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COMMITTEE ON THE PEACEFUL USES
OF OUTER SPACE

REPORT ON THE FIFTH UNITED NATIONS INTERNATIONAL TRAINING COURSE ON REMOTE SENSING EDUCATION FOR EDUCATORS

(Stockholm and Kiruna, Sweden, 2 May to 9 June 1995)

CONTENTS

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INTRODUCTION

A. Background and objectives

1. The Fifth United Nations Training Course on Remote Sensing Education for Educators, held at Stockholm and Kiruna, Sweden, from 2 May to 9 June 1995, was organized by the United Nations Programme on Space Applications in cooperation with the Government of Sweden. It was co-sponsored by the Swedish Board for Investment and Technical Support (BITS) on behalf of the Government of Sweden, and hosted by the Department of Physical Geography of Stockholm University and by the Swedish Space Corporation (SSC Satellitbild).

2. The course was conducted specifically for the benefit of university educators from developing countries with the objective of enabling them to introduce elements of remote sensing technology into the curricula of their academic institutions.

3. The present report describes the organization of the training course, its technical contents, and the projects undertaken by the participants during the course. The choice of projects reflected both the academic interests of the participants and current national development issues in their countries of origin. The report presents the results of the course evaluation and the proposed follow-up plan of action. It was prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee.

B. Organization and programme

4. Application forms and information brochures on the training course were sent out in early December 1994 by the Office for Outer Space Affairs of the United Nations to offices of the United Nations Development Programme (UNDP) for transmission to the relevant national authorities. The same materials were also sent out simultaneously by Stockholm University to the embassies of Sweden in 75 countries and to previous participants in the course for local distribution. The target group comprising 75 countries whose development needs reflected the priorities of Sweden was selected by BITS. Over 110 completed applications were subsequently received and jointly processed by the Office for Outer Space Affairs of the United Nations and Stockholm University.

5. The training course was attended by 25 participants, three of whom were female. Participants came from the following countries: Egypt, Ethiopia, Kenya, Nepal, Nigeria, Pakistan, Senegal, Sri Lanka, Swaziland, Uganda, United Republic of Tanzania, Viet Nam and Zimbabwe. Instructors came from the Office for Outer Space Affairs, BITS, the European Space Agency, SSC Satellitbild, Stockholm University, the Swedish National Space Board, the Swedish Royal Institute of Technology, the Swedish Society for Nature Conservation and Uppsala University.

6. Funds for the international travel of 12 participants from developing countries were provided by the United Nations. All other support, including air travel for 13 participants, room and board, course materials and inland transport for all 25 participants was provided by the Government of Sweden.

7. Addresses were given at the opening ceremony by the President of Stockholm University and by the representative of the Office for Outer Space Affairs. The representative of BITS presented an overview of Swedish aid policy, and gave some insight into the ongoing restructuring of Swedish aid organizations. The restructuring had been completed and the BITS replaced by the Swedish International Development Cooperation Agency (SIDA).

8. The programme of the training course (see annex I) was prepared by the Department of Physical Geography of Stockholm University in consultation with the Office for Outer Space Affairs. The course consisted of a series of lectures and laboratory and field exercises. Technical visits were made to a number of sites of interest, including the ESA/Salmijarvi and Esrange satellite receiving stations, and the Kirunavaara underground mine. Six days of the course were spent at Satellitbild, the Swedish Space Corporation facility for data processing and map production at Kiruna. The participants were allowed three and a half days for the visual interpretation of remote sensing images of regions of their countries which they had selected. Among the highlights of the course were the presentations

made by participants on the results of their visual interpretation projects. A description of the projects is presented in annex II.

9. A summary presentation of the topics introduced during the training course is given in section I below. This presentation selectively describes basic aspects of satellite remote sensing and geographic information systems (GIS) which must be sufficiently appreciated by users of remotely sensed data for their effective application to the national development problems or academic issues identified by the participants. An analysis of the course evaluation as well as the plan for follow-up action are presented in sections II and III, respectively.

I. SUMMARY OF THE CONTENTS OF THE COURSE

A. Acquisition of remote sensing data

10. Data from several different satellites (for example, European Remote Sensing Satellite (ERS), Land Remote Sensing Satellite (Landsat), Système pour l'observation de la Terre (SPOT), Resurs, Japanese Earth Resource Satellite (JERS), Indian Remote Sensing Satellite (IRS) and Meteosat) were useful in the analysis of problems related to national development, especially those pertaining to the assessment of natural resources and monitoring of the environment. For the training course, which stressed visual interpretation of Earth observation data over terrestrial surfaces, data from Landsat and SPOT satellites were emphasized.

11. Requests for satellite imagery and associated products could be made to a number of vendors, including Satellitbild. Users could also directly access metadata, in other words, information on the availability and quality of satellite images, and even preview samples of images. The metadata were increasingly being made available as databases on CD-ROM (for example, the Ocean Color European Archive Network (OCEAN) image-base consultation system, the advanced very high resolution radiometer (AVHRR) CD browser known as Ionia). Some databases could also be accessed via Internet.

12. A number of important criteria, such as cloud cover, date and frequency of image acquisition and spectral and spatial characteristics, must be borne in mind when ordering satellite remote sensing images. While, for example, the overall percentage of cloud cover in a given image might be acceptably low, the clouds that were present might obscure the specific geographical zone of interest. It was therefore desirable to preview images prior to purchase.

13. The date of image acquisition had a direct bearing on the various uses to which it could eventually be put. For example, whereas wet season images would be useful for determining vegetative cover, they were less useful for mapping landforms and soils. The revisit capability of the satellite also played a role in the potential applications of the images collected. While a given geographical area of interest might be imaged by the AVHRR instrument on a daily basis, the Landsat TM and SPOT series of satellites offered revisit capabilities of 16 and 26 days, respectively. In the case of SPOT imagery, the revisit capability could be reduced to 1 or 4 days using the off-nadir viewing capability of that sensor to facilitate the monitoring of short-lived phenomena, such as certain categories of natural disaster.

B. Image interpretation and applications

14. The appearance of remotely sensed images was determined by several factors, including sensor, atmospheric and terrain characteristics. Multispectral data, such as those acquired by the IRS, Landsat, Meteosat and SPOT series of satellites, were collected in multiple spectral bands. Those bands had been chosen so as to enhance the detection of and discrimination among features of interest (for example, vegetation, soils, water and clouds), and ranged from the visible to the infrared portions of the electromagnetic spectrum. The optical, multispectral scanners sensed the solar energy reflected or emitted by surface features. By contrast, radar satellites, such as the ERS-1 and 2, JERS and Radarsat, exploited the microwave region of the spectrum. Those satellites carried instruments that transmitted microwave energy in pulses and measured the travel time of the back-scattered microwave signal.

15. The multispectral scanners were normally used to acquire images during daylight hours. While the data from those scanners might be affected by local atmospheric conditions (for example, clouds that blocked observation of surface features), the acquisition of images from radar satellites was not similarly constrained. In general, the multispectral and radar instruments exploited different regions of the electromagnetic spectrum, and could often yield complementary information useful for tackling a variety of national development problems.

16. Apart from a consideration of the radiometric characteristics (i.e. number and type of spectral bands) of a given sensor relative to the spectral characteristics of the features of interest, the type of satellite imagery that would be useful for a given application was dependent on the level of detail required. The ground spatial resolution of imagery was often a determining factor in its application, since it was indicative of the smallest distinguishable surface feature. In the case of Meteosat visible channels, for example, the ground spatial resolution was nominally 2.5 kilometres, whereas for SPOT multispectral imagery, it was 20 metres. That level of spatial resolution rendered SPOT multispectral imagery useful for preparing maps up to a suggested maximum scale of approximately 1:50,000.

17. The raw images collected by optical sensors on board the satellites were corrected for radiometric and geometric distortions, in order to facilitate subsequent visual image interpretation or computer classification and to assure that they could be superposed on pre-existing maps as required, for example, in a GIS. In response to user needs and capabilities, vendors of satellite remote sensing data usually offered several different value-added image products, each reflecting different levels of processing and correction (e.g. system- or precision-corrected images). System-corrected images were those which had been corrected for predictable distortions in the image because of factors such as Earth rotation during the imaging. In precision-corrected images, geometric corrections were made using mathematical transformations based on several common locations (ground control points) identified within both the unrectified image and a corresponding planimetric map of an appropriate scale (e.g. 1:50,000 for Landsat images). Alternatively, the required transformation could be developed using the locations of ground control points determined by a global positioning system (GPS) instrument. In order to facilitate comparisons between images acquired at different dates and under different conditions, radiometric corrections, which accounted for variations in scene illumination, viewing geometry and instrument-response characteristics, could be undertaken.

18. The end-user might request satellite data in digital format or as photographic prints. There were several different types of image enhancement (processing steps which rendered the images easier to interpret) which could be performed on the raw digital data to maximize their usefulness for a specific application. Many different types of enhancement were possible, including contrast stretching, filtering, formation of band ratios, intensity-hue-saturation transformations and the formation of colour composites. Photographic prints could be ordered from vendors with specific enhancements already made to satisfy the requirements of a chosen application. However, access to the data in digital format gave the user the added flexibility to carry out, at his or her convenience and as the need arose, local or global image enhancements or classifications appropriate for a range of applications. Having the data in digital format also facilitated eventual incorporation of remotely sensed information into a GIS. Digital image processing, however, required access to related equipment (e.g. a computer and large-format printer) and software which might be lacking in some academic departments. Visual interpretation of enhanced prints made from digital images was, on the other hand, less costly.

19. The field verification of thematic maps prepared from interpreted images was an important step in assuring the reliability of information derived from remotely sensed images. The traditional magnetic compass served as an invaluable and simple tool for establishing the correspondence between locations in an image and those in the field. However, the use of GPS instruments for that purpose was gaining in popularity owing to their simplicity of use, reasonable cost and high levels of precision.

20. Surface features in images could be digitally classified using a range of supervised and unsupervised approaches. The supervised approach required that the operator should have some knowledge of a few locations within the image of the classes (e.g. soil, water or type of vegetation) being mapped. Such information was used to guide the subsequent computer classification process. By contrast, in an unsupervised classification, the resulting classes were determined by analysis of the statistics of the multispectral images being analysed. For visual

classification, multispectral images were enhanced to emphasize features of interest (e.g. shallow water as opposed to land features) prior to printing and subsequent interpretation. The analyst used photographic interpretation elements (e.g. tone, texture, shape, drainage, landforms, topography, and lineaments) to facilitate visual classification. In visual interpretation, the geographical limits of the various classes were traced onto the print. Those traces could subsequently be input to a GIS in the form of a vector map through digitization. The vector map might be converted to raster format to suit analytical needs.

21. It was widely acknowledged that remotely sensed data were useful for a large range of applications. That was reflected in the variety of projects undertaken by the participants (see table in annex II), which included applications to terrestrial as well as marine environments. The terrestrial applications related mainly to agriculture (soil erosion, deforestation, land-use planning and siltation), geology and hydrogeology (river-bank erosion, groundwater management), the mitigation of natural hazards (landslides, glacial lake outbursts, snow avalanches, debris flows, floods etc.), meteorology, pollution and urbanization. The sole marine application focused on problems induced by the presence of algal blooms.

C. GIS data integration and map preparation

22. A GIS consisted of hardware, software and data components which allowed the efficient storage, analysis and presentation of information. The data in a GIS were georeferenced (i.e. they referred to precise, real-world geographic coordinates) with the result that different thematic maps of the same area could be exactly superposed. To achieve that, the different maps must all have similar levels of generalization (i.e. similar original map scales of preparation) and similar geometric projection. In general, the data within a GIS were of four generic types, namely, points, lines, tables and areas. The areas might be polygonal, vectorial or raster in nature. Several different operations (e.g. overlay, neighbourhood analysis, interpolation, classification and time-series analysis) could be performed on those four types of data during the course of spatial analysis prompted by a query.

23. Data within a GIS could be queried to respond to questions that only required the retrieval of data. That did not involve any manipulation between layers of data. Alternatively, the queries might involve simple to complex manipulation of several layers according to various rules or models (e.g. process, mathematical, heuristic, expert systems etc.). GIS could also be used in simulation studies (e.g. to determine the effects of land-use changes on run-off and flooding risks, or the effect of water availability on crop yields).

24. The capacity to respond rapidly and interactively to questions made GIS invaluable as a decision-making tool, since many "what if" scenarios could be examined prior to the implementation of a final decision. For example, a relatively simple query that was readily amenable to processing by a GIS was the following: "Where are the locations suitable for agriculture under rain-fed conditions which are amenable to the use of mechanized agriculture equipment and which are within 10 km of major roadways or railway lines or navigable rivers?" To respond to that query, the needed data must include soils, rainfall, surface slope and road, rail and river networks.

25. A major requirement in the establishment of a GIS was to assemble a database that would be useful for tackling the range of problems to be addressed. That could be a bottleneck to the implementation of a GIS, since unless the data already existed in digital format, they must be so converted, often by costly manual techniques (e.g. manual digitizing). Sharing data might help to quickly develop a GIS database. However, issues such as data exchange standards must be addressed in order to avoid problems of inaccurate data. In general, the acquisition and input of useful data constituted one of the most critical and often costly aspects of setting up a GIS system.

26. Apart from its analytical capabilities, a GIS system was often used in cartographic applications to prepare paper-based maps displaying selected spatial elements from one or more digital sources as well as the results of a complex spatial analysis. Such a GIS capability allowed maps to be tailor-made according to their proposed end-uses, as the need arose. A knowledge of cartographic concepts, including those relating to geodetic datum, reference ellipsoid, map projection and global positioning system was necessary to fully exploit that capability.

D. Curriculum development

27. Conditions which influenced the implementation of a new course varied considerably between academic institutions, even those located within the same country. A structured approach to programme formulation which took into account the specific constraints imposed on and opportunities available at a given institution was therefore necessary. A proposal for the implementation of a new course should include a discussion of the following topics: the placement of the course within the educational system (would it be part of a course or a separate course?); the target group (what were the entrance qualifications and educational level of the students?); the aim of the course (would it be theoretical or practical?); course implementation (what would its duration and composition be in terms of lectures and practical exercises?); the curriculum; project work (what types of projects would be possible given the information available?); assessment (would the students be evaluated on the basis of practical exercises and student seminars?); staffing (how many trained personnel were available and what was their level of proficiency); facilities and equipment; and financial issues.

II. COURSE EVALUATION

28. The responses on the completed course evaluation forms were analysed by a small committee of participants whose members were selected by the participants themselves. Formal presentation of the results of the analysis was made on the last day of the course by a member of the committee to all participants and representatives of BITS, the Department of Geography of Stockholm University and the United Nations. Discussions following the formal presentation allowed additional inputs to be made by all participants.

29. The key results of the analysis of responses were that:

(a) All participants would have liked more time to be devoted to practical exercises in remote sensing and GIS;

(b) Approximately 80 per cent agreed that the course was well conceived;

(c) Approximately 70 per cent felt that they had benefited significantly from the course;

(d) Approximately 90 per cent agreed with the duration of the course.

30. Some participants anticipated difficulties in applying the newly acquired knowledge in their current employment. Those difficulties, linked essentially to a lack of adequate funds, included access to remotely sensed data and to computers and software for GIS and image processing.

III. PROPOSED FOLLOW-UP PLAN OF ACTION

31. In light of the results of the course evaluation indicating strong interest by participants in having greater exposure to digital image-processing techniques, the Office for Outer Space Affairs proposed to examine the possibility of organizing, through SIDA, a more advanced course for remote sensing educators, during which operational computer techniques in the application of remotely sensed data would be emphasized. Such a course would require participants to be already competent in the visual techniques of image interpretation, and might therefore include graduates of the current course. It was envisaged that the proposed course would alternate with the current introductory course during successive years.

Annex I

PROGRAMME OF THE COURSE

Date/Time	*Subject*	*Speaker*
	Introduction	
Tuesday, 2 May 1995		
0900-0930	Opening ceremony: Welcoming addresses	
0930-1200	Introductory lectures:	
	Knowledge development Remote sensing in a global perspective	A. A. Abiodun L. Wastenson
1200-1400	**Opening luncheon**	
1400-1800	Management of natural resources and the environment - the role of remote sensing	M. Byström
	Presentation of the Department of Physical Geography - education and research	W. Karlén C. Christiansson and B. Lundén
	Fundamental principles	
Wednesday, 3 May 1995		
0900-1600	Electromagnetic radiation, the reflective properties of the Earth and elementary optics	J. Kleman, P. Syrén
Thursday, 4 May 1995		
0900-1600	Electronic imaging	F. Quiel
1830	Reception in the City Hall hosted by the Stockholm City Presidency	
Friday, 5 May 1995		
0900-1200	Georeferencing in the field, on the map and on satellite imagery	G. Alm
Monday, 8 May 1995		
0900-1200	Earth resources and environmental satellites	G. Alm
1300-1600	Image interpretation - theory	G. Alm
1700	Visit to the International Office of Stockholm University	

Date/Time	*Subject*	*Speaker*
	Image interpretation	
Tuesday, 9 May 1995		
0800-1015	Remote sensing for land-use planning and environmental monitoring	F. Quiel
1045-1200	Remote sensing for geological studies	B. Lundén
1300-1630	Introduction to visual interpretation and in-service training in developing countries	R. A. Larsson
Wednesday-Friday, 10 to 12 May 1995		
0900-1600	Case-studies	
	African participants	
	Land and water development in Ethiopia	R. A. Larsson
	Land-use mapping in the United Republic of Tanzania	L. Strömqvist
	Asian participants	
	Environmental impact assessment of the closure of a river arm in Bangladesh	R. A. Larsson
	All participants	
	Land degradation and soils in Lesotho	B. Lundén
	Digital image processing and analysis and GIS	
Monday, 15 May 1995		
0900-1200	Digital analysis (theory)	G. Alm
1300-1600	Computer enhancement (theory)	G. Alm
1600-1700	AVHRR reception and handling	O. Rud
Tuesday, 16 May 1995		
0900-1600	Geographical information systems (GIS) theory	F. Quiel

Date/Time	*Subject*	*Speaker*
Wednesday- Monday, 17 to 22 May 1995		
0830-1630	Digital techniques (computer-aided analysis, GIS applications, CD-ROM, data capture, compass/GPS)	G. Alm W. Arnberg B. Lundén M-L. Nordberg O. Rud P. Syrén K. Wester L-O. Westerberg
	Remote sensing applications	
Tuesday, 23 May 1995		
0830-1200	Introduction to radar imagery	J. Lichtenegger
1300	Departure by bus to the School of Forest Engineers, Skinnskatterberg	
	Introduction to fieldwork exercises	R. A. Larsson J. Lichtenegger B. Lundén
	Group exercises	R. A. Larsson J. Lichtenegger B. Lundén
Wednesday, 24 May 1995		
	Group fieldwork exercise	R. A. Larsson J. Lichtenegger B. Lundén
Thursday, 25 May 1995		
	Presentation of results from fieldwork exercises	R. A. Larsson B. Lundén
Friday, 26 May 1995		
	Presentations by participants	
Saturday, 27 May 1995		
	Sight-seeing bus trip in Dalecarlia; evening departure by train for Kiruna	

Date/Time	*Subject*	*Speaker*
Sunday, 28 May 1995		
	Sight-seeing trip around Kiruna and Jukkasjärvi	R. Bergström
Monday, 29 May 1995		
0830-1200	Welcome to SSC Satellitbild	J. Forsgren
	Introduction to next sections of the programme (needs of the user and remote sensing education)	R. Bergström
	Demonstration of production facilities	R. Bergström
1300-1700	Visits to the ESA/Salmijärvi and the Esrange satellite receiving stations	B. Eriksson L. Poromaa
Tuesday, 30 May 1995		
0830-1030	Archiving: catalogue updating, standard processing	T. Lundqvist
1100-1230	Value-added production; imagery production - radiometric, system and geometric corrections; image enhancement - stretching, filtering; digital elevation model (DEM) and digital terrain model (DTM) extraction and ortho image extraction	T. Westin
1330-1500	Computerized cartography, production system	M. Östling
1500-1800	Presentations by participants	
Wednesday, 31 May 1995		
0830-1200	Visual interpretation of satellite images, use of imagery in project planning	M. Byström
1300-1600	Presentations by participants	
1700	Visit to Samegärden alt Matarakka	
Thursday, 1 June 1995		
0830-1500	Visual interpretation of satellite images, project planning (continued)	M. Byström
1500	Visit to the Kirunavaara underground iron mine	

Date/Time	*Subject*	*Speaker*
Friday, 2 June 1995		
0830-1600	Visual interpretation of satellite images, project planning (continued)	M. Byström
1600-1730	Presentations by participants	
Saturday, 3 June 1995		
0830-1600	Presentation of results; visual interpretation of satellite images, project planning (continued)	M. Byström
1600-1700	Presentations by participants	
Sunday, 4 June 1995		
	River tour, wilderness camp, Lappeasuando, Kaitum/Kalix river	
	Needs of the user	
Monday, 5 June 1995		
0830-0900	Inadequacies in information-exchange in developing countries: a response by the Office for Outer Space Affairs	H. George
0900-1230	Projects and products	P. Zeidlitz
	Selecting satellite data for a project	R. Bergström
	Presentation of three projects	R. Bergström
1700	Train departure for Stockholm	
	Remote sensing education	
Tuesday, 6 June 1995		
1400-1630	Lectures and work in groups on remote sensing education	W. Arnberg
Wednesday, 7 June 1995		
0830-1630	Lectures and work in groups on remote sensing education	W. Arnberg

Date/Time	*Subject*	*Speaker*
Thursday, 8 June 1995		
0830-1200	Lectures and work in groups on remote sensing education	W. Arnberg
1300-1630	Presentation of results; preparations for course evaluation; practical aspects of setting up a remote sensing laboratory	W. Arnberg B. Lundén
	Summary and evaluation	
Friday, 9 June 1995		
0900-1000	Swedish foreign aid	S. Pettersson
1030-1200	Course evaluation	W. Arnberg R. A. Larsson B. Lundén S. Pettersson F. Quiel L. Wastenson
1900	Closing dinner	

Annex II

DESCRIPTION OF PROJECTS

Title and objectives of project	***Problems***	***Remote sensing inputs***
	Marine	
Monitoring of the algal bloom in the Bardawil Lagoon, northern Sinai, Egypt *Objectives*: to determine algal species composition and distribution, species behaviour, photosynthetic efficiency of bloom-forming algae	High nutrient input due to sewage discharge leading to algal growth; water discoloration, odours, eutrophication; death of fish and other biota; adverse impact on migrating birds	Enhanced, multi-temporal satellite images over several seasons for mapping zones of varying turbidity
	Agriculture; degradation	
Rehabilitation of degraded areas in the central plateau (northern Hamassen) of Eritrea *Objective*: to assess the extent of land degradation, identify causes and suggest possible remedial strategies	Land degradation due to effects of war and drought; low agricultural productivity due to decline in soil fertility; erosion due to deforestation, overgrazing	High-spatial-resolution satellite imagery, e.g. SPOT for land-cover mapping
Soil erosion assessment in the Mount Kenya region (Laikipia Plateau) *Objectives*: to document land use over the period 1972-1995, prepare soil-erosion hazard maps, determine the effect of land use on soil erosion	Land degradation, especially on small- scale farms	Multi-temporal SPOT imagery for land-use mapping
Towards an understanding of the apparent desiccation of Lake Naivasha, Kenya *Objectives*: to explain causes (human, physical) of lake desiccation and to elaborate a prediction model	Lake desiccation	SPOT or Landsat images for geomorphological and land-cover mapping

Title and objectives of project	*Problems*	*Remote sensing inputs*
Evolution of cultivated areas (1987-1991) in vicinity of Lac de Guiers, north-western Senegal *Objectives*: to improve rural development within the region	Poor economic development	Multi-temporal, multispectral SPOT images for land-use and land-cover mapping
Siltation in the reservoir of the Lyphohlo hydroelectric power dam in Siphocosini, Swaziland *Objectives*: to determine the influence of land use on siltation	Siltation; low water storage and insufficient power production from the dam	High-resolution satellite images for mapping land cover and land use
Land-use changes in relation to deforestation in tobacco-growing areas, Tabora, United Republic of Tanzania *Objectives*: to determine the impact of tobacco agriculture on the rate of depletion of the Miombo woodlands	Sustainable development of agriculture and woodlands; deforestation due to shifting cultivation on poor soils	Multi-temporal SPOT images for mapping the spatial and temporal changes in land-use and land-cover types
Rehabilitation of degraded lands in the middle catchment of the Deduru Oya River, north-western Sri Lanka *Objectives*: to map degraded lands, identify causes of degradation and make recommendations for improvement	Land degradation due to soil erosion and land slips in hilly areas	SPOT images for mapping terrain types, drainage features, land cover
Improving the economy and environmental management of Ungova Communal Area, Chivi, Masuingo, Zimbabwe *Objectives*: to improve environmental management and economic development of the community	Environmental degradation: severe erosion and siltation; overgrazing and deforestation; overpopulation; frequent droughts	SPOT images for land-use and land-cover mapping

Title and objectives of project	*Problems*	*Remote sensing inputs*
Geology, hydrogeology and natural hazards		
Shore-line recession of the Rift Valley lakes, Ethiopia *Objectives*: construction of the paleoclimatic and paleoenvironment of the Rift Valley regions; correlation with other geologic, geotectonic, hydrologic, hydrogeologic and geochemical studies	Academic research	Satellite images (Landsat, SPOT), SLR imagery
Mapping geological and geomorphological phenomena of north central Nigeria *Objectives*: providing information to enable the monitoring of erosion hazards and facilitating soil conservation practices; prospecting areas for rural water supply	Gully erosion of lateritic soil cover	High-resolution satellite imagery for land-use and land-cover maps and for aiding the preparation of geological mapping
River bank erosion and groundwater management in the Mekong Delta, Viet Nam *Objectives*: to assess the extent of riverbank erosion and investigate ways to minimize damages; to evaluate potable groundwater resources	Serious loss of human life and economic damage due to erosion Lack of sufficient potable sources of groundwater	Multispectral, multi-temporal satellite imagery for mapping the evolution of erosion
Natural hazard mitigation of the Nepalese Himalayan midlands *Objectives*: mitigation of natural hazards (landslides, glacier-lake outbursts, snow avalanches, debris flows)	Damage caused by natural hazards at different times throughout the year	High-resolution satellite images for mapping of surficial and bedrock geological features

Title and objectives of project	*Problems*	*Remote sensing inputs*
	Meteorology	
Rainfall monitoring over agricultural fields adjoining the main Rift Valley area of Ethiopia *Objectives*: comparisons between measured and satellite-estimated rainfall to facilitate development of a satellite-based rainfall model to be used in famine early warning	Applied research	Meteosat images (for developing a rainfall estimation model) and Landsat images (for mapping agricultural areas)
	Pollution	
Pollution of the Nakivubo Channel and its tributaries, Kampala *Objectives*: to investigate the sources of pollution of domestic water	Pollution caused by urbanization and industrialization leading to water-borne diseases	High-resolution satellite images to map the river channel, surrounding land use and possible sources of pollution
	Urban studies	
Changing pattern of urban centres in Pakistan: a case-study of Hyderabad Sind *Objectives*: to determine the factors of urban growth and investigate related problems (e.g. transportation, housing, sewage)	Pollution caused by urbanization and industrialization leading to water-borne diseases	High-resolution satellite images to map the river channel, surrounding land use and possible sources of pollution