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USE OF REMOTE SENSING TECHNOLOGIES FOR ENVIRONMENTAL APPLICATIONS, PARTICULARLY IN SUPPORT OF THE RECOMMENDATIONS OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT

Note by the Secretariat

1. The Working Group of the Whole to Evaluate the Implementation of the Recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), at its eighth session (A/AC.105/571, annex II, para. 17), recommended that further studies on space science, technology and applications should be carried out. The Working Group of the Whole identified a number of possible subjects for such studies, including the use of remote sensing technologies for environmental applications, particularly in support of the recommendations of the United Nations Conference on Environment and Development.

2. The report of the Working Group of the Whole was adopted by the Scientific and Technical Subcommittee at its thirty-first session (A/AC.105/571, para. 22), and the recommendations contained in the report were endorsed by the Committee on the Peaceful Uses of Outer Space at its thirty-seventh session[1] and by the General Assembly in its resolution 49/34 of 9 December 1994.

3. In response to the request of the Working Group of the Whole, the Secretariat prepared a study on the use of remote sensing technologies for environmental applications, particularly in support of the recommendations of the United Nations Conference on Environment and Development. The study, which is available in English only, is presented in the annex to the present note.

SUMMARY OF THE STUDY

4. Over the past several years there has been a growing realization of the link between preserving the Earth environment and ensuring that its resources are utilized in a sustainable manner. The United Nations Conference on Environment and Development, held at Rio de Janeiro, Brazil, from 3 to 14 June 1992, focused on global environmental and developmental problems, emphasizing that only the increased integration

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of environmental and developmental concerns and greater attention to them would lead to improved human conditions, in particular in developing countries.

5. The concept of sustainable development is based on the goal of maintaining a balance between human needs and economic development within the parameters of environmental conservation. A specific action plan on sustainable development was developed at the United Nations Conference on Environment and Development. The action plan, contained in Agenda 21,[2] calls for expanded global initiatives related to sustainable development, recognizing the important contribution that space technology can make to environmental monitoring.

6. Agenda 21 is a dynamic programme. The programme areas that constitute Agenda 21 are described in terms of their basis for action, objectives, activities and means of implementation. The agencies and organizations implementing Agenda 21 will vary, depending on the different situations, capacities and priorities of the countries and regions and taking into full consideration all the principles contained in the Rio Declaration on Environment and Development.[3] Agenda 21 could evolve in the light of changing needs and circumstances. This process marks the beginning of a new global partnership for sustainable development.[4]

7. A number of statements made on Agenda 21 during the United Nations Conference on Environment and Development[5] underlined the lack of adequate databases for environmental monitoring on a global, regional or national scale in a variety of fields and the importance of establishing systematic data acquisition, processing, analysis and archiving systems to support development and environmental monitoring and assessment systems.

8. The recent past has shown that space-based observation of Earth is an effective way for natural resource managers to view and analyse land, water and other natural resources, even in inaccessible areas, in any season of the year. Another advantage is that it provides information at a low cost compared with conventional ground monitoring techniques.

9. It is now well recognized that the unique capabilities of remote sensing satellites to provide comprehensive, synoptic and multi-temporal coverage of large areas at regular intervals have been and will be an indispensable tool for continuous and repetitive environmental monitoring. Agenda 21 stresses the fact that remote sensing technologies play an important role in both environmental preservation and sustainable development.

10. Remote sensing is defined as gathering information about an object without being in direct contact with the object. The technique of remote sensing includes the use of photographic sensors, as well as the use of radar, laser, multispectral scanner and sonar sensor systems. In the application of land and environmental resource management photography, solid-state scanners and radar have become the major elements of Earth observation systems.

11. Remote sensing technology can help a range of people and professions. It enables scientists to study environmental changes over time and across regions and to establish correlations with other factors such as population growth or farming methods. National planners can use information derived from satellite images to draw up action plans for the sustained preservation of the environment of a natural area, such as a watershed, or of a whole country. Regional planners can identify areas to be protected, monitor them and adjust their policies accordingly. In general, many of humanity's main concerns could be addressed, at least in part, by this technology, which is rapidly becoming operational.

12. Some of the major problems facing humanity include providing food security, education, shelter and medical services for the world's growing population. These are complex problems that have a direct impact on political and social stability. Interrelated problems include meeting relief needs when natural disasters occur, dealing with the associated economic losses, which are on the order of billions of United States dollars

each year, and meeting the basic needs of millions of displaced people, while at the same time preserving the environment. These problems will grow in the next 25 years, when the world's population is expected to range between 8 billion and 10 billion people.

13. Providing food security, education, shelter and medical services involves numerous factors, many of which are not directly related to environmental conditions; however, a healthy environment is necessary for sustainable solutions. Space technology, particularly remote sensing, could be used as a powerful tool to arrive at some of the solutions. For instance, the quality and quantity of agricultural areas are important factors in food production. At the same time, the clearing of natural vegetation to expand agricultural areas could lead to the loss of topsoil or, even worse, to desertification. Thus, sustainable management of agricultural areas would require an integrated analysis of the medium-term and long-term effects that alterations in the natural environment would have on the agricultural areas themselves, as well as on surrounding areas that contribute to the quality of life in the region (e.g. drinking-water resources).

14. Desertification is land degradation that occurs primarily in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification affects about one sixth of the world's population, 70 per cent of all dry land (amounting to 3.6 billion hectares) and one quarter of the total land area of Earth.

15. Global assessments by the United Nations Environment Programme (UNEP) of the status and rate of desertification have revealed insufficient basic knowledge of desertification processes. Remote sensing systems would be helpful for the development and implementation of effective anti-desertification programmes while still allowing for development.

16. It is estimated that more than 11 million hectares of forest are destroyed every year. More than one half of the world's tropical forests have disappeared since the beginning of the twentieth century. An incalculable number of trees have been lost, primarily as a result of over-exploitation of timber resources, overgrazing by livestock, clearing for agricultural land and other non-suitable land-use practices. Remote sensing and geographic information systems can provide better modelling capabilities that would allow demographic trends and factors to be integrated into ongoing studies of environmental impact.

17. The need for securing the multiple roles of forests and forest land by adequate and appropriate institutional strengthening has been repeatedly emphasized in many of the reports, decisions and recommendations of UNEP, the Food and Agriculture Organization of the United Nations (FAO), the World Bank, the International Tropical Timber Organization, the International Union for Conservation of Nature and Natural and Resources and other regional and international organizations. Agenda 21 stressed the fact that remote sensing technologies can play a vital role in managing forests in a sustainable manner.

18. Remote sensing systems are one of the most important sources of information on the Earth's climate system, which is influenced by the thermodynamic and dynamic states of the atmosphere, energy and water transport in the atmosphere and their exchanges at the Earth's surface. Changes in climate need to be monitored because of their potential for dramatic changes in the Earth's environment.

19. Data from both developed and developing countries are needed to obtain an improved understanding of the ocean-atmosphere interaction in climate models and of ocean circulation and the transfer of energy. Such data would also provide more reliable estimates of the mass balance of ocean ice sheets and a better monitoring of dynamic coastal processes.

20. Natural disasters can be defined as extreme occurrences of natural phenomena that inflict damage and outstrip the ability of an affected society to cope with them. Behind these events often lie chronic problems stemming from the interaction of natural, environmental and human-induced factors.

21. New technologies, both terrestrial and space-based, have contributed to the study of natural disasters, their prediction and their prevention and have provided relief of their effects. Remote sensing satellites can provide essential information for the preparation of hazard-risk maps, which are important in the planning of new developments, and possible relief and mitigation operations.

22. With the establishment of remote sensing satellite systems, a unique capability to collect, process, archive and distribute satellite-obtained environmental data on a continental or global scale has already been achieved. Such systems, together with Geographical Information System (GIS) technologies, are increasingly being used in developing countries to fill the gap in current information on natural resources, land use and the impact of natural disasters.

23. The capabilities that are being provided by Earth observation satellites are now being incorporated in most developed countries. Some developing countries will need short-term assistance, first, in identifying technologies that are useful in their particular conditions and, secondly, in providing satellite data to their decision makers, thereby promoting awareness of the usefulness of such data; they will also need long-term assistance in strengthening their national capacities to generate such information in an effective and timely manner.

24. Sufficient training and educational possibilities are critical in successfully integrating remote sensing and GIS technologies into national development plans. Training is required at a variety of levels and in a number of forms, ranging from seminars lasting 1-7 days for senior resource management personnel, or classes lasting 2-12 weeks for advanced technical personnel, to training at the undergraduate and graduate levels for candidates for university degrees.

25. Recognizing the importance of training, a number of regional and international organizations and agencies offer various training programmes. Despite those efforts, the lack of trained personnel in developing countries continues to be a critical constraint on the full exploitation of remote sensing and GIS technologies for a variety of short-, medium- and long-term applications for development purposes.

26. Since its creation in 1971, the United Nations Programme on Space Applications has been the primary vehicle through which the United Nations has worked to increase the awareness on the part of policy makers and the government agencies concerned of the benefits that can be derived from space technology, in particular remote sensing, and to organize training and education programmes to enable officials from developing countries to gain practical experience in the applications of such technology.

27. Through the United Nations Programme on Space Applications, the Office for Outer Space Affairs has led an international effort to establish centres for space science and technology education in developing countries in the regions covered by the regional commissions of the Economic and Social Council. The centres, which will be affiliated with the United Nations, will provide in-depth education (nine months or longer) to university professors and researchers and to application specialists, initially in the fields of remote sensing and GIS and subsequently in all areas of space science and technology.

28. In order to optimize the use of intellectual and material resources, the centres will begin in one or two countries in each region and will grow into a network of complementary nodes, each of which will be associated with a university or space institution with existing educational programmes. The first of the centres, for the region of Asia and the Pacific, was established in November 1995; its first node is in India. A similar centre, for the region of Latin America, is expected to be established in 1996; its initial nodes will be in Brazil and Mexico. Work is currently in progress to establish such centres in the regions covered by the other regional commissions.

29. A variety of other programmes relating to space applications for environmental protection and economic development exist within the United Nations system and other international organizations. For example, FAO

operates African Real-Time Environmental Monitoring using Imaging Satellites (ARTEMIS) in support of its Global Information and Early Warning System on Food and Agriculture.

30. ARTEMIS is a highly automated data acquisition, image processing, production and archiving system for real-time determination of precipitation and near real-time assessment of the condition of vegetation. The system utilizes visible and infrared data and is particularly useful for producing estimates of expected agricultural yields. The vegetation condition assessment capability is currently being expanded to include Asia and Latin America.

31. In the light of the magnitude of the losses caused by natural disasters and the need for a global initiative, the General Assembly, in its resolution 44/236 of 22 December 1989, proclaimed the International Decade for Natural Disaster Reduction, beginning on 1 January 1990. The Decade was launched with the objective of reducing through concerted international action, especially in developing countries, the loss of life, property damage and social and economic disruption caused by natural disasters such as earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions, wildfires, grasshopper and locust infestations, drought and desertification and other calamities of natural origin.

32. In the area of preservation of the environment, a programme named GEOMANAGEMENT has been initiated by the European Space Agency (ESA) as an umbrella concept for improving environmental management practices. This programme is based on the use of geographically referenced data and other information obtained by means of remote sensing satellites.

33. Participation in GEOMANAGEMENT programmes and projects at the international, national or local level requires a clear identification of priority environmental issues. Agenda 21 should serve as a basis for identifying national priorities (e.g. industrial pollution, waste management, land use, deforestation and the exploitation of renewable resources). Activities that could improve the operational use of space technology in this connection are the dissemination of local satellite data receiving stations, increased accessibility to environmental data and the stimulation of data sharing between international, regional and national organizations and agencies.

34. The Mercure system, a satellite-based communications system donated to UNEP by ESA member States, has also been developed to support sustainable development. Its objective is to provide UNEP with the means to make its global environment activities more efficient and to strengthen its role in the execution of Agenda 21, thereby stressing the importance of monitoring Earth's environment.

35. The Mercure system provides global access to important database systems maintained by UNEP such as the Global Resource Information Database (GRID), the International Referral Service for Sources of Environmental Information (INFOTERRA) global environment information exchange network, the Global Environment Monitoring System (GEMS) and similar databases of organizations and entities cooperating with UNEP.

36. Another important initiative for global environmental monitoring is the Tropical Ecosystem Environment Observation by Satellite (TREES) project, sponsored jointly by ESA and the Joint Research Centre of the European Commission. Its main objectives are as follows: (a) the development of techniques for a global tropical forest inventory using satellite systems, including techniques for detecting, monitoring and measuring deforestation rates in critical areas; and (b) the development of a comprehensive tropical forest information system that will also be used to support the modelling of tropical deforestation dynamics.

37. The Panamazonia Project was proposed, and is being implemented, as a cooperative project among countries whose national boundaries include a part of the Amazon subregion. The overall objective of the Project is to develop a system to monitor the tropical forest in Latin America using a remote sensing satellite system. The main goal of the Project is to obtain data that will facilitate repetitive monitoring of the South

American rain forest. It is anticipated that the Project will provide a database for planning the management and preservation of the Amazon environment.

38. To implement remote sensing satellite systems in national plans for social and economic development, a more effective coordination policy has to be established in many developing countries. There are examples of highly qualified individuals in well-equipped remote sensing laboratories who are not contributing to national plans because of insufficient communication with national policy and decision makers.

39. There is a need to strengthen coordination and to improve the performance of space-related international organizations in providing experience in remote sensing technologies, especially to developing countries. Institutions with experience in remote sensing should cooperate in the provision of expertise and other support and in the promotion of international research efforts, in particular with a view to enhancing data exchange and specialized training and ensuring access to experiences and research results.

40. The pricing and independence of remote sensing data are critical in incorporating remote sensing into national programmes. Governments and agencies should therefore be encouraged to reduce prices on remote sensing data and to loosen copyright restrictions.

41. Global concern for the environment and sustainable development has led Governments to cooperate further and to make available to other Governments a wider range of space-based technologies and know-how. Many policy issues need to be reviewed if remote sensing technologies are to be further developed in a world facing economic recession and limited financial resources. Such policy issues include financing, technology transfer, data dissemination, national, regional and international cooperation, institutional arrangements and national security.

Notes

[1]*Official Records of the General Assembly, Forty-ninth Session, Supplement No. 20* (A/49/20), para. 29.

[2]*Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992* (United Nations publication, Sales No. E.93.I.8 and corrigenda), vol. I: *Resolutions Adopted by the Conference*, resolution 1, annex II.

[3]Ibid., annex I.

[4]Ibid., annex II, para. 1.6.

[5]Ibid., vol. III: *Statements Made by Heads of State or Government at the Summit Segment of the Conference*.

*Annex**

STUDY BY THE SECRETARIAT ON THE USE OF REMOTE SENSING TECHNOLOGIES FOR ENVIRONMENTAL APPLICATIONS, PARTICULARLY IN SUPPORT OF THE RECOMMENDATIONS OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT

CONTENTS

INTRODUCTION

1. Since its formation roughly 4.5 billion years ago, the Earth and its surface have undergone significant changes in their physical configuration. Indeed, the entire history of the planet should be seen as a dynamic continuum, with changes occurring constantly. Presently, however, the rate of change of several key components of the Earth system is increasing. Human activities are the main impetus for this increased rate of change. Changes are now occurring so rapidly, that within the span of a single human lifetime significant ecological effects of human activities can be measured.

2. The United Nations Conference on Environment and Development (UNCED) in 1992 in Rio de Janeiro, Brazil, addressed the pressing environmental and developmental problems of today and also aimed at preparing the world for the challenges of the next century. It was stressed that only the increased integration of environment and development concerns and greater attention to them will lead to the fulfillment of basic

*The present study has not been edited.

needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future.

3. The concept of sustainable development is based on the goal of maintaining a balance between human needs and economic development within the parameters of environmental conservation. A specific action plan on sustainable development was developed at UNCED. The plan, contained in the Agenda 21 formulated by the Conference, called for expanded global initiatives related to sustainable development, specifically recognizing the important contribution that space technology can make to environmental monitoring.

4. The recent past has shown that space based observations of the Earth can play a vital role in providing feasible solutions to many environmental and developmental problems. Satellite remote sensing has become the most effective way for natural resource managers to view and analyze land, water and other natural resources, even in inaccessible areas at any season of the year. This technology, now available in one or more forms to most organizations and authorities dealing with resource management, is opening new possibilities for the improved and sustainable development of the Earth's resources at relatively low cost compared to conventional ground monitoring techniques.

5. Remote Sensing is defined, literally, as the observation of physical properties of an object from a distance. For environmental monitoring and resource management, the term is used as a contraction of "remote sensing of the near Earth surface environment", which generally includes the Earth's surface, the atmosphere and the subsurface of the land and water to the depth it can be observed from the normal observational range of hundreds or thousands of meters using airborne cameras or other instruments to the hundreds or thousands of kilometres altitudes of earth orbiting satellites.

6. The technique of remote sensing includes photography, as well as the use of passive and active radar, laser, and optical and multispectral scanners. For land and environmental resource management, photography, multispectral scanners and radar have become the most widely used sensors in present Earth observation systems. Aerial photography has been used for many resource and environment applications since the 1930s, and more sophisticated airborne scanner and radar instruments have been employed since the 1960s. However, it was not until operational space research programmes were implemented that high quality, distortion-free remote sensing images became available throughout the world. This wide availability of image data encouraged the development of dramatically improved analysis techniques, widening the range of potential applications. Further improvements in sensor characteristics, longer satellite life cycles and computer technology have improved the accessibility of meaningful information for environmental monitoring.

7. Remote sensing technologies have been developed primarily in the industrialized world. Many developing countries seek to use these technologies for their development plans and programmes, yet most of these countries are still not prepared to implement remote sensing due to the high cost of remote sensing data, limited manpower and funding resources and a lack of organizational structures.

8. Taking into account the context of the social and economic situations in particular of developing countries, the following study will focus on Earth observation through space systems including national, regional and international programmes, considering the goals of Agenda 21 for sustainable development.

I. AGENDA 21 AND THE CONTRIBUTION OF SPACE TECHNOLOGY

9. Agenda 21 contains the detailed considerations, conclusions and recommendations adopted by UNCED. Agenda 21 is a comprehensive plan of action for the sustainable development of the Earth's resources, encompassing virtually all aspects of the environment and economic development.

10. Agenda 21 contains a total of 35 chapters on substantive themes, and those chapters contain some 114 specific programmes covering all aspects of environment and development. For each of those programmes, Agenda 21 defines the basis for action, the objectives, the activities and the financial and other means required for their implementation. The programmes include activities at the national, regional and international levels.

11. The focus of Agenda 21 is on practical actions that need to be taken on the ground to protect the environment and promote sustainable development. In support of that effort, consideration is also given to the need for studying and monitoring the environment on a continuing basis.

12. In a number of areas, such as land use planning and management, deforestation, desertification, water resource assessment, environmental pollution and scientific studies of environmental dynamics, the value of space technology applications is already well recognized. In these and many other areas, Agenda 21 calls for expanded and improved environmental protection, data collection and resource survey activities in which space technology can also play a vital role.

13. Space technologies of interest with respect to Agenda 21 are primarily Earth observation technologies, including both remote sensing of the environment and natural resources and meteorological and climatic observations of the surface and the atmosphere. Communication satellites, broadcasting satellites, navigation satellites, search and rescue satellites and other space systems can also contribute in more indirect ways to the goals of Agenda 21.

14. Satellite communications systems play an important role in the collection of environmental data and distribution of information, especially when rapid action is required, for example in case of natural disasters such as earthquakes, severe storms or floods.

15. Compared with ground surveys, satellite observations provide less detail, but much greater economy, particularly where repetitive monitoring is required. Satellites are particularly advantageous, therefore, for regular, low-cost environmental monitoring of large areas. Large-scale phenomena or patterns that are not visible to a ground observer can often be seen on satellite images; transboundary phenomena that can be logistically difficult to survey from the ground or air offer no difficulty to space observations; environmental changes that occur gradually over periods of years or decades can be measured from the satellite images regularly acquired by the same sensors under the same conditions; and transient atmospheric or oceanographic phenomena can be followed by daily or hourly observation by weather satellites. In general, remote sensing images provide a unique and invaluable database for studying and documenting past, present and future environmental changes.

16. Satellites cannot, of course, be used directly to prevent environmental degradation; they can merely observe the situation on the ground. Those observations can be used for a number of purposes. In the case of ocean and climate dynamics, for example, satellite observations are used to observe sea-surface temperature and current patterns in order to improve the understanding of their effect on weather patterns and predict the long-term effects of climate change.

17. In the case of forestry, agriculture and rangeland, satellite data can reveal gradual degradation processes, allowing planners to develop effective policies for sustainable development. When environmental policies are adopted, satellite observations can be used to monitor the effectiveness of the policies and to revise the policies when necessary.

II. REMOTE SENSING ACTIVITIES FOR SUSTAINABLE DEVELOPMENT

A. Sensor Systems

18. The Advanced Very-High Resolution Radiometer (AVHRR) carried by the United States National Oceanographic and Atmospheric Administration's (NOAA) polar-orbiting satellites is the most commonly used source of remote sensing data at the continental and global scale. With 1.1 and 4 kilometer pixels, it covers a swath width of 2,500 kilometers per acquisition, and passes over the same place on the Earth every 12 hours.

19. For more localized environmental analysis, the first remote sensing satellite was the Earth Resources Technology Satellite (ERTS-1), later renamed LANDSAT. It provided a spatial resolution of 80 meters with a swath width of 185 kilometers by using the Multispectral Scanner (MSS) instrument. The satellite had four bands, corresponding to the green, red, and two near-infrared spectral regions.

20. While the first three LANDSAT's and their MSS instruments were a major step forward in providing digital satellite environmental and natural resource data, the user community also realized the need for better spatial capabilities. This led to the development of the Thematic Mapper (TM) on LANDSAT's 4 and 5, which has 30 meter resolution.

21. The French SPOT satellite has two different sensors, which have either 20 meter multispectral or 10 meter panchromatic spatial resolution. SPOT has three channels, and can receive infrared data that can be used to create land use and land cover maps. SPOT satellite data are used in cartography, agriculture, vegetation, forestry, geology, coastal studies, and town planning applications.

22. Additional satellites of the SPOT series are also planned. SPOT-5 and SPOT-6 are scheduled for launch in 1999 and 2003, respectively. Each will have 5 m ground resolution capabilities. Licenses for the operation of higher resolution satellites have been requested in the United States and the data of these high resolution (1 m resolution) shall be provided to the user community in the near future.

23. The Russian Federation is currently providing the highest spatial resolution data available on the market with the short term mission of RESURS-F, the ALMAZ and METEOR- PRIRODA systems and their ground resolution of 2 m. With the development of JERS-1 (Japanese Earth Resource Satellite) and MOMS (Modular Optoelectronic Multispectral Scanner), respectively, Japan and Germany are also among the key players in the Earth observation technology. A number of developing countries have also made outstanding progress in the development of satellites for Earth observations. The Indian Remote Sensing Satellite (IRS), for example, has already made a substantial contribution to global environmental monitoring.

24. The Indian Remote Sensing Satellites IRS-1A and IRS-1B were launched in 1988 and 1991, respectively. The satellites were entirely produced in India and are currently operating with the on board Linear Imaging Self-Scanning Sensor-1 (LISS-1) and LISS-2 and acquire important data for the environment. India's most recent remote sensing satellite IRS-1C, which was launched in December 1995, carries a multispectral LISS-3 camera, providing images with a spatial resolution of 23 m. This camera is also capable of producing images in the near infrared band (1.55 - 1.70 micrometers wave length). Other cameras on board are the panchromatic camera with a spatial resolution of 5.8 m and the Two-Band-Wide Field-Sensor with a swath width of 800 km.

25. Low resolution satellites that are very valuable for understanding global changes are the NOAA-POES (National Oceanic and Atmospheric Administration Polar-orbiting Operational Environmental Satellite) with the Advanced Very High Resolution Radiometer (AVHRR), the NOAA-GOES (Geostationary Operational Environmental Satellite) and the new TOPEX-POSEIDON (Topography Experiment for Ocean Circulation)

system. Relevant meteorological systems for understanding global effects on the environment include Nimbus, Meteosat and Insat.

26. An important contribution to continued Earth observation from space is the European Remote Sensing satellite (ERS) system which, due to the radar technology used, does not rely on solar illumination and is largely independent of weather conditions. Thus, ERS-1 and -2 can provide data at selected time intervals within the 24 hours of each day. Although ERS was not specifically planned to meet the needs of developing countries, its data today play a vital role in particular in the field of environmental monitoring, food production, soil moisture estimation and climate change.

27. ERS-1 was launched in July 1991 and carries several microwave sensors on board. Its primary instrument is the Active Microwave Instrument (AMI), which can provide high-resolution images (in C-band), wind speed through ocean wave spectra analyses and the length and direction of waves. While in an imaging mode, the AMI covers a swath width of 80 - 100 kilometers, with a resolution of the order of 27 metres in the range direction and 29 metres in the azimuth direction.

28. ERS-1 also carries a Radar Altimeter (RA) that operates at a wavelength of 2 cm. This altimeter is used to measure average wave height, wind speed and to determine meso-scale ocean topography. Data from this altimeter has been used successfully to determine ice type and topography as well as water/ice boundaries.

29. A third instrument on board ERS-1 is the Along Track Scanning Radiometer (ATSR) that operates in three bands in the thermal region of the EM spectrum. These bands are centered around 3.7, 11 and 12 micrometers. The ATSR looks through the atmosphere at the surface of the ocean from two directions, downwards vertically and at an incidence angle of 50°. The difference between the oblique and vertical measures provides information on atmospheric absorption while the differences between measurements at the three wavelengths are used to determine atmospheric water vapour content. ERS-1 will continue to supply data concerning the Earth and its natural resources. With the recently launched ERS-2 satellite, which will provide data similar to its predecessor, and RADARSAT, Canada's radar-equipped satellite for global land use and vegetation monitoring, the continuity of data will be ensured.

30. RADARSAT, which was launched in November 1995, is an advanced Earth observation satellite project developed by Canada to monitor environmental change and to support resource sustainability. With the planned lifetime of five years, it is equipped with a single C-band Synthetic Aperture Radar (SAR) which has the unique ability to shape and steer its radar beam over a 500 km range. Users will have access to a variety of beam selections that can image swath from 35 km to 500 km with resolutions from 10 m to 100 m respectively. Incidence angles range from less than 20 degrees to more than 50 degrees.

31. RADARSAT can provide complete global coverage through the satellite's 24 day orbital repeat cycle. Using the 500 km swath, it can provide daily coverage of the Arctic, and complete coverage of equatorial latitudes every six days. Normally, data are transmitted to ground stations for processing. However, its two onboard tape recorders enable data to be recorded over any region of the Earth, even when the satellite is out of range of ground stations.

32. The Japanese Earth Resources Satellite (JERS-1), launched in 1992, is also equipped with a Synthetic Aperture Radar (SAR) sensor. This sensor system operates in the L band (0.39 - 1.55 GHz). JERS also carries a Visible and Near Infrared Radiometer (VNIR) and a Short Wavelength Infrared Radiometer (SWIR); both instruments provide a spatial resolution of 18 m x 24 m. This satellite is equipped with an on-board recorder for transmission of gathered data when it comes within line of sight of one of its ground receiving stations.

33. Existing and planned Earth observation satellites will continue to provide large amounts of data relevant to the Earth's environment. A new generation of space systems carrying complex instruments will include

the United States Earth Observing System (EOS), ESA's Polar and Earth Observation Mission (POEM) and the Japanese Polar Orbiting Platform (JPOP).

B. Resource Management and Environmental Monitoring

34. Though remote sensing and Geographic Information Systems (GIS) are standard tools in developed countries, these technologies are just beginning to be used in some developing countries. Other countries such as Brazil, China, India, Morocco and Pakistan, already use such systems for various environmental and natural resource management applications. Nevertheless, the urgency of pressing environmental issues emphasizes the need for these technologies and their proper implementation in all countries.

35. The adoption of GIS and operational remote sensing in developing countries is mainly hindered by the high initial investment requirements and a lack of understanding by decision-makers of the full potential of these technologies in the planning and management processes. Despite these hurdles, there has been a steadily growing interest in GIS and remote sensing technologies. Advances in the development of PC based software packages for image processing and GIS, and the decreasing costs of these packages, are making the necessary technological tools increasingly attractive and accessible to developing countries. Their increased use will help these countries strike a reasonable balance between resource use and sustainable development.

36. In the Philippines, for example, remotely sensed data are processed to compile land use maps which are then used as a reference in establishing resource development and environmental management policies. Other examples include the use of multispectral and panchromatic images for the development of environmentally sound policies for farming and irrigation in Burkina Faso, Indonesia and Morocco. These programmes are supported by the World Bank, the Food and Agriculture Organization of the United Nations (FAO) and the European Commission.

37. While in some areas in developing countries the construction of large water reservoirs to ensure irrigation and drinking water have contributed significantly to mitigate the effects of drought, poor and inefficient management of land and water resources has resulted in massive land degradation due to salinity, large amounts of alkali, waterlogging, etc. In this context, satellite remote sensing has been applied successfully to increase the efficiency in managing land and water resources. In India and Pakistan, for example, remote sensing data are currently being used to delineate waterlogged and saline areas to determine their ecological impact.

38. Satellite remote sensing is also being used for monitoring environmental changes due to mining and the operation of large thermal power plants in India and in the Loess Plateau in China. Some specific studies are being carried out in India regarding the industrial pollution of major rivers in the country as well as the selection of appropriate sites for locating distilleries to prevent groundwater pollution. Potential sites for dams and irrigation schemes along tributaries of the Niger River in the Sibra region of Burkina Faso (Sahelian country) were identified using GIS and satellite remote sensing data.

39. In India, a project applying cost-effective remote sensing techniques at the village level has recently been launched. The project is aimed at investigating land and water resources to map "Basic Integrated Land and Water Resource Units" in the Anantapur district, located in the south-west of Andhra Pradesh State.

40. Detailed natural resources mapping on a 1:50,000 scale has recently been made using data of India's remote sensing satellite IRS-1A. The scientific information obtained through remote sensing data analyses were validated in the field by several experts. Several projects at the national level recently have become operational, relating in particular to land use and forest mapping, wasteland mapping and drought monitoring.

41. Based on the encouraging results of the pilot studies carried out in the Anantapur district, a nationwide project entitled "Integrated Mission for Sustainable Development" has been launched in 172 districts spread

over the whole country. These districts, which are frequently affected by droughts and floods and cover 45% of India's geographical area, are now under intensive research supported by satellite remote sensing systems.

42. However, for the utilization of Earth observation satellite data in developing countries to be increased, there needs to be coordinated efforts by the international space community to focus on areas which are essential for sustainable development. These areas include the assurance and continuity of remote sensing data by satellite operators, technical assistance in the implementation and operation of ground stations, access to data and price reductions, training and education for efficient and timely data processing and analysis, and increased efforts among national, regional and international aid agencies to coordinate programmes and project support.

C. International Cooperation and Interregional Programmes

43. Building indigenous capacity to implement Agenda 21 will require the efforts of the countries themselves in partnership with relevant United Nations organizations, as well as with developed countries. The international community at the national, subregional and regional levels, non-governmental organizations, universities and research centres, and business and other private institutions and organizations should also assist in these efforts. Transnational cooperation will be essential to increase the awareness of national decision-makers of the potential of space technology to improve living and environmental conditions.

44. International cooperation is effective only when it is derived from and related to a country's own strategies and priorities on environment and development and when development agencies and governments define improved and consistent policies and procedures to support this process.

45. It is essential for individual countries to identify priorities and determine the means for building the capacity and capability to implement Agenda 21, taking into account their environmental and economic needs. Skills, knowledge and technical know-how at the individual and institutional levels are necessary for institution building, policy analysis and development management, including the assessment of alternative courses of action with a view to enhancing access to and transfer of technology and promoting economic development.

46. International cooperation, including that related to technology transfer and know-how, encompasses the whole range of activities to develop or strengthen individual and group capacities and capabilities. It should serve the purpose of long-term capacity-building and needs to be managed and coordinated by the countries themselves.

47. A variety of programmes relating to space applications for environmental protection and economic development exist within the United Nations system and other international organizations. In achieving sustainable development, environmental monitoring through space remote sensing can constitute an integral part of the development process and should not be considered in isolation from it.

48. A number of interregional programmes relying on remote sensing applications include mapping, assessment and monitoring of renewable natural resources and natural disasters, environmental monitoring, desertification control and vegetation monitoring. Also, special projects are being carried out in marine pollution, tropical forest management and assessment of water and fisheries resources.

49. A milestone in international cooperation related to space technology application has been undertaken with the signing of the agreement of a group of member states of ESA with the United Nations Environment Programme (UNEP) to jointly finance a satellite system called MERCURE. Its objective is to provide UNEP with the means to make its global environment activities more efficient and to strengthen its role in the execution of Agenda 21, thereby stressing the importance of monitoring the Earth's environment.

50. The MERCURE system, a satellite based communications capability donated to UNEP by member states of ESA, has also been developed in support of sustainable development. Six European countries have provided the space segment and 16 antennas with their related hardware and software. It will provide UNEP with two different networks: subnet A, the backbone, using 7.3 meter antennas providing 384 kb/s, and subnet B for remote areas using 2.4 meter antennas providing 64 kb/s. The backbone system will be based on 64 channels each of which will have a capacity of 384 kb/s. Two INTELSAT satellites, one over the Atlantic and the other over the Indian Ocean, will be used.

51. UNEP currently transmits about six million pages of information to 3,000 recipients. Telecommunications costs have quadrupled over the past few years to the current level of $4 million annually. The service based on MERCURE will be much more effective and the cost to UNEP will be only $6 million over a period of four years.

52. The MERCURE system will also provide much wider access to the Internet in Africa. In addition, it will facilitate a much more efficient means of disseminating documents, environmental data, images and messages, and will result in substantial savings in telecommunications costs.

53. The MERCURE system will provide global access to important database systems maintained by UNEP programmes such as the Global Resource Information Database (GRID), the INFOTERRA Global Environment Information Exchange Network, the Global Environment Monitoring System (GEMS) as well as similar databases residing in other organizations and entities cooperating with UNEP.

54. Since 1988, after a development period of 3 years, the FAO Remote Sensing Centre has been operating African Real-Time Environmental Monitoring using Imaging Satellites (ARTEMIS) in support of the Global Information and Early Warning System and the Desert Locust Plague Prevention Programme of FAO.

55. The ARTEMIS system was implemented by FAO in close cooperation with NASA, Goddard Space Flight Centre, United States of America, the National Aerospace Laboratory of the Netherlands and the University of Reading, United Kingdom of Great Britain and Northern Ireland. ARTEMIS is a highly automated data acquisition, image processing, production and archiving system for real-time determination of precipitation and near real-time assessment of the condition of vegetation. The system utilizes visible, infrared and NOAA-AVHRR data. The vegetation condition assessment capability is currently being expanded to include Asia and Latin America.

56. ARTEMIS data products, generated by the system on a 10-day and monthly basis, are currently used operationally by a variety of users at FAO Headquarters and by regional and national food security early warning systems in 16 Eastern and Southern African countries. The ARTEMIS system plays an important role in the generation and archiving of global satellite derived environmental data sets for use by FAO and other organizations with global monitoring and assessment mandates.

57. An extensive ARTEMIS rainfall estimation calibration programme, covering Sahelian countries as well as Eastern and Southern Africa, has been developed in cooperation with the University of Reading, United Kingdom, and regional field projects. This programme was started in 1990 and will continue through 1995 to obtain statistically valid regression parameters for homogeneous climate zones to allow automated translation of satellite-derived data on average cloud duration into quantities of estimated rainfall.

58. Jointly with ESA, FAO has been implementing during 1989 - 1992 a dedicated satellite communications system, DIANA (Direct Information Access Network for Africa), which allows real-time transmission of high volume ARTEMIS digital products to user terminals in Accra, Ghana, in Nairobi, Kenya, and in Harare, Zimbabwe. The DIANA system, which operates through the INTELSAT satellite over the Indian Ocean and the Italian INTELSAT groundstation of TELESPAZIO in Fucino, is currently being tested and demonstrated for a wide variety of applications of an operational, technical and administrative nature.

59. In 1993, FAO and UNEP, in close cooperation with ESCAP, initiated a long-term regional environmental information technology development programme named OLIVIA ("Operational Low-Cost Integrated Vital Information Access"), aiming at implementing information technologies for natural resources and environmental management in the Asian and Pacific region. The OLIVIA Programme should support and strengthen cooperative decision-making relevant to sustainable environment and natural resources management in agriculture, forestry and fisheries in Asia and the Pacific, with particular emphasis on standardized and harmonized data and information exchange between interregional programmes.

60. Currently FAO is starting to implement a new project, AFRICOVER to produce a digital geographic database and associated thematic map of land use and vegetation cover of the whole African continent. The first phase of the AFRICOVER project is being implemented in East Africa. The map of the entire continent will be produced at scales 1:250,000 and 1:1,000,000. The overall objective of AFRICOVER is to provide the African decision-makers, regional and international development agencies and United Nations organizations with reliable information on current land use and vegetation cover.

61. Scientific and technological cooperation between developing countries and the European Commission is becoming an increasingly important and comprehensive activity concerning the transfer of technology and know how. In this context, the European Commission has launched a study on "Analysis of the Constraints and Opportunities for Cost-Effective Implementation of Earth Observation Techniques in Developing Countries". The overall objective of this study is to assist decisions on future European investments in space technology applications by providing an assessment of potential opportunities for Earth remote sensing in developing countries.

62. Environmental resource management is an activity involving a well defined community, who needs a wide range of rather specific tools and data types, for a wide range of activities, going from data acquisition to decision-making and control. In this context, GEOMANAGEMENT, which is based on geo-referenced data and information derived by remote sensing satellites, has been developed by ESA as an umbrella concept for typical environmental management practices.

63. GEOMANAGEMENT programmes and projects at international, national or local levels should be defined on the basis of a clear identification of priority issues. Agenda 21 should serve as a basis for identifying national priorities such as industrial pollution, waste management, land use and allocation, deforestation and the exploitation of renewable resources. Activities which could improve the operational use of space technology in this connection are the dissemination of local receiving stations, increased accessibility to environmental data and the stimulation of data sharing between international, regional and national organizations and agencies.

64. Another important initiative for global environmental monitoring is the Tropical Ecosystem Environment Observation by Satellite (TREES) project, jointly sponsored by the Joint Research Centre of the European Commission and ESA. Its main objectives are the development of techniques for a global tropical forest inventory using AVHRR and ERS-1 data, including techniques for detecting, monitoring and measuring deforestation rates in critical areas, and the development of a comprehensive Tropical Forest Information System. The Tropical Forest Information System will also be used to support the modelling of tropical deforestation dynamics. In the future, research methodologies will be tested for monitoring deforestation and other data sources, including SPOT and ATSR-2 will be examined.

65. In 1992, the Panamazonia Project was proposed with the objective to develop a system to monitor the tropical forest in Latin America using satellite remote sensing. A technical team was selected from experienced agencies in Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname and Venezuela. The main goal of the project is to develop a data set that will allow the easy and repetitive monitoring of the South American rain forest. It is anticipated that the Panamazonia Project will provide a database to plan the management and preservation of the Amazonia environment.

66. Satellite data obtained from the NOAA series of meteorological satellites and the METEOSAT geostationary satellite are operationally used in near-real time to provide objective assessment of famine early warning for Africa. Advantages of the use of time-series satellite data are timeliness and consistency. When combined with ground-collected socio-economic information, an integrated assessment of distributed agricultural potential is possible at a fraction of the cost of traditional inventories.

67. This is the approach taken by the United States Agency for International Development's Famine Early Warning System (FEWS) and by FAO's Food Security Programme. In addition to providing spatially continuous and objective information in a timely fashion for a complete continent, these satellite-based early warning systems enable famine relief resources to be directed to those areas most affected at a fraction of the cost of previous methods of relief allocation for Africa.

68. Sufficient training and education possibilities are critical in successfully introducing remote sensing and GIS technologies into national development plans. Training is required at a variety of levels and in a number of forms, from one-day to one-week seminars for senior resource management personnel to two-week to three-month training classes for advanced technical personnel, to university degree training at undergraduate and graduate levels. Recognizing the importance of training, a number of regional and international organizations and agencies offer various training programmes. However, despite these efforts, the lack of trained personnel in developing countries continues to be a critical constraint on the full exploitation of remote sensing and GIS for developmental purposes.

69. Through the United Nations Programme on Space Applications, the Office for Outer Space Affairs has led an international effort to establish Centres for Space Science and Technology Education in developing countries of the regions of the United Nations regional commissions. The Centres would provide in-depth education (nine months or longer) to university professors and researchers as well as for application specialists, initially in the fields of remote sensing and GIS and subsequently, in all areas of space science and technology. These Centres would begin in one or two countries of each region and grow into a network of complementary nodes, each of which would be associated to a university or space institution with education programmes to optimize the use of intellectual and material resources. The first of these Centres has been established in November 1995 for the Asian and Pacific region, with its first node located in India. A similar Centre is expected to be established in Brazil and Mexico in 1996 for the Latin America region. Work is currently on-going to establish such Centres in the regions covered by the other regional commissions.

III. ENVIRONMENTAL CHALLENGES

70. The Agenda 21 Programme of Action for Sustainable Development adopted at UNCED recognizes the importance of Earth observation and GIS for systematically obtaining objective, synoptic and holistic data on the state of the environment. UNCED also determined that within the United Nations system and other relevant international organizations, data collection activities such as remote sensing should be strengthened and that these data should be analyzed and applied to the objective of sustainable development.

71. In a number of areas of Agenda 21, such as population growth, desertification, deforestation, climate changes and disaster management, the important contribution that space technology can make to environmental monitoring and sustainable development is already well recognized. In other areas space technology is seen to play a significant role in expanded and improved monitoring, data collection and resource survey activities.

A. Population Growth

72. The growth of world population and production combined with unsustainable consumption patterns places increasingly severe stress on the life-supporting capacities of the Earth. These interactive processes

affect the use of land, water, air, energy and other resources. Human dimensions are key elements to consider in this intricate set of relationships and they should be adequately taken into consideration in comprehensive policies for sustainable development. Such policies should address the linkages of demographic trends and factors, resource use, appropriate technology dissemination and development.

73. In this context, demographic trends and factors should be integrated into ongoing studies of environmental changes, using the expertise of international, regional and national research networks. In integrating demographic analysis into a broader social sciences perspective of environment and development, the use of remote sensing technologies will play a vital role. National, regional and international space agencies should therefore enhance their scientific capacity and disseminate the experience gained to the user community.

74. Remote sensing can provide better modelling capabilities, thereby identifying the range of possible outcomes of current human activities, especially the interrelated impact of demographic trends and factors, per capita resource use and wealth distribution, as well as the major migration flows which may be expected with increasing climatic events and cumulative environmental change that may destroy people's local livelihoods.

75. Socio-demographic information, interfacing with physical, biological and socio-economic data, should be gathered including the use of satellite remote sensing data to provide compatible spatial and temporal scales, cross-country and time-series information.

76. Within the next 35 years, the world's population will increase by 50%, from about 6 billion in 1995 to about 9 billion in 2030. Food production therefore will have to be increased, which requires a more efficient management of natural resources. There is no doubt that new information technologies of remote sensing and GIS will play a vital role in meeting these requirements.

77. Rapidly growing cities, unless well managed, also face major environmental problems. Satellite data are presently widely used for urban planning. In Karachi, Pakistan, for example, satellite data are utilized to plan new infrastructure projects, and in Manila, Philippines, SPOT images help officials monitor the implementation of new development plans. In India, IRS data have been successfully used to align roads and railways in the country. In the United States, maps derived from satellite image are replacing traditional country topographic maps at 1:24,000 scale for day-to-day urban management.

B. Desertification

78. Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification affects about one sixth of the world's population, 70 per cent of all drylands, amounting to 3.6 billion hectares, and one quarter of the total land area of the Earth.

79. The most obvious impact of desertification is the degradation of 3.3 billion hectares of the total area of rangeland, constituting 73 per cent of the rangeland with a low potential for human and animal carrying capacity; decline in soil fertility and soil structure on about 47 per cent of the dryland areas constituting marginal rainfed cropland; and the degradation of irrigated cropland, amounting to 30 per cent of the dryland areas with a high population density and agricultural potential.

80. The global assessments of the status and rate of desertification conducted by UNEP have revealed insufficient basic knowledge of desertification processes. In this context, remote sensing systems will be helpful for the development and implementation of effective anti-desertification programmes.

81. Agenda 21 stressed the fact that desertification will be among the major global environmental concerns in the next decades. In this context, remote sensing technologies will become essential for understanding the dynamics of desertification and drought processes. Remote sensing is also important for developing adequate measures to deal with desertification and drought and improving socio-economic conditions. However, the capacity of existing international, regional and national institutions, particularly in developing countries, to generate and exchange relevant information on desertification is limited.

82. China, with it's vast territory, various physical environments and huge population has been confronting the problem of desertification. Consequently, China has in place a large-scale effort to combat the effects of desertification. This effort has included the implementation of a comprehensive management strategy and a series of engineering and biological measures. These measures have included slope modification, valley construction, soil erosion protection, creation of tree or shrub shelterbelts which helps increase surface roughness and thereby decrease erosion, a major contributory factor in desertification.

83. The Chinese anti-desertification programmes makes significant use of satellites and remote sensing data. Maps of erosion types and erosion intensity are compiled through the use of LANDSAT Thematic Mapper (TM) and Multi-Spectral Scanner (MSS) data. In addition, the Chinese authorities have achieved excellent results in combining geographic analyses with remote sensing interpretation techniques and land survey data allowing the evaluation of the erosion intensity. The use of such maps in China have clearly demonstrated how the use of satellite remote sensing can lead to a better understanding of short-term and long-term erosion processes and improve counter-measures against these problems.

84. Another example of large-scale desertification is the Aral Sea, which is bordered by Kazakstan and Uzbekistan. The area of the sea has shrunk from 68,000 km^2 in the 1950s to 40,000 km^2 today. Satellite imagery has revealed the fact that the shoreline has receded up to 20 km since 1970 and thus illustrate the catastrophic effect of development decisions that were taken without consideration of their potentially adverse effects on the environment. These actions included the massive diversion of water for irrigation of cotton fields which led to the deposit of toxic salts - themselves caused by the overuse of pesticides and industrial pollutants - that have transformed once arable land into dessert.

85. Detailed knowledge of the extent of the phenomena are required in order to go beyond the local studies that have been conducted of the Aral Sea and other similarly affected areas, and to establish policies and programmes to combat desertification and diminishing water resources in these areas. Satellite imagery is an essential component for a coherent approach to the problems of desertification.

86. In India, a remote sensing based National Agricultural Drought Assessment and Monitoring System (NADAMS) has been developed and is currently being used for monitoring seasonal drought conditions based on the vegetation index derived by satellite remote sensing data.

C. Deforestation

87. The need for securing the multiple roles of forest and forest lands through adequate and appropriate institutional strengthening has been repeatedly emphasized in many of the reports, decisions and recommendations of FAO, the International Tropical Timber Organization (ITTO), UNEP, the World Bank, the International Union for the Conservation of Nature and Natural Resources, and other regional and international organizations.

88. Today it is well recognized that remote sensing technologies play a vital role in ensuring awareness, appreciation and management of forests as an indispensable resource system for humanity. Remote sensing related institutions therefore should cooperate in the provision of expertise and other support and the promotion of international research efforts, in particular with a view to enhancing data exchange and specialized training and ensuring access to experiences and research results. However, there remains a need

for strengthening coordination and improving the performance of existing forest related international organizations in providing experience in remote sensing technologies especially to the developing world for management, conservation and sustainable development of forests.

89. It is estimated that more than 11 million hectares of forest are destroyed every year. More than half of the world's tropical forests have disappeared since the beginning of the twentieth century, and an incalculable number of trees have been lost, primarily due to over-exploitation of timber resources, overgrazing by livestock, and other non-suitable land use practices.

90. Deforestation occurs rapidly and is a particular problem in large areas of Africa, Asia and Latin America. These areas must be monitored effectively so that the processes involved can be objectively measured and controlled. Satellite images are now being used to monitor uncontrolled fire logging in Brazil, the retreat of rainforests in Africa and the destruction of forests in south-east Asia.

91. In this context, under the Tropical Ecosystem Environment Observation by Satellite (TREES) programme, the baseline assessment of tropical forest cover using AVHRR has now been completed. SAR data over 18 selected areas has been examined with the purpose of investigating the feasibility of vegetation mapping with ERS-1.

92. LANDSAT TM and SPOT data can be used to assess and monitor damage in coniferous forests and to establish damage patterns. By comparing these patterns with older data, damage factors associated with micro-climate and weather patterns, which can also cause deforestation, can be separated from human induced causes.

93. Detailed forest inventories can be quickly compiled by automatic interpretation. It takes only one hour on a medium-size computer to process a SPOT image covering 60 by 60 kilometers, or 360,000 hectares. Fields down to a quarter of a hectare can be identified in these images and maps based on satellite-derived images offering this same accuracy can be quickly made available to ground survey teams. Such maps provide an excellent overview as well as fine detail.

94. In Australia and Brazil, NOAA-AVHRR data are routinely acquired to detect, map and monitor large bush and forest fires. The method involves the calculation of the decline in the normalized difference vegetation index values across time, so that the sharp drop in greenness values in forest areas that result from intense fires can be detected. While the fires in Brazil are utilized to burn the tropical rainforest to gain farming land and the fires in Australia are mainly caused by dryness, both have devastating effects on the environment and can be effectively monitored by satellites.

95. Particularly in Brazil, enormous amounts of biomass has been burned for fuel production and cleaning the soil for cattle raising and other agricultural uses. Recent satellite images of the Amazonia region dramatically show deforestation patterns, especially in the States of Para, Rondonia and Maranhao. Presently, the Instituto Nacional de Pesquisas Espaciais (INPE), together with other national and international institutions, is studying the Amazonia region using both ground based and satellite remote sensing data. Satellite systems that have been used in this context are ERS-1, ERS-2, IRS, JERS-1, LANDSAT, SIR-C and SPOT.

96. Through the use of space remote sensing systems, worldwide awareness of the on-going deforestation in the Amazonia has been increased, helping to convince national policy- and decision-makers to react to these dramatic changes which degrade not only the regional environment, but also affect the world's climate.

97. However, deforestation and the impact on the health of forested areas is not limited to developing countries. Many developed countries are confronted with the effects of air pollution and fire damage on their forests. There are major weaknesses in the policies, methods and mechanisms adopted to support and develop

the multiple ecological, economic, social and cultural roles of trees, forests and forest lands. More effective measures and approaches are often required at the national level to improve and harmonize policy formulation, planning and programming.

D. Climate Changes

98. Remote sensing systems are also one of the most important sources of information on the Earth's climate system, which is influenced by the thermodynamic and dynamic states of the atmosphere, the energy and water transport in the atmosphere and their exchanges at the Earth's surface. A large amount of information still needs to be collected in order to understand these phenomena.

99. Protection of the atmosphere is a broad and multidimensional endeavour involving various sectors of economic activity. Concern about climate change and climate variability, air pollution and ozone depletion has created new demands for scientific, economic and social information. Remote sensing technologies should therefore increasingly being used to improve the understanding of processes that influence and are influenced by the Earth's atmosphere on a global, regional and local scale, including physical, chemical, geological, biological, oceanic, hydrological, economic and social processes.

100. Understanding the natural environment and its relationship with ecological processes is an essential pre-requisite for undertaking any developmental planning anywhere in the world. While man's dependence on environment is greater than that of any other organisms, his pursuit of progress, comforts and security, etc., have caused more stress on the environment. Global warming as a result of rapid increase in the greenhouse gases in the atmosphere, large-scale effects of acid rain, environmental pollution, etc., have become subjects of serious concern. The volume of CO_2 concentration alone has been steadily increasing, and has increased by 25% in the last century. If the present trends of economic growth continue to depend on expanded use of fossil fuel energy, the effect of global warming could result in change of climate, ozone depletion, rise in sea level, impact on agricultural output and biodiversity. As these changes could ultimately lead to an ecological disaster affecting the entire biotic species on the Earth, scientists across the world are analyzing data for input into various global and regional climate models.

101. Space remote sensing systems are being used to develop early detection systems concerning changes and fluctuations of pressure, density, temperature and humidity in the atmosphere, and also to predict such changes and fluctuations to assess the resulting environmental and economic impacts.

102. The cooperation in the building of scientific capacities, the exchange of scientific data and information, and the facilitation of the participation and training of experts and technical staff, particularly of developing countries, in the field of research, data assembly, collection and assessment and systematic observation related to the atmosphere will be essential in the implementation of successful remote sensing programmes.

103. Data from both developed and developing countries are needed to achieve an improved understanding of the ocean-atmosphere interaction in climate models and to advances in our knowledge of ocean circulation and the transfer of energy. The data would also provide more reliable estimates of the mass balance of ocean ice sheets and a better monitoring of dynamic coastal processes.

104. A relative new element in the research of atmospheric change issues is the recently launched programme of the European Commission entitled European Network for Research in Global Change (ENRICH). The goal of the ENRICH programme is to bring together a critical mass of resources and capabilities in both industrialized and developing countries and to provide a logistical basis for managing collaboration among the involved countries and international research institutes.

105. The World Meteorological Organization (WMO) has adopted a historic resolution defining, for the first time, a policy and recommended practice for the international exchange of meteorological data and products.

This new policy includes the free and unrestricted exchange of meteorological data essential to meteorological and hydrological services. It also meets the requirements of data and information exchange of several international conventions such as the United Nations Framework Convention for Climate Change and the International Convention to Combat Natural Disasters.

106. Regarding education and training in satellite applications, WMO requests that satellite operators participating in WMO's Global Observing System (GOS) should cooperate with at least one of its specialized satellite applications training centres located around the globe. In response to this policy, the EUMETSAT Council has recently decided to co-sponsor two training centres in Africa.

E. Disaster Management

107. Considering the magnitude of the losses caused by natural disasters and recognizing the need for a global initiative, this decade has been declared by the General Assembly of the United Nations as the International Decade for Natural Disaster Reduction (IDNDR). The IDNDR was launched with the objective of reducing through concerted international action, especially in developing countries, the loss of life, property damage, and economic and social disruption caused by natural disasters, such as earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions, wildfires, grasshopper and locust infestations, drought and desertification and other calamities of natural origin.

108. Natural disasters can been defined as extreme occurrences of natural phenomena that inflict damage and outstrip the ability of an affected society to cope with them. Behind these events often lie chronic problems stemming from the interaction of natural, environmental and human induced factors. These elements include floods, droughts and associated famines, forest fires, tropical cyclones (hurricanes and typhoons), thunderstorms, tornadoes, landslides, snow storms, earthquakes and volcanic eruptions.

109. New technologies, both terrestrial and space based, including remote sensing systems, have contributed to the study of natural disasters, their prediction, prevention and control. Remote sensing satellites can provide essential information for the preparation of hazard related maps, such as land use and land cover maps, which are important in the planning of new developments in order to avoid placing them in high-risk areas. Where developments already exist, particularly human settlements, such hazard-risk maps are useful for possible relief and mitigation operations.

110. Disaster assessment generally places an exceptional requirement on a satellite system because of the quick response time required. Sudden disasters require frequent observations. The rigidity of orbital mechanics and the costs of optical systems place considerable constraints upon spacecraft characteristics such as radiometric, spatial and temporal resolutions that are most desirable for response to natural disasters.

111. Also worthy of consideration is cloud cover, which is responsible for the loss of approximately half the opportunities for observing the Earth from space. In particular, optical sensor systems cannot guarantee availability of data from flooded areas because such areas are likely to be cloud-covered immediately after the flood. The use of radar data becomes essential in these cases.

112. Space technology offers tremendous potential assist in disaster response and mitigation. Telecommunications satellites address issues related to mass awareness, warning, education and training as well as emergency communication in the event of a disaster. Remote sensing satellites help in formulating disaster mitigation measures and monitoring, risk analyses by understanding the processes which lead to natural disasters.

113. A national risk assessment system is evolving in India to minimize the harmful effects of hazardous events. This is a national mission, integrating space applications along with other relevant information towards disaster warning, disaster mitigation and efficient management of hazardous events.

114. In North America, fire is the most important natural cause of forest destruction. Several projects are in progress to monitor the extent of this damage. The most advanced forest management information systems are those now used operationally to enhance the effectiveness of fire suppression activities. Many of these systems make use of satellite remote sensing data to categorize fuel type, which is an important factor in the determination of the risk of fire spread. Combining the fuel type with other parameters enables the fire suppression agencies to more effectively combat forest fires, dramatically reducing the annual losses and with significant savings in fire suppression costs.

115. Several projects using remote sensing in North America are related to monitoring forest damage caused by forest fires and insect infestations. Decision support systems are being developed to provide risk assessment and management planning to minimize the losses due to insects. In many of these projects, remote sensing is used as a tool to acquire information related to damage caused by insects. GIS are used to perform spatial analyses and to produce risk maps in all of these projects.

116. In Malaysia, the national meteorological agency, whose major role is to provide weather and meteorological services, is strongly supported by satellite remote sensing data. In the recent past it has been amply demonstrated that remote sensing from space platforms has contributed significantly to the advancement of meteorology, in particular to a better understanding of tropical weather systems, aiming at improving weather related disaster warning and response.

117. Environmental Impact Assessment (EIA) is a major instrument in decision-making related to developmental projects to ensure an environment-friendly industrial growth. Experiences have shown that satellite based studies offer an efficient, rapid and cost-effective conducting of an EIA so that the causes of environmental degradation due to various developmental projects could be identified. For integrated environmental management planning it is essential to generate baseline information on land use, surface and groundwater, topography and terrain characteristics, soil and vegetation, settlements and transport network.

IV. CONCLUSIONS AND RECOMMENDATIONS

118. Agenda 21 reflects a global consensus and political commitment at the highest level on development and environment cooperation. Its successful implementation is first and foremost the responsibility of governments. National strategies, plans, policies and processes are crucial in achieving this.

119. To be effective, however, environmental policies require the full support of a society and therefore widespread efforts are needed to educate the general public on both the potential effects of environmental change and the programmes that are being conducted to mitigate such change. Such educational efforts must not be limited to universities, but should also attempt to reach all segments of society.

120. For many developing countries, however, it is difficult to solve its environmental problems on their own, despite the fact that they have many indigenous experts. In this context, space technology can provide the necessary timely and comprehensive information on the status and changes in the environment. Outside assistance and expert advice is therefore critical in the successful application of space technology for sustainable development.

121. National aid agencies should substantially increase the use of satellite data in projects funded by them. However, in several cases, the agencies themselves require greater awareness of the potential of space technology for sustainable development.

122. Satellite remote sensing capabilities are increasingly being built into environmental monitoring units within ministries for environmental protection. While this is a significant improvement regarding the use of satellite remote sensing as a tool for policy- and decision-making, ministries in many developing countries

are still notoriously constrained by the lack of funds and the lack of executive responsibility. In this context, the need for improved access to inexpensive remote sensing data in a standardized format on a continuous basis needs to be stressed. Similarly, there is a need for making available low-cost hardware and software ensuring adequate compatibility and portability with necessary spares and continued maintenance support.

123. To implement satellite remote sensing in national plans for social and economic development, a more effective coordination policy has to be established in many developing countries. There are examples of highly qualified individuals in well equipped remote sensing laboratories who are not contributing to national plans due to the lack of communications with national policy- and decision-makers, thus not becoming aware of the benefits space applications could provide to a sustained national development.

124. Collaboration and exchange of information should be increased between research institutions and international, regional and national space agencies and all other sectors from both industrialized and developing countries. International cooperation should further support and supplement such national efforts.

125. One of the critical factors for future operational satellite remote sensing applications for global environmental studies will be the number of available ground receiving stations in developing countries. Areas which are not covered by local receiving stations are less well mapped than areas with local receiving stations. Although the coverage by ground receiving stations is sufficient in most areas of the world, there are large gaps, particularly over Africa and Latin America, where, at present, it is only possible to acquire limited amounts of data. As frequent repetition cycles are very important for environmental analysis, the further expansion of the ground station network is of prime importance.

126. Areas where cooperation could be improved include the assessment of developing countries' user requirements, accessibility of satellite data and information services at reasonable cost, promotion of well designed pilot projects in a manner to assure transition to on-going operational status, increased on-site education and training, need to provide infrastructures for satellite data acquisition, and better use of existing user interfaces. The Committee on Earth Observation Satellites (CEOS) would be one appropriate forum in which to discuss these issues.

127. In the future national and international space agencies should increasingly implement, in cooperation with developing countries, pilot projects to demonstrate to policy-makers the usefulness of remote sensing in the respective countries. Emphasis should also be placed on the increasing cooperation across national borders among private companies, as transnational industrial cooperation has become an important factor shaping the character of the world's space activities.

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