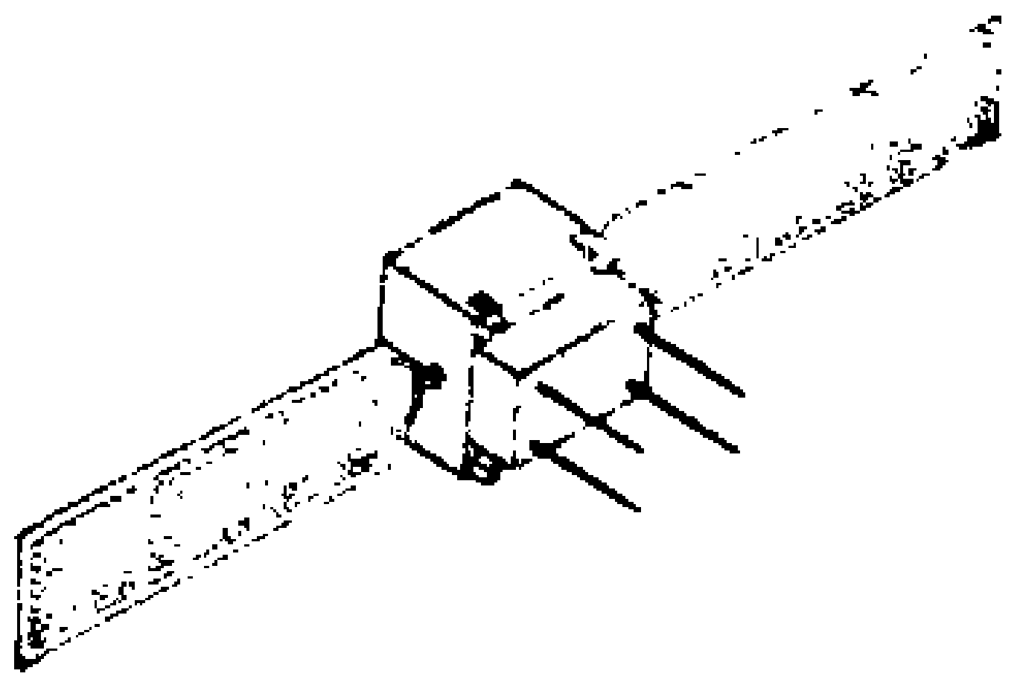

Special Issue on:
**Remote Sensing for
National Development**

The Economics of Remote Sensing

K. RADHAKRISHNAN, V. JAYARAMAN AND P. P. NAGESHWARA RAO

ABSTRACT: *Remote Sensing is now being used as an alternative technology for the inventory, survey, planning and management of natural resources and monitoring of environmental change. In the present paper, an attempt is made to identify the cost components and benefits of using remote sensing. It was observed that cost-benefit analysis is more difficult than cost-effectiveness analysis. Case studies, demonstrating the cost-effectiveness of using remote sensing along with conventional techniques, have been described. A set of guidelines is provided to determine the most remunerative alternative for implementing a remote sensing project for solving natural resources management problems. The emphasis here is to help the user in making suitable judgements to ensure returns from investments and enable him to utilise the limited financial resources for deriving the maximum benefits.*

INTRODUCTION

Spectacular transformations have taken place, over the last three decades, in the area of remote sensing technology. From an experimental/demonstration phase, where scientists/academicians in a few countries tried to study the potential of remote sensing technology, we have now reached a phase of operational application of remotely sensed data from multiple satellite platforms and aircraft, for management of natural resources and environment. The Remote Sensing activities in the country, initiated in 1969, got a major impetus in the early 80's when the Government decided to launch the Indian Remote Sensing Satellite (IRS) Series as well as to establish National Natural Resources Management System (NNRMS). NNRMS is a system combining optimally the data generated through remote sensing, coupled with conventional surveys, as necessary. Information generated through remote sensing is now becoming a vital component for management of natural resources and disaster management in the country.

This paper brings out (i) the cost-effectiveness and time-effectiveness of remote sensing data over conventional systems and (ii) an approach to arrive at the most remunerative remote sensing techniques for a given resource management task.

It is well established that the remote sensing technology provides the following:

(i) It will supply the same information quickly and at a lower cost.
(ii) It will supply more accurate and reliable information.
(iii) It will supply new information.

COST-BENEFIT ANALYSIS

Cost-benefit analysis is a generic term covering a wide range of evaluative procedures which can lead to an assessment of the cost and benefits relevant to the system under study.

Econometric methods have been developed for the study of the benefits accruing from the availability of timely/accurate/ new information. If the effect of the system is to generate the same information at a lower cost, then the net social benefit is the cost savings. If the system changes the characteristic of the information, i.e., supplies more timely and accurate information or new information, then the value placed on the information may change[1]. A method that can be adopted for estimating the benefits is to analyse the impact of the information on the economy, and thus arrive at an estimate of the value of the information. For example, if the accuracy of the information is increased, then the cost of erroneous decision can be expected to fall. This decrease in cost is the benefit[2].

Benefits may accrue from direct cost-savings, indirect/social benefits and from an understanding of the impact of global or regional changes on environment. Benefits can also accrue from the discovery of a new resource. While it will be possible to quantify the benefits accruing from direct cost-savings or economic finding on new resources, it will be difficult to quantify the benefits to the society from the long-term effects of environmental conservation and disaster management.

COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis deals with comparison of costs of alternative methods for achieving the same end result. A general model for estimation of the cost for satellite data must take into account all the cost elements that go into the development of the satellite platform, sensors, launch, mission operations, data reception, processing, and dissemination[2]. The cost of data analysis, interpretation and derivation of the final outputs will be dependent on (i) the objectives, (ii) accuracy thresholds, (iii) output scale, and (iv) terrain characteristics. Case studies have been carried out for four thematic applications, viz. geological studies for mineral exploration, forest cover mapping, forecasting of wheat production and inventory of irrigated crop lands.

Geological Studies for Mineral Exploration

The use of remote sensing provides a much faster method of identifying promising locations for detailed ground studies, thus, greatly reducing the time and effort required. The ground surveys could be reduced to about 5 per cent of the total area (as compared to about 50 per cent in the case of a conventional survey) as a result of the information provided from remote sensing and its conjunctive analysis along with the existing conventional data base. Detailed calculations have shown that the cost of mineral exploration studies without the use of remote sensing, works out to about Rs. 235/- per sq. km, whereas the introduction of remote sensing based information will reduce the cost to Rs. 37/- per sq. km[3].

Forest Cover Mapping

The Forest Survey of India periodically undertakes monitoring of forest cover for the inventory of forest types throughout India. Satellite remote sensing greatly reduces the inaccuracies and also the number of plots required to be sampled for such surveys. The reduction in the number of sample plots is estimated to be as high as 65 per cent to 70 per cent. This results in enormous cost savings. Also the process is much quicker, taking less than 40 per cent of the time otherwise required. As a result, it is possible to take quick strategic decisions for the management of forests without having to wait for several years to obtain the relevant information. It was estimated that the cost of forest cover mapping in the conventional method will workout to Rs. 85.50 per sq. km, while the introduction of remote sensing will reduce the cost to about Rs. 30/- per sq. km[3].

Wheat Crop Production Forecasting

It was estimated that the cost of providing crop yield forecasting for Punjab and Haryana came down to Rs. 13/- per sq. km using remote sensing data, compared to the conventional survey cost of Rs. 39/- per sq. km[4].

Inventory of Irrigated Crop Land

The cost of making inventory of irrigated crop land in the Krishnarajasagar command area using satellite data was estimated to be Rs. 39/- per sq. km. It has been reported that the cost incurred by the Directorate of Economics and Statistics for such an inventory is Rs. 200/- per sq. km, while the State Directorate of Agriculture incurs Rs. 75/- per sq. km[5].

SELECTION OF ECONOMIC REMOTE SENSING ALTERNATIVES

While remote sensing has proven to be a cost-effective tool for solving various resource management problems, it is extremely important to select the most economic and optimal route for implementing a remote sensing solution for the given resource management problem. An attempt has been made to describe the parameters involved in such an optimisation in the Indian context.

At the outset, the user must identify various information needs for a given resource management task. A list of specifications for the project and the benchmark requirements for the remote sensing technique should be determined. A detailed evaluation of the capabilities and limitations/gaps of the existing system should be done before selecting from the various alternatives of remote sensing. An evaluation of the merits of each of the remote sensing analysis techniques enables selection of the appropriate option before implementing the procedure. The accuracy and quality of the output must be carefully

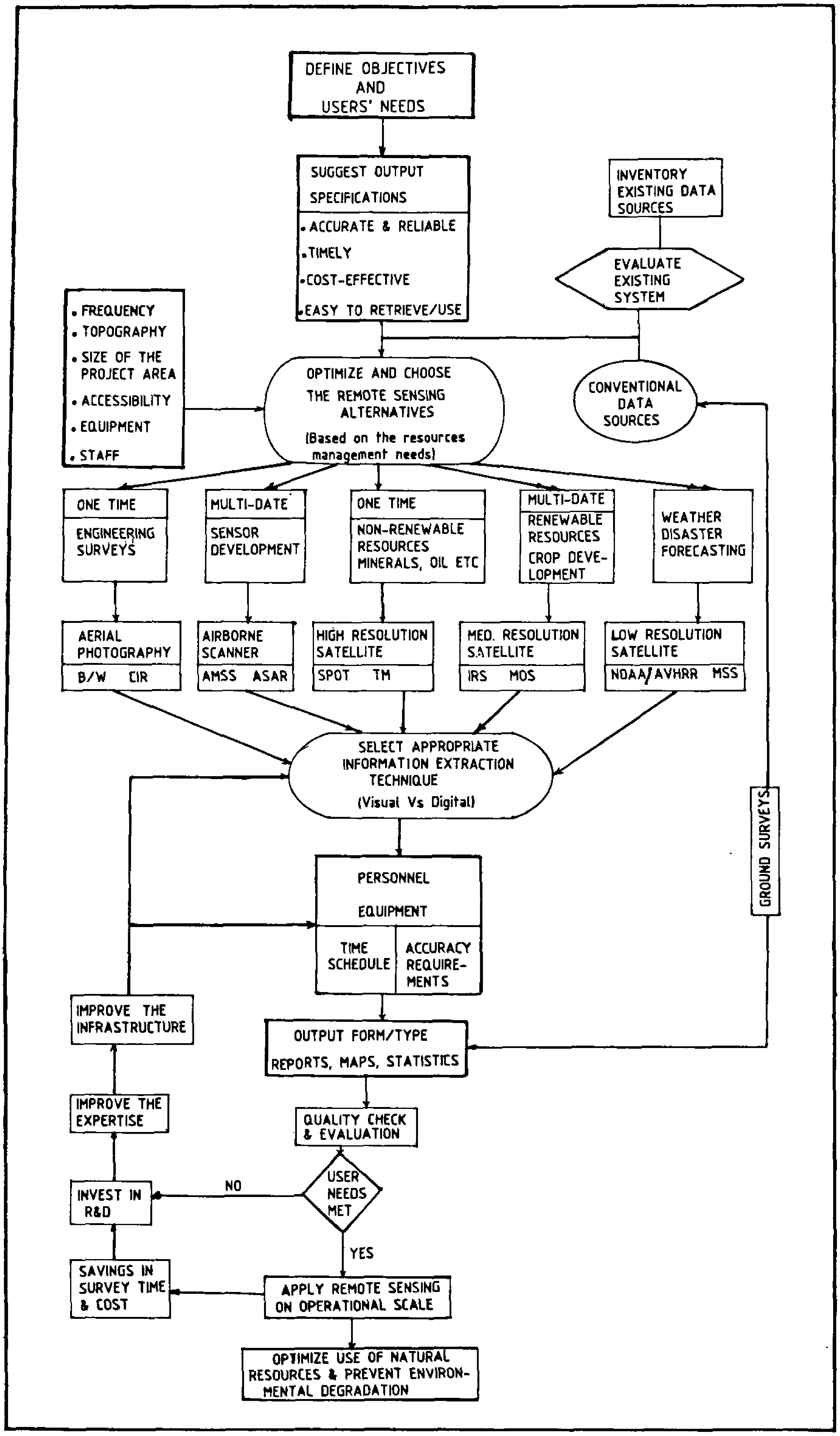

Figure 1. Optimisation of Remote Sensing Use

specified by the user. If user needs are not met, it is necessary to invest in training and manpower development so as to take-up further research and development to either stimulate new fields of application or improve the present techniques. A decision-flow diagram (Figure 1) is suggested for selection of alternatives.

Selection of Remotely Sensed Data

Selecting the appropriate data source will be the first step in improving the efficiency of a remote sensing project. This selection is influenced by the following factors:

The size of the project area: It is likely that national level studies must use satellite data, whereas small locale specific surveys, and urban studies would require conjunctive use of aerial photography with satellite data. Topography and accessibility of the study area also determine the type of remote sensing platform.

The type and scale of the output: A map on 1:250,000 scale can adequately be prepared using satellite imagery, whereas large scale maps or engineering type surveys at 1:5,000 would require airborne remote sensing information.

Planimetric and statistical accuracy: Higher planimetric and statistical accuracy could be best fulfilled by air-borne remote sensing.

The time schedule for output delivery: Ground and aerial surveys generally take more time than satellite-based data collection.

The infrastructure availability in the organisation: Availability of equipment, trained manpower and their experience in handling computer analysis algorithms and photo-interpretation equipment decide the type and form of input data for project implementation.

Nature of the resource theme: The more dynamic the theme being studied, the more frequently the information will be required. Satellite data will be more appropriate in such cases.

Spatial and temporal resolution: Careful consideration of temporal frequency and spatial resolution requirements for a particular project is a prerequisite to the determination of the appropriate satellite system. Remote sensing systems provide a synoptic view ranging from a kilometre or less with low-level aerial surveys, through 10's to a few hundred kilometres from polar orbiting satellites, to views of entire hemisphere from geostationary satellites. The larger the field of view, the coarser is the resolution of the images. Illustrative examples are given in table 1.

Table 1. Typical examples of satellite/sensor selection from Indian studies

Satellite/Sensor	Temporal Frequency	Application Theme
NOAA-AVHRR data (1.1 km)	Twice a day	Snow cover mapping and run off estimation, Nationwide agricultural drought monitoring.
Landsat-MSS (80mm)	16 days	Nationwide vegetation mapping, crop area estimation from homogeneous cropping patterns.
IRS-1A/LISS-I (72.5m)	22 days	Crop acreage estimation from homogeneous region.
IRS-1A/LISS-II (36m)	22 days	Hydrogeomorphologic mapping, National land use/cover mapping.
Landsat-TM (30m)	16 days	Urban sprawl monitoring of Bombay Metropolitan region.
SPOT-HRV (20m)	5 days	Ring Road alignment for specific area of Bangalore.
CIR Photographs	whenever required	Detection of crop diseases.

Selection of Remote Sensing Analysis Techniques

The selection of an appropriate information extrac tion technique (classification scheme) is a difficu and critical problem. The analyst should adopt th least expensive method of data analysis that ca provide reliable and accurate data.

The forest type mapping in two separate cas studies is an ideal example to illustrate the abov point. When the computer was used for image er hancement followed by manual interpretation, th cost was nearly 6 times less than that of the entir classification using supervised techniques. Anothe example, from China, shows that the cost per squar kilometre for thematic map making on 1:250,00 scale using visual interpretation of false colour con posite (FCC) was only 0.04 yuan, whereas tl generation of FCC using computer enhancement fo lowed by visual interpretation was 1.5 yuan, an computer classification (supervised) was 9 to 1 yuan[6]. Konrad and Rempel[7] made a comparison of computer-aided land cover classification of Landsat TM data with the manual digitisation and visual analysis of colour infrared photographs at 1:50,000 scale. They found the computer-aided classification more cost-effective (521 man-days) than manual interpretation (5232 man-days), i.e. the manual procedure required more than 10 times the man-days required by automation. These studies illustrate clearly that selection of an appropriate analytical technique plays a significant role in the cost of implementing the project.

Improving Information Extraction by Selecting the Best Spectral Bands and by Reducing the Number of Bands

While the future remote sensing/earth observation systems are going to have an increasing number of narrow spectral bands, it is fairly reasonable to suppose that a subset/combination of them would suffice for any one field of application. Careful trade-off studies have to be carried out to arrive at the minimum number of spectral bands which will maximise the information extraction while reducing the computation time.

The Choice of Classification Algorithms to Minimise Costs

Where computer classification has been chosen as the appropriate method for image interpretation and information extraction, it is necessary to choose an appropriate algorithm both to maximise accuracy and minimise computer time and therefore cost. Singh[8] objectively evaluated methods for change detection in order to identify the optimum algorithm for forest change due to shifting cultivation. The conclusions of the study were that the image regression method produced the highest change detection accuracy, followed by image ratioing and image differencing, than sophisticated transforms such as principal component analysis.

Increases in the spatial resolution and the number of spectral bands of the data produced by remote sensors are currently outstripping the ability of computers to process global-scale information[9]. Faster image processing algorithms are required to cope with these data, if the cost of remote sensing is to be kept within the budgets of end-users, and if global-scale studies are to be made feasible. Four different supervised classification schemes (minimum distance, decision tree, maximum likelihood and modified minimum distance) were applied to Landsat TM imagery by Booth and Oldfield[10]. The processing time required and the classification accuracy given by each classifier were compared. In this empirical study, it was found that although the *maximum likelihood algorithm* provided the most accurate classification, the use of a faster algorithm, such as minimum distance, followed by the application of a model filter to remove anomalous pixels could provide a classification of similar (albeit slightly lower) accuracy in less than half the time needed to use the maximum likelihood algorithm.

CONCLUSIONS

An attempt has been made in this paper to bring out the cost and benefit considerations in using remote sensing technology for solving natural resources management and environmental monitoring. While cost-benefit analysis will not be applicable in this case due to the problems in the quantification of the benefits, cost-effectiveness analysis has proven to be an efficient tool of evaluation of the economics of remote sensing technology over the conventional systems. Remote sensing technology has been a cost-effective solution when used in conjunction with conventional ground surveys on a selective basis. It can be concluded that only by a comparison of available technological alternatives, an optimum system configuration could be evolved to meet the end-user needs.

REFERENCES

1. Radhakrishnan, K., Chandrasekhar, M. G., Jayaraman, V., Jacob, N., and Manikiam, B., The impact of commercialisation on the remote sensing technology development of the ESCAP region., *Rep. Working Group Meeting*, Kuala Lumpur, Malaysia., 1989.
2. Rajan, M. S., A frame work for social cost benefit analysis of the Indian Space Programme — Project report., 1982
3. Vinod Hari, Cost-effectiveness of remote sensing in resource mangement applications — A "total cost" approach, 1990.
4. Madhavan, T., Venkatakumar, T. S., Das, B., Dasgupta, A. R., and Gopalan, A. K. S., A case study on benefit cost analysis of remote sensing based crop information system for major wheat growing regions of India, *ISRO-SAC-TR-40-84*, SAC, Ahmedabad, 1984.
5. Nageshwara Rao, P. P., Mohankumar, A., and Chandrasekhar, M. G., Crop land inventory in the command area of Krishnarajasagar Project using satellite data, *Proc. Natl. Symp. Rem. Sens. Agric. Applications*, New Delhi, 1990.
6. Xu, G., An economic assessment of the benefit of remote sensing for investigating and monitoring natural resources and the environment. *Proc. Regional*

Conf. Assessment of Economics of Rem. Sens. Applications to Natural Resources and Environment Development Projects in the ESCAP region, November 14-18., 1990, Guangzhou, China.

7. Konrad, S. L. R., and Rempel, R. S., Cost-effectiveness of Landsat TM Classification by Operations Staff, IEEE *Trans. Geosci. & Rem. Sens.* 1990., **28** (4), 769.
8. Singh, A., Digital change detection techniques using remotely sensed data., *Int. J. Remote Sensing,* 1989, **10** (6), 989.
9. Hardy, D. D., Advanced technology for monitoring and processing global environmental data, *Remote Sensing Society,* Reading, 1985.
10. Booth, D. J. and Oldfield, R. B., A comparison of classification algorithms of speed and accuracy after the application of a post-classification model filter, *Int. J. Remote Sensing,* **10** (7), 1271.

NATIONAL DRINKING WATER MISSION

The National Drinking Water Mission's objective is to provide 40 litres per capita per day (lpcpd) of potable water (with an additional 30 lpcpd for cattle in desert areas) to all the villages in India. Under the Drinking Water Mission the DOS took up the responsibility of preparing hydrogeomorphological maps on 1:250,000 scale for the entire country.

The feedback from different states indicate a high rate of success after using the maps prepared by Remote Sensing techniques in conjunction with hydrogeological and geophysical methods. The feedback from different states are given below:

Success Rate & Feedback

Sl. No.	State	Total No. of Bores drilled	Total No. of successful bores	Percentage success
1.	Gujarat	13667	12912	94.47
2.	Rajasthan	116	108	93.10
3.	Orissa	136	134	98.53
4.	Andhra Pradesh	216	169	78.24
5.	Bihar	1044	951	91.09
6.	Goa	628	560	89.17
7.	Karnataka	397	288	72.54
8.	Madhya Pradesh	290	282	97.24
9.	Meghalaya	112	99	86.39
10.	Uttar Pradesh	437	421	96.33
	Total	17043	15294	93.43

Source : NNRMS Bulletin, **13**, 1990. ISRO HQ, Bangalore.