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Remote Sensing

DEMONSTRATED APPLICATIONS IN INDIA OF EARTH RESOURCES SURVEY BY REMOTE SENSING

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A brief history of the remote sensing activities in India is given. Work conducted by the scientists in India, in different fields of remote sensing applications, such as geological studies, oil and mineral exploration, topographic studies, agricultural studies, soil survey, ground water survey, water reservoir monitoring, etc. is reviewed and summarised.

INTRODUCTION

AMONGST the several applications of Space Research remote sensing of the earth's resources is considered the most useful one by the applications oriented scientists. There has been enough speculation about the possible uses of remote sensing in resources survey and management during the last decade, and naturally at this juncture a question may be asked how much this technology is used in India and what are the future plans. In what follows a brief history of remote sensing in India and some of the demonstrated applications are reviewed.

EARLY AERIAL PHOTOGRAPHY IN INDIA

Aerial photography was first used in India, in the year 1920, in a survey experiment. In 1923–24, air survey of Irrawadi Delta Forest in Burma, which was then a part of India, was conducted. The first use of aerial photography in an application other than land survey, in India, was made in the year 1926, for flood assessment of river Indus at Dera Ismail Khan, then part of undivided India (Khosla, 1978). Since then, black and white aerial photography has been widely used for map making on a scale upto 1:15,000. The aerial imageries thus obtained, primarily for survey work, in black and white, were also used on a limited scale for geological survey purposes and the study of river basins. However, Remote Sensing, as practised in the present times, with the use of multi-spectral and false colour infrared imageries, was first introduced in India in 1970, with the conduct of an experiment aimed at early detection of coconut plantation disease (Dakshinamurti *et al.*, 1971).

PRESENT GROUPS AND ACTIVITIES IN INDIA

Since the conduct of this first experiment in India, with the use of multi-spectral and false colour infrared imageries, by Professor Pisharoty and his colleagues, several other groups have become active in the country. Following are some of these major groups who are engaged in this work :—

1. National Remote Sensing Agency (NRSA) (at Hyderabad and Dehra Dun)
2. Space Applications Centre (SAC), ISRO, Ahmedabad
3. Geological Survey of India (GSI), at several of their Centres and Units
4. Central Ground Water Board (CGWB)
5. ONGC
6. Survey of India
7. National Bureau of Soil Survey and Land Use Planning (ICAR)
8. National Institute of Oceanography

In addition, there are several smaller groups at Universities, IITs and Research Centres of States and Central Government Departments, who are busy with investigating and examining, mainly Landsat imageries, for possible applications in different fields of Resources Management and Survey.

The major fields of applications of the Earth Resources Survey by remote sensing are :

- Agriculture and Forestry
- Water Resources
- Oceanography
- Pollution Control
- Geology and Mineralogy
- Geography and Cartography

A large number of investigators have conducted studies using visual photo-interpretation techniques. Majority of these studies are of exploratory nature, covering one of the fields of applications mentioned earlier. In such studies, the investigator studies an imagery of a known area, with known facts, and confirms that the same facts are also revealed by the Landsat imageries. Such studies have some value only when one has to look for similar facts and features in regions which are unexplored, or the features which are dynamic and one wants to study them frequently and keep a track of changes in more or less real time, such as the area of a water reservoir, forest boundary line, snow cover, coast line, etc. A few more specific studies are being conducted where attempts are being made to find out and establish methodology to predict crop yield, determine bio-mass or predict possibility of underground water or a mineral rich area.

Most of the Landsat-1 and some of the Landsat-2 imageries are stored in India at three different places, Space Applications Centre, National Remote Sensing Agency and National Bureau of Soil Survey and Land Use Planning, and are made available to the investigators on certain conditions. NRSA alone has supplied imageries to nearly 100 users and Space Applications Centre has also supplied imageries to about same number of user scientists in India, and as per recent estimates, about half the country has been studied by remote sensing methods for at least one of the applications mentioned earlier (Rao, 1977).

Remote Sensing for Early Detection of Coconut Wilt

This earliest study by Pisharoty and his colleagues (Dakshinamurti *et al.*, 1971) has historical importance. Coconut plantations over 0.64 million hectares, in Kerala State of India, are affected by root wilt disease of coconut, resulting in a huge annual loss of about Rs. 10 million. It has been established that the disease is caused by rod shaped virus. When the disease is in its quite advanced stage, one observes flaccidity of leaflets, abnormal bending of leaves, outer whorl of leaves showing yellowing stunting of the leaves and great reduction in crown size. However, these symptoms become visible at a very late stage, and the remote sensing experiment was tried as a method for the early detection of the disease affected trees, which then could be removed before the disease spread over the whole of plantations. A large number of farms covering different soil groups, experimental station farms and large cultivator's plantations, having both the healthy and the diseased trees were photographed with a Hasselblad camera in seven different combinations of wave bands. Photographic exposures included colour Ektachrome infrared film, ordinary black and white film and black and white panchromatic plus X with three different filters in red, blue and green bands. The photographs were taken with hand-held camera from a helicopter flown at two different altitudes 500 and 1000 ft. Soil and leaf samples were collected on ground simultaneously, both from healthy and diseased plantations, for laboratory analysis and to correlate the ground truth with the photographic information. The studies indicated the potential of the Remote Sensing technique as a sensitive tool for early detection of plant disease.

Coconut plantations are mostly intermingled with other plant species, viz., Jack fruit, Mango, Bel and Banana. It was found that multi-spectral photography was useful in clearly distinguishing each of these species from one another by the colour patterns exhibited by them.

Detectability of Topographical Details

Bagchi (1976) has conducted studies to find out the imaging quality of the Landsat imagery for the study of certain topographical details pertaining to Indian sub-continent. He found :—

(*a*) Streams which appear on 1:250,000 maps are visible on the imagery.

(*b*) A township shows up only vaguely. Major building complexes in a large city are discernible but it is not possible to map the city on any scale. The shape of the city cannot be chalked out.

(*c*) Major roads and railway lines show up only at a few places and most of the time cannot be detected unless a map is used as a guide.

(*d*) Water bodies are clearly seen (band 7), but the dam of a reservoir is identifiable only by inference.

(*e*) Forest areas showup clearly in bands 5 and 6.

(*f*) Band 4 seems to be the least useful band except for studies in shallow sea bed areas.

(*g*) Bands 5 and 6 record vegetation and dry river beds/dry streams faithfully.

(*h*) Villages are not identifiable except the big ones.

(*i*) In a hilly terrain, using bands 6 and 7, water stream features are clearly visible. Ridges are also clear. Habitated areas consisting of settlements of small huts are not identifiable.

Usefulness of Aerial Photographs and Landsat Imageries on Different Scales in Geological Interpretations

Peshwa and Mulay (1978) have studied some parts of the Western India near Bombay in Maharashtra and Deshpande and Peshwa (1977) have studied, in detail, a part of the Great Vindhyan Basin covering parts of Satna, Shahdol and Jabalpur districts of Madhya Pradesh using multiband Landsat imageries. They conducted densitometric analysis of this area (Peshwa & Phadke, 1976). The studies were confined to geomorphology and geological interpretations, such as the study of Linears, Dykes and Flows. The area studied has alternate horizontal sheets of compact and amygdaloidal basalts belonging to the Deccan Traps. There are several basaltic and doleritic dykes intruding the area and fractures ranging from few to as much as 10 km in length. Panchromatic black and white aerial photographs of the area, on a scale 1 : 22,700 and 1 : 78,000 were available for the study. Simultaneously, Landsat imageries on 1 : 1 M and 1 : 250,000 scale covering the same area have also been studied.

It is well known that the study of linears help in location of potential zones of mineralisation. Lineaments are also indicators of joints, fractures and faults and indicators of possible subterranean water accumulation. For the study of the linears of smaller magnitude aerial photographs on a high scale, such as 1: 22,000 are more suitable, while the linears on regional scale can be best studied with the help of low scale imageries like Landsat.

It is also found that dykes which are supporting rectilinear band of vegetation, which are easily seen on the aerial photographs are not visible on Landsat pictures. Similarly, Landsat pictures are also of no use in mapping the flows.

Peshwa and Dessai (1978) have conducted visual photo-interpretations revealing useful information which could be used in selection of aerial photographs and satellite imageries on a suitable scale to provide maximum information regarding the geology of the area.

Neotectonic and Lineament Analysis of Landsat Imagery for Oil and Mineral Exploration in India

Landsat imageries in band 5 and 7 of some regions of the Eastern India have been examined by Rao (1977). The interpretation was done on 1:1 M scale but enlargements on 1: 0.5 M scale were also examined. A number of lineaments have been recorded from the imagery. The ultimate aim being identifying true faults, ground checks of these lineaments are required. Lineaments only help in localising the areas of interest. From the study of lineament intersection, two promising areas for mineralisation have been identified. The author has drawn the following conclusions from the study:

(*i*) Remote Sensing is only one of the tools available to geologists and cannot revolutionise geological sciences.

(*ii*) The study of lineament and neotectonic and geomorphic features becomes easier because of synoptic coverage of large areas by Landsat imagery.

(*iii*) Areas for mineral prospecting can be localised with a lineament map prepared from Landsat imagery.

Height Estimation from Landsat Imageries

Landsat MSS imageries are not perspectives and hence the height cannot be determined from them using the normal photogrammetric technique. Bagchi (1978) has tested the possibility of measuring relief in high hills by measuring the length of the shadow. The method is applicable only in hilly regions. Landsat is a sun-synchronous satellite and take imageries at about constant solar altitude, which is about 40° in tropical areas. Ridges whose slopes are greater than solar altitude cast shadows at that instant. By measuring the length of these shadows, the height differences between the top of the ridge and the valley at several points were determined. Imageries in bands 6 and 7 were chosen for this work because vegetation appears weaker in these bands, specially in band 7, and shadows appear darker against the light background. The shadow measurement method gives relief measurements at isolated patches, and not continuously, over the whole scene. Heights of 42 points on Landsat–2 MSS imagery on the scale 1: 1 M were determined using the above technique. The measured heights were compared with the available heights from the relief map. The r m s error of measurement was found to be 133.2 m. Part of the error is due to errors in the ground relief from the map, which is of the order of 50 m. With this the r m s error gets reduced to 120 m. This is, therefore, indicative of the precision which could be achieved in height determination using this approach.

Agricultural Resources Inventory and Survey Experiment (ARISE)

Sahai *et al.* (1975) carried out Agricultural Resources Inventory and Survey Experiment (ARISE), in Anantapur District of Andhra Pradesh, using multi-band aerial imageries. The choice of films and spectral bands, by using appropriate filters, was made keeping in mind to generate imageries in spectral bands as near as possible to the Landsat–1 imageries.

The experiment has proved beyond any doubt that various land-use features can be identified easily in the imagery taken at a scale of 1: 30,000. The land in agricultural use can be distinguished easily from that in non-agricultural use. Land in agricultural use can be further classified as irrigated or unirrigated. Practically all major crops can be identified and a comprehensive inventory of major crops and acreage can be prepared. The acreage calculations can be carried out fairly accurately and fast. The synoptic views of waste, eroded, marshy and salt-affected lands provide very useful information for adopting preventive as well as reclamation measures. Information available can be used for detailed agricultural land-use planning. The level of detail which remote sensing data can give is far more than the published and available statistical data based on ground-based observations. This has important planning implications at the micro-level.

MONITORING OF WATER RESERVOIRS

Gupta (1978) conducted a study, using Landsat MSS imageries, aimed at establishing possible operational use of the remote sensing data in monitoring the water resources. He studied the Landsat coverage over the Bhakra Dam reservoir by superimposing a set of pre- and post-monsoon imageries. His study has shown that the remote sensing information can be adequately used for monitoring the area of lake and hence the volume of water and its seasonal variations. He has also shown that possible areas of silting also could be detected.

Ramesam and Rao (1977, 1978) have used repeat Landsat MSS imageries in band 7 of the Vedavati catchment in Karnataka and Andhra Pradesh. Band 7 is very useful for the study of land-water contrast over large tracks and helps in the study of changes in spread of surface water and soil moisture, stream flow characteristics, as well as, monitoring of flood levels. From their studies they have established empirical relationship for the major reservoirs in the Vedavati River Basin between the volume of water stored in the reservoir and the spread of the reservoir as recorded in the MSS band 7 imageries.

GROUND AND SURFACE WATER SURVEYS

Srinivasan (1978) has made a detailed study to use the remote sensing technique for ground water studies in semi-arid regions of Dharampuri District in Tamil Nadu. It is a well-known fact that interstices in crystalline rocks such as joints, fractures, faults and thrust plains are zones in which sub-terranean ground-water accumulates and forms as underground reservoir. Visual interpretation was first used for delineating major geomorphological zonations, and structural features of interest, which are manifested as lineaments in Landsat imageries, were picked up. Relationship has been established between the occurrence of ground water and the above features. Landsat black and white imageries of 1: 5,00,000 scale and false colour composites of 1: 1,000,000 scale were used.

Singhal and Devendra Kumar (1979) have assessed the role of space observations in optimal and conjunctive use of ground and surface waters and concluded that space observations have definite advantage over the conventional methods.

USE IN SOIL SURVEY AND LAND RECLAMATION

Singh (1978) has reported on a very limited amount of work done with Landsat imageries at the Indian Photo-interpretation Institute for soil identification purposes. His study has shown that from Landsat imageries, band 5 and 7 maps for soil survey can be prepared by delineating landscape units. The boundaries can be drawn with a fair amount of accuracy. It is also possible to delineate geomorphic units based on terrain analysis for the purpose of correlating soil units with physiographic units without the additional help of aerial photographs. Using band 7, gully depth classification has also been achieved by connecting seepage prints which could be identified on the imagery through the use of ordinary hand-held lens. These observations coupled with some terrain features, such as drainage densities and bifurcation ratios, form the basis of identifying gullied areas and their classification into various reclamation units. Thus the Landsat imagery could be used to detect potential areas for land reclamation programmes.

Crop Yield using Remote Sensing

Sahai and Patil (1977) and his group at the Space Applications Centre have completed a preliminary experiment in cotton yield forecast using remote sensing. monoscopic interpretation of colour infrared imagery covering parts of cotton growing districts of Gujarat have been studied for this purpose. Aerial imagery on 1 : 20,000 and 1 : 24,000 scale were compared during the interpretation. Colour infrared imagery on scale 1 : 20,000 is found more suitable for the identification of cotton varieties and vigour classification. Total acreage under cotton and its yield have been estimated for the entire district.

In order to study optimum size of sample for the estimation of different crops in a given area using remote sensing methods, samples of 5, 10 and 25 per cent of the total area were taken. The results indicated that for major crop acreage estimation, 5 to 10 per cent samples of the total area are sufficient.

Experience of the Image Processing Group at the Space Applications Centre of the Indian Space Research Organisation (ISRO)

ISRO has plans for designing and orbiting an Indian Resources Survey satellite during the first half of 1980's. This goal is to be achieved in steps, and detailed studies are being conducted for defining and selecting the resolution and spectral bands to be used on the future Indian satellite. On the instrumentation side, as a first step, a multi-spectral aircraft scanner has been developed, which has now been successfully flown on several aircraft survey missions. Also India's first experimental remote sensing satellite—Satellite for Earth Observations (SEO) — would be getting ready for an early launch. This satellite will carry two television cameras to view the earth in spectral bands 0.54 to 0.66 μm and 0.75 to 0.85 μm with a ground resolution of about 1 km. To understand the possible capabilities of SEO spectral bands and spatial resolution, and to plan the usage of SEO data when available, simulation studies have been conducted by generating simulated SEO imageries out of Landsat scenes. The Image Processing Group (Kamat *et al.*, 1977 *a*, *b*, *c*, *d*, *e*; and George Joseph & Kamat, 1978) have looked at these different types of aircraft MSS, Landsat and simulated SEO imageries and processed them utilising the standard digital image interpretation techniques for different usages to understand the effects of changes in spatial resolution, spectral resolution and radiometric sensitivity. Visual inspection, study and comparisons have been made. They have also looked at multi-band aerial imagery and NOAA visible and thermal imagery. The study is incomplete and in progress. Following is the summary of their preliminary findings :

Study of the Landsat Imageries

(*a*) Black and white 1 : 1,000,000 scale photographic product has been found useful to identify small springs, roads, dams, water bodies, railway lines, etc., where the size of the object was smaller than the Landsat spatial resolution of 80 meters. This was because in all these cases, the contrast in the picture where the object was situated, was very high. In case of objects like railway lines, certain *a priori* knowledge of the place made detection easier.

(*b*) Out of 1 : 1,000,000 scale Landsat imageries of mineralised belt in Chhota Nagpur region, colour composites were made using MSS 4/5, MSS 5 and MSS 6 + 7. In the colour composites thus made it was found that vegetative cover over the total scene was enhanced and especially the drainage patterns having vegetative covers stood out. This example points to the need of not overlooking the value of combination of spectral bands in recognising features of interest.

(*c*) False colour composites made for selected areas on 1 : 250,000 scale around Navagam in Gujarat, Chilka Lake in Orissa and area around Hirakund dam in Orissa and West Coast of Gujarat showed changes in landscapes and land accretion as well as erosion of landmass when compared with earlier maps. These pictures essentially were used to detect changes.

(*d*) False colour composite pictures to the scale of 1 : 100,000 were compared with topographic maps. This also showed that significant changes in landscapes can be detected when spectral information is used even though the spatial resolution is low.

(*e*) From the comparison of Landsat imageries taken at different epochs it is found that on a 1 : 1,000,000 scale picture an observer can detect visually a change, or displacement of 200 to 500 meters easily without any special aid. Similarly, for 1 : 250,000 scale the change detection of 50 to 125 meters, and for 1 : 100,000 of 20 to 50 meters are possible.

Landsat Derived Data for Simulating Lower Resolution

(*a*) The 80 meter resolution Landsat digital data were reduced through computer processing to spatial resolution corresponding to 160 meters and 800 meters. This lower resolution data were transcribed into photo products. These images at 1 : 1,000,000 scale were interpreted. The 160 meter resolution imagery contained almost all information which the original image did have. As regards the 800 meter resolution imagery, when converted into a false colour composite, had almost all the information as the original data did contain. However, the single band B & W images did not possess interpretable quality. Thus it seems that multiband data with low resolution like 800 meters give information comparable to high resolution data in a single band.

(*b*) The 800 meter data in multiband mode was digitally analysed for a scene containing forest. It was found that the cover types using the 800 meter resolution data were as many as 6 compared to 7 cover types obtained using the original Landsat 80 meter resolution data. Thus, it seems that in practice, lower resolution but with multiple bands can give practically the same information as the original Landsat data.

(*c*) Although the simulated data has lower resolution, this data does not correspondingly suffer in its spectral sensitivity. In practice, spatial resolution is always a function of contrast and generally lower spatial resolution goes hand-in-hand with low contrast.

ISRO-MSS Data

(*a*) ISRO-MSS imagery which is collected in 5 spectral bands has a resolution of 15 meters on ground and is usually rendered into photographs of scale 1 : 150,000 or 1 : 75,000 which are used as reference images. This multi-spectral data was enlarged to 1 : 25,000. It was observed that this image of 1 : 25,000 scale in a single band did not contain sufficient capabilities to allow interpretation of agriculture types of covers. However, when a colour composite using 3 bands is made, discrimination between cover types improves.

(*b*) Enlargements to 1 : 25,000 was done electronically. Two types of image writing systems were used and it was noticed that one particular image writing system; which had a better MTF compared to the data source produced a better image. Thus, it seems that multi-band colour composites do contribute tremendous amount of information in spite of lack of spatial resolution in the original data.

Multiband Aerial Photographic Imagery

Multiband aerial photographic imagery of scale 1 : 30,000 taken over agricultural fields in Punjab was digitized to give a pixel resolution of 3 meters on ground. It was noted that the agriculture crop covers and the landuse identified using quadratic discriminant function analysis gave mapping accurary which was as low as 50 per cent for an area of 256 hectares. This classification was done using field information on test sites provided by an agency which had information on the test site collected three years prior to the actual experiment. There had been rotation of crops as well as cultivators had planted mixed crops between rows of the main wheat crops. Thus, it seems that information on significant and cultural practices is more important compared to purely spatial resolution which in this particular case was as high as 3 meters.

NOAA Data

The NOAA-VHRR system is optimised for albedo from clouds and is not found to be useful for resource information. However, the thermal data have been found useful for delineation of sea-land boundaries whenever cloud free conditions exist. This property of thermal IR band can be used for extracting edges at the land-sea boundary and then used for self-referencing dynamic coastal processes. Efforts in this direction are continuing.

In general, it could be summarised that the experience in the use of satellite and aerial survey data for extraction of resource information pertaining to land-use and agriculture indicates that the spectral information is vitally important in correctly mapping these resources. It was found, that, when using aerial imagery, very high spatial resolution is ineffective if suitable signature information is not available. It is also the experience that enlarged Landsat pictures to scale 1 : 250,000 and 1 : 100,000 do provide information leading to change detection when the pictures are made into colour composites by mixing of spectral bands. In most of the studies described, quantitative results have been obtained which could be used for future planning of a National Resources Survey System using remote sensing technique, and selection of sensor resolution and spectral bands for future spacecraft which could be effectively used in Indian conditions and needs.

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