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REPORT

TRAINING COURSE ON APPLICATION OF GIS TECHNOLOGY FOR PLANNING AND MANAGEMENT OF INDUSTRIAL AREAS

DAR ES SALAAM, TANZANIA
14 – 24 JUNE 1999

1.0 Background

The objective of ICS subprogramme 2.1 (Decision Support Systems for Sustainable Industrial Development) is to strengthen the decision making process at policy/ regulatory levels in developing countries related to the formulation and implementation of National or sub-national (area wide) policies, strategies and action plans for sustainable industrial development. ICS –UNIDO seeks to address the problem by transferring to developing countries suitable technologies such as Geographic Information System, Remote Sensing and Image Processing that can help to improve the decision-making within the explicit domain of industrial development and environmental management.

ICS has already carried out training activities for East African developing countries (Introductory Training Course on role of GIS, RS, IPS and DSS for industrial development, Trieste, Italy, 23-31 March 1998, and Training Course on Planning the Industrial Sitting in African Urban Areas, Nairobi, Kenya 22-26 June 1998). Following these courses, the Ministry of Lands and Human Settlements Development officially requested to ICS to organize a training Course on application of GIS technology for planning and Management of Industrial areas, with special emphasis on the integration of Remote Sensing, Image Processing and Geographic Information Systems. Twenty four people from the Ministry of Lands and Human Settlements Development (Division of Surveys and Mapping, division of Human Settlements Development and division of Land Development Services), five people from University of Dar Es Salaam (Institute of Resource Assessment, Geography, Geology and Civil Engineering will be attending.

2.0 Justification

In Tanzania, the use of computer technology has begun in many organizations, however it is mostly limited to the level of word processing, spread sheet, banking, accounts, etc. The use of computer technology for acquiring and processing data from satellites has not yet advanced very much. The Ministry of Lands and Human Settlements Development is the central core generator of land related data and information. The vision of the Ministry in this area is to establish a multi-sect oral GIS/LIS for the whole country that shall be the basic tool for planners and decision makers on many national planning, environmental and development programmes. This is quite an ambitious vision the success of which requires resources, in terms of expertise, facilities, funds, patience and commitment on the part of the implementers.

Nowadays, the price of computers and peripherals is affordable by many countries, however the training for acquisition of local expertise remains an obstacle because of the lack of trainers, facilities and finance. Therefore, the need for training in processing and using satellite information is very vital. The training, like the one offered by ICS, has been considered highly beneficial by the Ministry of Lands and Human Settlements Development in developing capacity in that field. As the need for this training exits in many organizations, it is felt however, that the Ministry of Lands and Human Settlements Development, by virtue of its role as the principal collector of land information and the University of Dar es salaam by virtue of being an institution of high learning and research in many fields including the use of remote sensing data in resource assessment, be considered the first place to form a nucleus for spread of use of space technology in Tanzania.

3.0 Objectives

To train staff form the Ministry of Lands and Human Settlements Development, the University of Dar Es Salaam and other governmental-organization on the integrated use and application of Image Processing Systems (IPS), Remote Sensing (RS), and Geographic Information Systems (GIS) technologies as basic tools for facilitation of decision making on land administration and environmental issues. The trained personnel will contribute towards the national ambition of building own local capacity of expertise in modern technology related with land administration that is geared towards increased efficiency in planning and decision making processes.

4.0 Expected output

As a starter course, the overall expectation was to end up with trained staff from participating institutions in the application of computer technology in the areas of imagery processing, GIS and RS systems. Once equipped with such knowledge it was envisaged that on returning to their respective work organizations, participants would use the acquired knowledge in work routines in the hope of complementing other methodologies in place for problem solving analyzing and decision making in land and environmental related issues.

5.0 Achievement

Training was conducted as planned. However experts from Canada and Hungary as initially expected could not manage to attend. Instead, substitute lecturers from Kenya and locally were made available. The number of participants remained more or less as planned but more ministries (ministry of Agriculture, ministry of Works, ministry of Trade, ministry of Water) other than of Lands were involved. This was considered important because there is cross-ministerial linkages and interactions on manner common issues related with land and environmental matters. As the result a total number of 29 participants came from 6 different institutions. Apart from the two trainers from Italy, Prof. Feoli and Dr. Toffoluti, five other lectures from Tanzania and Kenya were involved. Unfortunately it was not possible to get in time data and materials for formulating a typical case study in the vicinity of the training area whereby it would have been possible to demonstrate the taught skills on actual practical data. All the same the delivered lectures and hand-on exercises demonstrated beyond doubt the power and capability of RS and GIS tools in problem solving and analysis. Every participant appreciated that observation.

6.0 Recommendations.

As pointed out in the previous section, the training was conducted successfully. However some remarks worth noting are that

- Preparation time was not sufficient and that can be one of the reasons some lectures could not manage to attend because of short time notice. Therefore more time for preparation is required after confirmation of the course so that organizers get time to identify and collect all necessary materials for preparing case studies.

- Because these training courses most likely draw participants from production rather than academic institutions, it is important that they are formulated and organized with more practical than theoretical orientation. Delivering basic principles of RS eg radiometric characteristics sensors and the like, may be of less impact to the practitioner who is more interested and inclined to use RS as a tool to solving his problems. A farmer is more keen to use a hoe for tilling land for increased productivity than learning its manufacturing process no matter how interesting the process might be. In this context therefore, institutions aspiring to conduct similar training courses must in the first instance identify their problems sighting practical cases which they hope can be solved with the application of RS, IPS and GIS technology and tools.

7.0 Immediate Follow-up

No immediate follow-up programmes were identified except the emphasis on participants to use the acquired knowledge in their daily work routines. The Surveys and Mapping Division of the Ministry of Lands and Human Settlements Development is at the stage of procuring facilities for using digital images from aerial photographs and satellites, with which maps and other products needed for land administration and environmental issues can be prepared faster and cheaper than line maps alone. In one way this is a positive outcome of the training course whereby some senior official in the department participated and appreciated the power of RS and GIS, hence the move. Once the facilities are in place the Ministry might take initiative of organizing and conducting training courses to other ministries with close linkages in many similar and common aspects.

8.0 Programme

PROGRAMME AND TIME TABLE

Day and Time	Activity/lecture	Responsible
Monday, 14 June		
09.00 – 09:30	Registration	Organizers
09:30 – 10:30	Opening	Director, SMD
10:30 – 11:00	Coffee Break	
11:00 – 13:00	RS and GIS, to construct a D.S.S.	Prof. E. Feoli
13:00 – 14:30	Lunch break	
14:30 – 17:00	Solar energy: irradiation, absorption reflection	Prof. Toffoluti
Tuesday, 15 June		
09.00 – 10:30	Energy's detection: history, satellites, signals, data storage	Dr. P. Toffolutti
10:30 – 11:00	Coffee break	
11:00 – 13:00	Continuation of previous lecture	
13:00 – 14:30	Lunch break	
14:30 – 17:00	Raster data: sources, methods, formats, exercises	Dr. P. Toffolutti
Wednesday, 16 June		
09:00 – 10:30	Image processing: geo-reference; exercises	Dr. P. Toffolutti
10:30 – 11:00	Coffee break	
11:00 – 13:00	Continuation of previous lecture and exercises	
13:00 – 14:30	Lunch break	
14:30 – 17:00	***Historic and development trend of RS & GIS technology in Africa***	**Prof.S.Ndyetabula**
Thursday, 17 June		
09:00 – 10:00	***Continuation of previous lecture***	***Prof. S.Ndyetabula***
10:00 – 10:30	***Coffee break***	
10:30 – 13:00	***AFRICOVER –LCCS ;mapping & cartographic standards, multipurpose Database concepts, ongoing and future applications of the AFRICOVER database***	**A. Gregorio**
13:00 – 14:30	Lunch break	
14:30 – 17:00	***AFRICOVER experience- an overview on land cover mapping activities in the region.***	**A. Gregorio**

Friday, 18 June		
09:00 – 10:30	***GIS basic concepts, H&S/Ware, Cartography fundamentals and capabilities***	***Dr. P. Z. Yanda***
10:30 – 11:00	***Coffee break***	
11:00 – 13:00	***Continuation of previous lecture***	
13:00 – 14:30	***Lunch***	
14:30 – 17:00	***RS&GIS application- land use planning for agriculture***	***H.A. Dumea***
Saturday, 19 to	***Case Studies and Applications of RS and GIS***	***Dr. Yanda or Dr. Malende***
Monday, 21 June		
	Proliferation & state of the art of RS and GIS in Tanzania	***Dr. Mtalo***
Tuesday, 22 June		
09:00 – 10:30	Typical G.I.S. operations and DB management system; ex.	Dr. P. Toffolutti
10:30 – 11:00	Coffee break	
11:00 – 13:00	Continuation of previous lecture	
13:00 – 14:30	Lunch break	
14:30 – 17:00	Exercises	
Wednesday, 23 June	FIELD TRIP to project area, Pugu Forest	Dr. P.Z. Yanda
09:00 – 10:30		
10:30 – 11:00		
11:00 – 13:00	Lunch	
13:00 – 14:30	DEM creation, 3D data and model, 3D analysis, exercises	Dr. P. Toffolutti
14:30 – 17:00		
Thursday, 24 June		
09:00 – 10:30	Case studies: exercises, round table with participants	Dr. P. Toffolutti
10:30 – 11:00	Coffee break	
11:00 – 13:00	Continuation of previous exercise	
13:00 – 14:30	Lunch break	
14:30 – 17:00	Closing	Director IRA

9.0 List of participants

No.	Name of participant	Organization	Address
1.	Mr. Simon Mwansasu	Institute of resource assessment	P.O.BOX 35097 Dar es salaam (DSM)
2	Miss Anna Mushi	do	DoBox 35097 DSM
3.	Mr. Abel Kapela	-"-	Box 35097 DSM
4.	Mr. J. Rugemalila	Ministry of Works	Box 9423 DSM
5.	Mr. E Maduhu	Ministry of Works	Box 9423 DSM
6.	Mr. F.E Mahuha	Ministry of Agriculture	Box 9071 DSM
7.	Mr. J. Ningu	Ministry of Agriculture	Box 9071 DSM
8.	Dr. Ing. Crispin	University of Dar es Salaam	Box 35052 DSM
9.	Dr. Kristoko Msindai	University of Dar es Salaam	Box 35052 DSM
10	Mrs. Angela Malisa	National Environmental Management Council (NEMC)	Box 77257 DSM
11.	Miss Aida Kiangi	NEMC	Box 77257 DSM
12.	Mr. Edward Kihunrwa	Ministry.of Lands	Box 9132 DSM
13.	Mrs Paulina Thawe	Ministry. of Lands	Box 9132 DSM
14.	Mr. Stephen Kongwa	Dar es Salaam City council	Box 9084 DSM
15.	Mr. S.K Kajula	Dar es Salaam City council	Box 9084 DSM
16.	Mr. P.B Marwa	Min. of Lands	Box 9132 DSM
17.	Mr. A. K Maziku	Min. of Trade	Box 30097 DSM
18.	Miss Aisha Msonde	Dar es Salaam City council	Box 9084 DSM
19.	Miss Zuhura Mbegha	Min. of Lands	Box 9132 DSM
20	Mr. Alex Karaba	Min. of Lands	Box 9132 DSM
21.	Mr. S.D Mayunga	Min. of Lands	Box 9132 DSM
22.	Mr. John Kamuhabwa	Min. of Lands	Box 9132 DSM
23.	Mr. K.A Msago	Min. of Lands	Box 9132 DSM
24.	Mr. R. M Materu	Min. of Lands	Box 9132 DSM
25.	Mr. I.Marwa	Min. of Lands	Box 9132 DSM
26.	Mr. Z.Y Masele	Min. of Lands	Box 9132 DSM
27.	Mr. A. Julai	Min of Water	Box 9153 DSM
28.	Mrs. Rita Kilua	Min. of Water	Box 9153 DSM
29.	Mr. L.L Mollel	Min. of Lands	Box 9132 DSM

6.0 List of Lecturers

No.	**Name of participants**	**Country**
1.	Prof. E. Feoli	Italy
2.	Dr. Toffoluti	Italy
3.	Prof. S.L.P Ndyetabula	Kenya
4.	Mr. A.Di Gregorio	Kenya , Africover E.A project
5.	Dr. P.Z Yanda	Tanzania
6.	Mr. H.A Dumea	Tanzania
7.	Dr. E. Mtalo	Tanzania

List of Annexes

Presented Papers/Statements:

1. Statement by the Director of Surveys and Mapping Division when opening the Training
2. The Africover Project – General Presentation
3. Land Cover in the Pugu and Kazimzumbwi Forest Reserves and the Surrounding Areas between 1953 and 1987
4. Statement by the Acting Director of the Institute of Resources Assessment when Closing the Training.
5. Kilosa District: Land Use and Natural Resources Assessment (given as reading material to participants)
6. Financial Expenditure

STATEMENT BY THE DIRECTOR OF SURVEYS AND MAPPING DIVISION, TANZANIA WHEN OFFICIALLY OPENING THE TRAINING COURSE ON THE APPLICATION OF GIS TECHOLOGY FOR PLANNING AND MANAGEMENT OF INDUSTRIAI AREAS HELD AT THE INSTITUTE OF RESOURCE ASSESMENT, UNIVERSITY OF DAR ES SALAAM 14 - 24 JUNE, 1999

Dear Professor, Feoli, Scientific Coordinator of this training program,
Dear Distinguished Lecturers both foreign and local,
Dear guests and participants
Ladies and Gentlemen.

On behalf of the Permanent Secretary, Ministry of Lands and Human Settlements Development, I wish to express my appreciation for being invited to officially open this training course in Tanzania on the Application of GIS Technology for Planning and Management of Industrial Areas.

I feel it is worthwhile giving a short background on how this course was conceived and eventually materialized to-day. Sometime back in March 1998 I and my colleague, Dr. Yanda of the Institute of Resource Assesment, got an opportunity to attend a two weeks course on Remote Sensing (RS), Image Processing Systems (IPS), Geographical Information Systems (GIS) and Decision Support Systems (DSS) at the University of Trieste in Italy. The course was quite good, intensive and impressive. I recall spending quite sometime on a computer downloading data and information from space. My two weeks exposure to and knowledge of the existence of huge volume of data on land information and environment in space, free for use by whoever has the technical know-how and expertise, inspired me to pursue a similar training locally.

Therefore on return to Tanzania, we installed an e-mail facility at the Surveys and Mapping Division in order to be able to browse into space hunting for information and also to facilitate e-mail communication worldwide. This was done quite successfully. Thereafter we applied to Trieste University through Professor Feoli for training more people in RS and GIS so that the nation can benefit through access to data in space and therein foster faster development. We deliberately chose the Ministry of Lands and the Institute of Resource Assessment as focal points for the initial training by virtue of their role of being centres for collecting, processing and distributing land and environmental information for use by other organizations in various development endeavors. Our application stressed the need for more people to be exposed to the techniques and for a longer time. It is logical that such training could be organized and conducted cheaper in the recipient countries rather than in the donor country, provided that essential facilities are available. It was quite sometime since the application was sent without feedback and I thought probably it could be one of those many applications which go unattended and forgotten forever.

To my surprise sometime in April this year I received message from Professor Feoli informing of the acceptance of our application and that the course would be conducted in Tanzania. That is when I realized that the Professor had been busy working hard behind the scenes towards the realization of this course. Indeed I take this opportunity to thank him for the hard work which has produced fruits in the form of this course.

In Tanzania the proliferation of Remote Sensing, Image Processing and GIS technologies has just started. Consequently its application to solving problems is at infancy stage so to speak. Many organizations are aware of the capability and power of GIS technology to analyze and provide alternatives from which decision makers can choose the best option to solve problems. It is good and important to know the advantages of modern technology in providing solutions to our problems but it is another matter to use such tools to solve the problems in the most efficient manner. This course is geared towards attaining proficiency for the later case.

The Ministry of Lands and Human Settlements Development has the mandate of land administration in the country to ensure equitable land distribution, and monitoring utilization in order to conserve the environment to the advantage of generations to come. Land, being a prime and essential but non-renewable and not expandable resource, requires articulated methods and techniques for its management. Besides, in the light of rapid social and economic developments now taking place globally, faster, reliable methods and techniques are needed to address land management and environmental issues. Space technology and GIS tools are the answers to that need because they offer reliable timely information through which alternative solutions to most planning and management issues, both in rural and urban areas can be gauged

Industrialization has been brought about by civilization of mankind for betterment of life on earth. Unfortunately, over industrialization may be detrimental to human life if not well controlled. This is a consequence of emissions of huge volumes of pollution that threatens the ozone layer, which protects life on earth from destruction by harzadeous radiation from the sun. Indeed, it is the concern of every human being to sustain life on earth. Thus training courses like this one are highly welcome by developing countries because they aim at developing local capacity and expertise in managing our environment in a scientific manner more so in urban industrial areas.

It is my expectation that by the end of this course participants will not only be enlightened on GIS technology and its application but will be equipped with the necessary technical know-how to use modern techniques to fasten decision making.

With these few remarks I declare the training course open.

STATEMENT BY THE ACTING DIRECTOR OF THE INSTITUTE OF RESOURCE ASSESMENT, UNIVERSITY OF DAR ES SALAAM, DR. H. SOSOVELA WHEN CLOSING THE TRAINING COURSE ON THE APPLICATION OF GIS TECHOLOGY FOR PLANNING AND MANAGEMENT OF INDUSTRIAI AREAS HELD AT THE INSTITUTE OF RESOURCE ASSESSMENT (IRA) UNIVERSITY OF DAR ES SALAAM 14 - 24 JUNE, 1999

Prof. Enrico Feoli, Scientific Coordinator of the training program,
Distinguished Lecturers,
Dear guests and participants
Ladies and Gentlemen.

On behalf of the Director of the Institute of Resource Assessment, University of Dar es Salaam, I am grateful to be invited to officially close the training course in Tanzania, on the Application of GIS Technology for Planning and Management of Industrial Areas, that has run for ten days from 14June, 1999.

On the occasion of opening this training, the Director of Surveys and Mapping Division, Mr. Mollel, welcomed foreign guests and wished you a happy and enjoyable stay in Tanzania. I hope that has happened despite the tight schedule that might have denied you seeing and enjoying more of the attractive scenes of Tanzania and Dar es Salaam City. However, what matters most is the accomplishment of the intended mission and achievement of the desired objectives and results, which I can read from the beaming faces of the participants, that have been met fully.

May I therefore express thanks to the following:

- Mr. Mollel, Director of Surveys and Mapping Division and Dr. P.Z. Yanda of IRA for their intuition and initiatives of requesting for this training after their exposure to space technology at Trieste university, Italy sometime back in March, 1998.

- Professor Feoli, the Scientific program coordinator and architect of the training course that has just ended.
- The International Centre for Science and High Technology as technical facilitators of this course.
- The United Nations Industrial Development Organization (UNIDO) as financial facilitator of this course.
- Foreign lecturers,
  - Prof. Feoli and Dr. Toffolluti who have taken the lion's share of the training program without fatigue
  - Professor Simon Ndetabula. the Director General of the Regional Centre for Services in Surveying, Mapping and Remote Sensing,
  - Mr. Antonio Di Gregorio, a consultant with Africover Project, East Africa Module,

Also thanks are due to local lectures who on short notice were willing to give lectures on subjects not necessarily of their choice:

- Dr. E. Mtalo of the University College of Lands and Architectural Studies,
- Mr. H. Dumea from the Ministry of Agriculture
- Dr. P. Z. Yanda of IRA.

Also I thank all ministries and other government institutions who at this period of the year are busy closing the financial commitment and preparation of budget for next year allowed their staff to attend this training. This is quite rare, considering that most of the participants are senior officials who have to contribute to the budgeting process in their respective areas. Finally, I thank all participants for enduring such intensive training in environmental conditions that might have not been the best.

The Surveys and Mapping Division, Ministry of Lands and Human Settlements Development, the Institute of Resource Assessment, University of Dar es Salaam and the International Centre for High Technology have demonstrated good and successful collaborative venture in organizing training course of this kind. I am confident that the tripartite institutions are capable of organizing even international training courses of similar nature provided that each party plays its role well. On the other hand, there is a lot in common between IRA and SMD to share and to exchange concerning collection, processing and distribution of land and environmental data and information to the User community. Therefore, collaborative ventures like this one is not beneficial to participating institutions alone but is beneficial to the country by fostering and forging ahead development in the light of technological advancement.

Apart from initiatives by the tripartite institutions to explore areas of further collaboration, the participants have a role to play in ensuring success of such efforts. Participants when they return to their work place, must demonstrate in real terms that the training was worthwhile by putting in practice what you have learnt during this period. Most decision makers do not have enough time to read long reports in particular when they are highly technical; but have time to see and prefer actions. After all seeing is believing. Therefore you have to be good missionaries for bringing about technological development in the country

Technological advancement of to-day is quite dynamic, as such learning and training got to be a continuos process irrespective of whether one is in a training institution or production environment. In fact the mix of training and production institutions in training courses of this kind, I find it very good because it offers opportunities to exchange and share experience of what training institutions offer to the market and how the consumers benefit from it. So this should be encouraged to continue. I am hopeful and look forward for further greater cooperation in organizing similar training courses. I am sure that as a starter collaborative venture, there must be areas where we have not performed well but let us take it as a learning process and yard stick for better management of future courses.

With these few remarks, I wish our guests nice and safe journey back home and let us keep in touch through space contacts. I declare the training course on the Application of GIS Technology for Planning and Management of Industrial Areas closed.

TRAINING COURSE ON THE APPLICATION OF GIS TECHNOLOGY FOR PLANNING AND MANAGEMENT OF INDUSTRIAL AREAS
14 – 24 JUNE DAR ES SALAAM

EXPENDITURE SHEET FOR SERVICES GIVEN IN THE COURSE OF IMPLEMENTING
Project No. :*TF/GLO/96/105* Under **UNIDO Contract No.** *99/136/IR (10 – 18 June)*

Responsible	**Type of service**	**Nos**	**Rate**	**Total amount**	
				Tshs	US$
Prof. Simon Ndyetabula: lecturer from Kenya	Refund of air ticket Nairobi/Dar/Nairobi	1	352.00	-	352.00
	DSA in Dar es Salaam	3	149.00	-	447.00
	Deliver lectures	2	150.00	-	300.00
			Total 1	-	**1,099.00**
Mr. Antonio Di-Gregorio: lecturer from Kenya	Refund for air ticket Nairobi/Dar/Nairobi	1	352.00	-	352.00
	DSA in Dar es Salaam	3	149.00	-	447.00
	Deliver lectures	2	150.00	-	300.00
			Total 2	-	**1,099.00**
Mr. H. Dumea: local lecturer from Ministry of Agriculture	Deliver lectures	2	150.00	-	**300.00**
Dr. Mtalo: local lecturer from University College of Lands and Architectural Studies	Deliver lectures	2	150.00		**300.00**
Dr. P.Z. Yanda: local lecturer from University of Dar es Salaam IRA	Deliver lectures	2	150.00	-	300.00
			Total 3	-	**300.00**
Dr. A. Mwambela: Computer Sustems administrator from University of Dar es Salaam	Computer Systems , administration: establish network and configure all PC's at place of study and administer through the study. Re-establish former network and configure PC's as they were before the course, at SMD where the PC's were borrowed	12 3	150.00	-	**2,250.00**
Dr. P.Z. Yanda: course organizer from IRA	Buying accessories for LAN: cables, hub, power extension cables				**400.00**
Manager Canteen catering services	Tea/refreshment at 10:30 a.m. and 4:0p.m for 35 participants	10	150.00		**1,500.00**

Dr. Yanda: Course organizer from IRA	Transport services for visiting lectures (4): Airport to Hotel to Airport Hotel to IRA to Hotel, every morning & afternoon				**1,450.00**
Z.Y. Masele: course coordinator Dr. Yanda	Buy stationeries. Pads, pens, folios, Ids, transparencies, DHL courier				**1,650.00**
Dr. Yanda/ TANRIC	Secretarial services & Photo copying of lecture notes, handouts and papers				**570.00**
Dr. Yanda	Tour guide to Pugu and preparation of study materials				**1,500.00**
Dr. Yanda	Transport service to Pugu forest for field study: 3 vehicles				**750.00**
Dr. Yanda/IRA	Preparation and printing of certificates				**600.00**

TRAINING COURSE ON THE APPLICATION OF GIS TECHNOLOGY FOR PLANNING AND MANAGEMENT OF INDUSTRIAL AREAS
14 – 24 JUNE DAR ES SALAAM

SUMMARIZED BREAKDOWN OF EXPENDITURE THE PERIOD 10 – 25 JUNE, 1999

nn	Description Service given (10- 25. June,1999)	Nos.	Amount in US$
1	Refund air tickets of foreign lectures	NRB/DAR/NRB *2	704.00
2	Payment of DSA for visiting lectures	6 @ 149.00	894.00
3	Delivery of total 10 lectures	150@lecture	1,500.00
4	Tour guide to Pugu forest for field study and preparation of study materials		1,500.00
5	Tea & refreshment at morning and afternoon breaks For all course participants		1,500.00
6	Transport services for lectures/receiving from Airport/Hotel- IRA-Hotel/escort to Airport City Centre-IRA-City center (morning, lunch time, afternoon after lectures)	4 visitors	1,450.00
7	Transport to Pugu Forest for practical exercise	used 3 cars	750.00
8	Stationeries, writing pads, pens, folio covers, Id badges, transparencies and postage services		1,650.00
9	Secretarial services & photocopying of lecture notes, handouts and papers		570.00
10	Buying accessories for LAN: cables, hub, power extension cables, connectors		400.00
11	Systems Administrator	12 days Re-establishing original network and configuration of PCs before the course	1,800.00 450.00
12	Preparation and printing of certificates	29	600.00
		TOTAL	**13768.00**
		First Invoice sent to Vienna upon signing contract	**12,000.00**
		Balance after expenditure	**-1,768.00**

First Invoice raised to Vienna: US$ 12,000.00

1. THE AFRICOVER PROJECT - GENERAL PRESENTATION

1.1 Aims of the AFRICOVER Project

For the last two years, FAO has been involved in a very important project called AFRICOVER, its purpose is to establish for each African country, a georeferenced digital database of land cover and a geographic reference system (toponomy, roads, hydrography) at a scale of 1:250 000/1:200 000 (of which 1:100 000 for certain priority areas and small countries). The database will then be generalised to 1:1 000 000 and updated. This will provide a set of maps that will be comparable from a thematic and geographic point of view throughout the African continent.

AFRICOVER also aims to increase and up-grade national and subregional capacities to facilitate the establishment, updating and operational use of the geographic reference system and land cover maps.

This Project was created to meet the numerous country requests for reliable and geographically referenced data on natural resources both at national and regional levels.

Analysis of the information requirements revealed that of the countries concerned, sets of data could be compiled on resources whether they concern early warning system monitoring of forests and grazing land, planning, management of drainage areas, production of all the necessary sets of statistics, biodiversity or climate changes, without a reliable and homogenous geographical database, data on infrastructure, habitat, hydrographic systems and land cover.

The goal of AFRICOVER is therefore to gather the basic geographic information comprising that of the usual points of reference as well as common to data for future programmes on natural resources in Africa.

1.2 Implementation of the AFRICOVER Project

From a technical point of view, the preparation of AFRICOVER products relies essentially on remote sensing techniques and geographic information systems (GIS).

Land cover will be established by interpreting recent high resolution and digitally improved enhanced satellite images. Maps will be created according to a hierarchical land cover classification system which an international working group has now completed. This classification will also make it possible for all classification systems and nomenclatures in the concerned countries to communicate and homogenise. The geographic reference system will be based on existing topographic maps and then updated using remote sensing data and land survey georeferenced by means of GPS. The basic geographic referential will depend on the geodetic network and on the quality of existing topographic maps. It may consist of existing topographic maps, or satellite images geometrically corrected using GPS points and spatio-triangulation techniques.

Mapping methods favour team work and the discussion of tasks in order to maximise synergies and scale economies (i.e. multiple approaches).

From an operational point of view, maps will be drawn-up by national teams assisted by international experts from other African countries when possible. Several compatible approaches may be adopted according to the countries and regions in establishing the Project.

- An exclusively national approach, in which each country participates independently in the Project. This approach is keeping with the policies developed by the World Bank and various bilateral cooperation agencies. In this case, the countries will be fully responsible for contracts and international expertise. When possible, certain responsibilities concerning coordination and follow-up/training issues could also be entrusted to a subregional organization.

- A national and regional approach, that would allow the countries of a subregion to carry forward the Project at the same place. This will require subregional coordination and the carrying out of technical activities in common.

The end users of AFRICOVER data will be the technicians and decision-makers involved in the management and monitoring of natural resources at regional and national levels, namely, ministries (Planning, Rural Development, Environment, Statistics, Agriculture, Forests, Fisheries, Water, etc.), international development organizations (the United Nations, the World Bank, the European Union, IFAD, ADB, etc.), inter-governmental organizations (IGAD, SADC, CILSS, OACT, etc.), agencies for bilateral cooperation, non-governmental organizations, local groupings and private operators in the concerned countries.

FAO plans to assist in setting up the AFRICOVER project (at a technical, institutional and financial level) and will be involved in technical monitoring of the Project.

In addition to the role of technical assistance, FAO will also oversee the introduction of standards or best practises for the AFRICOVER project: this involves the international working groups defining in detail, standards for information, tools, analytical methods and utilisation procedures which will be applied in all the countries. This standardisation takes into account as much as possible, national and subregional requirements. From a technical point of view, standardisation is essential to ensure as wide a distribution as possible for the end products (databases, maps). It also offers as a possibility, significant scale economies when it comes to the production, updating and use of georeferenced data on resources. FAO will ensure that these standards are respected and will issue an AFRICOVER label. FAO could intervene as an executing agency (or co-executing agency) of the Project for the countries and the subregions which may request it.

- The budget for the AFRICOVER project will be between US$1 and US$2.5 per square km according to the countries and the approaches used.

- It will take between two and four years, for complete national coverage, depending on the size of the country and the scale used.

1.3 Status of the AFRICOVER Project

The AFRICOVER project was approved at an International Meeting at the ECA Headquarters in Addis Ababa in July 1994, where eight subregional organizations participated (i.e. IGAD, SADC, CILSS, RCSSMRS, OACT, CRTO, CRTEAN, RECTAS) as well as four organizations of the United Nations (UNEP, UNDP, FAO, UNITAR) and nineteen international and national organizations (including OSS, CNITG and CSE).

In addition, surveys and detailed studies were carried out in each of the African countries. In order to evaluate national and regional capacities, existing maps and data, current and future projects/programmes which could be linked to AFRICOVER and the needs of the final users.

The Subregion of East Africa (twelve countries of the Nile Basin: Burundi, Democratic Republic of Congo, Djibouti, Ethiopia, Egypt, Eritrea, Kenya, Uganda, Somalia, Sudan, Tanzania and Rwanda) has been able to start work on the Project, following the receipt of US$5.4 million from the Italian Government. A combined national and regional approach is being adopted and FAO will be the executing agency of the Project for this Subregion.

Regarding the other subregions and countries, negotiations are at an advanced stage among the various African partners, financial backers and development agencies such as French Cooperation, the European Union, the GTZ, CIDA and the World Bank, which all support the AFRICOVER project in principle and plan to participate in different levels of the various countries. So far, a number of African countries, such as Equatorial Guinea, Guinea, the Ivory Coast, Mali, Mauritania, Mozambique, Namibia, Nigeria, Togo and Zimbabwe have submitted official requests while other requests are being examined by the ministries of other African countries. Some countries, such as Senegal and Tunisia, have set up national AFRICOVER working groups that will also be responsible for drafting project documents.

Given the latest developments and negotiations, the AFRICOVER database will almost certainly be created through national and subregional environmental information projects for the management of resources, such as the projects that are being prepared in Central and West Africa.

The countries of the Congo Basin (Cameroon, Central African Republic, Congo, Gabon, the Democratic Republic of Congo and Equatorial Guinea), the World Bank in partnership with FAO, the European Union and a number of bilateral agencies, have put together a major project, the Regional Environment Information Management Project (REIMP) (US$15 million) in which AFRICOVER standards were adopted for the preparation of a topographic map and land cover database.

For fifteen countries of the Sahel and coastal region of West Africa, AFRICOVER standards should be applied within the framework of the IRENE project, financed by the European Union, to create inventories of and evaluate natural and environmental resources.

Finally, FAO has been organizing international working groups responsible for specifications and technical standards for land cover, geometry and topographic maps and the technical methods to be adopted. These groups are made up of over fifty high-level experts from the international scientific community in which most African countries are represented.

- The first group met in Dakar in July 1996 and has already defined an exhaustive classification system for land cover. Regardless of the remote sensing instruments used or the working scale, this classification system will allow translation of main land cover legends or nomenclatures used in Africa. It has already met with approval among a number of African countries and various international, European and American programmes. The possibility of extending this classification to the rest of the world is being discussed.

- The second group, which prepared this report, is responsible for defining standard specifications for geometry and mapping in terms of datum spheroids, map projections, cartographic projection, planimetric and elevation accuracy, for all African countries.

The specifications defined by these groups were adopted in principle at the Ninth African Cartographic Workshop in November 1996. In addition, some advanced mapping and photo-interpretation assisted software has been developed which also includes different quality control functions.

Finally, a technical manual is being prepared containing all the methods and procedures to be applied in the various countries for the implementation of the AFRICOVER project. This manual will also include the results of pilot projects carried out in a cross-section of environmental conditions in the African continent.

THE AFRICOVER METHOD:
CONCEPT AND TOOLS FOR A MULTIPURPOSE ENVIRONMENTAL RESOURCES DATA BASE

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ABSTRACT

Despite the high demand for environment and natural resources information, many existing maps and digital databases are neither comparable nor developed to really meet multi-user requirements. In many countries resource managers require periodic information on land cover both to meet international requirements and to develop national strategic plans. Traditional resources inventories (such as land cover) are conducted independently on a sector basis. Very frequent is the case where the same geographic area is mapped several times for two or more different purposes (for example, forest timber assessment, agricultural census, animal habitat, etc.) but each type of data base produced can only be used for the particular purpose for which it was generated, or it gives too generic details to the sectors different from the one for which the data base was produced originally. This situation, especially in developing countries, causes serious problems due to lack of generating specific data bases several times (resulting in loss of financial and human resources). In general it hampers the possibility of the use of these data by a larger user community who could be envisaged in the age of GIS and easy Internet communications. In this context the AFRICOVER initiative wants to produce a so-called "Multipurpose environmental resources (mainly Land Cover) data base". It is a set of detailed Land Cover and Environmental information that can be used by a large community of specific end users.
This basic idea is supported and enhanced by a series of new tools that AFRICOVER is producing. Without these new tools the idea of a "Multipurpose data base" would remain at the stage of a simple concept without any concrete functionality.

Four basic tools are or will be produced by AFRICOVER to support this idea:

1. *Land Cover Classification System* (LCCS). It is one of the most important developments that gives to the multipurpose data base method the basic concept to be multi user oriented. It is a comprehensive standardized a-priori classification system, designed to meet specific user requirements, and created for mapping exercises, independent of the scale or means used to map. The classification uses a new concept based on the use of a set of well-defined independent diagnostic criteria that allow correlation with existing classifications and legends and can be the base for several specific disciplines. Thus, this system could serve as a worldwide land cover reference base. (already developed and finalized).

2. *Africover Interpretation and Mapping System* (AIMS). It improves the efficiency of the interpretation and interactive use of ancillary data as entirely required when a very detailed set of land cover information must be collected. It is an on-screen interpretation software that combines in a synergic way the advantages of the digital automatic classification and the traditional visual interpretation. It is directly linked with LCCS and set to follow all the

phases of the interpretation process as carried out in the AFRICOVER production chain. (already developed and finalized)

3. *Africover Database Gateway* (ADG). Together with LCCS gives to the multipurpose data base concept the feasibility to be really functional. Its main function is to allow an easy and fast recombination of the land cover polygons, not only by class names (as usually done in normal GIS) but also by classifiers. The end user then can create it one classes (using the set of existing classifiers) recombining the database polygons accordingly. (under development)

4. *Africover Interactive Database* (AID) for interpretation. It will be an interactive software to guide and homogenize the land cover interpretation. Selected portion of different type of images, ground truth data, ancillary data will be organized in a logical interactive way to guide the user in the identification of the variety of different land cover types existing in Africa. (development scheduled for the middle of 1999).

THE PROBLEMS OF CURRENT CLASSIFICATIONS: DEVELOPMENT OF A NEW APPROACH

ANTONIO DI GREGORIO – LOUISA J.M. JANSEN

ABSTRACT

Despite the high demand for environment and natural resources information, many existing maps and digital databases are not developed to really meet the various user requirements. One of the main causes, though generally underestimated, is the type of classification or legend used to describe basic information such as land cover and land use. Many of the existing classifications are generally not comparable with one another and very often single project oriented or taking a sectoral approach. Though many classification systems existent throughout the world, there is no single internationally accepted land cover or land use classification system.

The FAO developed a new Land Cover Classification System (LCCS) to try to rationalise this situation. This system is a comprehensive standardised a-priori classification system, designed to meet specific user requirements and to assure a high geographic accuracy. The classification takes a parametric approach and uses a set of well-defined independent diagnostic criteria, the so-called classifiers, that allow correlation with existing classifications and legends. Thus, this system could serve as a reference base for land cover. The developed methodology is applicable at any scale and comprehensive in the sense that any identified land cover anywhere in the world can be readily accommodated. Furthermore, the system can also be used to analyse the consistency of existing classifications. Because of the complexity of the classification and the need for standardisation, a software program, of which the beta version has been developed, will assist the interpretation process. This program facilitates the standardization of the interpretation process as well as contributing to its homogeneity. The next step will be to develop a reference land use classification, being based upon the arrangements, activities and inputs people undertake on the land. At present efforts are being made to develop a methodology to describe land use in a comprehensive and consistent way taking a multi-user oriented approach. This should result in a first approach for a reference base for land use classification.

INTRODUCTION

There is a high demand for improved land cover and land use information because of an increasing need to be able to precisely describe and classify land cover and land use in order to develop sustainable land use systems. Land use reflects the land's importance as a fundamental factor of production. Land needs to be better matched to its uses to increase production, while at the same time attempting to protect the environment, biodiversity, and global climate systems. It is, therefore, essential to have detailed and in-depth knowledge of potentials and limitations of the present uses in order to project future trajectories. Despite the high demand for environment and natural resources information, many existing maps and digital databases are not developed to really meet multi-user requirements. One of the main causes, though generally underestimated, is the type of classification or legend used to describe basic information such as land cover and land use. Many of these classifications and legends are generally not comparable with one another and very often single project oriented or taking a sectoral approach. There are many classification systems existent throughout the world, however, no global agreement on internationally accepted land cover and land use classification systems exists (UNEP/FAO, 1994). As a result many classification systems and innumerable map legends exist, and maps and statistics from different countries, and in many cases even from the same country, are incompatible.

THE PROBLEMS OF CURRENT CLASSIFICATION SYSTEMS

Many existing land cover and land use data sets, although valuable, are heterogeneous with respect to quality, nomenclature, scale and geometry. Moreover, in many countries the data are often only partial in coverage. The data frequently have inappropriate classes for a variety of user needs (e.g. statistical or rural development needs), have a spatial resolution related to a specific purpose and are mostly obsolete. Furthermore, often factors are used in the nomenclature or classification scheme which result in an undesirable mixture of potential and actual land cover (e.g. climate). One of the main problems, though generally underestimated, is however the type of classification or legend used to describe land cover and land use.

The reasons why none of the current classifications could serve as a reference base are manifold as will be explained below.

Problems related to purpose

A proportion of the existing classifications are either vegetation classifications (e.g. Eiten, 1968; Kuechler & Zonneveld, 1988; UNESCO Vegetation Classification, 1974), mixtures of land cover and land use (e.g. Corine Land Cover in CEC, 1993; Duhamel, 1995), broad land cover classifications, or systems related to the description of a specific feature (e.g. agricultural areas). Thus, they are limited in the ability to define the whole range of possible land cover classes. An illustration is the UNESCO Vegetation Classification (designed to serve primarily vegetation maps at the scale of 1:1,000,000) which considers only natural vegetation and all other areas such as cultivated areas or urban vegetated areas are not considered. Other vegetation classifications, even if they consider agricultural areas, do not describe these classes with the same level of detail as used for the natural vegetation ones. On the other hand, systems used to describe agricultural areas give very few details in their description of natural vegetation.

Many systems have been developed for a certain purpose, at a certain scale, and using a certain data type (e.g. the International Geosphere Biospere Data and Information Systems IGBP-DISCover global 1km data set based on NOAA-AVHRR; Townshend, 1992; Belward, 1996). This results in the fact that the derived classes are strictly dependent on the means used (e.g. in the example classes will be only those that can be detected using the NOAA).

Many current classification systems are not designed for mapping, and subsequently monitoring, purposes. If categories are as broad and few as those used to describe land cover in the FAO *Production Yearbook* (e.g. "forest and woodland", "arable land" and "permanent meadows and pastures"), then forest thinning, increased intensification of cultivation and overgrazing will not be registered. For monitoring land cover changes take two forms: *conversion* from one category to another (e.g. from forest to grassland) and *modification of condition* within one category (e.g. from cultivated area to intensively cultivated area). The broader and fewer the categories used to describe land cover, the fewer the instances from conversion from one to another. In the example given the classes identified in the field will not register as conversion nor as modification. Modification, however, is of extreme importance in the land use and land cover change as it relates to the more subtle changes that are thought to have a considerable impact (Turner *et al.*, 1993). A multi-user oriented classification system should capture the full spectrum of alterations from modification to conversion.

Problems related to consistency

In most current systems the criteria used to derive classes are not systematically applied. An often found example is the use of different ranges according to the importance given by the user to a particular feature (e.g. in many systems the canopy density ranges used to distinguish tree-dominated areas are many, whereas only one single range is used to define shrub or grass dominated areas).

In some classifications the class definition is imprecise, ambiguous or absent. This means that these systems fail to provide internal consistency (e.g. the frequency with which classes in the Corine Land Cover overlap with classes elsewhere in the same classification). The type of diagnostic criteria and their arrangement to form a class is very often in contrast to the ability to define a clear class boundary. This is, however, a basic requirement for any system.

The full combination of diagnostic elements describing a class is usually not considered (e.g. a system that wants to describe vegetation with the diagnostic criteria of three ranges of cover density matched with three ranges of height must consistently apply these ranges for all life forms considered). The reason why most systems fail in application of this basic classification rule is that the entire combinations of the possible classifiers would lead to a vast amount of classes which cannot be handled with the current methods of class description (e.g. imagine in the example above 10 classes of each leading to 100 combinations). Therefore, the current systems often create gaps in the systematic application of the used diagnostic criteria.

Threshold values are very often derived from knowledge of a specific geographic area. The result is that the class boundary definition between classification and classification may become unclear, that is with overlaps or gaps. In these cases' intercomparisons will be impossible or inaccurate.

Very often the systems contain a number of classes which due to their interrelation and hierarchical structure appear to be a proportion of a broader set of classes. Thus, these types of systems are mere legends. The characteristic of legends is that only a proportion or subset of the entire range of possible classes is described. The disadvantage of having a legend is that the user cannot refer back to a classification system that leads to the impossibility of making intercomparisons with other systems.

Problems related to lack of clear definition of the underlying common principle

An underlying common principle has often not been defined in land cover classifications. A mixture of different features is used to define a class, especially features such as climate, geology and land form (e.g. in the word *tropical rain forest* the term "*tropical*", which usually relates to climate, is used to describe a certain floristic composition). These factors influence the land cover but are not *inherent features* of it. This type of combination is frequently found and is often applied in an irregular way without any hierarchy. This may lead to confusion in the definition of the class.

Classification of vegetation using the diagnostic criteria of "height" and "cover" will lead to a different perspective of the same feature compared to the use of "leaf phenology" and "leaf type" (Figure 1.). It is therefore important to come to a basic understanding of the criteria to be used as underlying principle for land cover or land use description.

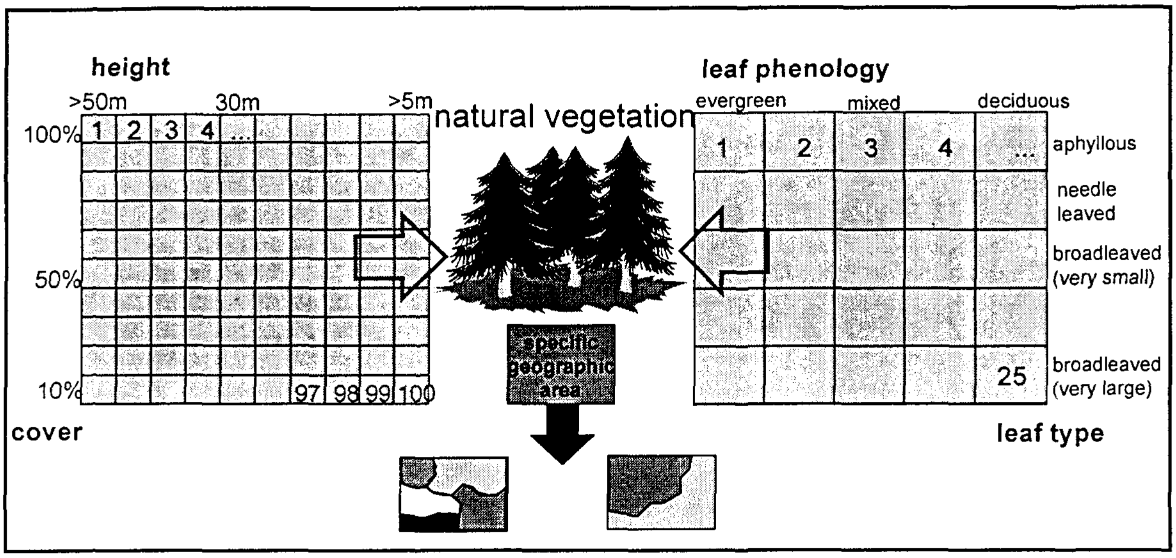

Figure 1. Example of description of a land cover using a different underlying principle.

Problems related to *a-priori* classification systems
Often an *a-priori* classification system is used in which classes are arranged. However, the use of such a classification assumes that all possible classes any user may derive, independent of scale and tools used, are included in the system (Figure 2). Having all classes pre-defined in the system is the intrinsic rigidity of *a-priori* classification. The main advantage, though, is that it is the most effective way to produce standardisation of the classification results between user-communities. The disadvantage is that to be able to describe in a consistent way any occurring land cover anywhere in the world one needs an enormous amount of pre-defined classes. Such a system should be flexible in the sense that any occurring land cover should be accommodated. However, how one can introduce this type of flexibility using the "classical" approach of class names and descriptions.

By increasing the number of classes in an *a-priori* system the problem arises of how the user will finds its way through a "jungle" of class names. Furthermore, this situation aggravates the standardisation, namely that every user may have a slightly different opinion on how to interpret some classes because the class boundaries between classes will be based on very slight differences. The wrong, or different, designation of the same land cover feature to different classes will affect the standardisation process that is one of the main objectives of the classification system. Finally, the attempt to harmonise will fail. The *a-priori* classification approach seems a vicious circle: if one attempts to create this type of classification as a tool for standardisation, one is obliged to fit the enormous variety of occurring land cover classes in a limited number of more "generic" classes, if one wants to try to create more classes, thereby attempting to minimise this problem, one will increase the danger of having a lack of standardisation, which was the very basic principle used as starting point.

The above illustrates that there is not as much compatibility between classification systems, or between classification and legend, as may be desired in an ideal situation. There are numerous inconsistencies in definition of classes, class boundaries, in the use of threshold values, etc. However useful the current classification systems may be, the above hampers the possibility of the use of such classification results by a large audience for a broad range of applications. In the context of developing a new system it is fundamental to identify the criteria to which any reference classification, to the extent possible, should adhere (box 1).

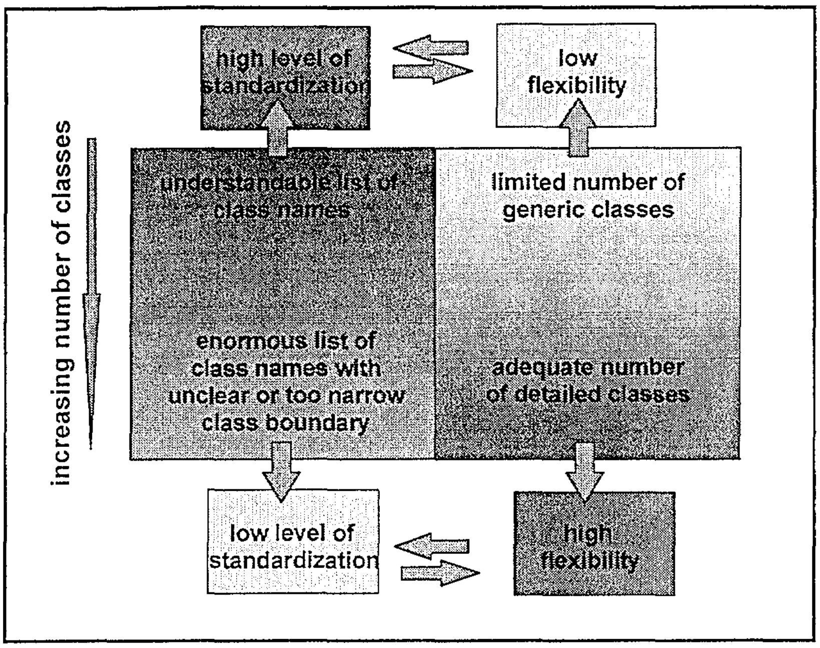

Figure 2. The apparent contradiction between an a-priori classification and flexibility.

DEVELOPMENT OF A NEW APPROACH

The common integrated approach initiated by FAO defines land cover as *the observed (bio)physical cover on the earth's surface*, but in addition to this it is pointed out that a *land cover unit must be considered as a geographical explicit feature.* Land is a basic source of mass and energy throughput in all terrestrial ecosystems, land cover and land use represent integrating elements in sustainable economies. The world ecosystem productivity is mainly governed by primary production. Land cover is the expression of human activities and as such changes with modifications in these activities. Therefore, land cover as geographic explicit feature may form, consequently, a reference base for other disciplines -such as land use, climatic and ecological studies- (Di Gregorio & Jansen, 1996; FAO, 1997).

The approach to create a standardised, hierarchical, consistent, a-priori classification system containing systematic and strict class boundary definitions leads to the basic requirement of having to increase the *flexibility* in the classification system. In this context flexibility has two different meanings. First of all, flexibility should address the possibility of the classification system to describe and accommodate the whole variation of existing land cover as described above. At the same time, however, flexibility should adhere to the strict class boundary definitions that should be unambiguous and clear. Secondly, the classes in such a system should be as neutral as possible in order to answer to the needs of a wide variety of end-users.

Many current classification systems are not designed for mapping (and subsequently monitoring) purposes. The integrated approach considers the clear boundary definition between classes essential. Furthermore, the use of diagnostic criteria and their hierarchical arrangement to form a class should be a function of the *mapability*, that is the ability to define a clear boundary between two classes. Hence, diagnostic criteria should be *hierarchically arranged in order to assure at the highest levels of the classification a high degree of geographical accuracy.*

Box 1. General criteria for a reference classification system.

GENERAL CRITERIA FOR A REFERENCE CLASSIFICATION SYSTEM:

- *be comprehensive, suitable for mapping and monitoring purposes, scientifically sound and practically oriented.*
- *meet the needs of a variety of users* (not single project oriented nor a sectoral approach); users may use only a subset of the classification and develop from there according to their own specific needs.
- *could serve as a common reference base.* It could serve as a system for intercomparisons of classes derived from different classifications.
- *be a flexible system* that can be used at different scales and at different levels of detail allowing cross-reference of local/regional with continental/global maps without loss of information.
- *be able to describe the complete range of land cover features* (e.g. forest and cultivated areas as well as ice and bare land, etc.). Each class boundary definition must be unambiguous and unique.
- be adapted *to fully describe the whole variety of land cover types with the minimal set of classifiers necessary* (the least classifiers are used in the definition, the less the error expected and the less time and resources necessary for field validation).
- *a clear and systematic description of the class exists.* The diagnostic criteria used to define a class must be clearly defined: pure land cover classifiers (e.g. structural physiognomic) versus environmental classifiers (climate, landform and altitude). The latter influence land cover but are not inherent features.

How to increase the flexibility of an a-priori classification while maintaining the principle of mapability and aiming at standardisation? These prerequisites can only be accomplished if the classification has the possibility to *generate a high number of classes with clear class boundary definitions.* In other words, it should be possible to delineate a larger number of classes in order to suit the enormous variation of land cover features, while maintaining the clear distinction of boundaries between classes. In the current classification systems this possibility of clear distinction of classes is hampered by the manner in which these classifications are set up. Differences between classes can only be derived from class descriptions. Therefore, it would be very difficult for the user to distinguish between such classes just based upon class names or unsystematic descriptions as is the case with most of the current classification systems.

One of the basic principles adopted in the new approach is that a given land cover class is defined by the *combination of a set of independent diagnostic attributes*, the so-called *classifiers.* The increase of detail in the description of a land cover feature is linked to the increase in the number of classifiers used. In other words the more classifiers are added, the more detailed the class. The class boundary is then defined either by the different amount of classifiers, or by the presence of one or more different types of classifiers. Thus, the emphasis is not given anymore to the class name, but to the set of classifiers used to define this class.

The straightforward application of using a set of independent diagnostic criteria is hampered by two main problems. First, land cover should describe the whole observable (bio)physical environment and is, thus, dealing with a heterogeneous set of classes. Evidently a forest is defined with a set of classifiers that differ from those to describe snow-covered areas. Therefore, the definition of classes by classifiers should not lead to the use of an impractical set of classifiers. Instead of using the same set of classifiers to describe such heterogeneous features, in the new approach the classifiers are tailored to each land cover feature. According to the general concept of an a-priori classification, it is fundamental that all the combinations of classifiers must be created in the system. By tailoring the set of classifiers to the land cover feature all combinations can be made without having a tremendous number of theoretical combinations of classifiers that would not have any relation to specific land cover features. Secondly, two distinct land cover features having the same set of classifiers to describe them may differ in the hierarchical arrangement of these classifiers in order to ensure a high geographic accuracy.

THE LAND COVER CLASSIFICATION SYSTEM

Design and Concepts

Addressing the issues mentioned above without incurring the difficulties mentioned, is the objective of the design of the Land Cover Classification System. Land cover classes are defined by a series of classifiers, but due to the heterogeneity of land cover and aiming at a logical and functional hierarchical arrangement of the classifiers, certain design criteria have been developed.

The Land Cover Classification System is designed according to two main phases (Figure 3):

1. a higher *Dichotomous Phase* where a subdivision is made to define eight major land cover types:
    - *Cultivated and Managed Terrestrial Areas*
    - *Natural and Semi-Natural Terrestrial Vegetation*
    - *Cultivated Aquatic Or Regularly Flooded Areas*
    - *Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation*
    - *Artificial Surfaces and Associated Areas*
    - *Bare Lands*
    - *Artificial Waterbodies, Snow and Ice*
    - *Natural Waterbodies, Snow and Ice*

from which point onwards,

2. a lower so-called *Modular-Hierarchical Phase* starts. In this phase the creation of a land cover class is based on the combination of a set of pre-defined classifiers. These classifiers are tailored to each of the eight major land cover types.

Three classifiers are used in the Dichotomous Phase, that is *primarily vegetated*, *terrestrial* and *artificiality*. These three classifiers have been hierarchically arranged. However, independent of this arrangement one would reach the same eight major land cover types, they would only appear in a different sequence. The hierarchical arrangement is thus unimportant in this Phase.

Formation of Classes and Class Descriptions

The tailoring of classifiers in the Modular-Hierarchical Phase allows the use of the most appropriate classifiers to define land cover classes derived from the major land cover types, and at the same time reduce the total number of impractical combinations of classifiers. This results in a land cover class defined by:

- a *Boolean formula* showing each classifier used (all classifiers are coded);
- a *unique number* for the GIS; and
- a *name* that can be the provided standard name or a user-defined one.

LAND COVER CLASSIFICATION SYSTEM

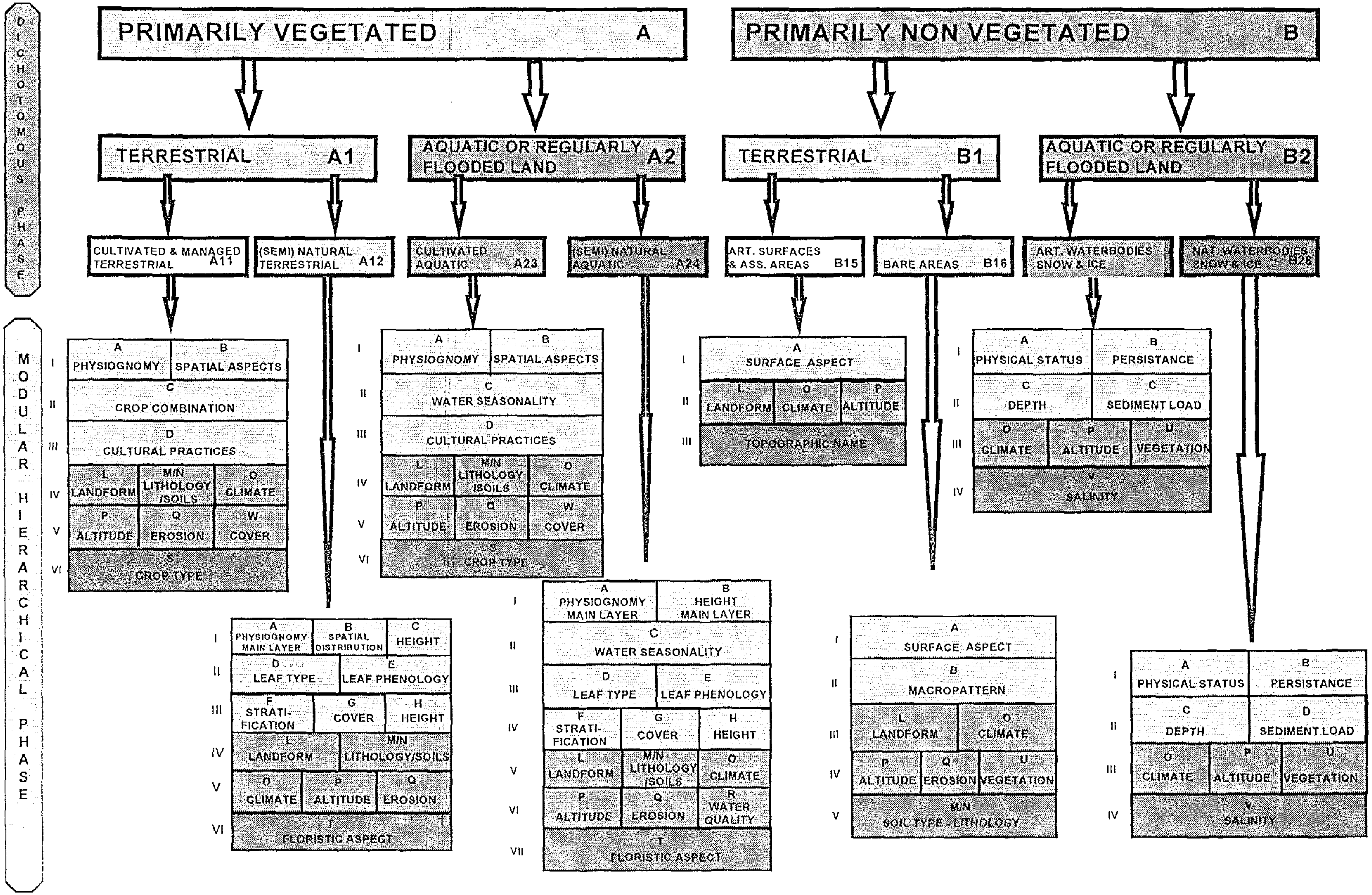

Figure 3. The Land Cover Classification System, its two Phases, classifiers and attributes.

THE SOFTWARE PROGRAM

Because of the complexity of the classification and the need for standardisation, a software program, of which the beta version has been developed, will assist the interpretation process. This software program facilitates not only the standardization of the interpretation process but also contributes to its homogeneity. Despite the huge number of classes one can generate, an interpreter is dealing only with one classifier at a time and each class is built up by stepwise selection of each classifier. So one does not need to scroll inside a big list of class names to select the appropriate one, but one is simply aggregating a number of classifiers to derive the class. This will assist in reducing heterogeneity between interpreters and with interpretations over time.

The software program consists of four modules:

(1) Classification: provides a standardised approach for classifying land cover classes.
(2) Legend: provides the possibility to save, edit and addition of user-defined attributes as well as storage of the legend, its standardised class descriptions and used classifiers.
(3) Field Data: provides structured storage for field observations according to a minimum, customised or full list of items selected for description (will be included in release 1.0).
(4) Translation: provides the possibility to correlate and intercompare classifications and legends using the Land Cover Classification System as a reference base.

The next step will be to develop a reference land use classification, being based upon the arrangements, activities and inputs people undertake on the land. At present efforts are being made to develop a methodology to describe land use in a comprehensive and consistent way taking a multi-user oriented approach. This should result in a first approach for a reference land use classification with a hierarchical structured format offering a high degree of flexibility and the ability to accommodate different levels of information. This classification is to be linked with the Land Cover Classification System.

CONCLUSIONS

The developed classification system is a real a-priori classification system in the sense that, for the classifiers considered, it covers all their possible combinations. Furthermore, a given land cover class is clearly and systematically defined making a clear differentiation or use of the classifiers as follows:

- pure land cover classifiers;
- environmental attributes (e.g. climate, land form, geology, etc.);
- specific technical attributes (e.g. Floristic Aspect for (Semi) Natural Vegetation, Crop Type for Cultivated Areas).

Therefore, all classes within the system are unique and unambiguous. The result is that the system is internally consistent and the systematic description of the class is a basis for objective and replicable classification.

The classification system is truly hierarchical. The class hierarchical arrangement is a basic component of the mechanism for class formation. The difference between a land cover class (at a more general level) and a further subdivision of it, is given by the addition of new classifiers (or a more detailed level of the one forming the previous class). The more classifiers used, the greater the detail of the defined land cover class.

The classification may be used as reference base for two main reasons:

- the classification contains a very big number of classes, that is all classes of existing classifications and legends can be readily accommodated; and
- the emphasis is given to the set of classifiers, instead of to the class name, which allows easy correlation even when a range of values, for instance percentage of cover of a given life form, do not fit with the proposed one. The dissimilarity is clear and remains limited to

only a portion of the classifiers forming the class. However, the cases in which a class cannot be correlated should be extremely rare due to the different levels and detail of classifiers.

The classification system is designed to collect information at a variety of scales, from small- to large scale, independent from the tools used. The design allows easy incorporation and integration into (geographic) information systems in order to give the user the ability to manipulate the results in various ways. The manner in which classes are built up facilitates overlay and query procedures.

The present classification system considers two types of final users: (1) the ones that use the classification to built up the database (the user essentially doing the data collection); and (2) the ones that are the final users of the created database. The system obliges the first user to follow specific rules in the combination of classifiers in order to assure a standardisation and comparability of the data set. The second user, however, is free in re-combination of the used classifiers and in re-aggregation of the original data. Because the class definition is linked with the classifiers' Boolean Formula this process becomes relatively easy. The possible re-combinations of classifiers are enormous and some combinations may be illogical, but this relates to the concept of multi-users with each one having very specific needs that are difficult to forecast.

The classification system facilitates the standardization of the interpretation process contributing to its homogeneity. Despite the huge number of classes the interpreter can generate to suit the whole variety of land cover, one is dealing only with a limited number of classifiers. One must simply aggregate a restricted number of well-defined classifiers. This will reduce heterogeneity between interpreters and with interpretations over time, thus adding to the overall consistency of the final product.

A new procedure of accuracy analysis is possible with the classifier approach. Until now the accuracy analysis was carried out for single classes, from now onwards it will be possible to assess the accuracy not only for the entire class but for each of the classifiers forming this specific class. This will give a high flexibility to the establishment of final land cover classes. For example, if a class formed by five classifiers shows an accuracy too low according to the established general standard, the influence of each individual classifier to the overall class accuracy can be analyzed. If in this example the last classifier has much lower accuracy than the previous four, the user may decide to eliminate this last and less accurate classifier in order to have a final class with less detail but with an accuracy according to the developed accuracy standards.

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