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PROCEEDINGS OF NEPAL WORKSHOP ON REMOTE SENSING

April 30-May 4, 1978

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Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57007

January 1979

Nepal Workshop on Remote Sensing

Kathmandu, Nepal
April 30 to May 4, 1978

NEPAL WORKSHOP ON REMOTE SENSING

April 30 - May 4, 1978
Goethe Institute Dharahara
Kathmandu, Nepal

PROGRAM

Session 1 - April 30 p.m.

Inauguration

Chairman: A.B. Rajbhandari
Secretary, Ministry of Forests

Conveyor: S. Bhattarai

1300 Registration

1330 Introductory Speech. . .M.D. Joshi, Director General, Department of Soil and Water Conservation, Kathmandu

1345 Inauguration. . .Prakash Bahadur Singh, Honorable State Minister of Forests, Kathmandu

1350 Welcome. . .John R. Wilson, Chief, Office of Agriculture, USAID/Nepal, Kathmandu

1400 Review of USAID/HMG Visiting Scientist Program for Nepal. . . Don Moore, Head of Training, RSI, Brookings, South Dakota

1420 Potential Needs of Remote Sensing in Nepal. . .R.S. Rana, Honorable Member, Nepal Planning Commission, Kathmandu

1430 Visual Analysis of Landsat: An Appropriate Technology for Nepal. . .Stan Morain, Director, Technology Application Center, Albuquerque, New Mexico

1500 Chairman's Summary. . .A.B. Rajbhandari, Secretary, Ministry of Forests, Kathmandu

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Chairman: S.B. Nepali
Director General
Department of Agriculture

Conveyor: K.B. Malla

1030 Interpretation Models for Using Landsat Data. . .Don Moore, Head of Training, RSI, Brookings, South Dakota

1115 The Form, Availability and Analysis of Landsat Data and the Geographic Information System. . .Mary DeVries, Computer Scientist, RSI, Brookings, South Dakota

1200 Example Remote Sensing Activities in Developing Countries. . . Tom Wagner, Environmental Research Institute of Michigan, Ann Arbor, Michigan

1245 Discussions and Comments

1300 Break

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Advisor, Ministry of
Forests

Conveyor: K. Upadhaya

1430 Land Classification in Nepal Using Landsat Imagery. . .DeVon Nelson, Land Evaluation Officer, Integrated Watershed Management Project, Department of Soil and Water Conservation, Kathmandu

1515 Summary of Landsat Interpretation of Forestry in Nepal. . .P.P. Shrestha, Photogrammetrist, Forest Survey and Research Office, Kathmandu

1535 Satellite Data and Interpretation of Vegetation. . .M.D. Rajbhandari, Senior Photogrammetrist, Forest Survey and Research Office, Kathmandu

1600 Landsat and Land-Use Change in Nepal. . .Stan Morain, Director, Technology Applications Center, Albuquerque, New Mexico.

1645 Discussion and Comments

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Director General
Department of Food and Agriculture

Conveyor: P.L. Maharjan

1030 An Agricultural Information System. . .William H. Wigton, United States Department of Agriculture; Economics, Statistics, and Cooperative Services; Washington, D.C.

1115 Drainage Analysis of Nepal Using Landsat Imageries. . .N.N. Vaidya and P.M. Joshi, Hydrology Section; Department of Irrigation, Hydrology, and Meteorology; and National Planning Commission Secretariat; Kathmandu, respectively.

1200 Interpretation of Landsat Data for Soil Resource Analysis and Protection. . .Bruce Worcester, Research Soil Scientist, RSI, Brookings, South Dakota.

1245 Physiographic Subdivision of Land forms of Nepal based on Interpretation of Base Maps and Landsat Imagery. . . P.L. Maharjan, Department of Agriculture, Soil Science and Agricultural Chemistry Division, Kathmandu.

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Deputy Director General
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Conveyor: S. Bhattarai

1430 The Use of Landsat Data in Geologic Mapping. . .A.S. Andrawis, Research Geologist and Training Officer, RSI, Brookings, South Dakota

1515 An Evaluation of Landsat Data for Geological and Mineral Exploration in Nepal. . .Kalyan Dev Bhattarai, UNDP/HMGN Mineral Exploration Project, Department of Mines and Geology, Kathmandu

1600 The Potential Contribution of Space Technology to Cartography in Developing Countries. . .Merrill Conitz, Director, Regional Remote Sensing Facility, Nairobi, Kenya

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Chairman: J.M. Tater
Raportour: K.D. Bhattarai

B. Hydrology and Agriculture Group -- Department of Irrigation, Panipokhari

Chairman: A.N. Ansari
Raporteurs: N.N. Vaidya (Hydrology)
P.L. Maharjan (Agriculture)
P.M. Joshi (Planning Commission)

C. Forestry Group -- Forest Research and Survey Office, Thapathali

Chairman: U.B. Shrestha
Raporteurs: M.D. Rajbhandari
P.P. Shrestha

Session 7 - May 4 p.m.

General Discussion

Chairman: M.D. Joshi
Director General
Department of Soil and Water Conservation

Conveyor: S. Bhattarai

1515 Geology Group Report. . .J.M. Tater

1530 Hydrology and Agriculture Group Report. . .A.N. Ansari

1545 Forestry Group Report. . .K.P. Prajapati

1615 Concluding Remarks. . .Mervin Stevens, Project Manager, FAO/UNDP, Integrated Watershed Project, Kathmandu.

1630 Conference Closing Address...M.D. Joshi, Director General, Department of Soil and Water Conservation, Kathmandu

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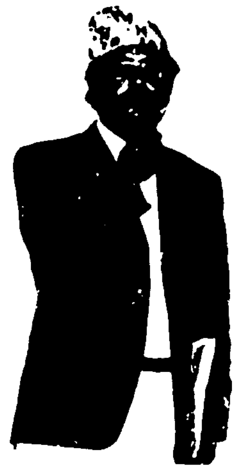
Honorable R.S. Rana
Nepal Planning Commission

M.D. Joshi
Soil and Water Conservation

A.B. Rajbhandari
Session Chairman
Ministry of Forests



S. Bhattarai
Session Conveyor
Soil & Water Conservation

J. Wilson
U.S. AID

D. Moore
RSI

S. Morain
TAC

Introductory Speech

M.D. Joshi[1]

Respected Chairman, Honorable State Minister of Forest, Distinguished Guests and Participants:

I would like to extend my hearty welcome on behalf of the Department of Soil and Water Conservation and myself to all the distinguished guests attending the inaugural ceremony of the Remote Sensing Workshop sponsored by DSWC in collaboration with USAID/RSI. I would confer my best compliments to the Honorable State Minister of Forest who has kindly spared his valuable time to inaugurate this ceremony and also to the Secretary of Forest who has been kind enough to chair the session. This workshop is second in a series in this country. The first workshop was held in February 1976 under the sponsorship of DSWC/USAID/UNDP.

I would like to take this opportunity to speak a few words on the introduction to the topic, its utility in Nepal and performance. It has been felt worldwide that natural resources are no longer plentiful and that improved management of these resources is the need of the day. As the supply of these resources dwindles and the number of environmental incidents grows it becomes evident that better information is needed to enable man to use his resources. Man's need for resource data is outpacing the capabilities of conventional survey and monitoring techniques. A few decades ago the resource managers had to depend entirely on ground observation to obtain the desired information. Periodic information is required to get the actual picture of the resource. Wise management of natural resources is determined by inventory, analysis, and operation. In the inventory the amount and quality of each type of natural resource that should be managed is determined; whereas, in the operation step each decision is implemented. While dealing with such renewable natural resources like crops, timber, and forage these resources are highly dynamic rather than static and call for periodic inventory known as monitoring. The need of monitoring is particularly important in the developing countries. It is becoming significant in the developed countries as well, as resource census formally taken every five of ten years are now becoming inadequate.

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[1] Director General, Department of Soil and Water Conservation, Ministry of Forests, Kathmandu.

For the last 50 years aerial photography has been used for various scientific and engineering fields to supplement the older methods. In Nepal, it was utilized only from 1964 and its application was limited to forestry alone; gradually it was used in other fields like agriculture, geology, irrigation, roads, and topographical survey. Recent aerial photographs are lacking in Nepal and complete photo coverage of the entire country is not available. Recently there is a program under a Canadian project to cover the whole country in 1:20,000 scale black and white photography. It will take 2 years to complete the photography involving 0.6 million dollars.

The various constraints in the availability of aerial photographs have been bridged over to a great extent by the advancement of satellite imagery. Compared to aerial photography, satellite imagery costs less, provides a comprehensive synoptic view, and perceives phenomena not observable from lower altitudes. Satellites that gather information about the earth involve a technique known as remote sensing. It senses the electromagnetic energy emitted or transmitted from various objects on the earth. The energy distribution not only differentiates the object from others, but it also points out its density, surface regularity, moisture content, and other physical and chemical properties. Color imagery can categorize conditions of vegetation, surface soil conditions, water depth, and other necessary information.

The Earth Resources Technology Satellite Program started with ERTS 1 on 23 July 72, continued with ERTS 2 on 22 Jan. 75 and in Feb. 75 was retrospectively named the Landsat program. This program has demonstrated that remote sensing from space is a practical means to supplement and improve present ground based and airborne methods of survey of natural resources. The data made available to different parts of the globe from a multispectral scanner on board are either in the form of photometric data, or in the form of computer compatible tapes. These data pertain to four different portions of the electromagnetic spectrum listed as bands 4,5,6, and 7. Each data pertaining to each band has its own characteristics and advantages in the interpretation works. These interpretation works will still be enhanced by the addition of one more band in the thermal infrared range. This addition will be made in Landsat C about the end of 1978.

As the technique of the visual interpretation of Landsat imagery does not differ very much from the photo interpretation technique, an experienced photogrammetist can handle the imagery interpretation within a short span of time. Practical application of imagery is made possible with some optical instruments, ground checks, and visual interpretation.

Remote sensing may be used as an aid to mapping land use and monitoring changes that are occurring in land use. Based upon this information, per capita demand for various kinds of natural resources like crops, timber, and water can be projected. This capability becomes still more prominent because demographic migration and demand creates collossal change in the requirements of natural resources. The rapidity with which land use information can be gathered from remote sensing helps detect problems early enough to allow timely changes to be made in planning strategy.

Satellite data could be used to estimate some crop types, densities and areas especially in the Terai and valleys. Using a historical data base and weather satellite imagery together with minor field studies, it may be possible to forecast crop yields. Landsat imagery may even be used for the estimate of extensive damage from diseases and infestation, both in crop and woodland.

For forestry purposes the satellite data could contribute to forest management by providing information on the extent and location of broad types of woodland. These data are relatively inexpensive and generally available with repetitive and recent coverage. With the aid of a computer, a comparatively detailed forest map could be generated by using satellite data in the form of computer compatible tapes. Data from satellites could be utilized even in the on-going forest type mapping project because aerial photographs serve as a complement to satellite imageries.

Forest encroachments of sizeable areas could be identified in the imageries and with the help of Landsat data, the present forest land use maps could be updated without incurring expensive projects like retaking of aerial photography and further photo interpretation.

Landsat imageries are almost ideal for obtaining micro-information of the large river basin by estimates of lake surfaces, seasonal and perennial river flow, and irrigation areas. Areal extent of snowcover, erosion problems, and flood hazards could be studied to identify and predict problem areas because satellite imageries offer a synoptic view of large areas on a repetitive basis.

For hydrological purposes sequential satellite surveying may be useful enough to correct and update the existing hydrological model. Similarily, dynamics of water pollution, that is the rate at which chemical and biological pollutants move and also their distribution and dispersion within the waterbody, can be studied.

For the purpose of geology and mining, satellite imagery can become an aid to assist geophysical surveys in the direction of minerals to detect major geological structures, to locate seismic activities, and to predict landslides, with the help of soil moisture and slope terrain.

As photographic data from the satellite are in a sun-synchronous orbit they afford several advantages to cartographers by providing a basis for mapping. Even more important, satellite imagery with narrow angle viewing systems are nearly orthographic, hence useful for making small-scale planimetric and thematic maps. These imageries are helfpul tools for updating existing maps also.

Regarding the utility of satellite imagery in Nepal, an introductory Remote Sensing Workshop was held in Kathmandu on 15-20 Feb. 1976 sponsored by Dept. of Soil and Water Conservation with the support provided by USAID/ UNDP. It also identified certain fields where immediate application could be made. However, as five participants had undergone training for three months at the Remote Sensing Institute in South Dakota, USA, they with other participants will find certain immediate applications of remote sensing techniques in Nepal. The FAO/UNDP/HMG Integrated Watershed Management has published the report "Land Inventory, Karnali-Mahakali Watershed" using Landsat imagery as its base. This inventory work is being spread all over the country. Hence, remote sensing is very useful in Nepal. It has been clearly elucidated by HMG Govt. of Nepal permanent representative to the United Nations, Mr. S.K. Upadhyaya, that the use of teledetection of satellites to obtain information for potential purposes, including the study of potential land use, potential agricultural productivity, erosion risk, etc., are of great interest to the developing countries like mine (The Rising Nepal Oct. 23, 1976).

The establishment of a Remote Sensing Center was recommended in Feb. 1976 resulting from Remote Sensing Workshop. Further encouraging developments were being followed in the form of provision of training in this field. Keeping active liaison with concerned Departments by RSI, South Dakota, eventually giving way to this present specialized workshop. The proposal to establish a Remote Sensing Center in Nepal is under process to be requested to USAID for rendering cooperation.

I hope this workshop will be helpful for the participants to get acquainted with the technique of remote sensing and its utility in Nepal.

Once again I would welcome all you distinguished guests and participants who spared their valuable time for this function and made this ceremony more charming.

Inauguration

Prakash Bahadur Singh[1/]

Distinguished Scientists, Ladies and Gentlemen.

It gives me great pleasure to have an opportunity to inaugurate this workshop on remote sensing. I hope this workshop will certainly help us to make important contributions on the use of satellite imagery and Landsat data for the assessment of the condition and extent of natural resources in Nepal. This technique can also be used as a valuable guidance for planning on our large-scale natural resource development and utilization projects.

As this subject is highly technical and specialized, it would not be wise for me to make precise comments. But still, I can tell my technicians that the knowledge of remote sensing would be very useful for forestry, agriculture, soil and water conservation, geology, mining, hydrology, rural and urban planning, cartography and many other subjects. Thus, I tell my technicians to learn the practical use of this technology that will be applicable for our country from the scientists of friendly countries who are present here in this workshop.

Our country lacks resource information for various development projects. It is now high time for us to use the available satellite data and imagery for resource interpretation and mapping. A considerable archive of aircraft and satellite data exists within the country. The aircraft data are useful for a detailed observation of parts of Nepal; whereas, the satellite data cover very large regions. Using these data simultaneously together with appropriate ground observations can surely provide resource assessments for our needs.

Under the dynamic leadership of His Majesty the King, Nepal is progressing its activities for protection and proper utilization of the natural resources.

His Majesty's Government has already recognized the necessity of opening a Remote Sensing Center in Nepal and the necessary process towards this direction is underway. Your ideas on the application of remote sensing in different fields, in this workshop, will help us to more fully identify the viable uses of remote sensing.

[1/] Honorable Minister of State for Forests, Kathmandu

To our friends who have come here from other countries, I extend my hearty welcome and hope that you will find your stay in Kathmandu both pleasant and useful. I hope that the exchange of your scientific ideas and experiences with our technicians will be of great value for us.

Lastly, on behalf of His Majesty's Government, I would like to thank the organizers and all participants of the workshop and wish every success of this workshop.

Thank you once again for inviting me to this occasion.

Welcome Speech

John R. Wilson[1/]

Honorable Minister, Secretariat, members of the Planning Commission and friends. I am very happy to be here this afternoon for several reasons. One of the first is that I am very happy to see Nepal utilizing the new technology of remote sensing that is developing in other countries and can be used to great advantage here. The second reason is a personal reason. About 14 to 15 years ago I was assigned to AID, Washington, for three years. It was right at the beginning of the time when AID's worldwide research project was getting started, and while I had nothing to do with this project, I did have alot to do with the development of a whole program. It gives me a great deal of pleasure to see something I helped start, in a sense, being used here in Nepal. I am particularly pleased that there are two other projects of the same kind being introduced into Nepal - one with the Ministry of Agriculture, the agriculture sector implementation project, and the other also with the Department of Agriculture, the energy resources for agriculture being administered by the soils department and the Peace Corps. So it gives me a great deal of pleasure to find that something I helped start years ago is having an effect here in Nepal. Lastly, it gives me a great deal of pleasure to welcome you to a meeting such as this on behalf of our organization and also on behalf of RSI. I hope that as many as possible will be attending the meetings over the next four days.

Remote sensing is not a new tool, at least not for research resource planners and managers. Aerial photography has been with us for many years. Remote sensing is just another part of developing a sensitivity to what is happening in other places which may affect our country, national environment, and the world. Remote sensing in the sense of aerial photography has been around for almost twenty years. It gives an excellent opportunity to see at close hand what is going on. But the problem is that as time goes on we get so interested in the individual trees that we forget what the whole forest looks like. We get so interested in the small things that it is very difficult for us to plan how to take care of the small things in relation to the totality of nature that we are concerned with.

[1/] Chief/Office of Agriculture, U.S. Agency for International Development, Kathmandu.

I am glad to find a member of the Planning Commission is present this afternoon. As a part of the plan, it was pointed out that around 4,230 people who should be here to work with the implementation of the development plan do not exist. We would reed that many more people to do the things that everyone has planned. Therefore, anything that we do which will make use of a technology that helps us to do things faster and a little better without the use of many people is bound to help the situation which is present here in Nepal. Major studies in development require that we review and analyze the entire spectrum of things that are going on in order to achieve an overall planning and understanding capability. Then only can we develop the individual sectors that must be developed. This alternative now exists. We can use the space sensors of remote sensing to see the whole country. This system provides a synoptic large-area view which allows the resource assessment of the whole country, which in turn enables us to observe the changes in the essential resources available to us. This provides the understanding to design and implement detailed studies in regions of high potential to maximize the benefits received from natural and manpower investments from the limited pool of resources which exist in Nepal. The capability exists to maintain the development resulting from your endeavors. Operational systems are now available which can continuously acquire the data you need. With the launching of Landsat 1 in 1972, Landsat 2 in 1975, Landsat 3 in 1978 and the projections for Landsat 4, the space shuttle, Stereosat and many additional satellites comes continued improvement on resolution, coverage, and data interpretation.

The United States has been working in space technology for a long time, but as more applications of these new techniques are being developed other countries are also becoming involved in the development of space vehicles and sensors. Two of Nepal's neighbors, India and Bangladesh, are developing capabilities in the operational use of remote sensors systems. Bangladesh for example, has a national program to train personnel in assessing and monitoring resource systems as does India. India will soon construct a receiving antenna to receive satellite data. The receiving antenna will be able to cover Nepal also. Nepal is expected to be able to use the information developed and retrieved by these systems. In fact Nepal is among the forerunners, having sent some of their scientists to acquire the skills needed to utilize the available data and having shown favorable enthusiasm and consideration to the development of a National Remote Sensing Center. This center should and can be used as a means of acquiring basic information vitally necessary for program planning, progress monitoring, and basic support of all resource projects.

When the various ministries and departments of His Majesty's Government of Nepal learn to use the equipment and data archives, it will provide a method for analyzing problems using a multidisciplinary approach. It will provide a forum for the study of transnational resource problems existing in Nepal, some of which affect your neighbors. However, the development of a center does not mean that we can change everything. We cannot. We must not disregard our traditional and well-tested use of ground surveys, aircraft photographic missions, and other methods of acquiring detailed information. But we must optimize the results from these costly and time-consuming methods. We must evaluate and implement traditional approaches using the space data where applicable to conduct studies, and make plans which will help in the development of resources in Nepal for the benefit of Nepal's people.

So again, I wish you a welcome to this session and hope that you benefit from it.

Review of USAID/HMG Visiting Scientist Program for Nepal

D.G. Moore

Mr. Chairman, Honorable State Minister of Forests, Mr. Joshi, Mr. Wilson, Distinguished Guests and Participants:

It has been the pleasure of the Visiting International Scientist Program (VISP) at the Remote Sensing Institute (RSI), South Dakota State University, sponsored by the Directorate of Science/Office of Science and Technology, United States Agency for International Development, to work with your scientists and the administration of His Majesty's Government of Nepal. The project entitled "Design and Implementation of a Training Program of Applied Technology in Remote Sensing for Nepal - Contract AID/ta-C-1468" had the following as project objectives and guidelines.

Objectives:

* To provide administrative personnel with an understanding of the economic and technological feasibility of applying remote-sensing technology to the resource and environmental problems of their country or region.
* To help scientists interested in applying remotely sensed data and aerospace technology design, implement, and administer programs concerned with the exploration, development, management, and conservation of their natural resources.
* To train scientists in laboratory and field techniques so they may carry out projects of special importance to their regions.
* To provide the administrative and technical training required to develop, implement, and maintain an operational remote-sensing program.

Guidelines:

* Stress application of remote sensing, emphasizing practical application rather than academics.
* Employ data from home regions.
* Prepare illustrative materials useful at home in seminars and workshops for sharing the participant's knowledge with concerned countrymen.
* Supply a base of satellite photographic and digital data, interpretation maps, appropriate statistics, and development potentials to the host country for immediate use.

Assistant Director and Head of Training, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota.

* Provide experience in using equipment and interpretation techniques with varying levels of equipment sophistication and costs.
* Stress training to equip participants with skills to establish their own training program at home.
* Build liaison between visiting scientists and experts from around the world in the field of remote sensing.

In pursuit of these objectives, personnel from VISP and HMG had initial contact in May 1977 through a visit to Nepal by myself, Principle Investigator, and Mr. Myers, RSI Director. Most resource and planning agencies were visited to develop a mutual understanding of resource investigation needs of Nepal and of the potential for applying remote sensing techniques to meet those needs. Mr. M.D. Joshi and staff, Department of Soil and Water Conservation, as well as the many HMG Government officials, were instrumental in selecting resource problems and HMG resource scientists to evaluate the techniques of remote sensing in Nepal.

An excellent group of scientists including M.D. Rajbhandari and P.P. Shestha, Department of Forestry, Ministry of Forests; P.M. Joshi, National Planning Commission Secretariat; N.N. Vaidya, Department of Irrigation, Hydrology, and Meteorology, Ministry of Food and Agriculture; and K.D. Bhattarai, Department of Mines and Geology, Ministry of Industry and Commerce; were selected to visit the facilities of RSI and evaluate the Landsat technology.

The initial training included lectures and demonstrations demonstrating the technology and instrumentation of remote sensing. Practical image interpretation exercises in the laboratory and the field were conducted for experience in the interpretation methods useful for Landsat, SKYLAB, and aircraft images. A field trip through South Dakota, Colorado, and Nebraska provided visits to many state and federal action agencies who are using remote sensing in the United States.

Landsat and SKYLAB data of the various spectral wavelengths and available dates for Nepal were secured from the EROS Data Center, Sioux Falls, South Dakota, the world archive of Landsat data products. These transparencies, prints, and digital tapes were appropriately enhanced and formatted for use and evaluation by the Visiting Scientists. The remainder of their three-month visit included their study and evaluation of remote sensor data in their respective disciplines. Where feasible, resource maps were prepared by interpreting the remote sensing data. These preliminary maps were not solely based on remote sensing interpretation since all the Visiting Scientists were well experienced in the field and had excellent local knowledge of the area for which they were evaluating. These preliminary maps can be used very effectively as the first stage of a multistage investigation for reconnaissance mapping. They are meant to provide a broad overview of the whole or a large region of the Kingdom of Nepal and not to provide great detail for any one area.

Each Visiting Scientist documented his comments concerning the applicability of Landsat to Nepal resource investigations, described the procedures used in his mapping, and produced a final map and report product. A summary report was prepared by all and was presented at an International Conference on Remote Sensing in Manila. Mr. Bhattarai also produced a paper of high scientific merit which has been submitted for journal publication.

Reports and Publications Produced by Visiting Scientists

Vaidya, N.N. 1977. An Evaluation of Landsat Data for Hydrologic Investigations in Nepal. SDSU-RSI-77-14, Remote Sensing Institute Technical Report. 17 pp + maps.

Joshi, P.M. 1977. Application of Remote Sensing by the Landsat Satellite in Resource Studies of Nepal. SDSU-RSI-77-15, Remote Sensing Institute Technical Report. 18 pp + maps.

Vaidya, N.N. and P.M. Joshi. 1977. Drainage Analysis of Nepal Using Landsat Imageries. SDSU-RSI-77-16, Remote Sensing Institute Technical Report. 8 pp + maps.

Bhattarai, K.D., N.N. Vaidya, M.D. Rajbhandari, P.P. Shrestha, and P.M. Joshi. 1977. Review of the Training Program for the Nepalese Resource Scientists. SDSU-RSI-77-18, Remote Sensing Institute Technical Report. 27 pp.

Rajbhandari, M.D. and P.P. Shrestha. 1977. An Application of Landsat Imagery in Forest Development in Nepal. SDSU-RSI-77-19. Remote Sensing Institute Technical Report. 26 pp + maps.

Bhattarai, K.D. 1978. An Evaluation of Landsat Data for Geological and Mineral Exploration in Nepal. SDSU-RSI-78-03. Remote Sensing Institute Technical Report. 35 pp + maps.

Bhattarai, K.D. and A.S. Andrawis. (submitted). The Applicability of Landsat Imagery for Mineral Exploration in Nepal. Submitted to American Society of Photogrammetry.

Andrawis, A.S., D.G. Moore, K.D. Bhattarai, N.N. Vaidya, M.D. Rajbhandari. P.P. Shrestha, and P.M. Joshi. 1978. An Evaluation of Landsat Technology for Operational Use by Nepal Resource Agencies. Twelfth International Symposium of Remote Sensing of the Environment, April 20-27, Manila, The Philippines.

The original reports and maps are available from the authors. Many of the maps are displayed as posters during this workshop. A condensed version of the reports are generally provided in this workshop by the authors.

During the training period and my various visits to Nepal, help was provided for the conceptual development and initial planning of the Nepal Remote Sensing Center. I urge your serious evaluation of remote sensing as it applies to your specific needs in acquiring basic resource data and in monitoring changes in the Nepal landscape. This workshop has been designed to present example interpretation techniques and to evaluate and apply those techniques to Nepal. Through the five scientists who have trained at RSI, the most careful and capable evaluation for their specific discipline specialities has been completed. Please address questions on topics for which you have specific concerns to them or the other available specialists.

As your remote sensing center develops, continue to use these experts to guide yourselves and your associates in appropriate techniques for the use of the data. They are now very competent training officers and will be of extreme value in advancing the techniques of remote sensing in Nepal.

Lastly, on behalf of the delegation from the United States, I extend my sincere appreciation for your excellent hospitality and friendship, and for arranging this workshop. The opportunity of visiting your beautiful Kingdom of Nepal and of working with you is truly a pleasure.

POTENTIAL NEEDS OF REMOTE SENSING IN NEPAL

R.S. Rana[1/]

It is indeed a great honor and privilege for me to be here today with the opportunity to address this cabinet. Unfortunately it so happens that I am not an expert in remote sensing. I start with this disclaimer not because disclaimers are usual in opening remarks, especially at a workshop such as this, or because of any false sense of modesty. The plain fact is that what I have to say is nothing more than my own broad impressions about remote sensing techniques in resource management and developmental programs, and the overall development strategy.

One eminent American historian has pointed out that everyone has his own world view of what is good and desirable. This is usually epitomized by expressive words. In this twentieth century this seems to be epitomized by the key word "development". We have also been engaged in this global task by slightly over two decades. We have realized that development is both urgent and difficult. Understandably, this has led to much frustration.

One of the causes of these disappointments has been that our planning at best is based on inadequate knowledge of our resources. As such, our planned approach in many areas of resource development and management tends to become like treating the symptoms rather than the disease. We cannot afford to do this any more. The need for rapid development has been more urgent now than ever before because of increased awareness and rising expectations. It is unrealistic of developing countries like ours to base the foundation for our development on something which is entirely imported. Development must find its basis on some resource which we already have. Land, water, forests, soil, and other natural resources are systems that must become the foundation for our development. Without fully understanding these resources, our developmental strategy would have to be formulated in blind ignorance of some of the vital aspects of our resource base. Hence, there is a great need to have a full understanding of these things and to do our developmental strategy upon this knowledge. It is not that we are not making an effort in this area. We have come a long way since the time when we launched our first Five Year Plan in 1956.

[1/] Honorable member Nepal Planning Commission

We had very little knowledge of many of our vital resources such as cultivated land, forests, etc. Since then much emphasis has been placed in all development plans to review information based on our resources. This has not been easy partly because of the difficulties imposed by the mountainous topography about which we are all familiar. In addition, since our resource information gathering has had project orientation, our efforts in this area seem to have been in bits and pieces. Hence the need to approach this problem in a more systematic manner than what has ever been is by applying new technology to fit to our needs. In my mind one such technology is remote sensing. It is common knowledge that space exploration has advanced along two major directions. The first is concerned with outward exploration which encompasses efforts to reach out into space to investigate the physical nature of the solar system of interplanetary space and so on. The other is concerned with looking back towards the mother planet earth from space. Remote sensing belongs to this kind of exploration. In broader terms it presents the joint effort of using remote sensors, data processing equipment, information theory, processing methodology, space/aircraft efforts, and coordination with the earth science disciplines for the purpose of carrying out area or space surveys of the resources of the earth's surface or just below it. It is concerned with the direct application of everything with space technology for the betterment of man. This has opened new opportunities for exploration, management, and development. Hence remote sensing is of great relevance to the developing countries like ours if it can be properly used for speeding up of our development objectives.

Remote sensing is not an entirely new enterprise. Indeed a few ministries and departments of His Majesty's Government have already been using these techniques in a number of the programs. What is needed now is to make more efficient use of this technology in a systematic and coordinated manner. Hence, the idea of setting up a Remote Sensing Center here is both timely and appropriate. In closing I want to thank everyone for this workshop and for inviting me to this occasion. I have no doubt that the deliverances in the next few days will be beneficial. I wish the workshop all success. Thank you.

VISUAL ANALYSIS OF LANDSAT: AN APPROPRIATE TECHNOLOGY FOR NEPAL

S.A. Morain[1]

INTRODUCTION

Nepal's 139,860 square kilometers are among the most rugged and inaccessible in the world. The needs and desires for resource survey and management are hindered at every turn by the inability to place sufficient people in the field or to collect all the appropriate data. Surely there are no nations in greater need of a satellite's "bird's-eye" view than those bordering and comprising the Himalayan region.

In the United States, New Mexico is a developing region that shares many common problems with Nepal. It is an area of approximately 314,944 square kilometers in the desert southwest. The region is sparsely populated but is rich in natural resources. An abundance of fossil, nuclear, geothermal and solar energy resources, combined in a region of little water and having an intricate pattern of land ownership provide all the ingredients for land-use problems, not to mention the associated socio-economic consequences of management decisions. There are urgent needs in the region for resource inventories on vegetation, grazing impacts, soil erosion, archaeological ruins and timber volumes, to name a few. There are also legal requirements for strip mine reclamation surveys, air and water quality monitoring, and a multitude of environmental impact assessments. As is common throughout the Rocky Mountain Region, data requirements far exceed the data currently available.

In many respects the economy of New Mexico is on a par with those of other developing nations. Large populations of native Americans and Chicanos earn less than the average American's annual income. They are often situated in inaccessible areas and thus are

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difficult to service in terms of their social, medical and economic needs. Landsat is among the many appropriate technologies that may alleviate their disadvantaged position by giving them a better view of their resource base. It may be instructive to review how this new technology has been employed in New Mexico in an effort to assess its transferability to Nepal and others in the international community.

Activity Spectrum for Technology Transfer

The steps involved in transferring Landsat technology are summarized in Figure 1. Two primary lines of consideration are involved: the technical approaches toward solving a resource information need, and the economic activities that must be evaluated to ensure operational efficiency. In the United States there has been rapid adoption of digital image processing techniques, but there is still widespread use of standard visual and analog interpretation approaches. Delineation and categorization of appropriately scaled Landsat images (or transparencies) are the primary activities in most visual interpretations. These, together with overlays of collateral data in map or numerical form, constitute the basic output products which must then be field verified for accuracy.

On the economic side, the primary activities include: 1) an analysis of the specific interpretation strategy and the full cost of its implementation; 2) an estimate of the user's need for information derived from Landsat image analysis; 3) the rate at which the user community is likely to adopt the new technique, if developed; 4) the implementation of demonstration projects; and finally, 5) an estimate of benefit-to-cost in social or monetary terms.

In practice we have discovered that most application projects are researched and developed in purely technical terms, without regard for their economic implications. However, our work in New Mexico has been sufficiently documented to allow some preliminary evaluation of costs.

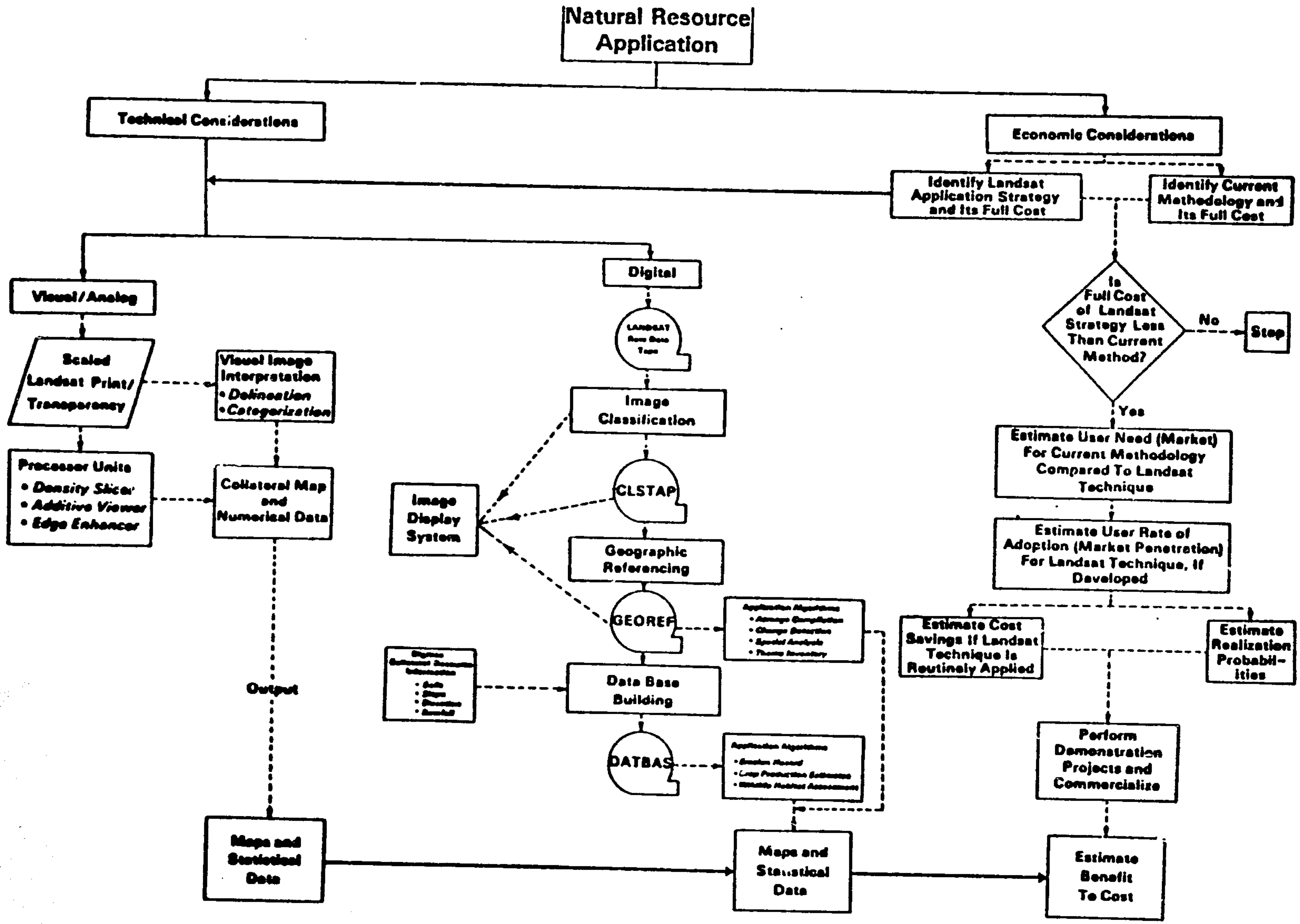

Figure 1. ACTIVITY SPECTRUM FOR LANDSAT TECHNOLOGY TRANSFER

COVER TYPE MAPPING

Over the past few years the Technology Application Center (TAC) has produced three detailed vegetative cover maps at differing scales and for different user agencies. Table 1 lists the basic parameters of each project. The data indicate that per square km costs decline rapidly as the size of the project area increases. Moreover, the data indicate that detailed and meaningful categories can be mapped even from the smaller scales normally associated with Landsat visual interpretations.* All three maps were produced using visual interpretation techniques and all were prepared by the same general methodology.

Mapping Methodology

Work began on the vegetation map of New Mexico with a review of existing maps. The detail and categorization of the maps varied according to the specific needs of the originating agencies. Although useful for their intended purposes, the maps were not intended for broader use. In some cases, data sources were not indicated; in others, the categories were ill-defined; and in all cases, the accuracy of boundary line placement was unknown because a photographic base was not used.

All of these problems were overcome by using satellite imagery from Landsat as the mapping base. Boundary placement between types at a scale of 1:1 million is accurate enough to meet mapping standards and this has been verified subsequently by comparisons of area measurements to those obtained by official sources.

The initial interpretation consisted of drawing boundary lines onto a mylar overlay of New Mexico. Topography and image tone were used as the basis for delineation. No attempt was made at this stage to type the vegetation or classify land uses. When each image had been studied and interpreted on the overlay, the map was re-examined to make sure that boundaries crossing from one image to another were consistent.

*The number of categories and their level of abstractness will depend, of course, upon user requirements.

The next step involved categorizing the delineated areas as to their vegetative cover, land-use and landform. Decisions on vegetative categories were made on the basis of field experience together with knowledge of ecological relationships in the southwest. Maps from existing sources were also consulted.

The compiled map was then field checked. Survey teams traveled most of the major and secondary highways in the state taking note of the vegetation types and boundaries. The boundaries were found to be accurately placed, particularly in forested regions where cover type changes proved to be within a few hundred meters of their plotted positions. Boundaries plotted between transitional vegetation types were less accurate. The accuracy of categorization was not as great as that for boundary delineation. Although correctly delineated, several areas were found to be incorrectly classified, and in some cases entire categories were added or deleted.

After field revisions were incorporated, the compiled data were drafted onto a 1:1 million scale base map. Area measurements of each vegetation type in each country were then made by using an electronic area planimeter. The results of that tabulation are given in Table 2.

A more detailed map of vegetation in the Socorro area was performed in exactly the same fashion (Figure 2). The mapping base, however, was U-2 color photography flown at a nominal scale of 1:112,000. After compilation, the data were reduced to 1:126,720 to match the highway base map for Socorro County as produced by the New Mexico State Highway Department. Figure 2 has been field checked and reviewed by two separate federal agencies for accuracy.

Mapping Costs

Table 3 provides detail on the costs for preparing the three maps listed in Table 1. The data indicate that the tasks of image interpretation and map compilation takes far less time than field checking or map drafting. The most expensive step in the preparation of resource maps by visual analysis is the field verification of

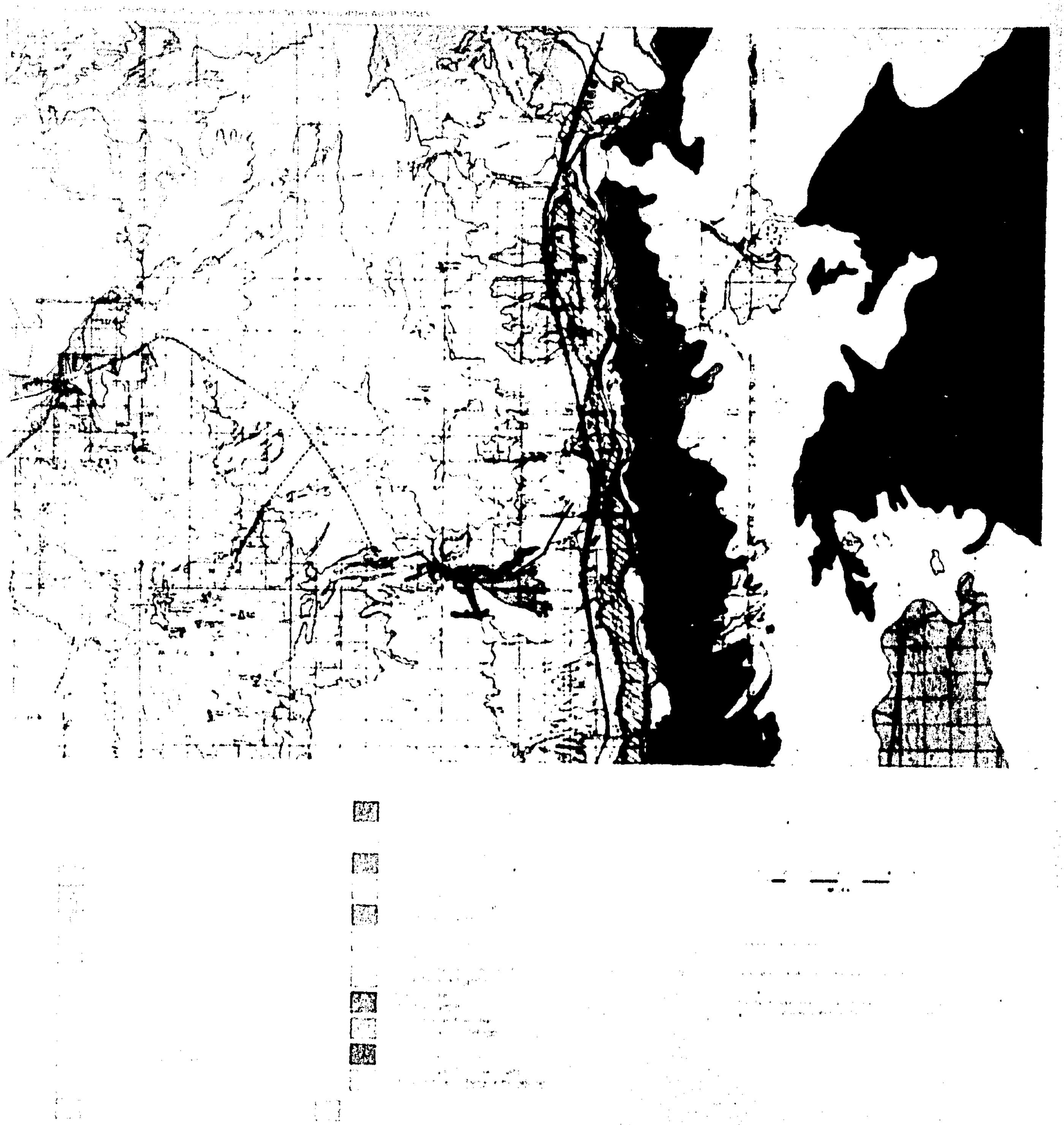

Figure 2. Vegetation Types of the Socorro Area, New Mexico. (Original in color).

TABLE 1

Vegetative Cover Maps of New Mexico Produced with Landsat and U-2 Imagery (See also Table 3)

Locality	Area in Sq Km	Type of Imagery Used	Categories	Total Cost/ Sq Km ($)
Statewide	314,944	1:1 million Landsat color transparencies	21	0.05
Middle Rio Grande Council of Governments	36,000	1:250,000 Landsat color prints	16	0.11
Socorro Area	3,108	1:112,000 U-2 color prints	25	0.40

TABLE 2

Major Vegetation Types and Extents in New Mexico from Landsat Measurement

VEGETATION	% of State Area
Forests and Woodlands	
Southwestern spruce/fir *(Picea/Abies)*	1.7
Pine/Douglas fir *(Pinus/Pseudotsuga)*	7.2
Pinon/juniper *(Pinus/Juniperus)*	12.5
Juniper oak *(Juniperus/Quercus)*	1.5
Cottonwood/willow/tamarisk *(Populus/Salix/Tamarix)*	0.9
Shrublands and Shrub Savanna	
Great Basin sagebrush *(Artemisia)*	2.5
Saltbush/greasewood *(Atriplex/Sarcobatus)*	0.7
Creosote bush/tarbush *(Larrea/Flourensia)*	10.2
Scrub oak *(Quercus)*	0.5
Grasslands and Steppes	
Grama/galleta steppe *(Bouteloua/Hilaria)*	20.8
Grama/tobosa/mesquite shrub steppe *(Bouteloua/Hilaria/Larrea/Prosopis)*	11.6
Alpine meadows	0.1
Intermontane meadows	0.1
Grama/buffalo grass "shortgrass prairie" *(Bouteloua/Buchloe)*	10.4
Yucca/cholla *(Yucca/Opuntia)*	1.3
Cultivated	
Irrigated agriculture	≈2.5
Dry-land agriculture	≈2.5
Orchard crops	0.1
Barren	
Playa	0.3
Sand dunes	0.3
Major lakes and reservoirs	0.2
Other - Urban areas and vegetation complexes	12.1
Total	100.0

TABLE 3

Time and Approximate Costs for Producing Vegetative Cover Maps from Landsat and U-2 Images in New Mexico 1975/77

	Level of Effort				
	Person Months	($) Cost	Materials($)	Total Cost($)	Cost/sq km ($)
New Mexico (state)					
Image Interpretation	.5	1150	300	1450	.003
Map Compilation	.5	1150	50	1200	.003
Field Checking*	2.0	4600		4600	.02
Drafting**	2.0	4600	150	4750	.02
	5.0			12,000	.05
Middle Rio Grande Council of Governments 4 county area					
Image Interpretation	.5	519	250	769	.03
Map Compilation	.5	519	50	569	.02
Field Checking*	1.0	1038		1038	.04
Drafting**	0.5	519	50	519	.02
	2.5			2,895	.11
Socorro Area					
Image Interpretation	.12	200	75	200	.07
Map Compilation	.05	80	25	200	.07
Field Checking*	.25	400		400	.13
Drafting**	.32	400	20	400	.13
	.74			1,200	.40

* Includes travel expenses and per diem.
** Includes preparation of black plate, grey plate, color separation plates, text editing, map editing.

Figure 3. SOIL EROSION POTENTIAL FOR BERNALILLO COUNTY, NEW MEXICO

classification units. However, by using Landsat this cost can be greatly reduced because the imagery helps us identify areas of greatest uncertainty or complexity.

The contribution of Landsat as an appropriate technology in resource mapping is in the reduction of time and cost to compile data. For example, a map of the vegetation of New Mexico prepared by traditional techniques would require well over one person-year. If other costs of production remained the same, the increase in costs per square kilometer would almost triple from 0.05 to 0.14 dollars. Additional costs savings can be realized if digital data processing rather than visual analysis techniques are employed. The use of digital processing for classification, area measurement and other inventory procedures significantly reduces the expense of field verification by assisting in the pattern of deployment and allocation of field time and personnel.

SOIL EROSION ASSESSMENT

One of New Mexico's critical problems is the abatement of soil erosion. As might be expected in a sparsely vegetated, low rainfall region, wind and water erosion represent a serious threat to agricultural endeavors. These natural processes, however, have been magnified to such an extent through overgrazing and other disturbances that the federal government has required each state to assess its soil erosion problem.

Our location in the southwestern arid and semi-arid belt, together with our heavy reliance on a grazing economy, means that we must concentrate on reducing sediment from gully and sheet erosion. Before we can effectively combat these sources and implement a program for accelerated corrective and preventive management practices, we must inventory the types, severity, and distribution of erosion throughout the state.

Mapping Methodology

Musgrave's equation, modified from the Universal Soil Loss Equation, provides a means for estimating sheet erosion for a given soil type, if one knows the inherent erodability of that soil, the amount of vegetative cover, rainfall, percent of slope and length of slope (Equation 1).

$$E = KCR \frac{(S)^{1.35}}{10} \frac{(L)^{.35}}{(72.6)}$$

where E = Sheet erosion in tons/acre/year
K = Soil erodability value
C = Cover factor (Crop Management Factor)
R = Rainfall index
S = Land slope in percent
L = Length of slope in feet

All of these values are available for the soils of New Mexico except the cover factor (C) which varies through time depending upon land use. The C factors range from a high of 1 for essentially bare soils to a low of 0.001 for a closed canopy forest. Erodability values range from a low of 0.03 for the Larimer soil to a high of 0.64 for the Karro soil. Most values are in the range of 0.2 to 0.4. The higher the value, the greater the prospect for erosion to occur. Degree and length of slope can be obtained from readily available topographic maps or from field measurements, if maps are not available. The longer and steeper the slope, the greater the prospect for erosion. Similarly, rainfall factors are available for the state.

The missing factor of cover type can be obtained from either visual or digital analysis of Landsat data on a once-only, annual, or seasonal basis. Interpretation of photomorphic regions observable on the imagery provides a delineation of vegetative cover types, and by inference, the major soil association boundaries. By further reference to existing soils and vegetation maps, like those previously discussed, a more detailed knowledge of specific soil and vegetation types occurring in a particular photomorphic region can be obtained. Once the soil type and vegetation are estimated, their respective K and C factors can be applied to estimate soil loss.

This methodology was altered somewhat for use in New Mexico. The U.S. Soil Conservation Service supplied soil erosion class delineations which were superimposed onto 1:250,000 scale Landsat color prints. These delineations were then visually compared to photomorphic regions on the imagery and modified accordingly. The areas were then measured with an electronic planimeter. An example of the results from Bernalillo County is given in Figure 3.

CONCLUSIONS

Use of Landsat technology for resource analyses in New Mexico has been in progress since 1973. For the past five years we have been developing technical approaches to better map vegetation, soils, land-use, water resources and minerals. Some of these approaches focus on visual analysis and, indeed, these appear to have the lowest unit area costs and the greatest prospect for near term adoption by state and local government agencies. Other applications are focusing on digital analyses, as for example, our studies in coal surface mine reclamation and in non-destructive testing techniques for archaeology. These are far more recherché and, hence, it is too soon to evaluate their potential benefits.

Less attention has been given to the economic considerations of transferring Landsat technology. For visual analysis of vegetative cover types we have identified the cost of Landsat applications and have begun a comparison with the cost of current methodologies (see Figure 1). For several other resource applications we know that the total cost of Landsat technology will be less than the costs of current methods. Benefits-to-cost will be more difficult to assess, if these must be expressed solely in monetary terms.

Session 2

THE DEVELOPING REMOTE SENSING TECHNOLOGY

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Session Chairman
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Session Conveyor
Soil & Water Cons.

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APPLICATION OF REMOTE SENSING BY THE LANDSAT SATELLITE IN RESOURCE STUDIES OF NEPAL[1/]

Puspa Man Joshi[2/]

INTRODUCTION

In 1956, Nepal initiated the First Five-Year Plan to strengthen the Nation's economy. Nepal is now in the third year of the Fifth "Five-Year Plan". The second Five-Year Plan, which was planned for only three years, was designed to gather information of the resources of Nepal. However, substantial financial resources have been allocated for collecting resource information in every plan. All the economic plans launched in Nepal offer a big share of investment for agricultural development, along with special attention to the development of other sectors like industry, transportation, and education. There is no doubt that this planned effort has contributed to the growth of the economy of Nepal, but at a slow pace in comparison to other countries.

One reason for this slow pace of development is lack of sufficient resource information. Nepal is a country characterized by inaccessibility. Resource investigations using methods requiring intensified ground surveys are difficult because of the lack of communication paths in the rugged terrain. This results in non-efficient management and exploitation of scarce resources. To make efficient use of these resources, adequate inventories must be prepared for an understanding of the regional potentials and limitations. Only then can cost-effective resource development which maximizes return from investment occur. Educational programs prepared by our own competent scientists who understand the specific resource problems can then be initiated.

In the past, the resource inventories have been achieved either by ground survey, or by aerial photography taken at low altitudes. This has been advanced by the innovation of satellite remote sensing techniques.

[1/] Condensed from report by Puspa Man Joshi, SDSU-RSI-77-15, Remote Sensing Institute, South Dakota State University, Brookings, SD 57007. Copies of maps have been excluded and are available from the author.

[2/] Section Officer, National Planning Commission Secretariat, Kathmandu, HMGN.

Ground, aircraft, and satellite studies each have their own characteristics. Ground surveys produce accurate, detailed information but are restricted in regional scope due to manpower limitations. The aircraft and satellite surveys cover increasingly larger areas. As the size of study area increases, the resolution decreases. A combination of the three levels is required to repetitively and timely map and monitor the resources of Nepal.

TECHNIQUES OF REMOTE SENSING

The launching of Landsat-1 in July 1972 and Landsat-2 in January 1975 greatly aided the technology of remote sensing. Each of these satellites consists of two sensor systems - a Multispectral Scanner (MSS) and three Return Beam Vidicon (RBV) cameras - plus two Data Collection Systems (DCS) receivers and two Video Tape Recorders. The MSS was designed to acquire true radiometric data; whereas, the RBV was for geometrically correct data.

The RBV in Landsat-1 stopped functioning within weeks after Landsat-1 was launched and the RBV in Landsat-2 is operated primarily for equipment testing purposes, and is being held in reserve for possible emergency use. This does not present a severe deficiency for geometric qualities of data since the MSS has been found to provide data suitable in cartography to scales as large as 1:250,000.

The MSS measures the reflected radiation from the surface of the earth and records the intensity of this energy by different objects in four discrete wavelengths of the electromagnetic spectrum. Accordingly, Landsat data are prepared in four MSS bands - 4,5,6, and 7 (0.5-0.6 μm, 0.6-0.7 μm, 0.7-0.8 μm, and 0.8-1.1 μm, respectively). Landsat imageries of these different bands have the following general interpretation characteristics.

Band	Characteristics
4 (green)	Useful to study turbidity in waterbodies, to distinguish green vegetation from other surface cover and to identify geological structure.
5 (red)	Useful for defining cultural and topographical features and for classifying different types of green vegetation with full ground cover. Topographic expression is especially apparent under low sun angle.
6 (reflective infrared)	Useful to identify differences in land use and to sense the amount of green biomass in vegetation.
7 (reflective infrared)	Useful for land-water delineation, and soil-crop contrast.

The radiation from the earth's surface is measured and recorded by MSS with the signal transmitted to a ground receiving station when in view of the satellite or recorded on the video tape recorder for storage until a receiving station is within the field of view of the satellite. The data received at the ground receiving station are later processed in two ways - imageries for visual interpretation and computer compatible tapes (CCT) for computer processing. One image, or one CCT, covers an area of 185 x 185 kms (34,000 sq. kms). There are six receiving stations presently operating. Three of these are in the United States, one each in Canada, Brazil, and Italy, and a receiving station is also under construction in Iran. Others, to provide complete global coverage, are in the planning stage. Each of these stations can receive the satellite data for an area within a 3000 km radius. Nepal does not fall within the range of any receiving station, thus Landsat-1, which cannot store the data due to the failure of its recorders, is of no value for Nepal except for the data already available. Landsat-2, however, has operational tape recorders which can provide data for Nepal. Thus, the recent Landsat data available for Nepal are only from Landsat-2. Plans for additional satellites - Landsat 3 is planned for 1978 - will assure continuous satellite operation in the future. However, Nepal may have to take an appropriate action to assure that data will be acquired when needed.

One of the important advantages the imageries have is that they can be obtained every 18 days, because Landsat makes 14 orbits a day scanning the earth from an altitude of 920 km (575 miles) in circular, near-polar orbit, and crosses the equator at an angle of 99^{0}. The 14 strips of the earth's surface covered each day by Landsat are successively 2800 km apart at the equator. Each satellite scans a strip 185 km wide and the next day it passes over the area at the equator 170 km west of that same strip. This provides 14% of overlap between two scenes nearby at the equator. This overlap increases with the increase of latitude. So imageries of Nepal have an overlap of about 25%. The repetitive coverage of the same area by Landsat every 18 days enables the interpreter to obtain up-to-date data as well as getting a repetitive coverage to monitor any changes on the earth's surface. This is one of the main advantages over aerial photography. Apart from this, aerial photography can be interpreted at considerably larger scales but at a higher cost to cover the same region. Secondly, the Landsat data are near-orthographic and do not require the same cartographic control for ground positioning. An index map of Landsat coverage of Nepal is shown in Figure 1.

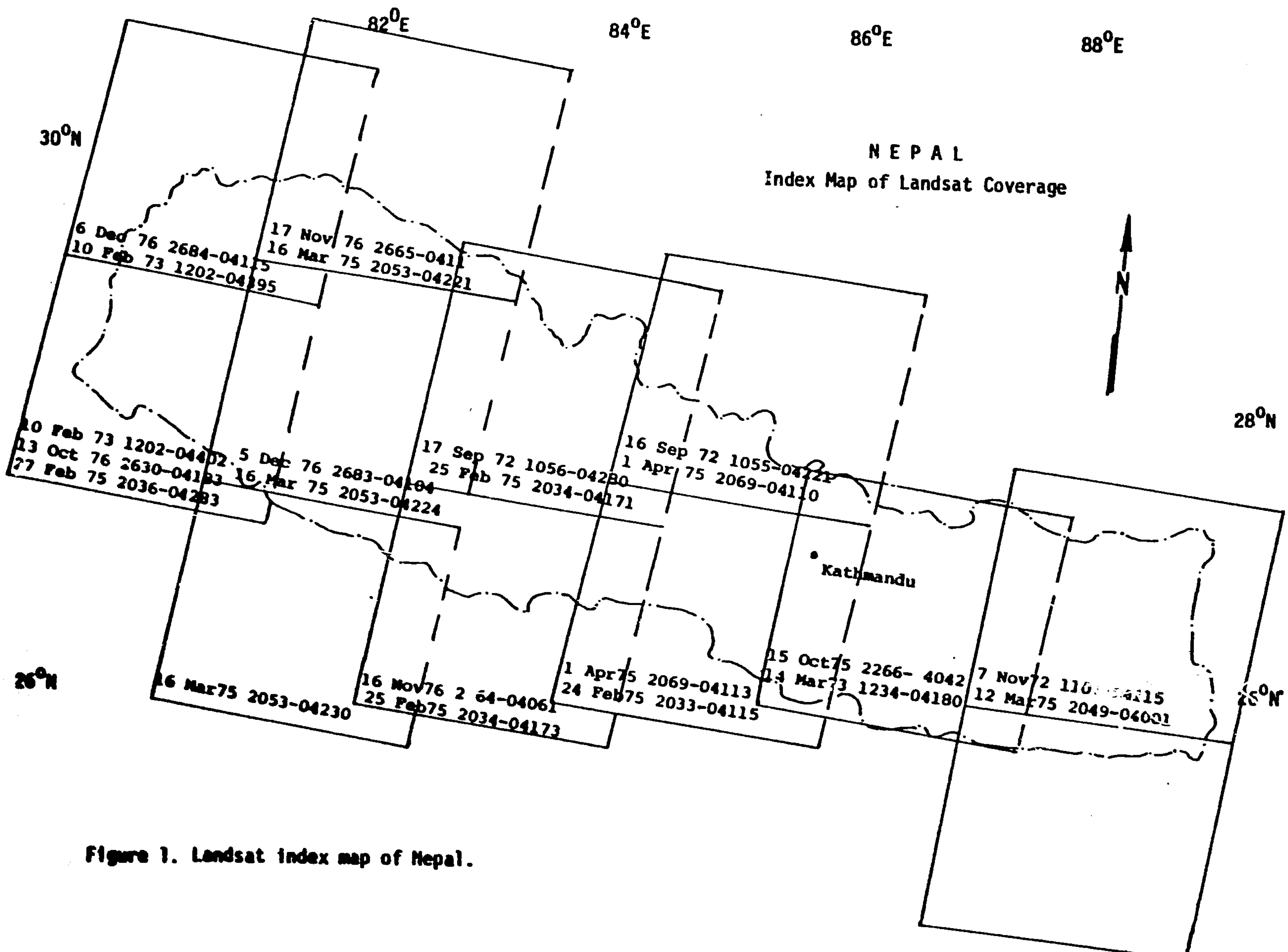

Figure 1. Landsat index map of Nepal.

RESOURCE EVALUATION USING REMOTE SENSING TECHNIQUES

The following summarizes the major resources of Nepal. This chapter examines how useful remote sensing is for study of these resources. It is not meant to be all inclusive but only to cover the highlights of importance.

Agriculture

Landsat data presently available with their defined "resolution" (term used synonymously with instantaneous field of view which is presently ≈60 by 80 meters) do not provide sufficient data for the study of crop identification in Nepal. A number of reasons are: 1) many fields are small and irregularly shaped, 2) small agricultural regions are commonly interspersed with non-agricultural regions, 3) fields are small due to fragmental land holdings, 4) cultural and microclimatic spatial variations in crop planting dates yielding various crop phenological stages on a given date render crop species identification difficult, and 5) reflectance variations are sometimes greater due to topographic positions of the reflecting scene, than to crop spectral signatures, especially in hilly regions. In such complex environments, numerous crops have similar spectral responses. For these circumstances, improved identification may be obtained by merging imageries of several different dates. However, the resolution of the present Landsat data or for that planned in the near future will not be such to identify individual fields for crop inventorying.

The level of inventory which can be appropriately conducted is to locate and measure the sizes of agricultural lands. As encroachment onto the forest land continually occurs, a changing total amount of agricultural land occurs. With this technique, both the area and location of these lands can be monitored.

Soil Survey

Exposed soils have different reflectivity which the Landsat senses and records. It is difficult for the Landsat to record soil reflectance in those areas where there is vegetation cover. In such a case, it is possible to obtain the soil data from the careful study of vegetation type covering that area. Under this condition, the Landsat imageries alone will not be an effective tool for this assessment unless the ground truth of the sample area is studied as well. General soil regions can be delineated based upon their potential development as determined by variations in parent materials, position on landscape, and climate. Perhaps a better use of the space technology is to utilize soil, slope, and vegetative cover parameters to identify those regions which have a high potential of soil erosion and degradation. Landsat imageries can aid in providing information to broadly categorize the soils and to monitor the dynamic vegetative cover.

Forestry

It has been estimated that one-third of the area of Nepal has been covered by forest. These forests range from hardwood to softwood species. They supply a sizeable amount of revenue to the country. Due to encroachment upon the forest by cropland and other domestic use, the amount of forest is decreasing. Effects of encroachment are increasing landslides, floods and siltation problems in hydroelectric and irrigation projects.

Preliminary assessment of Landsat bands 5 and 7 indicates that forest land densities may be discerned in the Kathmandu Valley. By merging imageries of different dates and with some ground truth, it may be possible to differentiate the deciduous forest from evergreen forest. There is a possibility from the research done in the United States and other countries that Landsat imageries could be helpful to obtain data of forest species also.

Encroachment on the forest, and landslides in large areas (large enough for the resolution level of Landsat) can also be detected easily. Necessary action for the protection can then be taken.

Water Resources

With the pace of development, the need of water for human consumption, irrigation, sanitation, power generation, mining and industrial processing increases. Nepal, though rich in potential water resources, has not been able to assess this resource adequately either as surface water or as ground water.

Landsat data are reliable in locating surface water. Band 7 shows contrast between water and water surface features so clearly that water bodies larger than 10 acres can be identified with 99% accuracy. By merging the imageries of different dates, perennial and intermittent rivers can be differentiated. Imageries can also be used to delineate watershed boundaries which affect the runoff of the river. This study of runoff is especially important for hydroelectric power.

As Landsat data can offer information on surface lithology, fracture patterns, vegetation, and geomorphic indicators of shallow aquifers, this study, if properly interpreted, can serve as an exploration base for future detailed ground water studies.

Geology and Mineral Resources

Since features like major rock types, faults, folds, and other landforms can be recognized from the Landsat data, geologists can study these features more easily through the Landsat data than with aerial photographs. Landsat data cover much more area than aerial photographs. On area coverage, 1500 aerial photographs of the scale 1:30,000 equals one Landsat image. Since Nepal has been trying to prepare the geological map for the whole country, the Landsat data may be able to simplify this work. This synoptic view offers a unique opportunity to observe a specific geologic feature over its entire extent thereby increasing the ability to locate anomalies which only present a subtle surface expression.

Demography

Developmental effort in the country is done for people, so any study relating to people is vitally important. Large proportions of people in Nepal live in rural areas and there are only few urban areas. Sizeable urban areas can be easily recognized in Landsat imagery. The study of imageries shows the growth of these settlements with repercussion on change in land pattern which may also be seen. This may be the basis for studying population density. In the study of dispersed villages, information of land patterns may help to infer population density with some accuracy. This will probably not provide quantitative population densities until the spatial data on land use as derived from space sensors are merged with detailed ground data concerning the average population per unit area of agricultural lands; however, the technique is beneficial to identify the qualitative directions of migration of people.

Land Use

The population pressures and natural effects have been bringing continuous changes in the land-use patterns of the country. From the examination of the value of Landsat data as studied above, it can be ascertained that this technology could be useful for this study at least on a reconnaissance level. This study at the reconnaissance level serves as a tool for further detailed study. Due to the repetitive data coverage, an analysis can be performed once per year to identify changes in land use patterns.

Tourist Development

Nepal has the potential to attract tourists because of her natural beauty. It is encouraging that every year the number of tourists visiting this country has been increasing. There are many areas which are inaccessible but have the potential to attract tourists. The exploration of those areas is important for the development of tourism.

The Landsat data can be used as a tool to study the natural phenomena such as vegetation, snowline and waterbodies. Moreover, Landsat imageries along with topographical maps can make a good study of landscape features. These studies can then help to prepare a base for exploration of touristic areas. These data can be beneficially used as backgrounds for maps, such as road maps, to illustrate to the tourist the type of terrain he is in at a certain point and to provide an illustration of the roughness and beauty of the landscapes of the entire country in one view.

Cartography

Although maps of different scales are available for Nepal, there is a great demand for up-to-date maps. The topographic maps prepared by the Survey of India with the scale of 1:63,360 and by the U.S. Army Map Service with the scale of 1:250,000 are widely used, even as reference material for preparing the thematic maps for different purposes. The maps prepared by the U.S. Army Map Service in the 1950's are only the compilation of the quarter-inch scale maps prepared by the Survey of India in 1920.

From the study of imageries, maps can be updated quickly and economically. Cartographers can find the imagery with virtually no distortion, because it is sensed from near-vertical (orthographic) perspective. A special advantage to the cartographers is that Landsat imagery has repetitive coverage of the same area. Thus, they get the chance to keep the maps updated.

CONCLUSION

In view of the wide range of use of Landsat data in resource assessment, and the necessity of resource information to Nepal for planning of development, the technology of remote sensing may prove useful. Considering its resolution, this technology should be first applied at the reconnaissance level of study. If successfully implemented, it will be easier to the planners to make correct decisions in planning priorities as well as proposing levels of resource study. This certainly saves time and money which are the main constraints for development. Furthermore, the proposed Landsat-3 to be launched in 1978 will provide a continuous data source and the Landsat-4, proposed for 1981, will have a better resolution, which will help much in more detailed studies in the future.

This space technology may be especially important to the National Planning Commission, His Majesty's Government of Nepal, since many decisions must be made concerning new and relatively unexplored lands. The ability to provide at least reconnaissance information can make these decisions based upon the best information available.

REVIEW OF THE TRAINING PROGRAM FOR THE NEPALESE RESOURCE SCIENTISTS[1/]

K.D. Bhattarai, N.N. Vaidya, M.D. Rajbhandari,
P.P. Shrestha, P.M. Joshi[2/]

INTRODUCTION

We arrived at the Remote Sensing Institute September 14, 1977. We then learned about the general outlines, aspects and philosophy of our training program and its schedule.

We continued our training program with lectures on different techniques of remote sensing, characteristics of Landsat imageries, interpretation, etc. Lectures were given by visitors from other universities and institutions on various topics such as: Microwave Remote Sensing, Remote Sensing Applications in Different Parts of the World, Remote Sensing in Forestry, and Soil Survey by Remote Sensing.

EQUIPMENT USED

We were introduced to and trained on the various machines which are available at the Remote Sensing Institute. These machines included an Electronic Graphics calculator, the photographic laboratory, the zoom transfer scope, the color additive viewer, the cromalin color display system, the Diazo printer and developer, the transparency illuminator, the Signal Analysis and Dissemination Equipment (SADE), and the Kargl Reflecting Projector.

1/ Condensed from report by K.D. Bhattarai, N.N. Vaidya, M.D. Rajbhandari, P.P. Shrestha, and P.M. Joshi, SDSU-RSI-77-18, Remote Sensing Institute, South Dakota State University, Brookings, SD 57007. Copies of maps have been excluded and are available from the author.

2/ Acting Senior Geologist, Dept. of Mines and Geology, Ministry of Industry and Commerce, His Majesty's Govt. of Nepal (HMGN); Acting Senior Hydrologist Dept. of Irrigation, Hydrology and Meteorology, Ministry of Food and Agriculture, HMGN; Acting Senior Photogrammetrist, Forest Survey and Research Office, Dept. of Forestry, Ministry of Forestry, HMGN; Photogrammetrist Forest Survey and Research Office, Dept. of Forestry, Ministry of Forestry, HMGN; Section Officer, National Planning Commission Secretariat, HMGN.

Following are brief descriptions of each of these machines.

1. Electronic Graphics Calculator

This instrument calculates areas and makes linear measurements on the imageries and interpreted maps.

The Numonics Model 1224[1/], available in the Remote Sensing Institute, has the following components:

a. Display Console - 16 digits of numeric, sign, and decimal point display; fully programmable. The only controls on the console are the power and reset controls which are located on the back panel.
b. Reading Head
c. Alphanumeric Keyboard - The keyboard contains all of the controls except power for the 1224, 0 through G numeric keys, T character keys and 4 shift keys.

2. The Photographic Laboratory

Imagery collected either by the Institute's aircraft or from other sources which are disseminated by the EROS Data Center are quickly processed by the R.S.I. photo lab to provide researchers with high quality products.

Processing techniques are carefully monitored by calibrated sensitometric control strips to assure the same range of densities throughout all processing procedures. Processing capabilities are unique in that they are tailored in-house to meet specific needs for research and analysis. Color composite transparencies and prints can be produced, for example, by combining filtered bands of imagery. Color and black and white transparencies and prints can be produced, ranging from 35 mm to 20" x 24" paper prints.

3. The Zoom Transfer Scope

The zoom transfer scope made by Bausch and Lomb is ideal for the interpretation of Landsat images. Through a beam synthesizer two images can be viewed simultaneously through the eye pieces. By placing a Landsat image at one film plane and an appropriate base map at the other film plane, interpretation information can be transferred simultaneously onto the base map. The 1x-14x magnification of the map image allows registration of varying and desirable scales. Optical image rotation and uni-directional stretching also provide convenience in use. The instrument is shown in Figure 1.

[1/]Any listing of product names does not imply endorsement by RSI, HMGN, or U.S. AID.

The multi-temporal or continuous monitoring of Landsat data lends itself to the use of the Zoom Transfer Scope. This can be achieved by placing images from two different orbits but having at least partially common aerial coverage at the two image planes of the instrument. Once the images are in the register, each image is alternately illuminated and darkened by manipulating the brightness controls. Through the binoculars, the temporal differences which occurred between the two image dates is readily apparent.

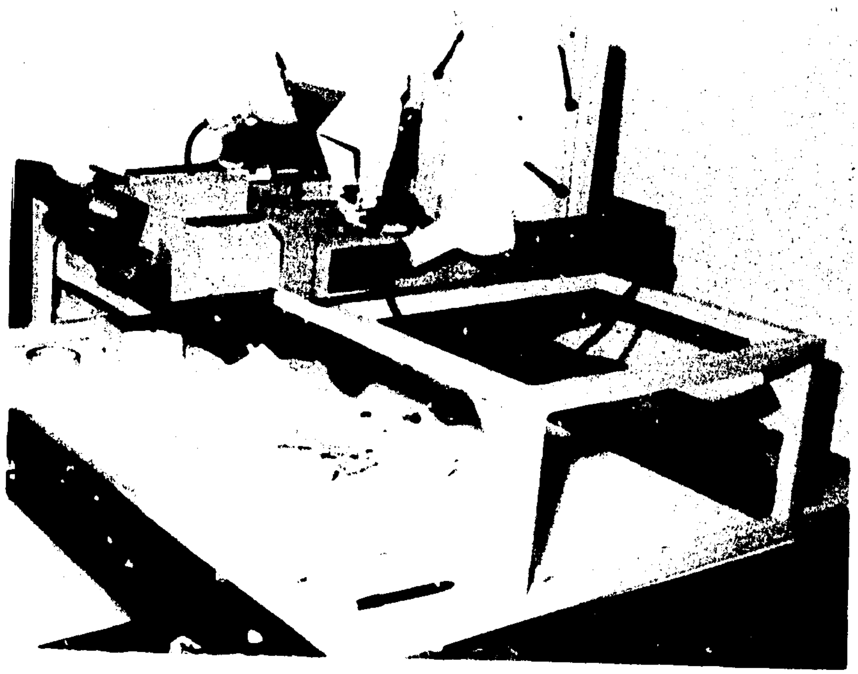

Figure 1. The Zoom Transfer Scope

4. The Color Additive Viewer

The color additive viewer available at the Institute is one manufactured by International Imaging Systems (I^2S). It requires 55-mm transparencies of one or more bands, which are projected on a screen through interchangeable colored filters and variable light intensities. The instrument is shown in Figure 2. It is a valuable piece of equipment for the interpretation of Landsat imageries. It enables viewing individual bands and comparing them with each other. Several combinations for color composites can be made by

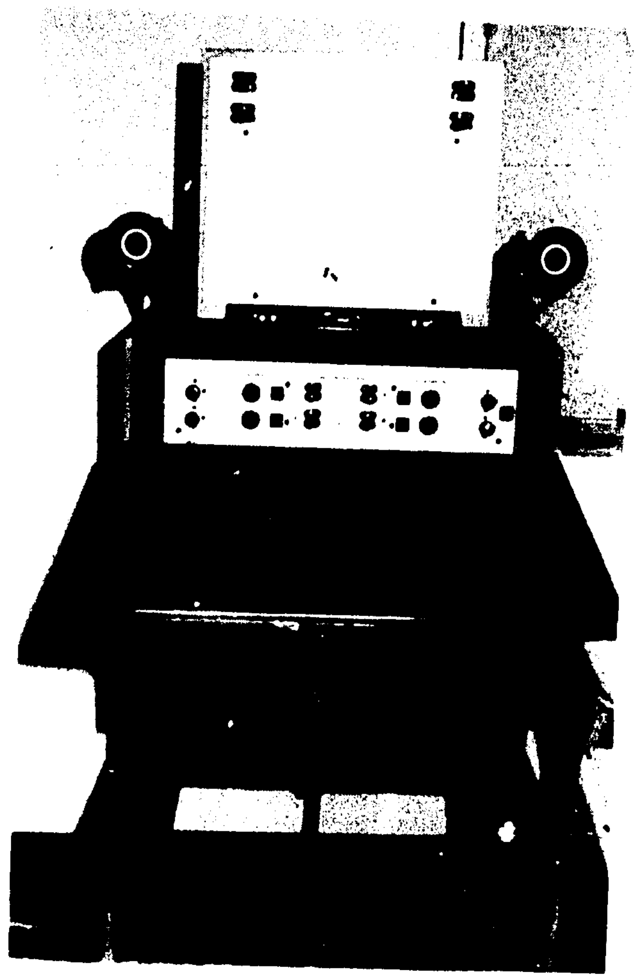

Figure 2. The Color Additive Viewer

superimposing several bands through different color filters, and by varying light intensities. Color photographs can be taken for the generated color composites on the viewer. The image is displayed at scales of either :1,000,000 or 1:500,000.

5. Cromalin Color Display System

The cromalin color display system is a rapid and simple method for producing high quality color displays from transparencies. The system consists of "CROMALIN" film, toners, and laminating and toning equipment.

A color display is prepared by laminating cromalin film to a selected display stock, then exposing it in contact with a transparency. After the Mylar cover sheet is removed, the unexposed tacky image is toned with a dry powder toner. Repeating the laminating, exposing and toning processes for each color, the multi-color cromalin display can be obtained. These operations are all done in room light.

6. The Diazo Printer and Developer

This process is based on the light sensitivity of certain diazonium salts to ultraviolet radiation. Where struck by light, the diazonium decomposes into colorless byproducts. If the coating is then made alkaline by solution or dry ammonia, a coupler (usually phenols or aromatic amines) becomes activated to form a dye with any undecomposed diazonium.

The diazo printer and developer have proven very efficient in producing color composites quickly and economically. This combined piece of equipment provides a quick and inexpensive method of producing Diazo color transparencies. This is done by exposing a Landsat 9 x 9 inch positive transparency and a sheet of Diazo film under the ultraviolet light for a specific period of time, depending on the density of the master copy and density of the Diazo color reproduction desired. Exposed film is then placed in an ammonia developer where the finished copy is developed. This process is repeated using a different color Diazo film for each MSS band exposure, which are finally registered to produce Diazo color transparencies which can be used for interpretation.

7. Transparency Illuminator

Illuminators are invaluable for analyzing Landsat images. Different types of illuminators are available at the Remote Sensing Institute. One such illuminator is a portable light table. The light table is 23 7/8 x 36 3/8 inches and its height is 2 3/4 inches. It has two switches, each controlling one set of lamps, permitting various lighting. Many portable light tables produced by Richards Corporation of California and others are simple and ideal for use with 7.3-inch size Landsat transparencies.

8. The Signal Analaysis and Dissemination Equipment (SADE)

The SADE system was developed interactively by the Remote Sensing Institute of South Dakota State University and the Dicomed Corporation of Minneapolis, Minnesota. With the specific objectives of analyzing and managing remote sensing data, the system is interfaced with the South Dakota State University's IBM 370/148 computer and represents a medium cost, state-of-the-art data analysis system with highly flexible modular design.

The South Dakota State University computer center facilities include the following:

1. One IBM 370/148 OS/VS1 Operating Environment
2. Four 3340 disc drives
3. Two 3344 disc drives
4. Four 3420 tape drives and 3803 control unit
5. One 3203 line printer
6. One 3505 card reader
7. One 3525 card punch
8. One 3705 communications control unit
9. One 2701 data adapter
10. One 1627 calcomp drum plotter

Also available at the center are standard card-data processing hardware, i.e. collators, sorters, punches, verifiers and alphameric interpreters.

The SADE system's hardware configuration consists of the following:

1. Video monitor - The video monitor is a complete color densitometry system for analyzing the gray levels of back-lighted photographs in 32 colors. Color analysis is controlled by a pushbutton keyboard and an electronic digital planimeter that measures the relative areas of one or more color bands.

2. Image Digitizing Unit - The Dicomed D57 image digitizer is the digital analysis interface to image transparencies. The film transport bed accepts roll or frame films up to 9 inches square. The digitization process takes place over a 57-mm area with a 50-micron pixel size. The digitizer has a density range of 0.05 to 2.45 density units. The image dissector tube (IDT), focusing lens, deflection system and electronics are located in an optical assembly above the film plane. A hood shields extraneous light during the digitizing process. The film is held between a set of glass plates mounted

on a large, flat movable surface. A 350-watt tungsten Halogen lamp and condensing lens are mounted beneath the glass film holder in the cabinet along with the electronics and operator panel. A holder is provided for filters.

3. Data Conversion Unit - The hardware contained in this includes Fabri-tek memory, Fabri-tek memory power supply, Atron controller, three logic decks -- Deck A - High speed memory (HSM) interfaces, Deck B - 2701 Local interface, Deck C - 2701 Analog tape converter (ATC) -- five logic power supplies, one control panel and one connector panel.

4. Lockheed Recorder - The Lockheed 417 is a portable wideband magnetic tape recorder. Completely modularized, the model 417 WB is capable of recording up to seven tracks of either FM or direct data on 7-inch reels of 1/2 inch instrumentation tape. The reproduce mode can be used to digitize from one to six channels of analog information. The recorder operates at three speeds - 3 3/4, 15 or 30 ips.

5. Film Printer/Viewer - This display unit is used either on- or off-line to display and record analog data. The option of level slicing the data before it is displayed on the CRT is available. Permanent record of the video information on the display unit is made by using a variable speed 70-mm continuous strip camera.

6. Digital Tape Unit - A Dicomed D15 digital magnetic tape drive allows reading or writing of data in the digital domain independent on the IBM facility.

7. Teletype - The ASR-33 teletype is used primarily for communication between the computer and the SADE equipment at the Remote Sensing Institute. Key word entries into the supervisory program allow selection of hardware and software combinations required to accomplish a specific task. Local and line modes can be used with off-line and on-line operations respectively. Paper tape serves as an optional input/output medium. The SADE system is shown in Figure 3.

With the benefit of computer interface and interactive control (on-line) SADE functions are exemplified by the following:

1. Transmission of teletype communications to and from the computer.
2. Transmission of digitized image information to the computer.
3. Digitization and transmission of analog tape information to the computer.

4. Transmission of digital or analog tape data to the display monitor through the high speed memory.
5. Transmission of processed digital or analog tape information to the film printer.
6. Registration of images via the digitizer and display monitor.
7. Display of digital information on the line printer.
8. Color separation digitizing.
9. Moving window dynamics of video information.

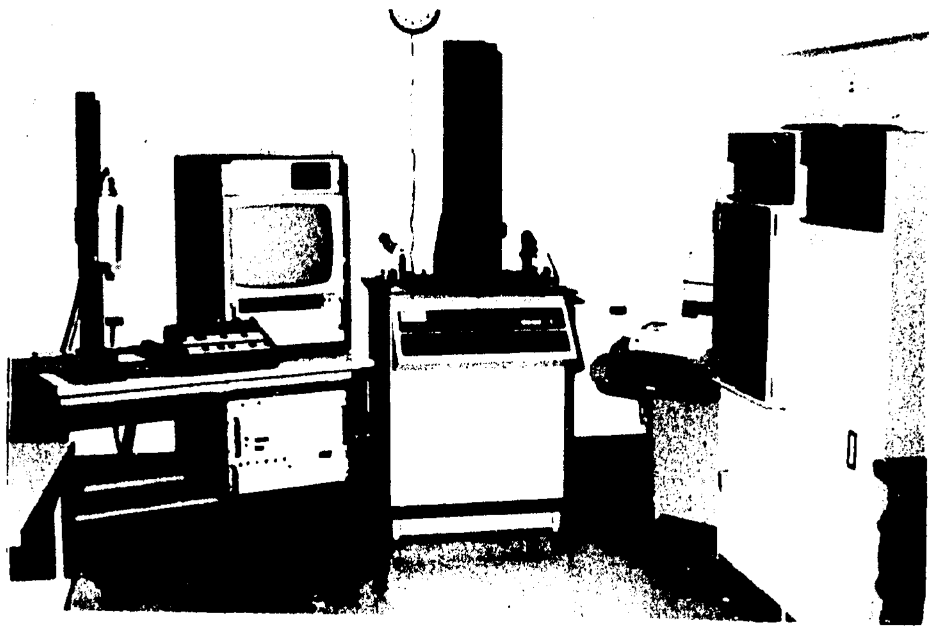

Figure 3. The SADE System

SADE can perform the following interpretation functions:

1. Video monitor display of digitized film information.
2. Video monitor display of analog tape information.
3. Transmission of analog information to the film printer.
4. Transmission of level-sliced analog information to the film printer.
5. Level slicing of vidicon scans or image dissector scan.

The cost of the SADE system is on the order of $180,000 excluding the computer.

9. Kargl Reflecting Projector Model RP-T-4B K & E 72-0402

This reflecting projector is designed to provide a rapid scale-changing instrument for drafting. Opaque or transparent copy of any type may be placed on the lower copy easel, illuminated by brilliant tungsten-iodine lamps or efficient, bright fluorescent lamps for backlighting.

The image is projected through a six-inch focal length, wide-angle lens onto a waist-level, clear View Glass. All mechanisms, lights, and lenses are under the view glass to allow the operator movement around the four sides of the instrument. No shadows are created by operator movement at any time. The Copy Easel is constructed with the front and both sides open and unrestricted to permit the placement of copy of practically any size or shape. Roll paper holders are provided on the front of the easel to retain roll-size drawings.

Focusing is automatic throughout the scale range from 0.25x reduction to 4.0x enlargement. The Top Light lamp holders also automatically move toward and away from the center of the copy easel to provide concentrated illumination of the copy to be projected.

The reflecting projector may also be used for limited rectification of distorted images present in aerial negatives or prints. The trial and error point matching method of rectification in which the projected image is fitted to a map or photograph on the view glass may be applied and limited rectification done.

The Form, Availability, and Analysis of Landsat Data and Geographic Information System

Mary DeVries[1/]

Abstract

This paper is a brief introduction to many topics involving Landsat data. Information concerning the satellites' life histories, orbital configuration, and sensors is presented. The processes of relaying information from the satellite to ground receiving stations and of generating imagery and digital products are reviewed. The procedure for acquiring imagery and computer compatible tapes from the EROS Data Center, Sioux Falls, South Dakota is presented. The concepts of photographic and digital image enhancement and analysis are introduced. Finally, the procedures, products, and utility of the geographic information data base are discussed.

Introduction

A basic understanding of the complete Landsat system is necessary for successful utilization of the data by resource personnel. Both photo-interpretive and digital analysis techniques require a knowledge of the sensor characteristics and the data generation process. The procedure for acquiring the imagery from the EROS Data Center must also be understood. This paper presents this basic information and, in addition, discusses some general image analysis techniques. A method of storing and retrieving the interpreted Landsat data as well as other spatially-oriented resource data is also presented.

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The Landsat System

To date three Landsat satellites have been launched into earth orbit. The first of these, Landsat 1, was launched July 23, 1972, and was officially declared inoperative on January 6, 1978. Thus the original life expectancy of one year was greatly exceeded. The second of the Landsat series, Landsat 2, was launched January 22, 1975, and remains operative to date. Landsat 3 was launched March 5, 1978, and appears to be working well.

The satellites are in orbit 920 km above the earth's surface. They encircle the earth every 103 minutes, or 14 times per day, and pass over the equator at approximately 9:30 each morning. The entire globe, except the poles, is covered every 18 days. With two satellites in operation their orbits are staggered by nine days, except for a short period of time when Landsat 1 and 2 were in a six and 12 day configuration.

Two types of sensors are included in each of the Landsat satellites. The first of these is the Return Beam Vidicon (RBV) system. This camera system was originally included because of its geometric accuracy. The RBV systems aboard Landsats 1 and 2 consist of three cameras, each imaging an area of 185 x 185 km per scene. The first camera, RBV 1, samples the 0.475 to 0.575 μm region of the electromagnetic spectrum. RBV 2 and RBV 3 sample in the 0.580 to 0.680 μm and 0.690 to 0.830 μm regions respectively (see Figure 1). Unfortunately, the RBV sensors on both Landsat 1 and 2 were shut down soon after launch because of the power drain they imposed on the system.

The RBV system aboard Landsat 3 differs from that aboard Landsats 1 and 2 in that it is a two camera system, each sampling in the 0.505 to 0.750 μm region (see Figure 1). Each RBV scene images an area 98 x 98 km. Thus, four scenes are required to cover the same area as that covered in a scene from Landsats 1 and 2, but the spatial resolution is improved by a factor of two.

The second sensor system aboard the Landsat satellites is the Multispectral Scanner (MSS) system. This scanner system, which utilizes a rotating mirror to reflect the incident light to the optical sensors, was chosen for its radiometric accuracy. Four regions of the visible and near infrared portions of the electromagnetic spectrum are sampled by the MSS system aboard each of the satellites. The first MSS sensor, MSS 4, samples in the 0.5 to 0.6 μm region. MSS 5 samples the 0.6 to 0.7 μm region and MSS 6 and MSS 7 sample in the 0.7 to 0.8 μm and 0.8 to 1.1 μm regions, respectively. A fifth sensor, MSS 8, which samples in the thermal infrared region (10.4 to 12.6 μm) is included on Landsat 3 (see Figure 2). An area of 185 x 185 km is imaged for each MSS scene. The spatial resolution of MSS 4, 5, 6, and 7 is 79 m while that of MSS 8 is 237 m.

A fourth Landsat satellite, Landsat D, is scheduled for future launch. A six-channel thematic mapper is planned to be included in the sensor package. The first five channels will sample in the visible and near infrared region and will have a spatial resolution of 30 m. The sixth channel will sample in the thermal infrared region and will have a spatial resolution of 120 m. A five-channel MSS system, the same as that aboard Landsat 3, is also planned for Landsat D.

At the present time there are six operational Landsat receiving stations scattered around the world. Three of these are located in the United States: Fairbanks, Alaska; Goldstone, California; and Greenbelt, Maryland. The other three operational receiving stations are located in western Canada, Brazil and Italy. Receiving stations are planned for eastern Canada, Iran, India, Upper Volta, and Chile.

Acquisition of Landsat Imagery

When a satellite is within the line of sight of a receiving station the data for that area are relayed directly to the station. For areas outside of the line of sight of a receiving station the data are stored on tape and dumped later when passing over a

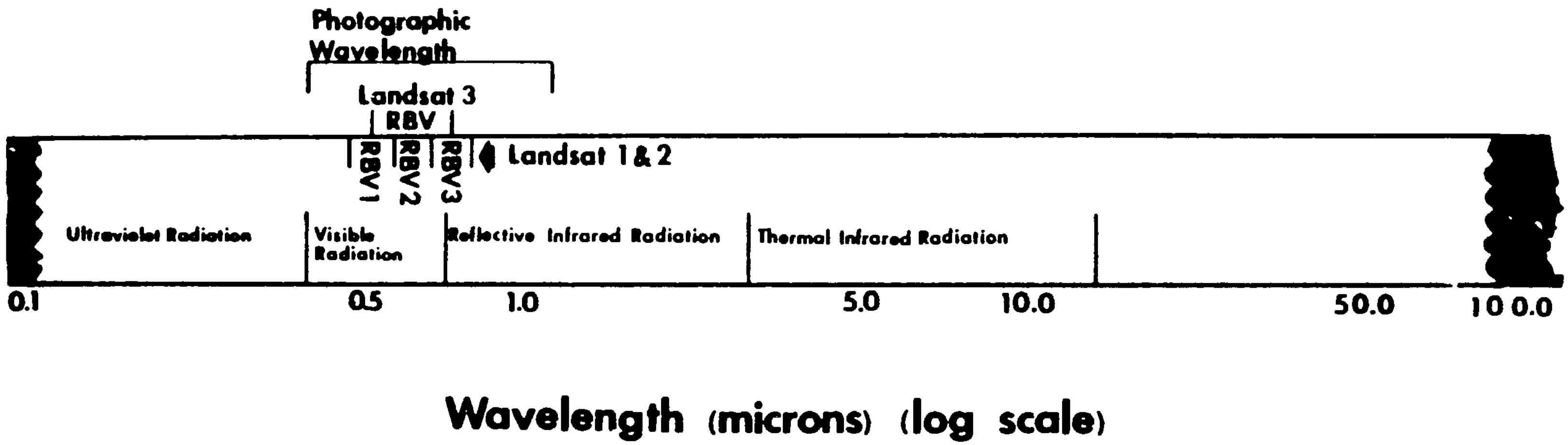

Figure 1. The Landsat RBV sensors relative to the electromagnetic spectrum.

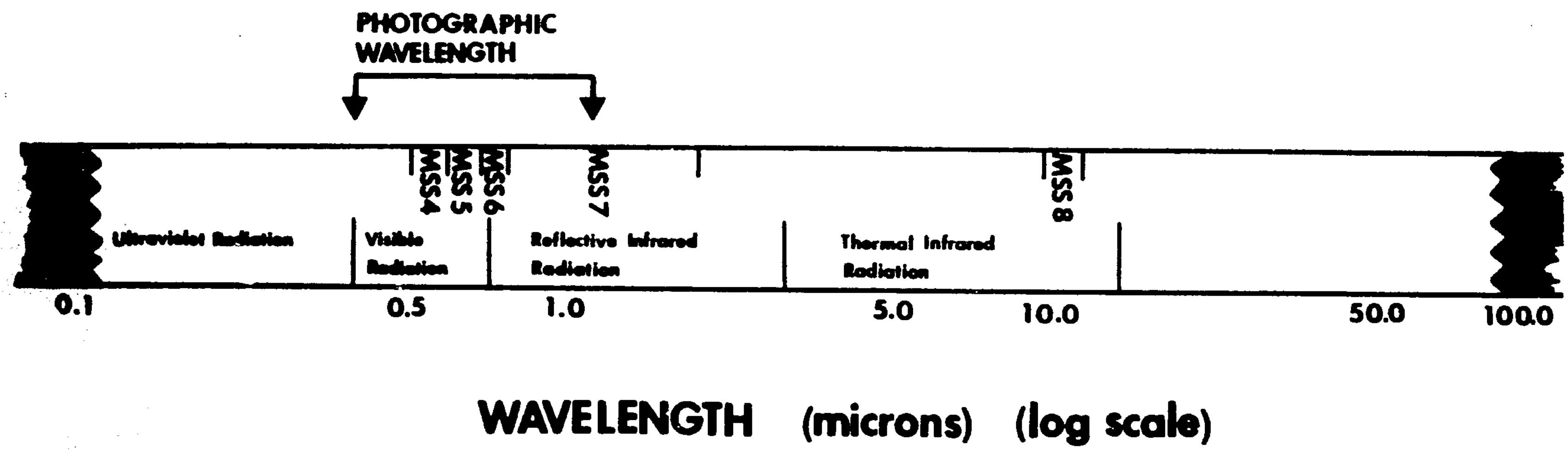

Figure 2. The Landsat MSS sensors relative to the electromagnetic spectrum.

receiving station. From the electronic data which are relayed to earth a master copy of both an image and a computer compatible tape (CCT) is produced. Negatives of the master copy imagery are sent to the EROS Data Center, Sioux Falls, South Dakota, USA. This second generation negative is used by the EROS Data Center (EDC) to produce imagery for dissemination to users around the world.

The procedure for ordering Landsat data products from the EROS Data Center usually begins with a request for a computerized geographic search. The user specifies the area for which coverage is desired by latitude and longitude or by path and row (a coordinate system which has been especially designed for Landsat). In addition to specifying the area of coverage, the date of coverage, maximum cloud cover acceptable, and minimum quality acceptable can also be specified. The result of the search is a computer printout listing all the scenes which meet the specified criteria. Other documents necessary for decoding the computer printout and ordering desired imagery are also sent to the user by EDC. These include decoding sheets, listings of available products, cost sheets, and order forms. Arrangements for payment must be made prior to processing an order.

Another service which is available from the EROS Data Center is that of a standing order. This service allows the user to specify the location, date, and acceptable quality and cloud cover for the desired coverage area. When new imagery is added to the data base at EDC which meets the specified standing order criteria, the user is notified. The user may optionally request that the imagery be sent automatically, or alternatively, that only a report be sent. The second option allows the user to be even more selective in his choice of imagery as well as keep informed of all available imagery for his area of interest.

Landsat data products are generally available to the user from EDC four to eight weeks after being acquired by the satellite. Imagery orders require a minimum of three weeks for processing. Orders for computer compatible tapes and large, complex orders may require longer than three weeks.

In addition to the standard black and white imagery and computer compatible tapes, many other Landsat products are available from EDC. Among these products are false color composites (FCC'S) and computer-enhanced imagery. False color composites are produced by exposing three of the four black and white MSS bands through different color filters onto color film. Generally, MSS bands 4, 5, and 7 are used. Computer-enhanced imagery is presently available for a limited number of scenes and may be requested for other scenes, although the cost is quite high. Future plans call for the implementation of a digital image processing system to be used for the production of standard Landsat imagery. This system, called EDIPS (EROS Digital Image Processing System) will provide both MSS and RBV imagery which has been enhanced and fully corrected both geometrically and radiometrically.

Landsat Image Processing

Analysis of Landsat imagery must take into consideration the multi-spectral design of the Landsat sensors. Different kinds of information are available from the various bands. For example, MSS bands 4 and 5 are valuable for delineating cultural features, MSS 7 is valuable for delineating water areas, and MSS bands 5 and 7 are most useful for vegetation analysis. However, combinations of various bands may also yield valuable information. This combination may be done photographically as is the case when a false color composite is generated. Other combinations of bands and color filters for visual analysis can be generated on a device known as a color additive viewer. Digital analysis provides for an almost unlimited number of combinations and transformations.

Another type of Landsat image processing is called contrast stretching. This process can be done either photographically or digitally. In either case, the purpose is to introduce more contrast into the scene or area of interest in order to make it more interpretable. The photographic process involves finding the grey levels which are represented in the scene or area of interest and then "stretching" that range of tones to cover the entire density range of the film. By doing this for each band used in the generation of a false color composite, a contrast-stretched FCC results. Digital contrast stretching is analogous to the photographic process in that a histogram of the picture element (pixel) brightness values is used to find the range of values represented in a scene or area of interest. This range of values is then "stretched" to fit over the entire dynamic range of the recording medium.

Many automatic and interactive image analysis devices are presently available to the user. One such device is a density slicer which quantizes the grey tones on a transparency into discrete levels Output from this process can be analog, such as a television monitor display, or digital. Other image analysis devices are much more complex and may include a density slicer as a small part of the total system. Input to such a system may be either photographic or digital. Often analysis functions are hardwired into the system for speed and efficiency.

The Geographic Information Data Base

It is often desirable to integrate Landsat data with other resource information into a spatially-oriented data base. Because of the large amounts of data involved it is necessary to automate the process. One such computerized information data base is described here.

Data which are input to the data base system may originate from a variety of spatially oriented sources and scales. Both existing thematic maps and those interpreted from remote sensing imagery can serve as input. The basic question which must be resolved prior to the input of data concerns the cell size which will be used. Factors such as the complexity of the input maps and the limitations of the sensor resolution need to be considered when the cell size is determined.

The process of digitization of the resource input data involves coding on a row-by-row basis those columns where a boundary condition exists. Row and column numbers are determined from a grid which has been computer-plotted at a scale to fit the map. When the digitization for a given input resource map is completed the encoded data are error checked in two steps. The first step involves a computer run which checks for obvious coding errors. Once these errors are eliminated the second error check is implemented which involves the generation of a computer-plotted map at the same scale as the original input map. Any discrepancies between the two maps are corrected and, if desired, the two-step error checking loop may again be entered.

Output which results from this basic data base operation consists of the corrected plotter map and frequency and areal tabulations. Additional interpretations may be made from each input resource map with the same output products. For example, once the basic soils data have been entered into the data base system, an interpretation for slope can be made and the output tabulated and plotted on this basis.

An additional feature of the information data base is the theme overlay capability which is extremely valuable when the interaction among various types of resource data needs to be analyzed. Any combination of resource data sets which are spatially registered and have the same cell size may be overlaid. Output products are again plots and tabulations.

Conclusion

Landsat data have proven to be a very valuable tool for many areas of natural resource investigation. The scientist who wishes to use this technology must be acquainted with the many aspects of the Landsat system. Equipped with this knowledge, the scientist is better able to utilize the data in the manner which most efficiently aids in the solution of his particular resource problem.

Example Remote Sensing Activities in Developing Countries

Thomas W. Wagner[1/]

Introduction

How does one begin to survey the applications and institutions of remote sensing in the developing world - for the simple fact is that within the last decade almost all developing countries have made increasing use of remote sensing technology? As evidence of this fact, some 85 out of 200 papers presented at the 12th International Remote Sensing Symposium, held in Manila in April 1978, were specifically concerned with projects or activities in developing countries. Of these developing country papers, three-quarters were authored or co-authored by developing-country investigators, themselves. Twenty countries presented papers describing the development of their national remote sensing programs. Nepal was represented by an excellent and well-received paper.

What is the reason for all this activity and, in particular, why is a technology which appears highly sophisticated and specialized of such interest to developing countries? The answer lies in the global availability of the remote sensor data and their applicability to a wide range of development needs. Indeed, in many respects remote sensing data may be more applicable to developing countries, where basic resource information is deficient, than to industrialized countries that have well-developed survey systems.

Remote sensing is basically an information gathering technology. Its products are useful primarily within the context of a natural resources management or environmental monitoring system. They provide an objective basis for making accurate and rapid assessments of certain natural resources, such as the extent of forests, the condition of grazing or cropland, the occurrence of surface water and the outcrop of geological structures. Because remote sensing data have been collected for most areas of the earth over a period of years, they also provide an ability to determine what changes, if any, have occurred to the land surface during this period.

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Thus remote sensing can be very useful to countries which need comprehensive and up-to-date resource information to assist in national planning and development processes. The purpose of the following discussion is to summarize some of the uses and plans that Nepal's neighboring countries have for modern remote sensing techniques. Needless to say, these are only a small sample of the many applications that are being pursued, and not necessarily ones of primary significance to Nepal. They are intended to provide an illustration of the scope of remote sensing activities in this part of the world. Ultimately, you will decide which applications are most suitable for Nepal's development needs.

The Technology

Currently the Landsat earth resources sensing satellites are the principal generators of global remote sensing data. At this stage most remote sensing technologies transferred to developing countries are intended to promote or complement the use of Landsat data - although aerial photography remains a most important operational technology for local or regional detailed surveys. Landsats have been collecting earth resources data routinely since mid-1972.

A note on data processing technology - generally speaking, processing of Landsat and certain other types of remote sensor data can be done either manually or digitally. Manual techniques employ simple optical or photographic procedures while digital techniques usually make use of some type of computer facility. By far the greatest practical uses of remote sensing imagery are derived using the manual techniques. Manual image analysis must be the backbone of any applications program utilizing remote sensing data in developing countries. However, digital techniques can be used for certain investigations which require detailed quantitative information. Some of these digital techniques are being explored by Bangladesh, Pakistan, Sri Lanka, Thailand and the Philippines. In time Nepal may wish to make use of digital facilities to test the use of these specialized processing techniques.

Bangladesh

The Bangladesh National Landsat Program was initiated in 1972, but only recently has gotten into full operation under partial sponsorship of the United Nations Development Program and technical assistance of the Food and Agricultural Organization. The Program is a multipurpose, multisector resources survey program involving agriculture, forestry, water resources, cartography, instrumentation, fisheries and oceanography, meteorology and geology.

The Program is coordinated through a national committee consisting of the Secretaries of various participating ministries. For technical and operational activities, there is a task force consisting of 25 investigators - three from each of the eight sectors plus the Principle Investigator. In addition to the part-time investigators there are two full-time directors, one deputy director, and supporting office and laboratory staff.

Activities being undertaken by the Program include:

i) predicting land accretion in the Bay of Bengal,

ii) preparation of land use studies and mosaic image maps of the entire country,

iii) studies of the mangrove or other important forests in the south, and

iv) inventory of winter cropping practices.

In respect to this last activity a study prepared by Jahangirnagar University under USAID sponsorship is of interest. In the northeast a tectonic depression, known as the Maghna Depression, is a shallow basin which completely floods during the rainy season - June to September. This basin is one of the few extensive areas in Bangladesh to have sufficient water to grow a winter rice crop - the Boro rice - during the dry season, December to April. The extent of flooding can be seen in the Figure 1-b Landsat band 7 image taken shortly after the rainy season in late 1975. In this image all surface water areas appear very dark in contrast to the light-toned dryland areas. For comparison note Figure 1-a which shows the same area recorded by Landsat band 7 prior to the 1975 rainy season. In this image it can be seen that only small areas are covered with surface water - mainly the meandering Meghna River and its tributaries.

From the Landsat imagery it was estimated that about two thirds of the area was used for Boro rice production, 15% for Aman rice, and 16% of the depression for grazing and fallow land. The remaining 3% was settlements and surface water during the dry season. Analysis of different Landsat patterns during the dry season showed information related to crop maturity. In the deepest part of the depression the rice is planted later than on the higher slopes around the edge. Therefore the Landsat imagery provides a clear picture of the maturing rice crop which varies as one proceeds from the edge to the lowest parts of the depression. This information is of interest in planning for the rice harvest at this critical season in Bangladesh. The Landsat data are being tested to provide vital information concerning the area and timing of Boro rice production.

It should be noted that in general the individual agricultural fields are too small to be identified with Landsat data, but that general cropping trends and local variations which cover many acres can be observed and monitored.

Pakistan

In 1972 a modest program of satellite data utilization was initiated by the Pakistan Space and Upper Atmosphere Research Committee (SUPARCO). Since that time several studies have been carried out with facilities developed and located in Karachi. The current facilities include a density slicer, color additive viewer, image transfer scope, zoom stereoscope, densitometers, and a fully equipped photo-lab. These facilities and an extensive archive of Landsat data have been made available to numerous user organizations within Pakistan. Some of the projects include:

i) flood plain mapping of the rivers of the Indus Basin,
ii) snowline mapping in the catchment of the Indus River,
iii) study of the morphology of the Indus Delta,
iv) geological and mineral exploration in Pakistan,
v) analysis of demographic patterns in the Northeast Frontier,
vi) study of soil salinity and land reclamation in the Sind Province,
vii) survey of protective bands along the Indus River,
viii) survey of rangeland resources in the Sind Desert,
ix) preparation of regional development plans for Baluchistan

and others, many of which are still in progress.

Under a cooperative agreement with NASA, Pakistan hosted a temporary Landsat receiving station at Rawalpindi for a period of one year (Nov. 1976 - 1977) and hopes to continue to receive data when the Iranian Landsat station comes on line this year. Over the next three years Pakistan proposes to spend approximately 3.7 million dollars (U.S.) in developing remote sensing programs and facilities.

One project in Pakistan has been concerned with a study of dynamic coastal processes related to current patterns, wave directions, vegetation distribution, channel networks and tidal saltwater intrusions in the Indus Delta. This information is being used for planning a large new industrial port, Port Qasim, located approximately 12 miles from the Karachi harbor and on the edge of the extensive Mangrove swamps of the Indus Delta.

The Indus Delta can be seen flowing from north to south in the single frame of Landsat data (Figure 2). In spite of its location at the mouth of one of the world's great rivers the changing patterns of the Indus Delta have for centuries confounded attempts at navigation and development. In particular, the large silt load deposited by the Indus, coupled with the ever-changing channels, tides, and currents along the coast, cause the Delta to change and grow from one year to the next. When visited by Alexander the Great, the shore was probably 50 to 80 miles from the present coast and the river was reported to be easily navigable via two large distributaries. Since that time, and particularly within the last two centuries, perhaps in part due to tectonic changes, the Delta has changed rapidly. Between 1873 and 1904 more than 100 sq. miles of land were added, and in the next 50 years the coastline advanced fives miles in some places. Needless to say, the remains of great coastal cities that once served a flourishing sea trade now are abandoned in the interior of the Delta. Karachi, Pakistan's largest city and only major port, is located on a rocky ledge just to the west of the Delta and 50 miles from the principal outlet channels of the Indus. In the 18th century it was just a fishing village.

Mangroves stretch for dozens of miles along the coast and extend inland for 10 to 20 miles. Landsat bands 6 and 7 imagery clearly show the complex channel patterns and the changes in inundation between high and low tides. Knowledge of the extent of this saltwater intrusion is useful in planning development and the precise location of the channels is helping in planning shipping and fishing activities.

Port Qasim, a large new industrial port designed to serve the needs of Karachi's heavy industry, is being constructed on one of the Delta channels several miles to the east of Karachi. Given the dynamic character of the ever-changing coastal landmarks, Landsat is providing valuable data concerning these processes. Both manual and digital techniques are being explored.

Sequential band 5 and band 4 imagery show patterns of coastal currents and sedimentation. These are being used to record areas of rapid erosion and accretion and to observe the action of currents and tides, particularly in regard to the dredging requirements for the Port Qasim channel. Recent studies have shown that band 5 provides reflectance patterns which correlate with near-surface turbidity profiles. In other words, water patterns seen in this band provide an accurate picture of the distribution and concentration of suspended materials in the water at the time of data collection. The tremendous current patterns are highlighted in a digital image (Figure 3). For example several large counter-clockwise spirals are clearly identifiable in the Arabian Sea adjacent to the coast. This current affects the way in which sediment is transported and consequently the necessity for dredging to keep the harbor open.

Sri Lanka

The third country on our survey is Sri Lanka, formerly known as Ceylon. Sri Lanka is an island republic in the Indian Ocean 20 miles off the southern tip of India. It has an area of 25,000 square miles - and a population of some 14 million people. Sri Lanka is a net importer of cereal grains (mostly rice), although it exports tea, rubber, and coconuts. Agriculture is the most important economic activity and the well-being of the population depends greatly on the success of the rice crop. A priority need is for accurate and timely information concerning crop production to help predict shortfalls - something on the order of 950,000 metric tons in 1974 - and to plan further development. An in-country capability using aircraft and Landsat data is being developed in Sri Lanka by the Survey Department in the Ministry of Agriculture. As with the other neighboring countries, manual interpretation is being supplemented with some testing of digital procedures.

The country is quite hilly and the land-use patterns are very complicated. Homesteads are dispersed and are mixed with coconut, rubber, and natural forest stands. Rice fields follow the drainage networks and vary in planting and harvesting dates, depending on what side of the island you are on. Irrigation represents an important factor in opening up new agricultural lands in the dry part of the island in the northeast.

A thousand years ago this area of northeastern Sri Lanka had been settled much more densely than is true today - in large part because of the elaborate irrigation facilities built by the Kings of Anaradapura and, later, Polonnawara. These facilities, which fell into disuse due to war and malaria, are gradually being revived and added to today. In particular some of the extensive reservoirs, known as tanks, are being put back into service for crop irrigation under United Nations and World Bank support.

Landsat is being used to monitor those tanks. Using simple techniques, both digital and manual, the Survey Department is putting to an end the disputes between the Agriculture Department and the Irrigation Department over the areas of cropland in production and the seasonal availability of irrigation water in the hundreds of tanks. Coupled with newly planned 1:40,000 aerial photography the land use, especially agricultural land, will be surveyed and monitored for the entire island using Landsat data.

The use of Landsat data by the Ministry of Agriculture has generated a great deal of interest and high-level awareness in Sri Lanka. The public press as well as government officials have given increasing attention to potential benefits to be gained from Landsat data and recently a formal Remote Sensing Centre was established with the Survey Department. Such a center will attach experts from various departments to perform interdisciplinary tasks using common facilities.

Philippines

The Philippines has a very active program in remote sensing and one of the projects of concern for mineral development is the revision of many of the geological maps using Landsat data. For example in Mindoro, an island 4000 sq. miles in area and seventh largest in the Philippines, little fieldwork had been done in the past and the geological structures were inferred from old aerial photographs. Now Landsat data are being used by the Bureau of Mines to reinterpret lithologic units, fracture lineaments and volcanic cones. Some new mineral areas have been identified in conjunction with interpretations of geophysical aerial magnetic data and a major fault zone has been determined to consist of a series of faults rather than a single continuous structure. Coupled with this study was the discovery that much of the forest cover of this under-developed island has already disappeared. Comparisons of forestry maps developed in the 1960's and currently in use with Landsat data shows that instead of two-thirds of the island being covered with primary forest, less than one-third remains today.

Conclusion

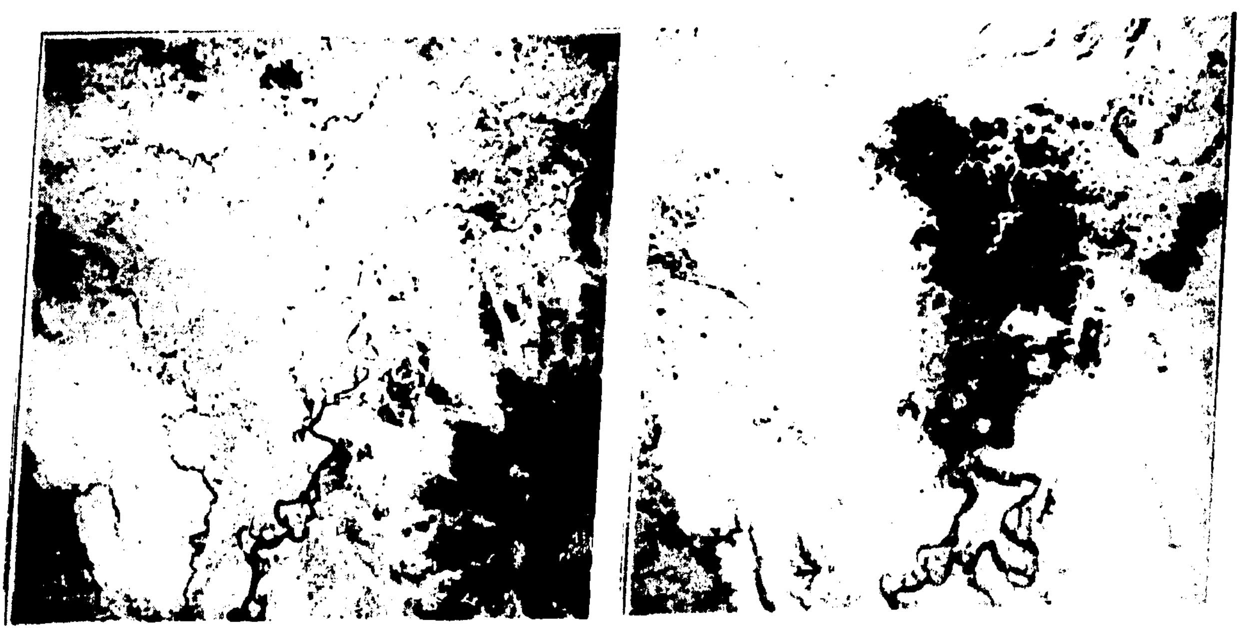
This concludes the brief survey of some remote sensing activities currently in progress in Asia. While there are many others, several points should be clear from these illustrations:

1) Remote sensing, especially with Landsat data, is a technology that is appropriate for all levels of national development and expertise. Simple techniques are highly useful and the development of more sophisticated techniques can add new dimensions to the established basic procedures.

2) A variety of institutional arrangements are associated with the uses of remote sensing in different countries. Some countries have administrative units totally devoted to the use of Landsat data, such as Bangladesh; other countries have integrated satellite data into ongoing research or survey organizations such as Pakistan and Sri Lanka, respectively. Some countries base national surveys primarily on Landsat data. It is difficult to generalize about optimal institutional structures. Clearly each country had its own information priorities and its own way of getting things done.

3) The main ingredients for successful remote sensing programs are highlevel management support, enthusiastic and resourceful investigators, and involvement in operational programs of concern to the country.

For remote sensing technology to be a component of development it must be adapted to the local aims of development. Only you can do that.



Dry Season
(Landsat frame E-2064-03434,
27 March 1975)
(a)

End of Rainy Season
(Landsat frame E-2316-03414,
4 December 1975)
(b)

Figure 1. Two Landsat band 7 images of the Hoar Region in northeast Bangladesh. The extent and duration of flooding largely determines how land is used in this region. Flooded areas appear dark in the second image.

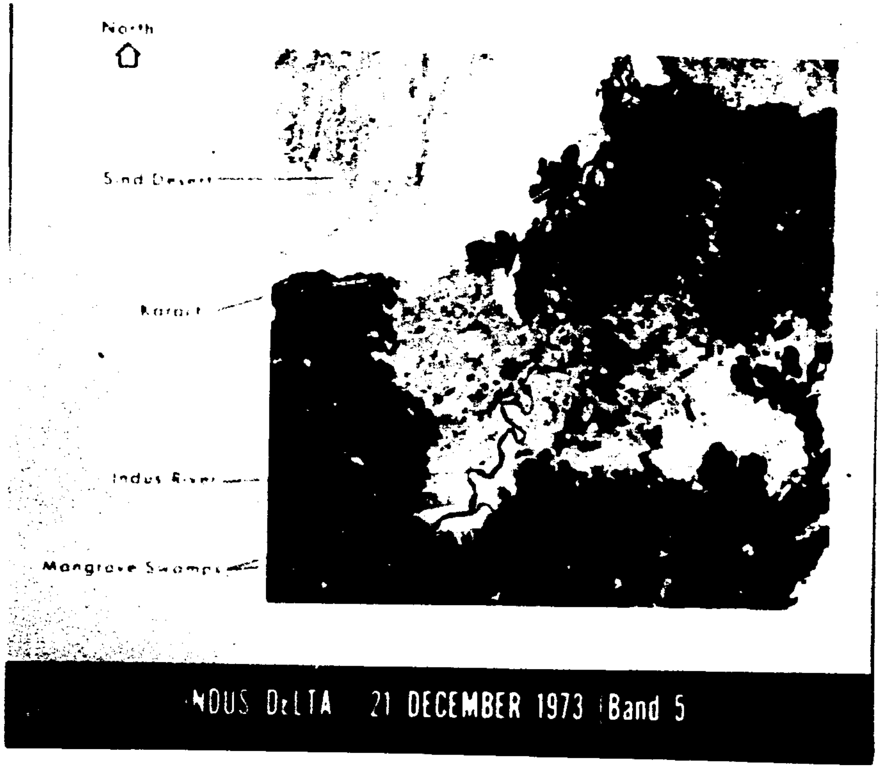


Fig. 2. The synoptic view of Landsat allows a view of the entire Indus Delta in one scene.

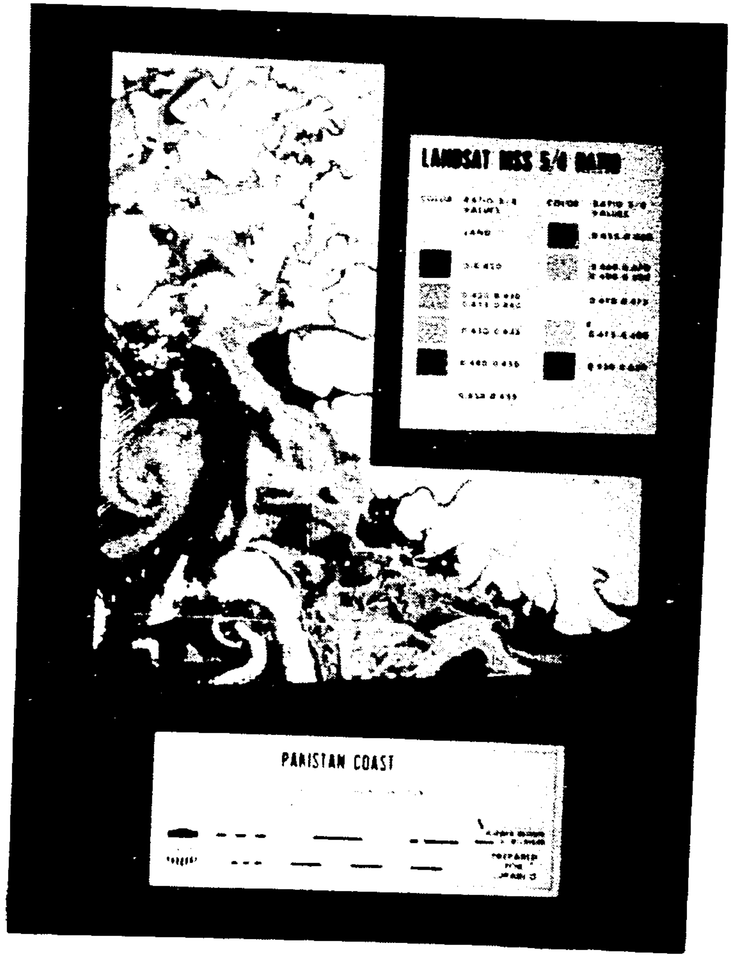


Fig. 3. Turbidity patterns highlighting current patterns off the coast of Pakistan as illustrated in Landsat data (original in color).

Session 3

APPLICATIONS IN FORESTRY

Picture Not Available

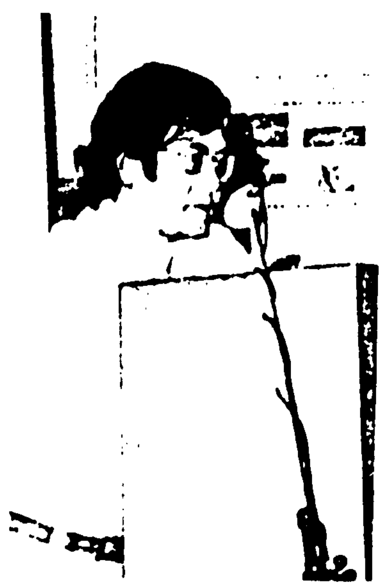
B.P. Baidya
Session Chairman
Ministry of Forests

Picture Not Available

K.P. Upadhaya
Session Conveyor
Soil & Water Cons.

D. Nelson
FAO/IWMP

P.P. Shrestha
Forest Survey



M.D. Rajbandari
Forest Survey

S. Morain
TAC

LAND CLASSIFICATION IN NEPAL USING LANDSAT IMAGERY[1/]

DeVon Nelson[2/]

WHAT WE ARE DOING

One goal of the Integrated Watershed Management project, a Food and Agricultural Organization Project attached to the Department of Soil and Water Conservation, is to conduct a country-wide inventory of the watershed conditions and natural resources. This inventory is to be a major contribution to a "Master Plan for Soil and Water Conservation" in Nepal.

What is this inventory? The inventory, when completed, will consist of a map of land units, descriptions of the basic land characteristics (soil, topography, geology, vegetation, land use) and watershed condition of the land unit, and interpretations for a few key management activities. The map will be on a 1:500,000 black and white mosaic of Landsat imagery.

HOW WE ARE DOING IT

Our methods are largely controlled by the resources available to make the inventory and by the nature of the information need. On the first point, we have a small inventory staff consisting of myself, an associate expert, three counterparts, and temporary assistants and consultants for social, economic, and statistical inputs. The time allotted to the inventory is two years. It is scheduled for completion in early 1979. In addition to staff size and time constraints, the mapping medium available to us dictates to some extent how the inventory will be made. As you know, complete aerial photographic coverage of Nepal is not available to us. We therefore are using Landsat imagery, which gives us the most natural representation of the country's surface features now available for all of Nepal.

1/ Part of FAO/UNDP Project NEP/74/020

2/ Land Evaluation Officer, Integrated Watershed Management Project, Kathmandu, FAO.

Information need has ultimate control on our methods. Basically this consists of (1) complete national coverage, and (2) watershed condition determined as a feature of interacting processes in an ecological setting.

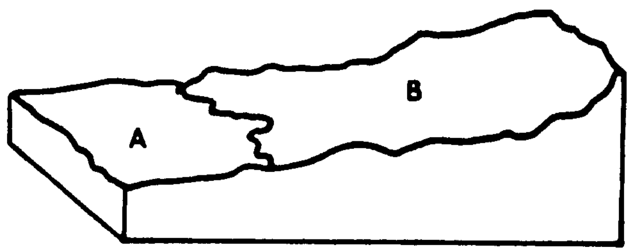
APPROACH

A land classification approach is used. We attempt to differentiate land units having similar ranges of land capability and common types of land use problems. The land units are sequentially distinguished at different degrees of resolution. Figure 1 illustrates this process. Collectively, the units identified at these different levels of intensity form a hierarchy of land units. This hierarchy is primarily the product of the need to successively stratify an area to arrive at the most detailed land units possible within the constraints of the project. It is difficult to be systematic, and consequently consistent, in the identification of refined land units by leaping from the unstratified, complex universe to a land unit with a comparatively narrow range of characteristics.

The hierarchy presents certain assets from the users' side also. The multiple levels correspond to intensities of information need at various administrative levels. The process of moving from general to the specific land units aids comprehension of the smaller units and places them in perspective with the whole. The essential objective of all classification is to make the object being classified more memorable. The hierarchical framework does this.

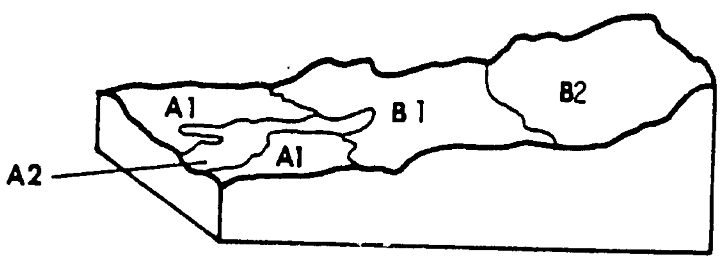
The hierarchy of land units used in the inventory is shown in Figure 1 and described in Table 1.

The area to be stratified. This example is for illustrative purposes and not necessarily to exemplify a given situation. Lands are stratified sequentially beginning at Level 1.

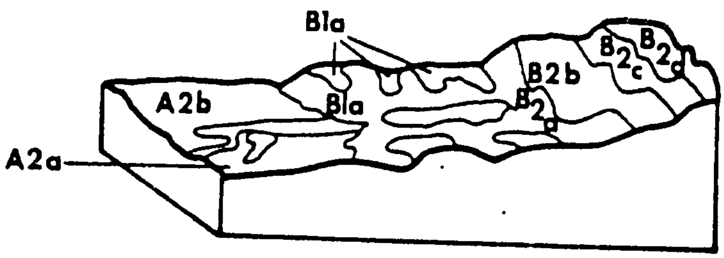


Level 1. Two units are delineated: A - lowlands; B - uplands.

Fig. 1. An example of sequential delineation.



Level 2. The units of step 1 are further divided into A1, lowlands surface. A2, drainageway; B1, foothills; B2, mountain lands.



Level 3. The step 2 units are separated into:

A2a - Bottom lands	B2a - Front slopes	B2c - Upper ridge slopes
A2b - Break lands	B1b - Ridge tops	B2d - Crest lands
B1a - Side slopes	B2b - Canyon lands	

Fig. 1. Continued

Table 1. Three levels in a land classification hierarchy

Level	Function	Criteria	Appropriate Map Scale
Ecological Zone (EZ)	General Orientation, Inventory Planning	Major Structural Regions, Five in Nepal	1:5,000,000 or smaller
Ecological Region (ER)	Mapping Units for National Inventory, National Planning	Geologic Structural-Climatic Regions, Relief and Dissection Pattern	1:1,000,000 to 1:40,000
Ecological Land Unit (ELU)	Description units for National Inventory, Map units for Regional inventory, Regional Planning	Slope position, Aspect, Vegetation Pattern	1:100,000 to 1:40,000

The intent in land classification is to identify land units which are an integration of several environmental factors: climate, vegetation, soil, geology, and physiography. These factors, operating in concert, produce land capability which in turn guides land use. Land use, together with environmental considerations, determines the watershed condition. This is the conceptual linkage which is the rationale for the inventory. Ground and air observations indicate its validity. The task then is to identify criteria for separation of land units by which we can delineate units which integrate a wide range of environmental factors. The actual criteria used depends on location and hierarchical level but generally the following were used:

1. <u>Physiography</u>: This is the most visible land feature on the satellite imagery. In a mountainous area it has overriding influence on land use. It reflects the action of the mountain building processes, geologic materials, and vegetation. It has in turn, controlling influence on local soils, climate and vegetation patterns. Physiographic attributes used were drainage pattern, density, and relief.

2. Climate: A climatic regionalization was made of Nepal. The climate is reflected in the satellite imagery as snow cover, sparse vegetation in low precipitation areas, and lighter colored south facing slopes.

3. Vegetation: Vegetation patterns have significance where they reflect land use, climatic, or soil differences, and therefore are important mapping criteria.

PROCEDURES

The major steps in an inventory of natural resources are mapping, data gathering, interpretation, and application. For purposes of this presentation, I will describe the first two of these steps as done in this inventory.

Mapping

We use three stages in mapping which are outlined below. The basic mapping job consists of separating units of land on the imagery according to our estimate of allowable variation and excessive contrast in the physiographic, vegetative, and climatic features described above.

1. Preliminary Mapping

Land units at the ecological region level were delineated on 1:800,000 color Landsat imagery. This map, which is on display, was made to satisfy the following needs.

a. General orientation - the principal land units are visible on satellite imagery. We can see the general pattern of the various kinds of land in Nepal. This is an absolute requirement for us without a long term acquaintance with Nepal.

b. Develop a tentative legend - The legend is a simple set of identifiers we use to talk about and think about the land units. It is a group of conceptual handles upon which we can build our knowledge of the land units.

c. Relate present inventory to past inventory - The preliminary mapping gives us a framework within which existing information in inventories, literature, reports, etc. can be brought into the present inventory.

d. Guide data collection - The location and pattern of land units as identified in the preliminary mapping helps us locate flight paths and field treks together the broadest range of information possible. Land units are necessary at this stage to stratify the country for sampling.

2. Secondary Mapping

This is the progressive revision of the preliminary mapping. It It is on 1:500,000 black and white, band 7 satellite imagery and is based on information accruing from:

a. Further study of satellite imagery, particularly at 1:250,000 scale and bands 5 and 7 black and white and Skylab photography.
b. Stereoscopic examination of selected aerial photography.
c. Field observations.
d. Overflights.
e. Literature and personal contacts.

The objective of the secondary mapping is to produce a set of land unit delineations that will serve as the final map for the inventory and to systematically record our growing understanding of the lands in Nepal.

3. Unit Correlation and Final Mapping

Each delineation of a map unit must be checked to see if it complies with map unit concept and description. Similar map units will be tested for their uniqueness to determine if simplifying combinations are possible. The uniformity of units is examined to decide if new units are required. Mapping on individual images is matched with adjacent images. The output of this process is a set of satellite images (our base map) with delineations and symbols suitable for transfer to a 1:500,000 base map which will be published and distributed as part of the final report. It is also the source of our final mapping legend.

Data Collection

Two approaches are used to collect new data on the land units we have mapped.

1. Field Transects

We travel on the ground, usually on foot, but also by four-wheel drive vehicle between various points that will give us a chance to examine as many land units as possible. So far, working in two teams, we have made 10 transects which averaged about 10 days each. During the transects observations are made which are periodically recorded on field data forms. Figure 2 is a copy of this form, showing the descriptive and interpretive information collected in the transects. This information will be summarized to describe and interpret the land units in the final report.

2. Randomized Plot Evaluation

We have very recently begun a second phase of data collection for our inventory. This phase is based on the detailed examination of randomly selected plots identified on 1:250,000 Landsat imagery. We have identified our sample plots and are just beginning to make observations on cover types. Other parameters will be identified and evaluated. We have not settled on an analysis technique other than a simple summary of data as a description of The Kingdom as a whole and analysis of variance as a test of the validity of our land units. Our objectives for this phase of the inventory at this time are very limited. We do see the linkage between this quantitative approach and the more traditional methods described previously and believe that the two are complementary.

We have the assistances of a geographer, Robert Warwick, in this phase of the inventory. An outline of our purposes and sampling methodology follows.

Date . . . . ELU . . . .

Location . . . .

Landform . . . .

Topography Slope . . . . Aspect. . . . . . Elev. . . . . Relief. . . . . . .

Geology Material . . . . Dip . . . . . % Fract . . . . Ptoc. . . . .

Soil Texture . . . . Color . . . . Depth . . . Stoniness . . . .%

Rock . . . . %

Vegetation Type. . . . . Cover . . . . Leyspec . . . .

Landsu Kind . . . .% Kind . . . . % Kind . . . . %

Population Density . . . . Groups . . . .

Wshed Sand Indic . . . .

Wshed Cor	. . . .	Roads	. . . .
Lslide Hazard	. . . .	Comm. For	. . . .
Eros Hazard	. . . .	Grazing	. . . .
Pote	. . . .	Agr. Dry	. . . .
Surf	. . . .	Agr. Irr.	. . . .
Terraci	. . . .	Hort	. . . .
R. Cors	. . . .		

Details on preparation of this form are given in the "Work Plan for Watershed Condition and Natural Resources Inventory of Nepal". This plan is now being revised.

Fig. 2. Field data form for recording observations.

SAMPLING TECHNIQUE AND METHODOLOGY

1. Purpose

   A. To estimate the proportions of Nepal's land area under different land cover categories, based on the interpretation of 1:250,000 Landsat imagery.

   B. To estimate the range and variation in a variety of morphological parameters extracted from 1:250,000 topographic maps.

   C. To check the significance of land units established visually on Landsat imagery.

2. Extent

   The sample is slightly greater than 5% of the total area of Nepal (≈141,000 Km^2).

3. Methodology: Two level random sampling.

   A. 1st Level: Selection of sites (5 cm X 5 cm on 1:250,000 scale ≈156 Km^2)

   1) Complete Landsat coverage of Nepal includes portions of 12 different Landsat scenes, each approx. 185 Km x 185 Km. Every scene includes portions of China/Tibet and/or India, in addition to both north-south and east-west overlap with other Landsat scenes. The first step was to define each Landsat scene.

      a) "Unique" means first delineating the national borders, and second, drawing match lines to eliminate zones of overlap between scenes.

      b) The match lines were drawn to maximize the use of the best image/scene for the areas of overlap, rather than a standard criteria (e.g. splitting the overlap). Thus, most of the unique scenes are irregular.

      c) The proportion of Nepal on each of the unique scenes was then estimated. This proportion of the 5% sample (i.e. 60 5 cm x 5 cm) was sampled from each sheet.

d) An imaginary rectangular grid of 5 cm x 5 cm squares, with the origin in the lower left corner of the scene, was placed over each scene, and this defined the population of the sheet. Each scene was completely covered, giving every area an equal probability of selection. Because of the irregularity of the national borders, and non-conformance of the imposed grid system with the Landsat scenes, (i.e. the grid had dimensions in multiples of 5 cm, while the unique Landsat scenes rarely exhibited exact correspondence) some sample sites were expected to either overlap the national border or the boundary of the unique Landsat scene. Only the area within a unique scene will be interpreted. However, this insures that each area has the same probability of being sampled.

e) The 12 unique scenes were placed in random order and the sample sites randomly selected. For both processes, the random number generator on an HP-67 calculator was used.

B. 2nd Level. Land Cover Estimation.

1. Rather than a full interpretation of Landsat imagery for each of the sample sites, a stratified systematic unaligned sampling design was used to estimate the proportions of the various cover categories for each site.

WHAT WE HAVE LEARNED

The inventory began in August 1977. Since that time we have tried to analyze the information need, develop a methodology, perform the mapping and field data collection tasks, and communicate to potential users of the inventory what we are doing and how we are doing it. We have scheduled our activities to make the most of favorable field time. We have been immersed in an intensive, multi-dimensional learning process. We are completing the first and major portion of our field work during this pre-monsoon period. Just as many of us in North America look forward to winter as the time to tie loose ends together, evaluate what we have done, and rechart our course for the future, the monsoon will be our stay-in-the-office and pull-things-together time. The observations which follow therefore are not conclusions based on review of long experience but impressions in the midst of the job.

1. Why was Landsat imagery used as the mapping medium?

   It provides the only complete photo-like coverage of Nepal. One requirement of the inventory was that it cover the entire kingdom. We had no alternative. With this said, certain attributes of Landsat imagery should be noted which made its use desirable despite the lack of an alternative medium. We are making a national level inventory in a short period of time. The range of scales available for Landsat, 1:250,000 to 1:1,000,000, are appropriate for the intensity of our mapping and data collection. What we can see in our widely spaced transects is adequately presented at these small scales.

   The focus of our inventory must be on units of land rather than individual resources, local problems, or even watershed conditions. Soil and water conservation needs are the functions of a wide range of environmental features. Landsat shows physiography quite well. Because the more dependent land features which determine land suitability are so strongly influenced by physiography in Nepal, Landsat is a very useful medium to delineate land units meaningful to our purposes.

   We can see a parallel between our inventory method and the soil and water conservation tasks we are facing. The "master plan" we are to prepare cannot take into account every local situation. This would be beyond the scope of a national plan. Our inventory methods therefore need not identify resources or problems at a level of refinement beyond the scope of our planning level capability. The influence is that the technical support must be appropriate to the need. Landsat imagery serves well at the national inventory level but other kinds of remote sensing tools will probably work better in support of more detailed planning.

2. What are the strengths of Landsat imagery revealed in our application of it?

   The "synoptic" view helps us to map regional land patterns in our stratification process. It makes obvious units of land long recognized as the basic physiographic units of Nepal, thus it is an important communication tool. Its advantages in "eye appeal" over other possible map bases add to its communication value.

   Over a period of time, Landsat is a means to document changes in stream channel and vegetation patterns. This knowledge is essential but not within the scope of the inventory we are now making. If we get a chance however, we will use imagery made at different seasons. Certainly two of the advantages of Landsat imagery in regard to our work in Nepal is its availability and relatively low cost. As indicated previously, alternatives are not available.

3. What are the principal short comings of Landsat in our inventory work?

   Lack of resolution adequate to directly see signs of watershed condition is a limitation.

   The problem of identifying ground cover types is one we are facing now. Extremes in cover, i.e. barren cultivated land, heavy forest cover, and snow are obvious. Mixed types and transitional plant communities are very difficult to distinguish. Brush, terraces with crops, brush with trees, and open forest cover are in a continuum of greys or pinks.

We have tried to resolve this problem by visually identifying cover types on the ground and relating these observations to points on the imagery. Our observations are made while trekking and during overflights. An obvious step we have yet to take to resolve this problem is to use aerial photographs as a source of ground truth. Other problems inherent to the use of these materials are tied to inconsistent color rendition among imagery, heavy shadow in high relief areas, and obscuring cloud cover.

4. What recommendations do we have for other users of Landsat imagery in Nepal?

Landsat imagery is an information tool. Like any tool it has a limited range of application. If the specifications of the information need call for a broad overview of the landscape, periodic updating, rapid, low cost average, then Landsat imagery has a contribution to make. These requirements fit most national level applications. If the need involves structures, precise location and design problems, or any other applications requiring high resolution, other remote sensing tools must be used.

Although the applications of Landsat imagery is probably a small percent of the remote sensing needs in Nepal, they are far from exhausted at this time. National and regional level resource inventories either already made or to be made, could benefit from the perspective offered by Landsat imagery. National planning for forestry, transportation, mineral development, agriculture, grazing, power development, as well as watershed management can be assisted by Landsat imagery if for no other purpose than to communicate their proposals.

Many factors determine the applicability of Landsat imagery to specific situations. The only general recommendation possible is for the potential user to acquire the imagery for their geographic area of interest and to experiment with it. We in the Department of Soil and Water Conservation - Integrated Watershed Project will be happy to assist you in any aspect of Landsat use.

AN APPLICATION OF LANDSAT IMAGERY IN FOREST DEVELOPMENT IN NEPAL[1/]

M.D. Rajbhandari and P.P. Shrestha[2/]

INTRODUCTION

Although Nepal lies within sub-tropical latitudes, the forest vegetation changes with the rise in altitude from sub-tropical, through temperate, to Alpine types with the timber line around 4600 meters above MSL. Therefore, the use and the management of forest ecosystems present a formidable as well as an interesting challenge.

The survey and management of the Terai and the Bhaber forests of Nepal has been accomplished by a reasonably thorough system of aerial photography. Because of the detailed information needed to prepare a forest management plan, Landsat data do not provide the spatial resolution adequate to interpret the detail required for this detailed assessment. However, in the context of forest encroachment, Landsat data could contribute to forest management by providing information on the extent and location of forest encroachment. The Landsat data are relatively inexpensive and are generally available with repetitive and recent coverage.

Since the last two decades there have been waves of migration from the hills to the plains and valleys. As a result, a considerable amount of forest has been encroached upon (Figure 1). Depletion of the forest has affected stream flow, reduced wildlife habitat, and increased erosion hazards.

For most of the hilly regions of Nepal, data on forest resources are either crude, incomplete or non-existent. Forest authorities are increasingly aware of the need to manage these hill forests, not only to meet the timber and energy needs of the people but also to preserve the

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[1/] Condensed from report by M.D. Rajbhandari and P.P. Shrestha, SDSU-RSI 77-10, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57007. Copies of maps have been excluded and are available from the author.

[2/] Acting Senior Photogrammetrist and Photogrammetrist, respectively. Forest Survey and Research Office, Dept. of Forestry, Ministry of Forestry, Kathmandu, HMGN.

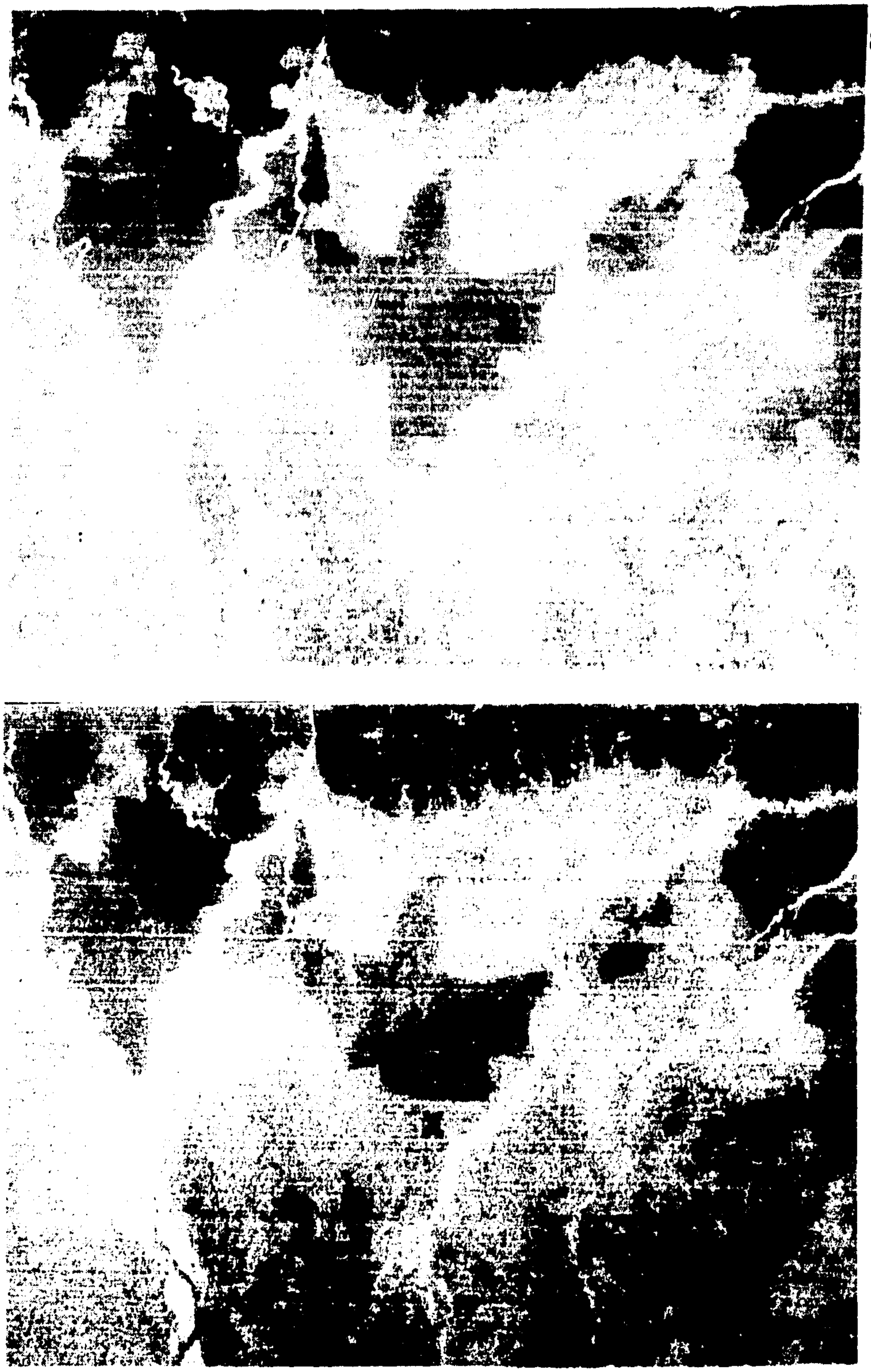

Figure 1. Depletion of forest land south of Kathmandu. Portions of band 5 Landsat scenes at scales of approximately 1:125,000. The top scene no. 1234-04180 dated Mar. 14, 1973. The lower one no. 2788-03493 dated Mar. 20, 1977. Notice the difference in area of forest between the two dates. The deforested area is marked by X in the lower scene of 1977.

ecological balance through conservation measures. In preparing preliminary forest working schemes, as stipulated in the National Forestry Plan, data requirements are substantially less stringent than those for a detailed forest management plan. In such a setting, the mapping of forest land, the rough estimation of timber volume and the measurement of forest depletion were some essential steps in the planning of control measures for forest development.

In the context of detailed land-use planning, Landsat data could not be substituted completely for aerial photography. It could, however, be a useful complement to photographic studies. Even for detailed planning in forestry, a Landsat "scene" could serve as a reconnaissance base to identify areas of interest, stress, or rapid change for which more detailed information could be obtained by aerial photography. This use of the satellite system can maximize the benefit obtained from acquiring the labor-intensive, high cost aerial photography at large scales. Statistical sampling of areas delineated on Landsat can be used to reduce the total-area coverage normally required.

STUDY AREA

An area in the far western development region of Nepal ranging from 250 meters to 1500 meters (MSL) in elevation was chosen to study the applications of Landsat data. The rationale in selecting this area was based on the fact that it not only embraces important forest zones, but also presents an area covered by some ground truth. Meaningful interpretation of most remotely sensed imageries is dependent on ancillary data. When extensive areas are involved, it becomes impractical to gather ground truth. Knowledge gained by study of the selected area can be used to aid in the interpretation of data extending from the known area to larger regions, even the entire country. The greater the variation in terrain within the known area, or "training area", the greater the potential error in interpretation. Therefore, with a sequence of these "training areas" to cover the major landscapes, interpretation accuracies increase.

The boundaries of the study area for this effort were the Karnali River on the west and Bheri River on the east. The northern boundary also included Surkhet Valley and Dang and Deokhuri Valleys form the eastern boundary. The southern boundary culminates on the Indo-Nepal border.

Surkhet is the center of the far western development region and is situated at 640 meters MSL. It is surrounded by high hills with altitudes ranging from 840 meters at Daulatpur to 1500 meters at Bailkanda. Recently, a forest working scheme has been prepared for the area to supply the increasing local demand of fuel, fodder, and timber.

Siwalik Hill, running in an east-west direction, is situated south of the Bheri River. It is often rugged and is comprised mostly of boulders and conglomerates supporting forest vegetation of medium to poor stockings. The forests are composed of an admixture of different hardwoods. Chir pine is often the dominating feature.

The Terai and the Bhaber land on the south have an average altitude of 110 meters above MSL. Planned forest management is taking place and changes in forest land due to encroachment have occurred. Because of the moist and deep soils, the Terai is intensively cultivated. The Bhaber region sustains economically important commercial forests comprised mostly of Sal (*Shorea robusta*) trees.

Agricultural lands in the hills are almost exclusively terraced to prevent soil erosion during the monsoon season (Figure 2). Due to the increasing population pressure, depletion of forest land through encroachment is noticeable even in the hilly regions. Much of the forest land around the cultivated fields is either poorly stocked or is covered by bushes of no economic value except as fodder for cattle.

STUDY OBJECTIVES AND LIMITATIONS

The purpose of this study was to explore the applicability of the low-resolution Landsat imageries, with support from available ground truth, to forest management. In fact, the main idea was to determine the gains to be made in using Landsat imageries as a first level of information when coupled with aircraft data and ground examination in a multistage and multidate inventory for quantification of forest lands.

Many difficulties did not become evident until the actual work with Landsat imageries was started. Lack of appropriate aircraft imageries, and availability of only a few seasonal Landsat images prevented our analyzing the multistage-multiseason part of the effort.

A considerable part of the northern portion of the study area is not covered by a good forest map. Under these circumstances, Landsat data

Figure 2. Terraced agricultural land in hill slopes, showing erosion in the background. (Original in color)

provide an obvious tool for obtaining basic information on the extent and location of forest lands. For the Terai and the Bhaber forests of the south, forest disturbance, originating primarily because of encroachment, is an important aspect to consider. Landsat imageries are a proper and beneficial tool for monitoring such changes in the available land-use maps.

Even though ground-truth data are available for a portion of the study area, considerable difficulty was experienced when attempting to differentiate forest types, such as conifers and various types of broad-leaved vegetation. Inability to differentiate among them may probably be attributed to the characteristic of the majority of Nepalese hardwood species to remain in leaf despite their deciduous characters. Although the shedding of their leaves is apparent, it is also invariably associated with the appearance of new leaves.

Net production of wood is basically related to the number and photosynthetic area of tree leaves. Fortunately, the spectral response observed when viewing vegetation from space is dominated by the leaves. Thus, the spectral response of vegetation in the Landsat data is worth examining in terms of vegetation cover, vegetation densities, and other productive indicators of forest land. As opposed to the estimate of biomass for ecological studies, differences in vegetational densities in forest lands are governed by parameters such as tree height, width, and crown diameter. Therefore, a second objective of differentiating the forested lands into different density classes wherever possible was undertaken.

MATERIALS AND TECHNIQUES

Landsat data used in this study were made available by a contract from U.S. AID through the Remote Sensing Institute at Brookings, South Dakota. In addition to 1:500,000 scale black and white and false-color composite photographic prints, the materials included 70-mm diapositives for bands 4,5,6 and 7. A set of 1:250,000 scale U.S. Army Map Service topographical sheets of Nepal were also available for use. A list of Landsat imageries used in the study is shown in Table 1.

Materials used from Nepal include 1:12,000 scale black and white aerial photographs, and a few 1:63,360 scale topographic maps.

No sophisticated techniques other than those inherent in visual interpretation of imageries were used. A mirror stereoscope was used to aid in the differentiation of forest lands in the imageries. However, a

Table 1. Landsat imagery available for evaluation of the study area.

Serial No.	Details	Scene No.	Band	Date	Landsat No.	Scale
1	Black & white prints	2034-04173	7	25 Feb 75	2	1:500,000
2	Black & white prints	2053-04224	7	16 Mar 75	2	1:500,000
3	Black & white prints	2053-04230	7	16 Mar 75	2	1:500,000
4	Color composite	2053-04224	4,5,7	16 Mar 75	2	1:500,000
5	Color Composite	2053-04230	4,5,7	16 Mar 75	2	1:500,000
6	Color composite	2034-04173	4,5,7	25 Feb 75	2	1:500,000
7	Color composite	2683-04194	4,5,7	5 Dec 76	2	1:500,000
8	Diapositives (black & white)	1147-04344	4,5,6,7	17 Dec 72	1	1:3,440,000

major portion of the study area was not covered by stereoscopic overlap. To identify forest land of this area, available topographic maps were utilized as aiding materials. A reflecting projector was used to enlarge or to reduce the base map.

As the study was primarily intended to delineate forest lands, available black and white imageries of band 7 were studied first and the varying grey tones of forest lands were mentally correlated with other land-use features. In order to take advantage of the detail arising out of the spectral combination of three portions of the electromagnetic spectrum (bands 4,5,7), false-color composites were utilized.

Water bodies appear blue to dark blue in false-color composites. Eroded land, dry agricultural areas and settlements, on the other hand, range in tonal difference from white to light blue in color. The color of the forested land varies from dark red to bright red. Fragmented agricultural lands of the valleys and plains range from light red to pink (Figure 3). The red tone associated with forest varied with topographic position because greater illumination occurs on the south facing slopes than the north facing slopes. Therefore, the interpretation was conducted with this anomaly in mind and by noting the topographic setting of the scene area by observing drainage or by evaluating the topographic quad sheets. These tonal variations differ during the course of seasons associated with phenological variations of the specific maps.

The output of visual interpretation was then studied using the I^2S Color Additive Viewer for further refinement (Figure 4).

Figure 3. Color composite of part of the study area, scale 1:250,000 with forests marked (F) and agricultural land marked (A). Image No. 2053-04224 dated March 16, 1975. (Original in color)

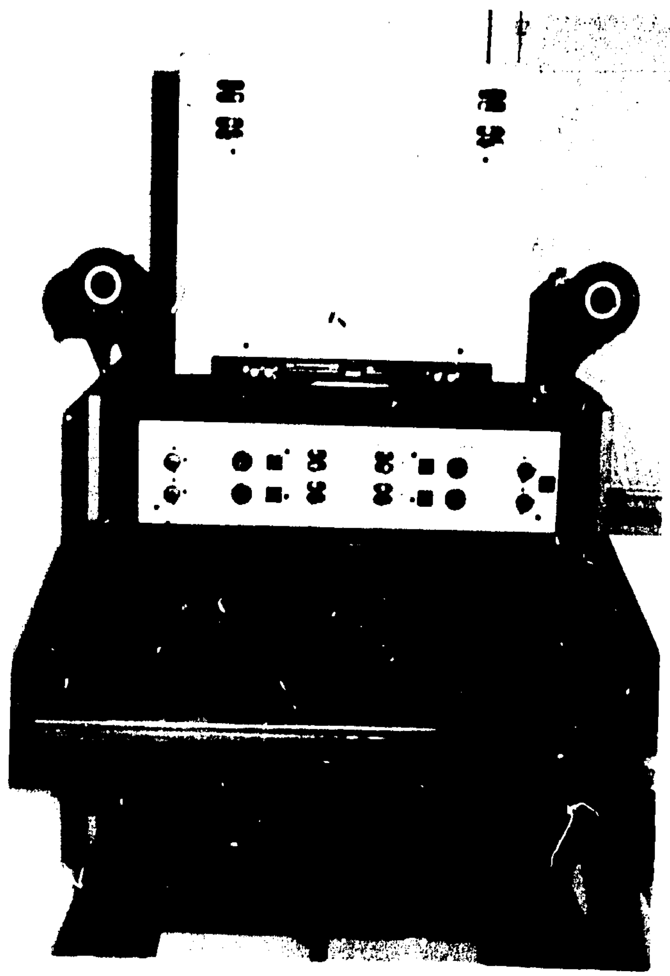

Figure 4. The I^2S Color Additive Viewer used during the study to enlarge and to combine individual black and white bands with colors, and to view and interpret the Landsat imagery.

Forested lands were differentiated into three different density classes. When forested lands were viewed in I^2S by superimposing bands 5,6 and 7 in red, blue, and green respectively, variation in forest densities were fairly discernible. The three tonal characteristics discernible in the color composites could fairly be referred to as dark red, bright red, and light red corresponding to well stocked (70 to 100% crown cover), mediumly stocked (40 to 69% crown cover), and poorly stocked (10 to 39% crown cover) forests, respectively. Due to the lack of adequate ground data, the differentiations are only estimates and remain to be tested. This testing and quantification of classes can only be accomplished through detailed field inspection or through evaluation of large-scale photography. However, the delineation on Landsat provides the spatial distribution of each class and thereby the delineation for the total area which can be further quantified by a statistical subsampling.

Although the clarity of Landsat data depends on many parameters such as weather conditions at the time of the satellite overpass and the topography of the terrain, it always places a practical limit on visual interpretation. Although a computer has the capability of discerning tonal differences down to 1 pixel (57 m x 79 m) or 1.1 acres, visual interpretation perhaps could not resolve less than 5 acres. Even with this limit some forest patches looked too small to discern due to their lack of contrast with their background. This problem was further aggravated in the hilly regions because of shadows.

RESULTS AND DISCUSSION

The final output of the study was a forest map of 1:500,000 scale[1/]. Although the forest lands of the study area have been differentiated into three density classes, the boundaries among them were not always sharp in the Landsat imageries. Boundaries between differently stocked forests were often diffuse. Such diffuse boundaries which could collectively be termed as transitional were common in the hilly regions.

Since no sophisticated data interpretation technique other than the visual one was used, it is hoped that further refinement of these results can be undertaken in the future through a comparative study of the aircraft over-flights and the available forest land-use maps of the home country.

[1/] The map is available for inspection through the authors.

Most of the mixed forests of the hilly region ranged from medium to poorly stocked forests due to many biotic factors such as overgrazing, lopping of trees for fodder, and forest fires. Overall tonal similarity among the spectral signatures to the forest floor and the scattered branches could naturally be expected in the Landsat imageries taken in summer (March). In spite of the transitions in boundaries in areas of moderate slopes, relatively abrupt changes in boundaries were the characteristics of the more precipitous slopes of the Siwalik Hills. In places, the differentiation of density classes could be dubious because the interpretation of forest lands beyond color recognition was called for due to sunlit and shadowed areas.

CONCLUSIONS

This report has concentrated on assessing the use of visual interpretation of Landsat data to assess the forested lands in the hilly regions and to update forest maps of the Terai region. In spite of the possible bias that could have been encountered in differentiating forest lands into different density classes, the objectives of the study were reasonably fulfilled.

Three potential uses of Landsat imageries were identified:

(1) Present survey methods which rely heavily on aerial photography from light aircraft are not without limitations. Although they provide timely and accurate data related to the extent and conditions of forest lands, the ability to present the data in a map format is inherently affected by the observer's knowledge of the local environment and his ability to relate this to what he can see from remote sensors[1/]. In addition, the necessity of covering vast areas in a short time span requires the use of several observers the difference between each observer's interpretations might be substantial. On the other hand, Landsat data could be profitably utilized to make forest maps of vast areas in a short span of time. The costs and time required for traditional surveys are often prohibitive; whereas, costs associated with Landsat inventories are minimal.

[1/] Rahbhandari, M.D. 1977. Forest Photo-Interpretation in Nepal. Forestry Journal, Tribhuwan University, Institute of Forestry.

(2) Where more detailed and accurate data are needed for forest management purposes, Landsat data can help to identify such areas for large-scale photography. Thus, Landsat data can be used as a valuable tool to augment already ongoing systems. Using this appraoch, a maximum benefit of the costly aerial photography can be derived.

(3) Updating the existing land-use maps of Nepal by conventional means will require a large investment in the form of air photo coverage and photo interpretation. Not only does it cost more money than the country could possibly afford, but it also requires more trained staff than is available. Landsat data have, however, exhibited its utility to monitor significant changes that have occurred in the landscape. In fact, utilization of repeated seasonal Landsat coverage should permit periodic updating of forest maps, both for monitoring effects of changing land use and for the more or less striking changes attributable to natural and environmental factors such as erosions, landslides, droughts, and perhaps floods.

The study of Landsat imageries has shown that it is a viable tool, capable of producing useful forest information, but with some problems yet to be resolved. The study results should be of great significance for use in inaccessible areas. However, as it cannot compete in accuracy with conventional forest maps without sufficient ground truth, it should not be considered as a stand-alone technique for forest data acquisition. Its best use is to integrate it into the total existing program and supplement existing procedures. Never before have the forestry scientists of Nepal had the opportunity to view such large regions (the whole country if needed) on a repetitive basis to provide information concerning the occurrence and distribution of forest resources and their changes with time.

LANDSAT AND LAND-USE CHANGE IN NEPAL

S.A. Morain[1/]

Honorable members of the rostrum; ladies and gentlemen:

It is my extreme pleasure to be back in Nepal having visited here first in 1976. At that time I participated in a remote sensing workshop co-hosted by the UNDP, the Nepal Department of Soil and Water Conservation, and the USGS Office of International Geology. Our intention was to introduce remote sensing technology through a series of lectures. We were so intensely busy that week that we had no opportunity to get into the field. I did have an opportunity yesterday, however, to visit the countryside around Kathmandu and during this time I was impressed by the industriousness of the people. Through their activities, they have created a terribly complex terrace land system that is now undergoing rapid land-use transition. There are parts of Nepal, I understand, that have had terrace agriculture for many centuries. The part of Nepal I saw has been converted from forest only in the past eight to ten years.

The intent of my presentation this afternoon is to show that remote sensing is indeed an appropriate technology for baseline data collection and that satellite data can be converted into meaningful information for use in land-use management and development planning. I do this for two main reasons. Firstly, as a contractor to the National Aeronautics and Space Administration, Technology Utilization Office, it is our function to assist in the transfer of space-generated technology to the industrial and public sectors in the United States. Specifically in remote sensing, it is our responsibility to assist in the transfer of this technology to developing countries. Secondly, I feel qualified to discuss the appropriateness of Landsat technology because I come from a

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[1/] Director, Technology Application Center, University of New Mexico, Albuquerque, New Mexico 87131 USA.

part of the United States that can be looked upon as a developing country in its own right. Many of the people who live in the desert southwest have annual incomes far less than the U.S. national average. We have a vast territory, not particularly rich in agricultural production, but very rich in energy and minerals. We are experiencing much the same kind of land-use and resource problems experienced in other parts of the world.

Figure 1 is an example of the complex land system that has evolved. If you look at that terrain, you will notice that there are very small elements of forest interspersed with agricultural land; land that has recently been cleared; land that has been under production for some considerable amount of time; and, other land just coming into production. What we have to do in remote sensing is evaluate the technical considerations for monitoring all or part of this complex system against economic and social constraints to determine whether the technology is applicable. Among the technical considerations there are two approaches. The visual and analog approach will concern us for the most part in the next few days. This involves acquiring and enlarging imagery to useable scales; and making an interpretation based on our inferences and our own experience with the landscape. The other approach has to do with digital image processing which I will not discuss at this time. The output products from visual interpretation become the input data that must be evaluated in economic and social terms. For successful technology transfer, the basic question is whether we can interpret Landsat images to obtain resource information in a more expedient and cost effective manner. In the United States we have found that, indeed, remote sensing data can be cost effective. We can accomplish more in a shorter period of time, and with fewer people. As in Nepal we have very few people available to carry out some of the requirements imposed by national legislation.

Figure 1: Terrace agriculture and recent forest clearings near Kathmandu, Nepal.

The essence of what I have just said is that all human activity in an agricultural economy leaves an imprint on the land: clearing, plowing, planting, irrigating, harvesting. All of these activities, and many more, have an appearance upon the landscape, either as a bare field or as a field with a crop; as a cleared mountain slope or as a terraced slope. Everything that people in Nepal do in their agricultural pursuit leaves an impression upon the landscape that can be viewed either as a pattern or as a color. Colors are usually referered to as "spectral" response. We believe remote sensing is useful because we have, in the essence of this technology, an ability to look at the changing patterns and colors (spectra) throughout the cropping seasons. If each of us could get into a satellite and circle the earth we would have the opportunity to view, in sort of a time-lapse movie format, all of the changes that are taking place - the agricultural landscape, forestry activities, the hydrologic landscape. All of these phenomena are changing constantly. We can no longer rely on the static, one map approach to record natural resources We do not have the time, because they are changing too rapidly.

In Figure 2A we see some individuals engaging in changing the spectral properties of their field by tilling it. In this view one can see a variety of field patterns and colors. Figure 2B shows some rice terraces. The bright spots in the center show that some of those terraces are actually flooded with water. What we are seeing is the glint of sunlight from those terraces. If we monitor at the right time and with the right kind of sensor, we can tell which areas are inundated, if indeed those areas are large enough to be detected. The job of resource managers is to watch these changes. They have to make decisions and they have to implement their development plans based upon their decisions.

The problem is that people change the landscape faster than managers create development plans. We cannot make good plans if we do not know where resources are changing or how fast they are changing. In short, there are too many hard working people and too few resource managers. Remote sensing technology can show where and how fast the land-use pattern is changing so we can optimize our few agency personnel to better manage the situation.

In New Mexico we have produced a land-use and vegetation map utilizing Landsat 1:1 million scale false-color composites. Our state is more or less rectangular compared to the shape of Nepal, and we have roughly twice the area. Figure 3A is a vegetation map of the southwestern part of New Mexico around the city of Las Cruces. It was prepared in 1964 by one of the world's leading vegetation mappers using traditional techniques. What it shows is his interpretation of the potential natural vegetation that would exist, if you took away all the effect of man. But we know in today's world we cannot take away the effects of man. Indeed, we are very rapidly converting one land-use

Figure 2A: All agricultural activities result in changing the appearance of fields and the relationships between fields. These people are changing the spectral response of their field as they prepare it for rice cultivation.

Figure 2B: The bright spots are flooded rice paddies. Their presence and detectability show the importance of viewing the landscape at the right times in the growing season using sensors that will record the spectral properties of interest.

into another. Consequently, this map is not particularly useful if we are making resource management decisions on a daily basis. It becomes a nice historical document and it does have value for grazing, but not for day-to-day uses in resource management. Figure 3B shows the vegetation and land-use categories interpreted from Landsat for exactly the same area. It shows that the map is far more detailed than Figure 3A; but the value of using remotely sensed data is that we can update this map regularly. In fact, one might argue that in many instances we do not need a map at all. What we need is to recognize those areas that are changing and to concentrate our attention on just those localities. It may be unproductive in a lot of cases to create a map. The imagery itself constitutes the historical document that can then be referred to at any future time.

Landsat is just one of a series of different kinds of sensors that can be used. The reason we tend to focus on Landsat in our discussions is that this series of sensors (Landsat I, II, III and IV when it is launched in 1980-81), provides us with the individual pictures to create a time-lapse series. In fact, Dr. William Fischer at USGS in the United States has actually taken some sixty frames of data over a portion of the United States and created a time-lapse film that shows the nature and speed of change in the landscape. Most of us are not in the business of making films; however, what we normally do is interpret individual frames, enlarge them, color enhance them, superimpose them over data from other sources, and ultimately make decisions that can be used for resource management.

Similar examples come to us from Thailand. In 1970 the Thai National Government produced a national atlas which contained a forest map. In 1973, enlargements from Landsat imagery showed that there was far less forest than had been mapped. This observation confirmed that residents in that part of Thailand were rapidly cutting the forest. There is a national policy in Thailand to preserve 50% of the nation as forest. There is already less than 50%, so the problem is to re-forest a large part of the territory. In further analysis of the seven eastern provinces of Thailand, the

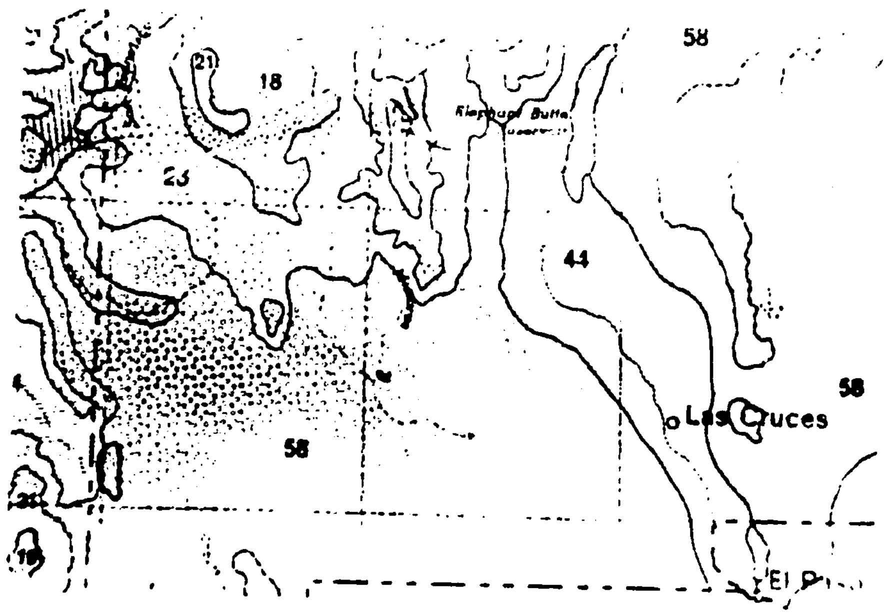

Figure 3A: Portion of a potential natural vegetation map of southwestern New Mexico. Though valuable for many uses such maps have limited utility for day-to-day resource management decisions. Compare with Figure 3B.

Figure 3B: Same area as shown in Figure 3A but illustrating actual rather than potential natural vegetation. These maps, derived from interpretation of satellite imagery, indicate a pattern of land-use at a specific point in time. Imagery obtained at yearly intervals can be used to measure the rates and directions of change in resource distribution.

Royal Forestry Department compared the forest distribution in 1976 with the 1973 pattern (Figure 4). By subtraction one can get an idea of the rate and direction of forest depletion. There are two provinces in Figure 4 (Chon Buri and Rayong) that are suffering forest depletion at a rate of about 12% per year. There are two other provinces suffering depletion in excess of 6% a year. The Landsat data have allowed the Thai Forestry Department to concentrate their re-forestation program on the two provinces that have suffered the greatest deforestation. They are concerned, of course, with all of the provinces, but they can maximize and optimize the utilization of their personnel by going to those provinces where depletion is most rapid.

Another example from Thailand shows an ability to map forest types Figure 5A shows a Landsat image obtained in February. Compare this February image with one taken in April (Figure 5B). In April all of the dipterocarp and dry evergreen forests have lost their leaves. We can make an estimate of the area of these different kinds of forests by using time sequence in the approach. Returning to my opening idea, we can utilize photography along with the satellite data. Figure 6 shows the results of a study that utilized aerial photography along with Landsat imagery. There were four time periods when aerial photographs were available. Five types of forests were discriminated and measured: hill evergreen forest, dry dipterocarp forest, mixed deciduous forest with teak, dry dipterocarp forest with pine, and dry evergreen forest. Included also is a category called "shifting cultivation." Shifting cultivators might be equated with the people here in Nepal who are building terraces. The major difference, of course, is that terraces tend to be rather permanent (barring landslides), whereas in shifting cultivation the land-use is continually changing. Comparison of the various photographs over the years reveals that, since 1966, there has been a phenomenal decrease in the hill evergreen and dry dipterocarp forests and a very rapid increase in shifting cultivation. In contrast, there has been relatively little change in the dry

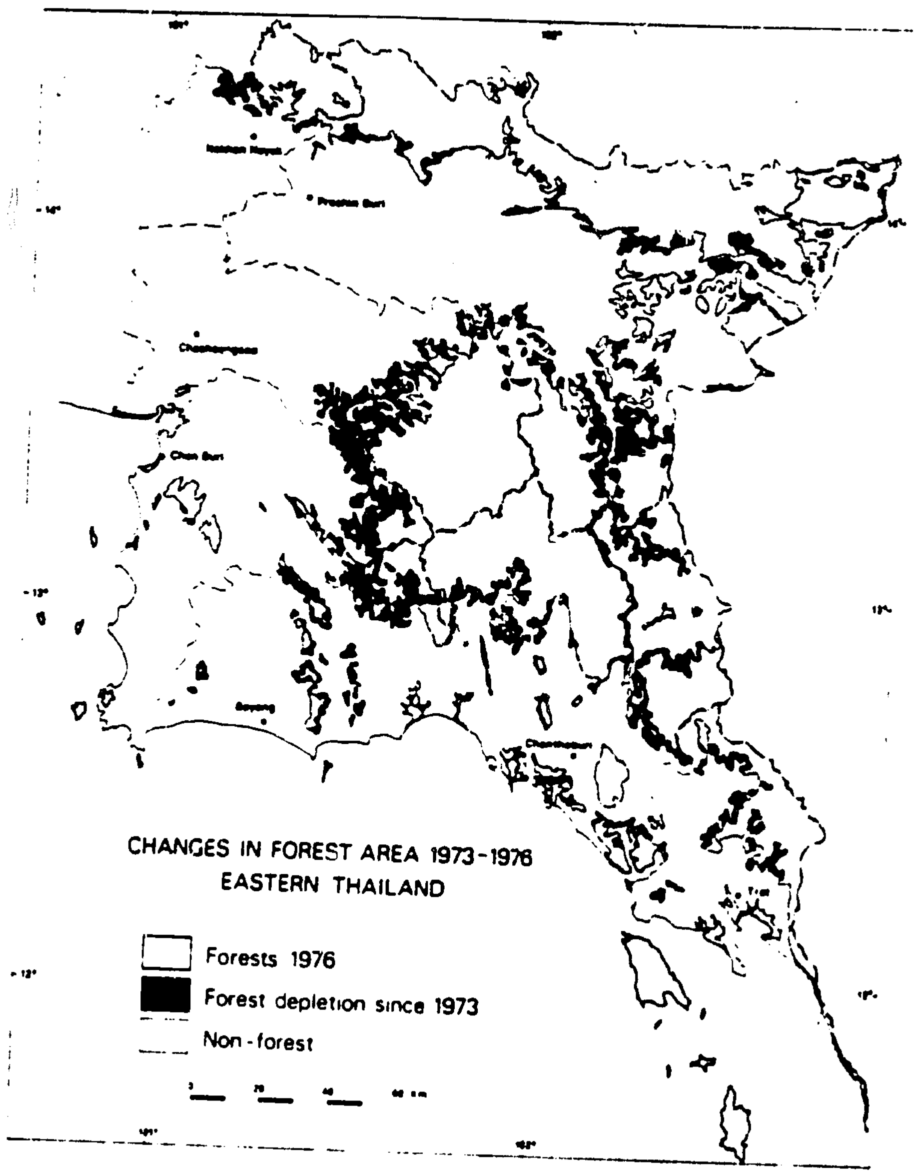

Figure 4: Changes in forest area in the seven eastern provinces of Thailand. The 1973 distribution derived from Landsat interpretation is superimposed on the 1976 pattern to reveal areas of forest depletion (shown in black).

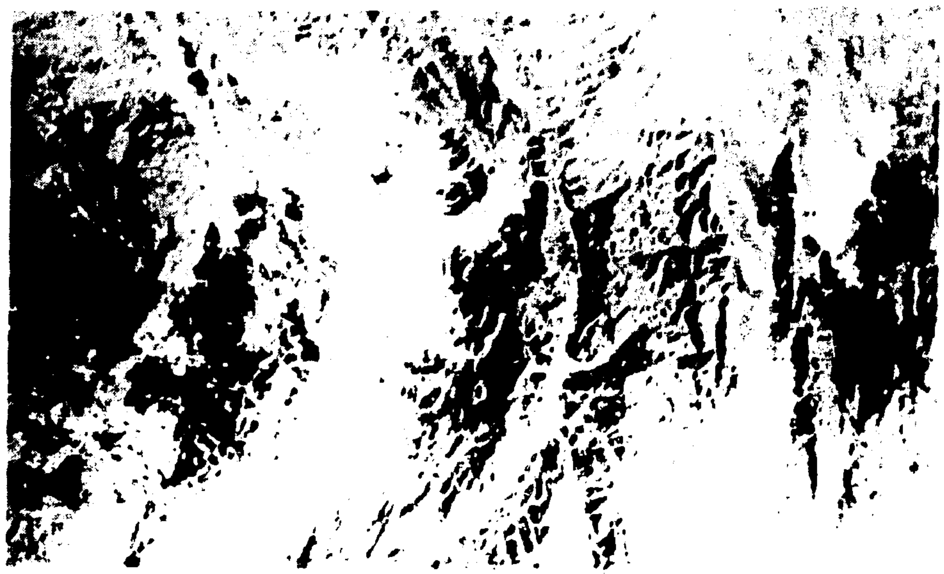

Figure 5A: Black and white reproduction from a Landsat false color composite for 12 February 1975. Compare the pattern of forest with that shown in Figure 5B.

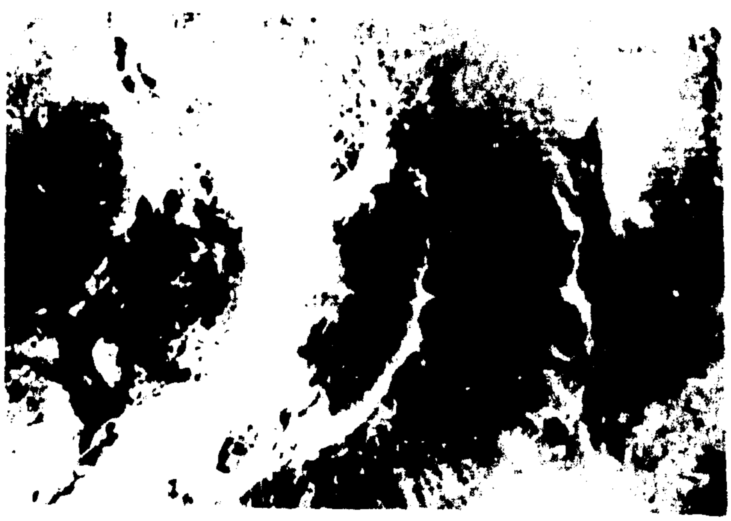

Figure 5B: Same type of photo as shown above for 7 April 1975. The forest pattern has changed to distinguish areas of deciduous from evergreen types.

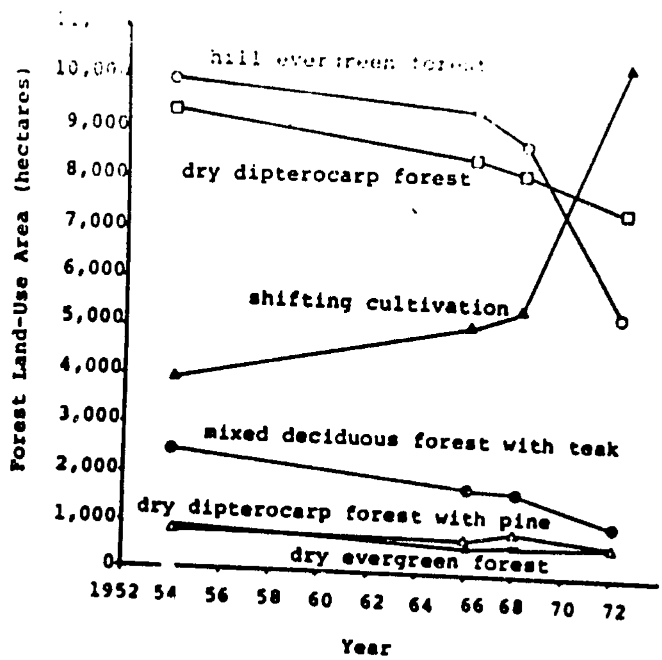

Figure 6: Relative areas of five primary forest types as measured from aerial photographs obtained in 1954, 1966, 1968, and 1972. Note the rapid increase in shifting cultivation since 1966 with corresponding decrease in hill evergreen forest.

dipterocarp forest with pine or the dry evergreen forests. The conclusion to be drawn is that, if one is looking at landscape evolution, one should pay attention to the conversion of dry dipterocarp forest and hill evergreen forest into shifting cultivation. The Thais are actively engaged in monitoring these two forest types so that they can implement a development plan that will convince the hill tribes to utilize the area more intensively, rather than continue to deplete the forest. They are also engaged in a non-remote sensing aspect of the same problem; namely, the adoption of new crops to replace those of the traditional economy.

Landsat imagery is therefore just one type of data in an array of possible systems. Data acquired from space are useful and inexpensive. They will get twice as good in future Landsat systems and I speak specifically of the thematic mapper on Landsat-D.

Once these benchmark maps are made, we can divert our attention to a whole range of questions regarding the resource base that we could never address before. One cannot find a single idea that sums up the utility of remote sensing better than the idea that Landsat provides us a means to ask questions and make measurements previously impossible to answer with limited means.

Session 4

APPLICATION IN AGRICULTURE AND HYDROLOGY

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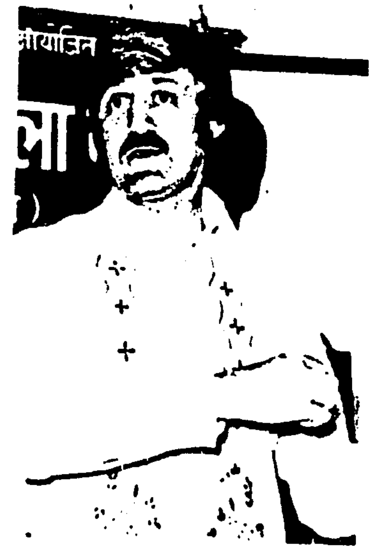
Dept. of Food-Agr.

P.L. Maharjan
Session Conveyor
Soil Survey



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An Agricultural Information System

William H. Wigton[1/]

Introduction

The need for better agricultural production data on a worldwide basis is well known. An individual country needs to know the amount of available food and fiber in order to make important marketing and policy decisions. In addition, the world community may need to know food supplies in order to provide assistance and give top priority to those commodities that fluctuate the most or fall into short supply.

This paper describes an agricultural data collection system that can produce accurate, timely, objective information, making effective use of people and the limited resources in many countries. We elaborate upon these ideas with respect to agricultural production.

An accurate estimate means that the value generated is close to the actual total quantity harvested. Usually, how close an estimator is to actual output is measured by the precision (the spread around the expected value of the estimator). In sample surveys generally we talk about sampling errors (precision) and nonsampling errors (bias). Sampling errors are reduced by improving the survey design and/or increasing the sample size. The nonsampling errors are controlled by concepts used, procedures, and training and measurement techniques. An important aspect of a survey system is that it is possible to measure both sampling and nonsampling errors. Controlling these errors helps make the data useful in defending the results against other official and private estimates of crop production.

Timely data means that information is available when it is useful. Specifically, we mean that the statistics for current crops are available soon after the basic data are gathered either from the grower or from in-the-field counts of crops or animals. Timely data imply that both the data collection and the office time to summarize the data are short. Objective data imply that the results do not depend on vested interests

[1/] United States Department of Agriculture; Economics, Statistics, and Cooperative Service; Washington, D.C., USA

of some group of individuals. Even more, they mean that the results depend on the use of random numbers to select those areas used for data collection. Further, when both sampling and nonsampling errors are measured, the statistics will hold up in a court of law. For example, suppose two areas are affected by drought. Funds will be distributed according to extent of damage. If personal biases are allowed to enter into the estimation process, people will not believe the statistics even if they are correct.

The effective use of resources in a data collection system is usually a comparative criterion. That is, compared with other possible ways to obtain estimates: How much money does it take or how many people are required or what equipment is needed? Is there a cheaper way to get the same information? This criterion is simply a matter of practicality.

Flexibility of a system to new problems means that the techniques have been tested and found to be applicable. For example, data can be obtained on seed crops, vegetables, fruit and nuts, food crops, feed crops, acreage planted, acreage for harvest, remaining stocks, livestock, dairy and poultry products, including births, slaughter for cattle, sheep, pigs, milk, egg production, as well as prices paid by farmers for fertilizer, seeds, labor, and prices received for agricultural products. Also, can the system collect other types of data, such as forest inventories and timber volume or household data as they are needed? If an agricultural data collection system meets these stringent test criteria, it would be very useful to a country's economic and policy planners.

Now, let me describe an agricultural information system.

Construction of the Area Sampling Frame

A. Explanation of terms used

The area sampling frame (ASF) is the total land area of a country broken down into N small parts called the sampling units (SU's). Out of these N sampling units a number "n" will be randomly selected for enumeration. The selected sampling units are called segments. These segments must be completely enumerated by personal interview. An interviewer must go to the area on the ground and locate the owners and operators of all land inside the boundaries of the segment. The data collected by the interviewer must be recorded in a suitable way. Questionnaires used by the Economics, Statistics, and Cooperatives Service of USDA in the United States may serve as an example.

In the process of constructing the area sampling frame there are several steps. The first step is to divide the total land into homogeneous areas with respect to the agricultural characteristics under study. These homogeneous areas are called <u>strata</u>. These strata will then be subdivided into intermediate parcels of land called <u>primary sampling units</u> (PSU's) to each of which a certain number of sampling units will be assigned. For example, the United States is broken down into approximately 3,0[illegible]0 sampling units and a sample of only 16,000 segments is selected to be interviewed. This means that only some 0.5% of the total land is sampled. Nevertheless, careful frame construction and interview procedures provide timely and sufficiently accurate estimates of the total agricultural production. The total is estimated by expanding the data collected from the n segments by the proper <u>expansion factor</u> N/n.

B. <u>Survey priorities, resources and difficulties</u>

Before one begins the frame construction process one should have a clear idea of which specific agricultural products are most important and must be emphasized. It is also important to know how accurate these estimates must be and how soon they must be available. Hopefully, once these questions are answered, the relative order of importance will remain fairly stable over time and the various crops and livestock items will not switch priority positions relative to each other.

Another item that needs to be determined is how much money will be available to develop the area sampling frame as well as to conduct each necessary survey. In general it is much easier to devise a frame for a single crop than it is for a general purpose survey where a long list of priority items are being estimated, but one usually does not have this luxury, so many compromises are necessary.

The total money available to conduct the survey determines the overall sample size n and the specific list of agricultural items that are to be emphasized determines how these n segments will have to be distributed among the individual strata. The allocation of segments to strata is done according to one of several schemes outlined in most sampling books.

Normally, in agricultural surveys, most of the available segments are allocated to the intensively cultivated strata so that most of the money is spent obtaining information in those areas which have the biggest share in the total agricultural production.

Also, important for deciding on the total number of segments to be selected is the determination of the optimum segment size for each stratum. A "rule of thumb" which can be used is that the enumeration of a segment be accomplished in one day. The obvious points to consider when deciding on segment size are density and structure of the population, length of questionnaire and type of transportation used. The structure of the population is a very subtle point and is referred to in statistics books as the intra-class correlation coefficient.

In practice the careful execution of the survey plan will meet with a number of difficulties, the first being that the segments must be easy to locate in the field. This problem will be dealt with in more detail.

Once the segment has been exactly located in the field, one has to be able to extract the wanted information. In a cattle census, for example, one would need to count the cattle in the segment. This may be possible, although difficult. If, on the other hand, one is interested in an insect survey, one would have to count all the insects in the segment. This task would be impossible to implement.

Some other items that are difficult to estimate are the potential agricultural production of a country, the crop production when enumerating early in the growing season of that crop, the hectares of crops when farmers do not know their own hectarage, or the number of cattle when farmers are unwilling to tell (perhaps they must pay taxes on a per head basis). If one is confronted with problems of this type, one should do serious thinking before starting to construct the frame or the results will be disappointing.

Finally, be sure that the interviewers are qualified and willing to do a good job. Training and regular instruction of the interviewers as well as quality checks of their work are indispensible.

C. Material and facilities needed

For the construction of the area sampling frame one needs topographic and/or land use maps or aerial photography or both. Satellite imagery can be useful supplementary material. Within reason, the more material one collects and uses in the construction of the area frame, the better the finished product. All materials used should be of the most recent date.

The scales of maps and photographic products used must be related to the size of the features on the ground. Not many countries in the world have sufficiently large field sizes to allow the recognition of single fields and their boundaries in Landsat imagery while, on the other hand, changes in land use pattern stand out clearly in that type of data. Landsat imagery can hardly be used at scales larger than 1:250,000 and fields smaller than 8 hectares are difficult to identify. Landsat imagery, therefore, will preferably be used in the stratification process while aerial photography at scales between 1:20,000 to 1:60,000 is particularly suitable for stratification as well as the delineation of the sampling units and their physical boundaries.

High resolution imagery from aerial photographic systems can provide basic maps at scales as large as 1:50,000. Such imagery could therefore replace or supplement standard aerial photography and also be used in areas with small fields (down to 0.4 hectares).

Besides imagery and maps, light tables, magnifying glasses, various colored pencils and suitable map storage space are needed for carrying out the construction of an area sampling frame.

D. Sequence of constructing the area sampling frame.

1. Stratification and boundary selection

Construction of the area sampling frame is carried out in several steps. The first step is the delineation of broad areas of homogeneous land use/land forms using all types of available data as outline in the previous section.

Areas of the same land use form a stratum. The number of strata into which the total population/land area can be or should be subdivided depends largely on the variety and distribution of various land use types in the areas under study, the significance of their visual differences in satellite imagery or aerial photography, the skill of the photo interpreter and the goal of the survey. If we wish to have seven strata, we could, as an example, subdivide an area into water, forest, cities (inner city), urban agriculture (suburbs), intensively cultivated land, less intensively cultivated land, and non-farmland, such as recreational areas, deserts, high mountain areas and military bases.

Cities and towns are often difficult to delineate on satellite imagery and all types of administrative and political boundaries are normally not visible but the latter can easily be derived from maps.

Many times one crop may be so important and cover large contiguous areas that a separate stratum is set up for that particular crop. In principle, however, the land-use stratification should be more general so as to accommodate different types of surveys for a number of years. Land areas smaller than 5 km^2 should not be separated out as a different stratum even though they might not fit the stratum definition.

The delineation of the strata on Landsat imagery should be completed without regard to physical boundaries on the ground. This allows the photointerpreter to concentrate on pattern recognition and differentiation. Another reason is that small physical boundaries such as country roads, footpaths, railraods, and small rivers can normally not be seen in imagery with a ground resolution coarser than some 30 m.

When transferring their strata from imagery onto maps of larger scales (scales of 1:20,000 to 1:50,000 are best suited) their initial boundaries might have to be changed slightly to coincide with physical boundaries on the ground that are easy to recognize and follow. Unique colors and roman numerals should be assigned to all strata and the strata boundaries colored correspondingly.

The need for good physical boundaries applies to all further subdivision of the strata into primary sampling units and sampling units. The importance of this cannot be overemphasized. Most of those sampling frames that do not work well fail because of poor enumeration. The key to quality enumeration is to have boundaries which can easily be located by both the interviewer and a supervisor carrying out quality control in the field.

2. Primary sampling unit construction

The next intermediate step in the construction of the area frame is to subdivide the strata into primary sampling units (PSU's). They vary in size depending on the stratum and the country. Since in the final step a specific number of sampling units (usually some 6 to 20 sampling units) will be assigned to them, they should be small enough to permit subdivision in a short time. However, they should be large enough to be useful for a variety of surveys. A statistician may be needed to help decide the optimum size.

Again, good boundaries must be obtained on the map and marked in the color of the stratum. Primary sampling units in non-contiguous parts of the same stratum must be grouped together and all PSU's be numbered in a unique way, separately for each stratum. Each primary sampling unit can then be identified on the map by the stratum number (roman numeral), its PSU number (arabic numeral) and the size of its area (in km^2). For example, I-3-16 means the PSU number is 3 in stratum I has an area of 16 km^2.

In numbering the PSU's one could begin in the northeast corner and number in serpentine fashion from east to west so as to guarantee that no PSU is left out. The area can easily be measured using a grid or, more accurately, by using a planimeter.

After this is done, all the primary sampling units are listed on a PSU identification sheet. A separate sheet is used for each stratum.

3. Sampling unit construction and primary sampling unit and segment selection

In order to save time, not all the PSU's will actually be broken down into sampling units; rather, a certain number of sampling units will be assigned to all of them. Only a few PSU's will then be randomly selected for further subdivision into sampling units (SU's). The probability that a given PSU will be selected is proportional to the number of assigned sampling units in it.

The number of sampling units assigned to a PSU depends on its size. The optimum SU size varies with the land use conditions in the survey area, the survey priorities and resources and the length of the questionnaire. It normally differs in different strata. As an example, the optimum SU size is given for two areas - Kings County, California, and Salcedo Province in the Dominican Republic - in Table 1. All cities and towns, no matter how small, should have at least one sampling unit.

The actual number of SU's assigned to each PSU is determined by dividing the area of the PSU by the optimum SU size, then round the quotient down to the nearest whole number. The number of assigned sampling units in each PSU is then listed on the PSU identification sheet in the column marked "S.U." and their cumulative number for each stratum in the column "Cum".

The whole PSU and segment selection procedure can be summarized as follows:

(a) Pick the random number (see 4) from 1 to N where N is the total number of sampling units in the particular stratum. Compare the random number selected with the cumulative numbers given for each PSU in the PSU identification sheet. The PSU selection for further subdivision into sampling units is the nearest one containing the random number.

Table 1. An example of optimum sampling unit (SU) size for two areas.

Area	Stratum		Optimum size of the SU's (in km^2)	Range of Tolorance (km^2)
Kings County, California	I	(Intensively cultivated agriculture)	2.5	1.3 - 5
	II	(Rangeland and desert)	15	10 - 31
	III	(Non-agricultural)	25	12.5 - 51
	IV	(Urban)	0.25	0.25 - 0.8
Salcedo Province Dominican Republic	I	(Intensive agriculture)	2	1 - 3
	II	(Coffee)	2	1 - 3
	III	(Extensive agriculture)	4	3 - 5
	IV	(Non-agricultural land)	4	3 - 5
	V	(Urban)	1/2	1/4 - 3/4

(b) Find the selected PSU on the map and divide it into the assigned number of sampling units using the best available boundaries. The actual size of the sampling units to be constructed may vary within the tolerance range.

(c) Number the sampling units in the selected PSU beginning in the northeast corner and proceeding in serpentine fashion as before. Select one at random and identify it with the segment number.

(d) Record the segment number, the stratum number, the PSU number, and the number of sampling units in the PSU on a segment location sheet. The final column on this sheet may be used to record the name of the cities/towns for segments in the stratum "urban" or any other pertinent information.

Since only one sampling unit is selected within each selected PSU, the sample selection procedure may be thought of as two-step single stage rather than two stage cluster sampling.

4. The use of random number tables in the selection of primary sampling units and segments.

(a) Divide the random number sheet into columns of the size needed.

(b) Count the number of one-digit columns, if any, and number them.

(c) Using another random number table, decide which column to begin with.

(d) Again using a random number table, decide whether to begin at the top or bottom of the column. Mark the start on the random number sheet.

(e) Again using a random number table, decide which column to go to next. Draw an arrow from the first column to the second. If you began at the top of the first column, draw an arrow from the bottom of the first to the bottom of the second.

(f) Randomly select the third column and draw an arrow from the second to the third as before.

(g) Proceed until all the one-digit columns are used up.

(h) Go to the two-digit columns and proceed as above. Continue until all the page is in order.

It may be helpful where you have a number of arrows crossing each other to use a different color for each set of different size columns.

To use the random number table, decide how many digits are in the highest possible number to be selected and use columns of the size. For numbers between one and ten, use a one-digit column (0 is ten). For numbers between eleven and one hundred, use a two-digit column (00 is 100); and so forth. Thus, if you need to select a random number between 1 and 11, go to the two-digit column and select the first number which falls between one and eleven.

As you go down the column, cross off each number considered even though these were not actually selected. In the above example, any two-digit numbers which did not fall between 01 and 11 should be marked off until a number is found. These numbers had a chance of selection and should not be used again. Don't start over at the beginning each time but begin where you left off the previous time. Random numbers are commodities to be used up and discarded.

Once the ASF is constructed and the segments selected the hard task of data collection should begin. This task is so difficult that even under the best conditions many things can go wrong. This phase of work needs much special planning also.

Drainage Analysis of Nepal Using Landsat Imageries[1/]

N.N. Vaidya and P.M. Joshi[2/]

INTRODUCTION

Landsat imageries are very helpful in determining hydrological conditions over large areas because of the synoptic observation of vast regions using different wavelength portions of the spectrum. The fact that the quantity and sometimes the quality of water in a given area is constantly changing requires that repetitive data be collected to monitor changes. Space technology offers the opportunity to view the landscape repetitively.

Remote sensing surveys offer the best opportunity to apply satellite data to the nationwide study of earth's resources. Satellite data are an asset especially for a country like Nepal where more than 75% of the area is hilly and inaccessible.

PREPARATION OF THE DRAINAGE MAP

A drainage map of Nepal was prepared to a scale of 1:500,000 using Landsat imagery. As a first step, black and white Landsat band 7 imageries were enlarged, scale corrected and tone matched, and a mosaic of Nepal was prepared. The whole area of the country was covered by 12 Landsat scenes. This mosaic was used as a base. The drainage lines and patterns as well as the watershed boundaries were studied, and then all were traced on an overlay.

While mapping the drainage lines using the band 7 mosaic, color composites were also studied whenever the drainage lines were not clearly visible on the black and white imagery. Then the major and minor basins were delineated by determining the watershed boundaries from observation of Landsat data and quarter-million quad sheets. There are about 6,000 rivers which are comprised of 9 river basins enclosing 18 sub-basins. The areas of all the major basins and sub-basins are furnished in Table 1.

[1/] Condensed from a report by N.N. Vaidya and P.M. Joshi, SDSU-RSI-77-16 Remote Sensing Institute, SDSU, Brookings, SD 57007. Maps have been excluded and are available from the author.

[2/] Acting Senior Hydrologist, Dept. of Irrigation, Hydrology and Meteorology Ministry of Food & Agriculture, Kathmandu HMGN, and Section Officer, National Planning Commission Secretariat, Kathmandu HMGN, respectively.

Table 1. Drainage basins as determined from Landsat data and quarter-million quads.

Major Basin	Sub-basin	Area in Sq. Kms. Major Basin	Sub-basin
1. Mahakali		4,652	
2. Karnali		49,196	
	a. Seti		7,251
	b. Bheri		8,056
	c. Thulo Bheri		7,039
	d. Sano Bheri		2,314
	e. Humla Karnali		6,106
	f. Mugu Karnali		6,218
	g. Karnali		10,149
3. Rapti		5,049	
4. Babai		4,770	
5. Narayani		26,764	
	a. Ban Gad		2,019
	b. Kali Gandaki		9,274
	c. Seti		2,662
	d. Marrshyangdi		5,054
	e. Buri Gandaki		3,733
	f. Trisuli		4,022
6. Bagmati		3,523	
7. Kosi		24,784	
	a. Sunkosi		14,134
	b. Arun		4,808
	c. Tamar		5,842
8. Kankai		1,440	
9. Mechi		579	

FINDINGS AND CONCLUSIONS

Following are the findings obtained from the study of drainage analysis using Landsat imageries.

(1) Mosaicking the imageries for the whole country was quite easy because of the presence of overlap of more than 14% between two adjoining imageries. This also helped to obtain cloud-free mosaics.

(2) The water courses of the second order, and many of those of the third order, were easily identified on the imageries. The visibility of river valleys has helped in finding river courses of other orders. Moreover, the bigger lakes such as Rara, Phewa, Rupa and Begnas were plotted on the map with the drainages feeding them and flowing from them. This study of incoming and outgoing drainage on Landsat imageries of different dates help to study the fluctuation of water levels in these lakes.

(3) Some difficulty was found in identification of river courses and watershed boundaries in those areas where there is snow cover and shadows because of the hilly nature of the terrain of the country. This difficulty was overcome somewhat by the study of imageries of different dates. The natural features change with time. For successful planning it is important to monitor such changes. In this case, Landsat imageries can offer the special advantage of studying this phenomena by supplying up-to-date data continuously.

Landsat imagery was compared with the topographic maps prepared by the U.S. Army Map Service at a scale of 1:250,000. This study showed some discrepancies in the river courses. However, Landsat imagery is the true recent picture of the ground and the topographic maps were prepared from aerial photographs taken a couple of decades ago. It was concluded that Landsat imageries are up-to-date and the topographic maps are either incorrect or outdated.

(4) Some difficulties were faced in delineating the international boundary to be included in the map prepared because of the lack of reliable reference for the international boundary with China. The reference maps that were used were the topographic maps of scales of 1:250,000 prepared by the U.S. Army Map Service and the geological map of Nepal prepared by V.A. Talallov, the Russian Geologist, at a scale of 1:500,000. It seems that the topographic map does not include the data of the Indo-Nepal Boundary Treaty of 1961. Moreover, there are some discrepancies in the extent of

watersheds in the northern mountains. Several features in Talallov's geological map do not coincide with those of the Landsat imageries. Although there is this limitation, the international boundary in the map has been fixed taking what was apparently the reliable information from those two maps. Therefore, the international boundary with China has to be checked. Boundaries with India to the east, south and west look nearly correct.

AN EVALUATION OF LANDSAT DATA FOR HYDROLOGIC INVESTIGATIONS IN NEPAL[1/]

N.N.Vaidya[2/]

Background

The hydrology section of the Department of Irrigation, Hydrology, and Meteorology has been collecting hydrometric data of rivers in Nepal since early 1961. This section is operating 48 regular stations of which 46 are equipped with cable cars to measure the surface flows of the rivers and 22 are equipped with gauge houses along with staff gauges in each of the stations. There are 124 additional partial and miscellaneous stations and 10 sediment sampling stations operated by this section. Mass curve analyses and flow durations of some rivers have been studied. To date, eight publications of surface water records and station network maps have been published.

The meteorological service is operating 230 meteorological stations and has published four volumes of climatological summaries. So far the Ground Water Division has drilled 192 test wells, constructed 42 production wells, and published the ground water potential map of the Rupandehi and Kailali-Kanchanpur districts.

Study Objectives

The use of remote sensing to provide the spatial information, i.e. bifurcation ratios, channel lengths, etc., can enhance the effectiveness of efforts required in obtaining ground station information. Studies can be initiated by combining the spatial and quantitative ground data for flood forecasting, sediment loading of rivers, etc. The use of the two types of data will provide better accuracy for prediction.

The main objective of this investigation was to study the applicability of remotely sensed data obtained from the Landsat imageries and SKYLAB photographs for hydrologic studies. Remote sensing has high potential for appraising and monitoring, on a regional scale, the earth's land and water resources.

Three main investigations were carried out:

[1/] Condensed from report by N.N. Vaidya, SDSU-RSI-77-14, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57007. Copies of maps have been excluded and are available from the author.

[2/] Acting Senior Hydrologist, Department of Irrigation, Hydrology, and Meteorology, Ministry of Food and Agriculture, Kathmandu, HMGN.

i) A preliminary study of drainage was made for the whole of Nepal (N Lat 26°15' - 30°30' and E Long 80°15'- 88°15'), an area of 141,577 sq. km.

ii) A siltation study in the Trisuli River Basin covering an area of about 5960 sq. km. which lies within geographic coordinates of E Long 85°-85°30', and N Lat 27°30'-29°.

iii) A delineation of minor sub-basins in the Narayani River Basin (N Lat 27° - 29°, E Long 82°50' - 85°15') with morphometric studies.

Methodology

Landsat imageries and SKYLAB photographs were available for the area under study (see Fig. 1). Although the area has been covered by aerial photography, no aerial photographs or photogeological maps were available for comparison during this study. A comparative analysis of Landsat interpretation will be conducted at a later date.

The Landsat and SKYLAB transparencies were procurred from the EROS Data Center and enlargements to various scales such as 1:500,000 and 1:125,000 were made at the Remote Sensing Institute in Brookings. The 1:125,000 and 1:500,000 scale imageries were found to be very useful for interpretation. Maps were prepared at scales of 1:125,000 and 1:500,000. Landsat black and white images of bands 5 and 7 and color composites were also used for interpretation. Various band and color filter combinations were investigated using the I^2S Color Additive Viewer for delineating the silt source and landslide areas.

Drainage Analysis

The drainage map of Nepal prepared from Landsat imagery was compared with the 1:250,000 topographic quad sheets. Results of that comparison are presented in a separate document[1/]. In addition, the drainage basins were mapped and the areas measured.

Siltation Study in Trisuli River Basin

The Trisuli River watershed, which lies northwest of the Kathmandu Valley in the hilly region, was studied in detail using Landsat imageries. A watershed map of the area showing the possible silt sources was prepared.

[1/] Vaidya, N.N. and P.M. Joshi. Drainage Analysis of Nepal. SDSU-RSI-77-16. Report submitted through Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57007 to His Majesty's Government of Nepal.

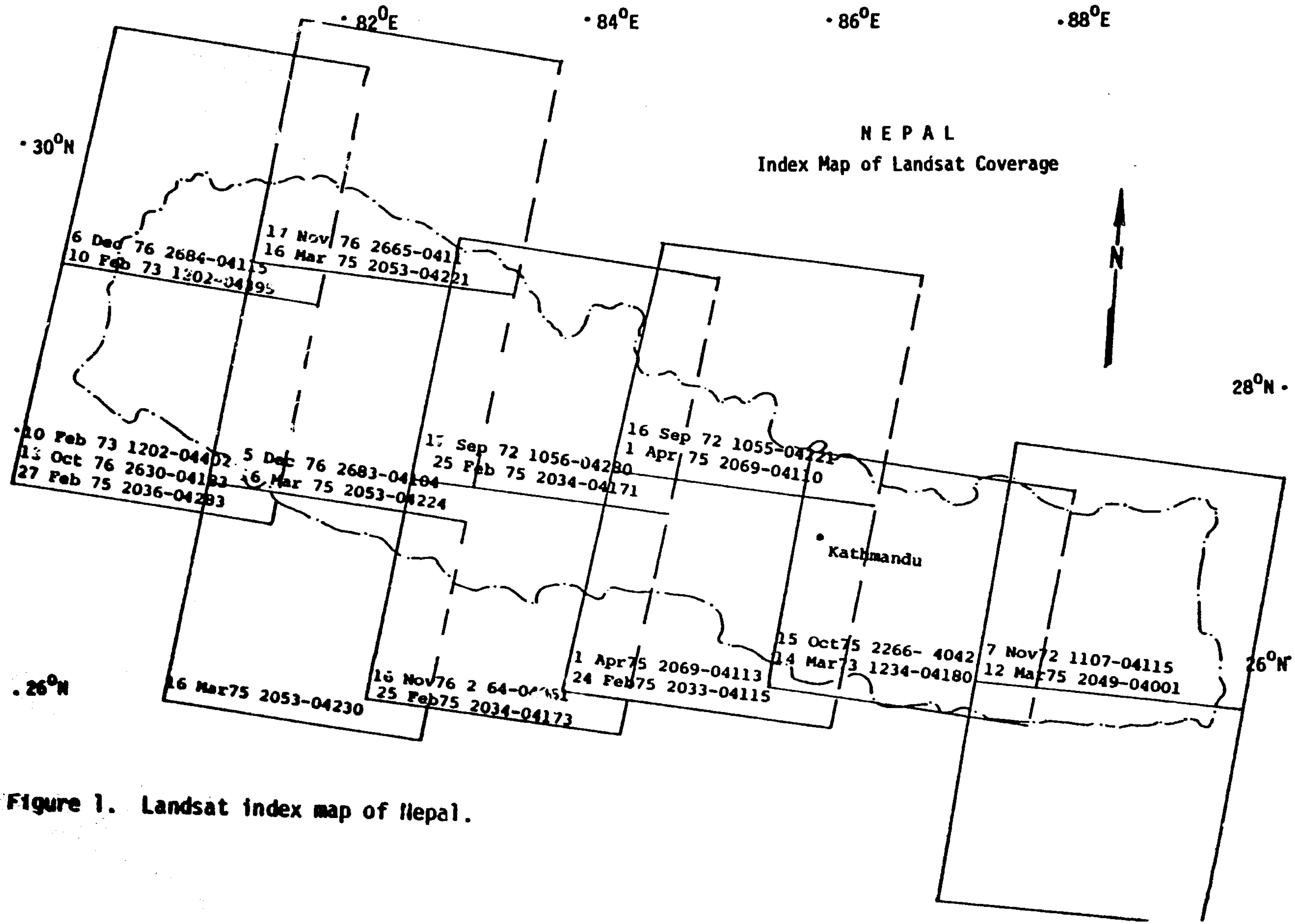

Figure 1. Landsat index map of Nepal.

The Trisuli area is vital for the national economy of the country because of the generation of hydro-electric power. There are many rivulets with steep gradients in this watershed which contribute considerable amounts of silt into the main Trisuli River. Because the silt is deposited near the intake area of the power house, it endangers the power house's efficiency.

Locations which were effected by landslides were delineated by the study of slope characteristics, tone, vegetation patterns, and the effect of damming in river courses. Several of these locations were mapped including Jharlang and Labu. The source areas of the silt materials which are barren or sparsely vegetated slopes showing high reflectance on the Landsat imageries were mapped. The river channels were mapped, along with the flood plains, showing the amount of alluvial materials which are comprised of coarse sands, gravels, pebbles, silts, and clays.

Morphometric Studies in Narayani River Basins

A map of the Narayani River Basin with minor sub-basins was prepared. The Kaligandaki River flowing out of the Mustang Bhot Himal joins the Trisuli River north of the Narayangarh in Devghat. From Devghat the river is named the Narayani River. The main tributaries of the Narayani River system are Kali Gandaki, Trisuli, Buri Gandaki, Marsyandi, Seti Barigad, and Rapti. There are several deep gorges in the Kaligandaki and Trisuli rivers which range in depth from 1200 to 1350 m.

The drainage areas of the above sub-basins were interpreted from Landsat and topographic maps and their areas calculated using the Numonics Electronic Graphic Calculator. The results are shown in Table 1.

Table 1. Results of interpretation and measurements of Landsat data for areas of sub-basins of the Narayani Basin

Sub-basin No.	Name of the Sub-basin	Area in sq. km.
1	Trusuli	5960
2	Buri Gandaki	5160
3	Marsyandi	5050
4	Seti	2660
5	Kali Gandaki	9270
6	Barigad	2020
7	Rapti	2640
Area which is not enclosed in sub-basins		730
	TOTAL	33490

A statistical analysis was conducted and the stream orders were correlated with the number of streams. The results are shown in the graph in Figure 2.

Table II shows the bifurcation ratio for the basin which refers to the ratio of the number of stream segments "n" to those of the next higher order "n+1". These are helpful in finding the relationship between the low order and high order streams in the basin area.

Table II. Bifurcation ratio as determined from Landsat data for Naiayani River.

	Stream Orders	
Stream Orders	No. of Channels	Bifurcation Ratio
1	894	1.44
2	618	9.59
3	64	21.30
4	3	3.0
5	1	

Image 100

The General Electric Image 100 is an interactive multispectral image analysis system which is available at the EROS Data Center near Sioux Falls, South Dakota. To demonstrate its operation and capabilities, it was used to analyze a small part of Landsat scene number 2788-03493 dated the 20th of March, 1977 and located southeast of Kathmandu.

The Image 100 operates on the principle that many ground features possess unique spectral reflectance characteristics or "signatures". For example, vegetation has high brightness values in bands 6 and 7 and rather low values in bands 4 and 5. On the other hand, soil has a higher brightness value in band 5 than it does in bands 4, 6 and 7. Surface water has low reflectance values in band 7, enabling it to be easily delineated from vegetation and soil. The Image 100 uses the various combinations of brightness values as recorded in the four MSS wavelength bands to classify the features in an image.

A part of the scene was analyzed using the Image 100 interactive system for the following two types of classification:

1) for monitoring the water courses
2) for identification of eroded areas.

An example of the resulting images of the display monitor is included in Figure 3. The dry stream beds and the erosion areas could not be separated, which is quite

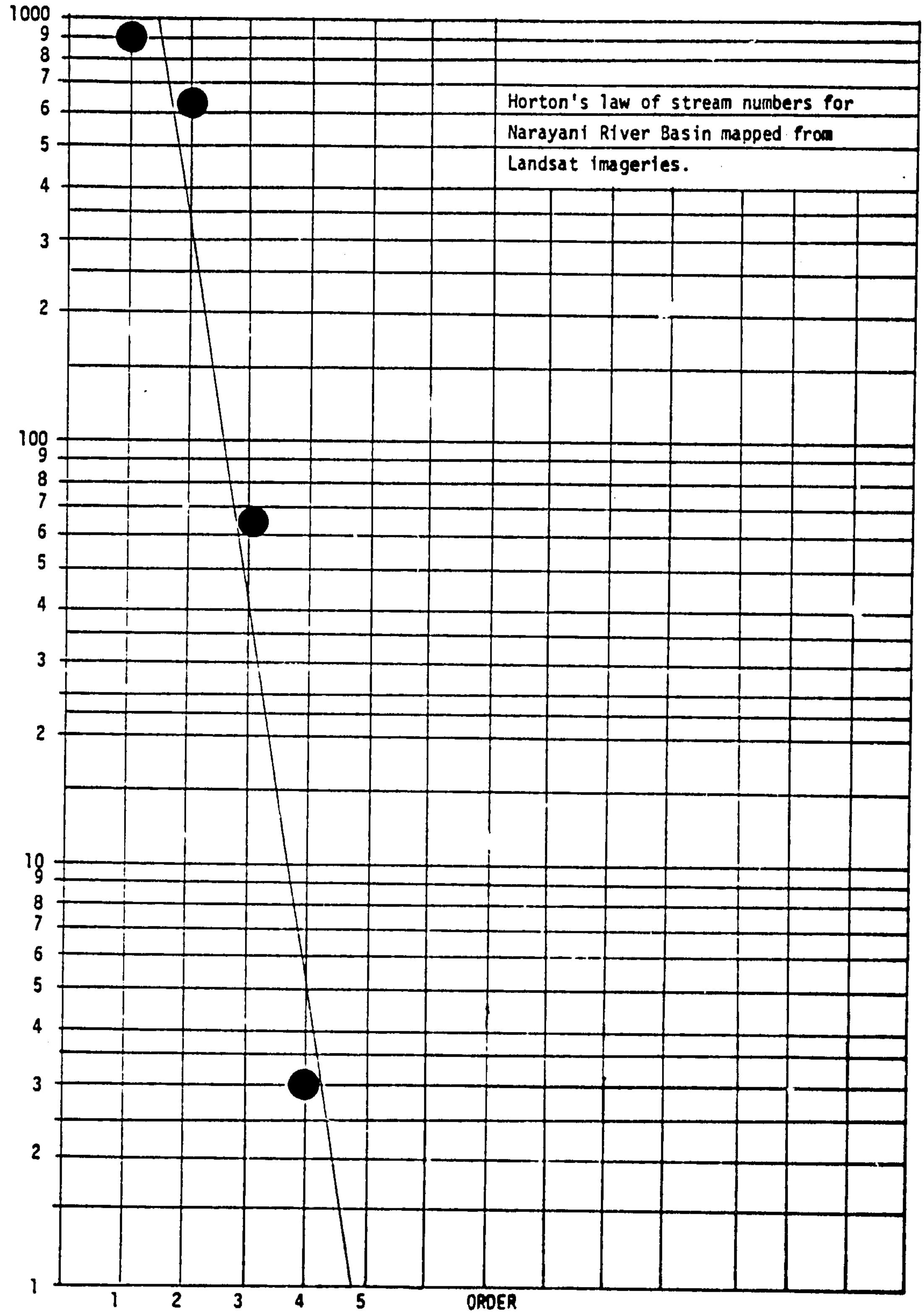

Figure 2. Correlation of numbers to orders of streams apparent from interpreting Landsat imagery.

Fig. 3. Apparent eroded areas (marked by arrows) together with water courses shown in light blue. (Original in color).

natural since both are exposed barren soil. Figure 3 shows water courses together with the eroded areas, marked by arrows, in a light blue color.

Conclusions and Recommendations

The Landsat data coupled with ground truth can give an overview of large river systems that can be used for the study of water supply, hydropower, irrigation, and planning and management of water resources. Surface flow patterns are evident on aerial photographs but Landsat imagery is most useful because of its synoptic, yet detailed view. Its seasonal coverage is very useful in monitoring any changes as well as helping in interpretation.

A 1:125,000 scale Landsat image provided sufficient details for interpretation of landslide areas and river courses of high silt content. Remote sensing techniques were found to have a broad range of uses including flood plain mapping and recognition of changes in river courses. The improvement of present watershed management techniques is dependent on the accuracy of watershed runoff prediction, for which Landsat can be effectively used to provide many inputs.

All the minor sub-basins of the Narayani River Basin were mapped using Landsat imageries in order to evaluate the basin characteristics for better watershed management. This offers fairly accurate, rapid, and economical determination of hydrologic parameters of watersheds which can be used for water balance studies.

Depending on the type of terrain, vegetation cover, and geology of the area, a suitable method of obtaining and utilizing remotely sensed data for water resource surveys should be applied. The economic feasibility of using Landsat data by manual interpretation can be determined by one or more integrated project studies in Nepal. The preliminary study conducted by this project could be used for selecting such areas and evaluating important watershed characteristics.

Interpretation of Landsat Data for Soil Resource Analysis and Protection

B.K. Worcester[1/]

Several other papers in this collection have dealt with the technology of remote sensing, the types of sensors aboard the spacecraft, the various satellites and types of data available from them and some of the manipulation which can be performed on the data to make it more useful for specific purposes. This paper deals more directly with the application of remote sensing to gain an understanding of naturally occurring activities at the surface of the earth.

One of the natural surficial resources of great concern is the soil. Soil is considered, by most people, as a non-renewable resource used primarily as a medium for the production of crops and vegetation. The conservation of this resource and the optimum long-term utilization depends on people and proper management. Prerequisite to the formulation of good management plans is an understanding and inventory of the soil. Remote-sensing technology provides a new tool to help achieve this goal locally, nationally and regionally. When considering soils, particularly from the synoptic aspect of Landsat imagery, consideration must be given to all environmental features which can and do influence soils and are influenced by soil. This includes vegetation, geology, hydrology, geomorphology and climate. This list is by no means exhaustive but simply indicates the wide variety of perspectives encompassed by soil science.

The conditions of erosion and associated sedimentation and landslides are considered by most people as detrimental activities since previously productive areas may be rendered unproductive. Although these phenomenon are considered negatively, they are a set of natural occurrences throughout the world. Erosion is a natural process since it is the force which forms the landscape upon which we live. Erosion is a continuous process in varying

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degrees of severity. Erosion of surfaces upslope occasions sedimentation downslope. These are the destructive and constructive forces, respectively, which are acting upon and forming the surface of the earth at all times and at all places. Landslides can be viewed as a sudden and catastrophic form of erosion.

There are basically two approaches to viewing erosion. The amount of erosion, including landslides, which has occurred in the past may be mapped on Landsat imagery to assess the current status. The amount of erosion and most likely location may be evaluated if sufficient information is available. The first may be helpful in definition of the second. For this purpose the conditions associated with and leading to erosion must be known and understood. This requires inventories of certain resources.

Geology, soils and vegetation inventories are examples of useful information base data. Geologic stratification in areas of sedimentary deposits could be significant in predicting areas of potential landslides. The interface between two strata could create a condition conducive to slumpage of land surfaces. The exposure of different geologic materials at the surface provides the parent material for soil formation. The properties of the parent material are inherited by the soil making some more conducive to erosion than others. Vegetation tends to stabilize slopes; therefore the presence or absence and type of vegetation is essential knowledge. Vegetation, soil and geology are features of the earth's surface which can be interpreted from Landsat imagery. Specific interpretations of this information can include susceptibility to landslides or erosion. In this manner, sensitive areas can be identified. This is essentially a process of eliminating areas which are not prone to erosional problems and thereby allowing concentration of manpower, time and finances on problem areas.

An approach such as this can logically be implemented as a three stage activity. Landsat imagery can serve as the basis for delineation of areas where landslides have occurred in the past and the conditions associated with them can be identified. Other areas with similar conditions can be located and thus defined as potential problem areas. A second, and more detailed perspective of these areas may be gained from study and interpretation of aerial photography. By careful definition of areas of concern, the costly process of acquisition of aerial photography has been reduced. The third stage is field investigation. This stage physically characterizes the areas where landslides have occurred and permits a comparison of these conditions with those in areas previously identified as potential problem areas.

With the information gathered from this type of investigation, the scientist may make further use of the Landsat imagery. Aerial photography interpretation and field verification and investigation results may be related to characteristics of the land surface which can be discerned on Landsat imagery. By this, the scientist may extrapolate the results of his detailed studies with considerable confidence into areas which may be inaccessible on the ground. This extrapolation of results is very important in time and cost savings for large area projects. It may be concluded that Landsat imagery can play a very meaningful role in general resource inventories and further, that specific interpretations, such as landslide susceptibility, may be made, verified and extrapolated over very large areas rapidly and efficiently by knowledgeable scientists. Furthermore, changes in the land surface, such as landslide monitoring, can be accomplished by interpretation of the repetitive coverage available from Landsat as other speakers have discussed.

PHYSIOGRAPHIC SUBDIVISION OF LANDFORMS OF NEPAL BASED ON INTERPRETATION OF BASE MAPS AND LANDSAT IMAGERY

P.L. Maharjan[1/]

General comments:-

1. There is not much snow in the Great Himalaya Ranges
2. The Himalaya mountains are changing through time
3. Nepal has unique landforms and culture.

The following landform map[2/] of Nepal is based on interpretation of base maps and Landsat imagery. The base maps are the topographic maps of 14 zone^ of Nepal at a 1:250,000 scale (Topographic Survey Branch, Dept. of Survey); topographic map of Nepal at 1:250,000 scale (U.S. Army Map Service, Corps of Engineers); geological map of Nepal at ≈ 1:500,000 scale (Tolalov 1971); geological map of Nepal (Rov) at 1:1,000,000 scale (Tater, Shrestha); ecological or vegetation map of Nepal at 1:250,000 scale by Dobrmez and others 1971-75 and Landsat imagery black and white MSS bands 5 and 7 and color composite MSS bands 4, 6 and 7.

Later this map has to be checked in the field using toposheets at 1" = 1 mile scale (Survey of India 1957-62) and aerial photographs at 1:50,000 scale or 1:20,000 scale to be provided by the Canadian Project.

Reference is made to my earlier paper "Nepal Himalaya: A Broad Physiographic Outline" (P.L. Maharjan 1977) for physiographic divisions of Nepal into Piedmont (Terai plain), Subhimalaya (Siwaliks), Lower Himalaya (Midlands) and Higher Himalaya (the Great Himalaya Ranges), their cross sectional sketches and general information of the regions. They are essentially based on three factors: 1 - similar materials, 2 - similar surface expression, and 3 - similar processes occurring in the region through geologic time.

This present paper deals with the subdivision of those regions - Piedmont, Subhimalaya, Lower Himalaya and Higher Himalaya into physiographic subdivisions

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[1/] Soil Science and Agricultural Chemistry Section, Dept. of Agriculture, Kathmandu.

[2/] Maps available from the author.

or landform units on the basis of further stratification of lithology, local relief, slope, climate, and vegetation. For example, on the basis of stratification of lithology or surficial materials the region could be divided into Upper Piedmont (Bhabar), Lower Piedmont (Proper Terai) and Floodplains.

Similarly the Subhimalaya or Siwaliks on the basis of relief, lithology, drainage density (tonal patterns on Landsat imagery) and failures or mass wasting - erosion, landslides, mudflows, piping, etc. - could be divided into larger or small valleys (Inner Terai valley), ridge and valleys and their intensity of dissection.

In the same way the Lower Himalaya (Midlands or midmentane) could be divided into mountains (Parbat and Lekhs), hills (Danda), plateau (Tars) and fluvial terraces (Besi).

The Higher Himalaya (the Great Himalaya Ranges) on the other hand could be subdivided into permanent ice and snow including glacier ice, rocky areas or rocklands, and those covered by some sort of vegetation - pasture, scrub and forest and/or Inner Himalayan Valleys.

The main purpose of this physiographic subdivision of landforms of Nepal is to derive some land units or land type associations which could be treated as homogeneous at regional scales in terms of lithology, topography, climate, vegetation and soils including their potential for biomass production and/or limitations. Further, this may be treated as "natural land resource units" for agriculture, forestry, land use, and other uses. Lastly these units could be studied, interpreted and transferred to and from similar and/or related units.

I tried to divide Nepal on the basis of similar material, similar processes and similar surface expression into broad physiographic region or province land as follows:

Higher Himalaya - above 3,500 m to 4,000 m -- Precambrian granite, gneiss, migmites.

Lower Himalaya - less than above -- Cambrian to Precambrian phyllite, schist, calcareous schists, etc.

Subhimalaya (Siwaliks) - about 1,500 m -- Tertiary shale, sandstone, conglomerate

Piedmont -- less than 300 m -- Quaternary gravels, sand silt and clay.

It seems that the division between higher and lower Himalayas was rather more conceptual than realistic because the Himalaya slopes transpress from higher to lower ranges. The break at about 3,500 to 4,000 m seems only to indicate the climatic change or difference as expressed by elevation.

The Subhimalaya or Siwalik is fairly similar in material, processes, and surface expression (being Tertiary shale, sandstone and conglomerates) while the piedmont plains, though having similar material and processes, vary slightly in surface expression (e.g. upper and lower piedmont and flood plain versus interdivide terraces).

I hope that as the information on geology and surficial material, vegetation and climate becomes available, further subdivision can be done.

Session 5

APPLICATION IN GEOLOGY AND CARTOGRAPHY

J.M. Tater
Session Chairman
Mines and Geology

S. Bhattarai
Session Chairman
Soil & Water Cons.

A.S. Andrawis
RSI

K.D. Bhattarai
Mines and Geology

M. Conitz
Regional Mapping Center

The Use of Landsat Data in Geologic Mapping

A.S. Andrawis[1/]

It is well known that geologists were the first to recognize the value of remote sensing and apply it since the first attempts at aerial photography using pigeons, kites, and balloons. Today, they are the major users of Landsat imagery among the countless number of users in the different fields of science. Maybe it is strange, but it is a fact, that the further you go away from the earth, the better view of the earth you get. Geologists all over the world have successfully applied Landsat data for regional mapping, structural geology, mineral and oil exploration, engineering geology, and ground water and surface water studies.

For studying the major geologic structures and lineaments of the area the synoptic view offered by a single Landsat scene, which covers an area of 32,400 square kilometers, is more useful to the geologist than a mosaic of aerial photographs covering the same area. In an aerial photo mosaic, the differences in tone from one photograph to another, the change in the sun angle, the joining lines, and moreover the minor details in the photograph obscure the lines and features we are looking for, which are the major structural features, regional lineaments, and faults.

Almost all of the small- and medium-sized geologic structures of the world have been extensively studied and mapped. However, there are still regional structures, which are very important, not yet discovered. Now is the time to see and study them through the new tool which we have in our hands, which is Landsat imagery.

One advantage of Landsat imagery is that it enables us to see the earth through four different windows or wavelengths of the spectrum, each one having its own characteristics. Band 4 is useful for studying turbidity, water quality, or siltation. Band 5 is helpful in showing cultural features, geologic formations, structures, and lineaments. Band 6 shows the different land use units and types of vegetation which can be related to a certain type of soil. This may be further related to a certain type of geologic formation from which it is derived. Band 7 has a most popular characteristic which is the sharp differentiation between land and water. It is also useful in showing some

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structural lineaments if they contain higher moisture, or when a certain greener-type vegetation is growing along those lineaments.

So, the geologist has endless choices for viewing his region through individual bands, or through a combination of bands in the form of a photographic product (a false-color composite). He may also view the regions by means of the color additive viewer. The color additive viewer is very useful in identifying the different geologic units. By trying different combinations of bands with different filters, a color composite is obtained which gives maximum contrast of one or more geologic formations depending on the reflective characteristics of each formation. A lateritic formation, or a gossan of iron oxides, will give dark tones in band 4 and light tones in bands 6 and 7. It is necessary that the interpreter has an idea about the reflective characteristics of the formations expected to be in his area. By studying their signatures in the various wave bands, he can differentiate between them fairly well.

Nobody can make a good geologic interpretation of an area except a well-trained field geologist, fully acquainted with the area under study. He knows the different geologic units there, how each one looks, and the most prominent characteristic of each formation.

The ideal case is when the geologic formations are exposed on the surface with a minimum of surficial and vegetation cover. Even when a rock is concealed under superficials, the resulting weathering products may be a good indication of that rock. For example, a silicous rock formation may be identified by the highly reflective sandy soils resulting from it. Sometimes the fracture patterns, their density, and their general trend are good indicators of the rock type. Also the drainage patterns may be a good indicator. The topography, sharp pointed ridges, flat topped hills, or undulating terrain, which can be recognized by close examination of the shadows formed, are additional indicators on the type of rock.

The studies of structures and lineaments are best viewed through the individual bands, and more lineaments can be revealed by studying the area in different seasons, since many lineaments are enhanced by changes in moisture conditions and changes in the vegetation cover. Fractures and lineaments can even be seen through a considerable thickness of surficial cover as it is reflected on the surface by its influence on drainage patterns, vegetation density, and tonal differences in the soil. Several geologists found that they can trace 20 to 40% more lineaments from Landsat imagery than those traced from aerial photographs and field checks. This increased ability in tracing lineaments, when combined with ground data about mineral occurrences, may lead to the location of other zones with high potential for mineralization. The ability to trace structures and lineaments is of great importance in the process of mineral and oil exploration, as well as for ground water investigation.

A Landsat image can be an excellent base map for the geologist when enlarged to the scale convenient to his work. He can locate himself more accurately and plot on it all his measurements and boundaries. Due to the high relief of The Kingdom of Nepal, it was possible to view images under the stereoscope for the areas covered by the sidelap of the adjacent Landsat paths. This adds a new dimension giving more ability for interpretation of Landsat imagery. The repetitive coverage study of an area is very useful in disclosing many processes that are taking place in the area.

Another use of the stereoscope is the comparison of two imageries of one area in two different dates. When both images are fused together under the stereoscope, any change will immediately crop out such as river meanders, landslides, snow cover, growth of alluvial fans, soil erosion, etc.

Landsat imageries are a good tool for the measurement of surface water bodies and the monitoring of their seasonal and annual variation, thus enabling better assessment and management. Due to the high contrast given by surface water on band 7, it was possible to take 9 x 9 transparencies of the one million scale Landsat diapositives (or negatives) and project them through a lantern projector to a scale of 1:50,000 or larger. The surface water bodies were then delineated and measured by a planimeter to a good degree of accuracy.

Drainage systems can be easily delineated as well as watersheds. The area of river basins can be measured to supply a parameter necessary in runoff models. This is particularly important for The Kingdom of Nepal as it has great potentials for hydroelectric power - enough for local consumption and industrial development, as well as for export to neighboring countries.

Using Landsat imageries, the snow cover in each basin can be measured, and if the average thickness is exceeded, dangerous floods can be predicted and the necessary precautions can be made. The study of Landsat imageries can help in choosing suitable sites for hydroelectric power stations if there is no reliable topographic map of the area. Snow cover subdues the accurate location of watersheds. In such a case another date may be chosen where there is less or no snow cover for better delineation of the watershed.

I will not mention the examples of work done in The Kingdom of Nepal as Mr. Bhattarai will discuss it in his presentation. Instead, I will give an example of a study made by a geologist from India, at the Remote Sensing Institute (Fig. 1). He prepared a mosaic of Southern India, then he delineated all the lineaments found on the imageries, and made preliminary geologic interpretations of the region. He studied in more detail the Tamil Nadu State, which was covered by three Landsat scenes. A lineament map and a lineament density contour map were preapred. Bore holes drilled for ground water were plotted on the map. By comparing the productivity of these wells with their position in respect to the lineaments it was found that the bore holes lying in areas of high lineament density, or at the intersection of two sets of lineaments gave the highest yield of water.

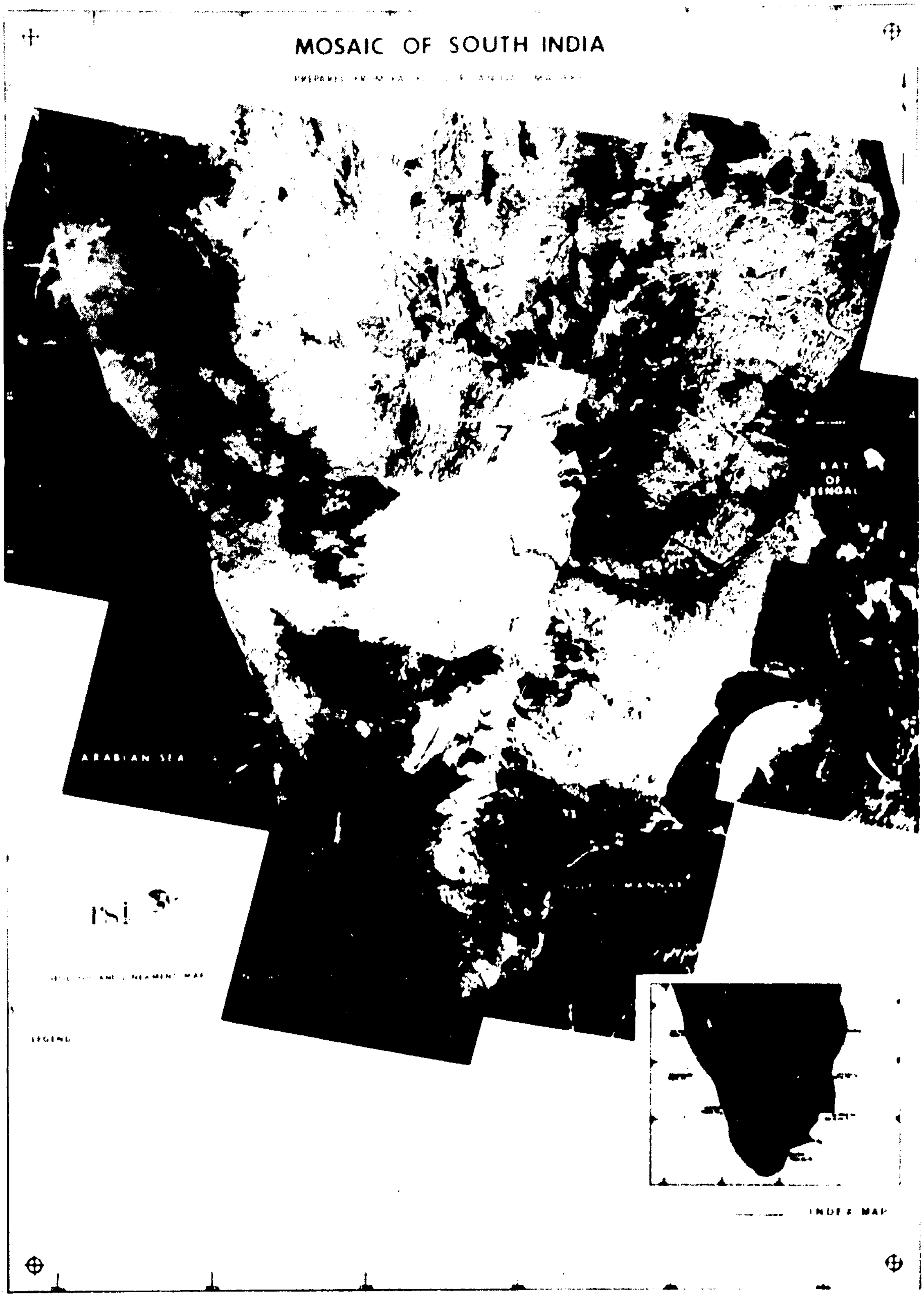


Figure 1. An example of the ideal use of Landsat imagery in the study of regional structures. A Landsat false-color mosaic of South India (reproduced in black and white) with interpretation of regional features and lineaments. The Landsat offers the advantage of a synoptic assessment for regional analysis. This is especially an advantage in photo geologic analysis for regional structure and lineaments. Interpretation provided by S. Thillaigovindarajan, Public Works Department, Tamil Nadu State, India, while in training at the Remote Sensing Institute.

An Evaluation of Landsat Data for Geological and Mineral Exploration in Nepal[1]

by

Kalyan D. Bhattarai[2]

Introduction

An area, which was previously studied and mapped, was selected as a training area to be examined in detail through the use of Landsat imagery and Skylab photographs. An extension of two months was arranged at RSI to complete a similar study covering the entire area of the country, but in relatively less detail.

The second part of the work was the preparation of a lineament map and a fracture density contour map. The interpretation of Landsat imagery for various geological features is very interesting and beneficial. Also, the location of potential sites for mineralization on the basis of lineament intersection and density is the first of its kind for Nepal.

Geology of the Study Area

No proper geological maps of the study area were available other than the historical photogeological map. This map was used as a ground check for the various geological and structural interpretations derived from Landsat imagery.

For geological interpretation, mostly 70-mm diapositives were used in the color additive viewer (I^2S). Most of the geological features are easily noticeable in the Landsat imagery. However, detailed differentiation of the various formations was found to be somewhat difficult, mainly due to the fact that the area is mostly covered by vegetation, and there are only few exposures. The topography is very rugged. This also contributed to the difficulty of interpretation. Some of the features, however, are very clearly noticeable in Skylab photos and Landsat imagery.

Out of the high Himalaya, lesser Himalaya, and Subhimilaya (or Siwalik), the study area lies in the lesser Himalaya with only a small portion to the south falling in the Siwaliks. The geology is divided into three main groups: the Siwalik group, (2) the Nawakot complex, and (3) the Kathmandu complex. The various group, formations, subdivisions, lithology, and thicknesses are shown in Table 1.

[1] Condensed from report by K.D. Bhattarai, SDSU-RSI-78-03, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57007. Copies of maps have been excluded and are available from the author.

[2] Acting Senior Geologist, UNDP/HMGN Mineral Exploration Project, Department of Mines and Geology, Ministry of Industry and Commerce (Kathmandu).

Table 1. Stratigraphic Subdivisions

Name of unit	Main Lithology	Approx. thickness	Age
PHULCHAUKI GROUP			
Godavari Limestone	Limest., dolom.	300 m	Devonian
Chitlang Formation	Slate	1000 m	Silurian
Chandragiri Limestone	Limestone	2000 m	Cambr.-Ordov.
Sopyang Formation	Slate, calcphyll.	200 m	? Cambrian
---------- Transition ----------			
BHIMPHEDI GROUP			
Tistung Formation	Metasadst., phyll.	3000 m	Early Cambr. or Late Precamb.
Markhu Formation	Marble, schist	1000	
Kulikhani Formation	Quartzt., schist	2000	Precambrian
Chisapani Quartzite	White quartzite	400	"
Kalitar Formation with Jurikhet Congl. Pandrang Quartzite Bhimsen Dolomite Lower schist member	Schist, Quartzt., partly garnetif.	2000	"
Bhainsedobhan Marble	Marble	800	"
Raduwa Formation	Garnet-schist	1000	"
---------- Mahabharat Thrust ----------			
UPPER NAWAKOT GROUP			
Robang Phyllites with Dunga Quartzites	Phyll., Quartzt.	200-1000 m	? Paleozoic
Malekhu Limestone	Limest., dolom.	800	? "
Benighat Slates with Jhiku calc. beds	Slate, augill, dolom.	500-?3000	? "
---------- ? Unconformity ----------			
LOWER NAWAKOT GROUP			
Dhading Dolomite	Stromatolitic dolom.	500-1000	Late Precambr.
Nourpul Formation	Phyll., quartzt., dolom.	800	" "
Dandagaon Phyllites	Phyllite	1000	" "
Fagfog Quartzite	White Quartzite	400	" "
Kuncha Formation with Labdi Phyllites Banspani Quartzite	Phyll., Quartzt., grit	3000+	" "
---------- Main Boundary Thrust ----------			
SIWALIK GROUP (undifferentiated)	Sandstones, mudstones, conglomerates	Several km	Noogene

The Siwalik group as a whole reaches a thickness of several thousands of meters. Most of the places on the main boundary thrust is seen clearly in the Landsat imagery. However, in the imageries the thrust was not seen as a continuous line, but as broken lines. The Siwalik rocks are identified by their monotonous tone south of the fault line. They show much change in texture and color within the Siwalik which suggests that there are many differentiations which can be well marked and mapped with only a few ground checks.

The various quaternary covers, however, are very distinctly and easily noticeable in the Landsat imagery like Kathmandu, tistung, palung, etc. It seems the Landsat imagery are accurate and reliable for drawing the boundary of such deposits.

The Nawakot Complex

In the Landsat imagery of a few places some faults seem to exist between the lower and upper Nawakot group. None of the individual formations were distinguishable in the imagery, mainly due to the fact that they were very thin and the resolution of imagery being 57 x 79 meters could not provide the ground resolution necessary to distinguish between the areas.

At some places remarkable changes in the tone, texture and color fit well with the position of the various formations when the photogeological map (redrawn on a transparent mylar sheet) was overlain on the same scale imagery. However, it is difficult to say that these changes are due to the difference in the rock type.

The Mahabarat thrust is seen clearly almost through its whole extension. As in the case of the main boundary thrust the Mahabarat thrust also does not show as a continuous line in the imagery. The sharp bends of the thrust along with the Nawakot formation are very clearly seen in the SKYLAB photo I.D. No. 91182 dated 9 December 1973 (Figure 1). The same distinctiveness, however, is not seen in the Landsat imagery probably because of the lower resolution of the imagery.

By using the color additive viewer, a more detailed study was done and many features from the Landsat imagery were identified that correlated quite well with the map.

The Kathmandu Complex

In Landsat imagery the different formations of the Kathmandu complex are not readily recognizable; however, with close study using the Color Additive Viewer some of the formations can be identified at some places. The limestones, however,

Figure 1. "Dhuseni" area as seen through Skylab photo no. 91182 dated 9th April 1973 to the left, enlarged to scale 1:270,000, and the corresponding photogeological map of the same area on the right at the scale of 1:250,000. It is obvious that the geological features are clearly seen in the Skylab photo.

show one clear relationship with the vegetation, which is distinctly marked in the Landsat imagery. Wherever the limestone rocks are present they show well-developed vegetation and hence the color of the imagery is reddish tinted. There are various shadows of red and only with close study will one be able to see the marked relationship of the limestone with the vegetation.

Granite and Migmatites

In the Landsat imagery the granites seem to be easily recognizable. They show sharp boundaries and distinctive tonal differences from the surroundings. At some of the places like Narayan, slight modification in the map can be done with little ground checking. The granitic body can be easily and reliably mapped from the Landsat imagery.

LINEAMENT MAPS

For the preparation of lineament maps, the apparent lineaments of the area were studied in the imagery of different dates. A transparent mylar sheet was overlain above the imagery on which was traced all the linear features interpretable from the imagery. The same was repeated for the different black and white bands and for color composites. Finally, all the traced linear features were transferred onto one sheet which was then finally redrawn in a separate sheet. In this final tracing, all the care was given to avoid false interpretations of lineaments caused by cultural features.

The lineaments were measured with the electronic graphics calculator. When all the measurements were completed, the points showing same value were joined to prepare the fracture contour map. For convenience, the values between 0 to 0.9 were taken as 1, and the values between 1 to 1.9 as 2, and so on. Once the fracture density map and the lineament map were ready, they were studied closely and the possible site for localization of minerals were inferred on the basis of their intersection and density.

This method has been used in many parts of the world and found to be successful according to various symposium papers published. To prepare a rose diagram, the lineaments were counted and were summarized according to their direction. When the number of the lineaments in different directions were noted, they were plotted in the rose diagram showing their numbers and direction. For enlargement and reduction the Kargl Reflecting Projector was used. For image enhancement the Signal Analysis and Dissemination Equipment (SADE) and the zoom transfer scope were used to trace and study some of the features. A light table was used for study of transparencies.

Lineaments of Study Area

The term lineaments refers to apparently natural lines or bands. Field geologists formerly used the term "lineament" to describe linear features having topographic expression. Linear features are often enhanced by vegetation and soil tone and the photogeologist has expanded the meaning of the term lineament to include these features as well.

The lineaments were plotted on a transparent mylar sheet overlain on the imagery. After tracing all the lineaments, the mylar tracing was compared with the existing photogeological map of the area. The two maps were found to agree fairly well. However, it was interesting to notice that the Landsat map gave about 35-40% more lineaments than the photogeological field-checked map.

This is good evidence of the practical applicability and value of Landsat imageries, particularly in the study of linear features and hence in the interpretation of the main structural features.

The possibility of getting more lineaments in the imagery may be due to various factors. First, the linear features of the imagery cover the aligned or straight rivers, ridges, vegetation, cultural features and geological features including faults, dykes, joints, shear zones, contacts, folds, and plaeovalley. Secondly, due to its unique characteristic of viewing the earth "synoptically", covering areas 185 by 185 kilometers in size with a resolution of 80 meters, additional subtle linears may be visible which are not apparent when viewing normal areal photography at larger scales. A single view of such a large area under fixed solar illumination and from near vertical (orthographic) perspective makes it particularly possible to recognize indications of large-scale geological features and vegetation patterns difficult to detect by other means.

The lineaments of the study area can be grouped in the following ways. While considering the lineaments of the study area, proper care was taken to eliminate various linear features associated with cultural features such as roads, fence lines, tree lines, etc. by using the different enhancement techniques such as photographic methods and subtractive methods, and by comparing existing topographic maps and Operational Navigation Charts (ONC).

Lineaments of Nepal

The lineament mapping for the total Kingdom of Nepal was prepared with the aid of a black and white mosaic. Unlike the method for the detailed study area, no individual imageries were used. A transparent mylar sheet was laid over the black and white mosaic of the scale 1:500,000. Lineaments were then drawn on the mylar sheet.

As only the mosaic was used without the aid of color composites or individual bands, the map is not as detailed. Only the major lineaments were traced. A considerable number of lineaments could be additionally located with a further detailed study of larger scale data; hence, it is to be noted that the present lineament map does not show all the lineaments of the country that can be traced and represented. The detail can be done for the required area whenever necessary. In this case, the lineaments are divided into major and minor depending upon the size of the lineaments.

FRACTURE DENSITY CONTOUR MAP

Fracture Density Contour Map of Study Area

From the lineament map of the study area a fracture density contour map was prepared. This was completed by measuring the traced lineaments for total length within a centimeter grid area. The total length of the fractures in "miles per sq. mile" was tabulated with the resultant groupings having values in miles. The fracture density contour map, in which a contour line connects areas of equal numbers of line miles of fracture per square mile, was prepared. The contour interval is one mile with values of each contour not furnished in the map to avoid overcrowding.

Regional lineaments were assumed to be the expression of structure, and lineament density and complex intersection were important criteria in selection of possible sites of mineralization. Though proper care was taken to avoid the confusion of cultural lineament with other linear features, some of the linear features of the map may represent features other than fractures.

There is little doubt that the linear trends in images are not always a true representation of linear trends of the area as some of the geological linears may not be represented in the images due to various courses and factors. However, for all practical purposes it seems from the present study that the comparison of the lineament map with the field-checked photogeological map was good.

Fracture Density Contour Map of Nepal

From the lineament map, a fracture density map of the country was prepared. A total of 1308 lineaments were measured. The fracture density map gives a maximum value of 16 which lies on the eastern part of the country. There are considerable areas with values higher than 9.

There seem to be more high value points in the eastern part of the country. Another interesting point is that a few higher values generally are clustered together, thus making it possible to separate zones of high potential. However, to select target areas from such potential zones we have to study the available geological data and other data. In Kathmandu at least 13-14 highly potential target areas can be selected covering quite a number of structural anomalies.

Some of the areas show the sudden change of the value from high to low. With close study of such areas from the available data as well as the necessary field study, some relationship can be established between the topography and stratigraphy of the area and the existing features of the lineaments expressed remarkably in the fracture density map. This type of sudden change may be due to the stratigraphical changes. The source of lower values is not susceptible to the fault affecting the rocks of the higher valley around them. It may be that on these areas, some of the intrusions have taken place after the fault pattern which occupied the area and thus conceal the fault patterns.

ROSE DIAGRAM

Rose Diagram of Study Area

One rose diagram was prepared for the study area showing the number and direction of lineaments. Eight different directions were selected. Each direction shows the number of lineaments in that direction.

Maximum numbers of lineaments (63) are in the NE-SW direction. The lineaments along the NWW-SEE direction total 55. There are 53 lineaments running in the NEE-SWW direction. We found 45 lineaments running along the NNE-SSW direction. There are 36 lineaments running along the NW-SW direction. We found 30 lineaments running along NNW-SSE direction. In the N-S and E-W direction there are only 9 and 13, respectively. Thus it shows the maximum number of lineaments run along the NE-SW direction and the minimum along the N-S direction.

Rose Diagram of Nepal

A total of 1308 linear features were counted and measured and their directions were noted. The maximum number (427) of lineaments was noticed in NE-SW direction and the minimum number (54) was in the E-W direction.

The maximum number of lineaments in the NE-SW direction corresponded to the deviation of the highest drainage density. This suggests that the linear features play an important role in the drainage pattern. However, any relationship that exists between the two features can only be established after the detailed study along with the ground data.

MINERALIZATION SITES

Possible Mineralization Sites of Study Area

Possible mineralization sites were selected on the basis of lineament intersections and densities. Those selected areas were later (after receiving the geochemical anomaly map from Kathmandu) compared with the geochemical anomaly map.

Of the 18 possible sites, five sites including "Skharphue", "Lopchae", "Labang", "Banspani", and Khirduli" area were found to be closely coinciding with geochemical anomaly areas. Other areas like "Sindhuli", "Dolalghat", "Kabre", "Dhading", and one east of "Chitwan" do not show high correlation with the anomalous areas. The remaining eight sites of the structural anomaly show close coincidence with one or two of the geochemical anomalous areas.

This suggests that of the 18 structural anomalies deduced from lineament intersection and density, 13 of them are very closely positioned with areas of known geochemical anomalies. Some of the structural anomalies do not correspond with any of the geochemical anomalies.

Some sites for possible localization of mineral were selected entirely on the basis of the lineament density complex intersection. About 182 possible sites were deduced from the above mentioned methods. The sites are scattered all over the country. However, it is very interesting to note that they are clustered at few places. It is possible to divide the country into five potential zones where more than three structural sites are clustered. Three of those potential zone areas occur in the eastern side of the country and two occur in the central part of the country. No such association of structural anomalies was noticed in the western part of the area.

Due to the lack of ground data, no comparison with the indexed structural anomalies was possible. However, it was interesting to note that there are two structural anomalies close to each other near Wapsa, a place which is well known due to the copper mineralization. Similarly, near Kathmandu two structural anomalies seem to coincide with the Phulchauki, where hematite occurs.

For an inaccessible country like Nepal, where locating any geochemical, geophysical, or other anomalies is expensive and time consuming, remote sensing techniques and density maps will be much cheaper and highly valuable. Comparison of sites located with Landsat imagery and the existing anomalies derived from the geochemical method further showed that most of the structural anomalies are fairly close to the ground checked anomalies.

Conclusions

The Landsat imagery was useful mainly because: (1) it gives a synoptic view of the large area, particularly which is helpful in the deduction of large lineaments and other structural features; (2) repetitive coverage of the area every 18 days provides imagery of the landscape under various vegetative and snow conditions and avoids cloud cover problems; (3) the sun angle over the image is uniform. In a country like Nepal which is highly mountainous the shadows may lead to an incorrect interpretation. However, due to sun angle uniformity and the availability of different dates imagery of the same area, it was possible to avoid such misinterpretations; and (4) certain parts of the image, due to side lap, provided a stereoscopic view which was helpful in the interpretation. The technique of remote sensing is practical, helpful, and can be accepted as one of the essential techniques in mineral resource studies, especially in a country like Nepal. Orbital imagery in itself is not sufficient to fulfill the exploration and geological needs in Nepal where due to the dense vegetation, terrace cultivation, and less exposure of rocks, the geological features are less extinct. It can be, however, a powerful tool when used in connection with aerial photography and field work. The Landsat imagery can and should be used for various geological and exploration needs of Nepal as it provides the opportunity to very quickly and cheaply provide the reconnaissance information necessary to implement detailed studies in a timely and cost-effective manner.

THE POTENTIAL CONTRIBUTION OF SPACE TECHNOLOGY TO CARTOGRAPHY IN DEVELOPING COUNTRIES

Merrill W. Conitz[1/]

Data collected by Landsat and other remote sensing sources are largely unintelligible to those outside the specific scientific discipline responsible for their collection. These data must be translated into information - verbal, digital and graphical information. For a comprehensive understanding of most resource problems, all three forms are necessary, but it is the latter form - graphical information - which this paper will address.

Cartography is the scientific and technical discipline which provides graphical information and thereby becomes a vital link between resource scientists who collect remotely sensed data and development planners who use the resulting information in the preparation of plans and programs.

Almost anyone can trace soil, water and vegetation boundaries from Landsat imagery once these boundaries have been identified, but this is not necessarily mapping. Maps are precise documents which have mathematically rigerous standards for accuracy, scale, and conformance with various projection systems. They are often in use for decades, sometimes undergoing several modifications. Even after they have been replaced with more up-to-date versions they are still useful as historical documents. Accordingly, great care must be taken in their construction to insure that they convey as much information as accurately as possible, meet nationally recognized standards, and have scales which are consistent with other mapping activities being carried out in the country.

While cartography supports all other scientific disciplines involved in the collection of resource data, it is also an important application area in its own right. Landsat, as will be discussed in further detail later, is an ideal mapping tool for medium and small scales. According to the U.S. National Academy of Sciences, "More than half the geographic areas of Asia, Africa, and Latin America have not yet been mapped at scales larger than 1:1,000,000 and many of the base maps for other areas are outdated."[2]

[1/] Director of Regional Remote Sensing Facility, Nairobi, Kenya.

[2/] Resource Sensing from Space, National Academy of Sciences, Washington, D.C. 1977

Landsat, supported by other satellite systems is probably the only way in which this situation can be improved in the foreseeable future.

Space-age technology, therefore, is certain to have as profound an impact on the mapping profession as aerial photography did about the time of World War Two. During that war the need for maps was greatly accelerated and the technology developed rapidly. Precision cameras, stereoplotters and automated mapping systems were refined or developed and have become the standard tool of the mapping profession. Even with these tools, however, the mapping profession has been limited in the products it is able to provide. The mapping of large areas is costly and time consuming and as a result, maps are updated only at ten to fifty year intervals at best. Medium and large scale topographic maps have become the standard products of most mapping organizations throughout the world, not entirely because of the need for them but partly because they represent the most advanced state of the art. While we do not question the need for these products there is a question as to whether other map products might be equally or more useful to development planners.

Space-age technology is removing the constraints previously imposed on the mapping profession. It is no longer necessary to think in terms of what can be produced but rather, what is most needed for development planning. Certainly development planners want to know topography, drainage patterns, road networks and human settlement patterns, all of which are shown on topographic maps. But, they also want to know about vegetation, soils, rainfall patterns, areas threatened by soil erosion, and areas of population change. Furthermore, they want to know about the distribution of these phenomena, not at just one point in time but at different seasons and in different years. How does the vegetation change from spring to autumn, what are the changes in surface water from wet to dry season, and what changes have taken place in agriculture and grazing areas from one year to the next are all questions of vital importance.

What development planners need are not just the relatively static topographic maps but <u>thematic maps</u> which show specific phenomena such as surface water and vegetation and <u>seasonal maps</u> or <u>temporal maps</u> which illustrate the changes in these phenomena throughout the annual cycle.

Furthermore, they want these maps to be updated periodically to show trends in agriculture, desertification, land clearing and population movement.

Space technology is recognized as the only economically feasible means of collecting the enormous amount of data required to satisfy these needs. To be sure, these data can be collected from aircraft but the fact that this has not been done regularly and systematically indicates that it is probably not economically feasible. This does not suggest that satellite systems will replace aircraft systems for resource sensing. There is no satellite system projected for the foreseeable future that offers the flexibility that can be achieved from aircraft. Rather the two systems are complementary with cartographers utilizing the best aspects of each system.

The production of thematic and seasonal maps also calls for a multidisciplinary approach - something that has been sorely lacking in the past. Hopefully we are passing out of the era where survey departments, ministries of agriculture, geological surveys and others all collect data of interest only to their own agencies and remain oblivious of each others efforts.

Cartographers in particular must recognize the contributions other resource specialists can make in helping them design thematic products which are useful to development planners in a variety of disciplines. Cartographers must also recognize the contributions they themselves can make to other agencies and be willing to assist them in the preparation of thematic and temporal maps which meet recognized standards. Generally speaking, most resource specialists do not have the mathematical background and technical training needed to understand map projections and other technical details of mapping nor do they necessarily appreciate the need for accuracy and scale consistency in mapping. Therefore, the multidisciplinary approach is needed to produce products which are accurate, readable and useful.

While Landsat is the most prominent of the space-age mapping tools now available there are others which are much less visible but which are still key elements of the system. There are geodetic satellites which have added greatly to our knowledge of the shape of the earth. The earth is not a perfect sphere, but rather it is a spheroid which is slightly flattened at the poles. Furthermore, it is an irregular spheroid with various bumps and depressions and is commonly known as a geoid. In order to map large areas accurately, the characteristics of these bumps and depressions must be known in order to know the shape of the geoid in that particular region.

There are also geophysical satellites which contribute to our knowledge of gravity and gravitational anomalies. Mapping must be accompanied by some form of ground control and the instruments used to establish this control are oriented by level bubbles. These level bubbles are subject to the force of gravity. In areas adjacent to such large land masses and depressions such as the Himalayas or the Rift Valley system in East Africa there are gravitational anomalies which can seriously disturb the orientation of precise surveying instruments. A knowledge of the nature of these anomalies is necessary for the development of precise geodetic control networks.

To aid in the establishment of precise geodetic control points, navigational satellites have been utilized. These satellites can beam data to small portable ground receivers which can be translated into precise geodetic positions thus eliminating the need for much of the expensive and difficult triangulation which has previously been a necessary part of mapping operations.

These are remarkable developments considering that we are only a few years into the space age. The next few years will see the introduction of new satellite systems. Already Landsat has been improved with the introduction of thermal imaging capability and use of a new higher resolution Return Beam Vidicon system. The use of this new RBV data should extend the useful scale range of Landsat from approximately 1:200,000 to 1:100,000. Radar mapping and radar altimetry from satellites offer possibilities for obtaining topographic data and land form detail which are not presently available from the Landsat system. In a few years the first space shuttle will be launched. At least one shuttle mission will carry a large format camera capable of obtaining stereo photography from space with resolutions similar to that of Skylab imagery. Plans are also being drawn for Stereosat, an unmanned satellite capable of producing stereo images from space on a regular basis.

The preceeding discussion has been presented, not with the idea that all of the systems mentioned have immediate application in developing countries, but to illustrate the rapidly changing nature of the application of space technology in cartography. There are many simple and direct applications of Landsat imagery in cartography which can be applied with very little in the way of specialized equipment or expertise.

Let us now look at some of the technical considerations which make satellite imagery - particularly Landsat - a unique and useful mapping tool. Landsat has three principal advantages over aerial photography for medium and small-scale mapping. The first of these is platform altitude. Because Landsat views the earth from an altitude of about 920 kilometers the resulting image is a near-orthographic representation of the terrain compared with aerial photographs which show the terrain in perspective. Figure 1 illustrates the relative viewing situation of the Landsat and aerial photographs. Light from the outer edge of a Landsat image is reflected back to the scanner at an angle of only about 5.7 degrees from the vertical whereas with conventional short focal length mapping cameras the outer rays are slanted at much greater angles. This results in an outward displacement on the photographic image of points above average terrain and an inward displacement of points below average terrain. Of course these displacements are corrected in the photogrammetric mapping process but this serves to illustrate the simplicity of the geometry of the Landsat image.

The high platform also permits the imaging of much larger areas on a single frame. Figure 2 shows the relative area covered by a conventional photograph taken with a mapping camera at an altitude of 20,000 meters above the terrain. It would require at least 49 aerial photographs to cover the area of one Landsat image not allowing for overlap and substantial overlap would be required for photogrammetric mapping.

The second advantage of imaging from space is platform stability. Since Landsat is not affected by air turbulance, its imaging system can maintain a near-vertical attitude. Aerial photographs, on the other hand, are further distorted due to the fact that the cameras are seldom pointed exactly straight down due to air turbulance. The scale of a tilted photograph can vary substantially from one edge to the other depending on the angle of tilt. Like terrain relief distortion, tilt distortion is completely removed in the photogrammetric mapping process, but Landsat imagery by comparison is virtually free of this distortion.

The third advantage of remote sensing from space is the opportunity for repetitive coverage which is so important in agriculture, hydrology and other disciplines. Of course repetitive coverage can be achieved from aircraft sensing but not as economically as from satellites.

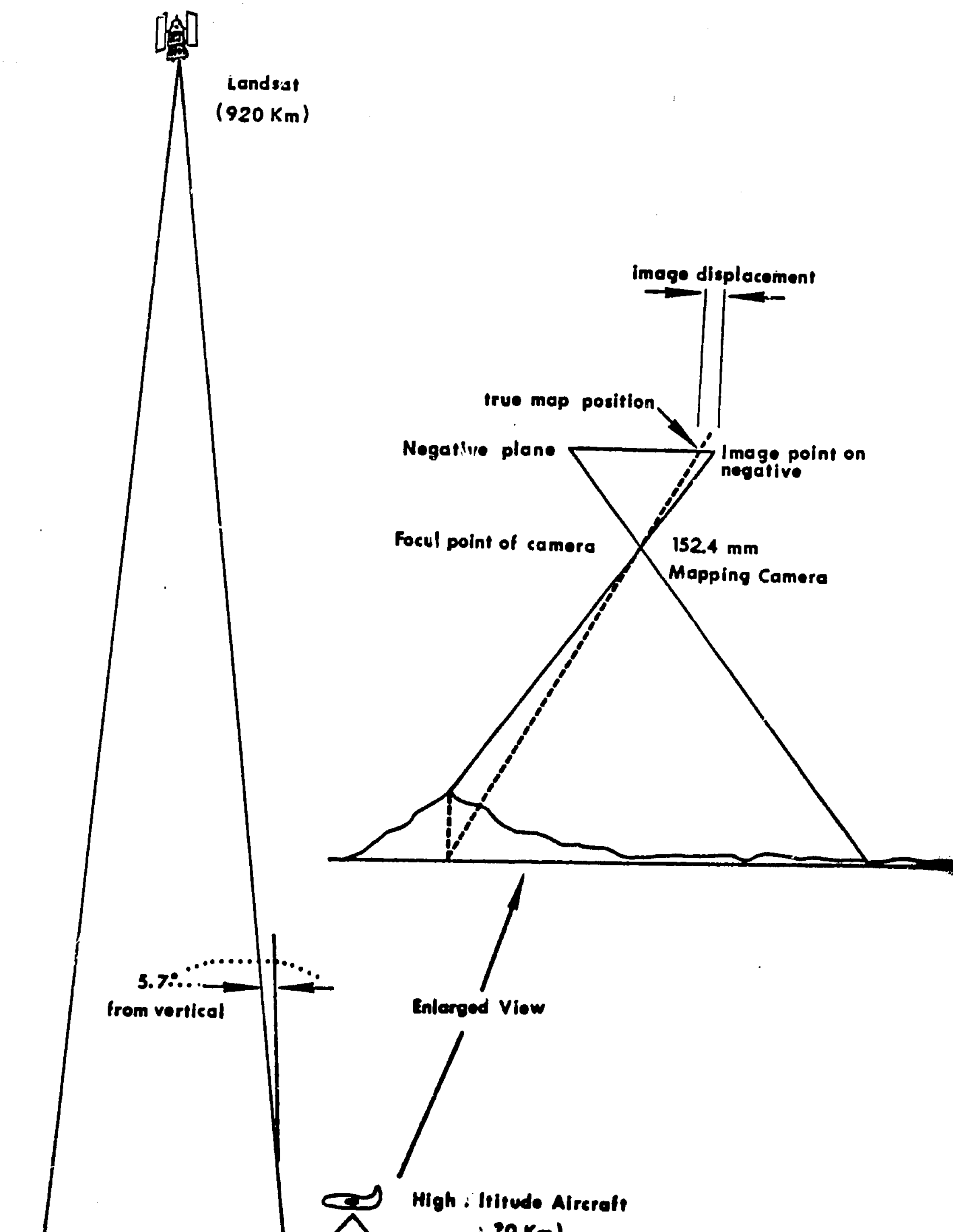


Figure 1. Geometry of the Landsat on aerial imaging systems.

Figure 2. Band 5 Landsat image of the Kathmandu region of Nepal. Image ID number 2266-04042. The relative area of coverage of a Landsat image and a high-altitude aerial photograph taken with conventional 152.4 mm focal length mapping camera is shown. Approximately 49 aerial photographs are required to cover one Landsat scene, not allowing for overlap.

Before the traditional photogrammetrists become too upset over these comparisons, let us again point out that aerial and space systems are complementary rather than competitive. Comparing Landsat imagery with aerial photographs is somewhat like comparing apples and oranges. Landsat is designed for mapping large areas repetitively at regular intervals. Aerial photography is preferable when stereo coverage of specific areas is needed. It is preferable where large-scale, high resolution imagery is needed and where timing is critical such as in frequently clouded areas or in fire or flood photography.

Because of the various characteristics described above, Landsat imagery can be employed at a much lower level of technological sophistication than aerial photography. This is another characteristic which makes it such a valuable tool for the developing world. Let us now see how these principles apply in typical mapping operations at various levels of sophistication.

Figure 2 is a typical Landsat scene of a portion of Nepal. It is in essence a map of the area. Of course it lacks many of the important element of a map but these can be added without too much difficulty. If this is a standard EROS Data Center product it will have a nominal scale of 1:1,000,000, 1:500,000 or 1:250,000. If scale accuracy is critical, it might be preferable to obtain the negatives of the imagery and have the negatives enlarged to an exact scale in a photo lab. To do this, of course, requires a knowledge of the exact geodetic positions of at least two and preferably more points which are identifiable on the imagery. Triangulation stations by themselves are usually not visible but positions can often be transferred with a limited amount of field surveying to river forks or road intersections which are visible.

The image could be made even more useful by the addition of latitude and longitude lines or grid lines but these require more geodetic control. Sometimes Landsat imagery can be enlarged to exactly the same scales as existing country maps and overlain with the transparencies of the grid lines and cultural features which were used to prepare those maps. Even without these transparencies, however, the use of the images can be increased with the enhancement of cultural features and the additions of the names of identifiable features. One feature that the imagery does not provide is topographic data. However, because of the low sun angle at the time all Landsat images are recorded, the natural shading enhances terrain features.

Landsat images of Nepal and other areas of rugged terrain look very similar to shaded relief maps which require many hours of exacting labor to prepare. For the preliminary planning of roads, dams, settlement schemes, etc., the terrain relief as seen on Landsat may be adequate even without contours.

A mosaic of 12 scenes of Landsat data can be constructed to cover all of Nepal. The mosaic on display was constructed of 1:1,000,000 images which were trimmed along the edges and matched according to visible terrain features. It is, therefore, an uncontrolled mosaic. When two or more images are joined together in this manner one should be especially cautious about attempting accurate measures on the mosaic. In addition to possible scale variations within each image there are scale errors introduced when joining the images together.

The next step in producing an image map from two or more images is to produce a controlled mosaic. In the preparation of a controlled mosaic the scale of each image is checked according to geodetic control information and enlarged or reduced accordingly so that all have exactly the same scale. These control points are then plotted on a map board at that scale and the images carefully overlaid so that the control points which are visible on the images exactly match the control points plotted on the map board. A controlled mosaic produced in this manner is much more reliable as a base map.

The controlled mosaic can then be overlain with grid lines, place names, etc. to become a true image map with a geometric accuracy that nearly meets U.S. map accuracy standards. This type of map product is relatively easy and inexpensive to produce and is vastly more useful to a development planner than either a conventional line map or a group of satellite images by themselves.

Further refinements are possible by using controlled color mosaics as backgrounds rather than single band mosaics. These require somewhat more elaborate mosaicking techniques along with color balancing but the actual construction was essentially the same as described above.

When comparing Landsat images and line maps, it is well to remember that both are useful and both have their own special applications. If one were merely interested in getting from one point to another in the metropolitan area the line map would be more useful as the road and street pattern is more clearly defined. On the other hand, if one were trying to locate a site for a new residential area or a manufacturing plant the image would be much more useful.

Another example of the use of the image is in viewing dynamic earth features such as a river at normal and flood stages. Taking advantage of the water delineation qualities of the infrared sensors on Landsat, an image can clearly show which areas are subject to flooding and where the river channel is located during normal times. An agricultural development planner, for example, would find this product of immense value in his work.

Using multi-date imagery of this type combined with the mosaicking and image mapping techniques previously described, it is possible now to provide a form of map which has nearly universal applicability. Thematic and temporal map products such as these represent a fresh new approach to mapping and are potentially the most powerful tools ever devised for physical development planning.

Session 6

WORKING SESSIONS IN GROUPS

Geology

Agriculture and Hydrology

Forestry

Tea Break

Forestry Working Group Members

1. Mr. U.B. Shrestha - Chairman
2. Mr. M. D. Rajbhandari
3. Mr. P.P. Shrestha
4. Mr. Devendra Amatya
5. Mr. Rajendra Bdr. Joshi
6. Mr. K.B. Malla
7. Mr. S. Bhattarai
8. Mr. G.R.B. Mathema
9. Mr. E.R. Sharma
10. Mr. B.P. Shrestha
11. Mr. K.P. Prajapati
12. Mr. M.K. Bajracharya
13. Mr. T. Maskey
14. Mr. L.L. Rajbhandari
15. Mr. K.B. Shrestha
16. Mr. P.M. Shrestha
17. Mr. P.K. Manandhar

Hydrology and Agriculture Working Group Members

1. Mr. A.N. Ansari - Chairman
2. Mr. P.L. Maharjan
3. Mr. Sankar Pradhan
4. Mr. Ram Man Joshi
5. Dr. S.N. Lohni
6. Dr. K.C. Sharma
7. Dr. K. Manandhar
8. Dr. Sarad Adhikari
9. Mr. N.N. Vaidya
10. Mr. Rameshwar Lal Shrestha
11. Mr. Rabi Shrestha
12. Mr. Rabi Singh
13. Mr. M.S. Karki
14. Mr. K.P. Upadhaya
15. Mr. Tej Man Singh
16. Mr. Sundar Man Shrestha
17. Mr. P.M. Joshi

Geology Working Group Members

1. Mr. J.M. Tater - Chairman
2. Mr. Sailendra Bhakta Shrestha
3. Mr. Purusottam Raj Joshi
4. Mr. Ramesh Kumar Aryal
5. Mr. Manda Ram Sthapit
6. Mr. Dibya Ratna Kansakar
7. Mr. Ram Nagina Yadav
8. Mr. Trailokya Raj Sakya
9. Mr. Upendra Man Singh Pradhan
10. Mr. Triratna Bir Kansakar
11. Mr. Amodmani Dixit
12. Mr. B.S. Shrestha
13. Mr. K.D. Bhattarai

Session 7

GENERAL DISCUSSION

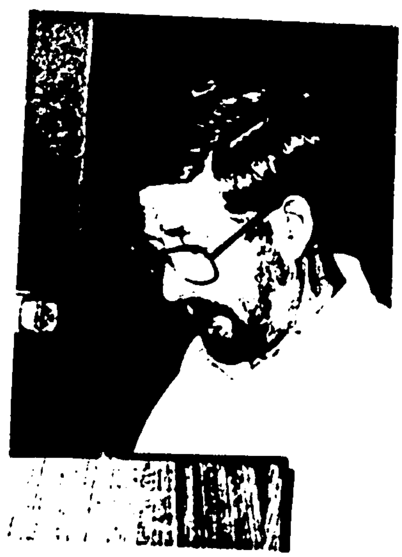
M.D. Joshi
Session Chairman
Soil & Water Cons.

S. Bhattarai
Session Conveyor
Soil & Water Cons.

J.M. Tater
Mines and Geology

A.N. Ansari

K.P. Prajapati



M. Stevens
FAO/IWP

GEOLOGY WORKING SESSION

J.M. Tater[1/]

Following the general sessions of the Remote Sensing Workshop organized by the Soil and Water Conservation Department/HMG in cooperation with USAID and RSI (South Dakota State University), a working session of a Geology Group was held at the Department of Mines and Geology, Lainchour, on May 3 and 4, 1978. Mr. Sam Andrawis of the RSI conducted the session, and in all 13 participants took part.

Materials: A set of Landsat 1 and 2 imagery on Nepal in different bands and scales, color composites of images and Skylab photographs, marking pens, etc., were made available by the RSI. The geological studies and interpretation were helped by the use of mylar overlays, quarter-million scale topographic sheets and the existing geological maps.

Work Accomplished: Sam Andrawis introduced the subject to the participant and outlined the various characteristics of the Landsat images and narrated the host of findings that could possibly be deciphered from such images. Special stress was given to the scope of the benefits that could be attained by individual bands of the image, and how the images could play a significant complementary role to the existing aerial photographs, topographic and geological maps of a given area. The participants took advantage of the opportunity to have a closer look at various images displayed and some of the lineaments and geological features were traced on mylar overlays, and this was followed by exchange of ideas and observations among the participants.

A previously recorded narration on applications of Landsat images was played simultaneously with a projection of relevant slides. The advantageous application of GE Image 100 along with level slicing, classification and ratioing of bands was also projected and discussed.

The methodology used in preparation of a mosaic from Landsat imagery was explained by Sam Andrawis, and a mosaic covering all of Nepal in band 7 was collectively prepared by the participants.

[1/] Chairman of Geology Working Session, Deputy Director General, Department of Mines and Geology, Kathmandu.

Conclusion:

The two-day working session displayed the importance of Landsat imagery in identifying and predicting various geological features with the aid of available ground information. The session was very ably conducted by Sam Andrawis, and the participants enjoyed the discussions highly and felt the importance of further using the images in their future work. It is a great pleasure to record the successful conclusion of the working of the geology session, and grateful thanks are extended to Mr. Sam Andrawis and all the participants for their very active interest.

HYDROLOGY AND AGRICULTURE WORKING SESSION

A.N. Ansari[1/]

The Working Session of the Hydrology and Agriculture Group was held at the Department of Irrigation, Hydrology and Meteorology, Panipokhari, on May 3 and 4, 1978. Dr. Bruce Worcester of the RSI conducted the session. Participants from Departments of Irrigation, Hydrology and Meteorology, Soil and Water Conservation, Agriculture, and National Planning Secretariat, took part in the Session.

Since the Group consisted of multidisciplinary activities, the discussions were very interesting. Discussions were made mainly on "How the Landsat Images Could be Used for Agriculture, Irrigation, Hydrology and Water Resources Planning".

Dr. Bruce Worcester explained about the remote sensing tools for the interpretation of imageries to all the participants. The participants found this technique very useful for planning agriculture and irrigation projects and also in water resources development as a whole. The group practically acquainted themselves with the interpretation of imageries of Landsats, which were brought by Dr. Worcester. Slides were also shown during the session to illustrate the wider use of this technology. In the last session, a mosaic was prepared by the participants which will remain as a gift in the Department of Irrigation, Hydrology, and Meteorology. Dr. Chaudhury, a scientist from Bangladesh, also participated in the group by discussing the activities of the Bangladesh Landsat Centre established with the assistance of NASA. He emphasized the necessity of joint Nepal-Bangladesh technical exploration for water resources planning by using this technology. All the participants realized that Nepal must get the benefit from Landsat programs.

Due to the rugged and difficult terrain of Nepal, most of the areas are unapproachable and thus the Landsat imageries will be useful to identify the problems as well as the total natural resources planning.

[1/] Chairman of Hydrology and Agriculture Working Session, Superintending Engineer, Department of Irrigation, Hydrology and Meteorology, Panipokhari.

The workshop has also been attended by many other senior engineers of the department. The group finally made the following concluding remarks:

1. Remote sensing technology is useful in Nepal in various studies of natural resources.
2. In view of its wide applicability and use, a Remote Sensing Centre should be established as a separate directorate where every department could have easy access.

Thank you.

FORESTRY WORKING SESSION

K.P. Prajapati[1/]

The Working Session of the Forestry Group was held at the Forest Survey and Research Office, Babarmahal, on May 3 and 4, 1978. Dr. Stan Morain of the RSI conducted the session.

During the Workshop, the participants had the opportunity to study Landsat imageries in each individual MSS band and able to identify the forested regions and areas of major interest. Computer printout maps of and around Kathmandu Valley showing cultural features and forests in band 5 and 7 were exhibited. Lectures concerning the generation and interpretation of the computer maps were presented by Dr. Stan Morain and Miss Mary DeVries. Participants had the opportunity to prepare a forest map of a part of the eastern hill of Nepal. The participants also prepared a 1:500,000 scale Landsat mosaic using MSS band 7 black and white prints.

During the Workshop, the junior forest officers, in addition to the participants, took keen interest in the workshop and gained a great deal of knowledge about the Landsat imageries.

The coordination offered by Dr. Moore during the Workshop is excellent and thanks is extended to him.

Finally, I would like to thank Mr. M.D. Rajbhandari and P.P. Shrestha who took keen interest in explaining the subject matter to the participants.

Thank you very much.

[1/] Reporter of Forestry Working Session, Soil Scientist, Forest Survey and Research Office, Kathmandu.

Concluding Remarks

Mervin E. Stevens[1]

Mr. Joshi, Mr. Bhattarai, and Colleagues:

It is an honor to present the concluding address for this workshop on remote sensing. I am not sure what gives me this honor. Maybe it was thought that I could play an impartial role. However, I am not impartial when it comes to finding a more effective and efficient way of doing things. My professional career has been associated with mountains where communications and accessibility dictated using tools allowing me to extend my knowledge from a small area to a larger area and vice-versa. For almost thirteen of these short years I was a soil scientist. I know what it is to dig a hole, describe it, and collect surrounding resource data. Digging holes is just plain hard work. But after the hard physical work was over then came the mental gymnastics of displaying and presenting the information to the land manager. On the one hand we collected thousands of bits of data which for a scientist is valuable, but to the manager is useless unless reduced to simple terms. Often they are in conflict with each other. Well, as a soil scientist from the hole digging view, I always tried to find ways to make the job easier such as a portable seismograph to detect water tables, changes in strata, and depths to bedrock. This is a remote sensing technique with a different twist which helped reduce the number of holes I dug.

From the management view, managers always wanted the data yesterday with detail sufficient to make a certain level of decision. Like most of you, I spent hours, days, weeks, and months staring at aerial photos to extend the knowledge I saw in a 1 x 2 x 2 meter pit coupled with surface data from a 17 meter circle. Unfortunately we did not have Landsat to assist us.

This week we have learned that we can and are adding another dimension to our list of tools to be more effective and efficient. The honorable State Minister for Forest, Mr. Singh, noted that satellite imagery and

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[1] Project Manager, Integrated Watershed Management (NEP/74/020), FAO

Landsat data could be effectively used for resource interpretation as well as its management. Dr. Ratna Rana pointed out that remote sensing techniques would be of great importance to developing countries like Nepal. Mr. M.D. Joshi underlined that our need for resource data was outpacing the capabilities of conventional survey and monitoring techniques. Mr. John Wilson said Nepal is taking advantage of this technology like her neighbors Bangladesh and India.

Under the guidance of Dr. Moore and his capable international team we were shown and discussed the various approaches for assessment and planned use of Nepal's natural resources. The question was asked, is remote sensing remote? From what I heard this week the answer is no. What is remote is bringing together the information available in Nepal and putting it into a form available for timely use.

Two independent studies on land classification in Nepal concluded that remote sensing is highly suitable. It is nice to have this kind of correlation. However, it is time to collaborate these efforts and make full use of a small number of trained individuals that exist in Nepal.

It was pointed out that in forestry there is no difficulty applying the information to be gleaned from Landsat with complementary tools of low altitude photography and ground truth. A forestry type map at a scale of 1:250,000, similar to the smaller scale hanging on the wall, could be made in short order given the manpower.

Water resources are the country's most important resources. We either have too little or too much. It needs assessment and an effective early warning disaster system established. A study done at RSI coordinating accumulated hydrology-meteorology data with Landsat scenes since 1972 showed there is a good contribution to understanding runoff conditions and predicting water supplies.

From a five month study of geology it was pointed out that with the experience of Landsat data there is no question that remote sensing is of immediate value to Nepal. These conclusions are based upon work carried out on problems that are of real concern to Nepal. These reports are available or should be made available from the authors.

We were provided with many examples of application in other countries. Dr. Morain demonstrated cost effectiveness from using Landsat data in contrast to aircraft photography for a land use inventory in New Mexico, USA.

The message was conveyed that the availability of Landsat imagery will continue and the resolution will increase. Imagery will be available at a reasonable cost from the receiving station scheduled for India. If a training and user assistance center is located at Bangkok it appears that we will have ready access to world-wide information, assistance to Nepal National Center, and a testing ground for new techniques. However, these service centers are no substitute for in-country capability. It would appear very wise for Nepal and its neighbors to get together on the scientific and technical level to exchange ideas and information on common transnational problems.

Probably one of the most important uses of remote sensing is its application as a very efficient data collection system. This week we heard alot about early warning oriented around a small sampling number and the monitoring capability of scenes available since 1972 and those that will be available in the future.

There is a rapid evolution taking place with use of Landsat in cartography, particularly when linked with other satellites such as weather and navigation. While testing is required it does appear to have value in speeding up the map-making process. One example of direct application is the ability to produce a seasonal flood map that could be used by planners and the affected people.

Side looking radar was introduced and its compatibility with Landsat stressed. This is the next generation of tools. I hesitate to say Nepal is not ready for SLAR, because many of us will say we have not effectively used satellite or other sensing systems. Yet, we must be aware of these developments. Our outlook must be that anything that provides us with a better way of assessing and managing the country's resources is necessary for Nepal.

This was a session primarily oriented to Landsat simply because it is a readily available product. However, yes, there are limitations and cautions. For example, Landsat imagery with its present resolution is not suitable for project operations where much detail is needed for individual check dam placement, individual farm planning, or final road location. This requires low altitude photography or highly controlled planimetric maps.

Up to now the use of remote sensing has been mainly limited to simple interpretations with single scenes from a single period. And, the work was done almost in isolation by single individuals. The work shown to us by the team that was at RSI and part of this last year's investigation on the use of remote sensing in Nepal, was not only conducted in a timely fashion, but of high quality. We must make more effective use of low altitude photography to reduce costs and get interpretations into the hands of the user.

We were advised on the establishment of the Remote Sensing Center of Nepal within the Department of Soil and Water Conservation. Within the building to be constructed by UNDP/FAO, space is being made available for the center. HMG has made a proposal for equipping and training the center staff. When the center is functioning the people who have been trained should be principle participants serving as investigators. There is a need for a constant supply of imagery. One of the first jobs at the center should be to prepare a plan of operation for submission to NASA and become recognized and receive any free benefits possible.

The center should be looked upon as a symbol of integration so that maximum benefit can be received. There may be those who visualize a remote sensing center as what we were shown this week in slides as an army of people in white coats surrounded by flashing lights and banks of computers. This is not the case or what is in mind for Nepal. In many ways it is a place to focus on and be managed by someone with knowledge who can assist all units and coordinate with Bangkok, Bangladesh, India, and Iran. It is an inter and multidiscipline organization.

This was one of three major workshops held in the valley this week. Next week another will start on Science. (By the way, I hope that those who have presented papers here have been invited to present them to this conference). As all of the distinguished speakers on the opening day and panel moderators said, "Now is the time for action". I think we can help the agriculturists in their action program for increasing food production as pointed out at the fertilizer seminar for example.

Mr. Chairman, I suppose I could continue and point out all the specific areas identified this week where remote sensing techniques can get put to immediate use. The panels on geology, hydrology, agriculture, and forestry have done that better than I could. Now it is time to get on with the implementation of their findings and direction.

In closing I would like to say that all of the products seen and worked with here this week plus all we have at the Department of Soil and Water Conservation are available for everyone's use. We have an open door policy.

Let this be the start of implementing the Remote Sensing Center for Nepal and the beginning of a new generation of support for making wise use of Nepal's abundant resources. While the Department of Soil Water Conservation through the Ministry of Forests and other agencies fully support the center, its real success is wholly dependent on cooperative use of the center from all Ministries.

Conference Closing Address

M.D. Joshi[1/]

For the last four days we have had an intensive deliberation on remote sensing and its application to various fields like agriculture, forestry, soil conservation, hydrology, geology and cartography. Today we heard the deliberations of the three working groups presented by the chairmen of the groups and finally summarized by Mr. Merv Stevens. I should like to thank the chairmen: Mr. Tatar, Deputy Director General of Dept. of Geology and Mines; Mr. A.N. Ansari, Deputy Director General of Dept. Irrigation, Hydrology & Meteorology; and Mr. U.B. Shrestha, Chief of Forest Resources & Research Office for successfully conducting the group discussions and also providing necessary facilities and equipment for the respective groups, and Mr. Merv Stevens who has helped me to summarize the gist of the workshop. I would also like to thank all the conveyors and reporters for smoothly running and reporting the general and group discussions.

Remote sensing based on satellite imagery may sound sophisticated for Nepal but there is no doubt about its applicability for planning purposes. This technique is not completely new for Nepal. Some departments have already utilized satellite imagery as the base material to find out land use and erosion problems. This tool has to be developed to satisfy our needs and objectives. Some of the participants present over here in this hall have undergone some training in foreign countries like Thailand, U.S.A., and Japan and have achieved preliminary concepts of remote sensing which were shared by other participants as well in this workshop. This transfer of knowledge was smoothed by enlightening lectures and assistance by our friends from abroad. But this knowledge may be diffused in the outer space itself if it is not accumulated and further put into action in the form of a center where all kinds of data archives will be stored; and knowledge, equipment and materials may be utilized for further use by any interested department, organization, or individual. This center should be executed by the inter-disciplinary personnel associated with the resource planning or management as to extract maximum benefit out of this center. This center should cater

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[1/] Director General, Department of Soil and Water Conservation, Ministry of Forests.

to the needs of the various departments concerned and this center should have representatives from concerned departments and commissions.

We have been highly honored by the participation of distinguished delegates from Bangladesh which not only opens the door for exchange of information but also for regional cooperation in this field.

Before closing the session I should like to thank Honorable State Minister of Forest for Inaugurating the workshop; Honorable Member of National Planning Commission, Dr. Rana, for delivering his valuable lecture; Secretary of Forest, Mr. A.B. Rajbhandari; Mr. B. Pal, Forest Advisor of Ministry of Forest; Mr. S.B. Nepali D.G. of Dept. of Agriculture; Mr. I.R. Mishra D.G. of Dept. of Food and Agricultural Marketing Services; and Mr. Tatar D.D.G. of Dept. of Geology and Mines for presiding over the general sessions. My special compliments goes to Dr. John Wilson/USAID who has given a lucid welcome speech and supported me in various facets of remote sensing program. Special thanks goes to Dr. Don Moore who made a number of hectic travels gathering experts and materials, for helping in the organization of the workshop, and for delivering the lectures. I should also like to thank Dr. Stan Morain, Miss Mary DeVries, Mr. Tom Wagner, Dr. Bill Wigton, Dr. Bruce Worcester, Mr. A.S. Andrawis, Dr. M. Conitz, Mr. Devon Nelson, and Mr. P.L. Maharjan who have enlightened us with their experiences and valuable lectures. My compliments go to Mr. M.D. Rajbhandari, Mr. P.P. Shrestha, Mr. N.N. Vaidya, Mr. K.D. Bhattarai, and Mr. P.M. Joshi who have exposed their experiences to us during their training in South Dakota and have shouldered the responsibility of mobilizing the workshop to the specialized scale. I should thank Mr. S. Bhattarai and the staff of the Dept. of Soil and Water Conservation who have taken most of my responsibility for arranging this workshop. I would also like to thank all the participants who have actively participated in this workshop.

Last but not the least, this workshop would not have appeared in this form had we not had the space to conduct the meeting. I should therefore thank Prof. Hinnuber and the staff from Nepal Research Center and Goethe Institute for providing facilities even at the eleventh hours. I should like to thank all of you once again.

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