Distr.: LIMITED

ECA/NRD/CART.9/4
August 1996

ENGLISH
Original: ENGLISH

UNITED NATIONS

ECONOMIC AND SOCIAL COUNCIL

ECONOMIC COMMISSION FOR AFRICA

Ninth United Nations Regional
Cartographic Conference for Africa

Addis Ababa, Ethiopia
11-15 November 1996

REMOTE SENSING: A TOOL FOR SUSTAINABLE DEVELOPMENT

An assessment of the Remote Sensing Activities in Africa

I. INTRODUCTION

1. Since the United Nations Conference on Environment and Development, commonly known as the Earth Summit, held in 1992 in Rio de Janeiro, Brazil, the global awareness of the interrelationship between earth resources, environment and development has greatly increased. The recommendations of the Conference became an action plan or an agenda for the 21st Century with a view to advocating the establishment of cooperative, collective and global environmental conservation and management strategies. Agenda 21 identifies information as an essential means of achieving sustainable development and calls on countries to: "Strengthen information, systematic observation and assessment systems for environmental, economic and social data related to land resources at the global, regional, national and local levels and for land capability and land-use and management patterns".

2. Although Africa is endowed with rich natural resources, there are numerous development problems yet to be solved before the benefits of those resources could fully be utilized. Agricultural development, for example, has to meet the challenge of providing enough food sufficiency for the increasing population. This means that agricultural land use should be monitored carefully and managed properly so as to increase the productivity and avoid over-exploitation of marginal land. Equally important is the monitoring and management of forests, rangeland and water resources. Further, the exploration and development of mineral and energy resources for national development need proper planning and management. Therefore, systematic and reliable information is an essential element for obtaining an adequate knowledge about the extent and location of the national natural resources and the status of the environment.

3. Considering the magnitude of the task of assessing the earth's resources, it is essential that modern technologies and tools such as remote sensing and geographic information systems (GIS) be employed to their maximum advantage. Satellite remote sensing data provide reliable information concerning earth surface, allow us to integrate with other ancillary data thus enabling us to use the information to develop strategies for sustainable development. Successful applications of satellite remote sensing technology have been demonstrated at national, subregional and regional levels in physical planning, water, mineral and energy resources development, environment impact assessment, as well as food security planning.

4. Seminars and workshops were held in the continent at the beginning of the early 1970s as part of the global awareness raising on the peaceful uses of space science applications and in order to assess the interest in and acceptability of the technology. The African countries with encouragement of the United Nations Economic Commission for Africa (ECA) recognized the importance of the technology for identifying and monitoring resources and supported the

establishment of regional centres in Kenya, Nigeria, Burkina Faso, whose main objectives are to provide training and technical assistance for resource managers. Also, the use of the technology was expanded within the framework of technical assistance through the international agencies and the donor countries. Though with varying degree, remote sensing and related technologies are accessible to potential user institutions in most of the African countries.

5. This paper reviews the status of remote sensing technology in Africa giving a historical background, analyse the current activities by identifying problems encountered and achievements made, and make recommendations for future orientations.

II. REMOTE SENSING TECHNOLOGIES

6. Advances in space technology during the last 20 years have opened up many new opportunities for the spatial processing of data useful for the development and management of natural resources. The most important of these technologies relates to rapid development in powerful computers with reasonable prices, communications, and thematic application softwares.

7. Remote sensing is broadly defined as obtaining information about objects by measurements made at a distance, without coming into physical contact with the body by means of electromagnetic waves. The main elements of remote sensing techniques comprise recording, measuring, analyzing and interpreting the properties of an object such as the earth or phenomena under study. Remote sensing systems can be classified according to the inherent characteristics of their operation such as active and passive systems, photographic or scanning systems, or according to their platform on which the sensors are mounted into airborne or space-borne systems.

8. Satellite remote sensing as applied space science and technology has become operational, and is being widely used in many countries for resource management and environmental applications. As Africa's economy is based largely on natural resources such as agriculture, forestry, mining and energy, there is a continuing need for technologies that offer an efficient means of collecting and analyzing resource and environmental data for effective development and management of these resources. Remote sensing and its associated image processing technology provide access to spatial information on scales ranging from global to local. Current and future remote sensing programmes are based on a variety of sensors that will provide timely and repetitive multisensor earth observation. These technologies are also increasing the capability to acquire digital spatial information at very high resolution.

9. As the practical use of the technology for resource management and monitoring natural disasters, particularly drought and desertification, improved, drought monitoring programmes were initiated. Moreover, some countries began establishing national centres to ensure that government departments have access to the technology.

III. COMPONENTS OF THE REMOTE SENSING ACTIVITIES IN AFRICA

10. The United Nations Economic Commission for Africa held an intergovernmental meeting in Addis Ababa, Ethiopia in 1976, which founded the African Remote Sensing Council. Further, several regional centres for training and applications services, data receiving and processing ground stations were recommended as a continental network. Of these, only two remain functional: RCSSMRS in Nairobi, Kenya and RECTAS in Ile-Ife, Nigeria.

11. The remote sensing programme in Africa became an informal network of interrelated activities carried out by different organizations having different roles, different functions and objectives. These are international, regional, subregional and national organizations, whose roles include financing and execution of development projects, institutional capacity building in mapping, resource management, environment monitoring and physical infrastructural development.

(a) National Institutions

12. Remote sensing and geographic information systems technologies as tools for resource information have been introduced in the member countries in one way or the other. The national institutions that are involved in remote sensing activities can be grouped into the following departments or agencies: (a) mapping and survey; (b) natural resources and environment; (c) physical infrastructure planning and development; and (d) education and training.

(i) Survey and Mapping Departments

13. Through the experience with aerial photography and photogrammetry, the mapping and survey departments and agencies were among the first institutions to have access to satellite based remotely sensed data in Africa. As a result of human activities and the rapid land use changes taking place there is an urgent need to update and extend map coverage, especially at the scale 1:50,000. Because of the need for improved map coverage, most survey departments have taken a keen interest in the utilization of remote sensing for mapping and map updating. However, as this type of data did not have the stereoscopic coverage needed for precise

mapping, it is only after SPOT data, and photographic images from space were available that this kind of data could be used for topographic mapping.

14. While it is generally agreed that presently available satellite imagery is not quite adequate for topographic mapping at the scale 1:50,000 and larger, the urgent need for new map coverage seems to overweigh the considerations of map quality and map accuracy standards. Further, the data proved to be useful for map revision and for providing services to other agencies whose demand for qualitative image photo-interpretation are relatively high.

(ii) Ministries of Natural Resources and Environment

15. Besides the survey and mapping institutions, the other major group of users of remote sensing technologies are those departments and agencies that are involved mostly in natural resources development and the management of the environment. The use of aerial photography and satellite imagery to agriculture, forestry, water, mineral and energy resources development, environmental monitoring has improved the methodology of data collection, processing and analysis in cost effectiveness and timeliness. Through the needs of such departments many of the several types of national centres or institutes for remote sensing and environmental information systems (EIS) came into existence.

16. The Environment and Remote Sensing Institute (ERSI) in Zimbabwe, the Centre for Ecology and Resources (CSE) in Senegal, The Comite National de Teledetection et d'Information Geographique (CNTIG) in Côte d'Ivoire and the Department of Remote Sensing and Resource Surveys (DRSRS) in Kenya are examples of such national institutions. National centres should therefore be encouraged and strengthened as they serve the country as focal points and accelerate the transfer of these technologies and simultaneously help avoid costly duplication.

(iii) Education and Training

17. The pace of introducing courses in remote sensing technologies to the education programmes in African universities has been limited despite the fact that many academic staff members benefited from training courses or academic studies given at universities outside Africa. However, through the recent rapid development in GIS technology the involvement of universities has increased and courses are now being offered in a number of universities in the various applications.

(b) **Subregional Institutions**

18. There are two types of subregional intergovernmental institutions that are involved in remote sensing and related activities. The first group are those that have the technology and the expertise to carry out training and provide user assistance in these fields. Centres such as RCSSMRS, RECTAS, AGRYHMET, ACMAD, etc. belong to this group. The second group of institutions are those that are development policy-oriented and which because of their mandates as subregional decision-making bodies became involved in these technologies as important users. Organizations of this type are the Comite Permanent Inter-Etats de Lutte contre la Secheresse dans le Sahel (CILSS) in Western Africa, the Intergovernmental Authority on Development (IGAD) in Eastern Africa and the Southern African Development Community (SADC).

19. The first initiative to establish intergovernmental institutions in geo-information for Africa goes back to the first United Nations Regional Cartographic Conference for Africa, held in 1963 in Nairobi, Kenya in which the conference passed a resolution calling for the establishment of such service rendering centres in the continent. This resolution was submitted to the ECA Council of Ministers and endorsed as resolutions 280 (XII) and 313 (XII). Subsequently, on the initiative of the member States and the support of the United Nations Economic Commission for Africa (UNECA) several subregional centres were established in different locations of the continent.

20. One of the main objectives for the establishment of subregional and regional resource information centres is the training of personnel from member States. The duration of training period offered by the different centres varies from one week to two years. RECTAS offers regular courses in several areas while RCSSMRS training courses are on adhoc basis.

(a) RCSSMRS

21. The Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS)in Nairobi, Kenya was established in 1975 initially as a regional centre for services in surveying and mapping with the principal role of providing services in these areas. In 1977 USAID concluded a hosting agreement with the Centre for a semi-autonomous Regional Remote Sensing Facility which eventually became a department of remote sensing. The Facility obtained equipment for a modern photo laboratory and photo-interpretation, and established a browse file of imagery of the Eastern and Southern African region which was later augmented by a complete set of 70 mm negatives of all Landsat imagery from 1972 through 1977 as donation from NASA.

22. The Facility began by offering fully funded short-term courses to resource managers in the region. Later project oriented training and longer term courses were added to its activities to meet the needs of member States. Meanwhile, USAID phased out its direct support and the facility had been transformed into a department within the Centre.

23. However, other donors such as France, European Space Agency and several International Organizations provided technical and financial assistance. The French Government for example has been providing technical experts to RCSSMRS who conduct user assistance and training on specified projects in the participating countries which improves the Centre's image and capability to provide training and technical assistance.

24. The Centre attained an active role in the utilization of a remote sensing applications and developed itself to accommodate geographic information applications. It collaborates with FAO and the Kenya Meteorological Department in processing weather satellite data for early warning system. Further, the Centre had been selected to host the FAO-Executed AFRICOVER project for the Eastern Africa Subregion.

25. UNEP, besides contracting the Centre for certain assignments, will also contribute to the activity at the Center by establishing a node for its global resource integrated database (GRID) programme. Under this project, the Center's staff will help to analyse and distribute natural resources and environmental data that has been collected by GRID for the Africa region.

(b) RECTAS

26. The Regional Centre for Training in Aerospace Surveys (RECTAS) in Ile Ife, Nigeria was established in 1972 primarily as a centre for training in aerial surveys, photogrammetry and photo-interpretation. Its role was broadened a few years later to include the new aspects remote sensing technology. Though the Centre's mandate covers the whole continent, however, as it is now it draws students mainly from the West Africa subregion. The Centre offers courses both in English and French.

27. RECTAS receives its funding from member States with a notable share from the host country. During the period of development of the centre, there were donor funds available for the purchase of equipment and for trainee fellowships. The Swiss, the Dutch and French Governments and the UNDP were the principal donors. RECTAS has relatively large technical staff whose members are available to undertake, besides the regular training courses, consultancy contracts for development projects. A related source of funding is from the sale of data products

such as maps and photographic reproduction. These kinds of activities are viewed by the staff as the best way to keep the centre operational.

(c) CRTO

28. CRTO was established in 1977 as a regional remote sensing centre to provide training and user services in the applications of remote sensing technologies to resources management. CRTO offered long and short-term training courses and has thus trained over 600 trainees from its member States. During its development period, plans were drawn up to establish a West African satellite receiving station at CRTO. However, funds for this project never materialized and with the phasing out of donor funding and the reduction in member States' contributions , CRTO has been facing more financial difficulties than other centres.

29. To enable CRTO to survive as well as carry out its training and technical services, substantial investments in computer hardware and software will need to be made available to the Centre. Further, some refurbishment of the buildings and laboratory facilities will be required and additional staff would need to be recruited and funded to enable it carry out a training programme.

30. Because of these financial difficulties, the duplication of activities and the inability of the member States support two or more regional institutions aggravated its financial problems. In order to improve the operationality of the ECA sponsored institutions, ECA carried out a study which recommended to merge RECTAS, CRTO and AOCRS. While a merger of RECTAS and CRTO appears to be favourable, there is a question to whether AOCRS should be included as it is a different kind of organization and would not necessarily be harmonized with the other organizations in the merger process.

(d) AGRHYMET

31. The AGRHYMET Regional Centre in Niamey, Niger was established in 1974 through the cooperation of the nine CILSS (Intergovernmental Committee for Combating Drought in the Sahel) member States. AGRHYMET is a specialized subregional centre for training and services in the areas of agrometeorology, hydrology and plant protection. It is also an environmental information centre which is well equipped for receiving meteorological satellite images that are used for agroclimatic information for early warning purposes.

(e) ACMAD

32. The Regional Centre for Meteorological Applications for Development (ACMAD) in Niamey, Niger was founded in 1987 by ECA member States with the following objectives: (a) to provide an advanced weather and climate monitoring system over Africa; (b) to develop and adapt practical methods for the application of meteorology to sustainable socio-economic development in Africa; and (c) to develop progressively into a centre of excellence for designing and developing of new capacities in meteorological and climatological research for Africa.

33. The main customers of ACMAD are the national meteorological services, the regional and national drought monitoring centres and the regional institutions in charge of environmental issues. ACMAD has established strong working relationship with subregional organizations such as AGRYHMET. Further, the Centre receives a good technical assistance from the World Meteorological Organization (WMO) and some donor countries.

(c) **International Institutions**

34. International cooperation and support in remote sensing is considered vital for the promotion of this technology in Africa. Through financial and technical assistance it has been made possible to establish institutions and train skilled manpower in this field. The regional centres and most of the national centres would not have come into light without the generous donations of the developed and the international organizations and agencies. Food security and early warning programmes in Africa could be realized only through the international collaboration.

35. The number of international initiatives to support and strengthen resource information for sustainable development in Africa has increased over the last decade. For example, FAO with financial support of the Government of the Netherlands, developed the Africa Real Time Environmental Monitoring using Imaging Satellites (ARTEMIS), an advanced remote sensing data receiving and processing system for regional monitoring of precipitation and vegetation. This initiative proved to be very useful for food security programmes in the IGAD and SADC countries. Another important project is the AFRICOVER project whose overall objective is the production of a land cover map and digital database and a topographic reference at 1:250 000/1:200 000 and 1:1000 000 scale for the whole of the African continent, with some specific areas and few small countries (below 30 000 sq km) for the land cover at 1:100 000, based mainly on satellite remote sensing and GIS.

36. The United Nations Institute for Training and Research (UNITAR) have been providing GIS training to personnel from African countries. UNITAR in collaboration with the Sahara and Sahel Observatory (OSS) and other United Nations and donor agencies have initiated the AFRICAGIS that has been held every two years since 1993. The participation from Africa and abroad has been very high owing to generous sponsorship by the organizers. The AFRICAGIS, besides the United Nations Regional Cartographic Conference for Africa, serves as a forum for exchange of experience and information on geo-information technologies applications in Africa. The AFRICAGIS had a wide media coverage which drew the attention of policy and decision makers to this field.

37. Financial institutions such as the World Bank support country programmes on natural resources and environment management, many of which depend on remotely sensed data in their planning and execution. Several African countries benefited from the environment information systems (EIS) programme.

IV. APPLICATION SECTORS OF REMOTE SENSING TECHNOLOGY

38. Natural resources management and environmental monitoring are dynamic areas that are require a huge amount of data collection, processing and analysis. This can only be effectively carried out by the use of modern technologies such as remote sensing, geographic information systems and improved communications systems. Remotely sensed data from satellite have become an indispensable tool for users involved in various fields. Many projects undertaken in Africa during the last decade would have been virtually impossible or too expensive without the availability of this type of technology. As a result of the commercialization of remotely sensed data, various types of data are available for the users that are offered by the different owners of the existing satellite systems.

39. The systems which image in the visible and near infrared range of the electromagnetic spectrum are those which are most commonly used for resource analysis and environmental monitoring. Satellite based remote sensing systems have several advantages over aircraft based systems. The high altitude of the satellites makes coverage of large areas on a single frame feasible whose geometric conditions could be compared to that of an orthophoto. This kind of imagery is good for mapping resources and monitoring environmental conditions over large areas. Exposure conditions over the entire frame are constant leading to more precise interpretation of regional vegetation distribution. Repetitive coverage is economical and enables many aspects of resources management and monitoring which include crop monitoring during growing season, rangeland assessments, weather forecasting, as well as flood and fire monitoring.

(a) Food Security and Environment

40. One of the challenges facing the African countries is to achieve food self-sufficiency with a rapidly growing population in a sustainable manner. This involves managing the productive land and simultaneously minimizing land degradation. Remote sensing technology can help to monitor crop health, predict harvests, etc. In agriculture, the use of high resolution satellite imagery to the classification of traditional farmland in Africa has been limited due to the size of plots and the mixture of crops. However, in large farming areas, this type of data have been useful for the estimation of areas under cultivation and in distinguishing the types of crops.

41. During the last decade a number of drought monitoring centres have been established or the existing regional resource information centres such as RCSSMRS expanded their activities to these areas as a response to the various needs of their constituent members. These centres monitor the vegetation growth in order to provide an early warning for those responsible for food security. With the combination of weather and earth observation satellite data along with modern hardware and software used for processing these data, we are approaching the possibility of monitoring the carrying capacity for particular provinces or the whole country on a year to year basis.

42. Land use management is the key to understanding and addressing the problems of land degradation such as deforestation, soil erosion, declining soil fertility and over-grazing. Land use management is influenced by a number of factors such as land use practices, land distribution, resource and land tenure, technology, investments, local knowledge, policies, legislation, access to resources, local participation, indigenous knowledge systems and governance issues and population.

(b) Vegetation/Land Cover

43. Natural vegetation is an important resource for the African population as it is the main source for fuelwood, shelter materials and other uses for daily life. The rate of removal of trees for these purposes exceeds much that of regeneration and the competition between the various interest groups to the same resource is immense. Though, most African countries are aware of the importance of reforestation and afforestation programmes and mostly developed strategies for national forest action plans, nevertheless their practical implementation has been limited. A major constraint is the lack of a systematic, accurate and timely information about the type, distribution and condition, especially over large areas.

44. The use of remote sensing and GIS technologies in the management of vegetation landcover have been demonstrated and found helpful for execution of integrated resource development and management projects in many African countries. These techniques provide valuable information at a variety of spatial, temporal and spectral resolutions which can help map and monitor the extent, type and condition of natural vegetation over large and diverse areas.

45. Another type of projects that has been carried out at national level are the woody biomass projects. Though the main objective of these projects has been to assess the potential availability of fuelwood and ultimately come up with strategic plan on how to develop and manage these resources, nevertheless the amount of geographic information compiled for the overall strategic development planning process for the provinces concerned and the country as a whole is amazing.

(c) **Environment**

46. The management of natural resources and the environment is a development issue which involves socio-economic, administrative, legal and political decisions. The purpose of environmental monitoring is to provide information that could affect its management. Environmental information means better knowledge and fuller understanding of the interactions between nature and human activities on which decisions and measures are to be taken. Remote sensing and related technologies have been useful in providing valuable inputs into such environmental information systems. Experiences at the subregional level in the CILSS, IGAD and SADC programmes indicate the potentiality of these technologies.

47. The Meteosat series of the geostationary meteorological satellite has now been in operation for almost two decades and has been providing data that proved to be useful for weather forecasting, agrometeorological research and many other environment monitoring applications. In relatively less populated regions, where recording stations are limited, remotely sensed data play a much more central role in forecasting the weather conditions. Access to data from operational meteorological satellites had been free until September 1995. Because of the fact that many countries have become dependent upon these systems and as the information derived from this data has been crucial for food security and emergency preparedness programmes, it is necessary to ensure the continuation of its data at reasonable user charges.

48. Multitemporal data sets acquired by NOAA satellite are used to produce maps showing the vegetation index at country and subregional scales. These proved to be very useful for drought monitoring.

(d) Physical Infrastructure Planning and Development

49. As a result of the rapidly growing population in Africa urban areas are expanding at an uncontrollable pace so that existing utilities such as water, electricity, sewage, etc. are becoming overstretched. Furthermore, lack of up-to-date information contributes to the problem of poor urban development programmes including telecommunications, and transportation systems. The need for integrated information systems is increasingly being recognized by many town and regional planning authorities and some countries such as in Botswana have adopted the use of geographical information systems for planning resource management and infrastructure development.

50. Aerial photography has been the one of the main sources of data for the production of town plans, however satellite images such as those from SPOT and Thematic Mapper are complimenting this type of data, especially for the compilation of strategic urban and regional development plans.

(e) Mineral and Energy Resources

51. Airborne remotely sensed data has traditionally been used in the exploration of mineral and energy resources in Africa as this was the only source of information because maps were hardly available for most of the regions. Multispectral satellite remote sensing technology improved the detection of different rock types which is an important aspect for mineral analysis. The synoptic view of satellite images is an asset for regional geology in observing large scale plate tectonics, faults and foldings.

52. Oil exploration companies use remotely sensed data for planning and implementing their activities and the monitoring of oil spills resulting from their production operations.

VI. ASSESSMENT OF THE REMOTE SENSING ACTIVITIES

53. A total of eighty organizations in 13 countries were visited during a study in which all but a few use the technology to collect, process, store and analyse geographic information for projects they are implementing. These organizations utilize remotely sensed data for mapping, agriculture, forestry, water and hydrologic studies, land use, geology, rangeland carrying capacity, environmental monitoring, etc.

54. In the 1970s attention was focused on the application of satellite remote sensing for developing countries as a new technology for the management of natural resources and the

environment. In the 1980s similar attention was put on GIS. Currently, we are experiencing an era in which remote sensing and GIS are being integrated and applied to priority areas such as food security and environment. A multisensor, multispectral, multiresolution and multitemporal imagery data will eventually be available in most parts of the continent. Therefore, the processing, analysis and management, and the proper utilization of such information will be the major challenges of the coming decades.

55. In making an assessment of the contribution of remote sensing technology applications to sustainable development in Africa, it was necessary to select appropriate indicators that could show whether remote sensing technology is being adapted and utilized properly in the resource and environmental fields for which the technology was developed.

(a) Institutional Infrastructure

56. During the various missions ECA undertook it was observed that the organizational pattern of remote sensing technology applications in the countries visited were quite similar. All the countries have trained personnel and some equipment and experience with both remote sensing and GIS. The variation occurs in the extent to which the technology is utilized and which agencies have taken the decision to use the technology.

57. In each country there are agencies and government departments which are using or planning to use remote sensing and GIS technology. These are typically departments of environment, forestry, water, geology, natural resources, agriculture etc. In general, coordination between the various departments is rather weak. There is no particular pattern or reason why one agency adopts the technology and another does not. In many cases it is probably due to one or more senior persons in the department having or being exposed to the technology in courses at the regional centres in Africa or in conjunction with higher education overseas.

58. Further, it had been noticed that wherever an agency is developing a GIS, there is also donor support that is related to the project on which the GIS is being used. In these cases, introduction to the technology probably came with a donor funded project that required the use of remote sensing data or the development of a GIS. The project package probably would have included training at home or abroad for project personnel and equipment which would remain with the department at the completion of the project when the external support ends.

59. The extent to which ECA member States have invested in the remote sensing technology is one of the most important indicators as this shows the financial commitment and the level of understanding that the decision makers have with these tools and techniques. In discussions with

the concerned managements and the technical staff, the responses clearly indicate that owing to the priority of the country to other pressing issues hardly any funds have been allocated by the governments for the acquisition of hardware and software. However, funds are usually allocated for the national staff.

60. Now with almost every country having centres or agencies using remote sensing and geographic information system (GIS) technology, there is a need to examine the role of regional centres to ascertain whether they are continuing to meet the needs of member States. There is also a need to maintain coordination and linkages among these various organizations that have begun utilizing these technologies since the establishment of the centres.

61. The subregional environmental and development oriented organizations such as CILSS, IGAD AND SADC appear to be emerging as major players in food security, drought monitoring and other development issues. All the three organizations recognize remote sensing technology as a vital tool for the execution of their programmes and projects in resource management and environmental monitoring. CILSS and SADC are mobilizing resources and channelling them to their subregional or national centres respectively. IGAD had already an important early warning project in RCSSMRS and in principle is willing to integrate the Centre and other relevant institutions into its subregional activities. Because of the importance of resource information technologies for the subregion, the link between the subregional development organizations and the ECA-sponsored centres should be strengthened

(b) Availability and Cost of Data

62. In general we are experiencing an era in which more satellites are in space and others are planned to be in orbit for earth resources observations. Consequently, more data is, and will be, available from a new generation of satellite remote sensing systems.

63. Satellite data ground receiving stations are an integral and indispensable part of the satellite remote sensing system. Until such a time as the technology evolves to the point where earth resources observation satellite signals can be received and processed in each user's facility like those of meteorological satellites, users will remain dependent upon a few ground receiving stations. At present ground receiving stations are very complex installations with sophisticated receiving and processing facilities and a relatively high operational costs, a major factor for inhibiting the acquisition of such a system in the region.

Table showing countries and type of organizations visited

Country	Organization (No)	Mapping/ Survey	Agriculture/ Forestry	Meteorol.	Education/ Training/ Research.	Phys. Infrastruct.	Environment.	Mineral/ Energy/ Water
Botswana	4	1	1				1	1
Burkina Faso	6	2	1		1		2	
Cote D'Ivoire	6	2			1	1	1	
Ethiopia	7	1	3	1			1	1
Kenya	11	1	2	1	4		2	1
Niger	4	1	2				1	
Nigeria	9	1	2		3	1	1	1
Senegal	6	1			3		2	
South Africa	7	1	3		1		1	1
Swaziland	2	1	1					
Tanzania	4	1	1		1		1	
Zambia	5	1	1	1	1			1
Zimbabwe	6	1	2		1		2	

64. Africa as continent is poorly served by satellite receiving stations. The only permanent ground receiving station presently receiving satellite data is located in South Africa. The South African receiving station receives data from all satellites and produces top quality data. However, the coverage is limited to the Southern African region with the northern arc of coverage extending as far north as central Tanzania.

65. Recently a number of smaller portable mobile stations have been developed to cover the few areas which are not covered by permanent ground stations. These mobile stations only collect data which they send to the permanent stations for processing. Mobile stations have an advantage that they can be moved and installed at different sites to collect data on seasonal opportunities and unusual events such as natural disasters.

66. It has been observed that African organizations purchase less satellite imagery than similar organizations in other regions. The suppliers of satellite imagery apparently have some flexibility in establishing costs and terms for the use of the imagery. They appear to be interested in working with an organization such as the subregional centres in the sale of imagery and in the deployment of mobile receiving stations for Africa. There appear to be some opportunities for collaboration with the major imagery suppliers such as EOSAT and SPOT that would expand the utilization of satellite data. ECA should therefore explore opportunities for working with these and other organizations to help improve the availability of satellite imagery in Africa at reasonable prices and deploying mobile stations that would serve the entire continent.

(c) Quality and Compatibility of Databases

67. National map archives contain maps made over a substantial space of time by different agencies and with different equipment and techniques. Therefore, sources and reliability of information should be included with any geographic information that is entered into a national database. While the staff members of the regional centres and the survey departments generally have the mathematical skills and awareness of map accuracy standards to produce reliable products, there are many resource and environmental specialists who do not have this training and awareness.

68. With the rapid development of national geographic databases that is taking place in most countries, there is concern about the accuracy and consistency of the information that is being entered into these databases. There is evidence of duplication mainly owing to lack of communication and coordination between the various users. Simultaneously, there are substantial opportunities that need to be properly exploited.

(d) Training

69. A closely related issue is the need for training in the use and maintenance of equipment. Remote sensing and all of the technologies related to the development and use of resource and environmental information are rapidly changing and it is extremely difficult for individuals to keep
up with changes. ECA and other regional and subregional centres should take the lead in acquiring and disseminating information about technological advances that impact on resource managers in the continent.

70. Technology transfer can significantly be strengthened through a network of cooperation between the subregional and national institutions. Long-term commitments to, and investments in, the capacity building with a view to developing a critical mass of technicians, professionals who understand the technology and who are able to adapt, further develop and maintain the technology as well as develop applications suitable to their local environment.

71. Training should not only focus on the use of a particular software, but should go further to upgrade the skills of data organization and management and the dissemination of data to other users within and outside the ministry or agency.

72. In Africa the role of national universities as a stable source of ongoing training has been overlooked. Therefore, donor support to the countries should include the institutions of higher learning dealing with space science technology and related areas. This would in the long-term contribute to building capacities within the countries and alleviate the bottlenecks in obtaining skilled manpower.

(e) Organizational and Management Aspects

73. During the past few decades, when most of major technological breakthroughs have occurred, we have been experiencing that the keys to utilizing and reaping the benefits of new technologies are not always technical in nature. The limiting factors in implementing a new technology is often organizational and financial. And so it is with the remote sensing activities in Africa. Computer hardware especially microcomputers and software are now available and accessible to most Africa managers.

74. Technical skills for resource data processing and analysis are available in all organizations dealing with resource data processing and analysis for resources management and environmental monitoring. Through the many training programmes that have been developed in Africa as well as the generous support of donors to provide funds for training in and outside Africa, there has emerged within the past two decades a large pool of persons skilled in all aspects of digital processing technology. In many countries information that

exists is not accessible owing to various factors, including organizational and management problems.

VI. CONCLUSIONS AND RECOMMENDATIONS

75. In Conclusion, the status of remote sensing technology applications activities in Africa looks positive. Despite the problems identified at regional centres it must be recognized that the majority of those interviewed feel that the centres are needed and means must be found to keep them operational. With some adjustment of their programmes and the creation of stronger ties with their member States and the donor countries and agencies, there is no reason why the centres should not be able to continue as viable institutions for many years to come. At the country level the interest and awareness in the use of GIS is rapidly increasing and therefore improves the utilization of remotely sensed data.

76. Remote sensing and the related technologies are powerful monitoring and management tools. These technologies provide the planners and resource managers a means for managing resources and the environment that will accelerate the sustainable socio-economic development of the member States. Remote sensing systems are currently the most effective methods of generating environmental and resource information at different spatial and temporal resolutions.

77. A dozen of recommendations have been adopted in every workshop, expert meeting and conference that took place in the last successive years. The question to ask is how is the status of the practical implementation of these recommendations? Knowing the existence of such recommendations that have been drafted by experts, the Secretariat would confine itself on a few which are based on our observations and discussions with professional colleagues, recommendations from ECA consultant reports and other studies:

(a) Resource information at varying spatial and temporal resolutions is required for planning, management and sustainable development of the critical sectors of the African economies such as agriculture, mineral and energy resources development etc. Therefore, African governments, the subregional and regional organizations, the international organizations and developed countries should pursue the implementation of the recommendations made in the various conferences such as the AFRICAGIS, MARISY, etc.

(b) ECA in close collaboration with the national, intergovernmental and international organizations should undertake a review of selected elements in the remote sensing network to identify problems confronting Africa.

(c) The international agencies should be encouraged to strengthen national and regional expertise by using the services of country or regional experts in the fields of geo-information technologies.

(d) The African governments and the donor countries (agencies) should promote the private sector involved in natural resources development and the management of the environment similar to the promotion of any other sector.

(e) More support should be provided to the African universities in establishing or strengthening their teaching and research capabilities in space science technologies and its applications to the various fields for sustainable development.

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