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REMOTE SENSING FOR RURAL DEVELOPMENT

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ABSTRACT

Spaceborne Remote Sensing is fast emerging as a front running provider of information on natural resources in a spatial format for rural development planning process. The article briefly discusses the physical basis of remote sensing, its evolution in India, status of application projects relevant to rural development and a few case studies where Remote Sensing has made a positive difference. Directions of future development in this area are indicated.

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Introduction

India, inhabited by sixteen per cent of the world's human population and twenty per cent of the world's cattle population has only 2.4 per cent of world's land area. It is under constant pressure for meeting the basic needs of human life. Seventy four per cent of Indian population live in rural areas. Though the average landholding in the country is 2.6 ha, in the rural areas 34 per cent hold on an average less than 0.2 ha of land each (India, 1996). A large percentage of rural population lives below the poverty line. Agriculture is the primary source of livelihood. Only about 180 M ha cultivable land is available for food production. Productivity from these lands is low.

Rural development is an obligation on the government to raise the standard of the population living in rural areas. Rural development is indeed, an extremely difficult task due to complex nature of social, economic and ecological situations. Since independence, the Government has initiated developmental planning measures and implemented them through five-year plans. So far, although eight five-year plans have been implemented, still the problem of rural poverty and unemployment has remained largely unsolved. Basic infrastructures also are lacking in most of the villages.

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To achieve economic growth, development plans are often conceived mainly based on the socio-economic data ignoring the natural resources set-up of the region. In fact, for effective planning and development, a variety of data on natural resources, human resources, social practices and economic aspects are essential. In general, the following information is required for planning development of a region.

(i) Information in spatial format on current land use (cropped land, extent and type of wastelands, grasslands, status of forest lands), surface water bodies and their conditions, drainage, ground water potential areas, terrain characteristics etc.

(ii) Demographic data on population, scheduled caste and scheduled tribe population, literacy, percentage of agricultural workers migratory behaviour etc.

(iii) Infrastructure data on transportation networks, communication links, agriculture credit facilities, fertilizer depots, primary health centres, industries, housing, markets, educational centres, water supply and drainage etc.

(iv) Economic data related to irrigation, cropped area, agricultural production, livestock population, industrial activities etc.

Space technology through its earth observation capability provides information on natural resources in a spatial format, while satellite communication facilitates education, awareness and connectivity among the rural population.

Remote Sensing

WHAT IS REMOTE SENSING ?

Remote sensing (RS) refers to the branch of science which derives information about objects from measurements made from a distance i.e. without actually coming into contact with them. Conventionally remote sensing deals with the use of electromagnetic radiation as the medium of interaction. Remote sensing refers to the identification of earth features by detecting the characteristic electromagnetic radiation that is reflected/emitted by the earth surface. Every object reflects / scatters a portion of the electromagnetic radiation incident on it depending upon its physical properties. In addition, objects also emit electromagnetic radiation depending upon their temperature and emissivity. Reflectance / emittance pattern at different wavelengths for each object is different. Such a set of characteristics is known as spectral signature of the object. This enables identification and discrimination of objects.

Remote sensing, as we understand today, is nothing but opposite of astronomy. As part of astronomy, man looked from the earth towards heavenly bodies to understand, gain more insight about them. He built instruments to measure `light coming from these bodies' to understand their movements, evolution etc. On the other hand, remote sensing refers to going up in the sky and looking downwards towards the earth itself to learn more about the place, we have inhabited (Joseph and Navalgund, 1991).

Advantages of Satellite Remote Sensing

* Synoptic view - Large area coverage : Facilitates understanding of inter-relationships amongst various natural resources.
* Temporal coverage : Helps understand changing physical processes and in monitoring its dynamics.
* Different spatial resolutions / coverages : Information is simultaneously available at macro as well as at micro level.
* Cost-effective compared to aerial and traditional ground surveys.
* Microwave remote sensing : All weather capability and penetration through soil to some extent.
* Provides timely, reliable and spatially comprehensive data on various resources for effective planning, prioritisation, implementation and monitoring.
* Helps bringing about transparency in the planning process.

Remote Sensing System, Orbits

Remote sensing system broadly comprises three components - the space segment, the ground segment and applications/ utilisation programme. The spacecraft houses the payloads/sensors required for detecting reflected / emitted radiation from the earth surface features. The ground segment comprises broadly network of telemetry and tracking stations and data reception system. Data processing system involves checking the quality of data, various radiometric and geometric corrections and generation of data products in standard user-friendly formats. Applications programme is designed to realize the intended objectives of the mission. It consists of demonstration / validation studies in the first few months over selected test sites and operationlisation of the methodology over large areas subsequently.

Conventionally, polar, sun-synchronous and circular orbits in the range of altitudes 500 - 1000 km are employed for spaceborne remote sensing. Sun-synchronous orbits ensure acquisition of data over a given region at the same time, under similar illumination conditions. Polar orbit facilitates global coverage, and same spatial resolution / scale is ensured by a circular orbit. Geosynchronous orbit (~36,000 km above the earth surface in the equatorial plane) provides a platform for constant observation but spatial resolutions achievable are rather coarse.

How does one extract information from spaceborne images?

The earth surface as seen by the camera in different wavelengths, (reflected, scattered and or emitted) is provided either in the form of a digital tape or a photographic product. Such a product is radiometrically corrected, geometrically registered to a reference scheme and properly annotated. Interpretation of such a product for deriving information on the earth surface requires, understanding of spectral signatures of different earth surface features, apriori knowledge of the ground and subject experience. On many occasions, it is necessary to study images taken at two different times / seasons to discriminate objects. Interpretation also makes use of texture, association, shape and size characteristics of the objects for identification. Digital image processing techniques predominantly use magnitude of reflected/ emitted radiation of objects at different spectral bands to identify and classify objects. Let us illustrate this process taking examples of land and water resources.

LAND RESOURCES

Agricultural area having standing crops appears in red tone in view of the high infrared reflectance of vegetation in the false colour composite (FCC). False colour composite is a visual data product generated by assigning red, green and blue colour to images taken in near infrared, red and green spectral bands and composited. Hence, vegetation is seen in red tone in view of its high NIR reflectance. Different shades within this tone may indicate different growth stages, density of crop, its variety, cultural practices, per cent of soil cover, etc. Dense forest areas appear in dark red tone at all times

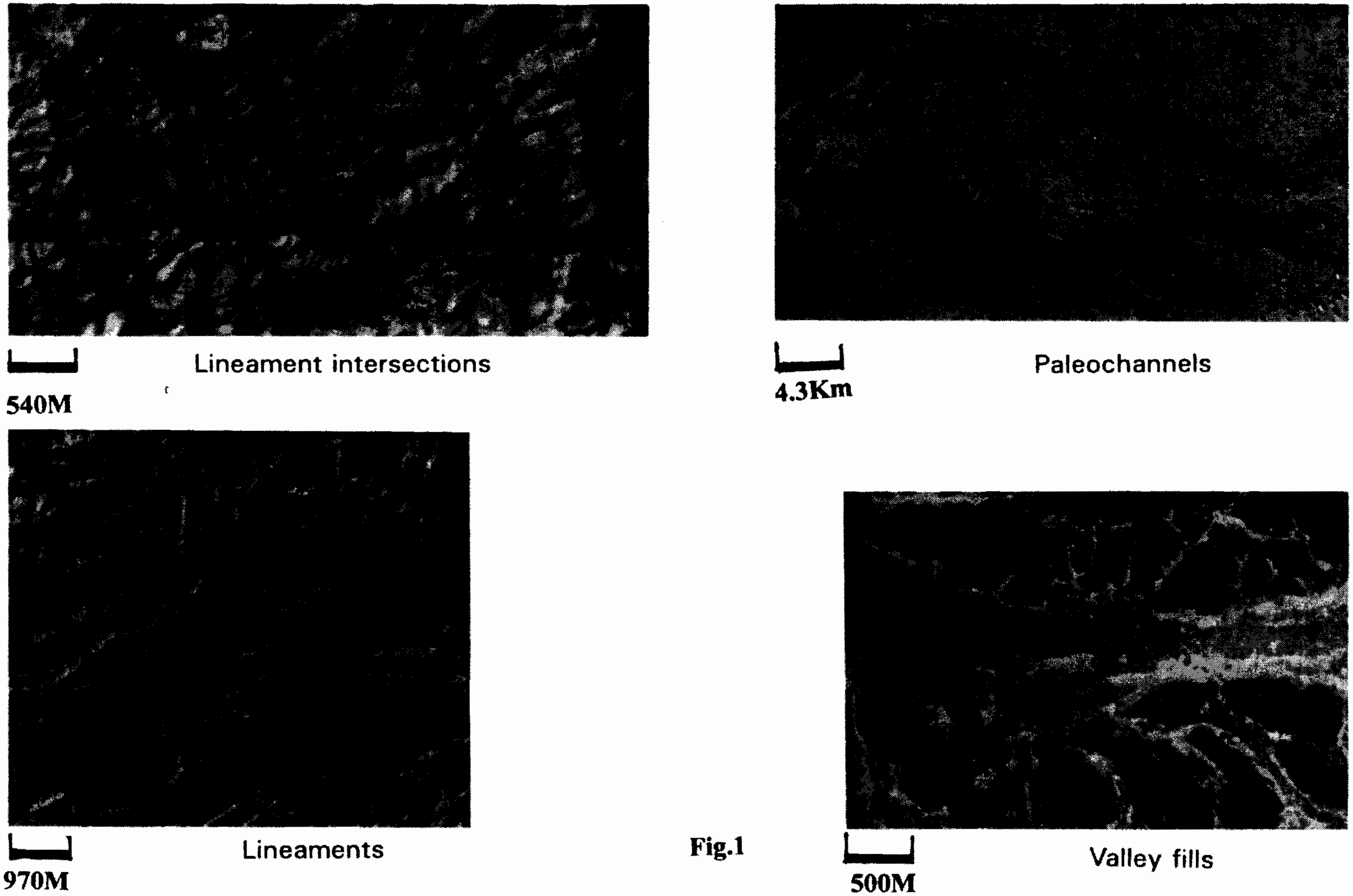
540M
Lineament intersections
4.3Km
Paleochannels
970M
Lineaments
500M
Valley fills

Fig.1

of the year, if it is ever-green type. Fallow lands, bereft of any vegetation would give cyan tone. One could also distinguish long fallow from the current fallow by studying images of different seasons / years.

Wasteland categories are distinctly identifiable on the satellite images due to their characteristic pattern, association and signatures. Land with or without scrub appears like crop land in kharif season image and like 'fallows' in rabi season image. Sandy areas due to their high reflectivity would appear in white tone. Gullied / ravinous lands are identified by their pattern and association with river / stream systems. Barren rocky areas and stony pavements are discriminated because of their characteristic spectral response.

RS images allow identification of roads connecting rural areas including cart roads, provide a spatial format for understanding rural connectivity.

WATER RESOURCES

Surface waterbodies are easily identifiable on RS images through their dark blue tone resulting from absorption of infrared radiation by water. Geometrically registered images of different dates season provide information on the spread of a surface waterbody, be it a village pond, lake or a reservoir. Volume of available water can be inferred by studying area-capacity curves. Presence of suspended sediment (turbidity) and aquatic vegetation in the waterbody can also be inferred from the images.

Occurrence of ground water at any place is a consequence of the interaction of climatic, geologic, hydrologic and topographic factors. The porous and permeable rock formations form good aquifers storing sufficient quantity of water. Hard rocks also store water in the network of fractures, faults, joints and other weak planes. Weathering and disintegration of hard rocks lead to favourable conditions for ground water occurrence. Thus, search for ground water depends on locating the most promising zones having good porosity and permeability. Some of the indicators of ground water occurrence such as intersection of lineaments, fractures, faults, dykes, valley fills, abandoned and paleo channels, flood plains, areas of anomalous vegetation growth can be identified on the images (Fig. 1). Remote Sensing provides a quick first-cut information for targeting the prospective zones for more detailed hydrogeological / geophysical investigations. Images facilitate delineation of watershed / subwatershed boundaries, and provide information on drainage pattern, landforms and land use information pertaining to the watersheds. (Fig. 2).

Evolution of Spaceborne Remote Sensing

Spaceborne remote sensing of the earth as we understand today, began with the successful launching of the Earth Resources Technology Satellite ERTS-1 (later renamed as LANDSAT) by the United States of America in 1972. Since then, remote sensing has made rapid advances in the last over two decades. LANDSAT series of satellites (1-5) provided data over the entire world on operational basis for natural resources survey and management. The French SPOT series of satellites (1-3), in mono as well as in stereo mode facilitated more detailed mapping and digital elevation modelling. Marine Observation Satellites (MOS-A & B) were launched by Japan for earth resources studies. India entered the era of spaceborne remote sensing with the launch of Bhaskara-I in 1979. With the successful launching of operational Indian remote sensing satellites IRS-1A in March 1988, IRS-1B in 1991, and IRS-P2 (indigenous launch) in 1994, carrying state-of-the-art sensors, remote sensing applications in India got a tremendous boost in several areas of natural resources survey. In many areas of applications, remotely sensed data is being used routinely. Successful launching of the second generation Indian Remote Sensing Satellite IRS-1C on December 28, 1995 and IRS-P3 on March 21, 1996 (indigenous launch) have added further dimensions to imaging of the earth from space. IRS-1D, identical to IRS-1C was launched on September 29, 1997 by the indigenously built Polar Satellite Launch Vehicle (Table 1).

RS Applications Relevant to Rural Development : Status

The Indian remote sensing programme, since its inception has adopted an applications-driven approach. Many applications have been taken-up in the areas of agriculture, land use, ground water, surface water, soils, environment, watershed development, forestry etc. with active involvement of user departments. National level / large scale projects have been carried out in selected themes under Remote Sensing Applications Missions. Many of them are relevant to rural development. Results of many remote sensing applications have been summarized in the special issues of Current Science (Vol. 61, 1991 and Vol. 70, 1996).

National Natural Resources Management System (NNRMS), set-up in 1983 at the behest of Planning Commission, Govt. of India is an integrated resources management system aimed at optimal utilisation of country's natural resources by a proper and systematic inventory of resource availability using remote sensing data in conjunction with conventional techniques.

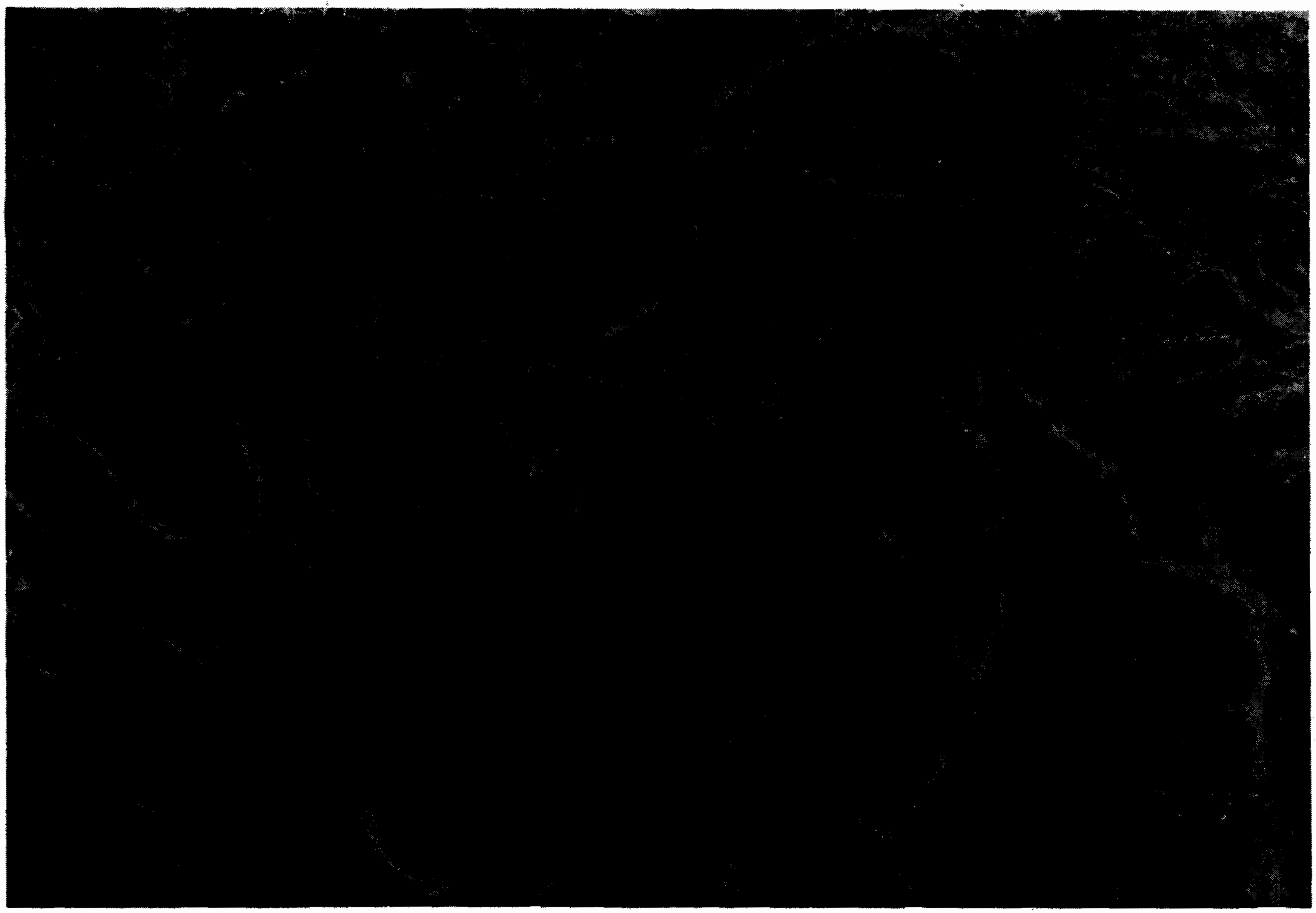

Fig. 2 False colour composite for part of Saurashtra region showing drainage pattern, watershed boundaries

Table 1 : Major Specifications of LANDSAT MSS & TM, SPOT HRV 1 & 2 and IRS, LISS-I & II and LISS-III WIFS and PAN

Satellite Sensor (Year of launch)	Spectral bands in micrometer	Ground Res. (m)	Quantisation levels	Repetition Cycle (days)	Swath (km)
Landsat 1, 2, 3, 4, 5 (1972), 75, 78, 82, 84)					
MSS	0.5-0.6, 0.6-0.7 0.7-0.8, 0.8-0.9	79	128	18 (Landsat 1/2/3) 16 (Landsat 4/5)	185
TM	0.45-0.52, 0.52-0.60 0.63-0.69, 0.76-0.90 1.55-1.75, 2.08-2.35 10.4-12.5	30 120	256	16	185
Spot 1, 2, 3 (1986, 90, 93)					
PAN	0.51-0.73, 0.61-0.68	10	256	26	60
HRV	0.50-0.59, 0.79-0.89	20	256	26	60
IRS-1A & 1B (1988, 91)					
	0.45-0.52, 0.52-0.59 0.62-0.68, 0.77-0.86	72.5 (Liss-I) 36.25 (Liss-II)	128	22	148.48 145.48 (A & B combined)
IRS-P2					
	0.45-0.52, 0.52-0.59 0.62-0.68, 0.77-0.86	37x32	128	24	131
IRS-1C/1D (1995, 97)					
Liss-3	0.52-0.59, 0.62-0.68 0.77-0.86, 1.55-1.70	~23.5 VNIR, ~69 MIR	128	24	140
WiFS	0.62-0.68, 0.77-0.86	188	128	5	804
PAN	0.05-0.075	5.8	64	5 (revisit)	70

NNRMS activities are coordinated at the apex by Planning Committee - NNRMS and it provides guidelines for implementation of the system. Major RS applications are initiated through the many NNRMS - Standing Committees pertaining to major resource / technology areas such as Agriculture and Soils, Water resources, Geology, Ocean resources, Bio-resources, Urban studies, Cartography, Technology and Training. NNRMS Standing Committee on Rural Development has been constituted recently to provide greater impetus to RS applications for rural development.

Land Use

Increasing agricultural production demands bringing more area under agriculture, increasing productivity and cropping intensity. Pre-requisite to this, is reliable information on spatial extent and distribution of present land use to decide on what additional lands are to be brought under agriculture. To work out a strategy for country wide integrated land use planning inputs on spatial distribution and areal extent of different land use categories, changes in cropped area over a period of time etc. are required. Towards such an exercise, district-wise land use maps for all districts of the country distributed in the 15 agro-climatic zones, using two-season (1988 kharif, and 1989 rabi) data from the Indian Remote Sensing Satellites on 1:250,000 scale have been prepared. National level land use / land cover classification system (Table 2) showing 6 level-I and 23 level- II classes has been developed and used for the project (Rao et.al., 1991). The results of the land use / cover mapping are brought in the form of statistics, line maps / colour coded photo-write outputs and reports. These inputs are expected to facilitate drawing up plans of agricultural land use based on Agro-climatic Regional Planning approach adopted by Planning Commission, Govt. of India.

Table 2 : Land use / land cover classification system

	Level - I		Level - II
1.	Built-up land	1.1	Built-up land
2.	Agricultural land	2.1	Crop land
			i) Kharif
			ii) Rabi
			iii) Kharif + Rabi[a]
		2.2	Fallows[b]
		2.3	Plantations[c]

Table 2 : (*Contd.*)

3.	Forest[d]	3.1	Evergreen/semi-evergreen forest
		3.2	Deciduous forest
		3.3	Degraded or scrub land
		3.4	Forest blank
		3.5	Forest plantation[e]
4.	Waterlands	4.1	Salt affected land
		4.2	Waterlogged land
		4.3	Marshy / Swampy land
		4.4	Gullied / ravinous land
		4.5	Land with or without scrub
		4.6	Sandy area (coastal and desertic)
		4.7	Barren rocky/stony waste/sheet rock area
5.	Water bodies	5.1	River / stream
		5.2	Lake / reservoir / tank / canal[f]
6.	Others	6.1	Shifting cultivation
		6.2	Grassland / grazing land
		6.3	Snow covered / Glacial area

a - It includes land under agricultural crops during Kharif, Rabi (both irrigated + unirrigated) and the area under double crop, during both the seasons.

b - It is that land which remains vacant without crop during both the Kharif and the Rabi seasons

c - It includes all agricultural plantations like tea, coffee, rubber, coconut, arecanut, citrus and other orchards.

d - It includes those areas which occur within the notified forest boundary as shown on the Survey of India topographic maps on 1:250,000 scale. Those occurring outside the notified areas are also included under forest class, but the area estimates of the two will be shown separately.

e - It includes plantations within the notified forest boundary eg., cashew, casuarina, eucalyptus, etc. Those occurring outside the notified areas will be classified under category 2.3.

f - It includes inland fresh water lakes, salt lakes, coastal lakes and lagoons.

Note : 1. Mining and industrial wastes, salt-pans, reclaimed lands, classes relevant to a particular district will be mapped separately, wherever feasible. These will be classified under others.

2. Tidal /mud flats which are visible during low tides along the coastal areas will also be mapped separately if these are identified on satellite imagery. These will be classified under Others.

(Source : Rao, *et. al.*, 1991)

Wastelands

Wastelands are described as 'degraded lands' which can be brought under vegetative cover, with reasonable effort, and which are currently under-utilized. Wastelands are also those lands which are deteriorating due to lack of appropriate water and soil management or on account of natural causes. A systematic effort has been made in India to map their extent and categories using space borne data. Mapping of wastelands of the country on 1:1M scale using satellite data was carried out during 1980-82 period. This study showed that 16.21 per cent of the geographical area of the country is under wastelands. Based on this study, 146 districts which had more than 15 per cent of their geographical area under wastelands have been mapped on 1:50,000 scale, showing 13-fold categories of wastelands (Rao et.al., 1991). Studies have also been completed for another eighty five districts. The wasteland classification system (Table 3) evolved by a Task Force which was set up by the Planning Commission in 1986 has been adopted for mapping. Village boundaries were superposed on these maps for facilitating the location of wastelands. The information is being utilised for prioritising the villages and for drawing up optimum development programmes like afforestation, agro-forestry, social forestry, fodder cultivation etc.

Table 3 : Wasteland Classification System

01.	Gullied and / or ravinous land	07.	Mining / industrial wastelands
02.	Upland with or without scrub	08	Under-utilised / degraded notified forest land
03.	Water-logged and marshy land	09.	Degraded pastures/grazing land
04.	Land affected by salinity / alkalinity (coastal or inland)	10.	Degraded land under plantation crops
		11.	Barren rocky/stony wasters/sheet-rock areas
05.	Shifting cultivation area	12.	Steep-sloping areas
06.	Sandy (desert or coastal)	13	Snow covered and / or glacial areas

Soil

Mapping of soil types for their productivity potential and problem soils for reclamation/conservation measures is an important aspect of sustainable agriculture. Active erosion by water and wind alone accounts for 150 million hectare area of land which amounts to a loss of about 5.334 million tones of nitrogen, phosphorous and potash costing around Rs. 700 crore in India.

In addition, 25 million hectares area have been degraded due to ravines and gullies, shifting cultivation, salinity / alkalinity, waterlogging etc. In order to utilise such lands judiciously and arrest further degradation, information on their spatial distribution, degree of severity etc. is required. Preparation of soil maps on 1:250,000 scale using space images and ground surveys has been taken up by the premier agencies for Soil Survey and Land Use Planning in the country. Mapping of saline and alkaline soils of India showing different categories of salt - affected soils namely slight to moderately saline, highly saline, saline-alkali, coastal saline etc. has been carried out.

Forest

In case of forestry, mapping forest extent and its density is being routinely done by the Forest Survey of India every two years using RS data. Forest cover estimates arrived at for the period 1972-75 to 1991-93 are shown in Table 4 (Anon, 1983, 1987, 1989, 1991).

Table 4 : Forest cover estimates in India using satellite data

Year	Closed forest (%)	Open forest (%)	Mangroove (%)	Total (%)
1972-75	14.12	7.38	0.1	21.60
1981-83	10.98	8.41	0.12	19.51
1985-87	11.51	7.83	0.13	19.47
1987-89	11.73	7.63	0.13	19.49
1989-91	11.73	7.61	0.13	19.47
1991-93	11.73	7.58	0.14	19.45

The country has an area of 75.23 M ha as notified forests. 40.61 M ha is classified as reserved forest and 21.51 M ha as protected forest. Unclassified forest areas is spread over 13.11 M ha. The total forest cover is only 19.45 per cent of the geographical area of the country which is lower as compared to 33.3 per cent recommended by the National Forest Policy 1952 and 1988. The closed forest has decreased from 14.1 per cent (1972 - 75) to 11.7 per cent (1991 - 93). Since 1981 there is no increase in forest cover. One of the eye-catching application of RS data has been identification of encroachment status in the notified forest areas at different years. The first example of this kind was for Shivpur and Sanghvi forest ranges, Dhule, Maharashtra. Recently in the case of Sanjay Gandhi National Park, Borivali, multi year satellite data (1989-94-95) have been utilised to identify forest areas encroached at different years. These maps, prepared by using satellite data, have been used as evidence by the Bombay High Court in a legal case, to pass judgment in favour of the Forest Department of Govt. of Maharashtra and against the illegal encroachers. Satellite data has also been used to detect forest fires. Satellite data are used to monitor the plantation / afforestation activities under Joint Forest Management (JFM).

Agriculture

In the field of agriculture, crop production forecasting has been an important area of application. In-season RS data is used to provide district wise acreage estimates for foodgrains such as wheat, rice, sorghum, oil seeds like groundnut and mustard, fibre crop like cotton and sugarcane in fifteen states of the country. Yield models have been developed using vegetation indices and other collateral data and are used to provide production forecasts about a month in advance of harvest (Navalgund *et. al.*, 1991). Experiments have also been conducted to estimate areas under horticulture crops such as coconut and tea. Some of the other RS applications in agriculture are estimating branch-wise in-season crop water requirement in command areas, identification of water-logged areas in a command, soil moisture estimation, cropping system and sustainability analysis etc. (NNRMS Bulletin, 1997).

Drinking Water

About 1.62 lakh villages (28 per cent of the total 8.75 lakh villages) in the country were identified in 1985 as problem villages having either nil / inadequate (quality / quantity) supply of drinking water. The National Drinking Water Mission (now renamed as Rajiv Gandhi National Drinking Water Mission) was launched in 1986 to provide safe drinking water to rural population @ 40 liter per capita per day (LPCD) and an additional supply of 30 LPCD per cattle in the desert areas.

Using satellite images district-wise hydrogeomorphological maps on 1:250,000 scale were prepared for the entire country. These maps depict spatial information on various hydrogeomorphological features including structural lineaments having different ground water prospects. This information has been extensively used for locating prospective sites within 1.6 km radius around problem villages as part of the scientific - source -

finding approach involving remote sensing based hydrogeologial and geophysical investigations. This approach has raised success rates to better than 90 per cent in most cases. Remote sensing data are now being made use of in suggesting sites for rain water harvesting as well.

Watershed Development

Watershed development aims at implementation of developmental plans for optimum utilisation of natural resources of the area on sustainable basis for the benefit of living beings. Generation of locale-specific action plans on watershed basis for land and water resources development plan using remotely sensed data in conjunction with ground data has been a major project under "Integrated Mission for Sustainable Development (IMSD). This project has been taken-up by the Department of Space along with various state and central agencies at the behest of the Planning Commission, Govt. of India (Navalgund and Tamilarasan, 1995). IMSD is being carried out in 174 districts. Participation of voluntary agencies and the local people is an important component of this programme.

The major goal of this mission is to generate locale-specific plans by integrating natural resources information generated from satellite data in conjunction with socio-economic data to meet the needs of the local people for sustainable development of the region. The tasks involved are : i) Analysis of socio-economic, demographic data of the region to find the felt/perceived development needs of the region, ii) To critically assess the existing infrastructure and to arrive at augmentation schemes (suitable sites for location, alternate strategies, etc.), and iii) To generate various thematic maps of natural resources using satellite images on 1:50,000 scale and integrate them to identify homogeneous units of land parcels for suggesting measures for soil and water conservation, water resources development, agriculture/ horticulture development, fodder development and forest development (Ghosh, et.al., 1993). The methodology adopted for the project is shown in Figure-3.

Thematic maps, land and water resources development plans generated for various watersheds / blocks have been submitted to the district level officials and project implementing agencies (PIA) for implementation. At the request of many PIAs the action plans have been transferred onto cadastral maps to facilitate implementation. In view of the availability of 6m panchromatic data alongwith 23m multi-spectral data on IRS-1C/1D, it has been possible to

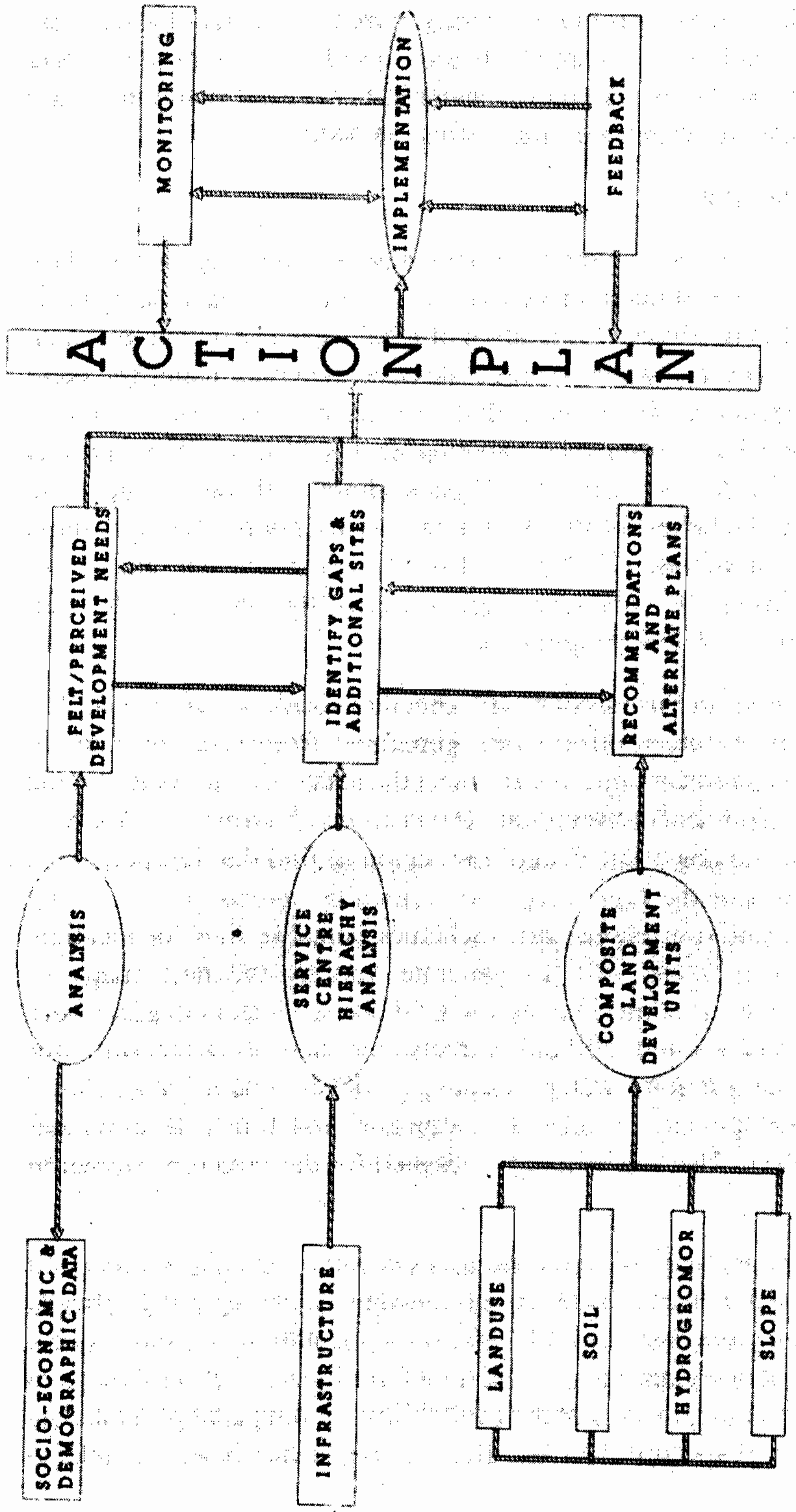

FIG. 3 : INTEGRATED STUDIES FOR SUSTAINABLE DEVELOPMENT : A POSSIBLE APPROACH

generate action plans at 1:12,500 scale for microwatersheds (1000 ha). Simultaneously, efforts also need to be made to develop models for quantification of sustainable development i.e. sustainability. Availability of stereo data will add an additional dimension.

Fisheries

Remotely sensed data is playing an important role in advising the fishermen on the fishery prospect zones in the coastal and sea waters. Based on the thermal features seen on the sea surface temperature charts derived from the satellite sensors, potential fishery zones are identified on the naval hydrographic charts and made available in near real-time at fishing harbours in the local language. Availability of ocean colour data will improve these forecasts. Coastal land use maps are helping in the selection of sites for brackish water aquaculture.

Information Systems

Area of information systems is fast becoming another important component of rural development process. Agroclimatic Planning and Information Bank (APIB) initiated by the Planning Commission and currently being operated from the Regional Remote Sensing Service Centre, Bangalore is a unique example of its kind. APIB addresses collection of relevant information, its analysis and advice to farmers on 'agricultural issues. Natural (National) Resources Information System initiated by Dept. of Space in thirty districts is a major initiative under NNRMS.

Other Studies

Remotely sensed data is also being used for studying the state of the environment, impact assessment and in monitoring changes. Some of these are wetland inventory for the entire country, assessing the impact of mining activities, landslide-prone area zonation, etc. Detailed land use /land cover maps, location and spatial distribution of settlements and their connectivity with roads have been mapped on 1:12,500 scale. Existing road network in rural areas have been clearly identified and mapped on IRS-1C merged data product (LISS-III + PAN) in plain areas where the contrast between the road and the background is high. (Fig. 4).

Case Studies

While there have been many RS applications relevant to rural development carried out by different agencies in the country, only a few case studies will be discussed here.

MONITORING TEMPORAL CHANGES IN FOREST COVER IN CHAMOLI DISTRICT

Alaknanda Valley in the Chamoli district of Uttar Pradesh is considered one of the most severely degraded area in the central Himalayas. Large scale commercial destruction of the forest between early fifties and sixties has led many areas prone to rapid land degradation. This has led to tremendous hardships in the day - to - day life of the local people. To improve the natural resources condition and to minimize the burden of the local people, the Dasholi Gram Swarajya Mandal (DGSM), a non-government voluntary organisation and also a parent institute of CHIPKO Movement launched large scale environmental conservation programmes through community participation in the watersheds of Nagolgad Amritganga, Menagad and Kalpaganga and other watersheds of Alaknanda since last two decades. At the behest of DGSM, the Space Applications Centre took-up study to monitor the impact of CHIPKO Movement using multi temporal satellite data available since 1972. Satellite data of 1972, 1982 and 1991 were interpreted and the spatial distribution of forest types and other land use / land cover have been mapped. Analysis of these results in terms of forest lost and gain showed (Kimothi and Juyal, 1996) that the CHIPKO Movement, launched in 1973 by Chandi Prasad Bhatt has helped forest gain of 8.2 per cent during 1972 - 1991 against the forest loss of 12 per cent prior to 1972, in the watershed area. Detailed analysis of RS data for the watersheds was carried out to suggest areas for fodder and fuelwood development.

PROVIDING DRINKING WATER TO VILLAGES IN AKOLE

Bharatyia Agro Industries Foundation (BAIF), Pune, a voluntary agency jointly with Space Applications Centre, (ISRO), Ahmedabad took up land and water resources development plan using spaceborne data for a group of villages in Akole taluka of Ahmednagar district, Maharashtra. Fourteen villages of Akole taluka, Ahmednagar district of Maharashtra state comprise a population of 8672, primarily tribal. In spite of average annual rainfall of approximately 2000 mm (more towards west) the area faces acute shortage of water from the month of February onwards. The terrain is undulating (varying between 600 m to 1300 m above MSL). Vegetative cover is very poor in these

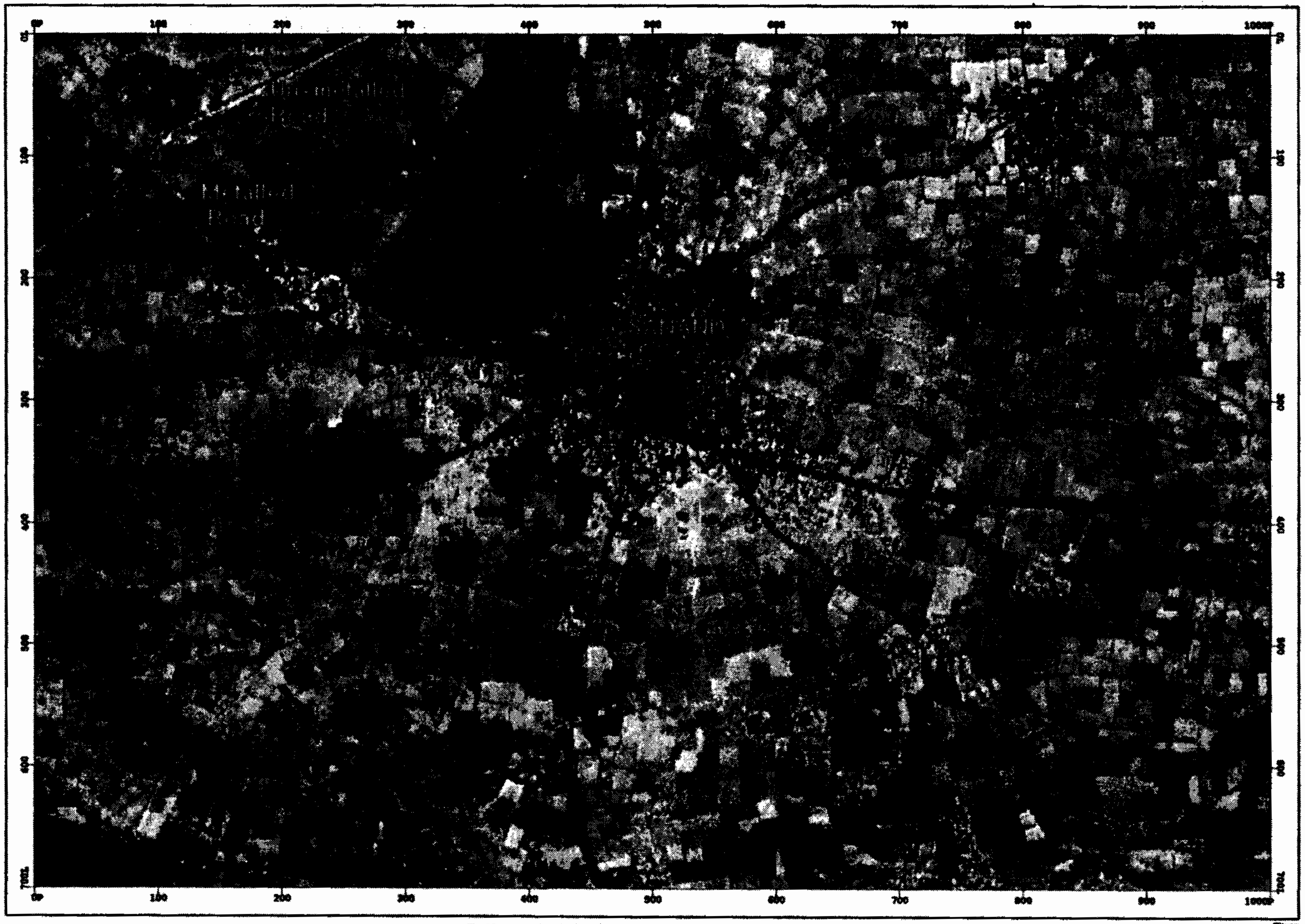

Fig. 4 RURAL AREA ROAD NETWORK, SANAND.

IRS-1C Merged data (Jan 1996)

Pixels 100 0 100 200 300

villages and therefore run off is high. Cultivation is primarily monsoon dependent whereas valleys are cultivated in the rabi season depending upon the soil moisture status.

In order to provide details of plans at a scale as close as possible to cadastral level, various thematic maps such as land use, wasteland, forest and hydrogeomorphology maps were prepared by the personnel of voluntary agency at 1:25,000 scale using IRS LISS-II and SPOT multi-spectral and panchromatic data. Slope information was derived using 20m contours available on Survey of India 1:50,000 scale topographical maps. Integrating various thematic information, various water resources development and wasteland development measures have been suggested. Information was transferred onto cadastral maps (1:10,000 scale) for priority villages to facilitate implementation. Integrated wasteland slope information was transferred onto the water development sites to help taking up simultaneous soil and water conservation measures. Various water resources development measures suggested are trenches and pits, underground Bandhara, nallah bunds, surface, water storage and gravel packing wells (Sohani et. al., 1992). Construction of a masonry dam, contour trenching and gully plugging have been under taken by BAIF with local people. Availability of drinking water for people and cattle even during the fresh summer months has already been ensured.

INTEGRATED LAND AND WATER RESOURCES PLAN FOR DAHI BLOCK

Dahi block of Dhar district was taken up as one of the special blocks for the study on the basis of its large fraction of wastelands and SC/ST population. It is located in south-west part of Dhar district. The southern and western boundaries of the block are marked by the rivers Narmada and Hatni, respectively. It comprises 62 villages covering an area of 48,222 ha. It has an average annual rainfall 631 (mm), with 16582 ha wasteland, agriculture land of 11361 ha and forest area covering 17959 ha. Its highly undulating terrain is characterised by dominantly 5-10 per cent slope class covering about 51 per cent area of the block rainfed agriculture and poor crop yield.

Keeping in view these characteristics of this area, and the present and future development needs, a plan for optimal development of land and water resources was prepared for the Dahi block using RS and other collateral data. Various layers of information were integrated in GIS environment and composite Land Developments Units (CLDUs) were generated. Based on the characteristics of CLDUs, land and water resources development plans have been suggested. Results from this study have been utilised as technical inputs for the implementation programme under Rajiv Gandhi Watershed Mission of Govt. of Madhya Pradesh.

Implementation of the proposed plans resulting in the increased productivity, check in the soil erosion, overcoming the depletion of water table and improvement in the socio-economic status of tribal population are the ultimate goals of the project. Implementation of the proposed plans has been achieved in the steps as following : i) District Rural Development Agency (DRDA), the funding department identified a milli-watershed (approx. area 6000 ha) comprising 12 micro-watersheds as priority areas under two schemes i.e. Drought Prone Area Programme (DPAP) and Employment Assurance Scheme (EAS) with six micro-watersheds under each scheme. ii) Action plans were transferred onto cadastral maps pertaining to these micro-watersheds. iii) Project Implementing Agency (PIA) was constituted under DRDA to carry out the project and a watershed committee with the representation of local people in each micro-watershed. Involvement of local people is an important component in successful completion of watershed development programme was ensured. iv) Scientists from DOS, officials of DRDA and PIA members carried out joint field visits to discuss proposed plans in the field along with local members of watershed committee. It has resulted in the best utilisation of technical inputs and local knowledge. The summary of implementation details has been presented in Table 5.

Table 5 : Summary of the treatment undertaken at Dahi Block

Treatments	Extent / Number
Soil and water conservation work (including staggered trenches and boulder checks)	1890 ha.
Pasture development	150 ha.
Percolation tank	3
Plantations	435 ha.

Future Perspectives

Brief scenario of applications and case studies discussed so far gives an idea of the tremendous role played by remote sensing in natural resources survey and management in the country today. Of course there are several improvements required in the quality of details / information provided by the technology. Some of the data needs felt acutely by the user community are: i) improved spatial resolution (2-3m) of RS data to provide terrain details on cadastral level (1:10,000), ii) stereo capability (2-3 height resolution) to help planning / execution of development plans, iii) high resolution (5-10 m) multi-spectral data to facilitate identification of crops grown in small fields (~0.1 ha), iv) high repetivity data (-3 days) to monitoring dynamic phenomena such as flood, changes in snow line, crop growth etc. and v) data pertaining to physical and biological parameters of the ocean.

Considering these, in the next 6-7 years, a host of spacecraft systems carrying different sensors have been planned in India. The next satellite in the series, IRS-P4 which is scheduled for launch in 1998 will carry a state-of-the-art Ocean Colour Monitor and a Multi Frequency Microwave Scanning Radiometer. Marine fisheries exploration should get a boost with the availability of IRS-P4 ocean colour data. A cartographic satellite IRS-P5 carrying a Panchromatic camera providing data at 2.5 m resolution and stereo capability is planned for launch before 2000. This should help large scale mapping. Commercial RS satellites providing data at high spatial resolution (1-4 m PAN, 3-15 m MS) would facilitate large scale mapping essential to meet rural planning needs (Fritz, 1996).

Resourcesat carrying a LISS-4 camera providing 5-10 m multi-spectral data, and a 4-band Wide field Sensor providing data at 100 m spatial resolution at 5-day repetivity is also planned. It is also proposed to have an Oceansat carrying Ku-band scatterometer, Ku-band altimeter and radiometer. All these missions providing data at higher spatial and temporal resolutions, and in different parts of electromagnetic spectrum, alongwith the technical advances made in processing and modelling techniques including GIS should be revolutionizing the field of remote sensing applications in the country. Several new application experiments and demonstrations using interactive satellite based communication system for development training and continuing education using INSAT satellites are also playing a crucial role in rural development. Jhabua Development Communications Project (JDCP) is a step in this direction. It is a two-way audio and one-way video experiment addressing issues related to watershed management, health, education and panchayat raj. It is for us, the community of scientists, policy and decision makers, planners and implementation level officials of various government and non-government agencies to make full use of this opportunity for national development.

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Dr. R.R. Navalgund, a physicist from TIFR Mumbai, is presently working as the Group Director of Remote Sensing Applications Group at Space Applications Centre, Ahmedabad. Since he joined SAC in 1977, Dr. Navalgund is engaged in basic research in the area of spectral signature studies, development of crop-yield modelling, and in the implementation of the crop production forecasting project utilizing remote sensing technology. He is providing able leadership to the multi-disciplinary team of scientists successfully carrying out national level projects of remote sensing technology applications in different areas of natural resources.

Dr. Navalgund has an impressive list of contributions in the form of research papers in national and international Journals and several technical reports. He is also responsible for contributing to the definition of Earth Observation Systems of India's Space Programme. Dr. Navalgund is a key figure in the applications segment of Indian Space Research organisation programmes and provides technology linkage for rural development activities at the national level.

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