Implementing Remote Sensing Technology for Economic Development

Workshop Report *
Prepared by
Jean-Paul Malingreau
with
Richard A. Carpenter, Program Area Coordinator,
and
Ricardo M. Umali

March 1984

*Based on papers presented and discussions at a workshop conducted in Manila, October 3-7, 1983, co-sponsored by the Environment and Policy Institute of the East-West Center and the Natural Resources Management Center of the Philippines. Additional support was provided by the U.S. National Science Foundation.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>iii</td>
</tr>
<tr>
<td>Glossary</td>
<td>v</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Presentations by Participants</td>
<td>1</td>
</tr>
<tr>
<td>Findings</td>
<td>3</td>
</tr>
<tr>
<td>What Is an &quot;Operational&quot; Remote Sensing System?</td>
<td>4</td>
</tr>
<tr>
<td>An Appropriate Remote Sensing Technology</td>
<td>5</td>
</tr>
<tr>
<td>Data Banking and Data Dissemination</td>
<td>6</td>
</tr>
<tr>
<td>Benefit-Cost Assessment of Remote Sensing Technology</td>
<td>11</td>
</tr>
<tr>
<td>Manpower Development and Training</td>
<td>12</td>
</tr>
<tr>
<td>The Future of Orbital Remote Sensing</td>
<td>12</td>
</tr>
<tr>
<td>Conclusion</td>
<td>14</td>
</tr>
<tr>
<td>List of Participants</td>
<td>17</td>
</tr>
</tbody>
</table>
FOREWORD

The Environment and Policy Institute (EAPI) of the East-West Center was established in October 1977 to conduct research and education programs through multinational collaboration on environmental aspects of policy and decision-making in the Asian-Pacific region. The program of the Institute emphasizes (1) analysis of various dependence and impacts on natural systems and thus on the objectives of the policies, and (2) assessment of scientific and technical information about natural systems for more coherent policy formulation and implementation through planning and management. This systematic approach avoids the polarization of environmental values versus sectoral goals.

The EAPI Program Area on Natural Systems Assessment for Development focuses on the practical methods that developing countries can use for gathering and analyzing information about the relationships and changes in the natural environment that are important to development. One aspect of these studies has been the broad range of issues related to the contribution of remote sensing technology to economic development. The Natural Resources Management Center of the Philippines collaborated with EAPI in designing a Workshop to examine these issues and in preparing the proposal that was funded by the National Science Foundation of the United States.

In October 1983, the Workshop in Manila, Philippines, was attended by more than a dozen leading authorities and experts from governmental and intergovernmental organizations, and academic institutions in six countries. Persons attended and participated in the workshop in their individual capacities and did not represent or speak for their organizations or countries. This report of the Workshop's findings, conclusions, and recommendations presents the spectrum of views expressed at the meeting. It should not be assumed that every participant subscribes to every statement, although a broad consensus was reached on most major points.

This report is one step in communicating some of the results of this Workshop. In future publications and in follow-up meetings, we anticipate that the work begun will continue and reach a wider audience. In this way, we hope we are contributing to a creative resolution of issues that are vital to national and international interests of countries in the region.

William H. Matthews, Director
Environment and Policy Institute
East-West Center
GLOSSARY

AIT — The Asian Institute of Technology, Bangkok
BAKOSURTANAL — National Coordinating Board for Survey and Mapping, Indonesia
EAPI — Environment and Policy Institute, The East-West Center, Hawaii
ERS — European Remote Sensing Satellite
ESCAP — Economic and Scientific Commission for Asia and the Pacific, Bangkok
EWC — The East-West Center, Hawaii
GMS — Geostationary Meteorological Satellite
IRS — Indian Remote Sensing Satellite
LAPAN — Space and Aeronautics Institute, Indonesia
LARS — Laboratory for Applications of Remote Sensing, Purdue
MOS — Marine Observation Satellite, Japan
MSS — Multispectral Scanner
NASA — National Aeronautics and Space Administration
NOAA — National Oceanographic and Atmospheric Administration
NRMC — Natural Resources Management Center, Philippines
NRSA — National Remote Sensing Agency, India
SPOT — Satellite Probatoire d'Observation de la Terre, France
TDRS — Tracking and Data Relay Satellite, U.S.A.
TM — Thematic Mapper
Implementing Remote Sensing Technology for Economic Development

INTRODUCTION

The objective of the Workshop on Implementing Remote Sensing Technology for Economic Development was to examine a broad range of issues related to the contribution of remote sensing technology to economic development in South and Southeast Asian countries. The empirical information and expert judgments provided by the participants were expected to produce findings leading to a realistic assessment of trends, opportunities, and limitations for the use of remote sensing technology in managing natural resources and maintaining environmental quality.

A series of invited papers summarizing the present situation in several countries, both developing and industrialized, identified and stimulated discussion on key issues in the implementation of the technology. A structured, in-depth analysis of some major research questions dealing with expectations and prospects in developing countries was conducted. In order to accurately reflect the diversity of individual views as well as the collective thinking, this report, which covers the main findings of the Workshop, has been circulated among the participants for additions and amendments. The contents, however, are solely the responsibility of the authors.

PRESENTATIONS BY PARTICIPANTS

The ten papers presented by the participants are reproduced in extenso in the Workshop proceedings, available from the Natural Resources Management Center of the Philippines. Only brief summaries are given here (in order of presentation):

**Landsat Remote Sensing Technology Transfer in the Philippines**
(R. T. Biña)

A survey among scientists in the Philippines shows that remote sensing is considered operational for resource inventories but that the number of beneficiaries is limited. Some remote sensing techniques have been useful in preparing policy resource maps for the country. Financial, technical, and manpower constraints are major roadblocks toward a broader use of the technology. Disappointment with remote sensing relates mainly to the inability to acquire real-time data; there are fears about the reliability of the Landsat series; high expectations are for alternative platforms such as SPOT, MOS, and ERS. Technology transfer should be better tailored to the needs and capabilities of the country. A number of queries have been raised in this respect.
Remote Sensing Technology: Problems and Prospects in Developing Countries
(R.S. Ayyangar)

Remote sensing for resource surveys is well established in India and this paper reviews the activities carried out by various agencies across the country. The role of the National Remote Sensing Agency in successfully promoting the development of remote sensing activities is emphasized.

The main goal of the Indian Space Programme is "to develop indigenous capabilities to image the earth surface" and to establish an operational system that can serve users' needs on a regular basis. The Indian Remote Sensing Satellite (IRS) is planned for 1986.

Problems encountered in the dissemination of this new technology relate to the lack of appreciation of the capabilities and limitations of remote sensing techniques among scientists and to the difficulty in maintaining an operational data bank, among others.

Remote Sensing Activities in Malaysia
(S. T. Mok)

The availability of adequate geographical information derived from topo-maps and air photographs coupled with disillusionment with satellite performance have made the development of a strong remote sensing program in Malaysia less urgent. Nevertheless, there seems to be potential for future applications, especially for monitoring changes in land cover and land use and crop development. Prospects are good if the technology can demonstrate its ability to deliver appreciable benefits.

(J.P. Malingreau)

The importance of remote sensing for resource inventory and monitoring over this vast and diverse archipelago is described in the light of current development programs. The general fields of application of air photography and satellite imagery analysis are reviewed.

Statistics show that little of the Landsat output has been tapped so far. Current constraints are lack of access to data, limited expert manpower, and an overall low operational performance. The list of institutions involved in remote sensing activities in Indonesia includes national agencies, research institutions, universities, and several government departments.

The growing importance of the NOAA and GMS satellites for global monitoring is briefly underlined using case studies. Issues have been raised concerning the appropriateness of the adopted technology.

The Remote Sensing Program in the United States
(M. F. Baumgardner)

A general review of the Landsat program is made; the present uncertainty of continuity of the effort is found to have severely affected the credibility of the program. The trend toward the commercialization of space is discussed.

While the future is uncertain, much remains to be done to analyze the wealth of data collected by space platforms in the last decade. Efforts should now be concentrated in the development of a resource management system that can improve the flow of information to policymakers. There are also gaps in fundamental research related to the physics of remote sensing.

Integrated Remote Sensing and Information Management Procedures for Agricultural Production Potential Assessment and Resource Policy Design in Developing Countries
(G. Schultink)

The Comprehensive Resource Inventory and Evaluation System (CRIES) has developed an integrated and reliable resource data base as a support to national development planning. The system relies on a geographical informa-
tion base to cross-reference agroecological zones with existing land use in order to identify areas having potential for agricultural expansion. Remote sensing plays an important role in providing timely and accurate information on present land use.

The Japan Remote Sensing Program
(T. Sakata)

Japan is actively developing its own space remote sensing capabilities. Plans are being made to launch a marine observation satellite (MOS) in 1986. While the basic policy calls for a strong effort in advanced technology, emphasis is also being placed on building up a multi-level user community. Meeting local data requirements is the priority, and the popularization of the technology is strongly promoted. Regional cooperation among those nations granting and receiving the technology is needed.

The French Remote Sensing Program
(D. Borel)

This paper reviews the institutional framework of the SPOT program. The launching of the SPOT Satellite is planned for 1985, and cooperative agreements for training, pretesting, and receiving the satellite data have been made with several countries in Asia. The problem of data banking and dissemination is to be handled by the SPOT IMAGE Company. The computerized catalog will be linked to several data networks and the continuity of the SPOT program is assured for 10 years to come. The security problems associated with the 10-meter resolution sensors were discussed.

The AIT Remote Sensing Program
(G. E. Johnson)

The AIT has been offering short-term training in remote sensing since 1982. A survey was conducted among 45 students in the program; a majority felt that remote sensing activities are on the increase in their respective countries. The lack of trained or skilled manpower is mentioned first among the major constraints to further progress. Forest mapping, crop inventory, and land-use surveys were among the applications cited most often.

UN ESCAP Remote Sensing Program
(Heng Thung)

The purpose of the Regional Remote Sensing Programme of ESCAP is to provide linkages between national programs by monitoring activities in the region and disseminating information to the various countries. The project will stimulate technical cooperation among developing countries. Training, workshops, seminars, joint research programs, and study tours will be organized. The establishment of an information system/data bank for the region is under consideration.

FINDINGS

The participants in the Workshop selected for discussion a series of issues related to the application of remote sensing techniques in developing countries. This selection was based on the presentations made in the early stages of the Workshop and on the varied and extensive experience accumulated in this field by the participants. Technical issues were avoided as much as possible in order to concentrate on more fundamental questions related to the future of this technology in the developing countries of Asia. Characteristically, most of the discussions focused on orbital remote sensing rather than on airborne platforms. This may have reflected the participants' feelings that outer space and the benefits from space vehicles should be
shared among nations but that airspace should be considered a national reserve.

Points of major concern were:

- What is an “operational” system?
- What are the objectives of an operational system and how can existing systems be made operational?
- How can remote sensing technology be made more appropriate for developing countries?
- Since data banking is becoming increasingly complex, what are the alternatives for internationalization of effort and what are the potential consequences?
- Is cost-benefit assessment relevant at this stage of technology development? How can such assessments be made?
- To what extent are manpower development and training a problem in implementation?
- What is the future of orbital remote sensing? What are the potential consequences of the alternative scenarios?

What Is an “Operational” Remote Sensing System?

The Workshop participants agreed that, from a user’s point of view, the existing remote sensing systems are not yet fully operational. The terms “semi-operational” or “pre-operational” were used, reflecting different approaches. Making the system operational is clearly an objective of the user community as well as of the system designers. Yet difficulties persisted with the definition of what an operational system is. Pragmatism was the rule:

On the one hand we have basic problems of resources inventory and monitoring, on the other hand we have the technology . . . if the technology can answer our needs, then it is operational!
A system is operational when it provides, on a sustained basis, the right data to the right user at the right time.

Users tend to blame the system operators for not being responsive to their needs. Comments were heard, for example, about the long turnaround time in the EROS Data Center at Sioux Falls — delays of up to one year were reported for large orders. Yet there are other factors that may also reduce efficiency of operation. Communications may be difficult, customs offices may be slow in clearing computer tapes, orders may get lost in shipping, or the user may not be ready to exploit the data when they arrive. Clearly the system will not operate more efficiently than its weaker links allow.

Full operationality is a relative state that must be judged from a specific point of view:

- The Landsat system is considered operational for geologic and general cartographic applications. In these cases, recent and repetitive data are not required and most of the interpretation can be done visually on original or enhanced-image products.
- National forest inventories have been facilitated by Landsat images. The value of the system is that it provides exhaustive coverage of forests of entire countries or regions. These capabilities have been exploited in the Philippines; they are just beginning to be examined in Indonesia. However, the ability of the sensors to distinguish among species is limited.
- Most countries in Asia now have Landsat images covering a 10-year span, and cloud-free scenes of virtually all areas are available. Such data are of tremendous value in this era of concern for environmental protection for assessing long-term changes in land use, vegetation, erosion, and coastal zone accretion.

It is for monitoring short-term changes, such as in crop growth and water resources monitoring, that the system presents serious limitations. The uncertainty of repetitive data acquisition due to cloud cover or technical failures drastically reduces the value of an orbital platform for such applications.
Some participants stated further that apparently no country in Asia is ready to fully exploit an operational system when it comes to agricultural monitoring. Problems of data processing are formidable considering the size, heterogeneity, and complexity of some of the regions to be monitored, for example, the rice-growing areas of India and Indonesia. Despite all claims to the contrary, it is evident that the current capabilities in interpreting repetitive data such as that generated by the Landsat system do not yet permit continuous agricultural monitoring in South and Southeast Asia. Thus, both the system and its users are not ready.

This situation is seen by some as an additional reason to strengthen research in remote sensing applications. Such research should not only cover the physical aspects of the measurement technique (i.e., sensors) but should also deal with the development of an integrated, systematic approach to remote sensing applications.

In summary, it was felt that although orbital remote sensing of land resources has sufficiently demonstrated its value in actual situations, much work remains to be done by the system designer and operator and at the user end to improve an important function of the technique: to provide short-term repetitive data on transient features on the surface of the Earth.

**An Appropriate Remote Sensing Technology**

While none of the participants doubted the general appropriateness of remote sensing for resource management, questions were raised regarding the appropriateness of its modes of application. Some countries, such as India, have opted for the development of a system of remote sensing technology based on self-sufficiency; the majority of countries depend on the transfer of technology and data from developed nations.

At first the participants reflected the desire of the majority of users to be increasingly involved in the design of Earth observation platforms; however, they also admitted this would be difficult. The gap between the two ends of the system is wide, and communication does not flow easily. This reciprocal lack of sensitivity to needs and constraints has sometimes led to ironic situations. It is known, for example, that procedures are worked out to degrade data sets that, because of their high ground resolution, may become too sensitive or too cumbersome for some user groups. This is a typical situation of system designers pushing the hardware beyond the capabilities of the users. Reacting to this perceived lack of responsiveness from system operators, some countries have begun to plan their own natural resources satellites, for example, the Tropical Equatorial Resources Satellite in Indonesia.

There are few established feedback mechanisms through which users can correspond with those designing remote sensing systems. Thus, it is at the interface between the output and the user that questions of appropriateness can be raised. There is wide variation in approaches, formats, hardware, and software at this interface.

Observing that "the world is going digital," the participants recognized that great advances in data processing are being made. Hardware and software for image analysis have reached such a degree of development that even small systems can be used to analyze data for a wide range of applications. Digital data processing equipment allows a great deal of manipulation and in-depth interpretation of multispectral remote sensing data. Large computer systems can manipulate the large amounts of data and computations required in some cases. Through linkages with cartographic reference systems, digital analysis may yield thematic maps ready for interpretation by the user.

However, while digital analysis systems are becoming necessary to cope with the growing amount of remote sensing data, the demand for quality visual products that can be used at the actual survey level is still high. It appears that in developing countries a large portion of the important benefits derived from remote sensing is the result of visual analysis of the imagery. Photographic prints will reach a wider
audience than computer tapes. Too often, however, Landsat prints are of a quality that does not do justice to the capabilities of the sensors. This may result in user discouragement and rejection of the technology altogether. More attention should be paid to the production of high-quality, affordable visual products.

Visual and digital approaches are not mutually exclusive; the right combination of the two must become part of the attempt to devise more appropriate technology. It has been clearly demonstrated that conventional and advanced analyses are mutually supportive, and this point was emphasized during the Workshop discussions. Thus, small-to-medium-capacity image data processing systems must be developed to support digital analysis away from large processing units. Such computerized systems must be of the stand-alone type, allow a high level of easy interaction with the user, and be moderately priced (less than US$50,000). Improvement of the visual quality of images derived from orbital platforms is also necessary.

An interesting aspect of the visual-digital interaction in remote sensing analysis was illustrated by a display of some of the few Landsat 4 Thematic Mapper images available so far. These high-resolution images are strikingly similar to small-scale air photographs and appear to be amenable to conventional air-photo analysis. It may be that when confronted with the enormous data load delivered by the high resolution sensors of the future, most users will go back to visual interpretation of high-quality image documents. It was also pointed out that realistic simulations performed over Bangladesh have shown that the SPOT images will have similar high-resolution characteristics.

The pacing of the transfer of technology acquires a special relevance for developing countries, which are generally short of qualified manpower and financial resources. Ongoing efforts to implement remote sensing applications are often upset by the constant acceleration of technological developments. There is serious concern that in this ever-changing context an appropriate level of technological application will be difficult to find. Where do you draw the line in buying new equipment? How far can you afford to go to keep up with changes? How much self-reliance do you have to maintain to reduce dependency? These are all important questions that developing countries face in their efforts to increase the benefits derived from remote sensing.

The impression derived from these discussions on appropriate remote sensing technology is that there is a need for devising forms of technical transfer and application better suited to developing countries. Field practitioners are interested in a technology that works, that supplies them with the right set of data at their own level of application. The handful of countries presently operating or actively designing orbital remote sensing systems have little means to reach these field users. It is thus the responsibility of the national gatekeepers to make sure that the available technology is translated into applicable and acceptable approaches. More responsiveness on the part of system designers and operators could improve the transfer and diffusion of a more appropriate form of technology.

Data Banking and Data Dissemination

Data banking and dissemination present a host of problems that were mentioned during the formal presentations. In addition, everyone agreed that the continuous growth of the data load will present a major problem in the years to come. The issue has delicate and complex political and technical dimensions. The recent proposal to commercialize the Landsat program in the United States may also have a major impact on data availability. Not enough information on the U.S. administration’s intentions was available at the time of the meeting to fully discuss the possible implications of such a move.

It is useful to distinguish between data banking and information dissemination. The former deals with the actual storage of digital data derived from remote sensing platforms; the latter mainly includes catalog information about such data.
It has been reported that the user often lacks access not only to the data but even to information about the data. The EROS-NOAA geographical search has performed adequately for data included in the U.S. collection. Regional receiving stations such as the ones in Bangkok, Australia, Hyderabad, and Japan operate differently and produce catalogs of their own. Some have therefore expressed the need to centralize access information, making it quickly and easily available to users. On the other hand, some participants have argued that it is the responsibility of the user to get in touch with the station within range to obtain the appropriate information. Such a bilateral approach has worked satisfactorily for Indonesia, for example, which is covered by three ground receiving stations.

The problems related to data banking per se are of a more complex nature. Various countries in Asia have expressed their readiness to operate their own satellite receiving stations. Ground receiving stations are a way for each nation to gain some independence in obtaining data. However, those national stations receive data of a multinational nature. The responsibility of efficiently disseminating such data among domestic and foreign users may thus place a heavy financial and logistical burden on the national agency in charge. The pooling of remote sensing data at a supranational level—worldwide, regional, or bilateral—is being seriously considered. How the boundaries of such a “region” would be determined was not elucidated. Justifications for a data bank of a regional nature are (1) potential reductions in operating costs for individual countries, (2) expectations for increased efficiency of data storage and retrieval, and (3) assurance of continuous access to data. (See Figure 1 for some alternative pathways of data distribution.)

Proponents of centralized remote sensing data banks face considerable problems. The amounts and rates of accumulation of digital data from space are truly formidable; communication with ground receiving stations must be established and kept open; and retrieval systems must be designed so that users can have ready access to data. In addition, a geographical reference system is highly desirable, although prohibitively expensive.

The importance of Landsat data archives was also mentioned during the Workshop. Archives have a unique value. They are historical documents reflecting resource conditions at specific time periods, and as such they can be used to study rates and patterns of change in surface features such as vegetation cover, land use, and irrigation systems. Archives can also be tapped to build seasonal and phenological models of change. In addition to monitoring capabilities, old Landsat data can be used to study stable landscape elements such as soils, landforms, and drainage systems.

One participant reported that the problems of archiving have not received enough attention. This was illustrated by the observation that early MSS data over India appear to have been destroyed, to the dismay of foresters trying to reconstruct the dynamics of forest cover in that country. Old Landsat data may be placed “off-line” in archives; however, they should never be destroyed.

While the political will to establish a remote sensing data bank has been expressed at the ESCAP regional level, such resolve may vanish when high-resolution data become available and freely accessible. The common political stand seems to be that countries want free access to data about their neighbors but will not allow other countries access to such data about themselves.

Questions have been raised in the past about the propriety of one nation having access to information about the natural resources of another nation. This issue has been the topic of countless debates in the United Nations and other international agencies. While the United States has kept an “open sky” policy for civilian applications during past programs, the improved resolution of coming orbital sensors has complicated the matter. At such levels of resolution (i.e., 10 meters) the information gathered will relate not only to natural resources but also to sensitive security matters. Some nations will object to such information being freely available.
Figure 1. Four alternative pathways for remote sensing data distribution.
Scientists characteristically want complete freedom and there are legitimate reasons for access to such data across national boundaries. There was a consensus among the participants that concerns over national security would continue to be heard but that it was the role of diplomacy to ensure that Earth resources data gathering systems perform their intended functions for the benefit of all mankind.

The problems of centralized data banks will be compounded when each nation implements its desire to be fully in control of its own data. A proliferation of ground receiving stations may solve the problems of each individual country, but the costs are likely to be high. The recent trend toward the commercialization of space data may further encourage each country to respond individually to market pressures or incentives in these matters. Sensitive issues of data banking could be avoided by limiting the access to data to countries participating in the program; however, this would defeat the global purpose of satellite remote sensing.

The proliferation of satellite ground receiving stations is a recent phenomenon that simultaneously indicates the strong interest of individual countries in controlling their data sources and runs counter to current efforts toward international cooperation. To assist in visualizing the situation in Southeast Asia, a map including the coverage area of the existing Landsat receiving stations is reproduced in Figure 2. There will be seven stations in the ESCAP region when the Jakarta station becomes fully operational at the end of 1984. The largest coverage overlaps are found between the Hyderabad, Dacca, and Bangkok stations. If the People’s Republic of China carries out its intention to add a station to serve the eastern part of the country, some regions will be covered by up to four receiving stations. On the other hand, no receiving station is in range when the Landsat satellites orbit over the major part of the Central and South Pacific basins. At this time, only the Australian receiving station is equipped to receive Landsat 4 signals. Pakistan, India, Bangladesh, Thailand, Indonesia, the People’s Republic of China, Japan, and Australia have expressed interest in direct SPOT data reception; however, only Bangladesh has so far made a firm contractual arrangement to receive the data by 1985.

It is argued that if nations are to benefit from supranational data banks they must themselves be ready to contribute to those banks. The implication is that national data banks on natural resources have to be fully operational before they can send and receive data to and from regional organizations. Problems of format incompatibility will arise. National Earth resources information systems seem to be at the conceptual stage at best in many Asian countries.

Three alternative approaches to deal with the problem of remote sensing data banking and dissemination can now be envisaged:

1. At present each country operating a receiving station has the responsibility to inform users in its range of the availability of data and to supply such data at cost upon request. Some participants indicated that this situation has performed satisfactorily. The high cost of acquiring and operating ground receiving stations coupled with the climate of uncertainty about space remote sensing discourages nations from acquiring their own facilities. On the other hand, concerns about security and guaranteed access to data have led nations to invest in data receiving stations directly under their control. Past experience has shown that archives of data about a given country may not be of enough interest to the nation operating the ground receiving station to warrant their preservation for a long period of time. This may be an additional argument for each country to acquire and keep its own archives.

Thus, the consensus is that more receiving stations would be established in a growing number of countries; some participants even talked about the need for short-range and cheaper stations, to be used at a national level only.

2. A regional center might assume the responsibility of assembling and disseminat-
Figure 2. Satellite remote sensing stations in the ESCAP region.
ing up-to-date catalogs of data covering the whole region, thus acting as a documentation center. Each ground receiving station would store and distribute the data it receives. This could be a transitional stage leading toward the third alternative.

3. All data derived from remote sensing platforms and received in the region could be compiled, archived, and distributed from a centralized location. (The pros and cons of this alternative have been presented earlier in this section.)

While discussing these alternatives the participants were reminded that within a short time new remote sensing data will be collected by a series of non-U.S. satellites. The SPOT IMAGE Company, a commercial venture, is setting up a computerized catalog on a worldwide scale; the data bank will be based in France but provisions will be made for efficient access through mail or telecommunications. Commercial agreements will also be established with receiving stations to disseminate their data over a defined territory. This option, which is actually a hybrid of the second and the third alternatives presented previously, appears to have been selected for commercial and technical reasons. The wide range of SPOT outputs (varying in angle of vision, stereoscopic coverage, repetitive coverage, and spectral bands) requires a central data bank of some complexity.

**Benefit-Cost Assessment of Remote Sensing Technology**

Remote sensing activities are increasingly costly and questions related to benefits and return on investment are raised by decision makers before they approve new programs. There is also a growing concern that the costs will become prohibitive in absolute terms, so that many developing countries can no longer afford access to the technology. If, as is often the case, the costs mount after the initial investment has been made, the user country is forced to continue investing, perhaps beyond its means. Stopping at that stage could indeed render most of the system obsolete. This technological trap and its impact on national policies is all too real now that several countries are experiencing financial difficulties and privatization (commercialization) of space technology is likely to reduce government subsidies.

The Landsat system was heavily subsidized during the research and early operation phases. The satellite-derived products sold by the EROS-NOAA Data Center are now supposed to generate enough revenues to cover the costs of data reception and processing. The result is that Landsat prices have more than tripled in a decade. Inflation has also been a factor. Proponents of full commercialization of the Landsat system argue that the system should now pay for itself in the open market. Opponents of this view reply that any attempt to charge the full cost to each individual user would result in a serious reduction in applications. France has stated that the SPOT IMAGE Company will sell data at prices competitive with the Thematic Mapper current prices. Future costs are uncertain, but they will be higher.

Most of the Workshop participants thought that benefit-cost questions are premature in the early phases of remote sensing development, as with other new technologies. Questions of cost-effectiveness should be raised instead. Among the range of resource assessment techniques available, does the use of remote sensing techniques offer advantages? The Workshop did not succeed in quantifying these advantages; conditions, in terms of needs, stage of economic development, and qualified manpower, are too different from one country to another. Speed of surveying and accuracy of data were mentioned as possible advantages having weight in the decision to adopt remote sensing.

One difficulty in assessing advantages is that remote sensing images often introduce a new dimension in the spatial analysis of Earth resources distribution. There are significant intangible benefits associated with the new look at the Earth provided by airborne or orbital sensors. The fact that a resource surveyor, planner, or manager can now have a view of a whole region, watershed, island, mountain
complex, or any other spatial unit offers potential opportunities for better integration of environmental factors. Synoptic views of large portions of the Earth's surface may reveal spatial relationships not otherwise discernable. Moreover, the spectral data collected by new sensors allow a more intimate look at the nature and conditions of each feature. The fact that orbital platforms provide repetitive data over entire regions at a low cost is also a unique advantage in some applications.

Remote sensing technology is still in the research and development phase in many countries, and it is difficult to make an economic assessment before the system is fully operational. It may be that, given its wide applicability and value, the technology will one day be an accepted overhead item in the economic development of a country and in its effort to better manage its natural resources.

Manpower Development and Training

The shortage of qualified manpower is recognized as an important constraint on remote sensing development. Shortages are especially felt in countries confronted with a certain urgency in carrying out development programs over vast territories. The participants agreed that manpower development is quickly improving in the South and Southeast Asian region. Several countries have made serious efforts to train large numbers of field specialists in remote sensing techniques and to develop university curricula in this field. The regional program at the Asian Institute of Technology in Bangkok can accept up to 35 participants per session. India has indicated that it is giving particular attention to training and education. The ESCAP remote sensing program is giving priority to the support of regional training activities, and a large number of Asia-Pacific practitioners attend training and university programs in the United States, Japan, France, and the Netherlands.

Therefore, it appears that the process of technological diffusion is actively taking place. In the last few years, the diffusion process was not necessarily tied to a specific remote sensing agency but was carried out in a variety of institutions. This probably reflects the fact that it is time to initiate more specialized training in this field. The technology has taken hold and efforts can now be concentrated on improving the applications in specific disciplines such as crop science, hydrology, pedology, geology, and water-quality control. We were reminded, however, that recipients of advanced training, especially in the field of data processing, are commodities very much in demand in the private sector. The risk is that government-sponsored trainees will be lured away from government programs for more lucrative employment with computer companies.

The Future of Orbital Remote Sensing

The uncertain future of orbital remote sensing programs is cause for uneasiness in many user countries. Indeed, the assurance of data continuity is a major consideration in developing a coherent and useful remote sensing program. Countries that have invested heavily in the Landsat program are now having qualms about the future of the operation.

A critical factor underlying the present atmosphere of uncertainty is the poor performance of Landsat 3 and the fast-failing year-old Landsat 4, the only platform of the Landsat series now in operation. The ongoing debate in the United States regarding the future of the Landsat program is also exacerbating users' fears. While frustration caused by technical breakdowns is understandable, one also senses a certain irritation at the fact that national remote sensing programs have become so dependent upon political events in a foreign nation.

The technological dependency criticized in some circles is now compounded by the recent political squabble surrounding space issues in the United States.

The participants realized that such laments were not likely to change this state of affairs. Instead, they tried to assess the reactions or attitudes of the user community when confronted with possible alternative scenarios.
Two of those scenarios were:

Scenario 1: Landsat 4 is failing; Landsat D is not launched; a data gap exists until 1985 when the SPOT Satellite comes into operation.

Scenario 2: Landsat 4 is reactivated or Landsat D is successfully launched; the Thematic Mapper is operating. SPOT (France, 1985), IRS (India, 1986), and MOS (Japan, 1986) are successfully launched.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>SPOT 1</td>
<td>IRS</td>
<td>ERS</td>
<td>MOS</td>
<td>SPOT 2</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario</td>
<td>Landsat</td>
<td>SPOT 1</td>
<td>IRS</td>
<td>ERS</td>
<td>MOS</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(TM/MSS)


Reactions to this scenario were surprisingly varied. Every participant agreed that a two-year data gap would be unfortunate, but whereas for some it would cause a serious loss of confidence in the approach, others almost considered it a blessing in disguise.

Disappointment with the Landsat program was expressed by those who invested heavily in that technology. Scientists have been hard at work in several countries of Asia selling the advanced technology to their governments, and a strong selling point has been the capability of orbital satellites to cheaply monitor changes in Earth features. Great expectations were also placed on the high-resolution Thematic Mapper carried on Landsat 4, which was thought to be more appropriate for surveying the highly fragmented landscapes of Asia. Malfunctions affecting the acquisition or transmission of data by this sensor have further deepened the crisis of confidence.

Yet for all the recrimination, no expression of total disillusionment with orbital remote sensing was heard; participants were, in the majority, true believers. Concerns were clearly expressed, however, about the impact of repeated failures on the cost of future undertakings.

A different reaction to this scenario was also recorded. Some participants were not inclined to focus single-mindedly on the data gap problem but preferred instead to examine how the enormous amount of existing satellite data could be better exploited. The reasoning is that if, as shown by recent events, the orbital remote sensing satellites cannot be considered fully operational, it would be wise at the user end to extend the “learning curve” as far as possible before the concept of operationality comes of age. Large backlogs of unexploited data lie on the shelves of receiving stations. These data will not help in monitoring contemporary events but they can be used to conduct general resource inventories, to assess long-term changes, to study the dynamics of such changes, and, above all, to increase our understanding of the relationship between spectral reflectance measurements and ground features.

This scenario implies that orbital remote sensing data will next become available with the launching in 1985 of the French SPOT Satellite. The SPOT program is designed to assure continuity of operation for 10 years (1985–1995). Although worldwide coverage of imagery will be made available through the France-based SPOT IMAGE Company, it appears that further efforts to ensure that new ground receiving stations are erected or old ones upgraded are desirable in order to make the SPOT data over countries of Asia more directly available.

Scenario No.2: The data gap is reduced.

If the launching of Landsat D in March 1984 is successful, the immediate data gap will be shortened to six to twelve months. This presupposes that ground receiving stations cover-
ing Asia are upgraded to receive Thematic Mapper data. Transmission via the TDRS (Tracking and Data Relay Satellite) could alleviate the problem, but that spacecraft is itself still undergoing checks. Thus, as one participant mentioned, the continuity of data supply must also extend to the Earth segment of the technology. As it stands such continuity is not assured, and the fear is real that, in dealing with this fast-advancing technology, countries with limited financial resources will not be able to keep up with changes in data receiving and processing techniques. Complete reliance on the Landsat Thematic Mapper, for example, may endanger the large investments made by some countries in image processing systems designed for other sensors.

A recurring concern is the enormous rate of data output that will suddenly be imposed on national data banks by high-resolution sensors. While the technology itself cannot be blamed, national remote sensing programs may quickly experience an "obsolescence syndrome."

All this may lead to the conclusion that developing countries are in a no-win situation. Being at the receiving end of the technology, they may be forced to cope with the outcome of decisions made beyond their reach. Clearly, many countries have a legitimate desire to keep abreast of technological advances, especially if it is proven that such technology can speed national development. Few can afford to do this; however, each country can control its own rate of adoption of the technology. In addition, several participants in the Workshop indicated that the time is past when policymakers can be convinced of the merits of large investments in remote sensing on the basis of generalized claims. Hard facts and the assurance of long-term benefits now must be presented.

CONCLUSION

This report does not fully examine the variety of situations found in countries of South and Southeast Asia. Intercountry differences can be large, and from a policy point of view it is of interest to identify the factors or combinations of factors that influence the adoption of the technology in specific circumstances.

The process and outcome of remote sensing technology transfer is influenced by a number of interconnected factors, some of which are related to internal conditions such as the geography of the country, its present needs in the framework of development programs, the availability of qualified manpower, a historical or colonial legacy, and the important role played by pioneer scientists. These are important pull factors. An examination of recent developments reveals, for example, that in many Asian countries the introduction of remote sensing can be traced to the efforts of a small but active group of pioneer scientists. This is clearly the case in Indonesia, the Philippines, and Thailand. Those pioneers are natural scientists or engineers who, once in contact with the technology abroad, were quick to recognize its potential benefits and were able to translate their interest into implementation programs.

External (push) factors are also at work, as would be expected from a technology entirely developed in the industrial countries of the world. At first, the advanced remote sensing techniques are presented as prestigious activities; as such they are a lure to curious scientists and sophisticated planners of developing nations. Technological isolationism is a thing of the past and the desire for the new quickly overcomes old constraints. Other external stimuli are the desire to play a regional leadership role in this prestigious technical/scientific field and, in some instances, peer pressure to join regional remote sensing programs. In
such a climate, the availability of low-interest international funding and sales pressure from commercial ventures have succeeded in leading several countries to make massive equipment purchases. While a more skeptical view now prevails among policymakers and scientists, the continuing importance of such factors must not be underestimated.

A summary of the push and pull factors that have favored the adoption of remote sensing technology in countries of Asia and the Pacific is presented in Table 1. The absence of these factors may explain the slow response of other countries. Table 2 summarizes the situations in the five developing countries represented at the Workshop.

Table 1. Internal (Pull) and External (Push) Factors Influencing the Adoption of Remote Sensing Technology

<table>
<thead>
<tr>
<th>Pull</th>
<th>Push</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearly perceived needs for Earth resources management</td>
<td>Availability of foreign aid</td>
</tr>
<tr>
<td>Pioneer scientists in remote sensing</td>
<td>Commercial pressure from manufacturers/processors</td>
</tr>
<tr>
<td>Progressive technological gatekeepers</td>
<td>International or regional pressures to lead or join</td>
</tr>
<tr>
<td>National pride</td>
<td></td>
</tr>
<tr>
<td>Individual leadership interests</td>
<td></td>
</tr>
</tbody>
</table>

15
### Table 2. Factors at Work in the Adoption of Remote Sensing Technology in Selected Asian Countries

<table>
<thead>
<tr>
<th>Factors Advancing the Adoption of the Technology</th>
<th>Factors Inhibiting the Adoption of the Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INDIA</strong></td>
<td><strong>INDONESIA</strong></td>
</tr>
<tr>
<td>Size of the country</td>
<td>Insular geography of the country; large territory; difficult access</td>
</tr>
<tr>
<td>Pressing resources development/protection needs</td>
<td>Colonial legacy and political turmoil in early years resulting in little information being available in the 1970s on natural resources</td>
</tr>
<tr>
<td>Large class of qualified scientists and engineers</td>
<td>Accelerated development programs in the 1970s (transmigration, regional development)</td>
</tr>
<tr>
<td>National pride in developing indigenous technology</td>
<td>Access to liberal international funding</td>
</tr>
<tr>
<td></td>
<td>Role of dynamic pioneers</td>
</tr>
<tr>
<td></td>
<td>Commercial pressure from manufacturers/processors</td>
</tr>
<tr>
<td><strong>THAILAND</strong></td>
<td><strong>PHILIPPINES</strong></td>
</tr>
<tr>
<td>Critical resources development and conservation problems in north and northeast</td>
<td>Qualified manpower lacking</td>
</tr>
<tr>
<td>National priorities</td>
<td>Limited financial resources</td>
</tr>
<tr>
<td>Desire to play a leading regional role in this field</td>
<td>Growing financial problems</td>
</tr>
<tr>
<td>Role of dynamic pioneers</td>
<td>Slow rate of diffusion among users</td>
</tr>
<tr>
<td>Commercial pressure from manufacturers/processors</td>
<td>Training efforts not at par with needs</td>
</tr>
<tr>
<td><strong>MALAYSIA</strong></td>
<td><strong>PHILIPPINES</strong></td>
</tr>
<tr>
<td>Growing interest in monitoring capabilities of remote sensing</td>
<td>Acceleration of resource degradation and urgent need for monitoring</td>
</tr>
<tr>
<td>Pressure from peer countries</td>
<td>Lack of accurate background data on resources</td>
</tr>
<tr>
<td></td>
<td>Insular geography</td>
</tr>
<tr>
<td></td>
<td>Role of dynamic pioneers</td>
</tr>
<tr>
<td></td>
<td>Trained manpower available</td>
</tr>
<tr>
<td></td>
<td><strong>MALAYSIA</strong></td>
</tr>
<tr>
<td></td>
<td>Growing interest in monitoring capabilities of remote sensing</td>
</tr>
<tr>
<td></td>
<td>Well served with existing maps and accurate data based on natural resources</td>
</tr>
<tr>
<td></td>
<td>Qualified manpower is limited</td>
</tr>
<tr>
<td></td>
<td>Qualified manpower is limited</td>
</tr>
</tbody>
</table>
LIST OF PARTICIPANTS

R. S. AYYANGAR  
Head, Agricultural Division  
National Remote Sensing Agency  
Hyderabad, India

M. F. BAUMGARDNER  
Director, Laboratory for Applications of Remote Sensing  
Purdue University  
W. Lafayette, Indiana, U. S. A.

R. T. BIÑA  
Head, Remote Sensing Technology Application Division  
Natural Resources Management Center  
Quezon City, Philippines

D. BOREL  
Remote Sensing Expert  
ESCAP-OES Environmental Coordinating Unit  
Bangkok, Thailand

R. A. CARPENTER  
Research Associate, Environment and Policy Institute, East-West Center  
Honolulu, Hawaii, U. S. A.

I. GUERRERO  
Assistant, Remote Sensing Technology Application Division  
Natural Resources Management Center  
Quezon City, Philippines

HENG THUNG  
Project Manager  
Regional Remote Sensing Programme  
ESCAP  
Bangkok, Thailand

T. JIMENEZ  
Remote Sensing Systems Development and Maintenance Division  
Natural Resources Management Center  
Quezon City, Philippines

G. E. JOHNSON  
Associate Professor of Remote Sensing  
Asian Institute of Technology  
Bangkok, Thailand

J. P. MALINGREAU  
Visiting Fellow, East-West Center  
Formerly Project Specialist, The Agricultural Development Council  
Yogyakarta, Indonesia

MOK SIAN TUAN  
Assistant Director General  
Forestry Department  
Kuala Lumpur, Malaysia

NIK NASRUDDIN MAHMOOD  
Senior Researcher, Malaysian Agricultural Research and Development Institute  
Kuala Lumpur, Malaysia

TOSHIBUMI SAKATA  
Director, Research and Information Center  
Tokai University  
Tokyo, Japan

G. SCHULTINK  
Director, CRIES Project  
Department of Resource Development  
Michigan State University  
East Lansing, Michigan, U. S. A.

R. M. UMALI  
Deputy Director General  
Ministry of Natural Resources  
Natural Resources Management Center  
Quezon City, Philippines
THE EAST-WEST CENTER is an educational institution established in Hawaii in 1960 by the United States Congress. The Center’s mandate is “to promote better relations and understanding among the nations of Asia, the Pacific, and the United States through cooperative study, training, and research.”

Each year nearly 2,000 graduate students, scholars, professionals in business and government, and visiting specialists engage in research with the Center’s international staff on major issues and problems facing the Asian and Pacific region. Since 1960, more than 30,000 men and women from the region have participated in the Center’s cooperative programs.

The Center’s research and educational activities are conducted in four institutes — Culture and Communication, Environment and Policy, Population, and Resource Systems — and in its Pacific Islands Development Program, Open Grants, and Centerwide Programs.

Although principal funding continues to come from the U.S. Congress, more than 20 Asian and Pacific governments, as well as private agencies and corporations, have provided contributions for program support. The East-West Center is a public, nonprofit corporation with an international board of governors.

THE EAST-WEST ENVIRONMENT AND POLICY INSTITUTE was established in October 1977 to increase understanding of the interrelationships among policies designed to meet a broad range of human and societal needs over time and the natural systems and resources on which these policies depend or impact. Through interdisciplinary and multinational programs of research, study, and training, the Institute seeks to develop and apply concepts and approaches useful in identifying alternatives available to decision makers and in assessing the implications of such choices. Progress and results of Institute programs are disseminated in the East-West Center region through research reports, books, workshop reports, working papers, newsletters, and other educational and informational materials.

William H. Matthews, Director
East-West Environment and Policy Institute
East-West Center
1777 East-West Road
Honolulu, Hawaii 96848