

PANDIT GOVIND BALLABH PANT MEMORIAL LECTURE - IV

**Space for Sustainable Development with Special Emphasis on
Himalayan Regions**



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About Prof. U.R. Rao, M. Sc., Ph. D., F.A. Sc., F.N.A.

Prof. U.R Rao is a very renowned space scientist who has made original contributions to the development of space technology in India and its extensive application to communications and remote sensing of natural resources. Prof. Rao started his career as a cosmic ray scientist, under late Dr. Vikram Sarabhai, which work he continued at MIT, based on which he was able to firmly establish the diurnal and semi-diurnal variation of galactic cosmic rays and their relationship with the electromagnetic state of the interplanetary space. In association with JPL group, he was the first to establish the continuous nature of the solar wind and its relationship with the geomagnetic activity using Mariner 2 observations. Prof. Rao's experiments with Pioneer and Explorer spacecrafts, in association with Prof. K.G. Marcracken, led to a complete understanding of the solar cosmic ray phenomena, interplanetary magnetic fields, acceleration of particles in the shock fronts and Forbush events.

Prof. U.R. Rao and his group have also carried out extensive work in high energy astronomy, particularly on the detection and time variation of various X-ray sources using rocket and satellite borne payloads. Prof. U.R. Rao and his group have also carried out significant investigations on energetic gamma ray bursts using Indian satellites and have been responsible for the discovery of an unusual gamma buster which show strong pulsations and its possible association with a young pulsar.

Convinced of the imperative need to use space technology for rapid development, Prof. Rao undertook the responsibility for the establishment of satellite technology in India. Under his guidance, the first Indian satellite 'Aryabhata' was designed, fabricated and launched from USAR Cosmodrome in 1975. Following this, Prof. Rao and his team were responsible for the launch of two experimental remote sensing satellites Bhaskara-I and Bhaskara-II, the first experimental geostationary communication satellite APPLE, two "Rohini satellites on India's launch vehicle, SLV-3, INSAT-1 series of four satellites. Which revolutionized the communication scenario in the country and IRS-1A and 1B two state-of-art remote sensing satellites. These have been followed by the launch of INSAT-2A and INSAT-2B, second generation geostationary satellites in 1992 and 1993 respectively. Three more INSAT-2 satellites and the second-generation remote sensing satellites IRS-1C and 1D are now currently under development.

After taking charge as Chairman, Space Commission and Secretary, Department of Space on October 1, 1984, Prof. Rao was responsible for accelerating the development of rocket technology, resulting in the successful launch of ASLV rocket capable of launching 150 kg satellites into a low earth orbit in 1992. The perfect launch of ASLV (D4) which orbited SROSS satellite into a orbit of 437 x 938 km in May 1994 has fully established the reliability of ASLV launch vehicle. The development of PSLV, capable of launching 1000 kg IRS class of satellites into a polar orbit, was taken up, which will form the work horse for launching future remote sensing satellites. Cryogenic engine technology development was initiated under his guidance for achieving the launch of GSLV (Geo- Synchronous Launch Vehicle) for launching of 2.5 ton class of satellites into a geostationary orbit by 1997.

Prof. Rao has tirelessly worked towards the utilization of the vast benefits from space technology for the development of India, in particular its weaker society. INSATs have initiated a total communication revolution in India, providing human connectivity even to the remotest corners and off shore islands of India. INSATs are now continuously used for promoting business communication, emergency communication, nation-wide radio

networking, and information networking services and rural telegraphy. Installation of over 150, selectively addressable, disaster warning systems along the cyclone prone eastern coast of the country are saving thousands of lives and livestock every year. Most dramatic impact has been in the expansion of TV from a mere 11 stations to over 550 stations, providing access to over 80% of India's population. Prof. Rao has directed the conduct of novel experiments, for providing education in rural areas in health, hygiene, family planning and better agricultural practices using satellite TV network with a talk back facility.

Prof. Rao's leadership in the application of space remote sensing to the development of the country, has made space input a vital part of the management of India's national natural resources. Space inputs are now operationally used in the monitoring and management of agriculture, forestry, fisheries, wastelands, underground and surface water, drought and flood. The most significant contribution of Prof. Rao is in evolving highly innovative integrated management strategy leading to the development of sustainable management at micro level to meet the immediate needs of the present as well as the projected needs of the future generations without affecting ecological balance. As Vice President of IAF he has taken great initiative in promoting the use of Space technology in developing countries.

Prof. Rao's research interest varies over a wide range of subjects such as cosmic rays, interplanetary physics, X-ray and gamma ray astronomy, solar physics, space applications satellite and rocket technology. He has published over 220 scientific and technical papers in various journals of national and international repute and also been editor and co-author of many books, including "Physics of the Communication".

Prof. Rao is an elected Fellow of many academics such as Indian Academy of Sciences, Indian National Science Academy, National Academy of Sciences, Institute of Electronics and Telecommunications Engineers and Third World Academy of Sciences besides being a member of a number of national and international scientific bodies. Prof. Rao was the Vice President of International Astronautical Federation (IAF) during 1984 to 1992 and continues to be the Chairman of the Committee for Liaison with Developing Countries (CLIODN) since 1986.

Prof. Rao is the recipient of many national and international awards such as, Group Achievement Award of NASA, Karnataka State Award, Vikram Sarabhai Research Award, Shanti Swarup Bhatnagar Memorial Award, National Design Award and VASVIK Research Award. He was also awarded PC Mahalanobis Medal, Yuri Gagarin Medal of USSR, Meghnad Saha Gold Medal and P.C. Chandra Award. Prof. Rao was awarded 1992 Allan D. Emil Memorial Award for International Cooperation by International Astronautical Federation.

Prof. Rao is a recipient of D.Sc. (Hon. Causa) from the Universities of Mysore, Rauri, Calcutta, Mangalore, Banaras, Udaipur, Sri Venkateshwara University, Tirupathi, Jawaharlal Nehru Technological University, Hyderabad, Anna University, Madras, University of Roorkee and the oldest University in Europe, University of Nalogna (Italy).

Prof. Rao was awarded "Padma Bhushan" by the Government of India in 1976.

Pandit Govind Ballabh Pant Memorial Lecture

Prof U.R. Rao
Member, Space Commission
Bangalore, India

I truly feel it a great honour to deliver the 4th G.B. Pant memorial lecture of the GB Pant Institute established in memory of one of our greatest statement and freedom fighter of this country. Bharat Ratna Pandit Govind Ballabh Pant's contribution to this nation is as monumental as the hills of the Himalayan belt from where he hailed from. I have chosen the topic of "Space for Sustainable Development with special emphasis on Himalayan regions" for my talk today.

The spectacular achievements in the last three decades have firmly established the capability of Space technology for bringing out a socioeconomic revolution in the world because of its immense potential to transform even stagnant societies in a most cost effective and timely manner. With the unique ability of a Space platform to provide a synoptic view of the universe in the entire electro magnetic spectrum, Space exploration has virtually extended our vision to the very end of the universe and the beginning of time, providing for the first time a breath taking glimpse of interplanetary Space, solar planetary system and the deeper Space filled with hitherto unknown exotic celestial objects like quasars, pulsars, neutron stars, X-ray stars and black holes. Even more spectacular is the unleashing of the vast and unlimited potential benefits of Space technology which already operationally extend over communication, meteorology, TV broadcast, education, agriculture, industrial growth, resource management, environmental pollution, disaster mitigation, flood and drought management, health and entertainment virtually touching every facet of human endeavour.

The Himalayan mountain chain spanning across a length of about 2500 km and width of 400 km, situated between 27^o. 30^o latitude and roughly 70^o – 98^o longitude regions, covers Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh Nepal, Bhutan, and large part of India's northern five states. Together with the hilly and plain regions especially in the north eastern adjacent regions, Himalayan region forms one of the most beautiful, bio-diverse and precious heritage of India. Geologically the youngest yet the highest mountain system of the world, through which much older Himalayan rivers such as Indus, Ganges, Brahmaputra and their tributaries have cut across is undoubtedly one of the most interesting formations in nature. This vast area of over 60 m.ha. having varied forms of climate, geology and soil structure, blessed with most precious bio-reserves covered under their rich tropical evergreen, subtropical pine and moist temperate forests is the home of about 30 million people. The very nature of the terrain, however, has made it vulnerable to severe floods affecting more than 30% of the total area and causing damage, year after year, to the tune of over 250 m. US dollars. The top soil denudation and the lack of conservation measures combined with highly fragmented land holdings have directly led to the poor agricultural yield. The availability of 1200 MW of energy, which is just about half of the per capita availability of

energy in the rest of India in spite of the extraordinarily vast hydro-potential, has in turn resulted in less than 1 m. ha. of land being irrigated; while illiteracy continues to be at 45% level encroachment of forest land for agriculture, widely prevalent jhumming practice, environmental degradation due to mining, particularly in the Siwalik region, perennial exposure to flood disasters, extremely poor communication infrastructure and rapid exploitation of the forest wealth over decades have significantly impacted on the quality of life in this area.

2. Space for human connectivity

Satellite based communication, with its inherent flexibility, distance insensitiveness, ability to reach even remotest comers and cost effectiveness has already revolutionized communication throughout the world by virtually shrinking time and distance. In spite of these developments, only one out every 100 persons in developing countries like India has access to a telephone and in the rural areas the picture is even more dismal with 2000 persons having to compete for a singly telephone as against the availability of one telephone for every two persons in a developed country. The problem in the hilly regions of Himalayas is at least a factor of two worse than the rest of the country.

Fig. 1. INSAT TELECOMMUNICATIONS TRUNK ROUTES AS OF JUNE 1992

Following the conduct of the celebrated Satellite Instructional Television Experiment (SITE) in 1975-76 using NASA's ATS-6 satellite to promote rural education in health, hygiene, environment, better agricultural practices and family planning and successful launch of the indigenously developed experimental communication satellite APPLE in 1981, India embarked on the development of operational multipurpose communication satellites INSAT. The four, first generation INSAT-1 satellites were procured from Ford Aerospace Communication Corporation, of which INSAT-1B from 1983 to 1991 and INSAT – 1D since then have been providing domestic long distance telecommunication, nationwide TV, radio networking, data relay and meteorological services. The successful launch of totally indigenously built INSAT-2A in 1992 INSAT 2B in 1993, each having about 50% more capacity than INSAT-1 system, has substantially increased our space segment capacity from 14 transponders to 54 transponders.

INSAT system, with over 5000 two way speech circuits covering 140 routes amounting to 1,50,000 route kms has initiated a communication revolution in the country (Fig.1) connecting for the first time, even remote rural areas and off shore islands with the main stream of the nation using Low Cost Terminals (LCT). The nation wide geographic reach of INSAT is being advantageously used for a variety of applications such as administrative, business and computer communications through a number of captive networks using small terminal. New specialized services such as PTI news service, facsimile transmission and emergency communication for post disaster relief operations have been commissioned. The highly innovative, pilot rural telegraphy network in the hilly regions of north-eastern part of the country with the hub station at

Shillong and number of rural telegraph terminals has been implemented (Fig 2). The National Information Center's Network (NICNET) using VSATs and spread-spectrum techniques with almost 500 micro terminals provide reliable data communication links inter-connecting district headquarters, State Capitals, and Central Government Departments. The Remote Area Business and Message Network (RANMN), to provide data communication between city based industries and construction projects located in remote areas is already operational with over 250 micro terminals and with a registered demand for more than 1000 terminals.

Fig. 2. SATELLITE BASED RURAL TELEGRAPH NETWORK (SBRTN)

Fig. 3. INSAT DISASTER WARNING SYSTEM CONCEPT

One of the most innovative use of INSAT has been the implementation of the unique, unattended, locale specific Disaster Warning system (DWS) consisting of over 150 disaster warning receivers installed in selected, cyclone prone east coast areas of the country. The DWS implemented with INSAT (Fig -3) effectively combines the communication and meteorological capability of INSAT to provide a unique humanitarian service, which has been in operation since 1987. Most dramatic use of DWS system was during the cyclone that hit the Andhra Pradesh coast on 9 May, 1990, enabling the Government to evacuate over 170,000 people from the cyclone affected region, thus saving thousands of lives and livestock. Half hourly meteorological images being regularly derived from the INSAT geostationary spacecrafts have enabled us to track cyclones and hurricanes, predict their movement and obtain information on cloud cover, cloud temperature, winds and other meteorological parameters on a continuous basis, thus significantly enhancing our capability for long range meteorological prediction. Backed up with theoretical modeling efforts and monitoring of global phenomena such as El Nino and Southern Oscillations, we have achieved a quantum jump in our ability to provide timely agro-meteorological information. From unattended remote platforms has been able to fill the gaps in our ground based meteorological information. Deployment of similar unattended platforms at strategic river sites to transmit river water level using INSAT can easily be implemented to continuously monitor flood levels and combined with the use of disaster warning system can become an effective method for dealing with river floods particularly in the large inaccessible north-eastern regions of the country.

Increasingly all over the world the future trends in communication is towards meeting the needs of the people at individual and group level. The coming decade will see a revolution in coding techniques and video compression techniques which can transmit video programmes at very low bit rates for most economical use of Space segment. The land mobile satellite systems with small mobile terminals are presently entering the operational phase to meet the requirements of the transport sector, emergency communications, and remote area communications, in a big way. This service is the precursor for satellite based personal communication systems of the future, which is likely to emerge as one of the major services in the next two decades. Several Low Earth, Orbiting (LEO) satellite systems such as the Indium system of

Motorola, Globe Star of Loral and Project P-21 of INMARSAT, are under consideration for providing messaging and voice services for millions of users. ISRO has decided, as an interim measure, to use the high power S band system beginning with INSAT-2C to be launched next year for establishing a national mobile communication network, which should be particularly helpful in dealing with emergency situations in the hilly regions.

Fig. 4. SATELLITE TV COVERAGE OF INDIA

Fig. 5. ISRO-NPC TALK BACK EXPERIMENT

3. Space and Education

Accomplishment of an ecologically sound and environment friendly, new green reevaluations possible only when rural farming families team to optimally manage their valuable land and water resources. The most dramatic impact of INSAT has been in the rapid expansion of TV dissemination in the country. As of today more than 550 TV transmitters have been installed in the country, covering over 80% of India's population (Fig 4). Additionally, 35000 direct reception sets are now in operation to provide TV services to very remote population. Regional Networking Services, introduction of transportable earth stations and Satellite News Gathering (SNG) vehicles, now enable extensive TV coverage of the country. INSAT is being extensively used for Educational TV broadcasting with about 100 hours of programme per month to about 4000 schools and colleges.

An effective educational system requires not just a one way system of instruction but a two-way interactive communication system enabling the target audience to ask questions and obtain clarification from experts, in real time. Special inexpensive talk back facilities have been developed within ISRO to promote this activity in the country and a few selected large scale experiments have been conducted (Fig 5) to demonstrate the effectiveness of the satellite media for imparting interactive education. Two such experiments involved the rural sector for providing relevant educational instructions to village officials, social workers and teachers in the remote Rupal Village of Gandhinagar district in Gujrat and the farmers in Bhiwani district of Haryana. Likewise, oan ISRO – UGC experiment with the participation of students ina number of universities and continuing education experiment involving shop floor mechanics and tradesman in a number of widely dispersed industries were also successfully conducted. While these experiments demonstrated the importance and efficiency of adopting such an interactive system for rapid dissemination of education, eradication of illiteracy as a goal requires the use of dedicated satellites, specially tailored to effectively disseminate culture and region specific information to each of the individual language groups and regional entities. The task of providing continuing education in vital economic and industrial sectors of the nation al to overcome the rapid technological obsolescence is no less important, if we are determined to keep the competitive edge of our industrial sector.

It is in this context ISRO has conceived of dedicated GRAMSAT satellites which carry six to eight high powered C-band transponders which together with video compression techniques can disseminate region and culture specific audio visual programmes of relevance in each of the regional languages (Fig 6). The high power transponders will enable even remote area viewers outside the reach of TV transmitters and special group of people to receive programmes of their choice in a direct reception mode with just about 2 m antenna. Addition of 2 or 3 high power spot beam Ku-band transponders to GRAMSAT will further enhance this capability by permitting direct reception to be achieved with just 0.8 m antenna, which is particularly useful for transmitting educational programmes to industrial workers in urban areas and the rural population in the hilly regions. While hardware technology is well within the competence of ISRO, it is necessary to ensure the production of suitable educational programmes in various languages, which must be both instructive and entertaining. It is our dream that GRAMSAT will usher a new revolution in the country for transforming our dormant society.

Fig. 6:

4. Social dimension of pollution of poverty

The greatest problem world faces today is chronic hunger. The developing countries in particular, which occupy less than 55% of the geographical area of the world but carry over 75% of the global population, suffering from serious shortage of resources, capital, lack of trained manpower, large scale illiteracy, low agricultural productivity, industrial backwardness and rapidly growing population, are facing a grim future, which can only be averted by the extensive use of space and biotechnology inputs for realizing the goal of sustainable development. In spite of the average food production in India increasing at the rate of about 3% per year in the last few decades, from a mere 55 mt. in 1950's to 180 mt. per year, thanks to the green revolution, the per capita availability of food has not significantly changed due to the explosive growth in population from around 350 million to 890 million. Even more alarming is the fact that while we seem to have reached a plateau in our food production, the requirements continue to grow to meet the demands of increasing population, expected to cross 1 billion by 2000 and estimated to reach almost 1.8 billion by 2050. The limited land resource available in India which is just about 0.17 ha per capita as against over 1 ha in developed countries, large scale fragmentation of available agricultural land of about 160 m. ha between 100 million farmer families, continuing fragmentation of land into uneconomical units because of population pressure and non optimal management of land and water resources are mainly responsible for reaching the stagnation level in food production.

In spite of the green revolution the agricultural productivity in India is one of the lowest being about 1.6 t/ha. as against world's average of 2.6 t/ha and world's best of 5 t/ha. The average yield of rice in India is just about 1.7 t/ha as against 3.7 t/ha of world average and 5.4 t/ha in USA. It is important to note that the green revolution and increased productivity realized by most of the developing countries like India has been

partly due to large scale irrigation of over 30% of their land area, as against less than 10% in developed countries. However, this very practice of large scale irrigation, extensive use of chemical fertilizers, inadequate drainage and bad agricultural practices has led to an alarming increase in the soil salinity, making some of our most fertile land, unproductive and severely degraded. Over 25% of the arable land in all the continents (Fig.7) has become problem land with another 25% having very low productivity.

Fig. 7: CURRENT GLOBAL LANDUSE AND PRODUCTIVITY

The large pressure of growing population, increased demand for food, fodder and fuel wood, incapacity of land to sustain large population, phenomenal growth in industrial activity, have inevitably led to the migration of millions of population to urban areas, in search of gainful employment. The rapid deforestation due to the pressure of population industrialization particularly in the developing countries has reached the rate of 14-17 ha/year. An imperative consequence of deforestation is increased run off of rain water and soil erosion resulting in the deterioration of the top soil, degradation of land and sedimentation of water basis resulting in desertification and flooding. The high rate of soil erosion in deforested areas in India and elsewhere ranges from 10 t/ha. in the plains to almost 30 t/ha. in the north eastern hilly regions, as against just 1 t/ha in the forested area. The resulting sedimentation load from Ganges and Brahmaputra exceed 2200 m.t/year, the largest dumping of suspended load anywhere in the world. World wide soil erosion has reached the limit of 100 m. tons per year as against 45 m. t in 1860 and less than 16 m. tons three hundred years ago. Extensive deforestation has resulted in the increased carbon dioxide in the atmosphere, increased albedo from deforested areas altering the energy balance between the terra firma and the atmosphere, increased rain precipitation run off from 20% to almost 50%, and a gradual extinction of biodiversity.

While in the distant past, climatic fluctuations were responsible for the expansion and creation of deserts, today it is overgrazing. Deforestation, encroachment by agricultural crops and general mismanagement of land and water resources which are responsible for increasing desertification in Africa, Asia and Latin America. About 3000 m. ha, a quarter earth's land surface has now turned out as desert or damaged by factors that contribute to desertification. On a global scale the desertification is increasing almost by 1 m. ha. per year. Worldwide reforestation efforts are hardly making a dent, making up for just less than 10% of the annual loss. The changes in climatic and rain pattern gradually setting in because of deforestation are yet to be fully understood due to our inadequate understanding of the phenomena, particularly the energy exchange between the surface roughness over the forest and the atmosphere above it.

Fig. 8: ATMOSPHERIC TRACE GAS CONCENTRATIONS

Management of water resources particularly in the developing countries, has been even more pathetic. Optimal management of water becomes crucial particularly in

the dry land tracts of tropical countries where most of the precipitation occurs in less than 100 days as compared to a high latitude countries like Europe where snow and rain precipitation continues for at least 8 months in a year. With the added problems of higher temperature regimes and higher evapotranspiration rates, need for optimal harvesting of run off and recharging of underground aquifers in tropical countries assumes paramount importance. Although major irrigation projects and big dams have contributed to improved agricultural production in the last few decades, the problem of water logging, salinization and loss of valuable bioresources have led to gradual degradation of land in many areas in the developing world. Intensive use of chemical fertilizers and pesticides combined with poor management of watersheds has resulted in severe water stress, pesticide contamination not only in the water but also in the agriculture crops and unacceptable degradation of soil.

Superimposed in these seemingly insurmountable difficulties is the real prospect of the widely accepted global warming scenario due to the unprecedented anthropogenic intervention through indiscriminate industrial activity, and deforestation, threatening to upset the delicate greenhouse equilibrium which could lead to irreversible climatic changes. Rapid increase in the greenhouse gases in the atmosphere (ig8), large scale affects of acid rain, environmental pollution by oil wells, smoke etc are changing the ecological balance in a definitive way. Particularly since the beginning of the industrial revolution, CO₂ concentration in the atmosphere has steadily increased from 280 ppm to 350 ppm and at the present rate of increase is expected to reach atleast 450 ppm by 2050, due to the continuous estimated addition of about 3 billion metric tons of carbon due to fossil fuel burning in the world, a considerable part of which comes from India and china. Concentration of methane in the atmosphere has also been increasing steadily at the rate of about 0.9% per year and has now already reached 1.7 ppm. Detailed rigorous analysis of surface temperature over the last century substantiates the average increase in temperature of about 0.5⁰ K, which is also bome out by the Paleo-climatic evidence gathered from deep ice cores from Arctic and Antarctic region. While the primary cause of the global temperature increase in the past has been the increasing atmospheric concentration of CO₂ due to industrialization, fossil fuel burning and extensive deforestation, the rapid increase of CFCs in the last decade which has large residence time of over 100 years in the atmosphere has further added to the global environmental problem. Even with the adoption of the revised Montreal Protocol regulation, the expected increase in global temperature due to CO₂, methane, oxides of nitrogen and CFCs is likely to reach about 3⁰ K which can cause a rise in the sea level by 18-20 cm resulting in the recession of shore line by 27-30 m, change in the rain fall pattern particularly affecting the tropical countries, fall in food production by about 15% and 10% depletion of ozone. Taking into account the sensitivity factor, 10% depletion in ozone will result in a 15-20% increase in the incidence of U.V. with serious ramifactications on the entire biotic life on this planet.

5 Forest Management

Successful management of forest has to be based on a quantitative understanding of three critical factors, namely the total requirements in terms of fuel wood, timber etc., improvement of regeneration capability through proper silvicultural practices and preservation of forest land through implementation of appropriate protective measures. The adoption of space remote sensing techniques in the last few decades has provided a new thrust in this area by making available quantitative means for monitoring the growth and degradation of natural forestry, the effects of deforestation on soil, watersheds, underground water recharge and green-house gases. Even the coarse resolution meteorological satellite payloads, particularly the NOAA/AVHRR have greatly helped in studying vegetation dynamics in relation to climatic changes at regional and continental levels on a gross basis. The Normalised Difference Vegetation Index (NDVI) derived from NOAA/AVHRR data which is well correlated with vegetation parameters such as green leaf biomass and green leaf area, has been successfully used to classify eight major global vegetation types of the world and derive their individual primary productivity function which varies between $1.2 \text{ kg/m}^2/\text{yr}$ in the case of deciduous forests to $2.2 \text{ kg/m}^2/\text{year}$ in tropical forests. Use of high resolution imageries such as the ones obtained from LANDSAT, SPOT and IRS satellites have obviously greater advantage in providing basic discrimination of vegetation types at a much higher accuracy level.

Repetitive monitoring of forest cover using space remote sensing also provides the most economic and timely means of obtaining information on forest cover changes evaluation of the efficiency of adopted conservation measures in increasing the forest cover and even estimation of biomass. Fig.9 shows the change in forest cover in India since 1975 derived from the combined use of space imageries from LANDSAT and IRS drawn up on 1:250,000 scale. While the closed forest cover showed a decrease of 25% during the decade of 1975-1982 from 14% to 11%, awareness brought in by satellite studies since then has enabled the country to conserve its forest cover through adoption of strict control measures. These figures must be viewed against the background of the national policy of 1952 recommending 33% forest cover across the country with 60% coverage in the hilly areas. The remote sensing imageries indicate that excepting in Manipur, none of the other hilly states meet this requirement and the average forest cover is just about 15 m.ha or 25% in these areas. Encroachment of forest land for agricultural purposes, construction of poorly planned hill roads and communication infrastructure, environmental impact of mining and quarrying industries combined with unrestricted exploitation of forest timber has led to this sad state of affairs in the hilly regions.

Qualitative estimation of biomass change due to deforestation and degradation can be derived by formulating appropriate regression models relating the biomass and forest canopy cover for different biomass zones, using appropriate sampling techniques. While it is true that such regressions will be specific to each region depending on the climate, soil condition meteorological parameters, nutrient availability and site

productivity, it is nevertheless possible to identify homogeneous regions satisfying similar regression models to arrive at quantitative biomass estimates as a function of biomass/canopy cover density. Fig.10 shows one such typical regression model, where the average biomass density for closed forest with 60% cover is found to be about 68 tones/ha. Cluster wise classification and use of regression models expressing the functional relationship between the volume of wood and their height and diameter have been successfully used to derive biomass volume in homogeneous forests. Use of higher resolution imageries from IRS-IC and better classification techniques will undoubtedly make it possible to accurately estimate biomass changes even in heterogeneous forests.

Fig. 9: FOREST MAP OF INDIA THROUGH SATELLITE REMOTE SENSING (1987-89)

Even for sustaining the presently available forest wealth, the total biomass requirement for fuel wood, timber, paper pulp etc., have to be carefully evaluated and balanced against the available fuel wood/forest productivity. The presently estimated requirement of fuel wood alone in India is about 150 m.t./year which will increase to 200 m.t./year by 2000 AD, which is much greater than the 80 m.t./year available fuel wood resource from natural forest productivity output and agricultural and animal wastes. Even with the present level of consumption of kerosene, petroleum and coal which provide about 60 m.t./ year of fuel wood equivalent, the remaining shortfall of over 60 m.t./year in the fuel wood and timber demand are obviously made up by deforestation to the extent of almost 1.0 m.ha./year. There is an increasing awareness that with the multiple use, forest can provide additional source of food, particularly to the 40 million tribals living in our forests. It is an established fact that the food derived from forests contain highest potential for energy, carbohydrates, minerals and medicines. Sustainable forest management strategy must therefore critically address the increasing needs of growing population to evolve appropriate strategies of afforestation.

Management of forest is a complex, multidimensional task, which can succeed only when a total integrated approach is adopted for each region or country. Obviously the first step is to compute input/output requirements and model the deorestation profile along with the projected population growth to estimate the increase in the requirements of forests products with time. Continued maintenance and further enhancement of forest cover can then be appropriately planned keeping the ecological, environmental and climatic considerations in mind. An obvious method of increasing forest cover is through social forestry schemes on suitable fallow or unutilized lands, which can be easily identified using remote sensing data. Planned development of wastelands, which can be priority areas for carrying out afforestation and social forestry programmes, is now possible because of the availability of remote sensing data providing information on all physical aspects of the area such as physiography, topography of terrain, soil type soil erosion status, land cover, land use pattern, land tenure system, hydrology and climate. Combining with the relevant socio-economic information such as economic structure, infrastructure facilities, demand and supply status, appropriate species suitable for plantation in a given particular locality can be identified.

Fig. 10: FOREST DENSITY VS BIO-MASS (TROPICAL DECIDUOUS FORESTS – INDIA)

Conservation of bio-diversity can only be achieved through conservation of biological habitats which require a detailed survey and inventory of the existing bio-resources and conservation of the eco systems through protection of bio-resources, marine resources, parks, sanctuaries, forests wet land and coral reefs. Remote sensing techniques are most useful in locating different types of bio-resources, to enable us to identify appropriate corridors surrounding the natural habitats to protect them from human intervention and other harmful influences which endanger the existence of these habitats. Periodic monitoring of changes in vegetation cover over forests and sanctuaries and changes in the surrounding wet land, often described as the “kidney” of the terrestrial ecosystem using remote sensing techniques has become very useful for gross monitoring of wild life habitats in these areas.

6. Land and Soil Conservation

Exploitative use of land without providing adequate protection to the soil against hazards, results in severe land degradation and less of productivity. The rapid replacement of numerous locally adopted varieties with monoculture farming system having one or two high yielding strains in large contiguous areas have often been the cause of loss of soil fertility and the spread of serious diseases capable of wiping out entire crops, typical examples of which are the Irish potato famine of 1845 and the Bengal rice famine of 1942. Inappropriate land use, soil erosion, salinisation, water logging and chemical pollution are undoubtedly the major causes for degradation of land environment. The environmental problem caused by increased sedimentation due to loss of vegetation cover has extensively affected the capacity of reservoirs as well as the aquatic ecosystem in inland waters. Increase of salinisation and alkalization in India, particularly where excessive irrigation with poor drainage is practiced has become a major problem of soil degradation.

Ready and timely availability of satellite observations of existing land use pattern from various remote sensing satellites now provide a most cost effective means of identification of different forms of land degradation enabling us to take appropriate measures for improving the land environment and recover the degraded land for productive use. One of the major operational projects carried out in India using IRS satellite data on 1:250,000 scale was the mapping of current land use/cover of the entire country to facilitate the innovative ‘Agro-Climatic Regional Planning’ approach. Using multispectral data from IRS and LANDSAT satellites, the department of Space in India has mapped the entire country on a one million scale to identify various land use categories at gross level. The above study carried out in 1982 estimated the total wasteland under different categories to be around 53.3 million hectares or 16.2% of the total geographical area of the country (Fig.11). In order to further improve the accuracy of identification and location of wasteland at micro level, the study was further extended to map 142 severely affected districts, about a third of the country, on a 1:50,000 scale to identify 13 different types of wasteland at village level. Preparation of such detailed cadastral maps along with village boundaries, containing remotely sensed inputs have

been cross checked with ground truths on a sampling basis to validate the data, which has been used extensively for initiating reclamation procedures at each village level.

In spite of the recognition of the importance of preservation of grass and pasture land, which form an integral part of land ecology for providing basic sustenance to the cattle and other live stocks, it is the least protected environmental heritage in most of the developing countries and particularly in India. Agricultural expansion driven by population increase has heavily encroached on the green pasture lands, which has directly encouraged indiscriminate grazing practice resulting in the destruction of a number of plant species and severe degradation of land particularly along the Himalayan foot hill regions and in the forested areas. Comparison of the results of the detailed mapping of land use in all the districts of India on 1:50,000 scale by the Department of Space with the earlier statistics have clearly shown that in most of the districts where just two decades ago pasture lands accounted for 10-15% of the land area have now dwindled to less than 5%. These dramatic findings have at least created an awareness of the environmental degradation problem to enable the government and social groups to take appropriate remedial measures.

Shifting cultivation (jhumming), which originated in the Neolithic period, has been historically considered as the first step in the transition from food gathering to food production. Jhumming involves removal of forests by slash and burn techniques followed by mixed cropping for a short period till the productivity declines, before abandoning the fallow site for a period of time to recover its natural fertility. The growing pressure on land, however, has shortened the fallow periods from 10-15 years to about 2-3 years with the result the fallow lands in the north eastern regions of India are unable to regain their fertility resulting in the severe degradation of land under shifting cultivation. Analysis of remote sensing imageries from IRS clearly show that about 3m. ha. of land in India, primarily in the north eastern regions, have been affected by shifting cultivation with serious implications on the ecology of the region.

Fig. 11: TYPICAL LANDUSE PATTERN IN A DEVELOPING COUNTRY – INDIA

Release of carbon dioxide due to burning of biomass, destruction of forest, loss of productivity, increased erosion resulting in siltation of rivers and lakes are the outcome of this pernicious practice. The most appalling example of the compounded impact of excessive jhumming is seen in Chirapunjee, which has turned into a desert bared hill in spite of it being endowed with the highest rainfall (1200 cm) in the world. Satellite remote sensing with its capability to provide synoptic and repetitive high resolution images in the narrow and discrete bands of the electromagnetic spectrum have proved highly useful in monitoring jhumscapes.

The successful use of space remote sensing to identify underground water aquifer, which formed the basis of drinking water mission in India, is undoubtedly one of the major uses of satellite technology. Based on the study of geomorphological features, the satellite imageries have been able to identify such areas which has resulted in increasing the success rate of finding drinking water by digging borewells to 93% from

42% level achieved using purely conventional techniques. Similarly satellite based glacier inventory have paved the way for the exploitation of such water resources through mini and micro hydroelectric stations. Remote sensing information is also now widely used to predict snow-melt run off, use of water resources. It is an undeniable fact that the ground water irrigation is roughly twice as efficient as large dam irrigation, which are subject to losses due to evaporation and seepage in the canals. Now withstanding, poor water management practices followed over centuries, has resulted in ground water extraction significantly exceeding the amount of recharge in most parts of India, which has led to the increasing exploitation of the static water table. The water table in the city of Ahmedabad in India is reported to have gone down from 100 feet in 1965 to a level of 300 feet in 1990.

In spite of the unacceptable increase in salinisation and alkalization of the soil, resulting from bad agricultural practices, large scale use of chemicals and pesticides, water logging and inadequate drainage, large scale irrigation continues to get the popular political support. In India, for example the irrigated area is 46.2 m.ha., about 33% of total agricultural area under cultivation, of which 22.7 m. ha. is through surface irrigation and remaining 23.5 m. ha. is served by ground water. If adjustment is made for the inefficiency of surface water irrigation, the net Ground Water Equivalent Irrigation (GWEI) area works out to only 34.9 m.ha. in 1990. While the construction of large dams per se cannot be avoided, the height and capacity of such dams cannot be purely based on power and water requirements but must fully take into account the need for minimizing the consequences of submergal of vast forest ad living areas, and uprooting of the lives and live stock.

Most often, in all such social problems, tempers and emotions are raised, controversies are generated and issues are politicized between those who argue for bigger dams and those who dam all dams, instead of resorting to a scientific approach for solving the problem of increasing productivity consistent with healthy strategy of environmental protection. Just as space remote sensing has proved its immense use in optimally locating soil conservation programmes and in the construction of water harvesting structures such as small ponds, tanks and check-dams based on the inputs derived form the geo-morphological features of the area, satellite imageries can provide unique input for determining the optimal height of dams. Information derived from remote sensing satellites on the terrain, soil characteristics, agricultural practices, natural eco system status and habitat can be used to compute the area of submergence and quantity the damage to the ecosystem as well as the habitat within the submerged areas as a function of the dam height. Such an analysis provides the basic information which can help in fixing the optimal height of the dam to be constructed based on cost benefit analysis. Fig. 12 is an example of a typical dam, which clearly brings out that a reduction in height of the dam by just 20 meters, form 260 to 240meters, results in reducing the inundation of forest from 40,000 ha. to less than 15,000 ha., and submergal of villages needing total rehabilitation from 135 to just 15, but at a cost of about 35% loss to power generation.

7. Environmental Pollution

The over-whelmingly enthusiastic response of all countries, developed and developing, in dealing with the problem of environmental pollution and adopting agreements towards initiating sustainable integrated strategies at the earth Summit Conference held in June 1992 at Rio-de-Janerio, clearly brings out the world wide awareness of the problem. Remote sensing technology has proven its capability to identify the source of pollution and accurately determine the location, extent and type of pollutants. Variety of environmental pollution problems in land, are and sea can today be effectively dealt with using multi-sensor approach, involving observations in the visible, infrared and microwave regions of electromagnetic spectrum. Three dimensional modeling of various parametric forcing functions need to be developed to predict the short as well as long term effects of environmental pollution on a regional as well as a global scale. Even though the operational status of using remote sensing techniques to deal with all aspects of environmental problem is yet to be achieved, the progress to date, nonetheless have established the capability of remote sensing techniques for tackling a number of specific areas of environmental pollution.

Fig. 12: IMPACT OF A TYPICAL DAM

A major area of the application of both satellite and aerial remote sensing has been in the study of the environmental impacts of opencast mining and mine fires. A combination of multi-date Landsat TM and IRS imagery provide an effective means of monitoring open-cast mining and reclamation activities. Remote sensing in the thermal infrared region (3 to 5.5m of 8 to 14 m) unusually during the night or early morning is particularly useful for detection and monitoring of surface and sub-surfaces mine fires. A typical example is the use of aerial multi-spectral data to detect sub-surface fires in the Jharia Coal field in India, which showed 65 currently active fires in the density sliced colour coded images of pre-dawn thermal data. This study, which used appropriate models relating thermal diffusivity of the soil and measured surface temperature, was able to identify active fire zones ranging in temperature between 30 to 70 c (against an average ambient temperature of 12 C), at a depth of 40 to 50 metres below the ground.

Satellite remote sensing techniques are now being employed to obtain information on water quality parameters such as turbidity, suspended sediments, chlorophyll concentration and presence of large sized aquatic weeds. Spectral bands in the optical wavelength domain (blue, green and red) where light penetrated water medium to a greater extent provide information on water quality. Reflection in these spectral bands is influenced by the size, type and concentration of the optically active water quality parameters (such as algae, suspended matter and aquatic humus). Indian remote sensing scientists have made extensive use of satellite imageries for carrying out water quantitative studies in a number of lakes and reservoirs in the country, to identify regions of different turbidity levels. Studies carried in the Chilka Lake area in Orissa during the fifteen year period of 1972-1987, have clearly shown a reduction of 100 km² or 20% in the water spread area, due to increased sedimentation and agricultural encroachment. A significant outcome of such studies has been the application of remote sensing imageries for the location of domestic sewage water

treatment plant sites in 15 cities on the banks of Yamuna river using drainage and slope information from topo maps along with the land use information derived from satellite imageries. The encouraging results obtained from these studies have led to the formulation of a major programme or dealing with sewage disposal problems along all the 18 major river in India.

Management of coastal zone environment, which forms the important interface between the land and oceans, has been receiving increasing worldwide attention since 1970's. In addition to the fact that about 50% of the world population live in the coastal regions, rapid industrialization, urbanization and use of coastal areas for locating major power plants requiring large quantities of cooling water, have become a common cause for the deterioration of coastal environment all over the world. Sedimentation of reservoirs and rivers due to soil erosion finally end up in discharging the entire waste picked up enroute, along with particulate, chemical and biological pollutants, into the oceans. The annual sediment load resulting from Ganges, amounting to 1450 m. tons per year is one of the largest and unless the Himalayan watershed is properly protected, 300 million people living in the plains of India and Bangladesh will be seriously affected. Mangroves in tropical areas have historically provided excellent rooting conditions against sediment and loose mud transport thus enabling them to act as an effective barrier against coastal erosion. Systematic denudation of mangroves, which have been the nursery ground for the productive harvesting of prawn and fish, has not only resulted in increased coastal erosion but also in destroying biological productivity of these areas.

Space technology, has proved to be very useful method for studying coastal features including mapping of water lines. Coral reefs. thematic mapping of bare sand, mangroves, sea grass, reef flats and wetlands. In India, wetland and coastal landform maps showing mud flats, beach, mangroves and coastal dunes have been drawn on 1:250,000 scale using IRS data for the entire coastline of the country. More detailed mapping on 1:50,000 scale has been carried out for all the maritime states, to identify suitable sites for mangrove afforestation, aquaculture and industrial development. Repetitive imaging has helped in identifying seasonal as well as long term changes of wetlands and coral reef features enabling the scientists to initiate appropriate measures for the preservation and conservation of coastal environment.

Pollutants from industrial, commercial and agricultural waste enter the marine environment through river discharges, direct run-off from adjacent land areas deliberate dumping or accidental spillage of oil from ships. Pollutants that affect marine environment are generally categorized under physical, chemical, biological and thermal components. While physical pollutants, essentially in the form of suspended particulate matter and sediments as well as the thermal pollutants are mostly restricted to coastal zone, chemical pollutants (toxic and acidic waste) are widespread. Biological pollutants (sewage and dissolved organic compounds) and their derivatives such as algal blooms have high variability in their spatial and temporal distribution. Sewage discharge from cities, oil pollution due to tanker accidents, refinery effluents and spillage from oil pipelines and offshore production platforms, are the most important point sources of

marine pollution, most of which are amenable to monitoring through remote sensing techniques. Experience over the last two decades shows that on an average over 3,00,000 tones of oil is spilled into the ocean each year. Remote sensing of turbidity, sea surface temperatures, sea upwelling characteristics and surface wind speeds form the basic inputs for monitoring marine pollution. Satellite monitoring of ocean colour (upwelling visible radiance) has become a powerful tool for detecting the concentration and type of suspended sediment and dissolved organic matter in the coastal regions and phytoplankton chlorophyll in the deep seas.

The most common application of remote sensing in marine pollution has been in the detection and mapping of oil slicks, which takes advantage of the difference in the emissivity properties of petroleum products from that of the surrounding sea surface. Since the first reported large scale monitoring of oil spills in 1972 using thermal infrared scanners, which take advantage of the lower temperature over oil spilled area compared to that in the surrounding water, remote sensing imageries have been extensively used to keep a continuous watch of oil spillage over the oceans; Passive microwave radiometers and imaging radars have become additional armours in the tool kit of the remote sensing scientists particularly for detecting the area of pollution discharge and for studying the general characteristics of its dispersion pattern. From the measurement of the ocean surface temperature derived from NOAA-11AVHRR data in the 10.5-11.5 m band and visible data from IRS for detection of oil smoke plumes, we have carried out detailed analysis of the nature and temporal variation of the oil slick as well as of the smoke from the burning oil wells in the Persian Gulf area that resulted from the Gulf war. With appropriate modeling, these observations have also been used to estimate the long term climatic effect due to smoke-induced cooling of key thermal subsystems of the monsoon over the Indian subcontinent. The estimated short term local area cooling of 9K over Kuwait based in modeling of the relevant parameters was in good agreement with observed 8K cooling over these areas.

8. Space & Disaster Management

Major natural disasters such as floods, cyclones, droughts and earthquakes, which have been plaguing the world through centuries inevitable affect the economic system as a whole and more importantly the vulnerable rural economy. Natural disasters of geophysical origin, such as earthquakes, volcanic eruptions, tsunamis and land slides as well as disasters of climatic origin, such as earthquakes, volcanic eruption, tsunami and landslides as well as disasters of climatic origin such as droughts floods and cyclones have been taking a heavy toll of human lives and natural resources year after year, particularly in areas having a high density of population. The impact of natural disasters on the population and economy of developing countries has been particularly severe due to their lack of preparedness to meet such calamities, poor organizational infrastructure, inadequate financial resources and inability to undertake mitigative and ameliorative measures. During the period 1980-92 alone, over 69% of all the reported major natural disasters have occurred in the developing countries. In the last twenty years alone, extreme natural disasters have caused destruction to property estimated between 50 and 100 billion dollars, loss of nearly 3 million lives and have affected over

800 million people, nearly one-sixth of the global population, most of these being in the highly populated Asia-Pacific region.

Space systems, which derive their basic advantage from the altitude of their operation, unaffected by natural disasters, have become a most valuable tool in disaster management. The inputs from satellites have unambiguously demonstrated their capability in providing vital information and services towards all the three major aspects of disaster management namely prevention, preparedness and mitigation. The unique capabilities of remote sensing satellites to provide comprehensive, synoptic and multitemporal coverage of large areas at frequent intervals with a quick run around time, have been valuable in continuous monitoring of atmospheric as well as surface parameters related to natural disasters. The vast capabilities of communication satellites are now available for dissemination of information on early warning, data transfer and real time coordination of relief operation. The advent of Very Small Aperture Terminals (VSATs), Ultra Small Aperture Terminals (USATs) and phased array antennas have enhanced the capability further. The most important and probably the most significant contribution of meteorological satellites like INSAT has been the systematic monitoring and tracking of tropical cyclones. Sequential cloud imageries taken at intervals of about 5 minutes from INSAT and other similar geostationary satellites along with conventional data, are being operationally used to track and forecast the cyclone motion. Combining persistence approach with the sequential imaging of cyclones at short intervals has been successful in predicting the movement of the cyclone 24-48 hours in advance, and also in continuously updating the information based on the observed real time perturbations in the movement of the cyclone storm. The innovative use of INSAT for providing locale specific disaster warning to the affected areas has helped greatly in minimizing the damage and to cyclone disaster.

Execution of effective flood control measures and development of scientific planning procedures for efficient flood management have to be based on timely availability of accurate information on rainfall precipitation, river flood channalisation, terrain information pattern of water shed behavior and regular monitoring of cloud cover and meteorological information from unattended platforms in inaccessible areas using communication and meteorological satellites. Real time cloud imageries and meteorological information obtained from geostationary satellites in particular, combined with automatic data collection platform deployed at strategic points over the rivers have provided for the first time capability to forecast and monitor flood levels. Most successful application of satellite remote sensing has however been in the near real time mapping of flood affected areas, and assessment of flood damage, particularly to agricultural crops and habitats, through comparison of imageries prior to and following the major floods in each area. Despite limitations imposed by cloud cover and relatively long revisit period, remote sensing satellites like IRS and Landsat have been providing the basic information on the terrain and the river flood conditions besides enabling the mapping of inundated areas and assessment of damages, by virtue of their ability to provide comprehensive multi-date and multispectral information covering very large

areas. The advent of microwave satellite unaffected by cloud cover has added a new dimension to flood monitoring capability.

Fig. 13: FLOOD RISK ZONE MAP OF PART OF GANGA BASIN

Analysis of satellite imageries of floods of different magnitudes over a period of time in terms of the quantity of standing water and vulnerability of different areas to flood risk have turned out to be very useful in identifying various flood risk zones across different river basins, a typical example of which is shown in Fig.13. flood risk zone-1 affected, year after year, by even smaller floods and drainage congested areas identified from such analysis are the obvious candidates requiring appropriate structural treatment to reduce their flood risk. Damage reduction strategy may just call for providing only a localized additional channel for flood water retarding dams, a well established engineering practice for controlling the excess run off, and providing water storage reservoir for later use.

Even though on an average drought occurs once in 5 years, continue onset of drought conditions for 3-5 successive years, common feature, has resulted in the total decapitation of already unbeatable populations in India. A major difficulty in dealing with drought is in its nature of a slow creeping phenomena, which makes it difficult to identify its onset as well as its end. The first rainless day in a spell of fine weather can contribute to the drought as much as the last dry day. While drought has meant different scenarios to different scientists, drought conditions can arise from each of these causes. To meteorologists, for example drought means deficient rainfall, long spell of dry weather or even unseasonal rainfall. Depletion of ground water due to continued drought condition can result in agricultural drought. Short term fluctuations as well as long term climatic perturbations can cause severe meteorological drought. Satellite derived Vegetation Index (VI), which is sensitive to vegetation stress, is now operationally widely used to monitor drought conditions. A most significant development in this regard has been the operationalisation of a remote sensing based national Agricultural Drought Assessment and Monitoring System (NADAMS) for countrywide monitoring in India. Biweekly Drought Bulletins for 246 drought prone districts of the country are being regularly issued to the concerned user agencies at all levels for necessary action. Regular composition of bi-weekly VI data sets for each month of the year at district level for a number of years, has also enabled the advance detection of drought condition and qualitative assessment of its severity by comparison of the VI indices at any place with the corresponding VI indices of the same place and time of the season compiled for a normal year (Fig. 14). Availability of two band imageries with 180 m resolution and swath width of 800 km in IRS-1C to be launched in 1995, will further enhance our capability to detect drought conditions at taluk level.

Fig. 14: FORTNIGHTLY MONITORING OF DROUGHT BASED ON VEGETATION INDEX

Earthquakes and volcanoes are the most violent and extreme geophysical events in nature. The Himalayan arc, which constitutes the central part of Alpidic seismic belt, is

known to be one of the most earthquake active regions in the world, because of the continued collision between the Indian and Eurasian plates. Since the beginning of the century over a dozen earthquakes exceeding 7.5 magnitude of the Richter Scale have occurred in this region. With the increased population density, if an earthquake of magnitude larger than 8, similar to the one which occurred in 1905 in the Kangra valley, were to occur today it is estimated that over 150,000 houses will collapse with an additional 100,000 suffering severe damages and result in the loss of human lives ranging between 100,000 to 350,000 depending on the time of occurrence.

The extensive mapping capability of geological and geomorphological feature by remote sensing satellites is of immense help in locating townships even in earthquake prone areas. In the recent earthquake which occurred at Khilari, houses which were even 2 km away from the major lineaments were left intact. Even though the science of earthquake prediction is still in its infancy, the possibility of measuring even small tectonic movements using laser ranging techniques or differential GPS system combined with temperature measurements on the surface, for predicting earthquake disasters is truly exciting. The communication net working

Through satellites are already being effectively used for both providing some advance information to the affected areas as in the case of Mexico and also initiating rescue, health care and rehabilitation measures as has been amply demonstrated through the well known Space Bridge telemedicine experiment in Armenia in 1988. With the available space resources remote sensing and efficient communication networking. I hope that the use of space technology in earthquake management will get a boost in our country.

Hilly terrains in the unstable mountain systems face the perennial problem of landslides involving large mass movements of surface material, rocks and soil from the sloppy areas, the degree of their vulnerability closely depending on the lithology of the terrain and extent of vegetation cover. Landslides are mostly induced by heavy rains or by dynamic geophysical disturbances such as earthquake shocks. Availability of accurate information on landslide proneness and their impact on the surroundings is essential for any development in these areas. Landslide proneness is assessed through identification of critical combinations of site conditions, such as soil characteristics, degree of slope, type of bedrock, vegetative cover, and rainfall and snow-melt condition that correlate well with the past occurrence of landslides. The inherent spatial variability of terrain conditions on all scales greatly complicates the accurate mapping of hilly terrains. Remote sensing satellites with their ability to provide synoptic and stereoscopic view together with aerial remote sensing are very effective in determining the slopes, landforms, soil characteristics and vegetation cover over even smaller areas, which has greatly enhanced our capability for preparing land hazard maps in the mountain regions. A number of studies have been made in India using remotely sensed Landsat and IRS data along with aerial photographs, to develop appropriate methodologies for terrain classification and preparing land hazard maps in the Garhwal Himalayan region, Nilagiri hills in south India and in Sikkim forest area. In the Tehri dam reservoir periphery, these imageries have helped in identifying 71 potential

landslide areas. While at present, aerial imageries because of their capability to map terrain contour at intervals of better than 2 m in height, are proving to be most effective, incorporation of stereoscopic imaging capability in IRS –1C will enable us to use even satellite imaging most effectively to deal with micro problems of landslides.

9. Space for Sustainable Development

We define sustainable development as development of the carrying capacity of land and natural resources to meet the immediate as well as the projected requirements of the people without endangering the ecology and environment. Sustainable development of natural resources has to be based on maintaining the fragile balance between productivity function and conservation practices through constant monitoring and identification of problem areas which require application of alternate agricultural practices, crop rotation, use of bio-fertilizers, Integrated Pest Management techniques (IPM), energy efficient farming methods and reclamation of under utilized or degraded lands. It calls for the integration of various renewable and nonrenewable resources, characterization of coherent zones of agricultural identities and identification of constraints/ecological problems at the micro level instead of the present practice of beneficiary oriented, arbitrary, sectoral approach.

Satellite based remote sensing inputs are the key to initiate integrated sustainable development at micro level. The first phase for this approach consists of preparing a set of resource maps using remote sensing data on surface water body, ground water potential, wasteland status, soil maps including erosion status, potential ground water recharge sites, existing land use including agricultural crop inventory, Forestry status and meteorological information. Combining these with the socio-economic factors, integrated land and water resource maps for each watershed are built up identifying high priority areas for development of agriculture, fuel and fodder, soil conservations and afforestation, type and location of recharging strategies depending on the terrain and the availability of underground water potential. Based on the site specific surveys using remotely sensed information and congenial data, each watershed is further sub divided into 400-500 microlevel units depending on soil characteristics for identifying suitable conservation and management practices and suggesting alternate cropping pattern for optimal exploitation of soil and water resources. For example, land units in the drought prone area (Fig. 15) having very fertile deep soil, which is well drained, but constrained by lack of irrigation facilities, have been recommended for rain-water harvesting and ground water exploration, whereas those lands having moderate soil depth, gentle slope undergoing large scale erosion have been suggested for applying soil conservation measures through contour tillage, strip cropping, etc. likewise in the hilly areas where the lands are characterized by moderate to steep slopes, severe erosion and unsuitable for agriculture, afforestation along with fuel and fodder plantation has been suggested (Fig.16). with the help of the planning commission and active participation of user departments, 142 districts in the country have been taken up under the sustainable integrated study programme, in six of which actual implementation of these strategies are being carried out to set practical examples for demonstrating the capability of this holistic approach.

The experience gained from implementation of this strategy in the selected districts of the country has already demonstrated the efficacy of this method.

Fig. 15: RESOURCE MANAGEMENT AT MICROLEVEL FOR SUSTAINABLE DEVELOPMENT – DROUGHT PRONE AREA

Fig. 16: RESOURCES MANAGEMENT AT MICROLEVEL FOR SUSTAINABLE DEVELOPMENT – HILL AREA

10. Conclusion.

Space technology has played and continues to play a crucial role in dealing with most of the major national tasks and in transforming our remote rural societies to bring them into the main stream of our nation. Innovative application of space technology for communication, TV broadcast, education, disaster management and optimal management of national natural resources for achieving sustainable integrated development alone can ensure food and economic security to the growing population in the coming decades. Together with advances in agriculture, biotechnology and industrialization, it is well within our means to improve the carrying capacity of the country to meet even the needs of the projected 1.8 billion population by 2050 without compromising on the integrity of the environment. If we have to survive as a healthy nation, the choice before is very clear that of application of technological advances for the integrated development of the nation as a whole to ensure a reasonable future to the coming generations of this nation.