorate this situation in four ways: 1) identification of position; 2) location of exploration targets; 3) logistics of developing targets and transporting commodity to areas of need, to industry or to ports; 4) monitoring and maintenance of low environmental impact. There are several railroad and road projects for which ERTS could be used in lieu of preliminary aircraft surveys. One such project is the planned joint railroad project of the Bolivian-Brazil Mixed Commission. COMIBOL is presently using ERTS to select limited areas for more detailed investigations with aerial photography. Alaska, as mentioned earlier, is using ERTS to help select a utility corridor, and their findings and techniques could be of value to the Bolivians.

Highway and utility corridor location surveys are conducted in four substages:[12]

1) reconnaissance surveys of an area to determine feasible routes;

2) reconnaissance surveys of route alternatives to select a route;

3) preliminary survey of the selected route;

4) location survey staking of designed location on the ground.

Because the first two stages evaluate general parameters, small scale regional coverage is required. ERTS would be an appropriate and inexpensive tool for such a task. The concluding substages require numerous details, necessitating large scale studies. The extreme requirements of these types of surveys necessitate the use of two or more scales for highway location and design. ERTS imagery would be useful for determining geologic feature and land use patterns. The uniform illumination of the imagery enables researchers to determine regional structural and faulting patterns and to differentiate certain

rock formations. In lesser developed nations, the transportation systems, often little developed, can act as inhibitors to economic growth and development. Using ERTS for preliminary corridor selection would be valuable to many nations.

Vegetative maps, another possible output from ERTS, have a number of useful applications: means of estimating depletion of resources such as cutting of timber; means of assessing the environmental impact of a given activity; means of improving management of resources such as forage grass so that optimum numbers of animals may be grazed at optimum times without endangering future production. These particular applications would be important for Kenya and Botswana with their large grazing herds and for Thailand where forests cover 50% of the nation.

Because many lesser developed nations are still in a project stage of development, an improved data base can lead to better formulated policies and decisions. The multidisciplinarian nature of ERTS allows many disciplines and functions to be served in unison and can promote cooperation and communication among various branches of the government. It can be a vehicle for strengthening communications between the technical community and government officials who are responsible for agriculture, hydrology, energy, natural resources, transportation, health and land use planning.

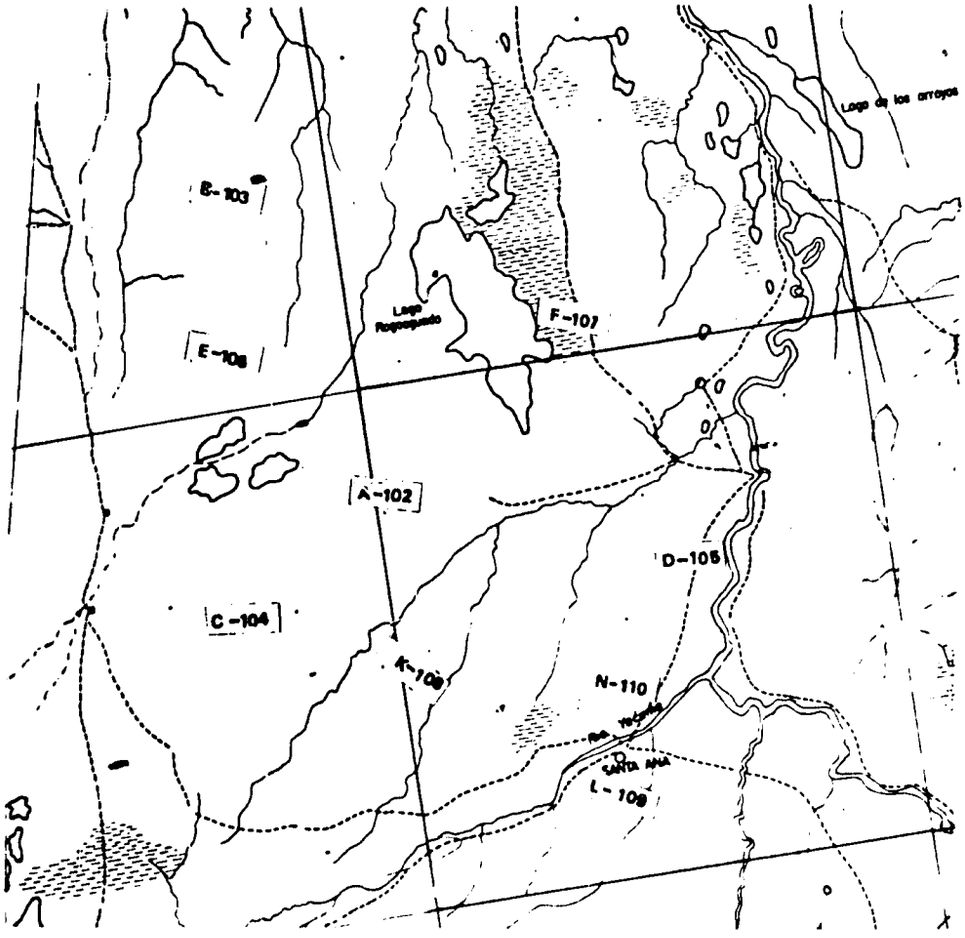

FIGURE E-1. SECTION OF AERONAUTICAL NAVIGATION CHART, 1943*

* "Analisis Preliminar Del Mapa Cartográfico de Bolivia con Imágenes ERTS" Programa del Satélite Technológico de Recursos Naturales ERTS-A Bolivia, C. Brockmann and A. Fernandez C.

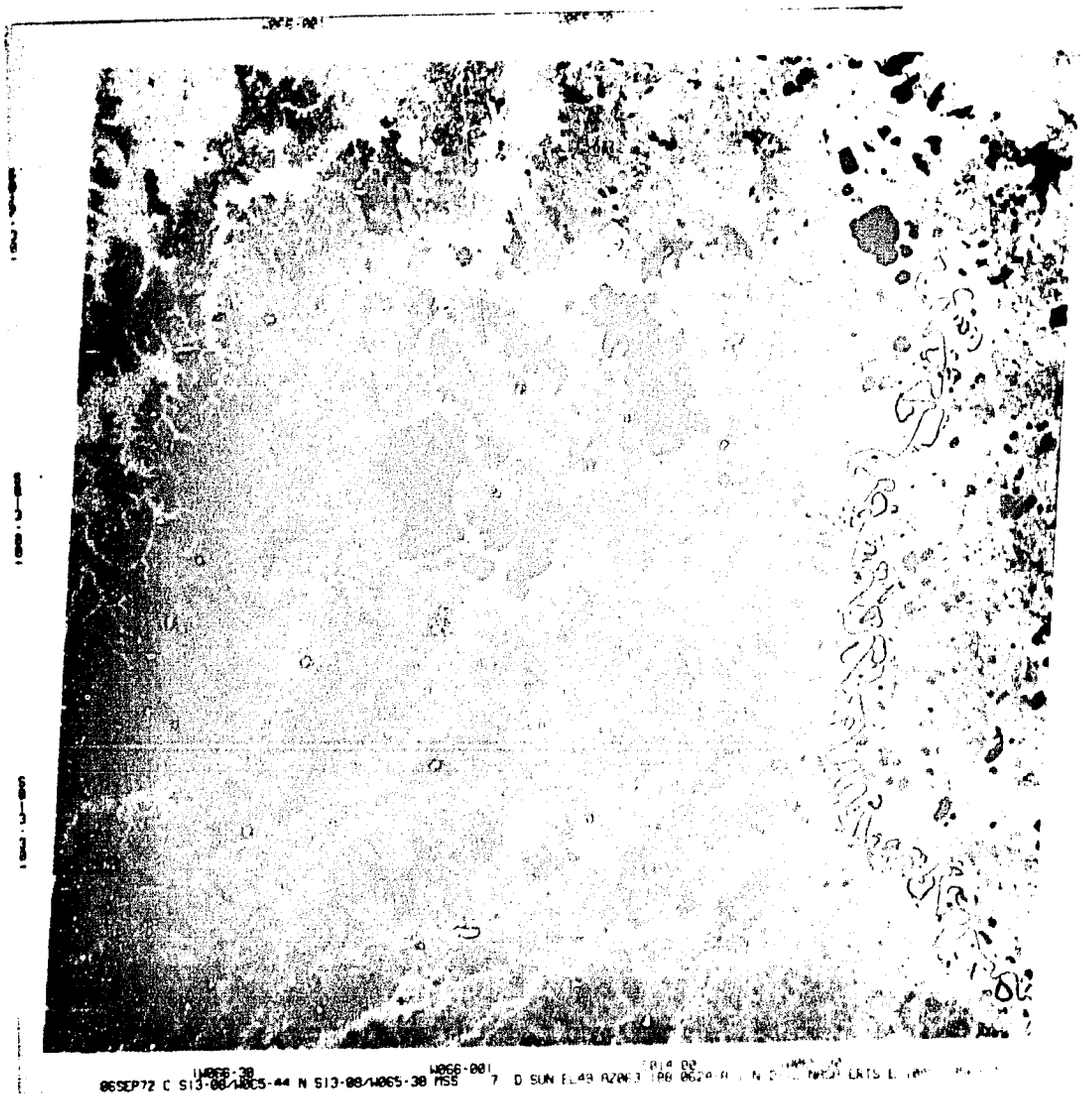

FIGURE E-2. ERTS IMAGE (BAND 7) OF AREA MAPPED IN FIGURE E-1

TABLE E-1. CURRENT MAP COVERAGE OF BOTSWANA [11]

Description	scale	# of sheets required	# of map sheets required	# of photomaps published	maps in production	maps to be completed
					sheets / photo	
Six color maps, originally produced in 1970, revised & reprinted in 1971.	1:1,000,000	1	1			
World Aeronautical Charts IACO	1:1,000,000	6	6			
General small scale series produced in 2 colors with relief shown by form lines.	1:500,000 uncontrolled	138	138			
Compiled from aerial photographs & produced as first stage mapping. Two colors with relief by form lines.	1:250,000 uncontrolled	232	108			124
Standard international medium scale, compiled from aerial photos, sheets available as conventional 6 color contoured map scenes & photomap format.	1:50,000	858	55	49	91 22	641
Photographic print laydowns standard aerial photos laved down to approximate geographical lines of latitude & longitude. Series covers whole nation	1:125,000 1:50,000	288 84		288 84		
Small scale aerial photos. (some as old as 1951)				211		
Geological mapping*. Multi-colored sheets. Monochrome sheets. Dyeline prints.	1:125,000	231	12 8 25			

* In addition, basic small scale geological maps are available at scales of 1:2,000,000 two color printed map, 1:1,000,000 hand colored dyeline print, 1:500,000 multi-colored map (Eastern Botswana)

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TABLE E.2 USA INTERAMERICAN GEODETIC SURVEY - BOLIVIA PROJECT

Country	FY 69		Grand Total thru FY 69	
	Maps Completed*	% Country Mapped**	Maps Completed*	% Country Mapped**
Bolivia	54	3.6	178	12
Brazil	184	2.3	600	7
Chile	48	4.0	316	30
Colombia	28	2.7	308	30
Ecuador	20	5.0	74	19
Paraguay	1		1	
Peru	53	4.4	265	22
Venezuela	30	3.7	268	33

*15.15 minutes 1:50,000 map equivalents at equator
1:100,000 maps valued at 2.5 1:50,000 maps

**Includes total 1:50,000 and 1:100,000 coverage

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Appendix F

SUMMARY AND EVALUATION OF THE USE OF ERTS-1 DATA BY EIGHTEEN DEVELOPING COUNTRIES, THE FAO AND MEKONG SECRETARIAT*

F.1 LATIN AMERICA

F.1.1 ARGENTINA

P.I.: Domingues, O. Dr.
INTA - Instituto Nat. de
Technologia Agropecuria
Chile 460
Buenos Aires, Argentina

Proposal No.: 528

Agricultural-livestock studies. Map drainage network, land use and ecological units, soils, and recommended management or use of humid pampa of Argentina

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P.I.: Garuti, Hamberto H.
Direccion Nacional de Economia
y Sociologia of Rural
Paseo Colon 974-3 Piso - of: 143

Proposal No.: 529

Evaluation of agricultural resources, inventory and identification, evaluation of crop vigor and stress, agricultural and land use census of several regions, to improve agricultural potential

Reports: None

Other Reports

P.I.: Dr. Oscar Dominguez

Proposal No.: 528

Internal Report, Instituto Nacional de Technologia Agropecuaria, March, 1974

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*Prepared as a joint effort with System Planning Corporation, Arlington, Virginia.

"A Few Considerations on the ERTS-1 pictures of the Wet Pampa area"

A nontechnical discussion of the natural and agriculture-livestock resources of the wet pampas, accompanied by ERTS imagery. General discussion includes local farming patterns, national mapping efforts, surface water, soil moisture and natural vegetation. Purely a narrative description of surface characteristics. National agricultural objectives are discussed. The paper was submitted to NASA in lieu of a report.

F.1.2 BOLIVIA

P.I.: Brockmann, Carlos
Servicio Geologico de Bolivia
Programa del Satelite Tecnologico de Recursos Naturales
Casilla 2729
La Paz, Bolivia

Proposal No.: 571

Mapping and evaluation of basic resources of Bolivia. Bolivia is interested in investigating the potential applications of the ERTS sensors and data collection system to provide data to aid in effective program planning and project management in the mining (including hydrocarbons), agricultural, and land use (including livestock production and forest products) sectors.

Location:

Geological and cartographic studies will cover the entire country. Agricultural studies will include the Western Altiplano valleys east of the eastern cordilleras, the Yungas region of lower valleys northeast of the eastern cordilleras, the semi-tropical lowlands, and the Chaco-Benianos plain grasslands.

Objectives:

Development of small-scale photomaps on a standard grid to assist in overall cartographic updating in Bolivia.

Development of analyses, (overlays to the small scale photomaps and to individual ERTS frames) depicting significant structural/morphological features of the geology of Bolivia.

Development of a series of analyses (overlays to photomaps/photomosaics or individual frames) of cash crop land use patterns, major physiographic features, significant land zone classification, etc.

Test of satellite data collection system for collection of stream flow data.

Confirmation of satellite remotely sensed data as an integral part of a regional resource evaluation and management program in the mineral and agricultural sectors of the Bolivian economy.

Establishment of a Bolivian center for resource management which can maximize the benefits to be derived from remotely sensed data from satellites, aircraft and ground.

Report: Type 1 Report, Period July - October 1972

P.I.: C. Brockmann

At the time of this report no ERTS images had been received and no firm operating organization had been formed to work on ERTS data. The various participating institutions and Ministries are identified and a proposed data handling flow chart is presented. This report covers the period corresponding to the first 3 months following the launch of ERTS-1.

Report: NASA - CR - 132999
NTIS 73 10695

Type I Report for period October 1972 - May 1973

P.I.: C. Brockmann

In view of the excellent ERTS imagery received a photomap of all of Bolivia (1:1,000,000) has been programed. At present the experimental publication of the first map using ERTS images on a 1:250,000 scale is in the preparation stage.

Report: NASA - CR - 130701
NTIS 73 10296

"Bosquejo sobre la geologia estructural y el vulcanismo en el altiplano central de los Andes Bolivianos" 1973

P.I.: C. Brockmann

Authors: S. Kusmull
J. Meave
P. Tomasi

Studies show ERTS imagery to provide a synoptic view of geological formations and structures and to present Bolivian geological problem in a manner which has not previously been possible using conventional maps. The investigators report

it has been possible to define obscured structure and lineaments, to differentiate the extent of volcanic formations, and to correlate regional fracture zones with volcanism

P.I.: C. Brockmann, DS #170/73, June 1973

The subprograms include:

Petroleum Exploration

Comparison and description of physical features observed on ERTS imagery corresponding to bands 4, 5, 6, and 7 by C. Vargas Flores

The physical features observed in the different bands include:

Lakes - best defined in band 7, progressively less in 6, 5, and 4

Salt flats - clear white in band 4, less bright progressively in 5, 6, 7. 7 is best since faint gray variations presumably related to impunities are noted.

Volcanoes - All volcanic features and gray tones related to texture are best seen in band 4.

Mountain ridges - best contrast in band 7, progressively poorer in 6, 5 and 4. Elevation and slope are easily seen in 7.

Plains - Band 7 has best gray tones for defining recent alluvial material and soil types.

Conclusion:

Not all features are well defined in a single band. To make a complete interpretation imagery from all bands are required.

Tectonophysics

Report of activities - by P. Tomasi

ERTS imagery is being used to assist preparation of a structural map of the Central Altiplano at a scale of 1:500,000.

A structural section of the central part of the Eastern Cordillera is being revised as to the location and orientation of faults after examination of ERTS images.

Regional geology

Report on band evaluation - geological interpretation providing best definition of physical features. Band 6 was used sporadically however, inasmuch as the edges of images

in band 7 often appear in very dark tones which makes observation difficult. Drainage, rivers, lakes, etc. are best seen in bands 7 and 6. Faults and structural features show best in band 7, also band 7 shows several faults and large longitudinal and transverse structural features were identified.

Hydrological subprogram

Report on band evaluation - by C. Velasco

The writer will limit hydrological studies to bands 6 and 7. Bands 4 and 5 were considered to be of no value whatsoever. The writer concluded the more valuable use of ERTS imagery is for regional comparisons or over-view analysis of large areas.

Volcanology

Report on band evaluation - by S. Kusmaull

The most suitable band for interpreting volcanic features is 7. Band 6 and 7 are used together for defining some faults. Band 4 has poor definition and lacks contrast. Band 5 is also unsatisfactory for volcanological studies. Band 7 was found to adequately define erosional features on flow tuff plateaus, differentiate between lava flows, identification of variations of cones and domes on volcanoes, and clearly identify characteristic features of calderas or tectonic collapses.

Soils

Utilization of ERTS images in soil surveys. - by O. Unzueta

A classification has been developed for major mapping of soils using ERTS imagery. The work is in its initial stage and ERTS images are viewed as a source of invaluable data.

Report: Internal Report: Applicacion de Los Imagenes ERTS a La Cartografia y Geologio 1973

P.I.: C. Brockmann

Authors: C. Brockmann
A. Fernandez C.
B. P. Martinez

ERTS-1 images were studied and compared with existing geological maps for the purpose of developing new cartographic techniques and for using the images to update maps of poorly explored areas. Both RBV and MSS imagery proved to be of

value for geological mapping. Studies were undertaken using negatives, positives, mosaics and false color composites. The images were found useful for mapping volcanic features, lithology, soil moisture and geologic structure.

Report: NASA - CR - 132011
NTIS E 73 - 10614

The application of ERTS imagery to geological mapping - by Fernandez, et al., 1973

A study was undertaken to consider the usefulness of ERTS imagery in geologic mapping and to indicate which bands are the more valuable for specific objectives. Bands 6 and 7 were found useful for lakes and rivers, band 4 and 5 containing little information. All four bands were considered valuable for physiography and geomorphology.

Volcanic features were particularly good objectives. The writer feels that ERTS imagery is valuable as an aid in the preparation of geologic maps but should not be considered a solution to geologic mapping problems. (This may well have been addressed to the Servicio geologico de Bolivia)

Report: Space Photomap of the Sucre, Bolivia Region, 20 September 1973

As proposed in the June - October 1972 Type I Report, a space photomap of the Sucre region has been prepared at a scale of 1:250,000. The map was made by the Instituto Geografico Militar (IBM), based on ERTS E-1008-13533-1 imagery. This is the first of several such maps which will comprise the first physical map of Bolivia. The map is experimental, based on RBV band 1, with such features and cultural data overprinted as cities, towns, rivers, mountains, forested areas, railways and six classifications of highways. Milage information (km) has been added. The obvious lack are elevations and contours; however, the map is preliminary and will serve as a basis for future products.

Report: Aplicaccion y Evaluacion de Imagenes ERTS de "Composicion de Color: al Inventiario de Recursos Naturales, by Alvaro Fernandez C. and Carlos Brockmann, GEOBOL, Programs del Satelite de Recursor Naturales, ERTS-Bolivia, La Paz, Bolivia, 1973.

With the purpose of extracting the maximum possible information from ERTS color composites prints for mapping natural resources, eleven thematic maps have been made from ERTS image 1010-14034, a scene of the central sector of the

Western Oruro Province, the main feature being the Solor de Coipasa. Maps, overlays and detailed interpretations are presented drainage, hydrology (floods and relative permeability), volcanism, structural geology, physiography, geological mapping (lithology-stratigraphy) and soil types. This effort appears to be the first through natural resource inventory made from a single frame.

Because of the high quality results obtained from the above study the investigators compared the information content with similar interpretations made of the same area using black and white products obtained from band 7. The comparison of results indicated that the color composite prints contain some 50% more data than the black and white prints at 1:1,000,000 scale in the areas of hydrology geomorphology, volcanism, geology, soils and vegetation. As a result of these studies the ERTS-Bolivia project is processing 9.5 x 9.5 negative transparencies of all Bolivia using Diazo color techniques on bands 4, 5 and 7.

Report: Interpretation of drainage from ERTS images of the area Cobija-Puerto Heath-Rio Madre de Dios-Ixiamas. By Carlos Vargas Flores; Geobol, ERTS-Bolivia. August, 1973 (rec. April 1974)

A drainage map was prepared from MSS band 7 imagery of the above area by the YPFB Department of Photography. The map is at 1:1,000,000 scale. The region is on the extreme northwest frontier. Results of the study include:

Definition of probable anticlines indicated by drainage patterns presumably controlled by regional fold structure.

Two photolinear patterns have been defined, apparently representing major fault and fracture systems.

Savana areas have been delineated from areas of dense vegetation.

The courses of the major rivers of the region have been carefully traced.

Report: Result of the Geomorphological-Geological study of Two ERTS Images of the Zones of the San Boya-Mamou River-Rogaguardo Lake East of Bolivia by Carlos Vargas Flores; Geobol, ERTS-Bolivia. July 1973, (rec. April 1974)

Geomorphological and geological studies were undertaken on ERTS imagery of the Chaco-Beniana region of north-central Bolivia. Newly discovered features of this remote area

include many square and rectangular bodies of water with parallel alignments. The most important discovery is the location of the contact between the Brazilian Shield and adjacent quaternary basin sediments.

The study was based on MSS band 7. Results of the study include:

Lake mapping-most of which do not occur on Bolivian maps. Two very large lakes were discovered.

The lakes of the region are rectilinear - the orientation suggesting a relationship to basement fractures. The orientation prevails within the shield area and in the sedimentary basin, regardless of vegetation cover.

The lake basins presumably formed due to recent downfaulting of the basement, the overlying quaternary sediments settling into the downfaulted blocks.

Between the west limit of the aligned lakes and the last sub-andian ridge there is estimated to be a large downfaulted block into which was deposited a 6000 meter thickness of sediments. (This phenomena is presented on two maps and a cross section profile.)

Other Reports:

1. Annotated Index of Aerial Photographic Coverage and Mapping of Topography and Natural Resources. Pan American Union, OAS, 1964. (an atlas of Latin American member countries providing an index of topographic maps, aerial photography, geological maps, soil maps and land capability maps.)

Aerial Photography: The Instituto Geografico Militar (IGM) and the Yacimientos Petroliferos Fiscales Bolivianos (YPFB) are the agencies concerned with aerial photography. Most is at 1:40,000 scales and is used for land classification, precolonization studies and cadastral surveys. It is used by the Direccion Nacional de Geologia (DNG) for geologic mapping. Several areas of western and south central Bolivia have been flown and mapped. Some small-scale photomapping has been undertaken for the highway program.

Topographic and Planimetric Maps: 1:50,000 Scale topographic maps are produced by ICM-YPFB based on aerial photography. The mapping program will eventually include all of the altiplano and mountainous area. The only accurate maps of the frontier regions are those produced by private oil companies. These are not published and have limited availability.

Geologic Mapping: Mapping is being done by the DNG and YPFB in cooperation with the USGS, UN Special Fund and a West German technical mission. Mapping is also being done by oil companies. Compilation scale is 1:50,000. Some 1:250,000 scale mapping has been sponsored by the U.N. (see Bibliografia geologia, Mineralogica y Paleontologica de Bolivia, Bul. 4, DNG. 1962)

Soil and Land Capability Mapping: Soil and land use maps are prepared by the Servicio Agricola Interamericano (SAI) to support federal colonization projects. These are based on U.S. Soil Conservation Service criteria. These are of limited extent, are not published, but are on file at SAI in La Paz.

There is essentially no mapping of vegetation, current land use, forest inventory of ecology. SAI has limited maps of temperature, altitude, rainfall, soil groups, genera and species.

2. Carter, W.D. (1973)
Geologic Mapping and Mineral Resource Inventory by ERTS-1 Satellite Data in South America. Type 1 progress report for 15 January 1973 -- 30 April 1973, EROS Program, U.S. Geological Survey, CR-132239, NTIS E 73 10648.

ERTS-1 data has provided significant new geological information on the remote areas of South America. Remarkable differences have been found as to shape and size of features shown on World Navigation Charts, which until now have been the best maps of many regions. New lineations which will probably be identified as faults have been identified in Bolivia.

3. Carter, W.D. (1973)
Status of Geologic Mapping and Mineral Resources Inventory by ERTS-1 Satellite Data in South America (73-225): Proceedings of American Congress on Surveying and Mapping: 32 Annual Meeting, 1973, Washington, D.C. (abst.)

4. Stertz, G.E. and Carter, W.D. (1973)
Hydrology of Closed Basins and Deserts of South America, ERTS-1 interpretations: NASA/GSFC Symposium on Significant Results Obtained from ERTS-1, New Carrollton, Md., March 1973.

Hydrology studies included desert areas of southwestern Bolivia. Positional discrepancies of 10 to 15 miles were noted in regard to current maps. 150 salars, salt encrusted playas, were mapped in the Argentina-Bolivia border desert area. Of these, only 86 were correctly located on current maps.

5. C. Brockmann to UNDP, DS 260/739/3173
Technological Satellite for Natural Resources - National Plar for Natural Resources of Bolivia; Implementation of the National Plan for Meteorology and Hydrology.

Contains detailed documents presented by Bolivia about expertise, equipment, training, others.

Brockmann states that because of its importance geology will get first attention. Little is known about Bolivian natural resources (which are rich) because of the difficult terrain, poor transportation and lack of funds for proper studies and equipment. ERTS has changed the situation since it will now be possible to prepare accurate maps for minerals, petroleum exploration, forestry, hydrology, etc., and identify areas of agricultural concentration and assess potential land use.

The lengthy document includes the Supreme Directives as to the creation of the ERTS-Bolivia program (#10135) and the creation of GEOBOL, Department of geology is presented in detail: Economic Geology, Petroleum Exploration, Soils, Geological Structure, Lithologic Mapping, Cartography, Hydrology, etc. Related activities in other govenment agencies are noted.

The section relating to UNDP assistance includes budget estimates, work plans, statements of objectives.

6. Yacimientos Petroliferos Fiscales Bolivianos, Resumen De La Geologia Petrolera De Bolivia by Rolando Prada Mendez.

The publication is a compilation of geomorphological, stratigraphic, tectonic and structural geology of the sedimentary formations with possibilities of containing petroleum. It summarizes the regional structure of the Brazilian basin area, the Chaco, the lowlands, the altiplano and the Cordillera. Detailed stratigraphy is presented and such tectonics as are known. A resume of geological exploration for oil is presented and the producing regions are described. Production data is included. Economic information is negligible.

7. 3rd ERTS Symposium, Abstracts, Dec. 1973, Washington, D.C., Paper L 16.

Earth Resources Technology Satellite Data Collection Project, ERTS - Bolivia

Carlos Brockmann, Geological Survey of Bolivia, La Pas, Bolivia

The Earth Resources Technology Satellite program of Bolivia, under the decision of the Geological Survey, had developed a

multidisciplinary project to carry out investigations in cartography and to prepare various thematic maps.

In cartography, investigations are being carried out with the ERTS-1 images and with existing maps, to determine their application to the preparation of new cartographic products on one hand and on the other to map those regions where the cartography is still deficient. The application of the MSS images to the geological mapping has given more than satisfactory results. Working with conventional photointerpretation, we were able to prepare regional geological maps, studies relative to mining, geomorphological maps, studies relative to petroleum exploration, volocanological maps and maps of hydrologic basins. In agriculture, the ERTS images are used to study land classification and forest mapping.

For the formation studies, we use the ERTS imaging process in black and white and in color, With Diazo film on a 23 x 23 cm format. We obtain 40% more information from the color film than from the corresponding black and white.

F.1.3 BRAZIL

P.I.: de Mendonca, Fernando, Dr.
Director general INPE
C.O. 515 Sao Jose dos Campos
Sao Paulo, Brazil

Proposal No.: 326-01

To develop techniques and systems for acquisition, interpretation, and potential resource utilization of agriculture in five states within Brazil by surveying the cultivated areas of coffee and other crops. The crop density and yield prediction will permit an up-to-date evaluation of the national coffee crop situation, also an evaluation of the forest exploration and grassland areas for grazing pressure will be examined.

Location:

Studies will be made in states of Parana, Sao Paulo, Minas Gerais, Espirito Santo and Rio de Janiero

Objectives:

To survey the land area occupied with coffee (and other agricultural crops that occupy big land areas such as sugar cane, cotton, etc.) with the purpose of delimiting the cultivated land area in the states of Sao Paulo, Parana, Minas Gerais and Espirito Santo, to study the crop density and yield prediction, that will permit an up to date and

general evaluation of the national coffee crop situation, in the principal producing area of the country.

Evaluation of Forest Resources of the different states of the country.

Evaluation of the grassland areas, estimating possible grazing pressures.

P.I.: Amaral, Gilberto O. Dr.
Projecto Sere INPE
CP 515 Sao Jose Dos Campos
Sao Paulo, Brazil

Proposal No.: 326-02

Regional geological and mineral resources survey, to study lithology, structure and morphological features of the main geotectonic units of central and southern Brazil and the relation to known mineral deposits, with the aid of remote sensing techniques (both air and spaceborne)

Location:

The geological studies will be undertaken in the following areas:

Brazilia folded belt
Parana alkaline rock complexes
mid-Goias ancient area
San Francisco platform
Paraiba folded belt
Parana sedimentary basin
Sao Paulo and Taubate tectonic basins
Espinhaco Ridge

Objectives:

Testing the reliability of visual interpretation, by comparison with known field data.

Testing of the data analysis computer programs.

Disclosure of geologic features through the combination of remote sensing and ground truth data.

Establishment of the best parameters for aircraft mission planning for specific problems.

Final conclusion on the feasibility of remote sensing techniques to the target problems and on the developed techniques of data acquisition and data processing.

P.I.: Gama, Emmanuel de Almeida
Comissao Nat. de Atevidades
Espacias
CP 515
Sao Jose dos Campos
Sao Paulo, Brazil

Proposal No.: 326-03

Develop method of bathymetric studies from satellite imagery in the Parcel de Abrolhos on the east coast of Brazil. Irregular subsurface topography and water clearness which allows light penetration defining the shallow zones dangerous for navigation will be mapped. Also environmental statistical studies will be made for a year to examine changing conditions.

Location:

Studies will be undertaken in the Parcel de Abrolhos on the Brazilian coast:

16° 47' S	-	39° 27' W
17° 02' S	-	37° 45' W
18° 26' S	-	39° 44' W
18° 41' S	-	38° 01' W

Objectives:

By means of the orbital imagery from the test site area, using light densitometric measurements related with real depths, the T.S.A. techniques will be used in an attempt to develop a method of bathymetric studies for defining shallow water zones dangerous for navigation.

Evaluate Statistical studies of the area for a year in order to determine the best conditions for ground truth data collection.

P.I.: de Azevedo, Luis Henrique, Dr.
Ministry of Mines and Energy
DNPM - Project RADAM (Radar Amazon)
54 Av. Portugal, URCA
Rio de Janiero, Brazil

Proposal No.: 370

Satellite and aircraft imagery is expected to advance the surveying of natural resources and environment of the larger Amazon Basin thereby accelerating the program of development. Analysis should reveal the potential of satellite imagery for the discrimination of major geological features. The

delineation of major vegetation communities, thematic mapping and the cartographic representation of drainage systems.

Location:

The areas of study include the Amazon Basin, Brazilian shield and Paramiba Basin.

Objectives:

To test the hypothesis that repetitive coverage by satellite can be used to produce a satisfactory mosaic by combining images taken through openings in the cloud cover on successive overflights.

To determine the quality and utility of the various types and scales of remotely sensed resource data (ERTS-A RBV and MSS, SLAR, infrared ektachrome, and multi-band aerial photography) used individually and in combination.

To determine the utility of remote sensing data for analysis of several types of resources (geology, vegetation, soil types, and hydrology).

To conduct a preliminary evaluation of the potential of satellite-borne imaging radars for acquiring earth resources data when cloud cover makes imaging in the visible spectrum impractical.

P.I.: Velloso, Marcos Henrique
Ministry of Ind. and Commerce
Brazilian Coffee Inst.
Rue Miguel Pereira 55
Hemaita - GB, Brazil

Proposal No.: 525

To test the viability of ERTS imagery interpretation of 95 percent of the coffee planatations of Brazil. This inventory of production, dynamics, cultivation and vegetation stages will be correlated with ground truth and aircraft data for the 620,000 km square area.

Location:

The areas to be studied are the states of Parana, Sao Paulo, Minas gerais and Espirito Santo in southern Brazil.

Objectives:

To determine if ERTS images can provide data relevant to such coffee plantation activities and dynamics as rotation of cultivated areas, variations of production, and use of modern techniques of planting in short term inventories.

Proposal No.: 326, Project SERE

Report: INPE-256-RI/35 a (Second Report) - previous initial correspondence

Resuetados preliminares orbitidos com imagens do Satelite ERTS-1 sobre a Amazonia, para encaminhamento a COBAE. Oct. 6, 1972 (2nd report - 1st report, not included, is academic)

A preliminary report on the interpretation of MSS multispectral data for the Amazon region. The initial work covers the Solimoes River and the region from Manaus to Porto Velho. The areas are examined in the different spectral bands, overlays have been prepared and a SLAR image of the Manaus area is compared.

Report: INPE-269-RI/35 b (Third Report)

This report covers initial studies of soil resources, minerals and marine resource applications.

Soils - areas of Tres Marias Resevoir and Pocos de Caldas

- Vegetation was mapped and areas of erosion were studied
- Various agricultural activities were identified and areas with large agricultural potential were defined
- Drainage systems and hydrographic basins were mapped

Minerals - same area

- The well mapped region includes diamonds, lead, zinc and silver. Geology and structure were defined.
- Recent deposits in river channels were noted
- Precambrian and Paleozoic stratigraphy were identified plus ore-bearing alkaline intrusive igneous rocks which are known to contain aluminum and nuclear minerals

Marine resources - NE region of Sao Paulo

- Initial inspection of imagery indicates bathymetric surveys will be possible
- Sedimentation zones, erosion, coastal currents, transport and deposition studies appear feasible.
- Shoals of fish were noted in principal sardine fishing area and it is believed that it will be possible to monitor fish migrations.

Report: INPE-302-RI/35 c (4th Report)

The report covers thematic geography, soils, minerals, and marine resource applications.

Geography - Rio Grande do Sul

- It was concluded that ERTS data can provide information for hydrographic mapping as pertinent to irrigation, drainage studies, engineering projects, and data on international frontiers

Soils - same area

- Lakes and dams were mapped, vegetation type distribution is noted, the potential of regional soils may thus be interpreted

Minerals - same area

- Lithology was identified on 1:1 M scale images
- Sedimentary rock series was defined
- Contacts are identified clearly

Marine resources - coastal - same area

- Color contrasts were noted between coastal and lagoon waters
- Interior sedimentary zones were differentiated due to vegetation differences

Report: INPE-320-RI/35 d (5th Report)

Preliminary Results Obtained with the ERTS-1 Satellite Imagery, Period Feb. - March 1973

Studies of the geography group at SERE included the northern part of Bahia, south of Piaui, northeast of Goias and south of Maranhao. Orbital images were used to make more exact positioning of drainage systems and relief. Thematic charts of this region based on ERTS imagery will be important to regional planning for this area where charts are lacking or out of date. Soil resource studies based on imagery of the Paraiba Valley, Sao Paulo; and the Campo Grande Region, Mato Grosso, identified agricultural activities and pastureland and provided information on forestry activities which will be useful in view legal regulations in respect to reforesting. Drainage systems were defined and will be of value in planning agricultural activities in the areas. Geological studies on images of the Sao Francisco and Parnaiba River basins will be used in soil permeability investigations. Rock types were

identified in the remote areas where there is deficient geological information. Marine resource studies were undertaken in the coastal region of Rio Grande do Sul using imagery from Apollo, Nimbus and ERTS-1.

Report: INPE - 326-RI/35 e (6th Report)
Preliminary Results obtained with ERTS-1 Satellite Imagery, April, 1973

An excellent treatment of thematic geography, cartography, soil resources, mineral resources making use of ERTS images. The studies show that the use of MSS channels 5 and 7 enable producing elaborate thematic relief charts, emphasizing crests, mountain ranges, and table lands. By comparing the two bands it is possible to differentiate perennial and intermittant rivers. Physiographic diagrams have been prepared. Areas of high erosion have been noted, suggesting the need for reforesting in specific regions. Geological studies indicate MSS channels 5, 7, and 4, in decreasing order, are of most value for photogeological mapping. ERTS images were applied to nautical cartography in coastal zones of difficult access with favorable results.

Report: INPE - 341 - RI/35 f, Project SERE (7th Report) Preliminary Results Obtained with the ERTS-1 Satellite Imagery, May 1969

Another highly sophisticated use of ERTS imagery for problems in geography, cartography, soils, minerals, and hydrology. New morphological charts have been prepared and existing charts have been corrected. Mapping of the more humid areas has been undertaken, providing valuable information for future regional planning. Coastal sediment distribution and the tendencies of coastal current propagation were observed in MSS 4 and 5 images.

Report: INPE - 341 - RI/35 g (8th Report) June-July, 1973

Studies of the State of Guanabara and part of Rio de Janeiro were made emphasizing problems of urban expansion, water supply, and potential dam sites. Soil maps are being prepared at 1:250,000 scale through use of MSS channel 5 engagements. MSS-6 was found suitable for mapping coral reefs. The distribution of transported material in coastal waters was best detected in MSS-5 and MSS-9.

Report: INPE-390-RI/35 h (9th Report)

The report covers geography, soils, minerals and marine resource applications. The imagery used in the soils and marine resources sections were obtained by the Brazilian

Recording and Reception Station at Cuiaba.

Geography - Capital area

- Drainage patterns were distinguished.
- Densities of superficial drainage indicate soil types and permeabilities.
- Applications to fertilizing and irrigation were noted.
- Imagery will be used as basis for exploitation of barren lands.
- Riverside forests were noted and information will be pertinent to the preservation of water bodies.
- Urban expansion will be mapped.
- Large soil groups were defined through use of different black and white images.

Minerals - Minas Gerais

- Geological contacts could be traced on the images. Channel 5, presenting the best contrast.

Marine Resources - Rio Grande do Sul coast

- The INPE images from Cuiba were found to be superior to those received from NASA. Previous studies will be re-evaluated in view of better imagery from Brazils' own station. Observations only suggested from study of NASA products have "become reality" now that better Brazilian products are available.

F.1.4 CHILE

P.I.: Saa, Rene
Instituto de Investigacion
de Recursos Naturales
Casillo 14.995
Santiago, Chile

Proposal No.: 372

To determine changes in land use in central and northern Chile. To determine annual and seasonal agricultural changes in central Chile, the differences between irrigated and unirrigated areas, extensive versus intensive land use patterns in concentrated and rural population regions. Compare water availability and agricultural practices in areas near Santiago, Temuco and La Serena.

Location:

Test sites at La Platena, Carillanca, Elqui Valley (La Serena)

Objectives:

- Determine which types of imagery, in which spectral regions, one can detect forest, agricultural and land use changes. Specific emphasis is on wheat, maize, rice industrial crops, species of forage and orchards.

Reports: None

F.1.5 COLOMBIA

P.I.: Koopmans, Bastiaan N. Dr.
Centro Interamericano de Fotointerpretacion
Apt. National
762 Chapinero
Bogata, Colombia

Proposal No.: 305

Automatic analysis of MSS data for thematic mapping (soils, vegetation, land use, surface hydrology, cattle grazing densities, grass burns, others) in the savannah areas of the Llanos Orientales.

Location:

The test area is on the Venezuelan border east of the Cordillera Oriental (eastern Andes range) including part of the Orinoco river basin. The Llanos, forming the northern part of the plains is covered by savannah vegetation. The political divisions include the Departments of Meta, Boyaca, Arauca and Vechada.

Objectives:

- The objective is to map large parts of the Llanos Orientales, eastern Colombia, by automatic analysis of ERTS data and specifically of Multispectral Scanning images. Automatic mapping will be specially centered around soil mapping, vegetation mapping, mapping of terrain physiography and surface water distributions. Specific studies will be made on land use, influence of cattle grazing densities, frequency and influence of grass burns on vegetation and recovery period necessary for grass types under different climatic conditions, for which a repetitive coverage is required. The extension of air pollution produced by the burns will also be studied.

- Comparative studies will be made of photographic images

obtained by conventional aircraft of scales 1:40,000 - 1:60,000, with MSS images obtained from conventional aircraft and with multispectral images and color images obtained from ERTS data.

- These comparative studies will be carried out along normal visual image techniques. For this comparative study ground truth data will be required and laboratory investigations will be developed. Parameters obtained in this way will be used to program computers to arrive at automatic data analysis.
- Detailed mapping of Carimagua farms may assist in future range management.
- The automatic mapping techniques developed, will be investigated in cooperation with LARS - Purdue University - which has already an extensive experience in automatic evaluation techniques.
- The ERTS color images acquired will assist the visual image evaluation and determination of the necessary parameters for automatic analysis, whereas digital tapes of MSS Data will be required for the automatic mapping procedure which will be carried out at LARS - Purdue University.

P.I.: Fletcher, Gonzales Alvaro
IAF
Apt. Nat. 762 Chapinero
Bogota, Colombia

Proposal No.: 624

ERTS application program for Lower Magdalena and Cauca Valleys to monitor and predict floods. Monitoring will take place during at least two years in order to map the normal flooding pattern to compare this with the disastrous floods of 1970-71. The area will be treated by geomorphic units while land use inventory will be carried out to formulate the impact of floods on the rural community.

Location:

Studies will be undertaken in the Northern Province: Departments of Sucre, Bolivar, Magdalena and Atlantico; including parts of Asar, Santander, Boyaca, Cundinamarca, Caldas, Antiquita and Cordoba.

Objectives:

The study objectives cover the following quantification of the flood warning by relating flooding patterns mapped with hydrographic ground truth.

- Provide a basis for flood prediction and flood warning by relating flooding patterns mapped with hydrographic ground truth.
- To establish detailed flood frequency predictions for the area studied relating known flooding patterns with historical hydro-data.
- To provide the basis for a land classification system taking flooding frequencies, land use data and soils data.
- To estimate the number of people involved in different flood situations.
- To classify the permanently and semi-permanently flooded areas and provide a basis for the extrapolation of detailed studies of these ecosystems in order to quantify future damage by flood protection and drainage projects.
- Contribute to the feasibility study of flood protection measures for the whole river basin.
- Furthermore, it is hoped that the observation period will be sufficiently long to see some changes occur in the estuarine areas included, leading to a better understanding of the behavior of the river there.

Reports: Initial correspondence only.

F.1.6 ECUADOR

P.I.: Moreno, Nestos Vega
Nat. Planning Council
Quito, Ecuador

Proposal No.: 371

Broad agricultural, geological and hydrological mapping to be used in land management planning.

Reports: None

F.1.7 GUATEMALA

P.I.: Garcia, Luis Dr.
Instituto Geografico Nat'l
Av. Las Americas 5-76
Guatemala City -3, Guatemala

Proposal No.: 369

To assess the utility of ERTS imagery for updating resource and land use data in addressing the problems of soil erosion agricultural deficit, deforestration and floods. To demonstrate the utility of ERTS imagery for extrapolation of geologic mapping beyond areas mapped in detail, and for tectonic structure delineation.

Location:

All of Guatemala is included in the studies.

Objectives:

- Update land use in a seasonally and secularly dynamic situation for addressing a complex of ecologically interdependent variables in the areas of hydrology, soils, vegetation and agriculture.
- Delineate tectonic structures and extrapolate geology in unmapped areas.

Reports:

A Type II Report for the period July - December 1972 has bee received by NASA. Cartographic accuracy was found to be ver good, and it was anticipated that in nearly all disciplines ERTS data will be useful for updating resource maps. Vegetation and soil features not previously mapped have been detected.

F.1.8 PERU

P.I.: Pomalaza, Jose C.
Instituto Geofisico del Peru
701 Arequipa Ave.
Lima, Peru

Proposal No.: 302

Evaluation of ERTS imagery in studying the components and dynamics of the hydrologic cycle in the Santa River basin of Peru.

Location:

The study will include the Santa River basin.

Objectives:

- Snowpack - determine snow line and seasonal variations. Estimate melt rates
- Lakes - estimate hydrologic potential
- Vegetation - map, classify, estimate transpiration as related to ground water

Reports: None

F.1.9 VENEZUELA

P.I.: Corao Manuel J.
Ministry of Public Works
427825 Caracas
Venezuela

Proposal No.: 117

Gross land use analysis in central region and analysis of urban growth in selected cities for purposes of urban-regional planning.

Location:

The study will focus on the Lake Valencia test site.

Objectives:

- Undertake detailed analysis of land use in the selected test area.
- Obtain gross measurements of land use for central region of Venezuela.
- Undertake detailed analysis of urban growth in selected cities.

P.I.: Romero, Adolfo C. Dr.
Direccion de Cartografia Nac.
EDF. Camejo
Centro Simon Bolivar
Caracas, 101, Venezuela

Proposal No.: 120

Development of techniques to investigate and estimate natural resources in remote areas, including geologic structure, landform analysis, lithology, vegetation communities and grazing lands.

Location:

The study includes the northern part of the Federal Territory of Amazonas.

Objectives:

- Geologic structure and landform analysis
- Identification of major lithologic changes
- Map alluvial areas

- Study regional drainage
- Extrapolate geology into unexplored areas
- Prepare thematic maps showing vegetation communities, pasturelands, relief forms.

Reports:

P.I.: Corao, M.J.

Proposal No.: 117

Type 2 Report, Rec. Feb. 1974

In the Lake Valencia basin land use and regional structure has been interpreted and depicted on thematic maps. A map at 1:500,000 scale is being made. Maps and overlays have been prepared vegetation and land use. False color products have been made from multispectral imagery. The Paraguana Peninsula was selected to test interpretations of geology, coastal geomorphology and sedimentary processes in forms useful for urban regional planning. The evaluation of natural resources has been completed and thematic maps have been prepared for the area south of the Lake Maracaibo basin. A methodical study has been completed on altitude determination of cloud cover over the Goajira Peninsula, the Paraguana Peninsula and over the central region of Venezuela. Similar studies will be made over other regions. Thematic maps are being made of coastal pollution in the areas of Cabo Codere and Cumana

P.I.: Romero, A.C.

Proposal No.: 120

Initial correspondence only

F.2 ASIA

F.2.1 BANGLADESH

P.I.: Hossain Anwar Dr.
Planning Commission
Dacca, Bangladesh

Proposal No.: 564

To interpret and evaluate the basic land and water resources for hydrology, soils, agriculture and topography; to develop flood control protection projects for the anges and Brahmaputra rivers; to fill gaps in basic data; to evaluate agricultural potential and long range planning; and to develop a systematic and comprehensive overall program evaluation.

Location:

Studies will cover the whole country.

Objectives:

Agriculture

- Yield prediction and production forecasting of rice, jute, sugar cane.
- detection of crop diseases and pest areas.
- soil moisture monitoring
- flood damage
- land use classification

Forestry

- inventory of timber and bamboo
- monitor and detect stress
- yield prediction

Hydrology

- forecast floods, assess damage
- surface water distribution
- water quality
- groundwater distribution

Oceanography

- locate biologically rich areas in Bay of Bengal
- Hydrography - detect navigation hazards
- map submarine topography
- study ocean waves and surges
- identify surface fish
- marine geology

Geography

- map physical features
- study morphological changes
- study settlement patterns

Reports: None

F.2.2 INDONESIA

P.I.: Katili, John A.
Indonesian Inst. of Science
Tengku Tjhik Ditiro 43
Djakarta, Indonesia

Proposal No.: 004-1

Topographic and geologic mapping, delineation of rock types and major geological structures, construction of land use maps. Investigation covers land use classification and change, organization, rural development, human population densities location and changes, disaster assessment, orthophoto mapping, mineral exploration, volcanoes, and geologic structure.

Location:

Investigation includes all of Indonesia

Objectives:

Immediate objectives include

- delineate geological features and lithology related to petroleum and economic mineral deposites
- delineate geological structure, as related to volcanism, earthquakes
- land use maps

Proposal No.: 004-2

Remote sensing of Barito River Basin and the Island of Bali

Location:

Studies will include Barito Basin in the South and Central Provinces of Kalimantan, Bornea and the island of Bali.

Objectives:

- obtain a key for the interpretation of remote sensing aircraft data by correlation with ground truth data
- obtain a key for the interpretation of remote sensing satellite data by correlation with ground truth and aircraft data
- development of remote sensing techniques adapted to the natural conditions in Indonesia

Reports:

P.I.: Katili, J.A.

Proposal No.: 004 (A and B)

Report: Type I report (received April 1973). "Rational Use of Earth Resources to Investigate if Modern Techniques Using Satellites Could Help in Accelerating Exploration of Natural Resources."

Work has started on a photo-map of Indonesia (1:1 M scale), a reconnaissance land use map, a map showing geomorphic and geologic features. Initial work is on an area of the Celebes. Attempts to rectify Lambert Conical Projection map control points to the imagery has been unsuccessful. The attempts to interpret land use from MSS images proved unsatisfactory for detecting volcanic, lithologic, and coastal features.

Studies of a region in central Java showed lineaments to coincide with areas of tectonic disturbance, the axes of anticlines to align with ERTS lineaments, river courses to be aligned with lineaments. The lineaments are suggested to identify areas of basement zone tectonic distrubance. A new geological map is being prepared.

F.2.3 KOREA

P.I.: Lee, Joung Hwan, Dr.
Geological Survey of Korea
Min. of Science & Tech.
125 Namyoung-Dong
Seoul, Korea

Proposal No.: 570

Investigation of geologic and structural features of Korean peninsula, including interpretation of lithologic and structural units, linear feature tracing, rock surface alterration, delineation of zones for mineral exploration and sedimentation studies at rivers mouth and at continental shelf for locating submarine placer deposits.

Location:

Study will include entire peninsula.

Objectives:

- identify all major geologic structures expressed through topography or soil moisture
- identify intrusive masses and alteration zones possibly
- identify high water tables and unmapped structure through surface moisture
- identify plants as secondary indicators of mineralized areas

- determine where currents and tides and sediments could form submarine placer deposits

Reports: None

F.2.4 PHILIPPINES

P.I.: Busuego, Fernando
Director, Bureau of Mines
Manila, Philippines

Proposal No.: 612

Use and evaluation of ERTS data for tectonic studies, preparation of photo maps, improvement of base maps, land utilization studies, coastal and nearshore marine studies, and agricultural and forestry industries.

Location:

Imagery of all Philippine islands is required.

Objectives:

- prepare tectonic map
- improve current geologic map (1:1M)
- prepare photo maps of selected areas
- improve base maps (1:500,000 and smaller)
- Assess where ERTS imagery can assist in land utilization patterns and pollution, shoals and navigation hazards, and for recognizing potential petroleum areas

Reports: Initial correspondence only

Other Reports:

Asian Seminar and Workshop on Remote Sensing, University of Philippines, Quezon City, Tuzon: May 1973. USGS Project Report (IR) DC-28, Stephen Gawarecki, September 1973.

The seminar was sponsored by the Philippine National Committee for Mineral Exploration and Survey Operations, funded by AID. 51 representatives from 9 countries. The seminar was part of an international training program conducted by the USGS and AID, similar to the Bamako, Mali, seminar. Workshops were held in the fields of geology-hydrology, oceanography-fisheries, cartography-land use, and agriculture-forestry.

F.2.5 THAILAND

P.I.: Cheosakul, Pradisth, Dr. (succeeded by Dr. Sanga Sabhasri, Secretary-General, NRC, as P.I.)
Nat. Research Council
Phaholyothin Rd.
Bangkog, Thailand

Proposal No.: 620

Assessment of utility/economy of ERTS data in planning and development and management of resources. Planned investigations cover all applicable disciplines (see objectives).

Location:

Imagery required for all provinces of Thailand.

Objectives:

Agriculture

- yield prediction and production forecasting for whole country; rice, corn, kenaf, cassava
- stress detection and monitoring; detection of crop diseases and pest areas, yellow-orange leaf diseases in rice areas, rice blast, locusts
- soil moisture monitoring
- changes in agricultural land use

Forestry

- inventory-crop-timber-range
- estimation of present and future forest production
- forest land use

Oceanography

- locating currents, thermal boundaries, shifts and rate of flow in gulf of Thailand and the coastal areas off west coast of southern peninsula
- locating biologically rich areas
- monitoring pollution dispersion

Geography

- land use classification and changes
- preparation of land use maps of entire kingdom (1:1,000,000 scale)

Reports:

A Type II Report for Nov. 72-Jan. 73 was received at NASA from Pradisth Cheosakul (P.I.: Proposal 620) dated April 1973. The report describes activities in several disciplines and identifies applications of ERTS imagery and features seen for the first time.

Agriculture - by Pongpit Piyapongse

The boundaries of crop regions in the Central Plain are clearly defined. Floating rice regions were identified on band 7. Horticulture and orchard crops were distinguished on band 7. Newly identified features include (1) an alluvial fan in the Northwest portion of the Central Plain and (2) the shape and size of the flood plains in the central region. Band 7 plus false color prints are considered a promising aid to the agricultural survey of Thailand.

Forestry - by Boonchana Klankamsom

Bands 5 and 7 enlarged to 1:500,000 were compared to photography taken at forest test sites. It was found that forest could be classified broadly, forest areas and non forest areas could be distinguished and mapped at a scale of 1:250,000.

Oceanography - by Dept. of Fisheries

The Department of Fisheries was able to detect contours of depth, sediment boundaries, effluents of polluted water. Plankton blooms were not identified. Fresh water was not discernible from salt water. The Department of Fisheries is not over enthusiastic stating that the usefulness of the imagery to the fisheries field is very small.

Geography - by Somchit Pongpagnan

ERTS imagery was found most useful for resource mapping. For example, the use of band 6 over a specific area showed 50% of the forests surveyed in 1969 had gone.

Geology - by Prayong Angsuwathana

The writer, after an initial study, considers that structure possibly related to mineralization can be mapped rapidly. Geological boundaries shown on the imagery indicate a need to change current maps. Several unknown circular features have been identified.

Land Use (by M. Omakupt)

Band 7 was found particularly valuable for identifying water tracts, flooded ground, drainage patterns, inhabited sites, varieties of vegetation, salt pans, shrimp farms, and shoreline boundaries. The Land Development Department is preparing a proposal to the U.S. Bureau of Reclamation for the use of IR film in the land use survey. This would be complementary to the ERTS imagery study.

Report: Type 1 Report, Period May - July 1973

P.I.: Pradisth Cheosakul

During a 6-week training course in early 1973 Thai Scientists and technicians had an opportunity to become familiar with various aspects of ERTS imagery processing and interpretation. In addition to the black and white imagery sent from NASA, false color enhancement methods were employed. An ERTS MSS mosaic of all Thailand was assembled using black and white data.

Findings through analyses of ERTS imagery included:

Agriculture:

Completion of a crop map from the Bangkok frame. Boundaries for different crop regions were delineated. In conjunction with the LARS computer system for data analysis, the agricultural sector did field checking against gray scale printouts. The LAR system was found to be highly accurate.

Geography:

The sugar cane cultivated area in West Central Thailand was mapped out using diazochrome transparencies. The cane area boundaries were delineated more accurately than by land use mapping of recent years.

Land Use:

A marshy area was identified between Sri Racha, where a nuclear power plant is being started, and Bangkok. Location of this hazard has led to soil tests in the area. The ground was found to be soft (former mangrove swamp location) so the number and type of a high voltage towers and the length of piles will be increased accordingly.

Other Reports:

1. RTG Budget Appropriations for Research FY 1972-73, by field of activity: US Operations Mission to Thailand, AID, Sept. 1973.

   A categorization of all RTG budget appropriations for research; basic investigations, applied research, experimental development and other scientific and technological research activities. Agriculture and Biology are shown to be the fields which receive the major funding. Forty-four pages of projects are listed including institution, budget and objectives. Whether or not ERTS data will be employed is not included information.

2. Third National Economic and Social Development Plan (1972-76), National Economic and Social Development Board, Office of the Prime Minister, Govt. of Thailand. Bangkok, Thailand.

   A summary of the third national plan, concerning economic development, regional plans, agriculture, industry, commerce, communications, power, public health, etc. Economic objectives are itemized and targets for agricultural, mining and industrial production are listed, many of which are reflected in the ERTS proposals. Budget appropriations for the 3rd plan are presented in detail as to government agency, project and budget through 1976.

3. National Resources Survey - Guidance Manual (Resources Atlas Project), ARPA, Applied Scientific Research Corporation of Thailand, US Army Engineers, Nov. 1971.

   Research was supported by ARPA for national planning of natural and human resources, to aid decision making by government agencies. Data included cover maps, aerial photography, cartographic techniques and thematic mapping. The study objectives were to provide the ASRCT Resources Inventory Group with the concepts and procedures needed to maintain and upgrade the capabilities of that office. Topical details for Resource Inventories are presented.

F.3 AFRICA

F.3.1 BOTSWANA

P.I.: Hepworth, J. V. Dr.
Geol. Survey & Mines Dept.
Pvt. Bag. 14
Lobatse, Botswana

Proposal No.: 643

Assessment of the value of satellite imagery to resource evaluation and development planning on a national scale. The investigation includes geological mapping as part of a large ongoing program; hydrological study of a critical swamp area, vegetation mapping, game concentrations, identification of ecologically degraded areas, construction and revision of maps of large uncharted areas. Existing ground truth and aerial data will be used as a base of the studies.

Location:

The entire country will be studied.

Objectives:

Geology

- Geologic structure of Kalahari Basin and implications of Ghanji Ridge and other lineaments
- Regional structure of Bushveld Basin
- Regional trend in eastern Botswana as related to mineralization
- Large scale photogeological contrasts between Rhodesian Craton and Limpopo Belt

Hydrology

- Flood patterns in Okavengo swamp

Agriculture

- Identify major vegetation types
- Identify degradation and erosion in over-grazed areas
- Identify areas suitable for development

Wildlife

- Identify and map plant formation
- Identify ecological-vegetational interfaces on Okavengo Delta, Kalahari Desert
- Map regional habitat/ecological types
- Identify effect of human activities
- Map seasonal distribution of game.

Cartography

- Complete photomap of Botswana to update existing maps

Reports: Type 1 Report, Period Sept. - Dec. 1972

P.I.: J. Hepworth

Author: S. Akehurst

The report assesses the first ERTS-1 data received in Botswana for their contribution to geological, hydrological and ecological knowledge.

Geology

Six of eight investigators concluded that ERTS imagery does not show anymore detail than ordinary aerial print layouts as a scale of 1:40,000 even when using MSS-7 imagery. One investigator believed conventional photography reduced to 1:1,000,000 scale would contain more geological information and that interpretation of an unknown area by ERTS imagery would be extremely difficult. On the other hand, two geologists who were concerned with more than resolution were favorable to the uses of ERTS images, one noting "the central zone of the Limpopo Mobile Belt can be traced right across the area, and the edge of the Karroo System can be defined", another noted one ERTS scene comprises an area comparable to coverage by nine print laydowns at 1:25,000, "this means that large areas can be viewed and that large scale structures, changes in structure and relations between structures can be more easily appreciated." (S.M. Akehurst was not enthusiastic, Messrs. Key and Walker found favorably.) Only preliminary assessments were made in the areas of hydrology and ecology.

Report: Type II Report, Period January-May 1973 was received by NASA, dated May 1973.

P.I.: J. Hepworth

Author: S. Akehurst

Study of ERTS imagery appears to confirm the new theory that Archean greenstone belts in NE Botswana and SW Rhodesia are co-extensive and cover a wider area than formerly believed. A central region is now believed to have been "granitized." Knowledge of this lithological pattern is important to current mineral exploration planning.

Indications of a pre-existing drainage system have been discovered on imagery of the area southwest of the Okavango Swamps. This indicated that a regional seismic instability may have

caused a radical change in the direction of river flow. Imagery shows the "drying-up" pattern of the swamplands and former strand lines of lakes which have essentially disappeared in recent years.

ERTS pictures delineate river areas infested with Salvinia Auriculata, a water weed. Continuous monitoring will permit determination of the extent of encroachment and would assist the planning of measures to be taken against the infestation.

Report: Type I Report, Period May - August 1973

P.I.: J. Hepworth

Author: S. Akehurst

(Since writing the Sept. - Dec. 72 Report, S. Akehurst has built up a little more enthusiasm about ERTS images, noting the identification of several features that had either been misinterpreted or could not be detected previously.)

The use of color composites made an important contribution to the Botswana ERTS studies. For instance - brush fires were identified, roads and railways could be distinguished, the vigorous growth of vegetation indicated water storage areas, although no streams flow through the region. It was noted that the recently completed Shashe Reservoir is filling with silt. (This reservoir feeds by pipeline to the Selebi-Pikve copper mining region.) The later-received imagery is considered superior to that originally sent (which raised minimum enthusiasm.) On the other hand, the hazy character of many of the earlier pictures is now interpreted as due to dust in the lower atmosphere raised during the preceding five months corresponding to the dry winter season.

There has been little or no progress in agricultural, cartographic, hydrological or ecological investigations.

Other Relevant Reports:

1. Boocock, C. and O. van Straten (1962)
Notes on geology and hydrology of the Central Kalahari Region, Bechuanaland Protectorate. Tras. Geol. Soc. S. Africa, Vol LXV; Johannesburg, S.A.

2. Litherland, M. (1973)
A Uniformitarian Approach to Archaean Schist Relics, Nature, London.

3. Jones, M. T. (1962)
Report on a photogeological study on the area between the Okavango Swamps and the S-W Africa Border. Geol. Survey of Botswana, Lobatse. (file report)

(The three above items are essential background to the geological and hydrological problems addressed in the Botswana ERTS-1 proposal.)

4. Wightman, J. (1973)
Detection, Mapping and Estimation of Rate of Spread of Grass Fires from southern African ERTS-1 Imaging. Canadian Forestry Service, Ottawa, Ontario. NASA/GSFC Symposium, New Carrollton, Md., 1973.

A study of dry season grass fires was made over the Zambezi River watershed, including the Okavango Swamps of Botswana. One example from northern Botswana indicates a fire consumes approximately 70 square miles of grassland over a 24 hour period.

5. Viljoen, M. And Viljoen, R. (1973)
Johannesburg Consolidated Investment Company, Randfontein, S. A., NASA/GSFC Symposium, New Carrollton, Md., 1973.

The granite-greenstone cratons of Rhodesia and South Africa are separated by the Limpopo metamorphic belt in Botswana. The geotectonic environment has been studied on ERTS imagery and it was found that the broad synoptic view provided by the imagery was well suited for interpretations of the macrostructures and geotectonic styles. The imagery permits a more accurate definition than exists at present of the contact zones of the two domains. This should prove to be of considerable economic importance inasmuch as similar geological situations have produced some of the worlds larger metal deposits (along basic/ultrabasic contact regions).

6. McKee, E., and Breed, C. (1973)
A Study of Morphology Provenance, and Movement of Desert Sand Seas in Africa, Asia, and Australia, U.S. Geological Survey, NASA/GSFC Symposium, New Carrollton, Md., 1973.

A study of desert sand patterns was undertaken on ERTS imagery of several areas including the Kalahari Desert of Botswana. A classification system is being developed for the principal dune patterns. The study will compare the the dune development in terms of winds, topography and vegetation present. The possible origins of specific patterns will be interpreted from ERTS imagery.

Sabatini, R. R., et al.
Nimbus Earth Resources Observations
Technical Report No. 2, Nov. 1971, NAS-5-21617
Allied Research Associates, Inc., Concord, Mass.

The resolution of the Nimbus sensors permits gross area temperature surveys of the larger man-made lakes. Nimbus imagery of Lake Karita, Rhodesia, and the Okavango Swamp of Botswana (see Figure F-1) yielded the surface temperature regime and local climatology information which may have prompted the ERTS-1 proposal study. The temperature information was used to calculate evaporation rates, an important consideration of the hydrological budget, particularly for lakes in otherwise arid regions. This was presented as "Applications of Nimbus Satellite Imagery to the Monitoring of Man-Made Lakes", Ackerman and Rabchevsky, Symposium on Man-Made Lakes, Knoxville, Tenn.

7. 3rd ERTS Symposium, Abstracts, Dec. 1973, Wash., D.C., Paper A 19
Vegetation Mapping from ERTS Imagery of the Okavango Delta
D. T. Williamson, Spectral Africa (Pty) Limited, P.O. Box 2, Randfrontein, Republic of South Africa.

The Okavango is Botswana's major water resource. As yet it is essentially undeveloped and supports large wild life populations both within the system and in the adjacent semi-arid areas. Development of the delta for its water resources and recreational potential is inevitable and imminent. Much basic resources data is urgently required to facilitate sound planning.

Other workers have studied ERTS imagery of the delta from a geological and hydrological perspective. The present study has been specifically directed at mapping vegetation types within the delta and generally concerned with finding what information of value to plant and animal ecologists could be extracted from the imagery. To date it has been found that

(i) It is possible to map broad vegetation types from the imagery. This has enabled preparation of a vegetation map of the delta which considerably refines existing maps.

(ii) Imagery of the delta records the state of the system in a manner which will facilitate long-term studies of plant succession.

(iii) Phenological events can be detected. This may allow inferences to be drawn about seasonal movements of animal populations.

(iv) The imagery can be used to detect and map wild fires. This will be useful in determining the role of fire in the ecology of the region.

Using the imagery it is thus possible to map existing vegetation and monitor both short-and long-term changes.

The results have been obtained after a few months of work using only colour composites of the delta and without sophisticated, automated techniques of data extraction and analysis. They demonstrate that ERTS type imagery can be a valuable tool to those responsible for planning and managing the exploitation of natural resources in the developing world.

8. Report of the UNDP on the investigations of the Okavango Delta as a water source for Botswana, March 1974.

Botswana Govt. contribution	624,525.R
UNDP contribution	$ 597,000, US

This project is included in the Country Programme Proposal for UNDP assistance to Botswana, 1973-1976, which was approved by the UNDP Governing Council in June 1973.

Long-range Objectives

The project will provide some of the key data needed to assist in the water plan and related national water policies and will thus help to develop a firm factual basis for shaping international understandings as to the use of Okavango waters.

It will furnish much of the information necessary to ensure that such a national water plan incorporates an effective long-term programme for expanding and controlling the uses of Okavango waters, while improving the living standards of the local people, conserving the varied resources of the Delta, notably its wildlife, and retaining the potential of the area for recreation and tourism.

The project results, combined with allied studies under the SIDA project, will help the Government to appraise the benefits and costs of agricultural and associated uses of Okavango water in or near the Delta.

Immediate Objectives

The project will provide a more complete understanding of the hydrometeorology of the Okavango Delta, of the ecology of the area

and of their inter-dependence.

It will provide base-line data on natural conditions in the Delta, and on the effects of the natural variations in the hydrology and ecology. This will include consideration of the effects of possible periods of several years of unusually low or high inflow into the Delta, of possible seismic events, and of possible major changes in vegetation (e.g., an invasion of Salvinia Molesta).

The project will help the Government to appraise the hydrological and ecological effects of withdrawing water from the Delta, at different locations, and in various amounts, assuming a range of inflows and other natural variations in conditions. In the interests of supplying water needs without waste, and maintaining the best possible environment for local habitation, wildlife, recreation and tourism, the project will explore the possibilities of modifying the hydraulic characteristics of water courses through the Delta, and influencing the growth of vegetation on the land and in the shallow waters in order to control the flow patterns in the Delta. Studies will be aimed at an assessment of desirable discharges at various outlets, and the areas of permanent and seasonal flooding.

The project will develop specific plans for the best ways to release from the Delta various amounts of water consistent with the general range of recommendations under the SIDA Feasibility Study and with regard to the time basis on which the early and long-term projections have been prepared by that Study.

Meanwhile, the project will provide the Government with information, gathered during field operations, relating to the influence of the current dredging programme for increasing the outflow from the Delta to the diamond mine. It will monitor the hydrological and ecological effects of such withdrawals.

The project will provide information on the incidence and predictability of the seasonal flooding, under natural conditions and under foreseen possible controlled conditions of those areas beside the Delta and its outlets which are used for agriculture as the water recedes.

By means of training, the project will help to strengthen the related Government Departments.

F.3.2 KENYA

P.I.: Ojal, J. M. (succeeded by J. Omino as P.I.)
Ministry of Natural Resources
P.O. Box 30126
Nairobi, Kenya

Proposal No.: 658

To test feasibility of carrying out agricultural and hydrological surveys using ERTS data. (see objectives)

Objectives:

Agriculture

- Tana River Basin - monitor effects of population pressure, forest destruction, cultivation of unsuitable land
- Monitor soil resources as related to crops, vegetation, livestock
- Narok District - study game movement between Kenya and Serengeti Plains in Tanzania

Range Management

- Northeastern Kenya - study nomadism as related to water availability. Range inventories. Vegetation mapping.
- Southeastern Kenya - seasonal vegetation changes - National Park range management
- Study effects of domestic livestock and heavy concentrations of elephants.
- Kajiado District - development of ranches in traditional Masai nomadic area, vegetation and game maps, man-livestock-game ecology problems.

Water Resources

- Locate underground water in arid areas
- Study changes in level of Lake Victoria, vegetation changes on lake shore
- Degradation of catchment areas of rivers flowing into lake
- Effects of Kenya shore erosion as related to harbors, fishing, tourism

Report: Type I Report, Period July - December 1972

P.I.: J.H.O. Omino

The 1-page report complains that it takes six weeks to obtain imagery, and that they find no value in the itemized printout sent with the images. The geologist investigator (not identified) was pleased with his first look at the imagery.

Report: Final Report, Type III

Five investigators report on usefulness of ERTS data. Deficiencies stemming from poor interpretive know-how, lack of equipment and lack of repetitive coverage are reported. Immediate benefits include the revision of lake shorelines, differentiation of basement system metasediments, identification of vegetation and plantation crops and specific forest types, some soil types, and various hydrologic and physiographic features. The studies have not progressed far from identifying features and simple map corrections. Interim Reports included in the Type III Report include the following:

1) Dr. J. Walsh, Chief Geologist
Mines & Geological Department, Ministry of Nairobi

- Lake Rudolf shorelines were revised
- Oma delta showed marked changes since last photographed 15 years ago
- Basement system metasediments were differentiated
- Little success was noted in identifying major structure, igneous rock types, soils, thermal areas

2) Dr. E. E. Zamierowski
Dept. of Botany, University of Nairobi

- Natural vegetation types were found to be separable
- Riverine forests were distinguished
- Tea plantations were identified
- Eleven vegetation types could be distinguished: grassland, bamboo, burned fields, conifer plantations, etc.

3) Dr. W. G. Sombrock, Project Manager
Kenya Soil Survey Project
Nat. Agricultural Laboratories, Nairobi

- Imagery is proving helpful in soil mapping in arid, semi-arid areas
- Imagery will be useful in teaching and training in physiography and land evaluation

4) Dr. Charles Pase
Habitat Ecologist
FAO/Kenya Wildlife Management Project, Nairobi

- Imagery is planned to be used in phenological studies

5) Mr. Simon Taiti, Biologist
Head, Research Div., Game Dept.
Ministry of Tourism & Wildlife, Nairobi

- Studies are underway for using imagery to assist in mapping vegetation.

There has been very limited interpretive work because of several excuses. To date there is no indication that the information content of the imagery has been used - or discovered.

Other Reports:

1. 3rd ERTS Symposium, Abstracts, Dec. 1973, Wash., D.C. Paper G 12

   STRUCTURAL GEOLOGY OF THE NORTHERN SECTOR OF THE AFRICAN RIFT SYSTEM: NEW DATA FROM ERTS IMAGERY

   Paul Mohr, Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, Massachusetts 02138

   Geological knowledge of the African Rift system is confirmed, amplified and extended from interpretation of ERTS imagery. Mapping of lithological and structural units in Yemen can be greatly extended from present data based on sparse ground traverses. The Eastern Rift structures in Kenya, well mapped by the Kenya geological survey, are shown to project NNE-wards from the southern Lake Rudolf basin directly towards the main Ethiopian Rift, and do not pass via the Lake Stefanie garden. ERTS imagery shows that the importance of en-echelon structures in the Eastern Rift has been overemphasized from ground reconaissances. The Western Rift of Africa is shown not to extend NE-wards beyond the Aswa mylonite zone in southern Sudan. In Ethiopia, the ERTS imagery reveals previously unsuspected calderas, local graben, lava fields and glaciated valleys, and enables an enormous improvement to be made over existing geological maps.

2. AID Memorandum, Nov. 23, 1973, N. Olsen, Assistant Program Officer

3. Mohr, P. (1972)
Mapping the Major Structures of the African Rift System, Smithsonian Astrophysical Observatory, Cambridge, Mass., NASA-CR-129929, NTIS E 73 1005.

4. Mohr. P. (1972)
ERTS-1 Imagery of Eastern Africa: a First Look at the Geological Structure of Selected Areas, Smithsonian Astrophysical Observatory, Cambridge, Mass., NASA-CR-129929, NTIS E 73 10005.

Imagery of the African rift system resolves major faults, volcanism and warping. It exposes "grain" of Precambrian outcrops. Newly discovered structural features include major faulting in western Kenya. ERTS imagery may require a radical revision of the present mapping of the Precambrian terrain in Africa.

ERTS

1. Project Purpose

To assist the GOK to develop a program that will effectively utilize remote sensing techniques and imagery in Kenyan development.

2. Current Status

An AID/W ERTS group just completed a visit to Nairobi in which they made preliminary arrangements for a regional conference in March 1974 on remote sensing techniques. Progress in arranging the conference appears to be satisfactory at this stage.

The GOK continues to desire an individual to spend up to two months organizing a Kenyan ERTS program. The AID/W groups feel that the conference and the cost/benefit group that will arrive in December should go a long way towards satisfying this requirement. However, it is unlikely that the GOK will be entirely satisfied with these arrangements and the peripheral assistance they provide.

3. Issues

Should AID provide the GOK with a short term expert in remote sensing techniques to organize an intergrated Kenyan ERTS program?

I believe providing such a person is outside of AID/air sector concentration practice. However, I also believe that it will take such a person if remote sensing is to be effectively used in Kenyan development. The benefits of such a program are great enough that I suggest it would be worth doing on both a program and political effectiveness basis. This is an area in which the U.S. clearly has a "comparative advantage" over other donors.

4. Recommendation for change in Project Design

None at this time.

F.3.3 LESOTHO

P.I.: Nixon, Peter Dr.
Dept. of Mines and Geology
P.O. Box 750
Maseru, Lesotho

Project No.: 681

Assess the value of ERTS imagery in accelerating agricultural and mineral resource development in Lesotho.

Location:

Studies will include entire country.

Objective:

Geology

- delineate kimberlite dikes, dike swarms, like those being studied in northern part of country (source of diamonds)
- identify vegetation indicators of underlying kimberlite
- map structure of Karroo basalts (petroleum and ground water)
- chronicle geologic history of Lesotho

Agriculture

- land use survey
- crop survey, seasonal inventory
- identify planting, harvesting, rotations
- detect stress
- map range vegetation seasonally
- monitor gully erosion

- compare present gullies to those mapped in 1960
- soil survey
- map water courses

Reports: Type I Report for Period July 1972 - February 1973

An initial report stating the imagery received was of adequate quality for the proposed studies. The P.I. notes that the images arrive 8 to 10 weeks after the satellite passes and the delay hampers interpretation of time dependent factors, such as crop evaluation.

Type II Report for Period September 1972-February 1973

The report covers the information obtained from a quick look survey of ERTS imagery received with reference to agriculture and geomorphology. Features were identified related to problems of land use, crop production, range management, soil conservation and hydrology. No interpretive work has been undertaken.

Other Reports:

ERTS-1 Experiment of the government of Lesotho, (in) Remote Sensing: a Developmental Framework and Case Studies; OS&T/AID, TA/OST 73-15, Jan. 1973.

The geology of Lesotho is a simple stratification of shales and sandstones overlain by a mile thick layer of basaltic lava. This series is cut by dikes of dolerite and kimberlite. Kimberlite contains diamonds, and diamonds have been found at two significant locations. These are being evaluated by the Rio Tinto and Newmont Mining Companies. Diamonds are the only known exportable mineral resource. Ponder Oil of Canada is currently negotiating for petroleum exploration rights.

Lesotho is also interested in intensifying its production of corn, sorghum and wheat, in increasing livestock (but reducing overgrazing) and the control of gully erosion. The objectives of the ERTS program include:

Geology

- Delineate kimberlite dike swarms in northern Lesotho
- Identify spectral responses of vegetation cover over kimberlite bodies to aid in discovery of other kimberlites

Agriculture

- Land use - baseline survey and land use inventory

- Showing major crops and their distribution. Identify when crops are planted and harvested. Detect and monitor attack by pests and diseases.
- Range management - map vegetation classes and seasonal changes, record growing seasons at different altitudes.
- Soil conservation - map eroded areas, prepare soil survey maps, map plant cover and water courses, define areas of likely future erosion.

F.3.4 MALI

P.I.: Konate Mamadu
Dept. of Mines and Geology
Ministry of Industrial
Development and Public Works
Koulouba, Bamaks, Mali

Proposal No.: 626

Delineate natural resources characteristics and their temporal and spatial changes to strengthen understanding of alternatives for agricultural, hydrological and geological development in Mali, where little base data exists. Correlation will be mainly with current and as-required ground truth.

Reports:

A Type I Report for July 72 - March 73 was received by NASA, dated March 73, which is an initial listing of imagery received and the identification of previously unknown geological and hydrological features.

Other Reports:

1. ERTS-1 Experiment of the government of Mali, (in) Remote Sensing: a Developmental Framework and Case Studies; OS&T/AID, TA/OST 73-15, Jan. 1973.

Mali has particular concern for the expansion of grain production, livestock production and the production of cotton and peanuts. The hydrological regime is not well described and a better understanding is needed as to the Niger and Senegal river networks and underground water resources. The structural geology, sedimentary formations and igneous lithology are poorly known. The objectives of the ERTS program include:

Agriculture:

- Survey of grasslands for livestock raising particularly for ranching in the regions of Bamako and Seogou

- Assess seasonal changes in soil moisture as pertinent to ranching, sorghum, millet, wheat and cotton
- Delineate dune sand, soil, and plant relationships in the southern Sahara desert steppe

Hydrology:

- Understand geographical distribution of underground water resources
- Clarify relationship between river waters and subsurface waters
- Delineate annual changes in Niger river floods

Geology:

- Map distribution and structure of Birrimian rocks of southern Mali to identify possible mineralized areas
- Delineate infracambrian structure in the system of Gourma
- Explore petroleum potential of Taudenni Basin
- Explore for water in Gaograben
- Search for metals in Adrar des inforas crystalline shield

2. 3rd ERTS Symposium, Abstracts, Dec., 1973, Wash., D.C.

   REMOTE SENSING EXPERIMENT IN WEST AFRICA

   N.H. MacLeod, Department of Biology, The American University, Washington, D.C.

In 1969, the investigation of seasonal changes in plant communities and surface water of West Africa was initiated using Nimbus III HRIR data. The Republic of Mali, in particular, had requested advice concerning remote sensing and initially the ERTS investigation was concerned with assessment of geologic, hydrologic, agricultural, and range resources to provide a basic resource inventory for this country. In late winter and early spring of 1973 there was a growing awareness of a very serious drought problem throughout the Sahel, the wide band between the desert and the woodland regions, and the investigation was extended to cover the entire region. We participated with USAID in studies incorporating remote sensing techniques into the West African Grain Stabilization Program and the Malien Livestock Production Program. Part of this work included assessment of locations where near-surface ground water was most likely to be found. Because livestock production in the Sahel depends on well-point development as well as productive rangeland, there

was a useful analysis of ERTS imagery followed by field confirmation of ground water resources in regions under consideration by USAID for ranching.

Though we found we could define the drought as a meteorological phenomenon extending from 1969, our field studies and analysis of ERTS imagery led us to realize that land-use practices over many centuries had led to substantial deterioration of plant, soil, and water resources, quite possibly by a change in climate across the Sahel. In fact, the ERTS imagery is forcing us to realize that the entire West African region is becoming drier all at the same time. At the same time, the imagery contains information that can be used as a basis for planning action programs to readjust land management practices (i.e., livestock, cash crops, and irrigation production) to increase production, stabilize the landscape, and rehabilitate the Sahel.

As part of the analysis of ERTS data acquired over the drought affected area, a large man-made feature with indications of improvement in vegetation cover and soil mositure and placed in a semi-arid region in which drought conditions were severe was observed in the Republic of Niger. The man-made feature proved to be a 110,000 hectare fenced ranch in which a simple grazing management program had been initiated. The ranch is five years old. ERTS imagery thus showed changes which have occurred in the five worst years of this century and which in fact represent a reversal of the process of desertification.

A joint effort led by people involved in this investigation is underway to provide planning assistance to the Sahelien governments, particularly in Niger-but to the Republic of Mali and the recently formed Interstate Committee as well. Interpreted remote sensing imagery from ERTS is used as the basic cartographic basis for project siting and broad analysis of regional potentials.

F.4 OTHER PROPOSALS

F.4.1 FAO

P.I.: Fischnich, O. E. Dr.
U.N. FAO
Via Delle Termi di Caracalla
00100 Rome, Italy

Proposal No.: 603

Use of ERTS data for FAO Integrated Resource Surveys in areas where a wide diversity of data is required and where

there is a wide diversity of ecological conditions.

Location:

Investigations will include areas of Sudan, Philippines and Colombia.

Objectives:

Sudan

- land and water resource appraisal
- water supply needs
- agricultural/livestock/water development
- development of Savannah Belt pasture lands
- desert locust survey and control
- extent and location of forest plantations
- identify site types
- identify over-exploitation, over-grazing

Colombia

- agricultural diversification in Magdalena area
- watershed development
- pastureland evaluation
- forest exploitation, agricultural clearing

Philippines

- soil and land classification surveys
- multidisciplinary resource evaluation
- demography
- agricultural stress
- erosion, sedimentation
- forest destruction, over-cutting

Reports:

None

F.4.2 Mekong Secretariat

P.I.: Van der Oord
Mekong Secretariat
c/o ECAFE, Bangkok, Thailand 817422

Proposal No.: 605

Applications of ERTS data to resources management of the lower Mekong Basin for purposes of planning and investigation of water resources development projects.

Location:

Studies will include areas of the four Lower Mekong Riparian governments (Khmer Republic, Laos, Thailand and the Republic of Viet Nam.)

Objectives:

- agricultural statistics and monitoring of cultural practices
- basin wide flood forecasting
- flood damage assessment
- hydrological photomapping
- obtain geological, hydrological, economic data

Report: Type I for Period July-September, 1972

Five Viet Nam images were received, none from the other countries included in the study. The initial report presents objectives. No research was reported.

Report: Type I Report, 18 April 1973

Contrast enhancement using color composite techniques gave satisfactory results with regard to forest cover and identification of other terrain and vegetational units. Color composites enabled recognition of areas of forest deterioration, the magnitude of inundation of agricultural lands, drainage problems related to the construction of gravity canals in the lowlands and the effect of flood regulation by tributary dams. Further use of ERTS-1 imagery in the mapping of forest cover, land use, hydrogeomorphologic features is being planned in cooperation with the Centre Nationale des Edudes Spatiales of France.

Report: Type III (Final), Period July 1972 - August 1973

Color enhancement techniques including diazochrome and false color composite images as well as system corrected MSS computer compatible tapes have been used for assessment of ERTS imagery potential. Three computer programs have been developed for preliminary analysis of the System Corrected ERTS-1 computer compatible tape data. The ERTS-1 MSS imagery

analysis has revealed a wealth of information and details, most of them impossible to detect through a classical survey approach, in the areas of physiography, vegetation cover, flood patterns, salt incursion and sedimentation. A systematic mapping program has been drawn up.

Other Reports:

1. Van Lire, W., Mekong Committee Secretariat, Bangkok, Thailand, Applications of Multispectral Photography to Water Resources Development Planning in the Lower Mekong Basin. NASA/GSFC Symposium, New Carrollton, Md., 1973.

Satellite data is particularly useful because repetitive coverage permits viewing gradual changes such as extent of flooding and moisture retention in various soil types, it complements data on forest cover from areas which have been inaccessible, refines ground surveys in regard to landforms and soil, and provides data on the mechanism of the flooding and drainage of delta areas.

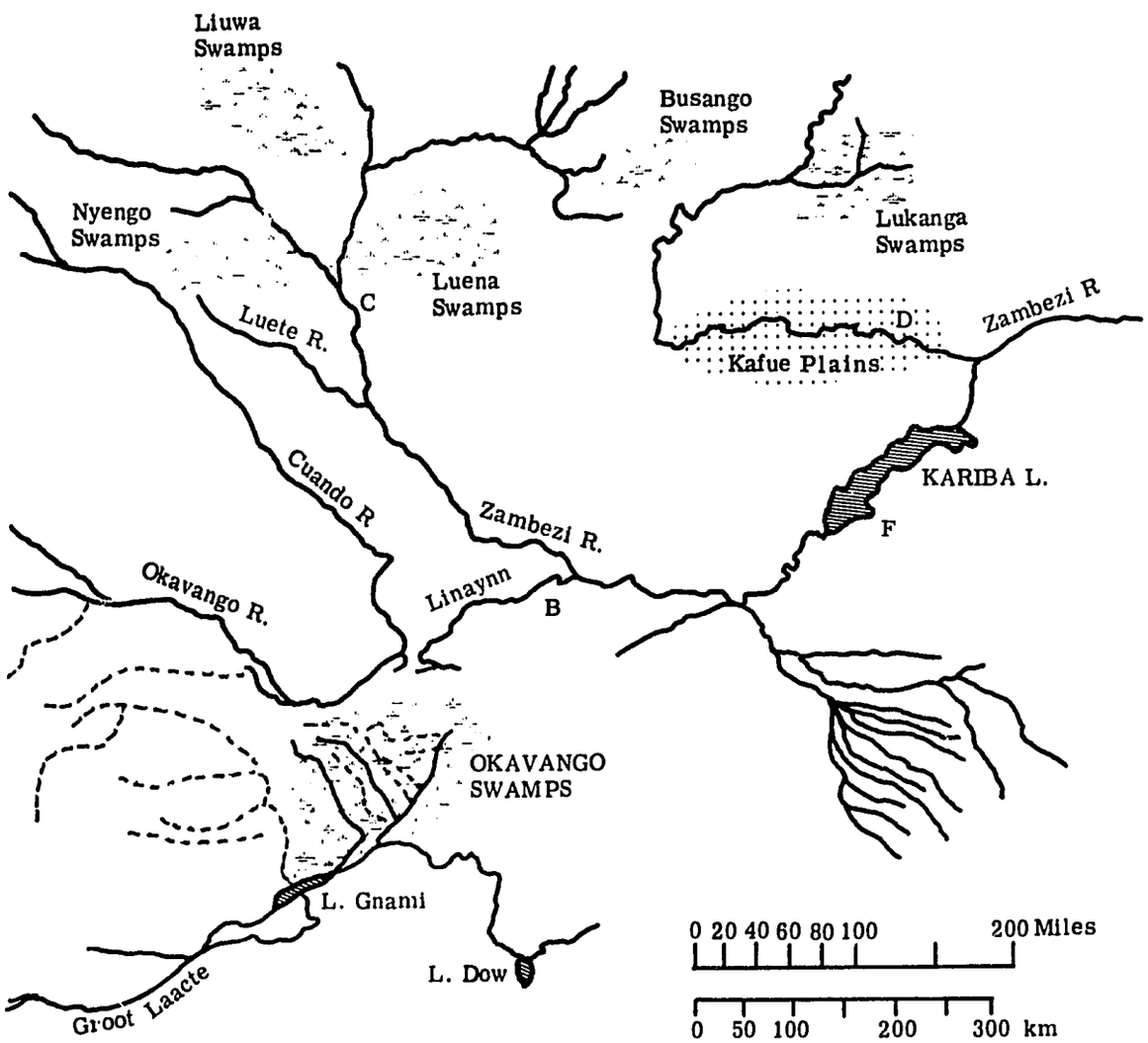

FIGURE F-1 NIMBUS IMAGERY OF LAKE KARITA, RHODESIA, AND THE OKAVANGO SWAMP OF BOTSWANA

TABLE F-1. LEVEL OF PROGRESS REPORTED (APRIL, 1974)

COUNTRY	PROPOSAL NO.	A	B	C	D	E	F	G	H	I
LATIN AMERICA										
Argentina										
	528 *		X	X						X
	529 *		X	X	X	X		X	X	X
·Bolivia	571		X	X	X	X				X
Brazil	326		X	X	X	X		X	X	X
	370	X								
	527	X								
Chile	372	X								
Colombia	305	X								
	624	X								
Ecuador	371	X								
Guatemala	369		X							
Peru	302	X								
Venezuela	117		X	X	X					
	120 *				X					X
ASIA										
Bangladesh	564 *	X								X
Indonesia	004		X	X						X
Korea	570	X								
Philippines	612		X							
·Thailand	620		X	X	X			X	X	X
AFRICA										
·Botswana	643		X	X	X					X
·Kenya	658		X	X						X
Lesotho	681		X							
Mali	626		X							X
OTHER										
FAO	603	X								X
Mekong S.	605		X	X	X			X	X	X

Level of Progress

A. No analysis of data, none reported or unknown status
B. Narrative analysis of imagery
C. Thematic maps hand drawn from single band
D. Thematic maps from multispectral imagery
E. Complete natural resource inventory from one or more frames
F. Complete natural resource inventory from all available imagery
G. Digital tape analysis of multispectral data
H. Change detection studied
I. User participation

* based on private communication

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TABLE F-2. EQUIPMENT IN USE

COUNTRY	PROPOSAL NO.	A	B	C	D	E	F	G	H
LATIN AMERICA									
Argentina									
	528 *		X						X
	529 *		X		X	X	X	X	X
•Bolivia	571		X	X					X
Brazil	326		X	X		X	X	X	X
	370								
	525								
Chile	372								
Colombia	305		X						X
	624		X						X
Ecuador	371								
Guatemala	369		X	X					X
Peru	302								
Venezuela	117		X	X					X
	120 *		X	X		X			X
ASIA									
Bangladesh	564 *	X							
Indonesia	004		X					X	X
Korea	570	X							
Philippines	612		X		X			X	X
•Thailand	620		X	X			X		X
AFRICA									
•Botswana	643		X						X
•Kenya	658		X						X
Lesotho	681		X						X
Mali	626		X						
OTHER									
FAO	603	X							X
Mekong S.	605		X	X	X		X	X	X

Equipment
A. Visual only or unknown
B. Light table
C. Diazochrome
D. Zoom transfer scope
E. Densitometers
F. Digital analysis of tapes
G. Color additive viewer
H. Photo laboratory

* based on private communication

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TABLE F-3 ERTS A-B FACT SHEET

AID Countries Which Submitted ERTS-A Proposals	Reported to NASA as of July 1974	Submitted ERTS-B Proposals as of July 1974	Follow-On Proposals Approved as of July 1974
LATIN AMERICA			
Argentina			
Bolivia	x	x	x
Brazil	x	x	x
Chile			
Colombia	x	x	
Ecuador			
Guatemala	x	x	
Peru		x	x
Venezuela	x	x	x
ASIA			
Bangladesh			
Indonesia	x		
Korea		x	x
Philippines	x	x	
Thailand	x	x	x
AFRICA			
Botswana	x	x	x
Kenya	x	x	x
Lesotho	x	x	x
Mali	x	x	x
OTHER			
FAO		x	x
Mekong S.	x	x	x

Developing Countries Which Did Not Submit ERTS-A Proposals But Which Have Submitted ERTS-B Proposals	Submitted ERTS-B Proposals as of July 1974	Follow-On Proposals Approved as of July 1974
AID PROGRAM COUNTRIES		
Afghanistan	x	
Central African Republic	x	
Ethiopia	x	
Gabon	x	x
Guinea	x	x
Liptako-Gourma Authority (Upper Volta, Niger)	x	x
Nigeria	x	
Pakistan	x	x
Shri Lanka	x	
Swaziland	x	
Turkey	x	x
S. Viet Nam	x	x
Zaire	x	x
OTHER		
CENTO	x	x

Appendix G

DETAILED TRIP REPORTS

G.1 MEMORANDUM FOR THE RECORD 12 April 1974

SUBJECT: AID Project: Trip Report on Visit to Bolivia, 14 - 20 October 1973

Present on the trip were: D. S. Lowe, E. J. Greenblat, R. A. Summers

Monday, 15 October 1973

On Monday morning we were met at our hotel, the Crillon, by Sam Allen and Lt. Col. John Furrer of the InterAmerican Geodetic Survey. They took us, by IAGS transportation, to the American Embassy where we were introduced to Mr. Amedu Landry, Administrative Head of the USAID Mission, and Randolph Mye, Economics Advisor at the US Embassy. Allen and Furrer then took us to see Dr. Brockmann.

10:30 A.M.: Dr. Carlos Brockmann, Director, Natural Resources Satellite Project, Geological Survey of Bolivia (GEOBOL), and the ERTS Principal Investigator (P.I.) and Alvaro Fernandez, a Geologist assigned to the ERTS Natural Resources Satellite Project. Dr. Brockmann is by training and experience a petroleum exploration geologist and is on loan from the government oil company (YPFB). It was noted that in addition to ERTS, they were interested in multidisciplinary experiments on Skylab using S-190 and B and S-192 instrumentation.

The principal interests for the ERTS program in Bolivia are cartography (with the assistance of the military cartography group and the IAGS), agriculture, petroleum exploration and hard rock

geology. The first imagery was received in December 1972, but the negatives were "too dark".*

About three or four months after receiving this imagery, the Bolivian government was asked to provide about $50,000 for use in interpreting the data. Due to the devaluation of Bolivian currency, this request was reduced to $26,000 but the funds were not made available. Some money was received from AID to start work on the first images. (We believe the program source for this money is known as PADAS, "Start of Projects for Development".) After, work was started on the first image and a need for diazchrome equipment was identified. Also needed were jewelers loops for examining imagery. One of the early items noted was the discovery of a massive dislocation of lakes and other shapes in the north central region. There were also some coordinate displacement questions to be resolved in the "bulk" ERTS imagery. This may have resulted from a misunderstanding concerning the accuracy of the latitude-longitude marks on bulk imagery.

It was noted that seismic work costs about $1,000 a day for one team. Concerning coordinate displacement questions, it was noted that the MSS products seemed to be "off" about 7 kilometers as were the RBV products; the RBV precision imagery seemed satisfactory in this regard. Brockmann felt that this was a system problem and indicated that he had sent a copy of his map with the coordinate questions noted on it to Broderick, the Technical Monitor at GSFC. He also noted that Doug Carter has a letter on this subject from him dated 8 October 1973.

Brockmann noted that they are submitting an ERTS support proposal to the UNDP for $150,000 to procure the assistance of experts and certain

*Subsequent discussion with NASA/GSFC/ERTS personnel indicated that "dark" negatives were intentional in order to retain maximum usable grey scale range. However, lower contrast paper must be used than is typical in photo-reconnaissance. Unfortunately, this latter piece of information may not have reached the LDC's.

equipment. The plan is for about six experts spending about one month each in Bolivia; this is budgeted as $6,000/month/expert.

Brockmann noted that the Provincial Government of Potosi is now entering into a contract with GEOBOL to utilize ERTS data. This contract should be signed within two or three weeks. Potosi wants a natural resource inventory of the Province and adjacent areas. The contract is for $7,000 and this natural resource inventory is to be completed by the use of ERTS data in 115 days. Twelve ERTS frames will be used; at a little under 3500 square kilometers per frame, this is about 42,000 square kilometers. This comes to about $6 per square kilometer for a complete natural resource inventory, i.e., approximately at 10 different types of thematic maps. The 10 types of thematic maps being considered are: (1) cartographic and toponymic, (2) hydrographic and hydrographic basins, (3) permiability of soil and rocks, (4) geological maps, (5) geomorphological maps, (6) structural map, (7) mining areas map, (8) volcanism, (9) land use and (10) soil classification.

By traditional techniques, i.e., ground surveys and conventional panchromatic aerial photography, it is estimated that it would cost about $10,000 per 2,000 square kilometers for a geological map only and would take about a year. Based on 21 x 2,000 square kilometer units, this is about $210,000 for a geological map only (about $5 a square kilometer for geological map only). If one assumes that the other nine thematic are of the same cost, this comes to about $50 per square kilometer for the ten-map set. This compares to about 17¢ a square kilometer for the Potosi contract using ERTS only. Therefore, there is approximately a 300 to 1 cost differential between the ERTS based natural resource inventory and that obtained by conventional means. It should be noted that there is no ground truth in this particular ERTS method, except that inherent in the general background of the resource scientists working on the problem. Brockmann feels that the two

products are comparable for many purposes and that 300:1 is, therefore, a reasonable assessment of the cost differential.

The Provincial Government of La Paz is also interested in a study of about 500,000 square kilometers. There is a desire to obtain a complete natural resource inventory of Bolivia. It is estimated that this can be done with ERTS data in about 1.5 years; with aircraft coverage and ground checks it would take about 6 years; without the use of aircraft or ERTS it would take about 25 years.

YPFB, the Bolivian National Oil Company, and the Occidential Oil Company have now requested ERTS data from GEOBOL, although they had earlier said that the data was not useful. There was a US grant of about $20 million after the last revolution of which about $125,000 (?) went to GEOBOL and to ERTS.

John Karman, a mining geologist from UNDP, came down to see Brockmann concerning the UNDP proposal. He was originally a doubter but became convinced that ERTS had very great potential for Bolivia and strongly supported the proposal.*

It was noted that there are approximately 100 professionals at GEOBOL. A comprehensive national 5 year plan is in preparation for Bolivia. There is a strong desire for an APT ("direct read-out") meteorological station; Brockmann noted that Bolivia is the only South American country without an APT capability. This is included in their current UNDP proposal.

At our request Brockmann described an oil drilling example "with and without ERTS data" based on YPFB experience. He cited a particular example in which at least two dry wells could have been avoided had they used ERTS imagery. He provided the following comparison for an area in the northeast:

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*Current information indicates that this proposal has been funded at the $185K level.

Without ERTS the following sequence would take place: (1) initial aeromagnetic survey costing about $2,000,000 and covering about 2 ERTS frames; (2) aerial photography at a cost of $2.14 per square kilometer (1968 dollars). This includes the aircraft and the development of the film, plus $5,000 for interpretation (about $10 per day per photo interpreter). A total of $100,000 was spent on this phase of the activity. (3) The ground exploration crew, consisting principally of geologists costing about $500 per month per geologist (total cost including overhead and field expenses). It is estimated that it would take about 8 months by this procedure to prepare a planimetric map at a cost of $15,000. He noted that the cost per 3rd order control point was about $1,000 according to the Institute of Military Cartography. This area which had been explored in the above manner has had no strike yet. The contract has been given to TOTAL.

For the same area utilizing ERTS imagery, Brockmann estimates that about 60% of the classification information could be obtained via ERTS in the pre-diazochrome period. About three ERTS images would be required and about three professional days per image. Each professional would cost $600 per month total (overhead included). He estimates the order of $100 to interpret one ERTS image. He feels that up to 90% of the classification information could be obtained via improved ERTS image interpretation, i.e., utilizing diazochrome color composites. He noted that a seismic crew would cost about $1,000 per day and would cover about a 5 kilometer line per day. For 300 kilometers it would take about 60 days and cost about $60,000.

Other examples he thought might be of interest to us were: (1) a pipeline case study (see Mollendo), (2) transportation planning, (3) hydroelectric power planning. (It has been found in ERTS imagery that a reservoir is already being built with a fault leak. If this reservoir is successfully built, Bolivia could sell electric power to

Argentina and Chile.) It was suggested that we check on thermal anomaly detection from existing satellite platforms including DAP, NIMBUS and ITOS.

Tuesday, 16 October 1973

Dr. Brockmann took us to see the TOTAL interim representative in Bolivia, Sr. Alberto Vascas. Sr. Vascas indicated that the arrangements between Bolivia and petroleum exploration countries was by means of "Operations Contracts" whereby YPFB acts as the government representative in the contact. YPFB owns all the oil and a fixed percentage of the produced oil is "paid" to the exploration company. There are now three operations contracts underway in the north. These are: Union Oil Company, Occidental Oil Company, and a TOTAL/Union combine. Occidental is also operating in the Santa Cruz area. Others include Philips in Cochabamba; Loan Star; Texaco to the north, Sun Oil just south; and Amerada-Hess all of which have submitted letters of intent only. There is a magnetometer survey being conducted by a German company in the Beni/La Paz area. The TOTAL people feel that they have received more information from a single ERTS frame than from all previous sources of data.

In all of these exploration activities there are difficulties in arranging the logistics to get the oil out. The ERTS data can be utilized to generate land classification information which in turn is useful in programming the seismic exploration. The Union Oil Company has set up a base camp at Reyes and is equipped with fixed-wing aircraft and helicopters. TOTAL found from the ERTS imagery that some 60 to 70% of their area was actually savanna rather than jungle so that helicopters were not needed for the activity. This is important since helicopters are quite expensive averaging at least $50,000 per month and up. Vascas also felt that the ERTS data had accelerated their activities by about 6 months.

It appears that because of some perceived coordinate uncertainty in the bulk imagery, they preferred to use precision imagery. There was also an interest in GEOS-C information which would be good to ± 6 meters. Reference was made to a relevant article in Photographmetric Engineering.

There is a need in the exploration activity to determine the limits of the Brazilian shield. This GEOBOL is doing. This information is needed in order to plan the seismic and drilling activities. The cost per drill hole is approximately $200,000. One company drilled recently and found bed rock at only 70 meters. This could have been avoided if they had known the approximate location of the Brazilian shield. Another possible useful application of ERTS data is in determining the initial corridor for pipeline routing.

Each of the oil companies involved in exploration contracts is required to invest $4 million/year minimum in accordance with their government contract. YPFB owns all pipelines and all oil at the "point of measurement". YPFB pays the exploration contractor with a certain percentage of the oil. Brockmann feels that YPFB provides "all the information it has". The exploration company holding the operations contract finances the construction.

Later in the morning we met at Brockmann's office with Jaime Gutierez, Economics Advisor to the President and a GEOBOL Economist. Mr. Gutierez indicated that there were no ERTS-related benefit calculations to date, only cost estimates. He noted that USAID has provided about $25,000 for the year. We were also referred to UNDP proposal. DMB is contributing about seven and a half thousand dollars. The Bolivian Air Force had been paid about $2.30/km^2 for 1:40,000 aerial photography. Gutierez indicated that a 15% rate of return was required for project viability in Bolivia.

In the afternoon Brockmann took us to YPFB, the Bolivian National Oil Company, where we talked principally with Roberto Santa Cruz and

Justo Quervedo; exploration geologists; Exploration Division. YPFB.
The conventional exploration sequence is: (1) aeromagnetic survey, (2) photography and photo interpretation, (3) seismic, and (4) drill holes. It was estimated that aircraft photography costs about $2.80/km^2 for 1:40,000 scale photos without interpretation. This is based on about 30,000 square kilometers of work. Three people are required for this activity.

An example was given of low lands coverage of 28,000 square kilometers which took about 4 months using aerial photography. Another example was near Santa Cruz with 50,000 square kilometers of photography; it was necessary to wait 2 years for the aircraft coverage to be completed due to the clouds, winds, and sands, etc. The later coverage is now available from ERTS with only 10% cloud cover.

The preparation of a geological/geomorphological map based on aerial photography and ground truth is estimated to cost about $15/km^2. This is typical for hilly country with outcrops. For flat country without outcrops, the cost estimate was $100/km^2 based on the use of a gravimeter in the interpretive process followed by seismic work. The cost of seismic work was estimated to be about $150,000/month/crew; about 200 linear kilometers can be covered in a month. The holes are about 10 kilometers apart in the intital activity with the spacing reduced to 4 kilometers when a structure is found and gridded information desired.

Based on the above mentioned unit cost for geological/geomorphological mapping in hilly country without outcrops, i.e., $15/km^2, producing a geological map covering the same area as an ERTS frame (35,000 km^2) would cost about $500,000. There is, of course, some questions as to whether the products are comparable.

Brockmann agreed to obtain for us the total exploration budget plus a breakdown of components. It is not immediately available since

it is located in Santa Cruz at the headquarters of the YPFB Exploration Division.

It was noted that each operation contractor must spend at least $2 million per year over his 10^6 hectares. Union spends about twice the minimum, or $4 million per year.

The use of ERTS imagery for pipeline location was discussed. The ERTS imagery is considered a great advantage in locating initial corridors. A suggestion was made that a sample of ERTS imagery be analyzed for possible corridor selection for the Sucre-Monteguru pipeline.

The individual exploration companies may select their operational areas, using a special book containing all the relevant geological information on Bolivia. Doug Carter at USGS Reston has a copy of this book entitled "Resume of Petroleum Geology in Bolivia." It was noted that Bolivia cannot afford conventional geological mapping of the entire country.

Wednesday, 17 October 1973

9 a.m.: Professor Franz Liszt at Dr. Brockmann's office. Professor Liszt is an exchange professor in applied geology from the Free University of Berlin. He is a P.I. in Chad (Tibesti mountains area). He now has one German Ph.D. student who is doing some manual interpretation on Bolivian data. He has acquired a second Ph.D. student who is doing work on radioactive mineral deposits. Liszt noted that the aircraft photography of Bolivia is generally very good where it exists.

In his Chad work he is employing ERTS, aircraft, Skylab and field data as well as some Gemini and Apollo data. He is using all the information he can get. The Free University has a research station in the Tibesti mountains manned by 6 persons. He noted that there was not a single geologist in all of Chad.

Liszt's objective in Bolivia was to set up an Institute for Applied Geology at La Paz University. Unfortunately, it has not been possible to make much progress in this effort.

Liszt indicated that the following items, in his opinion, were seen better on ERTS than by any other means: large structures, the significance of these structures, and slight tonal changes.

He noted that only one drill hole out of five yields oil in Bolivia, on the average.

Franz Liszt noted that an investigator had told him of a situation where he had spent four years in oil exploration activity which he now felt could be done in four to five days with the use of ERTS data. This involved four man-years of work over 20,000 square miles in south central Bolivia. He felt that the ERTS advantages were: no mosaicing required; retention of subtle features; large scale integrating effects; fewer ground control points needed. Liszt felt that the hard rock geologists had the advantage of being able to skip certain intermediate exploration steps by employing the ERTS data.

Personnel now assigned to GEOBOL/ERTS are as follows:

1 professional from YPFB (Brockmann)

1 additional professional coming from YPFB

3 from GEOBOL

1 from COMBOL

1 from Ministry of Agriculture.

There is also one person half-time at the University, two half-time French students at the University, two French geologists doing a tectonic map of Bolivia and one half-time person from Tubingen.

It was noted that the Bolivian Atmoic Energy Commission is now interested in ERTS data for uranium exploration. FAO has expressed an interest in the south central agricultural region.

Liszt felt that a spatial resolution of 10-20 meters would be desirable; 50 meters he considers very helpful. The geologist has little interest in the temporal aspects of the data. Brockmann felt that it would be at least two years before an "ERTS-based" geological

strike. The most promising area for this would be the northwest. There are large iron deposits in the far eastern corner, extending into Brazil.

Dr. Vega-Lopez, IDB (Inter-American Development Bank) Special Program

Dr. Vega-Lopez spent two years in D. C. as Bolivian representative to IDB. The National Investment Institute, affiliated with the Ministry of Industry and Commerce, was identified as the best connection to the private sector. It was suggested that Ed Greenblat make an appointment with Mr. Javier Campero, CONEPLAN, to discuss the Bolivian five-year plan. We received a copy of the Bolivian government document "Investments in Hydrocarbons" which contains the current regulations on operations contracts and other exploration activities for foreign firms in Bolivia.

Dr. Vega-Lopez indicated that there were 10 people in the IDB-funded group and that it was an international staff. He mentioned Ingro Basobezi, head of the "second group" and a generalist. The primary objective of the IDB is to increase the GNP. It is felt that income distribution cannot be improved in the medium term, i.e., 4 or 5 years hence, but can only be a long term objective. They are also interested in the improved utilization of natural resources including the forests in the Santa Cruz area. It was pointed out that the private sector controls 45 to 48% of the Bolivian economy. Again, the importance of the Hydrocarbon Law in petroleum exploration was emphasized.

In the hard rock mining area, a new arrangement between GEOBOL and the World Bank has been initiated, for developing an integrated program in the mining sector. The mining sector has three principal parts as follows: (1) COMIBOL, the government corporation which took over the large mines in Bolivia some time ago; (2) the "medium miners", of which there are about 25 to 30 companies; and (3) the "small miners" of which there are about 1,500. The question of whether the small miner can be integrated into "more efficient" medium mining enterprises is being investigated.

Juan Pascoe, UNDP Representative in Bolivia

(Accompanied by Dr. Brockmann) Pascoe indicated that Earth Satellite Corporation was very anxious to become involved in implementing Bolivia's UNDP proposal which in its present form, was not acceptable. It was indicated that the UN expert of the Natural Resources and Transport Division had helped on the earlier version of the proposal. Pascoe pointed that the proposal had been received in September but discussed in October 1973 start. The expenditure has been approved by the Governing Council of the UNDP, but they feel that the proposal must be resubmitted because of its references to arrangements with specific commercial enterprises and merchandise.

The UNDP had about 40 projects in Bolivia and had about six people in residence. The Ministry of Planning decides on projects in Bolivia. CONEPLAN, reporting to the Office of the President, is a key factor in the decision process. Pascoe noted that $15 million was the "indicative figure" of the UNDP for the next five years in Bolivia, thus averaging about $3 million per year.

Randolph Mye, Economics Advisor, U.S. Embassy

Mye indicated that an agricultural sectorial analysis is being done for both the Atiplano and the lowlands. Crop acreage determination for all Bolivia would be very useful. Soil maps are also needed to assist in resettlement decisions. He noted that the average agricultural plot on the altiplano was about 20 acres. The altiplano has isolated population centers with little or no communication among them. We were referred to "Plan Vial 3000" relating to 3000 kilometers of roads.

Morris Whitaker, Agricultural Specialist, U.S. Embassy

Mr. Whitaker joined the conversation. He indicated that an $8 million loan was under consideration by the World Bank to assist the medium miners. Part of this money would be for exploration and the total amount is still being negotiated. Walter Gomez was recommended

for discussion of small mining operations. Mention was also made of the New Lands Settlement Project in Oriente Province. It was pointed out that no new mineral reserves have been identified in recent years. COMIBOL is supposed to have about 20 years of reserves but this figure is considered quite uncertain (it may include tailings). We were referred to Mr. John Henderson, Minerals Attache at the Embassy.

Thursday, 18 October 1973

9:00 a.m.: Mr. Enrique Ackerman, Deputy Executive Director, National Investment Institute (INI). Mr. Ackerman indicated that a new investment law was eminent with increased incentives for investment. The function of INI is to operate in any sector except petroleum. There are essentially three phases of project review and approval; these are: (1) analysis of feasibility by INI: (2) incorporation into the five-year plan by CONEPLAN; and (3) an assessment of fiscal benefits by the Ministry of Finance. There are two general categories being considered: (1) raw material being turned into finished products, a vertically integrated activity and (2) agribusiness, including cattle raising in Beni, and cotton. He noted that cotton is now booming and has been developing over the past seven years in the Santa Cruz area. He indicated that, after four to five cotton planting cycles, the land is essentially burned out. At present, there is a complete lack of planning here. There is a possibility for cotton growing in Beni also. There is a considerable need for investment in infrastructure in order to realize the potential of these activities. The rate of return on cotton has been 40% last year (gross). The taxes on export are about 5%. Some activities in soy beans are starting, although a shortage still exists.

Ackerman indicated that INI is independent but linked to the Ministry of Finance. The Minister of Finance is Chairman of INI. CONEPLAN functions as a Secretariat reporting to the President of the Republic. Ackerman noted that the criteria for project evaluation include minimum

rates of return of 3%, (rates of return usually run to 12 to 15%). There is about a 3 1/2% to 4% inflation currently. There is also a desire for economic integration and a more acceptable balance of labor intensive activities.

Ing. Marcello Montero, General Director for Industrial Development, Ministry of Industry and Commerce and Jose Luis Daza, Chief of the Industrial Program joined the discussion. They noted that the government must provide incentives for the development of the necessary infrastructure. Reference was again made to "Plan 3000" and related highway costs. An unsuccessful attempt was made to obtain this plan. An irrigation plan was discussed and a copy of the investment law was provided. It was suggested that we obtain a copy of the five-year plan, as well as an A.D. Little study for CONEPLAN, which costs about $3 million. This was paid for by the Bolivian government and consists of 40 volumes covering the entire industrial sector. The study was completed in 1971. The following brief review of financial sources was given: The IDB, through CPF, provides short term and medium term loans for about a 5-year period at about 12% interest; there is a private bank and an industrial bank (BISA) which provide medium and long term loans at 10 to 12%; the FRI/FRA (Refinance Fund for Industry and Agriculture) provides funds in the medium and long term at 10%; the Central Bank, controlled by the government, has FRI/FRA funds; international or foreign sources are often used.

11:30 a.m.: Morris Whitaker, Agricultural Economist and Carl Parker, Range Ecologist both from Utah State University and Sponsored by AID at the Ministry of Agriculture.

Carl Parker is convinced that the altiplano may be much more productive than traditional wisdom indicates and he is now studying this intensively. It was suggested that contact be made with Mr. Cochrane, British Tropical Agricultural Commission, Santa Cruz, who has published

a significant soil map of Bolivia. It was noted that little resource inventory data on Bolivia exists, especially in agriculture. Mention was made of Bob Moffet, Rural Development Officer. Parker indicated that he would be able to attend the CONEPLAN meeting scheduled for 2:30 p.m., Friday. An IBM 370-40 is being acquired by the Ministry of Agriculture. Regarding predictions of crop yield, it was noted that both acreage and soil moisture were critical inputs.

Edward R. Atwill, V. P. and Resident Manager, Occidental, Bolivia. Mr. Atwill, whom we met somewhat by accident at lunchtime, indicated that it was difficult to obtain ERTS data from NASA. For further details, he suggested that we check with the Occidental California office and particularly Mr. Buz Ivanhoe in Bakersfield, California. Mr. Atwill is stationed in Santa Cruz but makes frequent trips to La Paz. We had lunch with John Henderson, Minerals Attache, U.S. Embassy, and Randolph Mye. John Henderson indicated that there was little hard-rock geological exploration going on in Bolivia. No new mines have been identified since 1952. Local investment is not constant.

2:30 p.m.: Meeting at GEOBOL with Carlos Brockmann, Carl Parker, USAID, Ing. Marcial Macias, Chief, Division of Soils, Irrigation and Engineering, and Ing. Orlando Unzuata-G, Bolivian Ecological Mapping Project, Ministry of Agriculture and Stock Breeding. A 1:2,000,000 soil map of Bolivia exists which was developed by Cochrave of the British Tropical Agricultural Commission. This mapping was begun in 1964 and the Bolivian government paid in about $250,000 including salaries, etc. The map took about ten years to make and was based on field work only. This period could have probably been reduced to five years through the use of 1:40,000 aerial photos. The soils have been classified according to the Australian system in relatively large units of 10 kilometers square. It was noted that this report is available in AID at the La Paz Embassy. An inventory of all existing maps is available and could be borrowed from Mr. Earl Smith.

There appear to be over 200 categories of soils. Comparisons with the FAO 1:5,000,000 soil map of the world indicate that the classification is acceptable and the shapes of the areas of common classification are approximately the same in the two cases. A 1:1,000,000 soil map of all Bolivia is expected to be available in about two years utilizing ERTS and aerial photography support. This would be a more detailed map than the one above. The 1:1,000,000 size is really for policy use only and not actual management of soils. For soil management, probably at least 1:250,000 is needed. A 1:50,000 scale seems useful for land management. The salaries only for this activity over a two year period were about $40,000 for eight university graduate technicians. The 1:250,000 is also useful for agrarian reform programs.

The following approximate salary estimates were made: a new engineer would get about $75 per month; a driver would get about $20 per month; a senior engineer would get $200 to $300 per month. A typical overhead on salaries would be 30%.

About 2,000 soil profiles were made in the above described mapping procedure; about 4 to 5 cores are made per profile and each core analysis costs about $3. It is estimated to take about 2 months to make the first ERTS based soil map.

Vegetation classification for all Bolivia is underway and should be available in about 6 months at a 1:1,000,000 scale. Cross associations only will be included; each frame will be treated separately.

Annual crop estimates would be useful particularly for sugar, potatoes, rice and wheat. Currently there is, at best, 70% accuracy. There is considerable infestation from insects which could be controlled by spraying. Crops often go four years without any rotation. Soy beans and peanuts could be good rotation crops in Bolivia. There is presently not much rotation and not much incentive for it.

About 60% of Bolivia is grazable and is used as such. Overgrazing is common in the south. Typical animals include llamas, alpaca, sheep,

and goats. North central area is undergrazed but has very little infrastructure; a cattle industry is being developed and meat is flown out. It should be noted that the only trained range specialist in the country is now the number two man in the agricultural ministry and so has little time to devote to range specialties. Another trained specialist is Carl Parker but he is not indigenous.

It was noted that there is an image or two missing in the ERTS coverage for the north central area near the border.

It was noted that there is no watershed management activity currently underway; there is also no hydro-power planning. Regarding an ecological map of Bolivia, it was estimated that about 20% assistance could be obtained from ERTS. Data included would be topography, altitude, rainfall, etc. Approximately 2 years will be required for completion based on one person half time.

Friday, 19 October 1973

9 a.m.: Dr. Carlos Brockmann. Brockmann again brought up the question of the natural gas line example in the Sucre area. He agreed to work up an example for our use.

It was noted that the YPFB is also interested in the Ixiamas-Titicaca-Arica pipeline. It was agreed that we should obtain annual reports of YPFB, COMIBOL, and GEOBOL; Brockmann will assist in obtaining them.

Brockmann again brought up the problem with NASA negatives and the feeling that they should be improved in quality. Reference should be made to a footnote on an earlier page in which the proper utilization of the intentionally dark negatives has been worked out by NASA but apparently not effectively communicated to P.I.'s. The principal clue is to use lower contrast paper than would ordinarily be used in aerial photography work.

Brockmann outlined what he was interested in from NASA. He needs the data for the gaps between the passes. He would like complete coverage of Bolivia and repetitive coverage if possible. Brockmann agreed to provide a map of what he wants and what he has. He would also like to have precision imagery of the whole country and will provide the ground control points if needed.

10:00 a.m.: Raul Salas Duran, economist, Fredy Arteaga Hayasida, Ministry of Agriculture, economist. Duran and Hayasida had brought crop production data. Some of this was actual data including prices at the farm, wholesale, and retail levels. They indicated that historical projections are often used but are not very good. Linear projects of historical data are also used. They were not certain if new forecasts would help.

10:30 a.m.: Mssrs. Crosby and Rivero, Union Oil Co. They indicated that use is made of the services of Geophoto in Dallas, a subsidiary of Texas Instruments. They are analyzing photography obtained by the Bolivian government.

They described their exploration procedure as follows: examine the area, review the geological reports of YPFB, conduct a brief reconnaissance, send out seismic crews to selected areas.

Much of the area they are looking at now has no outcrops at all and is principally flat jungle and savannah. They are using aerial photography and eyeball observation. They have already set up a basic camp at Reyes. They have been gathering magnetometer and gravimeter data. They felt that ERTS data would not be much use at this stage since they already committed to a set of locations and procedures. They felt that ERTS potential would be much greater earlier, i.e., before signing their operations contract and selecting their area. They noted that the actual utility of ERTS depends to a large extent on the geology of the particular area involved. They also pointed out that they were

particularly interested in accurate mapping in order to make sure that they are functioning within their own concession and not in someone elses.

2:30 p.m.: Meeting at COMIBOL. We met several gentlemen at COMIBOL, Government Mining Organization Headquarters in La Paz. It was noted that the Geology Department is located in Oruro. One of the people we met with we believe is Orelio Bustos. No translator was present, so language was somewaht of a barrier at this meeting.

It was indicated that their view of exploration was either (1) looking near present mines or (2) looking around "in other places". However, the communication was difficult and a rescheduling of the meeting later in the day was arranged.

3:30 p.m.: CONEPLAN Meeting. Dr. Brockmann, Dr. Fernando Campero Prisdencio, Under Secretary of Planning, Lic. Javier Campero Paz, Director of Global Planning and three consultants from the IBD to CONEPLAN, namely Dr. Julio Camba ("interpreter" for the Under Secretary), Lic. Alfredo Olmedo and Lic. Oscar Vega-Lopez. It is not feasible to do everything one would desire simultaneously in Bolivia at the present time. It is necessary to set priorities and these, for the present, are minerals, oil, and agriculture, in that order. Financial conditions are changing and there appear to be many excellent opportunities for development. They are planning to set a Central Information Center. Priority projects will be selected and they will build upon these. Projects will be evaluated with respect to the "global" plan. Specific data is being collected by sector. Sectorial plans will be completed within 10 to 12 months without the use of ERTS. It was felt that, with the use of ERTS, these could be completed within 5 to 6 months. Another example cited was a land use map of Bolivia which they felt would take 8 to 10 years without ERTS but might take only 2 years with ERTS.

In general the group seemed favorable to the use of ERTS. Dr. Gamba served as interpreter for those present who were not fluent or comfortable in English.

We inquired as to how ERTS utilization priorities were determined and how the desired information was identified. The answer was that the number one priority went to agriculture including land use, forestry and irrigation; the second priority went to mining. It was noted that Bolivia is still in the project stage. Studies can be improved so that decisions can, in turn, be improved. The primary needs for ERTS data utilization are: (1) trained personnel from Bolivia and AID and (2) equipment to take full advantage of the available information.

We next asked how much would Bolivia be willing to invest in an ERTS utilization program? The answer was that they felt that it was too early to say until definitive implementation had been demonstrated. They emphasized the critical need for proving the utility at the Bolivian level; this must come first before they could allocate Bolivian funds directly. Regarding mapping, it was felt that a general map could wait so that high priority areas could be identified and mapped earlier.

In general it was felt not possible to quantify the situation with or without ERTS at this stage. They were uncertain as to what the investment gestation period was.

They are not only interested in more information but better information and being able to organize to use it. In this way they hope they can design better projects. Gamba suggested that the appropriate discount rate would be about 15 to 20%.

5:30 p.m.: Meeting with Medium Miners. Discussions were held with Mr. Guillermo Gutierez, President of the Medium Miners and of International Mining Corporation and Mr. Ronald MacLean, Economist and Assistant to Mr. Gutierez. Gutierez indicated that there is no substantial exploration. He indicated that COMIBOL also does not do

any exploration. Regarding International Mining Corporation, he noted that they carried out 40% of the tin mining and 80% of the tungsten mining; in tungsten they provide 7% of world production. At present they are just using old mines; in perhaps 5 years they would be interested in starting exploration. Gutierez noted that he had taken over International Mining a couple of months ago. Mention was made of Johnny Delgado, the Technical Manager who was not present.

7:00 p.m.: Meeting at Hotel Crillon, with Mr. Raul Salazar, Technical Manager, COMIBOL, Mr. Orelia Bustos, COMIBOL, and several COMIBOL people. Dr. Salazar was fairly effective in English and we were also soon joined by Dr. Brockmann so that communications were vastly improved over the earlier meeting at COMIBOL.

Salazar indicated that he did exploration. This included (1) geological studies, regional geology plus aerial photography and (2) geophysical, geochemical, gravimetric and magnetometer surveys. They also did test drilling for veins. He depended on IAGS information for drainage and contours. Much of the equipment they use is at universities including Potosi and Oruro. He could offer no specific information on his exploration budget. They are dependent on development bank loans.

They are using ERTS imagery north of Lake Titicaca. Some UNDP support is being made available for work in copper as well as tin, gold and wolframite in the northern areas. Many of these areas have no usable conventional maps and ERTS data could be very helpful. They would like very much to have countrywide coverage for drainage and geological mapping. Other types of natural resource inventory maps would also be useful.

He indicated that the northeast in the northeast corner of Bolivia they had spent about $800,000 for aerial photography of very bad quality. They are now using ERTS to select more limited areas for higher resolution aerial photography.

We inquired as to what was the value of ERTS to them and what would they be willing to pay for it? We also asked what was the relative value of ERTS to black and white aerial photography? We asked would they be willing to pay the Brazilians $5,000 per scene/yr? The reply was that no answers were possible at this time to these questions.

It was noted that fault crossings, particularly north-south and east-west ones were useful indicators for location of tin and geothermal sources.

We inquired as to what kind of demonstration they felt would be needed to prove the economic utility of ERTS for them? The answer was that it was still too early and that perhaps in one or two years they could answer this question.

G.2 MEMORANDUM FOR THE RECORD 3 April 1974

SUBJECT: AID Project: Trip Report on Visit to Thailand, 12-16 November 1973

Present on trip were: D. S. Lowe, E. J. Greenblat, R. A. Summers

Monday, 12 November 1973

We met at 10:00 a.m. the next morning at USOM with Joe Morgan, the ERTS coordinator at USOM for Thailand. He has at various times been a staff member at Willow Run Laboratories, at SRI and is now about to become a permanent USGS employee assigned to the ERTS coordination job at USOM Thailand.

Joe is quite enthusiastic about the role of ERTS in developing countries and feels that the mere act of the U.S. providing free imagery to Thailand has created much good will there. Up to now, the total expenditure for ERTS-related activity has been $160,000 including the U.S. salaries -- this is AID money. They are proposing starting next year a $120,000 annual budget for ERTS. Joe offered to provide us with Thai user agency budgets and organization chart. He referred us to the following USGS report: "Thailand Remote Sensing Training Project, October 1973" by M. D. Kleinkopf, Project Director, USGS and J. O. Morgan, Project Coordinator, USOMT. They are proposing to obtain a zoom transfer scope, a $1,400 densitometer which can accept 9" positive transparencies, and a four-camera Spectral Data aircraft system and viewer (about $7,000 for the camera and $7,000 for the viewer). The Thais have asked for $2.3 million that in order to match the proposed U.S. funding. This request for Thai funding is being spearheaded by General Chan, the Thai Budget Bureau Director. Chan has suggested asking for more, including a multi-spectral scanner for an aircraft. The five-year plan includes establishment of an ERTS receiving station which will be "the first in S.E. Asia". There are three people currently assigned to the development of the five-year plan including three Budget Bureau people. Khun Prachit Kampco and two others are involved. The Mekong Secretariat has assigned a computer expert to the ERTS area.

Morgan indicated that we would be meeting with Dr. Fletcher E. Riggs, AID Assistant Director for Agriculture at USOM. There is a total of 150 U.S. personnel at USOMT.

Morgan pointed out that the private sector is very strictly controlled by the Ministry of Industry and these controls include mineral resources all of which are very closely held data. The USOMT priorities are roughly as follows:

1. Agriculture (including rice)
2. Forestry
3. Land Development (including geography, demography and cartography)
4. Geology
5. Hydrology
6. Oceanography.

These priorities are probably the same as those of the Royal Thai Government (RTG).

There is regular APT meteorological capability in Thailand. There are no DCS platforms, either controlled by Thailand or the Mekong Secretariat at the present time. These platforms could be useful to the National Energy Authority for water management purposes. Joe Morgan indicated that he would not be very interested in the addition of a thermal channel for the 9:30 a.m. ERTS orbit. He also noted, for our future reference, that the mangrove, which is seen in much of the Thai imagery, grows only in brakish water.

Morgan noted that there had been no imagery of Thailand since May 1973. For the period September 1972 through May 1973, they have good coverage and a total of 360 scenes have been received. All of these have less than 70 percent cloud cover which was the desired cloud cover cut off point. Forty scenes are required to cover the entire country. They have many images with zero cloud cover but background fog is always present in some areas.

For our next meeting of the morning, Joe Morgan took us in to see Dr. Fletcher E. Riggs, the Assistant Director for Agriculture. We inquired about the ECAFE activity, but Riggs indicated he had no substantive knowledge of it, and that it was principally staffed by Indians and Pakistanis. The Mekong Commission is under ECAFE. It was noted that the Applied Scientific Research Corporation of Thailand (ASRCT) assists the Mekong Commission with photo reproduction at cost. The

Mekong Commission activity is emphasizing land use and is focusing on a decision regarding the Pa Mong 5 megawatt dam. Riggs understood that the Mekong group feels that the ERTS imagery is the best input they have had. They have already spent about $76 million on research and a total of $260 million including ancillary construction. It is anticipated that the total cost of the Pa Mong dam will be between $2 and $2-1/2 billion. Riggs referred us to Mr. Van Liere, the Chief Agriculturalist in the Mekong activity. We were advised also to see the Mekong proposal.

ASRCT has two diazochrome technicians who have already made more than a thousand transparencies. The diazo process appears to be very good for developing countries. It was noted that a U.S. Bureau of Reclamation Team has done a study of the Pa Mong Dam. The implementation of the dam will create a resettlement problem impacting about 300,000 people. A Cabinet Secretary level letter exists authorizing an ERTS committee. RTG has trained about 72 people from Thailand and neighboring countries, utilizing AID dollars. Of these, 50 are from Thailand, mainly at the working level, in Agriculture, Forestry and some other disciplines. USAID has provided three economists to the Ministry of Agriculture specializing in sector analysis for agriculture. These people are from Ohio State University. The country has been divided into 19 agricultural/economic zones and they are building a model of each region. Each model will be based on 6 to 8 land classes and 12 commodities and will utilize a monthly labor input. The objective function may maximize output or income.

The major exports are rice, corn, cassava and kenaf. Most of the rice and corn is exported to Japan and its immediate area while most of the cassava goes to Europe. It was noted that 60 to 65 percent of the rice is for domestic consumption.

Statistical data is available from the Bank of Thailand and from the National Statistical Office. We were referred to the National

Economic and Social Development Board (NESDB) as the principal national planners. We were referred specifically to Mr. Forrest Cookson, an AID staff member who is provided as an in-house consultant economist in NESDB.

2:15 p.m.: Mr. Samarn Panichapongse, (SM Agriculture, Texas Tech. 1961), Chief, Land Development Department, Ministry of Agriculture and Mr. Manu Omakupt (Purdue University Fellowship), Soil Scientist. Mr. Samarn is principally interested in land use, mapping, land capability mapping and "cadastral" (land-holding) information. He pointed out that we should avoid the use of the term "cadastral" since this is officially in the domain of the Ministry of the Interior. Mr. Manu is active in land use mapping with ERTS data. He is interested in small scale surveys.

There is a project now underway for mapping 2.5 million rai (approximately 1 million acres) in the northeast, an area behind in development. There are available soil maps at 1:100,000. Their product is provided to the National Planning Bureau. Existing maps are at least 5 years old and change detection is needed.

Land capability depends upon two aspects: (1) physical characteristic and (2) socio-economic factors, and that both of these are primary inputs into land use planning. They are now dependent principally on physical characteristics only.

They have submitted a UNDP proposal but this was not accepted and has now been resubmitted at a lower cost level. For land characteristics, they use about 50 to 100 borings for each square kilometer. The principal scale they will be aiming at is 1:100,000. There are 1:50,000 aerial photographs available of some areas. Soil characteristics of interest include slope, drainage and fertility. It was indicated that a 15 percent error in classification over the entire country is acceptable for land capability purposes.

It was noted that there are over 2,000 varieties of rice, each with different yields. However, the purchaser is indifferent to these varieties.

Samarn was formerly at the Soil Survey. He indicated that they now have a pretty good country-wide soil map and are working on provincial level soil maps. It was noted that the forest cover in Thailand has apparently decreased from 50 percent to 40 percent in the past four years. At least some of this has been noted in ERTS imagery. A key question is what is the value of the information? It was noted that the goal of the Forestry Department is to keep the forest cover level in the country at about 50 percent. There has been a growth in population in the past four years from 30 to 38 million people. It is estimated that to bring the forest cover back up to the 50 percent level, i.e., a 10 percent reforestation, would cost on the order of 12,000,000,000 bahts. They have requested 20,000,000 bahts for this work but expect only about 12,000,000. This may be for their land capability work.

Of this budget, about 90 percent would go to field work with this being split evenly between salaries and other expenses. Ministry of the Interior has requested an acceleration of Samarn's program. He feels that he has an adequate number of personnel. He noted that the Ministry of the Interior is making a series of 1:15,000 maps of the whole country and is targeting at a 1977 completion date. Joe Morgan would like to see a complete land use mapping at 1:100,000 and suggests that either a better ERTS is needed or a better computer software/hardware capability. Samarn estimated that a 1:15,000 coverage of the whole country would cost 300,000,000 bahts. This has been requested by the cadastral survey people.

Corn is currently farmed at four crops per year. Without irrigation, only two crops are possible. The cultivation of the corn is

dependent on the monsoons and/or irrigation. The average field size is about 25 rai (about 10 acres). These fields are smaller in the central plain and in the northern region.

A copy of the revised UNDP proposal was received.

Tuesday, 13 November 1973

9:30 a.m.: Mr. Kris Sombatsiri, Deputy Secretary-General, NESDB (University of Michigan, School of Business, 1955-57) and Forrest Cookson, an AID economics consultant in NESDB. The northeast area is considered most important for natural resource development and has an interesting geology. There would also be potential for grazing except for a prevalent hoof and mouth disease. There are separate regulations for the exploration and extraction phases of mineral activity. There is a defined parallel of latitude above which Thai ownership is required but this is changing. Most of the mines are of the open-pit type.

NESDB is the principal national planning office and its responsibilities are:

1. To advise the cabinet on methods of solving social and economic problems; and
2. To perform a general planning function.

All proposed projects are submitted to the NESDB for approval. They are then submitted to the cabinet for a final decision. If approved, they are placed in the five-year plan. The criteria for approval includes cost-benefit studies based on established rates of return. Consultants are retained for doing the cost-benefit evaluations in project evaluation. Therefore, there are no common sets of assumptions since different consultants are involved in different projects. The minimum desired rate of return is considered to be 10 to 12 percent. This is the threshold for government interest. There is a Board of Investment which can confer tax incentives on particular activities and this has included manufacturing and hotels in the past. These

analyses are based upon the UN publication entitled, "Guidelines for Project Evaluation". Social costs are not considered.

Cookson noted that the pricing system "is a classical example of a competitive economy". In Thailand regulations cannot be enforced. "Corruption on income operations can increase competitiveness" (Forrest Cookson). There appears to be no real shortage of investment capital and amounts in the $1 to $5 million range are readily available for investment. It is Cookson's view that the classical conditions for a competitive economy operate in Thailand.

Cookson noted that improved information may increase instability in the commodity markets which are now in excellent equilibrium. He suggested that extreme caution be used in this instance.

Cookson indicated that, in the absence of unusual weather conditions the volume estimates on commodities are pretty good except for rice. Prices are not well forecast. The rice volume is often by a factor of two and this is considered unacceptable for a leading export commodity. Twenty to 25 percent of rice crop is exported. The rice economy is a major sector of the economy and as such it was noted that the management of the rice economy is critical to political stability in Thailand. He felt that ERTS could help in production estimates in general and especially with rice. Cookson has the equations for an econometric model in this area and will send them to Joe Morgan. He also offered to get any other data we wished and he will work from a list that could be provided to him. It was noted that government ministers were intimately involved with rice exporters.

Joe Morgan felt that computer analysis is required to do the rice prediction job. He felt the computer analysis would be needed to identify the rice growing areas.

Cookson noted that the economy in the northeast is precarious and is facing a land exhaustion situation since all arable land is now under cultivation. Therefore, it is necessary to increase yields. There is another view that enough land exists for 10 to 15 years of future expansion. ERTS could help to resolve this question and prepare a paper plan. Opportunity costs are significant here. A copy of the current five year plan was obtained.

11:00 A.M.: Dr. Snoh Unakul, Deputy Under Secretary of Commerce (formerly of the NESDB). Dr. Snoh had accompanied the President of the Assembly and General Chan, Head of the Budget Bureau, to Washington, D.C. in October to discuss the possibilities of a Thai ERTS receiving station.

Dr. Snoh indicated that there was a critical need for better crop statistics, particularly for rice and corn. Acreage information as well as conditions of crops and possible damage are needed in order to predict yields. It was suggested that the rice prediction was at least 16 percent low the previous year. The National Statistical Office provides bench mark data. ABout 5,000 village samples are taken and a yield estimate made on a statistical basis. Dr. Snoh stated that "estimates are now becoming pretty good but are too late". He noted that the National Statistical Office will be presenting its methodology the next day to the Trades and Farmers Associations for critique.

Field surveys this year for maize had a variation within two months from 2.5 million rai to 2.2 million to 1.9 million. These were field surveys plus very limited aircraft photography. Yield estimates are needed for cotton and tapioca as well. It was suggested that we see the Land Development Department for pertinent documentation. It was noted that the Traders Association for rice has about two dozen large members with hundreds of smaller members.

It was suggested that we obtain the "rice balance sheet" from Forrest Cookson. Cookson should also have information on price fluctuations.

Grazing and land management is not commercial yet although there are promising possibilities. There are technique and disease problems. This area is the management responsibility of the Department of Agriculture.

Mineral exports now include tin, tungsten, flourite and barrite. The German government is conducting some geological mapping in Thailand.

Dr. Snoh would like to have ERTS data incorporated into the National Development Plan and carried as a budget line item. General Chan has major responsibility for the five year plan.

It was noted that mixed planting practices make agricultural land use interpretation more difficult in Thailand.

2:00 P.M.: Mr. Apilas Osatananda, Deputy Director General, Department of Technical and Economic Cooperation (DTEC), Office of the Prime Minister and Mr. Niyom Pagamas, AID Division. Mr. Apilas noted that the former Director General of DTEC was General Chan who is now the Budget Bureau Director. The principal function of DTEC is to evaluate all foreign assistance projects transmitted to it by NESDB and to make recommendations on them to the Bureau of the Budget. Mr. Apilas indicated he is one of two deputies at DTEC.

Mr. Apilas indicated that 2,000,000 bahts were required for ERTS. He suggested that there were both salary and bureaucratic type constraints. He described his organization as being an "internal AID" which passed upon all foreign dollars as well as baht counterpart funds. He indicated that about 200 million bahts total were handled annually in foreign assistance (about $10 million). As mentioned above, NESDB must approve first and then submit the budget to DTEC. DTEC then submits the proposal to the Budget Bureau. They require

only qualitative statements of benefits. Mention was made of the Kra Canal conference and Dr. Boon.

Mr. Apilas raised the question to whether the use of outside dollars would be actually beneficial to Thailand?

The total staff at DTEC is about 200, in the following divisions: Technical Service, USAID, International Volunteer, UN Columbo Plan and Third Country. Mention was also made of a research team from the University of Kentucky (they had preferred Cornell but AID said that Cornell was too expensive).

3:30 P.M.: Mr. Edgar C. Harrell, Chief, Economic Analysis Division, USOMT. Harrell indicated that for maize there were bilateral agreements with Taiwan, Japan, and Korea and that these were based on Chicago commodity market prices. The goal was to avoid a short term over commitment. The strategy for rice is to estimate the supply and demand on a worldwide basis and then manipulate the export price by means of a tax. Other areas of interest are watershed development, erosion, irrigation, forests, reforestation; control and enforcement of reforestation is of considerable interest. Strip mining effects are widespread in the country but reconditioning has a low priority.

He noted that the U.S. Embassy issues an annual statistical abstract covering balance of payments, national accounts, rural activity, as well as a monthly economic report. He noted that the Embassy does not collect the data but does analyze the data collected by others. There is a research grant to construct an econometric model. He wondered if ERTS could detect village sizes and numbers? An industrial census is needed. Water management, flood prediction and associated remedial action are also of importance. He indicated that a 6% discount rate was used by the World Bank.

The Bank of Thailand Monthly Bulletin was recommended as the most reliable data source. The basic issues in data collection were noted as:

1. What will it tell you that you didn't know before?
2. Is it timely?
3. How can it be used to generate policies and actions?

Mining was noted as a growing economic sector in which the government will need more information for granting concessions. Oil exploration is growing. Land capability mapping is becoming important as is cadastral survey. He noted that only 11% of Thai villages have a safe, reliable source of water; about 85% of the population is in rural areas.

Wednesday, 14 November 1973

08:45 a.m.: Mr. Stanley J. Siegal, Deputy Director, USAID mission, Thailand. Siegal noted that opium poppy surveillance will be needed when the Thais agree to controlling the crops. Generally, diversification of crops is needed in Thailand. He noted that the price of rice controls other prices psychologically.

10:30 a.m.: Mr. W. J. van Liere, Agricultural Planner, Mekong Commission (ECAFE-UN). The Mekong Commission includes Cambodia, Thailand, Vietnam and Laos, all of which share the Mekong basin. Mr. van Liere indicated he had one man full time on vegetation mapping. He noted that forest usage was very clear on the ERTS frames. He also noted three important uses for ERTS imagery in the Mekong Basin, namely: (1) flood and drought management, (2) watershed management, and (3) soil mapping.

The watershed management program for the Mekong Basin includes forest reserves, replantation and regulated shifting of cultivation. The charter of the Mekong commission is "water resources of the Mekong Basin". It is important to see the basin in both the wet and dry seasons in order to assess deterioration. Van Liere's view was that

"the planning of specific projects must be done by traditional methods". He did feel that ERTS could provide substantial improvement to the broader problem of establishing projects and their objectives.

"Tank" is a Thai word for a small dam. There are many of these in existence in the watershed area and they cost about 500,000 bahts per tank. These tanks are an important part of the water resource management picture in the Mekong basin and the planning for these tanks can be improved with the use of ERTS data; of course, the detail tank design would not be affected by the ERTS data directly. Van Liere was generally very pleased with the ERTS data and felt that "the images have changed and sharpened the whole concept of the basin and the emphasis of the program."

In the area of soil mapping, they are using diazochrome color composites at 1:250,000. The limits of dry season cropping are clearly seen. He has some doubts about the computer process. Although any construction would be done by the individual countries (not the Mekong Commission), the Mekong Commission provides an overall planning umbrella for these activities. He felt that the entire program has been reshaped by the ERTS imagery. In particular, the Pa Mong Dam near Vientiane, is expected to cost about $1 billion to build and will have a great influence on the downstream dry season droughts in the area. It is for use in this overall planning that ERTS may have significant impact.

Van Liere introduced Mr. Nguyen Van Hung who is now with him full time on ERTS data interpretation.

It was noted that dry spells during the nominal wet season are the greatest cause of variation in the rice crop. Rubber statistics are considered to be the only reliable ones. Van Liere feels that its a longer road to obtain reliable statistics for rice. The desired prediction lead time is four months. Dry season cropping is easy to detect while wet season cropping is quite difficult.

2:00 p.m.: Mr. Pongpit Piyapongse, Technical Division, Department of Agriculture, and Mr. Amnard Tirarat, Agricultural Economics Division, (at Kasatsart University). Presentations were made on the rice models being developed for use with and without ERTS data.

Rice model without ERTS data: This model is intended to be used in about 5 years; there is no rational prediction now. Stratification for the sampling includes the province (Chang Wat) level and the county (Ampur) level. If less than 1,000 rai is considered it is grouped into a single county. Random selections amounting to about 5.5% are made from each county. At the village level, 5% of the villages are sampled. Simple random selection is used. A random selection is made of 8 plots from each village. Non-agricultural use, e.g., dikes, termite mounds, etc., are removed. Two 1 m^2 areas are randomly selected from each plot. Each plant is counted from each of the 1 m^2 plots; it is counted again before flowering. One month before harvest, the flag leaves are counted, anticipating about one rice cluster per flag leaf. Then the clusters are counted when they appear. The clusters are counted again when they have actually ripened. Then each of the 1 m^2 plots is harvested and the rice yield determined. Lastly, two of the larger plots harvested by the farmer are selected and used to measure the losses, e.g., due to mice and grain drops. A total of 3,296 samples are taken for the whole country. It is estimated that the cost exceeds 1,000 bahts per village, assuming one laborer per plot. Thus the total labor cost exceeds 3.3 million bahts. It is felt that the rice estimates from this process would be about 85% accurate. Total area under cultivation is based on an older census of about 10 years ago.

Rice forecasting model with ERTS data: This intended for initial use in test regions only. The rice growing region is divided into 10 x 10 km cells. Consideration is given to the three types of rice: (1) transplant, (2) broadcast and, (3) floating. These have been found differentiable by eyeball based on tonal differences in the black

and white imagery. It is noted that the transplanted rice has the highest unit of yield, 0.6 tons per rai, the broadcast rice yield is 0.4 tons per rai, and the floating rice 0.3 tons per rai. These are average numbers based on historical data.* There are a total of twelve 10 x 10 km test sites. In each 10 x 10 km test site, they select four areas of floating, four areas of transplanted, and four areas of broadcast rice. The selection is determined by manpower limitations and is for use in this limited experiment only. A sample harvest is then conducted in four 2 x 2 meter plots in each of the 10 x 10 km regions in order to get "actual" harvested unit yields. Flag leaves are counted one month before harvest. Precipitation effects could be included. The current ERTS budget includes funds for per diem, gasoline, and field checking for this experiment.

Thursday, 15 November 1973

10:30 a.m.: Dr. Sanga Sabhasri, Secretary-General, National Research Council of Thailand; Mrs. Boonthom Dhamcharee, Deputy Secretary General for Natural Science; and Dr. Boon Indrambarya, Director, Environmental and Ecological Research Institute, ASRCT, (retired). Dr. Sanga is the new official Principal Investigator for Thailand, succeeding Dr.Pradisth who has retired. Dr. Sanga is trained as a forester and previous to his present job (which he had been in one month when we saw him) he was Vice President of one of the local universities.

Dr. Sanga expressed interest in the whole spectrum of the development plan including land use and necessary infrastructure such as highways. He indicated that destructive use of resources was prevalent in each of the provinces. There is interest in a resettlement program, in

*Joe Morgan later commented that all of these figures seem high since the overall production is 0.3 tons/rai.

irrigation problems and some possibly emerging interest in pollution control. Dr. Sanga expressed doubt about the use of ERTS for "forecasting"; however, it should be noted that what he really meant was forecasting from one year to the next, not forecasting within one single growing season. He felt that existing estimates (from year to year) were probably satisfactory. It was noted that quantitative data is not a major input to high level decisions in Thailand. He emphasized the general social and human behavioral problems. A particular example are the hill tribes in the northeast which number about 500,000 people. Their practice is to cut, clear, farm and then move on.

Dr. Sanga indicated that six outside agencies had been involved with population control and they produced six different answers. He felt that probably there were too many foreign teams visiting Thailand.

We inquired as to the potential of new technology as a catalyst in the country. His answer was that what his country needed most were good leaders. An example of a promising individual was given as Dr. Boon's right hand man, Mr. Suvit, now a Ph.D. candidate at Colorado State University.

Sanga noted that a letter had just been signed for appropriating $2 million towards an ERTS station in Thailand. This has been forwarded to the Budget Bureau. He noted that the Head of the Budget Bureau, General Chan, had visited the U.S. very recently was quite enthusiastic about the ERTS program as well as the proposed station in Thailand.

Dr. Sanga noted the special social and philosophical context of Thailand which made it imperative that one avoid any indication of boasting; in other words you cannot "sell hard" in Thailand. This will only impede the whole information flow process.

Dr. Sanga indicated that there were about 28 million rai of rice total.* He noted that rice identification was considerably easier in

*Joe Morgan subsequently has informed us that the correct number is nearer 46 million rai this year. Dr. Sanga must have been referring only to the central plain.

the irrigated area, which is about 50% of the rice, and much harder in the treed area which is the remaining 50%. He felt that there was quite a good communications network in the irrigated areas.

He noted an example of the semi-governmental Chambers of Commerce, which had previously not known of ERTS based maps, who are now quite interested in using them.

Dr. Sanga indicated that computer-assisted interpretation examples would be very convincing for the next step in the investment decision process. He felt that of special importance would be a crop acreage printout. He wants to have a session with the Cabinet on these questions.

It was noted that Dr. Boon has recently given lectures on ERTS data to 20 secondary schools. About 40 percent of the secondary school graduates go on to university.

Dr. Boon then took the AID/ERTS group on a tour of the ERTS data handling facilities at ASRCT. We were shown, amongst other things, a partial-frame computer printout made by LARS/Purdue.

It was noted that there is an IBM 360-40 available in Thailand. They will be getting the LARS software and intend to utilize it. It is estimated that about 2 hours will be required to computer process each ERTS frame. At an approximate cost of $200 an hour this comes to about $400 to $500 per frame for computer processing with the LARS system on the IBM computer.

2:00 p.m.: Mr. Prayong Angsuwatana, Survey Division, Mr. Din Bunnag, Chief, Survey Division, and Mr. Suchit Puwakool, Economic Geology Division, Department of Mineral Resources. (Mr. Din left after a few minutes.) The Department of Mineral Resources is a part of the Ministry of Industry. Mr. Suchit has a masters degree from the University of Wyoming in 1969 and has conducted some geological exploration activities in Austria.

It was noted that 95% of the known mineralization in Thailand is along lineaments except for tin which is found in granite. They are now making a geological map of Thailand incorporating many new features and details. The present map effort combines the work of a German team in the north, the Thai Geological Survey in the northeast and other efforts. Desire is for a 1:250,000 base map. In about three months, they hope to have a new geological map of Thailand using ERTS imagery. They noted that, while it takes 11 years to produce a new map by conventional techniques, a map can be made in about 3 months using ERTS data. The ERTS based map would be less detailed but would show more lineaments.

Friday, 16 November 1973

09:00 a.m.: Mr. Niyom Purakam, Chief, Statistical Techniques Division National Statistical Office, Mr. Nantit Supamongkol Statistician. Mr. Niyom has a Ph.D. in Statistics from North Carolina State University. About $0.5 million a year is spent on rice statistics by all agencies including NSO and agriculture. Mr. Niyom emphasized the need for timely data. How many months before harvest this meant was not clear. He would prefer a numerical format with interpreted results. There are four major regions: the north, the northeast, central plain and the south. He is now preparing a paper on rice production methodology on a statistical basis and this will include area, yield and number of frames actually shown growing rice. He suggested that the irrigated/nonirrigated division is not as useful a concept as Cookson had suggested. NSO employs about 500 people each year as field enumerators and field supervisors for their rice survey. Aircraft use is considered too expensive except in urban areas. He indicated that the Ministry of Agriculture is the best statistical data source.

Rice, corn and kanaf are the three largest export crop commodities. A fourth rank one is second grade jute. He noted that the cost of

investment in second cropping program in a given year is double the cost of the first cropping. Therefore there is a need to forecast a relatively high price in order to encourage the farmers to invest in this second cropping. He also noted that there is considerable movement of people from year to year. Rain is a key input to the model and is not now used. Both the amount and temporal distribution of the precipitation is important. He feels that this could be obtained from the Thai Meteorological Service. He indicated that he would provide copies of maps of rice growing areas to Joe Morgan for transmission to the AID/ERTS team in Washington.

A courtesy call was made on Miss Annie Skunasingha, Chief, Mapping Division. She is a former student of Dr. Irma Adelman.

2:00 p.m. Royal Forestry Department: Dr. Chumi Boonyobbhas, Chief Forest Management Division. Dr. Chumi indicated that an ERTS-1 based forestry map had been made. About 12 people worked for about 1 year to complete the country-wide map. Ten of these people also do field work. The data was derived from ground checking, from 1:50,000 aircraft photos, and from ERTS. Eight (8) generic classes were utilized. It took about 10 years to do 25% of the country before the ERTS data was available (and no funds were available for printing these maps). The expenditure rate is about 50,000 to 100,000 bahts per year. Dr. Chumi also noted that the export of logs has been banned, but there may be a relief next month.

Saturday and Sunday, 17 and 18 November 1973. The ERTS/AID team made field trips in the vicinity of Bangkok, to the north (up by land and down by river), and along the coast to the southeast of Bangkok.

G.3 MEMORANDUM FOR THE RECORD

SUBJECT: Trip Report on Visit to Kenya in December 1973

Present on the trip were: D. S. Lowe, E. J. Greenblat, R. A. Summers

Monday, 3 December 1973

Our first visit was at 10:15 a.m. with Mr. John Gunning, AID Program Officer. Mr. Gunning mentioned the U. S. census project including its activities in Afghanistan and Thailand. He also mentioned the remote sensing regional seminar in March (April). Apparently they are trying to interest the Africa Bureau of AID in the use of ERTS data. Gunning feels the Kenyans are now becoming interested in the ERTS data. He noted that about 17 percent of Kenyan area was arable land. The principal focus of interest is wildlife and minerals. Coffee is the number one foreign exchange earner with tourism a close second. They are in need of both capital and technical assistance. The minerals activity includes oil exploration and natural gas exploration in the north near the Ethiopia/Somali border. Gulf is active in Kenya.

10:30 a.m.: A. B. Cahusac. Mr. Cahusac arranged a kick off meeting with Dr. J. Walsh, Chief Geologist, Mines and Geology Department; Mr. R. B. Contant, Faculty of Agriculture, University of Nairobi; Dr. Harvey Croze, Zoology Department, University of Nairobi; and Dr. T. M. Wormer, Ministry of Agriculture. It was noted that Dr. Omino, the P.I., was ill and could not attend. Dr. Wormer indicated his interest in grazing land, water management, and Game Department activities. He suggested that we visit Dr. Martin (UNESCO-sponsored) to inquire about the development plans of Kenya 1970-1974. He also mentioned Dr. H. Brian Ambrose of the Tana River Development Project. Wormer indicated that Canadian Technical Aid has been assisting in developing 1:50,000 maps from air photos over populated areas and 1:100,000 photo-based maps over desert areas. These maps are almost 100 percent contoured. He

also mentioned the UNDP Geo-Thermal Project and suggested that we might also see Dr. Mule of the Ministry of Finance and Planning, who is essentially the "head planner" for Kenya. Several future appointments were made as follows.

Cahusac indicated his environmental interest; he is preparing an environmental paper for Stockholm. His original area was forestry. He noted that the 1974-1978 National Plan will include an environmental chapter written by the Ministry of Finance and Planning. Cahusac indicated that he was not entirely pleased with the material. Cahusac indicated he would try to get us into to see Mr. Omino, the Principal Investigator. Cahusac indicated that the following ministries were the principal potential users of ERTS in Kenya: Natural Resources, which includes Forestry as well as Mines and Geology; Finance and Planning; Lands and Settlement which includes Survey of Kenya; and Agriculture which includes the Soil Survey. He also suggested that we make contact with the Institute for Development Studies, associated with the University of Nairobi. The head of that institute is Dr. Gachuhi. He indicated that Finance and Planning would play a key role and that we should be sure to see Mule, Martin and Heyer. He also mentioned that a cabinet paper was now being prepared by Omino and Cahusac. As for the private sector, he suggested that we contact Chevron Overseas, possibly asking Dr. Walsh for a specific name. We inquired as to what money had been spent so far in the ERTS area by the Government of Kenya. He indicated that none had been spent yet but that £ 2,500 sterling was in the next budget for a color additive viewer. He noted that the Vice President of Kenya knew of ERTS through the Canadian visit which then led to the cabinet paper.

Tuesday, 4 December 1973

In telephone conversation, Dr. Walsh recommended that we see James McNitt concerning the UNDP geothermal work. For the private sector, he

suggested we contact Bill Chapman, Chevron Overseas and someone at Whitestone International. Walsh indicated that BP, Shell, Caltex and Mobil were all involved in a refinery at Mombasa which is owned 50 percent by the Government of Kenya.

In a telephone conversation, John Gunning recommended that we talk with Dr. Mule who is the Chief Planner and, also, if we have time, to Dr. Jack Powelson, a macro-economist for the Planning Department on loan from the University of Colorado courtesy of the Ford Foundation. Gunning indicated that the new five year plan would be announced next week, although probably not distributed.

10:30 a.m.: Dr. Heyer, Chief Statistician, Ministry of Finance and Planning. Mr. Cahusac indicated that the Dutch sponsored soil survey was mainly using ERTS data. Heyer mentioned that they were currently attempting measurements of livestock distribution and wildlife using low-altitude data gathering from a Cessna aircraft. He felt that satellites would improve the sampling and he is quite interested in this for general applications other than livestock. He indicated that project evaluation was done by the Economic Planning Unit of the Ministry of Finance and Planning which is under Mule's supervision. Each Ministry has such an economic planning unit. There is a coffee disease problem in Kenya but it was quite different from the Brazil situation, namely it is not frost but a water stress situation. He indicated that next year they would be attempting a national labor force survey; a population census is scheduled for 1976-1977 and cartographic work would be needed beforehand. Heyer agreed to provide us with any documentation we required, particularly certain specific requests. It was arranged to ship a box of economic reports to us via the AID office, Washington.

3:00 p.m.: Dr. Robert Frosch, Deputy Executive Director, UN Environmental Program, and Peter Thatcher, UN, Geneva. Frosch mentioned that some 15 to 20 percent of the unskilled were unemployed in Kenya.

For the purpose of range management about 4 to 5 observations per year are required. Mention was made of the COSPAR Workshop, 2 - 16 June, and the COSPAR assembly after 17 June, which will include a seminar on the application of remote sensing for developing countries. This will be held in Brazil and Frosch suggested that we get in touch with Morris Temper or Len Jaffe concerning a contribution from our study to this meeting. Possible application to real time catastrophe management, such as by the UN Disaster Relief Organization in Geneva, was mentioned. The number one man there is Byokol; number two man is Rosborough. Jean Pierre Levy was also mentioned. There is considerable UN interest in global monitoring of pollutants in suburban and rural areas, land management, disasters, etc. The FAO's interest in a world soil map was mentioned.

A pressing question which Frosch and Thatcher were very much concerned is: "Is the ERTS capability to continue?" If a continuing capability is assumed, they strongly recommended that the applications to non-renewable resources be de-emphasized, particularly since they are the most sensitive, and that more emphasis be placed on renewable resource management (requiring repetitive coverage). Urban and rural planning was an important area they felt should be attended to. Recent interest of Chris Herter and Don King in the State Department was mentioned; they may have some useful documents. One particular document mentioned was "Plan for Earth Watch and Implementation of Monitoring."

5:00 p.m.: Geological Club of Kenya. On request, Low, Summers and Greenblat provided a brief review of the AID study and the ERTS status for the Geological Club of Kenya. After the meeting the club hosted a dinner at a local Chinese restaurant.

Wednesday, 5 December 1973

9:30 a.m.: Dr. Edward Zamierowski, Department of Botany, and Dr. Ross Robbins, Range Management/Ecology, University of Nairobi. We

met out at the University of Nairobi with Zamierowski and Robbins. Robbins has been posted to Kenya by the Australian government under a two year contract via their educational exchange program. He is to develop a range management/ecology course in the Faculty of Agriculture.

Zamierowski mentioned that he has ERTS imagery and has done some analysis with it. It appears that others have done less than he has. It was noted that there was a lack of effective communication between the university and the government, even though the Dean and Department Head in the University of Nairobi are Kenyans.

Mention was made of the range management/grazing/wildlife interaction, and a USAID beef production project. A 1968 committee was to classify the environmental and monetary value of range land. Two references were given:

1. "Classification of Rangeland in East Africa," by Pratt, Greenway and Gwynne. This defined ecological zones which have now been accepted by the Ministry of Agriculture.

2. Journal of Applied Ecology, III, 1968 (England). There is a need for updating and reassessment of the 1968 paper. It was noted that observations four times a year would be adequate for range management and, in fact, twice a year might even be sufficient, one during the wet season and one during the dry season.

The cattle and grazing activity takes place in two quite different modes:

1. Ranching in which the ranchers, mostly Europeans, operate on open land; there is some African ranching; however, company ranching predominates.
2. Massai operations which are either purely nomadic or in some cases, in a more pastoral, settled mode. The Massai own and manage the entire Ambaseli Reserve. The government is now negotiating to make a portion of it into a national park. Robbins offered to send us a bibliography

and assessment thereof on about the 15th of January via the USAID pouch.

It was noted that the FAO Range Land Management Project is phasing out and its documents are being transferred to the Ministry of Agriculture. Attention was called to the document: "East Africa -- Its Peoples and Resources," by W. T. W. Morgan, Oxford, 1972.

Dr. Zamierowski has done some preliminary vegetation and land classification interpretations of limited parts of Kenya from ERTS imagery.

11:20 a.m.: Dr. R. S. Odingo, University of Nairobi, Department of Geography. Dr. Odingo indicates that he has no capability for analyzing ERTS data and is in need of help in order to do this. He is interested in land use patterns for which he now uses aerial photography. He feels that, utilizing conventional techniques, he cannot afford to make a complete land use map for the country. Dr. Odingo feels that "the technology for the use of ERTS imagery is beyond our resources." He would like to receive some kind of remote sensing "guide" for land use. We agreed to send a document which would emphasize hand analysis for land use mapping of R/S data. Odingo emphasized that he wanted a large enough scale to carry him down to the district level.

Professor Ominde, Department Head, has mapped significant areas near Lake Victoria. A 1:50,000 soil map has been made near Lake Victoria.

It appears that Odingo is unfamilar with ERTS data and does not fully understand what can be done with just a light table, pencil and tracing paper. The forthcoming AID workshop would be beneficial for him.

2:30 p.m.: Mr. P. P. Anyumba, Director, Survey of Kenya. Mr. Anyumba indicated that 2/3 of the country was mapped at 1:50,000 and the remaining 1/3 at 1:100,000, mainly arid areas. The entire country has been mapped at 1:250,000. In addition, in the so-called highlands, which are intensively cultivated, there is additional mapping at

1:2,500, 1:5,000 and 1:10,000. Mr. Anyumba indicated that some of his maps are 10 years old. He indicated that he had not yet seen any ERTS imagery and expressed some doubt as to its utility since his customers are mostly interested in large scale maps between 1:50,000 and 1:2,500 scale.

3:30 p.m.: Mr. John Gunning, USAID. (second meeting) Gunning indicated that foreign investment is encouraged in Kenya and noted the existence of an Industrial and Commercial Development Corporation. Gunning expressed the view that, for Kenya, "the technology is still the property of expatriates at the present time." He noted that in the Ministry of Public Works, which has 100 engineers, only 5 are indigenous Kenyans. He indicated that the Medical School graduated first class this year. The School of Agriculture graduated its first class three years ago. He suggested another contact, Dr. Theodore R. Freeman Jr., Agricultural Attache at the U.S. Embassy, who is interested in regional agriculture problems.

Thursday, 6 December 1973

9:00 a.m.: Dr. Martin, Science Policy Advisor, Ministry of Finance and Planning (UNESCO). Dr. Martin, is advising the Ministry of Finance and Planning on how to develop a national science policy. Dr. Martin is by training a geologist. He states that his principal role is to advise on how to get science policy advice; he does not actually directly give science policy advice. He called our attention to the Science and Technology Act of 1973, the text of which is not yet available. He suggested that we obtain a copy of the Kenya Development Plan 1970-1974 and provided us with copies of "Kenya's National Report to the U.N. on the Human Environment," 1972.

Martin mentioned that Marv Citron (Forecasting International, Arlington, Virginia) was in Kenya recently on a UNESCO-approved trip to present a methodology for national planning. Although he had apparently

done well in Indonesia and possibly other places, his approach was not well received in Kenya. Apparently his technique depends upon assigning priorities to national objectives and this is politically unacceptable in Kenya. In fact, Martin quoted the Deputy Permanent Secretary for Planning in the following statement to Citron: "We have no priorities; we must move along in all sectors." Martin feels that, regarding ERTS, the principal issue in Kenya is: should it be an in-country effort or should they hire an outside group to assist them? Martin prefers to give the central operation to the Survey of Kenya with an advisory committee of users. Martin emphasized the general shortage of trained people citing as an example that there are only 4 to 5 senior African officers (total) in the Ministry of Planning.

10:30 a.m.: Mr. Omino, Permanent Secretary, Minister of Natural Resources. Mr. Cahusac took us in to see his boss and P.I., Mr. Omino. Omino confirmed the interest of Geological Survey and their observations of new faulting structures. He indicated an interest in forest boundaries and changes as well as range management and water resources.

12:45 p.m.: Lunch meeting with Mr. Cahusac.

2:30 p.m.: Dr. John Walsh, Chief Geologist. Walsh indicated that nine companies have exploration concessions: Cities Service, Chevron, Canadian Superior, Wainco (U.S.), BP/Shell, TOTAL (off-shore), and LL&E/Whitestone. These exploration concessions do not involve digging any holes. The activities are generally divided into three levels: (1) exploration, without any holes, (2) prospecting, and (3) actual mining operations. Walsh feels that all the likely oil areas are already taken by these exploration concessions. The arrangements are that a concessionaire has four years in a 20,000 sq. mile area to start. Each year his area is reduced. After the first year, his exploration area is reduced 20 percent, then 50 percent and so forth. Walsh feels the use of ERTS data is not very likely in these areas because of the lack of significant outcroppings.

Walsh indicated the present difficulty of attracting good personnel to senior technical positions in Kenya because of low salaries involved. For example, the position of Chief Geologist, without any "topping off" from London, would pay somewhat less than $7,000 a year.

3:30 p.m.: Mr. Abrams, Assistant Director for Settlement, and Mr. Saine, Assistant Director for Settlement (Technical) of the Ministry of Lands and Settlement. These people were unfamilar with ERTS data and had not had the opportunity to examine any. Our discussions with them, I believe, created considerable interest and were informative for them. Abrams indicated a need for data on soil moisture, water availability, weather prediction, dam locations, and ground water. Crop forecasting is also of interest.

4:30 p.m.: William Chapman, Manager Chevron, Overseas. Chapman noted that considerable ERTS analysis was being done by John B. Miller of their California office. ERTS is a great help to them in making regional geological maps. It is particularly useful in facilitating the extension of interpretations based on more local observations by ground or aircraft into unknown areas. He showed us a Chevron proprietary report entitled "An Application of Space Photography to a Geological Study in Kenya, Ethiopia, Somalia," dated August 1973 by John B. Miller. This report, which we browsed through briefly, makes some very positive statements about the direct utility of ERTS in the exploration activities of a profit-making organization. Chapman mentioned that a Canadian development group was flying over Western Kenya. He also suggested a visit to the UNDP Geothermal Project. It should be noted that Chapman had a great deal of ERTS data and was pleased to describe how the ERTS data had been used in improving the Chevron proprietary geological map for the East African area.

Friday, 7 December 1973

8:30 a.m.: Agriculture/Water Affairs Meeting arranged by Dr. T. M. Wormer. Present, in addition to the AID team, were Dr. Wormer, Ministry of Agriculture; Dr. H. B. Ambrose, Tana River Development Authority; Dr. M. D. Gwynne, UNDP/FAO Range Management Project with the termination of the FAO project, (he is transferring to the Ministry of Wildlife and Tourism); Mr. S. J. Meadows, Manager, Range Management Project, Ministry of Agriculture; and Dr. W. G. Sombroek, of the Soil Survey, National Agricultural Laboratory. No representative of the Water Department was present.

Dr. Gwynne indicated that the ERTS imagery was taken "three months too late for range use." He has been able to detect changes but he feels that the ground truth is unknown. Vegetation changes are important, particularly grass growth/precipitation effects. Vegetative changes show up well in color composites, i.e., false color IR. He is interested in habitat monitoring nationwide on a regular basis, and in knowing the stock population and distribution. He noted that Cahusac "keeps all the ERTS data." ERTS coverage has been provided from September 1972 through February 1973 but is "irregular and of poor quality." He is never sure which frames will be supplied. Gwynne is enthusiastic regarding the potential of ERTS data for habitat monitoring, but he needs assurance of continuing data and foreknowledge of where the coverage will be. He is satisfied with the ERTS spatial resolution as it is for his purposes.

Dr. Meadows feels that ERTS is useful at the "overall level" and is particularly anxious to see range conditions on the order of, say, 70 miles away from roads (from which much of the data gathering is done on the ground). Critical factor in the stock industry is market rate of cattle. He indicated that water was limited and that no additional feeding is done in Kenya beyond the range feeding. They are just initiating feed lots and about 30,000 head will be going through in 1974. He estimates that the cost of range management, including water

development and the government input, is about $1 per head per month. Of the water used, 60 to 70 percent is surface and the balance is ground water.

Dr. Ambrose indicated that only 12 percent of the country gets adequate rainfall for cropping.

Dr. Gwynne indicated that camels were still very important in many parts of Kenya, particularly those still in a tribal existence. He indicated that camels can be supported almost all over the country. If water were made more freely available, the camel might disappear and be replaced by cattle. He equated the presence of the camels to a subsistence economy. Dr. Gwynne indicated that the vegetation was in several categories: some was bush; some was grass; and much of it had a woody canopy. He was particularly interested in grass growth/soil moisture relationships. Also of interest is the surface water fill-up cycle and the water content of sand rivers.

It should be noted that Dr. Ambrose and Dr. Meadows had not seen any ERTS imagery before this day of our meeting.

Mr. Sombroek, soil scientist from Holland, indicated that he was also interested in the mapping of permanent features of the country. He felt that the state geological and topographical mapping was generally satisfactory for the entire country. However, soil resources mapping were very poor and hardly existed at all. Mapping at 1:1,000,000, 1:500,000 and 1:250,000 are especially important for him and he felt that ERTS was very good for these purposes.

Dr. Ambrose, Tana River Development Authority (part of the Ministry of Finance and Planning), just arrived from England to manage the program which is only a few months old and is entirely run by the Kenyan Government. Ambrose noted that one-fifth of the population of the country is in the Tana Drainage Basin. One of the goals is to coordinate the total land use development of this basin. There is a large-scale irrigation development potential. Areas of interest include range land, wildlife

and the tourist industry. He feels that they could double the tourist potential of the country through more effective management of this basin. He is also interested in habitat monitoring. Cultivation is spreading to marginal areas, and he would be interested in identifying the expansion of small-scale cultivation. Hydrological aspects are considered very important and he regretted the absence of a representative from the Water Department.

Dr. ormer interjected that a Dr. Dunn of Canada is launching a project in silting; Cahusac is aware of this project.

Dr. Ambrose continued stating that the Tana River Authority had no independent budget now and is awaiting on an act of Parliament for official statutory standing and a budget. An ecologist will be included in the group. He also indicated an interest in geothermal sources.

Dr. Wormer stated that, for crop forecasting, the prediction of unit yield was more important than acreage. He felt that acreage is "well known" for the commercial farms. Perhaps it is less certain for the other cropping, such as the small quarter-acre plots which are usually beans and maize.

11:00 a.m.: Professor Croze, University of Nairobi. Included in this meeting was David Mbuvi (M.S., University of Arizona), formerly the Educational Officer and now Research Scientist with the National Parks (Address: Box 4276, Nairobi). Mr. Mbuvi was sent by his boss, the Director of National Parks, who could not make the meeting. (We had dinner with Mr. Mbuvi who provided us informally with considerable insight into cultural and organizational aspects. He is very dedicated to the development of Kenya and willing to devote any required time to this end).

Simon Taiti, Game Dept. (Box 4021, Nairobi) is interested in census monitoring and has looked at ERTS prints. He is interested in village surveys which require imagery or maps in the scale range 1:50,000 to 1:250,000.

Professor Croze (Box 30917, University of Nairobi) indicated that he and Dr. David Weston (a British ecologist) are particularly interested in the Southern Amboseli and wish to tie in the ERTS data to aircraft underflights. Croze is a licensed pilot and has his own aircraft. Conitz (AID) and Deutsch (USGS), during their recent visit, indicated that this was possible. Right now, they are using eyeball data gathering, panchromatic photography from aircraft at 300 ft. altitudes, plus some higher altitude IR photographs. Weston, who is essentially resident at Amboseli, is doing a wildlife/ecological study of Southern Amboseli. Croze himself is going the elephant component thereof. Croze emphasized that Dr. Weston is in Amboseli now and it would be to our advantage to talk with him directly. The only way to do that would be to visit him on-site in Amboseli. Croze indicated that the key issue was the competition between cattle and wildlife. The tourist sector produces much hard currency. Masai cattle grazing is strong competition with the National Park. There is a need for alternative water and grazing possibilities outside the park. Dr. Weston has worked on this problem for about four years. His house is very near the Oldtuki Lodge, "about a two hour drive" from Nairobi.

Mention was made of the Canadian Aid Project (CIDA) in this effort. Parameters of importance include soil type, soil moisture, and the density and distribution of animals, the latter now being obtained through low altitude aircraft observations. Mention was made of a model description which would be delivered to our hotel. Croze expressed an interest in receiving a copy of the Mathematica grazing land study. It was noted that the Canadian GOK Agreement is not yet signed but is considered 95 percent sure.

We were referred to Mr. Frank Mitchell, formerly of the Treasury Department and now of the Institute of Development Studies of the University of Nairobi, as one who has been involved in tourism studies. It was also suggested that we discuss this with Mr. Mule, Ministry of

Planning, and Mr. Gitau, Tourism and Wildlife, Joogo Bldg. B. Mention was made of a Parks and Tourism project under the Permanent Secretary, Tourism and Wildlife Ministry. It was noted that Mr. Philip Ndibo would be a useful contact in the Ministry of Finance and Planning. We were referred to the "National Atlas of Kenya" which is available at bookshops or the Government Printer.

(Mr. Jarman was ill and therefore was unable to attend this meeting).

2:30 p.m.: Mr. Mburu, Chief Conservator of Forests, Ministry of Natural Resources. Mr. Mburu noted that we should be sure to see the people at the Karura Forest Station after talking with him. Mr. Mburu indicated that he had heard of ERTS iamgery and that it seems to be a useful tool, but he has no personal familiarity with it. Mr. Mburu seemed very knowledgeable both in general and specifically in the area of Kenya forests. He mentioned the continuing pressures from agriculture and that the Forests Guards, which he had to protect the forests, were not adequate in number. He noted that only 3% of the land is designated as forest by the Government and, therefore, protected. There is probably some additional land that should be so protected even though it is not officially designated a forest. Mr. Mburu can prohibit cutting through the District Commissioners and the Chiefs. According to the Forest Law, licenses must be obtained for cutting and arrests can be made for cutting without a license. Kenya exports conifers but imports hardwood and plywood. He noted that Kenya was now building its first pulp mill. It takes about 30 years to mature a conifer and at least 17-22 years in order for it to become of any commercial value.

3:30 p.m.: Forestry Department, Karura Station, Messrs. Rutherford, Wilson and Wanyama. Mr. Rutherford's primary interest is in mapping while Mr. Wanyama was principally interested in timber inventory. Their present approach to select areas for aircraft coverage and contract out the air services. The cost of these services is about one shilling per hectare with two sets of contact prints provided. We showed them a

9 September 1972 ERTS image of Kenya and it appeared that none of these people had seen one before. There was considerable interest in relating forestry and other information, which these people had in their field, to features which they immediately recognized in the ERTS image.

Wanyama indicated, for his own purposes he prefers 1:25,000 mapping while Rutherford uses 1:10,000. Apparently, the idea of improving the efficiency of their work through the initial use of smaller-scale imagery was novel to them. Rutherford indicated that his entire operation costs about 200,000 shillings per year. Twenty percent of this was data collection, using aircraft and field activities. Mention was made of the National Forestry Advisory Committee.

Saturday, 8 December 1973

8:15 a.m.: Mr. H. M. Mule, Deputy Permanent Secretary, Ministry of Finance and Planning, and Professor T. Davis, Director of Project Planning and Evaluation. Professor Davis' services are provided by the Canadian Government and he has 11 to 12 professionals working with him, mostly economists. Professor Davis is a Geographer by training and had, for a time, been the Head of the Geography Department at George Washington University, Washington, D.C. Erosion and forest plantations were mentioned as areas of interest. Davis' group spends its time mostly on micro-economic project analysis and is also interested in questions of balance-of-payments and GNP.

Mule indicated the following areas of interest and of possible application for ERTS in Kenya:

1. Land Use - the question of appropriate land use over 80 percent of the land surface of Kenya is important. A key issue is livestock versus tourism. Agriculture, forestry and urban development are also considered important. Land use can be categorized as either conflicting, complementary or neutral in nature. A land use committee is being formed to evaluate

situations where conflicts exist.

2. Soil Erosion and Denudation of Land - it would be desirable to estimate the magnitude of soil erosion in different parts of the country for use in implementing conservation measures.
3. Geological Applications - Mineral exploration.
4. Water Use - Water is in short supply in Kenya and a dynamic monitoring of river systems would be desirable, particularly estimating the magnitude of silting. Water conservation measures are needed and the Tana River Authority has recently been established for this purpose. Urban planning is important, since cities are growing at a rate of 7 to 8 percent a year.

An inquiry was made concerning the possible ERTS receiving station on San Marcos Island in conjunction with Italy. No definitive response was forthcoming.

3:00 p.m.: Dr. David Weston, Amboseli Game Preserve. Dr. Weston, an English ecologist, is supported by Rockefeller Foundation money and has been in residence in Amboseli conducting an ecological study. Dr. Weston noted, the great reduction in animal population and the dying-off of trees in the vicinity of his home within the past year or so. Weston referred us to the following document: "Amboseli Development Plan" by Weston and Thersher soon to be published by World Bank. He referred us to Eddie Quick, World Bank Office in Nairobi, for copies of these and other documents.

G.4 MEMORANDUM FOR THE RECORD 12 February 1974

SUBJECT: AID Project: Trip Report on Visit to Botswana, 10 - 15 December 1973

Present on trip were: D. S. Lowe, E. J. Greenblat, R. A. Summers

Monday, 10 December 1973

D. Lowe proceeded by airplane from Johannesberg to Gaborone (capital of Botswana) where he was met by Sam Rea, AID officer; they

then drove from Gaborone to Lobatse. Due to airline reservation difficulties, Greenblat and Summers drove a rental car from Johannesberg to Lobatse directly, arriving at the Geological Survey building in Lobatse about 4:30 p.m., 10 December 1973. They met there with Mrs. S. M. (Akehurst) Hutton, Sam Rea and several other members of the Geological Survey staff.

Mrs. Hutton has, in effect, been the ERTS program manager, although her official title is Technical Records Officer in the Botswana Geological Survey. Mrs. Hutton has a B.S. in geology circa 1970-71 and has had limited field experience. In Botswana I believe this has been limited to Lobatse and Gaborone although she appears to be making the principal geological interpretations of ERTS data in Botswana.

It was pointed out that one of the significant impediments to ERTS data utilization in Botswana is the very poor condition of the Lobatse/Gaborone road; except for the Geological Survey which is in Lobatse and has physical possession of all ERTS data and reports, all other ERTS users are in Gaborone which is a very treacherous one and a half hour drive away. Regrading and paving of this road is now in progress so that this particular problem should be resolved in the next six months.

An informal meeting was held in the evening with Dr. Hepworth, Director of the Botswana Geological Survey Department and the PI for Botswana.

Tuesday, 11 December 1973

The scheduled ERTS Symposium commenced at 8:30 a.m. at the Geological Survey Department Headquarters in Lobatse. The Symposium was chaired by Dr. Hepworth with the assistance of Mrs. Hutton and had as its express purpose to provide an opportunity for all the ERTS investigators in Botswana (most of whom came from Gaborone for the day) to present their results and, thus, enable Mrs. Hutton to assemble the ERTS-1 final report for Botswana. After introductory remarks by

Dr. Hepworth, the AID/ERTS group (Lowe, Summers, and Greenblat) gave a brief synopsis of the Aid project. In addition, some of the ERTS interpretation results obtained within the U.S. The points made were that: (1) the ERTS data was a means to supplement not replace other means, e.g., aircraft, and that (2) many problems would require a multilevel approach, as well as the use of multi-time data.

Mr. Trollope, principal photo-geologist for Anglo-American-DeBiers, (who came out from Johannesberg specifically to attend this symposium) commented that most of the ERTS material available to him, and presumably also to the Botswana/ERTS people, was 8-10th generation and so of poor quality. Mr. Trollope indicated that he could get better quality material from Spectral Africa than from the Sioux Falls EROS Facility Data Center. He indicated that channels 5 and 7 were most useful to him and, by using those two bands at a 1:1,000,000 scale, he was able to get a pseudo-stereo effect which he found useful. He felt that at the 1:250,000 scale there were too many artificial artifacts introduced; this latter scale was therefore not very useful to him. Trollope indicated that he had asked Robinove for negatives rather than positives which might improve the situation; it would be helpful if they had someone at NASA to talk to directly about this matter.

Dr. Hepworth commented that manual methods were of most interest to him but he wondered if this approach could suffice; he wondered how far it was necessary for Botswana to go into automatic data processing. He also felt that the Bolivian experience might be of some relevance to Botswana. Hepworth indicated that they were quite short of personnel so that there were only very low levels of time assignments to the ERTS experiments. For example, he indicated that in geology it was equivalent to between 10 and 20% of a professional, namely Mrs. Hutton. In the Wildlife management area he felt that perhaps only about one percent of a professional was being applied. The lack of regularity in receipt of the data tends to dampen professional interest. An example of such a

slackening of interest is forest fires in national parks where the time lag in data receipt has discouraged investigators. In Water Affairs there was only about 5-10% of a professional and in Survey and Lands approximately 5% as of this date. Surveys and Lands was only using Band 7 for their work. In Agriculture he indicated that they had lost their technical officer and now had a person who could only apply perhaps a few afternoons a week.

Mr. Trollope interjected again that he thought the ERTS data was quite useful for delineating large linear structures; however, he felt that other features are seen better in aircraft mosaics. Hepworth quoted another investigator in South America who indicated that he could find only "15% of the known vegetative banding" on ERTS imagery. However, the Okavango Delta work in Botswana indicated much better record than 15% in vegetation mapping, although they had as yet no access to seasonal coverage.

It was noted that no representative of the Ministry of Finance and Development Planning was present.

Dr. H. J. Cooke, Department of Geography, University of Botswana Lesotho and Swasiland (UBLS), indicated that botanists and geologists had quite an interest but that they had no financial support to pursue it.

Hepworth summed up his immediate problem which was to explore whether an ERTS data center is warranted or feasible for Botswana. He emphasized that the characteristics of quality, availability and regularity in the ERTS data were essential to developing an effective program in Botswana.

Mrs. Hutton reviewed the history of the program. She indicated that Botswana had originally applied for ERTS-A experiment status in December 1971. They heard nothing until May 1972 and so had little time to prepare. They received their first black and white imagery in October 1972 "two days after the first report was due at NASA." They

received their first color imagery in May 1973. It takes 36 frames to cover Botswana and they now have three coverages available. Their principal data analysis equipment are light tables. A "zoom microscope" bought recently was found not very useful due to its limited field of view. Mrs. Hutton felt that a central data center was needed in Botswana. For her immediate purposes, Band 7 in black and white seemed best in terms of resolution. Black and white seemed better in general for geological interpretation work. However, she felt that she did not see any more detail than was currently available on the national map at the same scale. Mrs. Hutton remarked that coordination of the Botswana program has been quite difficult because of the lack of a full time professional attending to the problem. She felt that the program needed more spatial resolution in the data, more personnel and a higher priority in their overall activities.

Mr. Trollope, of Anglo-American/DeBiers, commented that in Southwest Africa ERTS data provided "twenty times" as many outcrops and structural details as were on existing maps. He felt that ERTS was extremely useful here, noting that this was not a well-mapped area; on the other hand, he felt that Botswana is quite well mapped so that this degree of improvement may not be anticipated.

After tea, there was a brief general discussion of resolution requirements. Dr. Hepworth questioned whether spatial resolution was really a problem. Mrs. Hutton again indicated that the stereo microscope was less useful than her own "eyeball and magnifying glass" approach. Hepworth inquired about the utility of large color composites. Mr. Trollope indicated that color composites at 1:500,000 scale did not justify the twenty-five times higher cost. Note was taken of the past training programs run by AID in the Philippines, Thailand, Iran, Mali, and the Brazil/Mexico experience as well as the original work shop for UN country delegates held at Ann Arbor in May 1971. The forthcoming training session in Nairobi was noted and Botswana was urged to be

adequately represented.

11:10 a.m.: Mr. J. A. Raffles, Senior Cartographic Officer, discussed cartographic applications. ERTS-B experiment direction will come from the Surveys and Lands Department under its Director, Dr. Dickson (ERTS-B P.I.). However, it appears that Raffles will play a key role as "executive officer" of the ERTS-B effort. The first step will involve transferring of all the ERTS data and other related information to Gaborone, where all the non-geological investigators reside, and this should facilitate activity considerably. Mr. Raffles felt that ERTS facilitated a good multi-stage view point. He indicated that there had been seventy years between 1:1,000,000 scale maps of Botswana. In 1935 eleven sheets had been prepared at 1:500,000 to UK accuracy standards. There had also been a 1969 update. They had recently estimated a 1.8 million Rand cost to remap Botswana but the Ministry of Finance and Development Planning had rejected the request as excessive. ERTS may enable them to accomplish an equivalent task at a small fraction of that cost. Thirty maps will be needed to cover all of Botswana. ERTS was considered quite valuable for planning the aircraft flight lines at the next lower stage. The grids are OK at 1:1,000,000 but there is some wandering present at 1:500,000. Mention was made of the BOT-2 program, a water resources program sponsored by UNDP, and a follow-on to BOT-1. He mentioned Mr. McErnest who was present and is a water resources expert (a Ceylonese with Nigerian experience). This BOT-2 program focuses on the Okavango Delta.

The problems of communicating with Goddard Space Flight Center were discussed. It was noted that two months often elapsed before even acknowledgment of inquiries were made by NASA Project Officer.

Mr. Collin Reeves, a geophysicist with the Geological Survey of Botswana, discussed practical ERTS data utilization in field geology. Reeves had just completed a geomagnetic survey using a helicopter platform with limited range. Attempt was made to use 1:500,000 positive

enlargements of ERTS imagery for improving positional accuracy determination for gravity ground stations, especially in the so-called "featureless" areas of the central Kalahari desert. Grass burning had been observed in the ERTS data and the Southwest Africa-Botswana fence was noted to be about 3 to 4 kilometers off on conventional maps.

Mr. Trollope indicated that there was very variable quality in the photo work received from NASA.

Intermission for lunch.

The meeting reconvened at 2:40 p.m. Dr. Hepworth announced that the visitors on the AID project would discuss NASA applications programs, including SKYLAB, and a/c programs at 7:45 p.m. this evening at the Geological Survey offices, Labotse. He indicated that this presentation would be repeated in Gaborone later in the week. Some time was then given to scheduling further appointments for the AID project visitors for the rest of the week.

Mr. Brian H. Wilson, Senior Water Engineer, Department of Water Affairs, briefly reviewed his hydrological investigations with the ERTS-1 imagery in the Okavango Delta area. His available time has been limited and he has encountered considerable administrative problems, including staff and transport. The quality of the ERTS prints produced so far by the Department of Surveys and Lands has been very disappointing. The resolution does not permit effective analysis of water boundaries and there is still a need for imagery taken at different times during the season. Until the printed image quality is improved and sequential coverage is available, he feels that ERTS imagery will be largely redundant from a hydrological point of view. He indicated that they were anxious to utilize the ERTS-B data to obtain baseline information on swamp characteristics for application to the BOT-2 Program during the 74 through 76 period. Evapotranspiration data is also needed.

Mr. D. Williamson, a Research Fellow in Wildlife Management, (from Humboldt University, California) reviewed his work preparing a vegetation map of the Okavango Delta from ERTS imagery. This was followed by a travel period of six weeks photographing for ground truth in the Delta on the ground and from aircraft. His provisional vegetation map was at 1:250,000 scale. Seasonal coverage has not been accomplished yet. It was encouraging to find that Mr. Williamson was well aware of the U.S. literature on ERTS data interpretation and this is also quite encouraging. He is perhaps the only one in Botswana who seems to have done that in his field. He is aware that inferential models are required and is working on this approach also. He indicated that the effects of forest fires further confuse the vegetation mapping. He is aware of the Caribou movement experiments going on in Canada and will try to apply some of this knowledge to the Okavango.

3:30 p.m.: Dr. W. Von Richter, Department of Wildlife and National Parks, and a co-PI. He noted that the international boundary between Southwest Africa and Botswana was very clear due to different land use practices and that forest and grass fires show up clearly. Dr. Hepworth indicated that the Kalihari "Desert" is a delicately balanced ecosystem and a degraded habitat. He mentioned the problems of water and bore holes, particularly the use of water holes by cattle who have previously eaten thorn bushes; seeds are then provided via their droppings so that the water holes generally are surrounded by nearly impenetrable thorn bushes. He also mentioned the direct impact of bore holes on the general water table and that too many bore holes will reduce the water table level sufficiently to reduce the vigor of vegetation in the Kalahari. Mrs. Hutton noted that Sam Rea, AID, had requested from NASA repetitive coverage of the Okavango Delta in February 1973. Dr. Hepworth then summarized the session emphasizing that the quality of available data was a critical problem.

7:45 p.m.: Presentation by Lowe, Summers and Greenblat, ERTS AID team.

During an informal discussion Tuesday evening it was revealed that Mrs. Hepworth, a qualified private pilot, actually depends on ERTS imagery (provided by her husband) of the "featureless" Kalahari Desert as an essential navigational tool in that area. This is more than of trivial interest since Mrs. Hepworth, as a private pilot of limited experience, has been able to quickly adjust to the use of this medium for navigational purposes.

Wednesday, 12 December 1973

9:00 a.m.: Meeting with Mr. Raffles, and Mr. S. Hart, Lands and Surveys Department, and other staff members. Raffles indicated that ERTS photographs had been sold to hunters for safaris at 1:250,000 scale and they had been used as self-defining maps (cf, previous comments of Mrs. Hepworth in flying over the Kalahari.) Ground knowledge was considered essential for the effective use of the ERTS imagery. The imagery was considered important for reconnaissance mapping. Raffles mentioned again the Rand 1.8 million proposal for complete topographic mapping of Botswana to South African standards at 1:250,000. The South African standards are considered to be relatively high. The principal commercial and industrial users in Botswana were Anglo-American for diamonds and the Rhodesian Selection Trust for copper and nickel. He also mentioned the possible use of ERTS imagery by the firm building the Nata-Kazangula Road with USAID funds. This contract is held by Tibbets, Abott and McCarthy. At present without this road, it is necessary to go through Rhodesia to make this trip.

The Department of Lands and Surveys has a present internal budget of Rand 140,000 added to which is a Britich Development Program supplement of Rand 200,000.

At 1:50,000, which cost about Rand 8,000 each with contours, about 850 maps are required to cover the country. There are about 1,000

control points in the entire country mounted on four-feet pillars. The Overseas Surveys of UK does trigonometric surveys as well as the primary and secondary control for this mapping.

Some active new developments include the Orapa diamond mine, discovered by Dr. Lamont of Anglo-American, and the Pikwe copper mine, the duties for which have accounted for a large part of the present Rand 11 million surplus in Botswana.

In connection with the coming (April 74) training session in Nairobi, Raffles is quite interested but "needs an invitation" in order to be able to attend. We indicated that we would attempt to take care of this problem. Due to time limitations,he has only looked at Band 7. He indicated an interest in the sample space imagery overlay map products which had been prepared by USGS; we agreed to try to send a set. Lands and Survey is supported by three UK organizations: (1) the Directorate of Overseas Surveys, (2) the Ordinance Survey, and (3) the Military Survey. Raffles indicated that there was a considerable shortage of good photographic technicians. We were shown through his photographic laboratory by his chief photographic technician. They had some very good Swiss equipment for making rectified enlargements with good precision. It is interesting to note that the photographic technician who showed us around, a native-born Botswanian, had only a primary education when he started in the laboratory and has since acquired his secondary education while working in the laboratory. He now runs the photographic laboratory with a staff of two or three others working for him.

12:00 noon: Sam Rea arranged for us to meet for 30 minutes with U.S. Ambassador Charles Nelson. We briefly reviewed our study. It seemed that the Ambassador Nelson has had experience as AID Director in several African countries.

2:00 p.m.: Water Affairs Department, Mr. Wilson, and Mr. McEarnest of the BOT-2 UNDP project. Water Affairs is part of the Ministry of

Minerals and Water Affairs. Mr. Wilson was particularly interested in some rather narrow technical problems connecting with interpreting ERTS imagery for the Okavango water flow problem. The particular techniques for interpretation of the imagery concerned him and we discussed some of these techniques with him. His attention was called to the existing ERTS literature and to the forthcoming training session in Nairobi. Wilson is primarily concerned with the ecological effects of possible large scale withdrawals of Okavango water for development in Botswana. This is also a concern of BOT-2 UNDP project, which Mr. McEarnest is managing. Water is needed for mining, agriculture and domestic use; the problem is how to utilize existing water resources with a minimum of ecological damage. There are some tentative agriculture irrigation schemes. It is noted that supporting one cow on the Northern Kalahari requires about 30 acres.

The problems concern both engineers and ecologists. Wilson intends to prepare a conceptual model of the Okavango Delta then plug in the demands and determine the ensuing ecological effects. He is particularly interested in vegetation classification and needs information on what can be done in that regard. Apparently he is not familar with the GSFC-ERTS symposium volumes which reside at the Geological Survey in Lobatse; called his attention in particular to the Florida Everglades study by Kolipinski,Hieger,et al and MacLeod's work on the inland delta in Mali; there should be some spin-off into the Okavango problem.

The report on BOT-1 is "not yet released"; we were referred to Sam Rea. The UNDP BOT-2 study will include about 2-/1/2 years of field work.

The immediate crisis in Botswana may be briefly summarized as follows: The rate of development has suddenly become quite large, particularly in mineral exploration and extraction activity, including gold mines and the copper mines. This has resulted in a considerable increase in per capita requirements for water. The engineers are

continually pressuring the ecologists in this regard.

Wilson and McEarnest reviewed the professional staffing for the BOT-2 project: 9 resident UN staff, 9 government of Botswana staff, 15 consultants, 4 part-time government staff. The budget is about Rand 709,000 from the Botswana government plus $597,000 US from the UNDP. This totals about $1.5 million US. The program is executed for the UNDP by FAO. There is also the possibility of some additional Swedish consultants.

It was noted that March and April is the season for the maximum input into the northern Delta, while September and October corresponds to maximum outfall from the southern Delta. Input hydrograph data is available from Southwest Africa. Evapotranspiration is a key problem.

It was suggested that we request from the local UNDP representative the following report: "The Investigation of the Okavango Delta as a Primary Water Source for Botswana", Report No. BOT/71/506/C/01/12.

There is an on-going project to extract salt for export.

There is a UNDP-run agricultural project, which is complimentary to BOT-2 but smaller. Mr. Belien, an agronimist, is involved as well as a yet unidentified soils scientist. They will make an assessment of what crops can be grown adjacent to the east and west boundaries of the Delta. They will also look into the prospects for fishing in Lake Ngami, which is now dry. If Ngami had water, as it did in the past, it is estimated that a Rand 180,000 annual fishing industry could be supported. It is noted that Lake Ngami has internal drainage but a low salt content and many flamingoes. Some 100 or a 1000 years ago the outflow from the Delta was through Lake Ngami.

It was noted that the seismicity is quite high in the area and there is a need for flow height and rate gauges. We noted that the ERTS DCS could be utilized; platform cost would be important. A check should be made on reception possibilities for the DCS in this area.

3:45 p.m.: Through the courtesy of Mr. Pintz, a Peace Corp Volunteer assisting the government of Botswana, we had an appointment with Mr. Gaolathe the Permanent Secretary of the Ministry of Mining and Water Affairs. Mr. Gaolathe was well acquainted with the subject and asked many good questions at the appropriate policy level. Gaolathe was particularly interested in whether the activity was out of the research phase and whether it was yet operationally useful. We were later told Mr. Gaolathe is a recent B.A. graduate of UBLS, is only 28 years old and has had a meteoric rise in the government. He is from the Palanga tribe.

Thursday, 13 December 1973

8:00 a.m.: We met at the Agriculture and Land Utilization Building with Mr. Robert Baker, (an Australian), Chief Land Utilization Officer, Mr. Hearn, Land Utilization Division and a Co-investigator on ERTS-B, Mr. Bennison of Agriculture, and Mr. David Field a range ecologist in the Land Utilization Department. Mr. Baker led the discussion noting that land was classified as either arable, marginally arable, or arid. He indicated they were particularly interested in "water points" namely bore holes, dams, wells and sand river extractions. He is just now completing a land utilization map of the eastern agriculture part of the country at a scale of 1:125,000. He referred to it as a "quick and dirty" approach since "detail is not warranted" in this area in his opinion. Mr. Baker indicated that there were practically no unknown surface water in the country and, in fact, only a few known ones. He feels that arid land will stay arid and there is not much to be done about it.

Mr. Bennison seems worried about the amount of ground truth required for the utilization of spacecraft imagery. Bennison was well aware of the ground-aircraft-spacecraft multi-stage approach. He indicated that it was easy to note recent rains on ERTS imagery. He

pointed out the social and political problems concerned with moving grazing areas and felt that fixed site utilization was the only politically acceptable route.

Mr. Bennison was asked specifically if grazing location is a valid operational variable in Botswana. He felt that movement was quite difficult; if fixed site management is assumed, the following variables are available: stocking rate, mass of animals vs. mass of vegetation. Again, he pointed out the tribal constraints on variable site approaches. The recent Michigan Ph.D. thesis, which had effectively estimated the biomass or leaf index from ERTS multi-spectral imagery was pointed out. We felt this should be applicable here. It was not evident that these people in land utilization were aware of that work or familar with the ERTS P.I. literature in their field.

We inquired as to whether there were any non-tribal areas in which moveable grazing would be applicable. The answer was that these non-tribal areas did exist but the projects would have to be quite speculative and were probably politically infeasible. We also asked whether it was perhaps time for a change in the tribal pattern; the answer was that this was indefinitely in the future. (It should be noted here that others in Botswana disagree-or perhaps it's a matter of degree. Other views indicate that tribal problems are much less and may not be very difficult to solve in Botswana, expecially compared to a place like Kenya where the tribal problems seem overwhelming.)

Mention was made of a live-stock development project looking at five large and 30 small fixed-site ranches. Land utilization was very pessimistic about this activity. Mention was also made of a village area development project being sponsored jointly by SIDA (Swedish International Development Agency) and the government of Botswana.

Mr. Field and Mr. Hearne were somewhat more optimistic. Mr. Field felt that it was certainly useful to have ERTS along when doing planning in these areas. Baker felt that: Botswana has the highest ratio of

information to potential of any developing African country. More data won't help! It is one of the best documented countries. Baker did allow that the country was fortunate in that, in the eroded areas, thorn bushes have cropped up rather than sand dunes; however, these bushes are not useful for grazing.

Some data was provided on bore holes: The cost of drilling a bore hole is about Rand 6-10,000. A typical bore hole output is 350 gallons per hour per bore hole in the Kalahari. (We commented that this is just about the transpiration rate for one acre of maple trees in the U.S.)

It was noted that 60% of the people are engaged in subsistence agriculture, mostly in the eastern sector. A typical yield is 2 bags of sorghum per year in a good year; often there is a 1 bag or 0 bag year. (A bag is approximately 200 pounds.) The last corn surplus in the country was in 1961. The only agricultural export in general is meat from the cattle industry. There are a few irrigated farms along the Limpopo River but no real commercial farms (10 acres is a typical size.) There are some commercial cattle ranches.

Mr. Field inquired as to what training level was required to effectively utilize the forthcoming Nairobi workshop. The reply was that any resource specialist with motivation could benefit greatly from that course and that specific pre-training in photo-interpretation was not required.

Mr. Williamson arrived, representing Von Richter, Department of Wildlife and National Parks, (a co-investigator on ERTS-1) who was out of town on business this day.

One encouraging note from Mr. Baker was that he felt that the ERTS data might be useful in the Okavango because of the need to monitor changes. He felt that the water there must be utilized eventually. He also noted the possibility of a dam being built in Angola, which would affect the water source for the Okavango. If this Angola dam is implemented, it could have extremely serious impact on the Okavango and on

Botswana. It was noted that ERTS imagery might provide very effective before and after evidence should there be need for appeal to any international body or court in this regard.

A typical number now for livestock support is one livestock unit per forty acres.

We brought up the wildlife vs. grazing problem and posed this to Williamson; Williamson replied that he could only represent his own work even though Von Richter had sent him. He suggested that we see a Mr. Campbell, Director of Wildlife. Arrangements were made to see Mr. Campbell right after this meeting.

Mention was made of a Danish group looking into the economic viability of roads in the Kalahari. Mention was also made of Norwegian "AID," which is looking into range productivity utilizing meterological data. Bennison mentioned a USAID range development project to be started next year, including both land utilization and land development.

One of the key problems in the country is the lack of junior professional staff and qualified technicians.

10:15 a.m.: Meeting with Mr. Alec Campbell, Director of Wildlife. Mr. Campbell is concerned with wildlife and tourism in Botswana and has been here since before independence (1966). Campbell briefly reviewed the history of this area as he saw it. In 1956 the first interest developed in wildlife management by the administration, the former Bechuanaland Protectorate. At that time cattle were selling for only 3 pounds sterling each and were largely considered prestige objects. The protein for the native population came mostly from wildlife. Surveys indicated that approximately 206 pounds per year per person of game were consumed in one remote town. In 1966 the government "stepped up" its wildlife conservation policy. Though this was an increase, the total resources allocated to the policy is still very small. There was the beginning of a multi-disciplinary approach. Generally, wildlife

ends up on poorer land; an attempt was made to arrest this tendency, and it was possible to save some of the better land for wildlife since agriculture was slow in spreading due to water uncertainity. A deterrent to agricultural activity in the Okavango area has been the presence of the tsetse fly (which causes sleeping sickness). Attempts have been made to wipe it out but have not been especially successful thus far. Wildlife in that area has been largely undisturbed. The policy of the Wildlife Department is to insure the existing population of wildlife for all time even if in somewhat reduced numbers.

It was noted that the first game reserve was established in about 1930. In 1960, a large game reserve was established in central Botswana largely for the protection of the Bushmen, although it is listed as a game reserve. In 1965 the first qualified ecologist entered the scene; there was emerging interest in the tourist potential as well as the maintenance of viable ecological units.

On 15 January 1974 a Tourism/Wildlife project will be started under the direction of Dr. Sherbourne (USA), who is an ecologist and economist from the Smithsonian Institution. Three men will assist him and the program is planned for 18 months. The professionals will be hired through the African Wildlife Regional Foundation, which is funded by the Rockefeller Foundation, and has offices in Washington, D.C. and Nairobi. A Mr. McLaughlin, a professional park planner with Kenya experience will participate and for four months a toruist industry expert will also be available.

It was noted that the game herds in the upper Okavango and Chube areas are in the order of 50,000 per herd. The best observation times are August and September; May and October are also good.

3:15 p.m.: Meeting with Mr. Festas Mogae, Director of Economic Affairs, Ministry of Finance and Development. This meeting was also arranged by Mr. Pintz, the Peace Corp Volunteer. Mr. Mogae is an Oxford graduate. Mogae indicated that the cattle industry "has always

existed" but that decisions must now be made on cattle vs. wildlife/ tourism. A critical item is possible eradication of the tsetse fly (sleeping sickness in both humans and cattle). The conventional wisdom has been: "eradicate the tsetse fly and develop the cattle industry." Mogae is not sure this is the way to go. The contending view is that the tsetse fly actually protects the environment for the wildlife by effectively limiting man's incursions with the cattle industry. He indicated that the open range is a traditional system; the Kalahari is a very fragile system and conservation measures are required to preserve it.

6:30 p.m.: Meeting and dinner with Mr. Quill Hermans, Permanent Secretary, Ministry of Finance and Development Planning.

Hermans was quite interested in the ERTS-type of information for development planning in Botswana. Much of the conversation centered around current problems in Washington and the third world view thereof.

Friday, 14 December 1973

8:30 a.m.: Meeting with Mr. Skans, Director of Water Affairs and Mr. Barting of this group; Mr. Wilson also attended. Skans and Barting are sponsored by Swedish International Development Authority (SIDA). Skans indicated that the Government of Botswana is interested in ERTS including agriculture, local lands, geology, and wildlife.

Wilson noted that the Okavango Delta color composites lose spatial resolution. He needs data on blockages by such media as papyrus. He feels that a Band 7 transparency is better than the color composites for his purposes. The imagery suffers considerable degradation when they start from a positive and have to make negative transparencies. He indicated that hydrological information is obtained largely by inference and that there is considerable interest in the Bolivian's experience.

Government priorities are given to water and mineral development. The view was expressed that cattle are now the mainstay of Botswana and

will probably "outlive" the mineral resources. It was suggested that the the hard currency earnings from minerals could be used for the development of the cattle industry as a continuing source of national income.

1:00 - 5:30 p.m.: Mr. Lou Graveti, a cultural geographer, sponsored by AID (University of California, Davis) took the AID group on a tour of native villages in the general area of Gaborone, including a brief ride into the Kalahari Desert. It should be noted that the "Kalahari Desert" was quite green at this time due to recent rain, which made certain roads impassable by two-wheel drive vehicles.

Appendix H
COST OF ERTS DATA UTILIZATION

While the ERTS system represents one of the more sophisticated technological developments of the United States, the output products can be useful to all countries regardless of their degree of technological development. To be sure, the value of the information extracted from ERTS depends on the effort and technology applied to the extraction process. The ability to extract information from an image depends upon one's knowledge of how to interpret imagery and one's knowledge of the subject discipline for which the information is being gathered. Thus the extraction of geologic information from ERTS imagery requires a knowledge of how the image tones are produced and what factors may affect these tones as well as a knowledge of the field of geology. As in any technically skilled operation, more highly-trained or more experienced personnel can produce better results than those with lesser training or experience. Nonetheless, considerable information can be extracted even without extensive scientific background or sophisticated equipment. For example, the nearly orthographic images from ERTS can be used directly as photomaps of scale 1:1,000,000 without any modification. Such images are excellent substitutes for small-scale cartographic maps.

Since ERTS will be applied to problems identified by on-going projects within the country, it is assumed that the country already has access to user discipline expertise and skills. The cost to use ERTS data, then, will be the cost of the ERTS data products, the equipment and materials required to convert the ERTS data to useful information, and the training and image interpretation effort required by the user to extract the needed information.

There is no set order for progressively increasing a country's capability in ERTS data utilization. Each country must build upon its existing capability and needs. One can list ERTS activities, however,

which provide increasingly significant information at progressively increasing difficulty and cost. The simplest information extraction technique is visual observation (photointerpretation) of the multi-band images produced by ERTS. The next higher level consists of assisting man with instruments which help him extract and reformat the desired information. These instruments vary widely in sophistication and cost. As the ERTS data volume increases because of multiple users or repetitive coverage needs, there is a need to set up a centralized system for data storage, retrieval and distribution. Then if the demand warrants it, there may follow a requirement for a photographic facility to reproduce the ERTS data or the information products. As the information extraction process becomes more demanding, one reaches a point where it may be more economical and effective to use automatic classification techniques applied to ERTS video data stored on computer compatible tapes. ERTS has approximately 10 million resolution cells per frame (185 x 185 km^2) and classification of large areas on a cell-by-cell basis may best be done by computer processing of ERTS digital tapes. Finally, if a country outside the range of a direct receiving station wants assurance that it will receive ERTS data each time ERTS passes over its own territory, an ERTS receiving station becomes necessary.

An optimum information system will generally require data in addition to that provided by ERTS. It is visualized that a multi-tiered system is required to provide information at different scales and accuracies, ground data from selected sample points, aircraft data from medium-scale areas at high resolution, and ERTS for large areas. Thus, a country heavily involved in the utilization of ERTS data will inevitably have supporting remote sensing aircraft.

Representative costs for ERTS data utilization at the various levels described above can be derived from Tables H-1, H-2 and H-3. Table H-1 gives the cost of ERTS data products, Table H-2 gives the cost for data manipulation and information extraction, and Table H-3

gives the cost associated with large-scale ERTS operations. Costs are critically dependent upon the scale of the operation and level of training. In general, costs in Tables H-1 and H-2 are minimum values, e.g., 3 man-weeks of training in image interpretation is judged to be the bare minimum required to obtain effective and efficient skills.

The ERTS system was built and is operated by NASA. NASA's ERTS program is run under the concept that it is a public facility which serves experimenters. NASA negotiates contracts with institutions and investigators that propose applications and experiments deemed worthy of support. As indicated in Table H-1, NASA supplies the requested data free of charge to both U. S. and foreign contractors. Once the data are given to the investigator, duplicate copies are sent to the Department of Interior's EROS Data Center in Sioux Falls, South Dakota. EROS is authorized to sell the data products to anyone requesting them. While data products can be purchased from commercial sources, these products generally are reproduced refinements of data obtained from either Sioux Falls, a NASA experimenter, or from a foreign receiving station (Canada or Brazil). The costs of the ERTS data products given in Table H-1 were obtained from the EROS price list and represent the minimum costs for such products.

The costs for data manipulation and information extraction shown in Table H-2 are separated into fixed and variable categories. Fixed costs include capital investments and the required initial training. Variable costs are dependent upon the work load and consist of labor and materials. Fixed costs represent the amount of initial investment required to obtain any desired degree of sophistication in ERTS usage. Variable costs depend upon the amount of usage, and thus the extent of the area and amount of information of interest to the user. Thus, a balance must be found between initial fixed and continuing variable costs commensurate with the needs of the user. The labor part of variable costs are workload-dependent. These are given in Table H-2

only for operations which require specialized and dedicated staff, such as the ERTS data processing facility.

The costs in Table H-3 are given as fixed and variable. The ground receiving and processing stations are costed separately, as a country may wish to collect data each time the satellite passes over and send the high-density digital tapes elsewhere for conversion to images and computer-compatible tapes. The labor estimates are based on the assumption of a constant level of effort adequate for handling ERTS processing of a country of moderate size (e.g., 100,000 - 500,000 sq. km.).

TABLE H-1. ERTS DATA COSTS

IMAGES		COST TO NASA INVESTIGATOR	COST TO OTHER USERS (Available from EROS)*
70 mm	b & w transparencies	Free	$ 2.50 ea.**
9" x 9"	b & w transparencies	Free	3.00 **
9" x 9"	color transparencies	Free	10.00 ***
9" x 9"	b & w prints	Free	1.75
9" x 9"	color prints	Free	7.00 ***
20" x 20"	color transparencies	N/A	20.00 ***
40" x 40"	color transparencies	N/A	60.00 ***
20" x 20"	color prints	N/A	15.00 ***
40" x 40"	color prints	N/A	25.00 ***
20" x 20"	b & w prints	N/A	3.50
40" x 40"	b & w prints	N/A	9.00
COMPUTER COMPATIBLE TAPES (CCT)		Free	160.00/ERTS Frame

*Prices as of June 1974 and are subject to change.
Shipping charges on foreign orders is $2.00 plus 2% of order.

**One each of the four ERTS bands are usually required.

***These prices assume a color composite has been made by NASA or EROS. If the composite does not exist, there is an additional charge of $50/ERTS frame.

TABLE H-2. COSTS FOR ERTS DATA MANIPULATION AND INFORMATION EXTRACTION

Use of Image Products

A. Manual Interpretation & Trace Overlays		
Fixed: Labor:	3 man weeks of photo-interpretation training	
Capital:	Small light table	$ 30
	Magnifiers and scale	20
B. Instrument Assisted Interpretation		
1. Image projection and magnifying system		$ 600
a. Fixed: viewgraph projector and screen - used for inspection of an enlarged image by one or more persons.		$3,000 - 6,000
b. Fixed: zoom transfer scope - used for projecting an image on a map or another image.		$3,000 - 6,000
c. Fixed: zoom microscope and light table - used for detailed inspection of an image.		
2. Color Enhancement Techniques		
a. Fixed: diazochrome processor - used for making hard copy color composites.		$ 600
Variable: film for color transparencies		1/Frame
b. Fixed: color additive viewer - used for projecting multiband imagery as enlarged color composites. Rapid and variable color enhancement for object recognition.		$10,000
3. Supporting Operations		
a. Fixed: 35 mm SLR camera for recording ground truth.		$ 300
Variable: film and development		$ 6/roll
b. Variable: aircraft rental for site overflight and inspection.		$ 30/hour

TABLE H-2. COSTS FOR ERTS DATA MANIPULATION AND INFORMATION EXTRACTION (Continued)

C. Controlled Photo Maps

1. Scales < 1:500,000

   Variables: survey of ground control points, at least 3 per frame (185 x 185 km^2)
   Printing of maps

2. Scales > 1:500,000

   Variable: survey of ground control points, plus fitted grid
   Printing of maps

Use of Magnetic Tapes

Automated feature extraction or classification map with up to 12 categories.

A.	Variable: procurement of tape processing services for generation of classification map.	$ 5,000/ERTS frame*
B.	Fixed: Capital: ground data processing station for processing ERTS tapes. Contains interactive color display for selecting training areas and displaying processed results.	$300,000
	Variable: Labor: 1 engineer 1 technician	
	Expendables: tapes, film, etc.	$ 1,000/mo.

* Reduced cost for part of frame.

TABLE H-3. COSTS ASSOCIATED WITH MEDIUM TO LARGE SCALE ERTS PROGRAMS

Central Data Repository

Needed for filing, retrieving, inspecting and distributing ERTS data products and ancillary data.

Fixed:	Capital:	file, storage cabinets and light table	$ 300
Variable:	Labor:	1/2 scientist 1 file clerk	

Photo Laboratory

Needed for reproducing ERTS imagery in various formats. When possible, smaller operations should hire this service.

Fixed:	Capital:	contract printer enlarger dryer processor densitometer dark room modifications miscellaneous equipment	$ 5,000
Variable:	Labor:	1 photo technician	
	Expendables:	film, paper, developer, etc.	$ 200/mo.

Ground Receiving and Processing Station

1. Fixed: Capital: receiving station - needed to receive and tape record video data from the spacecraft during over flight. $ 600K

   Variable: Labor: operating staff - 2 engineers, 2 technicians

   Expendables: tapes $ 600/mo.

2. Fixed: Capital: processing station - needed to convert the tape recorded video data to multiband imagery and computer compatible tapes. $ 2,500K

   Variable: Labor: operating staff - 2 engineers, 2 technicians

   Expendables: tapes, film, etc. $ 1K/mo.

TABLE H-3. COSTS ASSOCIATED WITH MEDIUM TO LARGE SCALE ERTS PROGRAMS (Continued)

Remote Sensing Aircraft

Fixed:	Capital:	light aircraft ($50K - $500K) acft. nav. sys. ($5K - $100K) metric camera ($5K - $50K) multispectral cameras ($4K - $40K) thermal mapper or multi-spectral scanner ($35K - $350K)	$99K - $1,040K
Variable:	Labor:	1 pilot 1 engineer 2 technicians	
	Expendables:	gas, oil, film, tapes, aircraft maintenance	$ 3K/mo.

Appendix I

LETTER/QUESTIONNAIRES TO PRINCIPAL INVESTIGATORS (NON-CASE-STUDY COUNTRIES)

I.1 BACKGROUND

In order to obtain additional recent information on ERTS data utilization, letter/questionnaires were sent to the fourteen countries for which on-site case studies were not done. Countries queried by letter and the reply status were as follows:

Country Queried	Reply Received
Argentina	
Brazil	X
Chile	X
Colombia	X
Ecuador	
Guatamala	
Peru	
Venezuela	X
Bangladesh	X
Indonesia	
Korea	X
Philippines	X
Lesotho	
Mali	

A sample letter is attached. Information contained in the seven replies was incorporated into Appendix F and Section 2.1 as appropriate.

I.2 SAMPLE LETTER

SYSTEM PLANNING CORPORATION
1500 Wilson Boulevard • Suite 1500 • Arlington, Virginia 22209 • (703) 525-4904

11 January 1974

Dr. Alejandro Suels Aranda
Deputy Director
Officina Central deCoordinacion
y Planificacion
Palacio Blanco
Caracas, Venezuela

Dear Dr. Suels Aranda:

As part of a study we are conducting for the U.S. Agency for International Development (AID), we are very interested in soliciting the views of principal investigators and other key persons associated with the ERTS program in developing countries. The study is aimed at an economic assessment of the utility of ERTS-type data in accelerating the economic development of developing nations. It is this interest that has prompted this letter to you.

By way of explanation, our study seeks to identify the benefits potentially derivable from ERTS data utilization by developing countries. Likewise, we are also seeking to identify the costs--both material and human--associated with the use of ERTS data. The resulting analysis of benefits and costs is expected to be useful to

- agencies within developing countries that are responsible for economic development
- the UN for its development program
- U.S. Agency for International Development for planning its technical assistance program
- other countries and their agencies that provide bilateral support to developing countries
- NASA for planning future programs

The study is being conducted jointly by a team comprised of the Environmental Research Institute of Michigan, System Planning Corporation and Mathematica Incorporated. This combination ensures the necessary expertise in economics, systems analysis and ERTS data applications. A brief summary of our study is enclosed.

In order to get the best inputs to our analyses and, in particular, a view from each of the developing countries now participating in the ERTS program, we would like . ask if you would be willing to provide us with your personal assessment of the prospects for ERTS data utilization in your country. We would be very grateful for any information you can provide. In particular, we would be interested in some of your views (or those of your associates) on the following points:

(1) Do you feel that you are achieving the original objectives of your ERTS proposal?

(2) Do you feel that the user community in your country is adequately involved and to what extent are they involved, i.e., both public and private sector, e.g., ministries of agriculture, mines, energy, industry, etc?

(3) Do you feel that you have adequate trained personnel to pursue this task or are additional trained personnel required? If so, what kind and how many? Which training procedures appear most desirable? Two week regional workshops? Longer sessions?

(4) Do you feel that you need additional equipment for ERTS data utilization and, if so, what equipment and what would you anticipate would be achievable in terms of increased effective data utilization from the addition of this incremental equipment?

(5) What is your view or the view of your associates in your country's users groups on prospects for ERTS data utilization benefits and particularly benefits related to economic development in your country? Which economic sectors do you think will be most benefited and how?

(6) Could you describe the national organization(s) in your country which would benefit from the utilization of information derived from ERTS data? How would the improved information from ERTS impact the national decision processes, administratively and substantively?

Any comments, insights, or other discussions of topics would be much appreciated.

In particular, we would be interested in any comments you wish to transmit from government officials responsible for planning and development, budgeting, resource management (agriculture, minerals, water, etc.) and any others which you feel would be pertinent to this study. While our request may seem large, we wish to assure you that we do not wish to impose unreasonably upon you and will be pleased to receive whatever scope of reply you feel is consistent with your time availability.

Any existing planning documents or other relevant information regarding the use of ERTS data in your country for economic development would be appreciated if you could forward them to us.

We hope that you may share our enthusiasm for the need and desirability of this study and that you will have even a limited time to assist us as outlined above. Any assistance you can offer will be greatly appreciated. We look forward to hearing your reply and again wish to reiterate that we would impose on you as little as possible and will understand if it is not feasible for you to address all the questions that we have suggested above. In any event, your reply would be most help if it could be received by 22 February 1974.

I should point out that this study also has the support and endorsement of the NASA Office of International Affairs, which has been very helpful to us in pursuing our efforts.

Sincerely yours,

Robert A. Summers
Vice President and Director
Space Technology & Applications

Enclosure: Brief Summary of Study