Oration 2:
1995 K.R. Narayanan Oration

Message from the Vice-President of the Republic of India

In April 1994 I had the pleasure of inaugurating the Australia South Asia Research Centre at The Australian National University. I have vivid memories of the occasion. A distinguished audience was present along with the Foreign Minister of Australia, Senator Gareth Evans and the former Prime Minister of Australia Mr Gough Whitlam and representatives of the South Asian Missions in Canberra.

The establishment of an annual lecture to commemorate that occasion was a significant step. The first lecture in the series was given by Dr Raja J. Chelliah. I am glad that the second oration this year will be given by Professor U.R. Rao on 'Space Technology for Sustainable Development in Asia'. Professor Rao is one of the pioneers of India's space program to the present stage. He is taking it to the threshold of self-reliance in designing and building satellites and in achieving launch capability.

Space explorations and the practical applications for space technology have opened up exciting vistas for human knowledge and the progress of mankind. It has already conferred great benefits on humanity through the development of telecommunications, television broadcasting, meteorology, disaster warning and natural resources survey and management. India has developed these capabilities in the mainstream of international cooperation. The significance of space science and technology for sustainable development in Asia is self-evident. Large parts of this ancient continent are still afflicted by poverty, illiteracy and general underdevelopment, and therefore cooperation in this field among the countries of the Asian region is of great importance. I am sure that Professor Rao and his wide experience of expertise will throw light on the prospects of such cooperation in Asia.

K.R. Narayanan
New Delhi
1995

Space Technology for Sustainable Development in Asia

U.R. Rao

I am indeed honoured at being invited to deliver the prestigious second K.R. Narayanan Oration of the Australia South Asia Research Centre at The Australian National University, Canberra. My pleasure is all the more since I have intimately known and closely worked with Dr Narayanan, Vice President of India, who is an unique combination of an outstanding journalist, successful diplomat, honest politician and above all a self-effacing, humble and exemplary human being. He firmly believed that the welfare of the world depends on creating a new world order guided by the spirit of sharing and cooperation at the international level involving politics, economics, social engineering and all the resources of science and technology. Quoting his own words, 'The development of the awesome power of the science and technology has to be animated by the spirit of humanism for the good of mankind and not for purposes of exploitation or destruction'. In tune with his philosophy, I have chosen the topic 'Space Technology for Sustainable Development' for this lecture.

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. While the ability to view in entire electromagnetic spectrum enabled space exploration to unveil the magnificent panorama of the vast cosmos, satellites from their vantage point in space have been able to provide a synoptic, repetitive and instantaneous access to any point on our planet, virtually shrinking time and distance. The vast and unlimited potential

benefits of space technology have already extended to 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 (Rao 1995a).

In spite of these spectacular advances, as Smt. Indira Gandhi stated at the UNISPACE '82 conference:

> It is pertinent to ask if such spectacular advances, which in some way have brought the world together have also contributed to reducing the glaring disparities which divide people, the rich and the poor, the haves and the have-nots. The promise of gains from advanced technologies elude the majority of peoples, whose aspirations for a better and richer life remain unfulfilled.

Developing countries, in particular, which account for over 75 per cent of the world population, suffering from serious shortage of resources and capital, lack of trained man power, large-scale illiteracy, low agricultural productivity, industrial backwardness and exploding population, have become the target of the pollution of rampant poverty. In spite of the food grain production increasing at an average rate of about 3 per cent per year, the food productivity in the developing countries continues to remain very low varying between 0.5 to 2.5 t/ha as against the world average of 2.6 t/ha leave alone the productivity of over 4.5 t/ha in the developed nations (Figure 1). With the steadily increasing population in these countries more than offsetting the increased food production, over 65 countries are today facing serious food deficit and acute famine conditions (Rao 1991). The Asia-Pacific region alone accounts for a staggering 65 per cent of world's extremely poor population, sustaining on less than 2,000 calories/day. The gap between the total food grain production in the world and the demand is expected to reach 140 million tons by 2000 and with the projected increase in population from the present 5.7 billion to 8.5 billion by the year 2025 and 11 billion by 2100, the situation is bound to become explosive.

The term sustainable development coined several years ago has now become a common currency. The World Commission on Environment in its report *Our Common Future* (1987) defined sustainable development as:

> development that meets the needs of the present without compromising the ability of the future generations to meet their own needs. It is not a fixed state of harmony, but rather a process

> of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes are made consistent with future as well as present needs.

Unless sustainable development to overcome poverty alleviation concurrently addresses food, economic and health security for achieving substantial improvement in the quality of life across the world, we will surely fail in our attempt to reverse the prevalent state of scarcity and social structure of inequity in our society.

Serious concern for the well-being of humanity has led to the definition of more appropriate indices, such as sustainable livelihood security index (SLSI), for providing a realistic and accurate representation of the quality of life. Fundamentally, assessment of quality of life must encompass four basic components namely food sufficiency, ecological integrity, economic security and social equity. While ecological security covers environmental degradation over land, forest and water, economic efficiency deals with input/output ratio of productivity in monetary terms. The social equity factor essentially deals with human aspects in a given region in terms of their statistics below the poverty line, literacy rate, nutritional status, health care aspects and employment opportunities. It is only through the adoption of a holistic approach involving sustainable development strategies that we can ensure a reasonable quality of life to meet the basic requirements of the present as well as future generations. Considering that each 1 per cent growth in population would require at least 2.5 per cent growth in GNP as demographic investment, providing food, economic and health security to all the people in the world becomes our greatest challenge.

Social Dimensions of the Pollution of Poverty

The rampant pollution of poverty in the developing nations is further being severely stretched on an elastic scale due to the explosive growth in population. Even with the assumption of reaching the replacement fertility rate of 21 per thousand by 2025 based on an optimistic extrapolation of reduction in crude birth rate during the last two decades, the present level of population of 4.3 billion in the developing countries will cross 7.2 billion by 2025 and reach 9.4 billion in 2100 as compared to the total

population of the affluent societies, expected to stabilise below 2 billion (UN 1994). Asian regions, which accounted for 3.1 billion or 59 per cent of the global population of 5.4 billion in 1990, will cross 5.9 billion by 2100 (Figure 2) of which the share of India alone is likely to be around 1.8 billion. It is clear that the only choice we have is to appeal to science and technology for rapidly building up the necessary carrying capacity to meet the basic demands of the population projected by the realistic scenario. The impressive economic breakthrough achieved by the East Asian Tiger countries is a good example of the impact of rapid industrial development and massive literacy program in substantially improving their GNP.

An immediate consequence of the population growth is the decrease in the available per capita arable land from 0.17 ha to just about 0.1 ha (Rao 1991; World Resources Institute 1992), which will inevitably force large-scale migration of rural people into urban areas in search of gainful employment. Globally the urban population has increased from 1.4 billion in 1970 to 2.6 billion in 1992 and is expected to cross 3.5 billion by 2000, which means almost 55 per cent of the global population will reside in cities by the turn of this century. The developing countries in Asia, Africa and Latin America are witnessing exactly the same phenomena of urbanisation which occurred in the developed west 50 years ago. Urban population in Asia which has already crossed 1 billion is increasing at the phenomenal rate of almost 4 per cent per year as compared to less than 1.2 per cent in America and Europe (World Bank 1994). In India, the urban population has dramatically increased from a mere 30 million in 1900 to over 260 million and is expected to cross 400 million by 2000. Inadequate public transportation, scarcity of safe drinking water and poor sanitation have turned all our major cities into sources of concentrated hazard instead of engines of growth. The solid waste generated each day by the megacities in Asia is over 80 to 100 tons per million, almost twice that in the western cities, turning them into breeding grounds of all communicable diseases. The city of Calcutta alone produces over half a million ton of solid waste every year, half of which is not even collected, let alone recycled.

Despite of the exponential growth in communication capabilities all across the world in the last 50 years, the glaring differences in the development of communication infrastructure between developed and developing nations is very striking. Communication infrastructure like many other social parameters such as energy consumption and literacy, is traditionally

considered as an indicator of the level of economic development. Even with the impact of satellite communication revolution, the availability of telephones in the metropolitan cities of the developing countries is less than one for every 100 persons as against one for every two persons in the developed societies. The picture in the rural developing areas is even more dismal with over 2,000 persons having to compete for access to a single telephone (Rao 1993). While practically all the developing countries have taken some advantage of satellite communication, only just about 20 out of the 170 geostationary satellites in orbit today, belong to the developing nations and at the present rate of growth, the share of the developing countries either in leased transponders or in terms of dedicated satellites is unlikely to exceed 15 per cent of the global usage even by the year 2000.

The close organic linkage between development and education is abundantly clear from the existence of the powerful functional relationship between the literacy index of a country and its gross national product. Analysis indicates that least developed countries with 70–80 per cent illiteracy have only a per capita income of about $200 per year whereas middle-income group of nations with illiteracy rates of 35–50 per cent have an annual per capita income of about $600 as against over $10,000 annual per capita income enjoyed by the citizens of developed nations having less than 5 per cent illiterates (Gao and Rao 1992) (Figure 3). According to UNESCO 1985 statistics, almost 30 per cent of the global population were illiterates, 98 per cent of whom belonged to the developing countries. The geographical distribution of illiterate population indicates that Asia alone accounted for 75 per cent of the total illiterates, in the world, Africa coming a close second with 18 per cent and the rest 7 per cent being distributed in Latin America and other parts of the world (Rao 1995a; World Bank 1994), most of them being in dispersed and remote rural areas. Unless eradication of illiteracy is tackled on a war footing and not by mere slogan adoption, over 2.5 billion or about 30 per cent out of an estimated 7.2 billion population in the developing countries will continue to remain illiterate even by the year 2025 (Rao 1988).

In spite of the wide recognition that the existing socioeconomic imbalance between developed and developing nations is directly attributable to the significant difference in their levels of educational advancement, lack of adequate resources continues to prevent the developing countries from overcoming their fundamental disadvantage. In 1986 alone, out of a total investment of about $800 billion on education, 40 developed nations accounted for 80 per cent of this expenditure while the total share of

the 161 developing nations (Rao 1995b; Gao and Rao 1992) was just 14 per cent. The annual per capita investment in all forms of education including higher education in the third world countries is hardly $25 per year compared to over $500 per year in the developed world. Many of the rural areas of the third-world countries do not even possess an elementary education facility and where schools exist, they seldom have more than a single qualified teacher and are often run without even a blackboard. Typical is the example of China, where most of the teachers employed in the primary schools, are those who graduated from the same schools under poorly qualified teachers, resulting in massive inbreeding which has perpetuated the vicious circle. It is estimated that over 3 million poorly qualified teachers in China comprising of 40 per cent of teacher population in primary schools and 72 per cent in junior schools are continuing to cater to the educational growth of that country (Liu 1994). Statistics clearly indicate that the birth rate as well as infant mortality of children drastically gets reduced with the increase in female literacy level. Considering that education of women is most crucial for achieving social equilibrium, through population control and health care (Figure 4), the task of eradicating illiteracy among women who constitute over 60 per cent of the total illiterates in a developing society, becomes the single most important goal for promoting cultural growth and socioeconomic prosperity of any rural society. The answer clearly lies in the wide spread utilisation of distance education involving satellite-based TV and radio broadcasting media, which are most ideally suited to provide basic education as well as continuing education to the vast, inaccessible and sparsely distributed population of the world.

State of Agriculture and Environment

A dramatic increase in the global food grain production since the 1960s occurred with the initiation of the green revolution, which was primarily based on the high technology package involving large-scale use of chemical fertilisers, pesticides, high response better seeds and extensive irrigation. The increase in India's annual foodgrain production from just about 55 million tons in 1947 to about 180 million tons in the 1990s is clearly a result of the emphasis given to large-scale irrigation which has risen from less than 20 per cent to over 35 per cent of total arable land of 160 million ha during this period. Ironically however, the negative repercussions of the very practice of irrigation due to water

logging, inadequate drainage and indiscriminate use of chemical fertilisers have resulted in making the soil in the irrigated areas highly saline and unproductive. It is estimated that over one-third of the approximately 200 million ha of irrigated cultivable land in the world is already salt affected (Swaminathan 1980). Almost 40 per cent of the highly fertile Indo-gangetic plain in India, which was once the cradle of civilisation, suffers from intense salinity making it unfavourable for crop growth. Almost 25 per cent of the arable land area in every continent has become problem land with another 25 per cent having very low productivity.

The extreme pressure of population and industrialisation particularly in the developing countries has resulted in the annual rate of deforestation of 17 million ha including almost 4 million ha in Asia (Figure 5). An imperative consequence of deforestation is increased run-off of rain water and severe soil erosion resulting in the deterioration of the top soil, degradation of land and sedimentation of water bases. The high rate of soil erosion in deforested areas in India, China 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. Worldwide soil erosion has reached the limit of 100 million tons per year as against 45 million tons in 1860 and less than 16 million tons 300 years ago. Extensive deforestation has resulted in increased carbon dioxide in the atmosphere, increased rain precipitation run off from 20 per cent to almost 50 per cent, frequent flooding and a gradual extinction of biodiversity (Khoshoo 1990; Brown 1992). Overgrazing, deforestation, encroachment by agricultural crops and general mismanagement of land and water resources have resulted in increasing desertification in Asia, Africa and Latin America. About 3,000 million 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 million ha per year. The changes in climatic and rain patterns 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 aerodynamic roughness over the forest and the atmosphere above it.

Management of water resources particularly in the developing countries, has been even more pathetic. Optimal management of water becomes crucial in the dry land tracts of tropical countries where most of the precipitation occurs in less than 100 days as compared to mid- and high-latitude countries where snow and rain precipitation continue to keep the soil moisture intact for almost eight months in a year. With the added

problems of higher temperature regimes and higher evapo-transpiration 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, salinisation and loss of valuable bio-resources have led to gradual degradation of land in many areas in the developing world. Intensive use of chemical fertilisers and pesticides combined with poor management of water-sheds and highly fragmented land holdings have resulted in severe water stress, pesticide contamination not only in the water but also in the agricultural crops, resulting in the severe degradation of over 1.2 billion ha across the world, in the last 45 years alone (Figure 6). The material delivery from rivers to the oceans which was just 9.3 billion tons 50 years ago has now increased to 25 billion tons a year, with the largest discharge of over 15 billion tons per year coming from Asia alone.

Superimposed on these seemingly insurmountable difficulties is the real prospect of the widely accepted global warming scenario due to the unprecedented anthropogenic intervention causing a rapid increase in the green house gases, upsetting the delicate greenhouse equilibrium which could lead to irreversible climatic changes (Ramanathan 1985). Particularly since the beginning of the industrial revolution, CO_2 concentration in the atmosphere has steadily increased from 280 ppmv to 350 ppmv and at the present rate of increase is expected to reach 450 ppmv by 2050. Concentration of methane in the atmosphere has also been increasing steadily at the rate of about 0.9 per cent per year and has now already reached 1.7 ppmv. Detailed rigorous analysis of surface temperature over the last century indicates an average increase in global temperature of about 0.5°C. While the primary cause of the global temperature increase in the past has been the increasing atmospheric concentration of CO_2 due to industrialisation, 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. In spite of the universal adoption of the Montreal Protocol the spectre of global warming, which can cause depletion of ozone, rise in sea level, inundation of highly populated coastal areas and severe modification of climatic and rain pattern, continues to pose a real threat unless all countries, both developed and developing, make appropriate structural adjustments in their lifestyle and consumption pattern.

Communication Revolution

The remarkable developments in space communication in just three decades since the successful relay of TV signals across the Atlantic in 1962 using TELSTAR, have brought us to the threshold of achieving the capability of establishing human connectivity anywhere in the world, on land, air or sea. The superior quality and reliability of satellite links in combination with their high percentage of availability, distance insensitivity, high degree of flexibility for rapid reconfiguration and their ability to aggregate small requirements to provide cost effective specialised services across vast territories have made satellite communication the most vital link for establishing human connectivity promoting a new perspective of our planet, that of a global village. The evolutionary nature of satellite communication is reflected in their capacity increase, from just 240 voice channels in 1965 to the present day satellites which on an average can easily carry over 20,000 voice circuits, in addition to several TV channels (Pant 1994). Practically all the developing nations in the world today including Asian countries have taken advantage of satellite communication by either leasing transponders from international systems like INTELSAT, INMARSAT and INTER SPUTNIK or by establishing regional systems like Arabsat.

Recognising the paramount need of the governments, societies and institutions to quickly respond to fast changing situations in a demassified society where niche markets, customised services and rapid transactions are essential to successfully compete in the liberalised global market place, a few Asian countries like India (INSAT), Indonesia (PALAPA), China (CHINASAT), Japan (JCSAT) and Australia (AUSSAT) have already established their own satellite communication systems. Other Asian countries like Korea (KOREASAT), Thailand (THAICOM) and Malaysia (MEASAT) are in the process of establishing their own communication systems to meet their growing requirements of telecommunication and TV distribution services.

Unlike most of the countries, India decided to build its own indigenous technology base and use space technology for solving its national problems on a self-reliant basis. Establishing the feasibility of using satellite medium for imparting education in health, hygiene, family planning and better agricultural practices to over 2,400 remote rural villages through the year long Satellite Instructional Television Experiment (SITE) conducted using NASA's ATS satellite during 1975, India successfully launched

and operated its own three axis stabilised experimental satellite APPLE in 1981 followed by the introduction of the unique, multipurpose INSAT series of communication satellites to provide operational services on a continuing basis. INSAT system, with over 5,000 two-way speech circuits covering 140 routes amounting to 150,000 route km initiated a communication revolution in the country (Figure 7) connecting for the first time, even remote rural areas and off-shore islands with the main stream of the nation using Low Cost Terminals (LCTs). The nationwide geographic reach of INSAT satellite has been advantageously used for a variety of applications such as administrative, business and computer communications through a number of captive networks using small terminals. New specialised services such as rural telegraphy to remote areas, news service, facsimile transmission and emergency communication for post disaster relief operations have been commissioned. The National Information Center's Network (NICNET) using VSATs and spread-spectrum techniques with over 700 micro-terminals provides reliable data communication links interconnecting district headquarters, state capitals, and central government departments. The Remote Area Business and Message Network (RABMN), to provide data communication between city-based industries and construction projects located in remote areas is already operational with over 450 micro-terminals and with a registered demand for more than 2,000 terminals (Rao 1995b).

Similar expansion of telecommunication to provide low cost VSAT services in addition to point to point communication has been achieved in China, Australia, Indonesia and other countries in Asia either through satellites procured from abroad or through leased transponders. Increasingly all over the world the future trends in communication is towards establishing personalised communication services to meet the needs of the people at individual and group levels. Remarkable developments in digital compression techniques, use of advanced modulation systems for optimal utilisation of space segment and innovative use of low-cost VSATs to provide several value-added services have initiated the new age of information super-highway making it possible to have information on demand. The merging of large computation and communication capabilities through technological innovations are paving the way for the establishment of seamless networks to provide personalised communication and multimedia services including audio, video and data transmission, thus creating a world where communication, information, entertainment and motivation are literally at the will of one's fingertips. The imminent introduction of mobile communication services in the next

three years will surely make the dream of every communication engineer of establishing human connectivity anywhere in the world, on land, air or sea come true.

Space Technology for Universal Education

The phenomenal success of the Satellite Instructional Television Experiment (SITE) conducted in India followed by similar experiments conducted elsewhere in the Appalachian Region, Rocky Mountains, Alaska, Canada, China and Latin America in the mid-'70s and early '80s, clearly established the tremendous potential of using satellite TV for educational purposes (Rao 1987). It is very satisfying to note that operational beginning of satellite-based distance education facility is already making a significant impact in Indonesia, providing an effective educational system to the sparsely distributed population in 14,000 individual islands stretching across a distance of over 5,000 km, many of which are inaccessible mountainous or jungle terrain. Successful use of PALAPA satellite in Indonesia, INSAT in India and AUSSAT in Australia have prompted other developing countries like Brazil, China and Mexico also to develop their own satellite-based educational system. Extensive use of satellite medium in China provides 31 hour adult educational programs every day to 30 million people annually through 6,300 TVRO earth stations and more than 50,000 learning centres.

Most dramatic impact of INSAT has been in the rapid expansion of TV dissemination in the country through installation of more than 600 TV transmitters and use of a large number of direct reception community sets in sparsely populated areas, for providing access to over 80 per cent of India's population, through national and regional transmissions. INSAT is being extensively used for Educational TV broadcasting with about 100 hours of programming per month to over 4,000 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 clarifications from experts, in real time. Special inexpensive talk back facilities have been developed within ISRO to promote this activity in the country and a number of selected large-scale experiments aimed at improving the level of understanding of rural people, providing refresher courses to industrial workers in cities and specialised education to schools and colleges were conducted to demonstrate the effectiveness of the satellite media for

imparting interactive education (Rao 1995b). Recognising the acute need for eradication of illiteracy, particularly in the rural areas, ISRO has conceived of dedicated GRAMSAT satellites (Rao 1993) (Figure 8), carrying six to eight high-powered C-band and Ku-band transponders which together with video compression techniques can disseminate region and culture specific audio visual programs of relevance in each of the regional languages through rebroadcast mode on to an ordinary TV set.

Vast improvements in technology have made it possible to reach millions of homes with antenna dish sizes as small as 90 to 45 cm in Ku-band. The recent upsurge in video compression technology now enables several TV channels to be carried on a single transponder. Availability of about 150 channels from a single satellite location can entirely change the complexion of home entertainment through direct to home television broadcast. Video-on-demand which includes specific group interest programs in addition to general entertainment programs, allows individuals to choose and even manipulate programs of their choice. What was cost prohibitive yesterday has suddenly become affordable today with the availability of TV using only a small space segment resource in an economic way which can have a dramatic impact on educational and developmental services.

Management of Natural Disasters

The enormous havoc and dislocation caused by natural and man-made disasters have become a great burden particularly on the highly populated and poverty stricken developing countries causing perpetual misery to thousands of lives and livestock. Over the past 20 years alone, these extreme natural disasters have resulted in the loss of life of more than 3 million people and have affected over 800 million people all over the world, causing damage to property to the tune of $50–100 billion, 50 per cent of which is due to floods and cyclones. Over 60 per cent of all the major disasters have occurred in the developing countries, two-thirds of which have been in the developing Asian regions (Rao 1995a; World Resources Institute 1992). Even though extreme natural events such as floods, drought, cyclones and earthquakes are not totally under human control, prediction of occurrence of some of these events with a good degree of certainty is possible, thanks to the developments in space technology. Instead of collectively taking up the challenge of preventing or at least mitigating the effects of such disasters,

providing aids after the events which are both inadequate and untimely has only resulted in perpetuating the misery of the worst affected, silently suffering victims of disasters.

An effective disaster management system consists of four main components — disaster prediction, disaster warning, disaster management and disaster relief. Disaster warning is a basic prerequisite for ensuring disaster preparedness and in some cases to help in the prevention of disaster itself. Clearly the most important application of satellites is in detecting, predicting and delivering early warning of impending disasters such as flood, drought, cyclone and even forest fires (Rao et al. 1987; Heath 1994). Continuous monitoring by both geostationary and low earth orbiting weather satellites like GOES, INSAT, METEOSAT and NOAA is capable of providing early warning on cyclones and floods. Forest fires, environmental hazards, volcanic eruptions and even propagation of desert locust phenomena can be detected well in time by remote-sensing satellites like, LANDSAT, SPOT and IRS. Sustainable development strategy must address this important issue in order to provide stability and reasonable security to the vulnerable rural population in these countries. Remote-sensing information are now operationally used to regularly monitor flood conditions, volume of water flow and damage assessment. From such a database collected over years, it is possible to identify different risk zones in the flood prone area based on the severity index for flood proneness of each zone. Optimal treatment of each zone on a long-term basis, depending on the severity, can then be attempted to achieve reduction in flood damage without impairing environmental integrity (Rao 1993) (Figure 9).

Data relay and communication satellites have the ability not only to deliver early warnings on various disasters but also in disseminating requisite information on hazard awareness and educating the local people in preparing themselves to face such hazards. Locale specific unattended Disaster Warning Systems (DWS) installed by India along the vulnerable eastern coast of the country, using communication and meteorological capability of INSAT multipurpose satellites, have proven their immense value in providing timely warning on cyclone and flood disasters over the last 10 years. Most dramatic use of DWS, consisting of over 150 disaster warning receivers was during the cyclone that hit the eastern coast of India in May 1990, enabling the civic authorities to evacuate over 170,000 people from the cyclone affected area, which saved thousands of lives and livestock. But for the operation of DWS, analysis of cyclone events which

occurred in the pre INSAT era indicates that the total human death toll would have been at least 20,000 during this event, as against only 800 deaths recorded (Rao 1995a; 1995b).

Drought is a complex phenomena, the causes for which are many involving both natural and induced factors such as atmospheric perturbation, climatic variability, sea surface temperature changes and human intervention, ranging from deforestation and poor land management to destabilisation of greenhouse effect. While it is difficult to identify the exact onset and the end of drought because of its slow creeping nature, remote-sensing derived Vegetation Index (VI) has been very effective in monitoring drought conditions on a real time basis, often helping the decision makers to initiate appropriate strategies for recovery by changing crop patterns and practices. The use of meteorological satellite data to assess spatial and temporal inadequacies of rainfall at critical crop stages and subsequent assessment of the crop condition status based on VI analysis provide an excellent drought monitoring mechanism. Comparison of the temporal changes in the bi-weekly VI indices with the corresponding figures in a normal year can easily provide advance information on the onset of drought conditions in any given region (Figure 10). Under the National Agricultural Drought Assessment and Monitoring System (NADAMS), bi-weekly drought bulletins are issued, almost on real time, to all the drought prone districts in India to enable decision makers to assess the severity of drought and take appropriate remedial measures (Rao 1995c).

Food Security

The solution for providing food security to the world without affecting ecological balance lies in the adoption of new scientific tools available, particularly the use of vital inputs from space remote-sensing and biotechnological advances. While India and China have built an impressive capability in space technology by developing their own launch vehicles, communication and remote-sensing satellites and application programs, other countries in Asia have also successfully used space imageries available from international satellites for monitoring and management of their natural resources through cooperative arrangements. India for example, has effectively used its own IRS series of remote-sensing satellites to establish and continuously monitor its national forest inventory and to prevent further encroachment of its forest wealth. Extensive use of satellite imageries for mapping soil characteristics, land-use in terms of single crop,

double crop, fallow and residual land areas, meteorological parameters and water resources have led to the identification of agro-climatically coherent regions having homogeneous characteristics such as slope, soil depth, texture and water holding capacity, which are vital for developing locale-specific and agro-climatically suitable cropping patterns. The ability to identify saline/alkaline soils at micro-levels using space imageries have enabled the application of suitable measures to reduce soil salinity and adoption of alternate crops or cropping patterns to restore the fertility of the land to the original level. Country-wide mapping of wasteland at micro-level has been able to identify 54 million ha of wasteland (Figure 11), about half of which can be reclaimed for productive agricultural usage with appropriate corrective actions (Rao 1995a; 1995c).

Repetitive coverage provided by satellites has been widely used for mapping the temporal changes in water bodies and reservoirs in addition to providing a reliable estimate of water storage in the reservoirs thereby facilitating optimal scheduling of irrigation. A classic example is the country-wide hydrogeomorphological mapping from space showing ground water prospect areas which has improved the rate of success of finding underground water to 92 per cent compared to 45 per cent achieved using purely conventional methods. Models based on the area extent of seasonal snow fall have been developed to predict snow-melt runoff into the reservoirs. Identification of waterlogged pockets in the command areas of irrigation projects and inventory of crop lands and cropping patterns have facilitated efficient water use, thereby increasing the cropping intensity. Remote-sensing data are being extensively used to predict the acreage and yield of all major crops and also to identify degraded watersheds for initiating appropriate conservation measures for soil and water (Rao 1995c). Space imageries have fully established their ability for substantially improving the marine fish catch by identifying areas of rich fish shoals based on ocean temperatures and phytoplankton density measurements.

Doubling or in some cases tripling of food grain productivity is required to meet the basic minimal requirements of the projected population growth in many of the developing countries in Asia, Africa and Latin America. Even though the global cultivable land area can in principle be increased from the present 1,500 million ha to about 2,150 million ha through reclamation of culturable wasteland, the prospect of such increase is limited to less than 10 per cent, or about 60 million ha over the presently cultivated crop land of 820 million ha in Asian continent. Historically, it is recognised that increase in the area of cultivation in the recent past has in fact only contributed to less than 10 per cent increase in the food

grain output. Even with the possible reclamation of about 25 million ha of wasteland and exploitation of the full irrigation potential by doubling the presently irrigated area of 40 million ha, the annual food grain output in India can at best be increased to 250 million tons as against the requirement of 450 million tons by 2050. Analysis by the world bank and FAO have clearly pointed out that countries like India and China cannot support beyond 1.5 times their present population (FAO 1988; Murai et al. 1990) using the present agricultural technology.

The challenge of providing adequate food security to the growing population can only be solved by achieving substantially higher yields through initiation of sustainable integrated development strategies. Significant advances in biotechnology have resulted in a variety of new genetic breeds, early maturing dwarf varieties of crops, pest-resistant hybrid varieties and suitable cultivation strategies. Combined with integrated pest management strategy, use of bio-pesticides and conservation of top soil and water resources, these biotechnological advances have led to a substantial increase in the genetic potential up to 8–10 t/ha under controlled conditions, which implies that achieving an average yield of 4–5 t/ha even in field conditions is well within our technological capability. Practical realisation on nationwide scales, however, must take into account the boundary conditions imposed by ecological, environmental, social and cultural factors in each country to ensure long-term sustainability. This requires a clear understanding of land capability, continuous monitoring and optimal management of natural resources, and use appropriate agricultural practices.

Sustainable development of natural resources is obviously dependent on maintaining the fragile balance between productivity functions and conservation practices through monitoring and identification of problem areas requiring application of energy intensive agricultural practices, crop rotation, bio-fertilisers and reclamation of underutilised lands. It calls for the integration of various renewable and non-renewable resources, characterisation of coherent zones of agricultural identities and identification of physical constraints as well as ecological problems at the micro-level of each watershed. Combining space derived vital inputs on soil characteristics, agricultural practices, underground and surface water resources, forest cover, environmental status and meteorological information with collateral data on socioeconomic factors it is possible to subdivide each watershed into 400–500 micro-level homogeneous units for identifying suitable conservation measures and appropriate biotechnological practices to significantly enhance the production on

a sustainable basis (Figure 12). In the few selected watersheds where sustainable integrated development strategy has been implemented, as in the cases of drought prone districts of Anantapur and Ahmednagar in India, two healthy crops are now grown and the water table has gone up by almost 3–5 metres in the last three years as against non-availability of even drinking water in summer months (Rao 1995a; Rao, Chandrasekhar and Jayaraman 1995).

International Cooperation and Policy Issues

While the spectacular advances in science and technology and space technology in particular, can provide appropriate solutions to meet the basic requirements of all the nations, the success of meeting the global challenges of the next century clearly depends on the ability of both North and South in making wise choices concerning the future path of progress. Despite of the fact that space exploration, for the first time, has given us a new perspective of our own beautiful planet, true appreciation of this global view is yet to percolate into the conflicting minds concerned solely with immediate national interests and artificial geographical boundaries. The concept of oneness of humankind has been an integral part of the Indian heritage which was enunciated in our great epic Mahabharata:

> This is mine that is another's
> Such reckonings are for the narrow minded
> For the noble hearted
> The whole world is one family.

The last few decades of inadequate efforts to bridge the inequities between the developed and the developing societies have been primarily through aids and soft loans, largely due to moral dictates of guilt complex. It is essential that we clearly realise that the prevalent extensive deforestation, illiteracy, lack of basic resources such as food and water, non-availability of technological know-how will drive the developing world through the same suicidal pathway followed earlier by the developed world, in their anxiety to achieve rapid development. While the developed countries which have contributed maximally to the deterioration of the global environment in the past will discover alternate environment friendly technological solutions, rapid deterioration of the ecological state cannot be stopped unless such technologies are made available to the 75 per cent

of the world's population. In other words, the betterment of human society as a whole has to be viewed as an implicit requirement for the very survival of this planet.

The emerging independent nations of the South, on the other hand, have to create a new social order which starts recognising that not only the quantitative transformation but the very survival of their society depends on the optimal utilisation of science and technology. The sociopolitical system in most of the developing countries, which is self-serving, near sighted and devoid of scientific temper, still regards science and technology only as an embroidery and not the main social fabric of their culture. There is an urgent need for the developing countries to replace the widespread political opportunism with a healthy scientific attitude and seriously tackle the problem of rapid rural development, eradication of illiteracy, establishment of basic communication infrastructure and industrialisation not through vote-catching, populist schemes but by purposeful, action-oriented approach. Accomplishment of these tasks needs the total involvement of highly skilled and fully committed scientists, massive education at the grassroot levels and widespread dissemination of scientific culture — in other words, the 'greening' of the human mind.

Despite of the creation of a conducive atmosphere for promotion of international cooperation with the end of the cold war, agreements reached during the Rio summit, general acceptance of Montreal Protocol for the preservation of the environment and signing of the GATT agreement, the technological gap between the developed and the developing nations is continuing to grow. While GATT has introduced a few concessions to the developing nations for a limited period of time to enable them to compete in the global market place on equal footing, the possibility of invoking highly subjective criteria to apply trade sanctions and restrictions on newly industrialised countries continues to pose a threat to the third world nations. Even the so called free market trade in reality has been adroitly used for commercial exploitation. Exploitation of global market by fixing prices based on opportunity cost and not on production economics, till the competition builds up has been followed throughout history while at the same time propagating ethical approaches to market demand. Instead of providing preferential access to developing countries for selling their products and services in the global market, attempts are made to restrict the competition in the name of fair geographical returns policy, application of quota system and equally dubious arguments based on level playing field and human rights (Rao 1995a).

Security concerns as perceived by developed nations have greatly influenced the level and nature of international cooperation. One of the major regimes impinging on the transfer of components, equipment, information and technologies particularly related to space programs is the Missile Technology Control Regime (MTCR). Although at the beginning, MTCR had the laudable objective of restricting the proliferation of only missile related technologies and not peaceful space programs, slowly over the years, high technology components and equipment required even for peaceful programs have been denied as a part of the implementation strategy. The release of the same components for sale immediately after such components are either indigenously developed or become available from alternate sources has left a strong impression that such technology regimes have been turned into a strong weapon in the armour of the developed countries for commercial and political gains. Philosophical statements, such as 'if we are to lead the world towards a hopeful future, we must understand that technology is part of the planetary environment, to be shared like air and water with the rest of the mankind', are pronounced in every conceivable international forum. The reality, however, is that science and technology has become the most powerful currency of power, monopolised and zealously guarded by a minority of few advanced nations, who have employed technological hegemonism — as a means of influencing and controlling the developing world.

The key to the development of a proper strategy for survival clearly depends on achieving integrated sustainable development through both national and international cooperation. It calls for the initiation of a new sustainable green revolution, taking into account the lessons learnt from past experience, to meet the basic needs of the present and future generations through adoption of environment friendly scientific and technological approach aimed at achieving rapid progress without sacrificing the 'owl'. As beautifully summarised at the 1992 Rio Summit (UN 1992):

> Humanity stands at a defining moment in history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the eco-systems on which we depend for our wellbeing. However, integration of environment and development concerns and greater attention to them will lead to the fulfillment of basic needs, improved living standard for all, better protected and managed eco-systems and a safe, more prosperous future. No nation can achieve this on its own; but together we can in a global partnership for sustainable development.

Conclusion

Interconnectivity of both natural and anthropogenic phenomena occurring anywhere on the earth, through weather, climate, geosphere and biosphere have inextricably linked the fate of each country with that of the world as a whole. The fact that the increase in green house gases, deforestation and depletion of ozone result in global warming affecting the entire global climate, disturbances in El Niño and ENSO off the coast of Peru can result in severe drought across Asia, Australia and Africa, or volcanic eruptions and industrial activity can change pattern of rain precipitation across the world clearly emphasise the necessity to take a global view for the survival of humankind, as a whole.

The fundamental aspect of long-term sustainable development strategy is based on the paradigm of technological innovations, economic determinism and physical constraints arising out of the need to strike a judicious balance between ultimate exploitability and regenerative capacity. This essentially means that all nations must think globally and act locally, because the survival of the planet as a whole depends on the restoration of equity and assurance of minimal needs to all the people in the world. With his remarkable insight, President Kennedy stated over 30 years ago that:

> Never before has man had such capacity to control his own environment, to end thirst and hunger, to conquer poverty and disease, to banish illiteracy and massive human misery. We have the power to make this the best generation of mankind or to make it the last.

We hope that the human kind will have the wisdom to choose the former and strive ceaselessly towards achieving sustainable integrated development of our planet as a whole to enable all peoples of the world, both in the developed and the developing countries, to live a reasonably good quality of life. It is only then we can make Isiah's prophecy come true that

> The desert shall rejoice
> and blossom as the rose…
> The parched ground shall become a pool
> and the thirsty land springs of water.

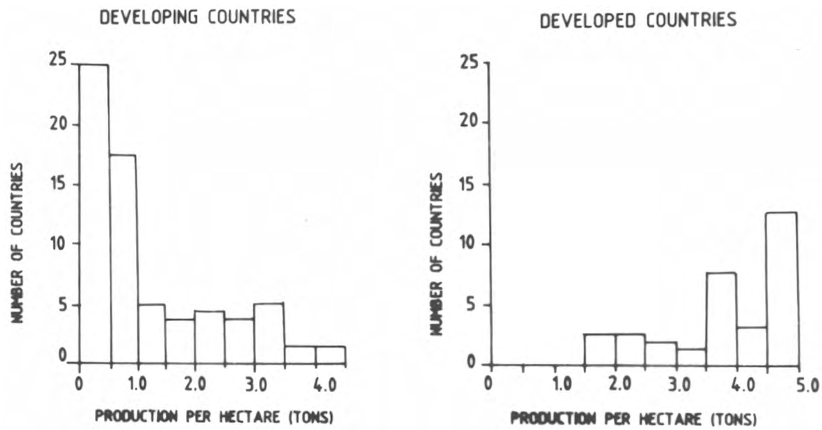


Figure 1: Foodgrain productivity in developed and developing countries

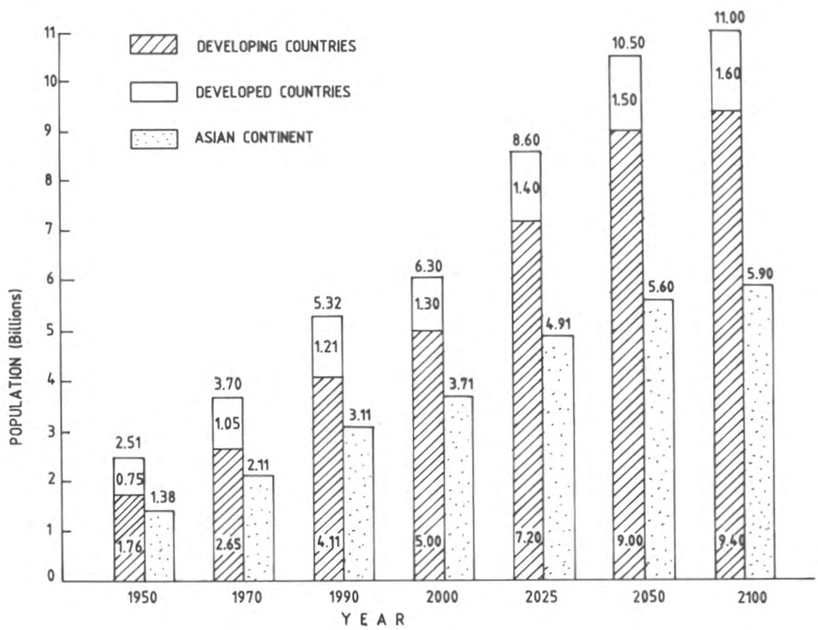


Figure 2: Growth of population in the developed and developing countries of the world

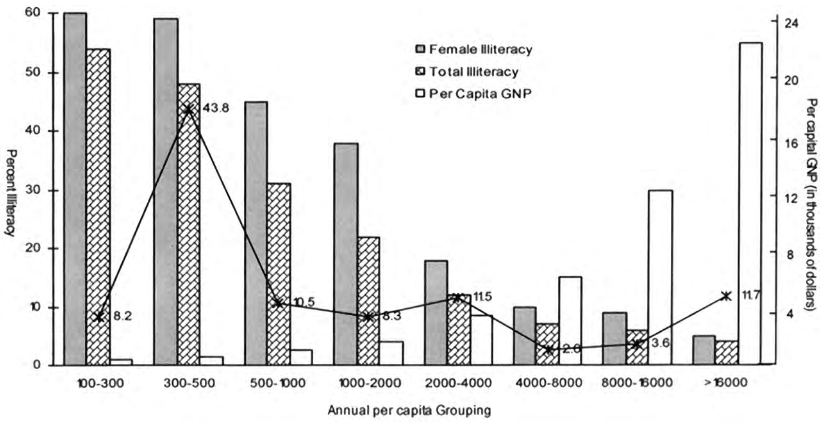


Figure 3: Literacy and per capital GNP (the numbers in the diagram indicate the per cent global population under each grouping)

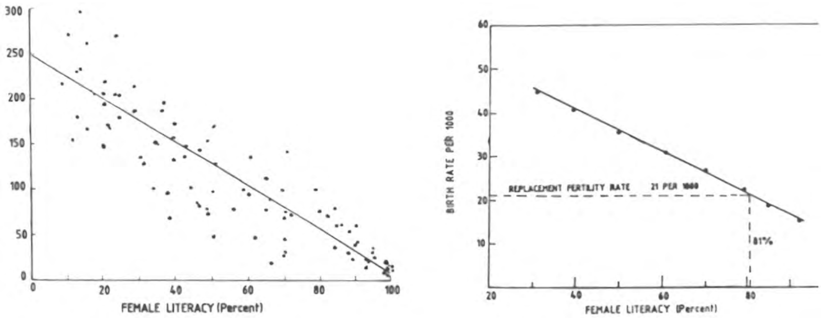


Figure 4: Relation between female literacy and fertility rate and mortality rate

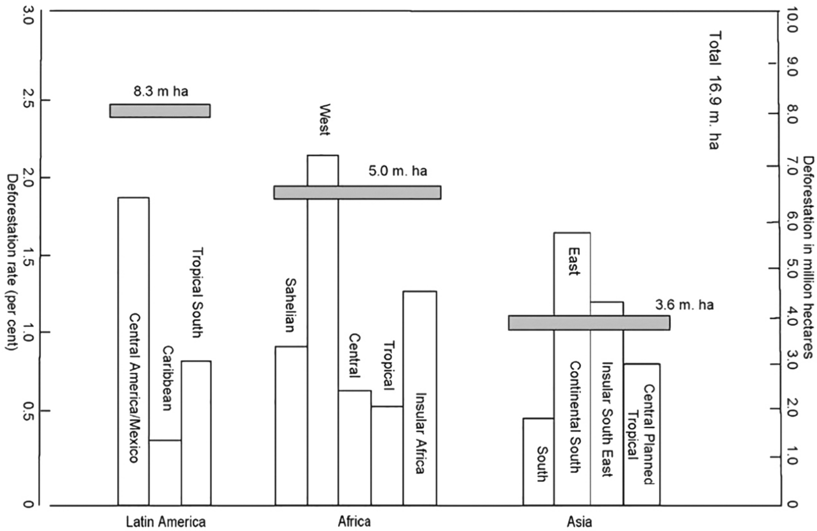
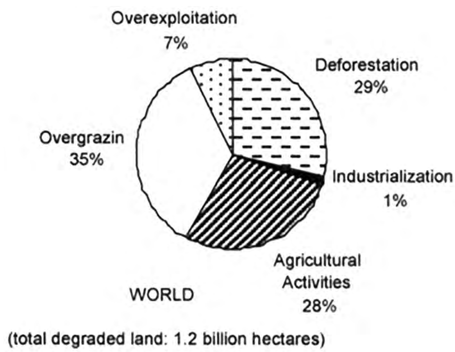


Figure 5: Annual deforestation in the tropical region (1981–90)



Causes of land degradation	Per cent of total degraded land						
	Asia	Africa	North America	South America	Central America	Europe	Oceania
Deforestation	40	14	0	41	22	38	12
Industrialisation	1	0	0	0	0	9	0
Agricultural activities	27	24	66	26	45	29	8
Overgrazing	26	49	30	28	15	23	80
Overexploitation	6	13	4	5	18	0	0

Figure 6: Causes of land degradation in past 45 years

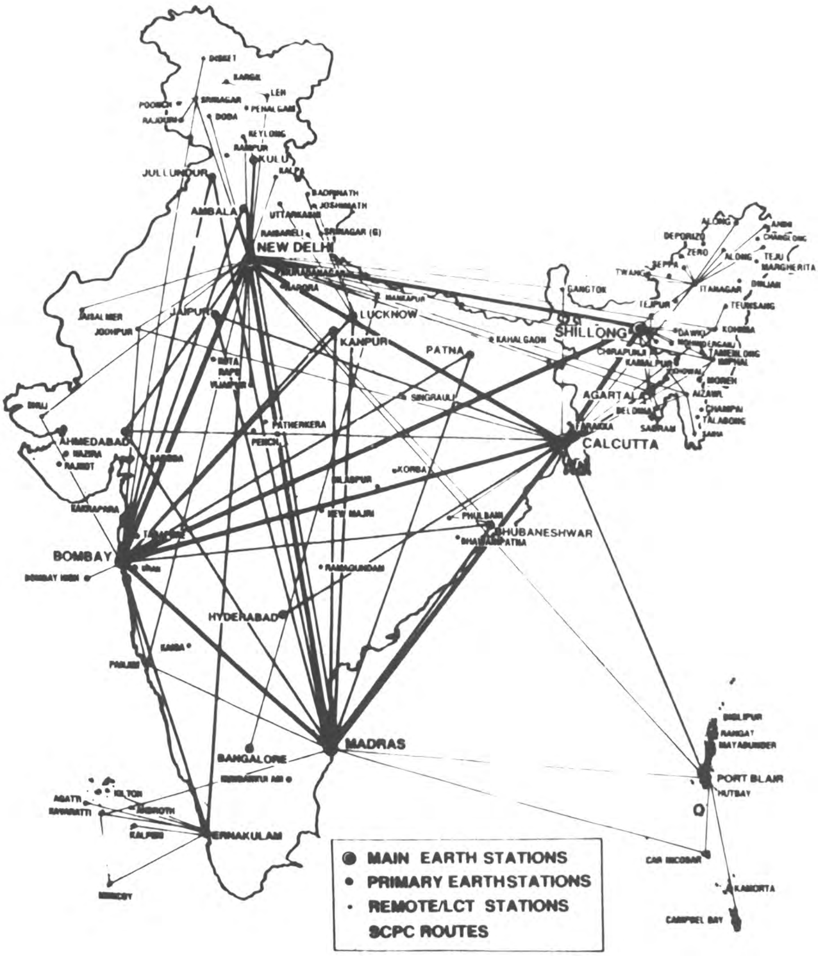


Figure 7: Satellite telecommunications in India

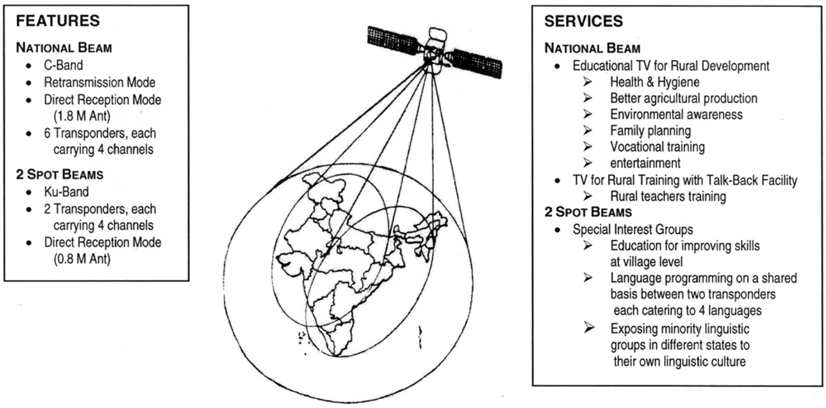


Figure 8: Gramsat (concept)

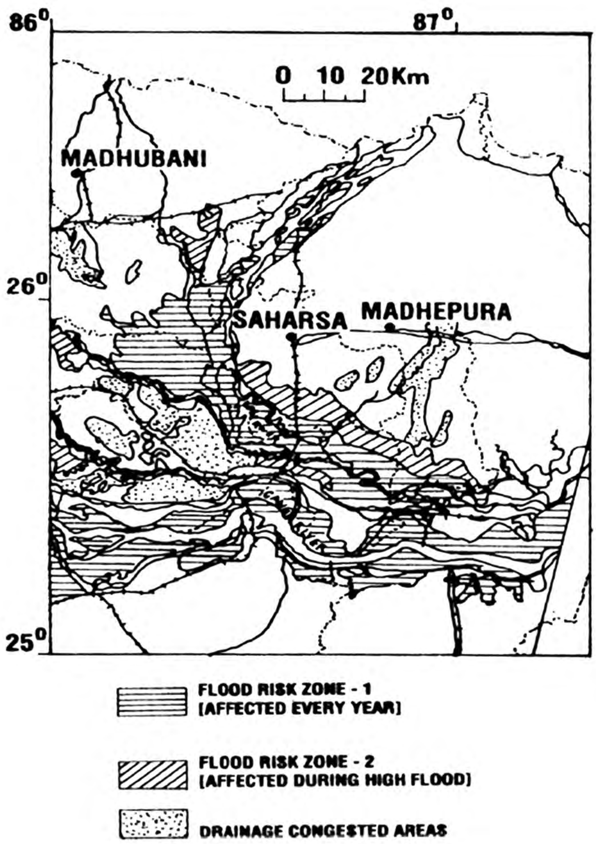


Figure 9: Flood risk zone map of part of Ganga basin

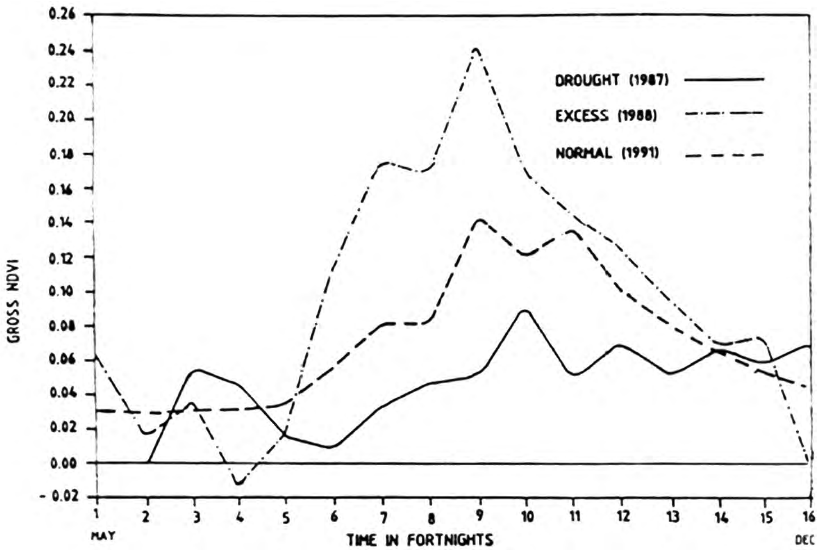


Figure 10: NDVI indicating seasonal vegetation conditions (Bhiwani district, India)

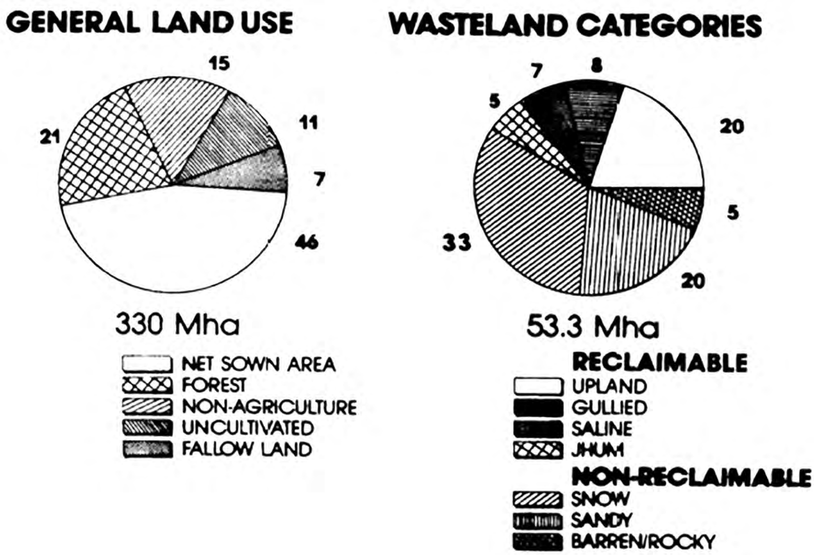


Figure 11: Typical land-use pattern in a developing country — India

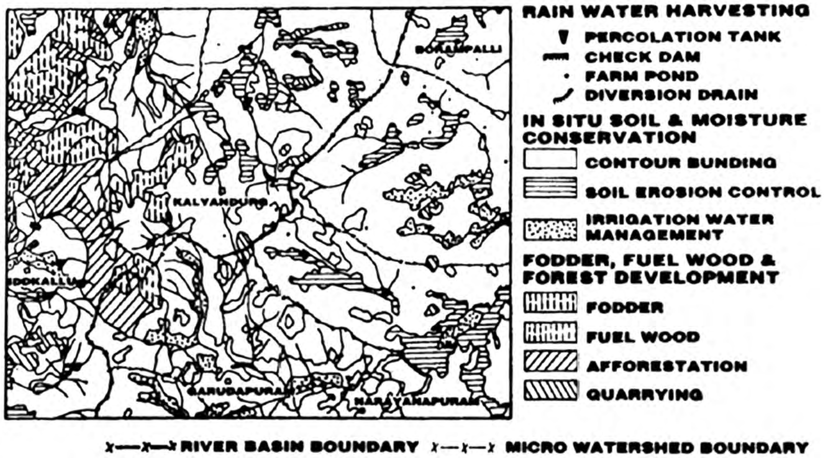


Figure 12a: Resources management at micro-level of sustainable development — Drought-prone area

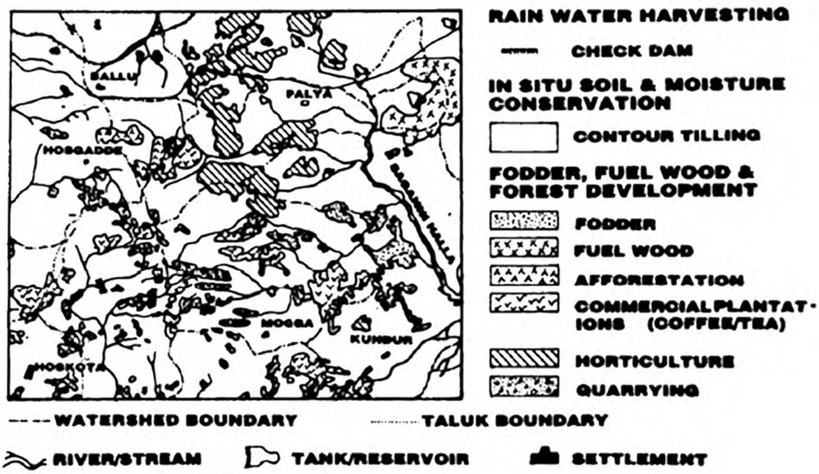


Figure 12b: Resources management at micro-level of sustainable development — Hill area

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