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GEOGRAPHIC INFORMATION SYSTEMS FOR ENVIRONMENT AND DEVELOPMENT

INAUGURAL – DISSERTATION

ZUR
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DER
UNIVERSITÄT ZÜRICH

VON

OTTO GAUDENZ SIMONETT

VON ANDEER UND LOHN (GRAUBÜNDEN)

BEGUTACHTET VON DEN HERREN
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Abbreviations

ACAP	Annapurna Conservation Area Project (Nepal)
ADB	Asian Development Bank
AFTEN	Africa Technical Department Environmental Division (The World Bank)
AIDS	Acquired Immune Deficiency Syndrome
AIT	Asian Institute of Technology
ARCED	African Regional Conference on Environment and Development
ARC/INFO	Vector-based GIS Software Package
BWP	Bagmati Watershed Project (Nepal)
CIDA	Canadian International Development Agency
DANIDA	Danish International Development Assistance
DCA	Directorate for Development Cooperation and Humanitarian Aid (Swiss) (DDA/DEH)
DDC	District Development Council (Uganda)
DEH	Direktion für Entwicklungszusammenarbeit und humanitäre Hilfe (DCA/DDA)
DSS	Decision Support System
DTM	Digital Terrain Model
ECA	Economic Commission for Africa
EDMZ	Eidgenössische Druck und Materialzentrale
EEC	Commission of the European Communities
EGIS	European Conference on Geographical Information Systems
EIA	Environmental Impact Assessment
EIS	Environmental Information System
EPFL	Ecole Polytechnique Fédérale Lausanne
ERDAS	Earth Resources Data Analysis System (Raster-based GIS Software Package)
ERL	Environmental Resources Limited
ESRI	Environmental Systems Research Institute
FAO	Food and Agricultural Organization, United Nations
FINNIDA	Finnish International Development Agency
GDP	Gross Domestic Product
GEMS	Global Environmental Monitoring System
GIS	Geographic Information System
GIST	GIS Software Package
GNP	Gross National Product
GRID	Global Resource Information Database
GTZ	Gesellschaft für Technische Zusammenarbeit (Germany)
HKH	Hindukush-Himalaya
HMG	His Majesty's Government (Nepal)
IBM	International Business Machines
ICIMOD	International Center for Integrated Mountain Development
IDA	International Development Association
IDRISI	Raster-based GIS Software Package
IPCC	Intergovernmental Panel on Climate Change
IHDP	Integrated Hill Development Project (Nepal)
IMF	International Monetary Fund
IPC	ICIMOD Participating Countries
ITC	International Institute for Aerospace Survey and Earth Sciences
IUCC	Information Unit on Climate Change
IUCN	International Union for the Conservation of Nature
IUED	Institute Universitaire d'Etudes du Développement
KDA	Karamoja Development Agency
KO	Karamoja Office
LANDSAT	Earth Observation Satellite
LDC	Less Developed Country
LIDC	Low Income Developing Country

LIS	Land Information System
LISSA	Low Income Sub Saharan Country
LLCD	Least Developed Country
LRMP	Land Resources Mapping Project (Nepal)
MAB	Man and Biosphere Program
MENRIS	Mountain Environment Natural Resources Information System
MEP	Ministry of Environment Protection (Uganda)
MLD	Ministry of Local Development (Nepal)
MoU	Memorandum of Understanding
MSAC	Most Seriously Affected Country
MSS	Multi Spectral Scanner
MWEMEP	Ministry of Water, Energy, Minerals and Environment Protection (Uganda)
NASA	National Aeronautics and Space Administration
NCCNCR	National Council for the Conservation of Natural and Cultural Resources (Nepal)
NCGIA	National Center for Geographic Information and Analysis
NCS	National Conservation Strategy
NGS	National Geographic Society
NEAP	National Environmental Action Plan
NEIC	National Environment Information Center
NEPPA	Nepalese Environmental Planning and Protection Agency
NERC	Natural Environment Research Council
NGO	Non-governmental Organization
NORAD	Norwegian Agency for International Development
NPA	National Parks Authority (Uganda)
NPC	National Planning Commission (Nepal)
NRM	National Resistance Movement (Uganda)
NSTL	NASA Space Technology Labs
ODA	Overseas Development Administration
OECD	Organization for Economic Cooperation and Development
OR	Operations Research
PADCO	Planning and Development Collaborative
PAR	Participatory Action Research
PC	Personal Computer
PRA	Participatory Rural Appraisal
RCSSMRS	Regional Center for Services in Surveying, Mapping and Remote Sensing
RISC	Reduced Instruction Set Computer
RRA	Rapid Rural Appraisal
RS	Remote Sensing
RT	Reduced Instruction Technology
SPANS	Spatial Analysis System (Quadtree-based GIS Software Package)
SPOT	Système Probatoire d'Observation Terrestre (Earth Observation Satellite)
SRPUP	Strategic Resource Planning in Uganda Project
SWK	Scott Wilson and Kirkpatrick
TERRASOFT	Raster-based GIS Software Package
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational and Scientific Organization
UNHCR	United Nations High Commissariat for Refugees
UNITAR	United Nations Institute for Training and Research
UNSO	United Nations Sudano-Sahelian Office
USAID	United States Agency for International Development
VIAK	VIA & AQUA (Norwegian company)
WRI	World Resources Institute
WWF	World Wide Fund for Nature
3D	Three-Dimensional

Summary

The main objective of the research is to give a comprehensive assessment of Geographic Information Systems (GIS) applied for the establishment of sustainable development strategies in Third World countries. The central question on how the technology should be used to meet broader environmental goals has been approached at three levels: The evaluation of published background literature, the development of a conceptual GIS model for environment and development, and the assessment of case studies in Uganda and Nepal. As the underlying methodology, Participatory Action Research (PAR) principles have been applied, an approach chosen because of its potential to link theory with practice.

Background
To place the research project in its larger setting, the essentials of the disciplines associated with GIS are being outlined. As an interdisciplinary tool, GIS requires a rather wide observation angle: Thus, a broad spectrum of literature – ranging from technical subjects to social sciences – is presented and discussed in the background section. The aim of this synthesis is to move the research subject out of a narrow technological frame and to highlight areas where future attention should be directed.

Model
At the center of the study stands the model on GIS for environment and development, a framework for implementing the technology in developing countries. It is subdivided into two problem areas, potential and conditions, because the applicability of GIS depends on the one hand on the tool's potential and on the other on the prevailing external conditions. The model recognizes above-all the political and educational nature of GIS and places the communication of environmental information at the center. Also the technology's networking potential – its organizational impacts – is seen as a vital component. Acknowledging the existing limits of GIS for handling uncertainties and errors, the model considers the technology's modeling potential as being rather modest. The conclusion is that, GIS technology – being far from objective or neutral – has in a way to be seen as an advertising instrument: An aspect, which should be taken into account with any GIS technology implementation in developing countries.

Case Studies
The third objective of the study is the confrontation of the model with real world GIS installations. In a participatory process – through active involvement in the case studies – GIS facilities in Uganda and Nepal have been observed and were assessed vis-à-vis the model. At the same time the model could be revised as well through the feedback gained in the field, attributing the case study evaluation a role beyond a mere project evaluation. The most striking empirical observation was that in both cases emphasis has been put on technology promotion and institution establishment rather than on applications. Both facilities have so far achieved relatively little in terms of communication of environmental information to decision-makers. This is the case despite of the fact that provision of information is on the agenda of both GIS sites. But taking the relative novelty of the technology and the facilities studied, it may still be early to expect concrete application results. The facilities are at this stage still open for input, and changes in direction may well be envisaged. One aim of my participatory approach is to provide substance useful to the GIS projects analyzed. Being conducted in a rather general manner, the case study evaluations are also intended to have a broader validity beyond Uganda and Nepal.

Overall – and this has also been my very first motivation to conduct the research on GIS for environment and development – the study can be considered as a contribution to bridge the gap between theory and practice, between GIS technology and its applications.

Zusammenfassung

Ziel dieser Arbeit ist es, die Anwendbarkeit von Geographischen Informationssystemen (GIS) zur Unterstützung nationaler Umweltstrategien in Entwicklungsländern zu evaluieren. Im Zentrum steht die Frage, wie GIS heute optimal eingesetzt werden könnten, um längerfristige Ziele des Umweltschutzes und der nachhaltigen Entwicklung zu unterstützen. Das Projekt ist in drei Teile gegliedert: Ein Theorieteil mit Auswertung von Literatur der verwandten Fachgebiete, ein Modell über GIS für den Bereich Umwelt und Entwicklung und abschliessend die Evaluation von zwei Fallbeispielen von GIS-Installationen in Uganda und Nepal. Methodisch bin ich nach einem Ansatz der Aktionsforschung vorgegangen, der in optimaler Weise die Verbindung von Theorie und Praxis ermöglicht.

Theorieteil
Im Theorieteil wird Literatur aus dem weiteren Umfeld von GIS ausgewertet, um den Rahmen des Projektes abzustecken. Die Interdisziplinarität der Anwendugsbereiche von GIS drängt einen weiten Betrachtungswinkel auf: Die untersuchte Literatur stammt aus so verschiedenen Gebieten wie Entwicklungsländerforschung, Umweltwissenschaften, Geographie, Kartographie und Informatik. Ziel dieser Synthese ist es, GIS aus seinem engeren technischen Rahmen hervorzuheben und auch aufzuzeigen, wo zukünftige interdisziplinäre Forschungsschwerpunkte gesetzt werden könnten.

Modell
Im Zentrum der Arbeit steht ein Modell über GIS im Bereich Umwelt und Entwicklung, ein Konzept für die Implementation der Technologie in Entwicklungsländern. Da der Einsatz des Werkzeugs GIS auf der einen Seite von der Technologie selbst, auf der andern von den operationellen Bedingungen in den jeweiligen Ländern abhängt, besteht das Modell aus zwei Teilen: Potential und Rahmenbedingungen. Es betont den Einsatz von GIS in den Bereichen Politik und Bildung: Kommunikation von Umweltinformation bildet einen Schwerpunkt. Auch die Fähigkeit, Gruppen mit traditionell verschiedenen Interessen durch die Benützung von GIS zusammenzuführen, wird als relevantes Element der Technologie betrachtet. Wegen begrenzten Fähigkeiten auf dem Gebiet der Fehlererkennung, betrachte ich die analytische Anwendbarkeit als begrenzt. Weil GIS weder neutral noch objektiv sind, muss anerkannt werden, das sie in einem gewissen Sinne ein Werbeinstrument darstellen: Ein Faktor, dem bei der Einführung und Anwendung der Technologie zentrale Bedeutung zugemessen werden muss.

Fallbeispiele
Das dritte Ziel der Arbeit ist die empirische Überprüfung des Modells anhand existierender GIS-Installationen. Über einen längeren Zeitraum wurden GIS in Nepal und Uganda beobachtet und bezüglich ihrer eigenen Zielsetzungen und gegenüber des Modelles evaluiert. Durch die Neuheit der Technologie und der Installationen ist es zwar noch relativ früh, eine eingehende Evaluation durchzuführen; demgegenüber sind aber die Institutionen noch flexibel genug, Kursänderungen vorzunehmen: Meine Diskussion im empirischen Teil ist daher vor allem als Anregung für die betreffenden Zentren gedacht. Die Evaluation der Fallbeispiele sollte aber auch Gültigkeit in einem weiteren Kreis – über Uganda und Nepal hinaus – haben.

Ich glaube, mit dieser Studie einen Beitrag zur Verknüpfung von Theorie und Praxis, von GIS-Technologie und Anwendungen gemacht zu haben. Dies war auch von Anbeginn meine Motivation, diese Arbeit in Angriff zu nehmen.

Preface

Background to this project has been practical work within the United Nations System and University research. Intended to be a link between theory and practice it turned also out to be a link to many individuals in various places in Geography: Kampala, Kathmandu, Nairobi, Genève and Zürich. Thus, despite the rather technical topic, there are people to whom I now want to express my sincere thanks:

For the very cooperative academic support, Kurt Brassel and Albert Leemann, my supervisors at the Institute of Geography at the University of Zürich.

For providing me with working conditions favorable to pursue my research and allowing me in a most generous way to use their facilities, Harvey Croze and Ole Hebin at UNEP/GRID Nairobi and Geneva.

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For a grant to cover travel expenses for the research abroad, the Swiss Directorate for Development Cooperation and Humanitarian Aid (DDA) in Bern.

For their sustained general support, my parents, sisters and brothers; and, of course, Susan and Robin, for being my companions in the world beyond GIS.

1 Introduction

1.1 Problem Area

Today's vast and complex environmental problems call for interdisciplinary solution approaches at a political as well as at a scientific level. In this context, Geographic Information Systems (GIS) have been proposed as a tool with a great potential to monitor and analyze environmental problems interdisciplinarily and to provide environmental information to decision-makers. Also the Bruntland Report (World Commission on Environment and Development 1987: p. 323), one of the milestone publications on environment and development, praises the role of the new technologies:

> «Fortunately, the capacity to monitor and map earth change and to assess risk is also growing rapidly. Data from remote sensing platforms in space can now be merged with data from conventional land based sources. Augmented by digital communications and advanced information analysis, photos, mapping and other techniques, these data can provide up-to-date information on a wide variety of resource, climatic, pollution and other variables.»

Other authors accredit Geographic Information Systems and Remote Sensing technology a revolutionary status, pointing out that they are the:

> «Biggest step in the handling of geographic data since the invention of the map.» (UK Department of the Environment 1987: p. 8)

The technology is even attributed the potential to change the world:[1]

> «This revolution is first about improving our understanding of complex phenomena and how they interrelate. Increasingly, we also seek to replace natural resources by human ingenuity. But above-all, it is a revolution in observation and measurement systems, without which there can be no progress in science or technology, nor any effective long-term action.» (SPOT 1991: p. 1)

[1] Such statements – made by commercial enterprises – can, however, not be attributed the same validity as scientific declarations.

> «The development of new GIS applications will move us toward a balanced sustained developed future.» (Conference Announcement GIS'90)

Developing countries with vast land and natural resources associated with many environmental problems seem to be ideally suited for this technology, or, as it has been formulated by the United Nations Institute for Training and Research (UNITAR 1990b: Foreword): «It appears essential for developing countries to master this technology.» Indeed, Geographic Information Systems are being more and more widely used for environmental applications in Third World countries: An almost exponential growth in systems installed has taken place over the last few years only. In a survey conducted when I started the research in 1989,[2] there were less than one hundred Geographic Information Systems operational in developing countries. Today, with systems virtually being installed every day, it would be a task far beyond the scope of this project to conduct a similar survey.

Geographic Information Systems certainly have one impact in developing countries: They raise high expectations among individuals and institutions up to the highest level. Questions concerning the true value of the technology have now to be asked. Do the systems have an impact on the environmental decision-making process and on the environment in general or is the current development just technology-driven experiments lacking real substance?

1.2 Objectives

As a starting point, I assume that Geographic Information Systems are generally applicable in the fields of environment and development. I accept the fact that information technology is rapidly expanding world-wide, making the issue less 'yes' or 'no' than 'how'. Thus, the question on how the technology will have to be applied to be useful to meet broader environmental goals stands at the center of my research.

The project's three main objective areas are the assessment of the theoretical background, the establishment of a model on GIS applications in an environmental context in Third World countries and the evaluation of existing installations. Underlying is the methodological goal of applying participatory action research (PAR) principles to the field of GIS and thus linking theory with practice, as outlined in Figure 1.1:

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[2] The survey conducted by UNEP/GRID included the then major multipurpose GIS software vendors in developing countries ESRI, ERDAS and TYDAC.

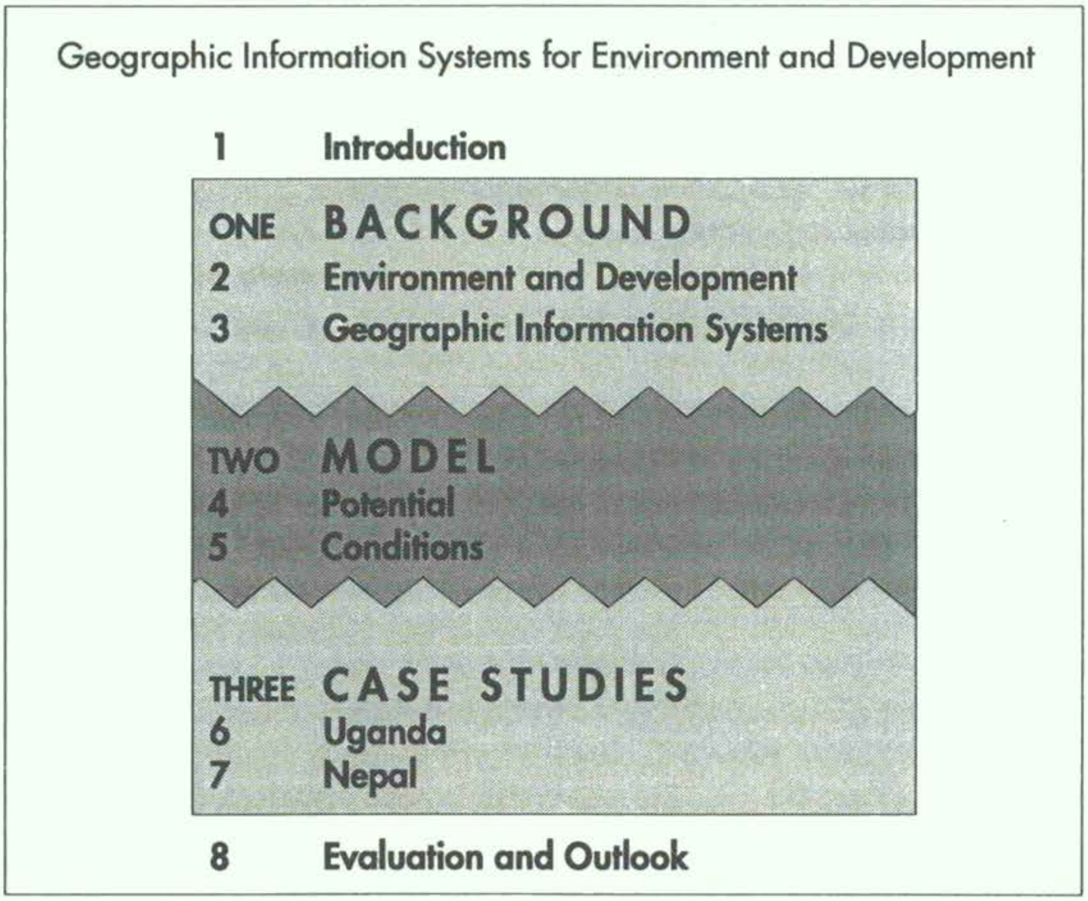

Figure 1.1: Objectives and Outline of Project

Background

Geographic Information Systems are undoubtedly an interdisciplinary tool. And since the technology is rather novel to developing countries, I will first have to outline the broader context: Illuminate general goals and visions of the associated disciplines and establish connections between the various fields relevant to the technology. The background part will also include an outline of the development of Geographic Information Systems and a review of GIS applications on environmental issues in developing countries. Primary aim is to place the technology in its broader context and to highlight areas relevant to practitioners as well as to research.

Model

Central to the project is the model on GIS for environment and development, a conceptual framework for implementing the technology in developing countries. Because the applicability of GIS depends on the one hand on the tool's potential and on the other hand on the prevailing conditions, I break the model down into two parts:

◊ What is the potential of Geographic Information Systems to contribute to the knowledge and the solution of environmental problems in the Third World?

◊ What are the conditions required for Geographic Information Systems in developing countries to reach their potential?

The two components 'potential' and 'conditions' represent different levels of abstraction. While I will evaluate the potential of GIS at a rather theoretical, more normative level, the investigation of the conditions will be more oriented towards applications.

Case Studies

The third broader goal is the confrontation of the model with real world situations. Through a participatory process I will evaluate Geographic Information System facilities in Uganda and Nepal vis-à-vis the model and at the same time also use empirical experience to build up guidelines. My aim is to bridge the gap between theory and practice. Besides providing relevant input to the study cases, this evaluation is also intended to have a broader validity beyond Uganda and Nepal.

1.3 Methods

With the underlying goal to link theory and practice I will make use of different methodological instruments. The theoretical background part – drawing mostly from literature – and the empirical field evaluations – with active participation in on-going projects and making use of personal experience – can be regarded as the thesis' two poles.

As an underlying synthesis, I have adapted the Participatory Action Research (PAR) methodology, «a powerful strategy to advance both science and practice» (Whyte 1991: p. 7), as a general umbrella to my research. Methods from the field of social geography, as for instance outlined by Werlen (1986), proved to be less feasible to this application-oriented work than the approaches chosen. This is mainly due to the research's main objective being the general valuation of the applicability of a technology, moving it methodologically closer to management science than to social geography. For specific field and interview work I have primarily used techniques from Applied Qualitative Research, as outlined by Walker (1985) and Jones (1985). Unavoidable with an action science approach, some field evaluations have been conducted in an ad hoc manner, to make optimal use of opportunities and resources while on site. As a base for the subsequent elaboration on the specific methods I have sketched out the methodological frame to the research in Figure 1.2:

Participatory Action Research Whyte (1991)	
scientific field techniques	**participation in projects**
Applied Qualitative Research Walker (1985)	Uganda
Depth Interviews Johnes (1985)	Nepal

Figure 1.2: Methodological Frame

Participatory Action Research

Participatory Action Research (PAR) has been defined by Whyte (1991: p. 7) as follows:

> «PAR involves practitioners in the research process from the initial design of the project through data gathering and analysis to final conclusion and action arising out of the research.»

Participatory Action Research has evolved from various branches of sociology and management science: The label PAR is an attempt to put existing similar lines of scientific development under a common umbrella. According to Whyte (1991), the following three disciplines can be regarded as roots to PAR:

- ◊ social research methodology
- ◊ participation in decision making by low-ranking people in organizations and communities
- ◊ socio-technical systems thinking regarding organizational behavior

Concerning these three background fields, the following thoughts are particularly relevant and applicable to my research topic:

PAR distinguishes itself from the professional expert model where a clear definition of process exists: Usually a client organization is determining the facts and recommending a course of action. In contrast, PAR, and with it also my approach focuses rather on longer-term involvement with interaction, participation and feedback mechanisms, as displayed in

Figure 1.3. I have accompanied the case studies in Uganda and Nepal since their initiation – in 1987 and 1989 – over a duration of several years.

Furthermore, through its roots in research on participatory decision-making, PAR does not support strict top-down models. The approach has clearly assigned space to use information gathered from persons involved in the field at all hierarchies. I have therefore selected a rather broad group to conduct the interviews: Managers, consultants, analysts and GIS users.

The third stream of PAR development, the socio-technical framework, is based on a «simple but important idea: That the workplace is not simply a social system; understanding behavior at work depends on integration of social and technological factors» (Whyte 1991: p. 11). This integrative element is quite relevant to the field of GIS, making a technology work in its institutional and social context.

Field Techniques: Applied Qualitative Research

The techniques used for systematic field evaluations are based on Applied Qualitative Research methodologies, as defined by Walker (1985: p. 3):

> «The techniques are traditionally termed 'qualitative' for they are generally intended more to determine 'what things exist' than to determine 'how many such things there are'.»

More specifically, the incorporation of GIS practitioners into my research has been facilitated by personal interviews, applying depth interview techniques, introduced by Walker (1985: p. 4) as:

> «A conversation in which the researcher encourages the informant to relate, in their own terms, experiences and attitudes that are relevant to the research problem.»

A comprehensive discussion of depth interviewing techniques has been offered by Jones (1985). The approach can be regarded as semi-structured, not making use of a rigid questionnaire but nevertheless relying on a structured aide memoire. In my case, I developed a quite extensive questionnaire that has been applied rather liberally according to the interview situation. The complete questionnaire is attached as an appendix (Appendix I) to this publication.

Methodology Adaptation

Figure 1.3 displays my adaptation of PAR, the processes and feedback mechanisms behind the research – inter-linking background, model and case studies. I now chronologically describe the various research stages and methods I have used, before valuing the methodology as a whole:

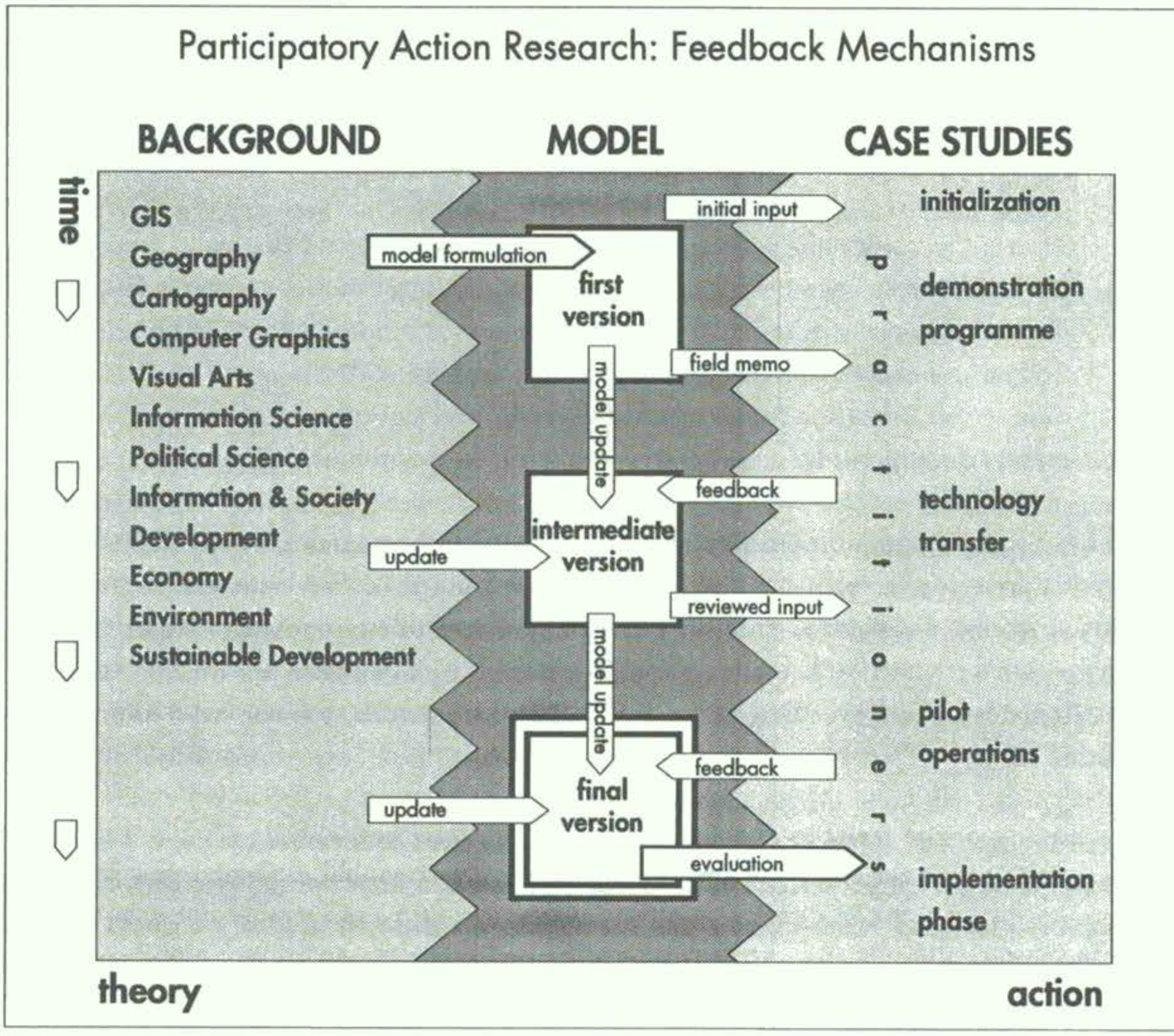

Figure 1.3: Methodology Adaptation

◊ A first version of the model has been deduced from theoretical background literature of an interdisciplinary nature: GIS, geography, cartography, environmental science, development studies, political science and information science. To a lesser extent also previous practical experience has been integrated in this original model.

◊ The model then has been translated to case-specific memos to be applied in the field: On the one hand to provide input to the projects, on the other hand as a framework for the depth interviews conducted with practitioners. Here, it proved to be particularly useful to have a broad theoretical foundation to conduct the practical work, which is usually not the case in consulting work.

◊ Through the evaluation of the field notes and the consultation of new literature – the research falls in a period of vivid developments in the GIS field – the model has been adapted to an intermediate version. Also a modified aide memoire for the second field evaluation has been compiled during this step.

◊ Another field stage gave the opportunity to provide additional input to the GIS facilities and interview their staff and users in-depth.

◊ At last, the model has been adapted to its final version, and the evaluations of the case studies have been issued. Admittedly, this last model version is less radical and progressive than the first one but still of a broad-based, rather idealistic nature and not merely an impression of reality. With its broad theoretical base it can undoubtedly be used as a theoretical backbone to any GIS implementation without being as rigid or remote as purely theoretical models.

Time is probably the most crucial limit in this interactive research process: While Participatory Action Research focuses on long-term involvement, it has nevertheless its principal validity in a limited window only: In times, when institutions and facilities are open for change, when the action is taking place. This was and still is the case with the study examples: The state of development of the GIS facilities in Uganda and Nepal still allows modifications.

The novelty of the facilities and GIS in general can, however, also be regarded as a drawback: The critical evaluation of the GIS installations in Uganda and Nepal may be premature. This is also one of the reasons I am not pursuing a rigid evaluation approach: It is quite obvious, that the sites are far from fulfilling their rather ambitious goals.

The interviews, despite having provided me with very useful information, did not deliver as prominent results as planned in the initiation of the study. This has mainly to do with the nature of GIS technology: Despite still being rather experimental with tremendous changes taking place rapidly, GIS are nevertheless being sold and installed in large numbers in developing countries mainly on beliefs that the technology will contribute to the solution of environmental problems. This leads to a very difficult situation to conduct interviews in the field, with goals, objectives, perceptions, plans and ideas constantly being mixed up with real results, obscuring the view on the factual truth. In addition, with GIS being an extremely complex subject area, very few people interrogated were able to independently judge the tool's nature and its ramifications: Answers were quite often stereotype, particularly about the broader goals and objectives implementing the technology. Thus, I was left with the vague feeling that I was extracting from the interview partners what others, or even worse, myself, had been feeding them earlier. In addition, some persons interviewed were preoccupied with the day-to-day tasks of running computers and their responses had only limited value for my research. I have to conclude that more relevant than the formal interviews was and is certainly my constant and on-going involvement in the projects that allowed observations over longer time periods to override superficial impressions gained in the field.

As researcher, of course, I also had to remain open to adapt the model, and – quite critical in conjunction with a methodology based on feedback – to draw the bottom line and to declare the model as completed.

Since the Action Research approach focuses above-all on crossing borders, I am aware that this may lead to problems at both ends, science and practice, as experience has already shown. While practitioners have labeled my model as too idealistic, thus the case study evaluation as too harsh, for scientists my elaboration may be too down-to-earth. But exactly here lays my aim: To create work comprehensible and thus also applicable by practitioners in the field, however with a theoretical background making it less positivistic or simplistic than professional expert studies and reports – with the clear motivation to get a job done or keep the business going – usually are. After all, environmental problems call for interdisciplinary approaches, and this also includes cooperation between research institutions, local government and international organizations.

1.4 Validity

The validity of the research is closely related to its background and its genesis in a University and International Organization context. In the following paragraphs, I want to outline the audience, the thematic coverage and the geographical area of principal applicability of my work. In an all-encompassing and highly variable field like GIS, it is important to put emphasis on the words 'more' or 'less': Because it is quite impossible to draw clear boundaries, the following delimitations have to be regarded as rather indicative, leaving some space for interpretation.

Audience

On the one hand, the work is directed at the scientific community: By the adaptation of the Participatory Action Research methodology to the Geographic Information Systems domain, I attempt to demonstrate how a highly interdisciplinary field with very strong application components can be integrated into research to contribute to scientific developments and at the same time meet the practitioners needs.

As the main goal of my work is to give an answer on how the technology should work, organizations and individuals involved in transferring GIS technology for environmental purposes to developing countries – practitioners in the international development scene – can be regarded as additional recipients of my work. Because it is predictable that also in the future most Geographic Information Systems in developing countries will be outside-funded, and the level of uncertainty among donors and receivers still being immense, my intention also is to fill this knowledge gap. Here, primarily senior officials and professionals at a rather strategic or political level in developed as well as in developing countries are being addressed.

Then, of course, this work is concretely written for persons and institutions involved in the Uganda and Nepal GIS facilities, to provide input for the future development of these Geographic Information Systems

Thematic Coverage

The study aims at Geographic Information Systems applied in an environmental context, a definition which in reality is rather unclear: Environment and geography are subjects widely overlapping and the terms are sometimes used complementarily. The label 'natural resources' may be characterizing the domain of interest more precisely, I do however prefer the word 'environment' because it encompasses also a political dimension and a holistic view. In chapter 3, I have grouped the environmental GIS applications according to the criteria scale, GIS function and institutional type. According to this scheme (Figure 3.2) as well as to the elaboration on sustainable development (Figure 2.3), I focus above-all on sustainable development strategies at the national level. My model is thus more applicable for the creation and management of general-purpose GIS centers operating on a nation-wide scale, than for project-based, local applications.

I generally exclude from the discussion systems primarily intended for surveying, engineering, facility and utility mapping, urban planning applications, base map production and military, although such systems may have relevant environmental components. Nevertheless, I believe that parts of the valuation are applicable to any kind of Geographic Information Systems.

Although I attribute remote sensing a great potential as a source of information, I treat the subject in my work only at the margins. As more explicitly outlined in chapter 3, I consider GIS being at a higher, more integrative level and a more political instrument, closer to environmental decision-making than remote sensing.

Geographical Area

Above-all, the group of the least developed countries (LLDC), being also the base of the case studies, is the area of principal validity of my research. Sections of the work, however, may certainly be applicable beyond this scope, even beyond Third World countries.

1.5 Outline

The dissertation consists of three parts, 'Background', 'Model' and 'Case Studies' that are further subdivided into the following chapters:

In part One, 'Background', I present the theoretical frame of the research in a chapter 'Environment and Development', giving an interpretation of 'sustainable development' for the research area and another 'Geographic Information Systems', sketching out the technology and its application. Part Two, the 'Model' is further subdivided into a theoretical and normative chapter 'Potential' that is followed by the application-oriented chapter 'Conditions'. In part Three, I will present the Case Studies; in chapter 6 'Uganda' and chapter 7 'Nepal'. In chapter 8, 'Evaluation and Outlook', finally, I will evaluate the results of my work and elaborate on potential future developments. The publication's organization is also visualized in Figure 1.1 above.

Part One

BACKGROUND

Part One: Background

In this part of the work, I want to outline the scientific frame to 'Geographic Information Systems for Environment and Development'. Since this theoretical background is compiled from many scientific subject areas, ranging from social sciences to quite technical subjects, including subjects such as development studies, political science, environmental science, geography, cartography and information science), I had to be highly selective and I will not discuss the various fields in-depth. I much rather want to draw an outline and highlight relevant aspects of the various scientific disciplines.

This background part can be regarded as an attempt of a synthesis, to widen the discussion around GIS as a subject and not merely look at it at a technical level. Thus, I also want to point out the interdisciplinary nature of applied GIS work, which is obviously needed in a sustainable development context. Here also rest some of the problems of using the technology: The surrounding subject areas are so vast that depth is often traded off for generalities, making GIS applications quite shallow at times. By defining the frame as widely as I do, also I run into the danger of becoming too vast, addressing issues that are only at the margin of the principal subject. I nevertheless believe that to be able to thoroughly value the potential of the technology, I have to establish the base as wide as possible.

In chapter 2, 'Environment and Development' I will outline and discuss literature evolving primarily around sustainable development: Today, a central and very fashionable topic. I will here also introduce additional environmental and development terms and issues, which are relevant to my work, and define them for subsequent use in conjunction with Geographic Information Systems.

Chapter 3, 'Geographic Information Systems' I start by outlining definitions, concepts and the historical development of GIS. Then I will elaborate on associated fields and issues, such as geography and other spatial sciences, environmental decision-making, cartography and computer graphics and establish links to the topic of main concern. Finally, in a more application oriented section I will review and discuss GIS applications concerning the environment and Third World countries.

2 Environment and Development

2.1 General Remarks

As I have outlined in the introduction, the environment is becoming an increasingly relevant issue for society. Environmental issues have moved to the center of the political stage and multi-disciplinary environmental science has emerged mainly out of the realization that nothing less than life on Earth is at stake due to our increased capacity to destroy our habitat. The recently held global conference on environment and development in Rio, short the 'Earth Summit', has received unprecedented attention mainly due to the attendance of many world leaders.[1]

Environment has been defined by Siebert (1987: p. 3) as:

> «The set of natural conditions defining the human living space.»

Environmental problems can be regarded as infringements to our natural living space with potentially grave repercussions on human life as a whole. Literature on the environment abounds, and catalogs of today's environmental problems are ubiquitous. Besides the works listed further down under 'Sustainable Development', I have principally used the following general references: Myers (1985), National Research Council (1986), Siebert (1987) and UNEP (1988a). A concise philosophical, historical and political treatment of the subject is the book 'Environmentalism' by Timothy O'Riordan (O'Riordan 1976), which has been updated in 1989. Works on the environment in the Third World are Hauser (1990) and Wöhlcke (1987). Among the mushrooming environmental periodicals, the following are relevant to my work: 'Environmental Conservation', «The international journal devoted to maintaining global viability through exposing and countering environmental deterioration resulting from human population-pressure and unwise technology» (Elsevier), 'Environmental Management', «An international journal for decision makers, scientists and environmental auditors» (Springer International), 'The Environmentalist', «The international journal for all professionals concerned with environmental awareness» and 'Zeitschrift für angewandte Umweltforschung' (Analytica Verlag). Just the explicitly cited mottoes of these journals show how broad the field has become today. Almost all units of science, govern-

[1] The Rio conference has been the largest environmental conference, even the largest diplomatic event ever. More than 150 countries have signed the Rio Declaration, the Agenda 21 and the two global conventions on Climate Change and Biodiversity (Journal de Genève, June 15, 1992).

ment and private industry have environmental branches attached and many aspects of daily life are affected by environmental issues and concerns. It is therefore no exaggeration to title the environment the issue of the 1990ies.

A broad-level classification of today's environmental problems has been issued by UNEP (UNEP 1988a) and is displayed in Figure 2.1:

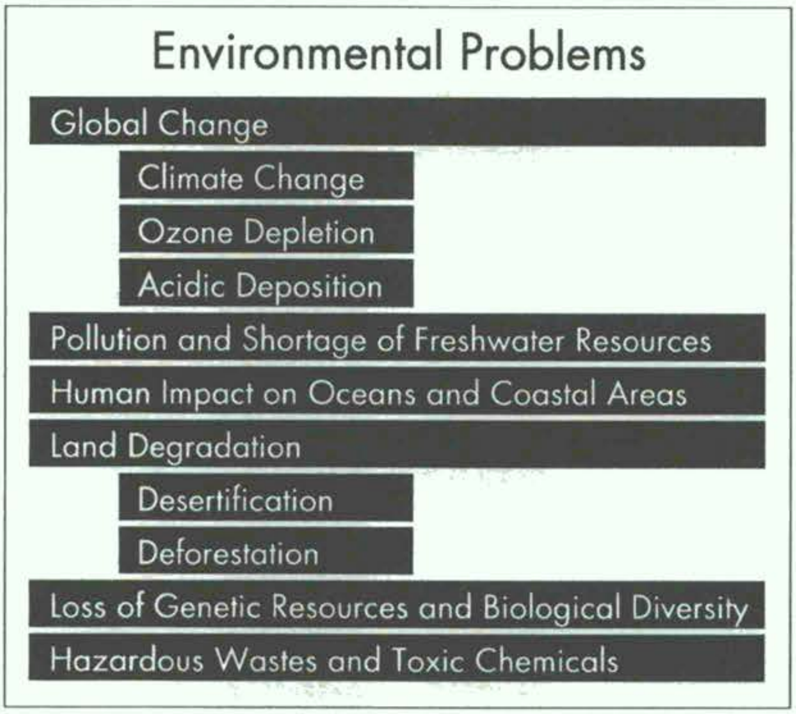

Figure 2.1: Today's Environmental Problems (Modified from UNEP 1988a)

For developing countries these problems have various implications: While some of them, such as water pollution and deforestation, have immediate physical impacts, others are rather difficult to assess. For instance, the effects of climate change are predicted to be particularly severe to many Third World countries.[2] But because of other, more acute problems, there are very little resources to deal with such long-term issues now, particularly since the principal causes of climatic change lie elsewhere. Of the problems listed above probably land degradation and freshwater shortage are the most pressing in developing countries today.

The cause of environmental problems world-wide is generally man. However, there are also environmental disasters with natural causes, for instance volcanic eruptions, with poten-

[2] The problem area of climate change is comprehensivley being discussed in publications by the Intergovernmental Panel on Climatic Change (IPCC 1990a, 1990b). Within the UN system, an Information Unit on Climate Change (IUCC) has also been established, with the goal to provide information on global warming to decision-makers, particularly from developing countries.

tially grave impacts. Due to the unpredictability and the randomness of such events, I exclude them from my elaborations and rather concentrate on man-made problems. Here, it has to be emphasized that the largest environmental damages are caused by individuals through their everyday actions,[3] as it has also been highlighted by O'Riordan (1976 and 1989) and Abler et al. (1970), and not by highly publicized 'uncontrollable' events, such as oil spills.

In developing countries in particular, such environmentally harmful day-to-day actions are often induced by the people struggling for survival. Thus, it is increasingly being recognized that the environment can not be approached in an isolated way. Concerning the Third World, this has directed international and developmental organizations to link economy and development activities with the environment, in brief, to sustainable development.[4] For instance, the above-mentioned 'Earth Summit' is officially called the United Nations Conference on Environment and Development (UNCED). The use of the terms environment and development in combination is very much en vogue today and has moved on the labels of many organizations in the development domain.

2.2 Sustainable Development

Sustainable development can be regarded as a conceptual synthesis of environment and development, the common strategy of the global community in the early nineties to tackle the vast global environmental problems. Although the idea as well as the terminology is older – summaries of the history are given in O'Riordan (1989), Dunand (1990), Smit and Brklacich (1989) – sustainable development appeared only recently in the limelight of the international communities' activities after the publication of the Bruntland Report in 1987 (World Commission on Environment and Development 1987). Both, environmental and development activities have a much longer independent past. In my opinion, the merge under the sustainable development label is often done at a rather superficial level. General literature on the subject abounds, for my work are relevant: IUCN/UNEP/WWF (1991), Archibugi and Nijkamp (1989), Bartelmus (1986), Clark and Munn (1986), Desai (1991), Dunand (1990 and 1991), Hanson and Régallet (1992), OECD (1991), O'Riordan (1989), Sachs (1992), Serageldin (1991), UNEP/ECA/ARCED (1989) and WRI (1990).

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3 This view of environmental problems as cumulative disasters is central to my work: Thus, I primarily assume that problem-solving has to focus on political and educational processes. I will elaborate more on this in chapter 3 under 'Environmental Decision-Making'.

4 Sustainable development, as propagated by international and aid organizations, seems to be primarily aimed at the Third World. In the context of my work, however, I want to emphasize the strategy's global validity, for developing as for developed countries, as also indicated further down.

Definitions

The definitions of sustainable development are manifold, as Figure 2.2 illustrates:

Sustainable Development

Meet the needs of the present without compromising the ability of future generations to meet their own needs

Development without destruction

World Commission on Environment and Development (1987)

Wealth creation based on renewability and replenishment rather than exploitation

Provision of basic needs ecologically and culturally acceptable

O'Riordan (1989)

Improving the quality of human life while living within the carrying capacity of supporting ecosystems

IUCN/UNEP/WWF (1991)

Figure 2.2: Definitions of Sustainable Development

Intensive discussions on the definition of sustainable development can for instance be found in IUCN/UNEP/WWF (1991) and Dunand (1990). I do not want to elaborate here more deeply on these definitions, in my opinion, all of them – being as broad as they are – are applicable to my work.[5] Later in this chapter, however, I will translate sustainable development specifically to problem area, Geographic Information Systems in developing countries.

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[5] The concept of sustainable development is in my opinion quite simple; thus I regard the discussions around its definitions in this context as rather fruitless. From a practitioner's perspective its translation to the application domain is more relevant.

Hierarchical Approaches to Sustainable Development

Sustainable development as an initially global strategy is now being more and more translated to hierarchical – or geographical – levels below, ranging from continental to local. To graphically represent these various hierarchical levels I have adapted the hierarchical systems method, as used in ecosystem research and introduced by Grossmann (1983), to sustainable development, as displayed in Figure 2.3:

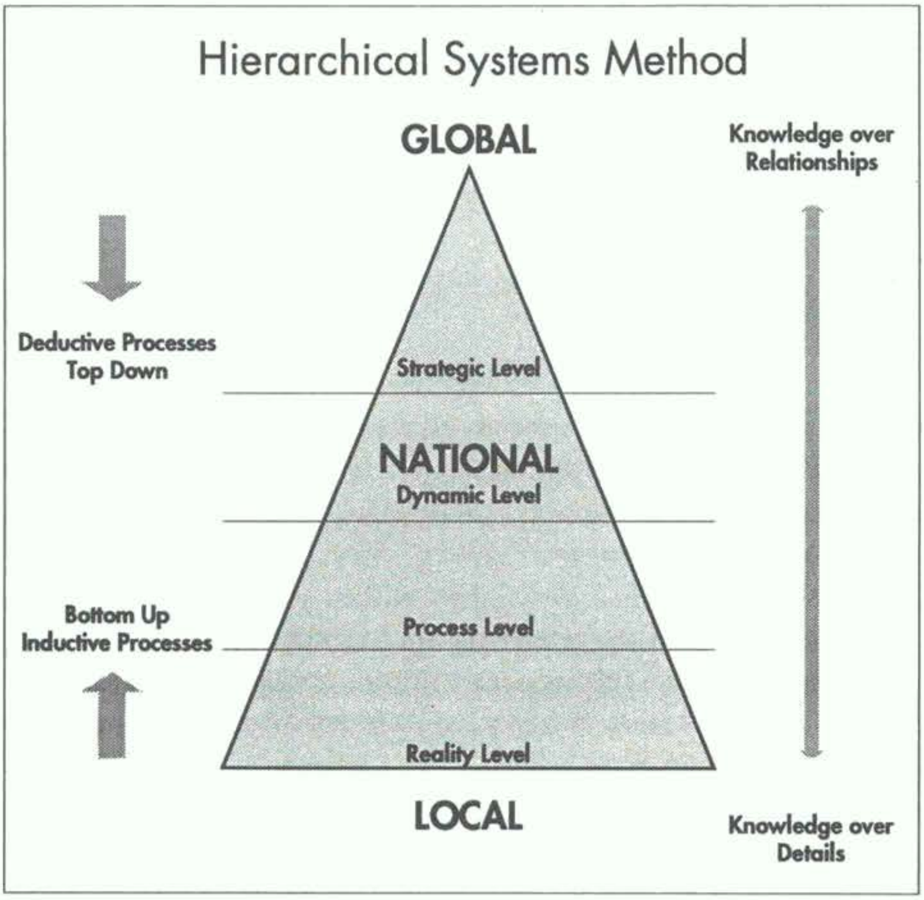


Figure 2.3: Hierarchical Systems Method (Modified from Grossmann 1983)

The hierarchical systems method integrates the various levels of observation – and policy – into one model. It will above-all serve as a background to place world-wide sustainable development efforts and applications. In chapter 3 (Figure 3.2), I will also adapt it to the field of GIS, as also Ashdown and Schaller (1990) and Spandau et al. (1990) have already done.

I now will outline sustainable development strategies and applications central to my work and localize them in the hierarchical systems model displayed in Figure 2.3, starting with global-scale efforts and then moving down the pyramid to the local level.

Global Approaches

The Bruntland Report (World Commission on Environment and Development 1987), for instance is to be positioned at the top of the pyramid, at the global-strategic level. Over the last few years the global community has seen several of such all-encompassing strategies emerging. One of the most recent of them being 'Caring for the Earth: A Strategy for Sustainable Living' published jointly by IUCN, UNEP and WWF (1991). The nine principles, by which a «sustainable society» will live have been defined as follows:

- ◊ Respect and care for the community of life
- ◊ Improve the quality of human life
- ◊ Conserve the Earth's vitality and diversity
- ◊ Minimize the depletion of non-renewable resources
- ◊ Keep within the Earth's carrying capacity
- ◊ Change personal attitudes and practices
- ◊ Enable communities to care for their own environments
- ◊ Provide a national framework for integrating development and conservation
- ◊ Create a global alliance

In general, the global-scale sustainable development strategies remain rather vague. Despite providing space for decentralized, bottom-up implementations they have to be regarded as being distinctly top-down efforts. Concrete guidelines are quite often lacking; proposed solutions to tackle the problems are at times not much more than wishful thinking. Critics, often originating from grassroots organizations or from academia thus mostly highlight the strategy's impracticability and they refer to it as

> «The refuge of the environmentally perplexed.» (O'Riordan 1989: p. 92).

The problem-solving approaches of the global sustainable development strategies are partly of a technological nature. The following statements, for instance, can be found in the Bruntland Report:

> Because «Technology had the power radically to alter our planetary systems» and «Human progress depends on technology» it is stated that «Capacity for technological innovation needs to be greatly enhanced in developing countries so that they can respond more efficiently to the challenges of sustainable development.» (World Commission on Environment and Development 1987: p. 60).

Realizing that such general technology-driven methods have probably limited effects, other authors look at politics first:

> «At the heart of the sustainability debate, therefore, is the essence of global communalism, namely an ecological basis to economies and local self-reliance. This means not just a comprehensive shift in power, but also wholesale changes in institutional alignments. Agriculture and forestry ministries, grazing and irrigation departments, minerals regulators and energy supplies – all would need to be transformed if they were to meet the demands of sustainability. This was a topic that, understandably yet frustrating, the Bruntland commission (1987) failed to address.» (O'Riordan 1989: p. 93).

The policy-oriented approaches generally have, in my opinion quite rightly, a rather prominent position amongst global sustainable development strategies. Directed at fundamental, policy-focused changes is for example also Desai's six point agenda (Desai 1991), presented in the context of an OECD seminar (OECD 1991), asking for nothing less than:

- ◊ Decentralization: Location-specific integration of environment and development
- ◊ Empowerment: Participatory decision-making
- ◊ Clear definition of Property Rights
- ◊ Enforcement of liability for damage
- ◊ Include environmental costs into prices of goods
- ◊ Conduct sustainability analysis of fiscal and monetary policies

Runnals (1991) also speaks about the empowerment of local people. Under this viewpoint, sustainable development would mean more equity, more democracy world-wide, and again, one might be confronted with the above-mentioned illusions.

These global-level, all-encompassing sustainable development declarations can certainly only be considered as a broad frame. They have to be transformed to the national or local level to be implemented, or, as it has been formulated by the World Resources Institute (WRI 1990):

> «In effect, the challenge is to translate this increasingly complex perspective into specific strategies for national action that encourage effective local participation.» (WRI 1990: p. 6)

National Approaches

IUCN/UNEP/WWF (1991) propose conservation strategies to be established at the national level. Here, efforts are being undertaken in most developing countries, for instance under the World Bank's National Environmental Action Plan (NEAP) program, IUCN's National Conservation Strategy (NCS) model or USAID's Country Environmental Profiles. All these activities «share the common characteristics of being comprehensive, multi-sectoral analyses of national or regional environment and natural resource issues» to «integrate environmental consideration in the country's planning and decision-making process for national development», as it has been formulated by Arensberg (1991: p. 275). Much rather than just the issue of a document, the NCS and similar activities are institution building processes, with the aim to establish structures for environmental policy establishment.

Examples concerning the case study countries are the National Conservation Strategy in Nepal (HMG-Nepal-IUCN 1988), and the National Environmental Action Plan (NEAP) in Uganda (Falloux, Talbot and Larson 1991, Slade and Weitz 1991). I will come back to these activities in part Three of this report when elaborating on the case studies.

Local Approaches

Even more concrete suggestions and descriptions of bottom-up implementations of the strategy exist at the micro-level, for instance by Carpenter and Harper (1989), Dunand (1991), Hough and Sherpa (1989), Technische Universität Berlin (1989), just to give a few examples. The contrast between such pragmatic, grassroots-type approaches at a small scale and the rhetoric of the international organizations operating at a global level can be quite striking at times. This may indicate that global Sustainable Development can probably only be achieved as the cumulative result of concrete small scale efforts within the frame of international strategies.

Adaptation of Sustainable Development to the Research Project

While the *exposé* above is vital to give an overview on the general issues surrounding environment and development, I now want to summarize the meaning of sustainable development for my research. Despite some reservations, I will accept sustainable development in an ecological sense as an underlying idea under the assumptions that:

- ◊ The strategy is applicable at all geographical levels, having both, grassroots as well as top-down, global-scale components.

- ◊ The strategy has to be applied on equal terms in developed as in developing countries.

- ◊ Solutions to environmental and development problems have to be found at all levels: Political, institutional as well as technical.

Concerning the geographical level, as also visualized in the hierarchical systems method in Figure 2.3, I will focus my work on sustainable development approaches aimed at national policy formulation. Primarily because this is the level where today many activities with large information demands are taking place, and, as we will elaborate in chapters 3 and 4, the technological constraints may here still be minimal. National approaches have to be regarded as belonging to the top-down domain, leaving however considerable space for bottom-up implementations as well.

As indicated above, sustainable development is a relatively novel field very much in fashion today. Thus, the connections between environment and development are often drawn in a rather superficial manner. For a broader understanding, and to define some of the thesis' central terms, I therefore add a section on development here.

2.3 Development

Relevant summaries on development issues are: IUED (1990), Knall and Wagner (1986), Nohlen and Nuscheler (1982), Nuscheler (1985 and 1992), OECD (1991) and Wälty, Knecht and Seitz (1990). Rather critical reviews of foreign development projects are Basler (1984), EDMZ (1987), Erler (1985) and Hagen (1988).

The world's inequities between the North and the South have lead to large scale development efforts. Development has been defined by Bartelmus (1986: p. 3) as:

> «Development is generally accepted to be a process that attempts to improve the living conditions of people. Most also agree that the improvement of living conditions relates to non-material wants as well to physical requirements.»

The goals of development strategies have to be all-encompassing; a good synthesis has been given by Boss and Weber, as visualized in Figure 2.4 :

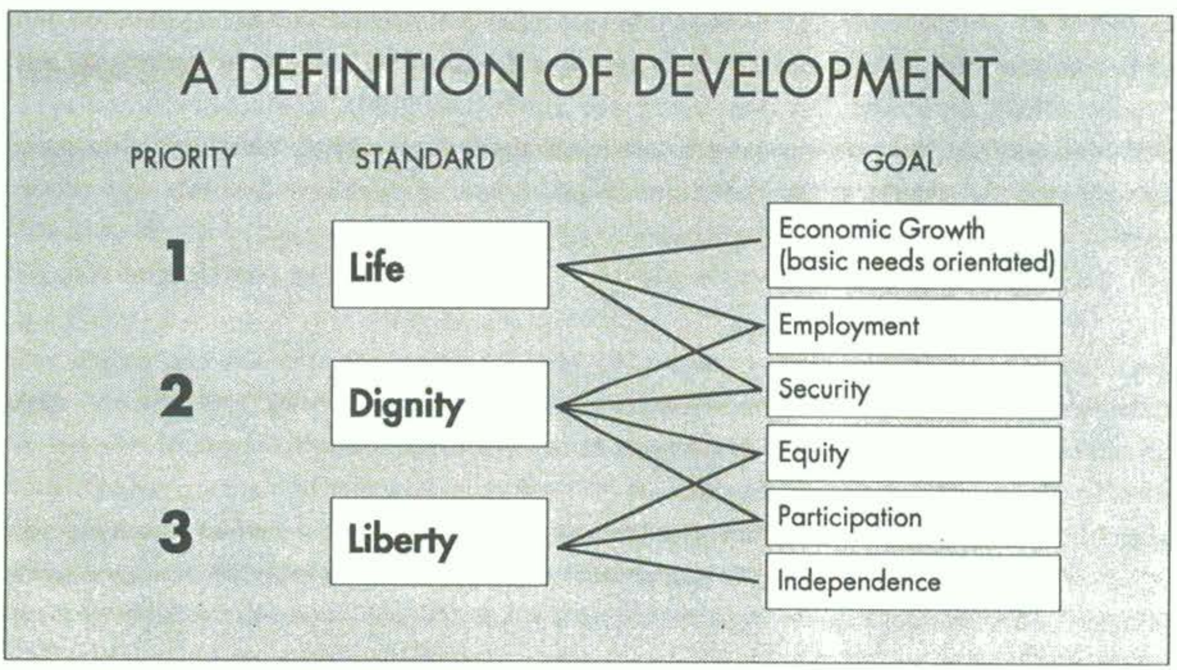


Figure 2.4: Definition of Development (Modified from Boss and Weber 1989)

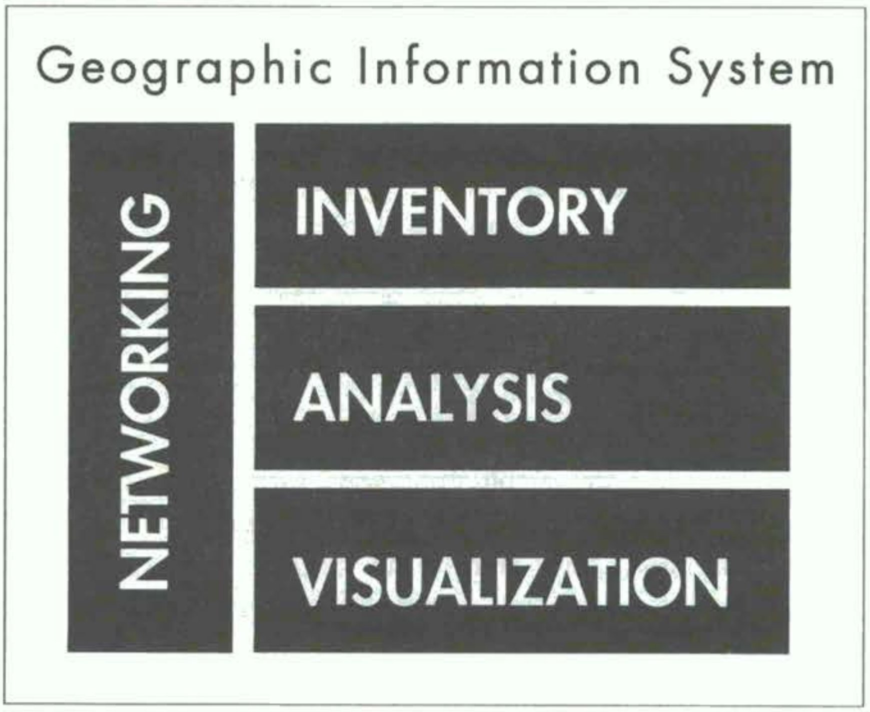
The translation of such broad goals into concrete strategies is not an easy task. The roughly 40 years of modern development have seen constant shifts in paradigms, depending mostly on the *Zeitgeist*. Economic growth in the 1950ies and 1960ies, basic needs and poverty in the 1970ies, participation in the 1980ies and finally, sustainable development in the 1990ies, have been – here grossly simplified – the principal targets of the global development activities (Nuscheler 1985, UNDP 1989). Foreign development assistance in 1987 reached a global total of 65.7 Billion US$, 41.4 billion US$ being official development assistance (IUED 1990).

The delineation between developed and non- or underdeveloped is rather problematic. Economic, social and cultural indicators, such as GNP, energy consumption, distribution of property, literacy rate etc., constitute the frame, but also more descriptive criteria can be of relevance. The geographical area affected by development is generally referred to as the Third World or Developing Countries. These expressions «inaccurate enough to mirror reality» (Nuscheler 1985) have found their way into everyday language and need no further explanation. Concerning the research subject – Geographic Information Systems – it is even more difficult to draw well-defined boundaries between individual countries: I will therefore employ the terms rather liberally and complementarily. Within the developing countries, other groups exist, such as: The LDC (Less Developed Countries) and the LLDC (Least Developed Countries) defined by the United Nations in 1971 and the MSAC (Most Seriously Affected Countries) to delineate the countries affected by the oil crisis in 1973, exist.

3 Geographic Information Systems

3.1 Definition and Concepts

A Geographic Information System is a computer-based tool to handle spatially referenced information. «Many definitions of GIS make reference to the four basic functions of input, output, storage and analysis» (Goodchild 1987: p. 327). Adding networking,[1] in my opinion a quite relevant institutional component, my own definition of GIS looks as displayed in Figure 3.1:



Geographic Information Systems (GIS) are computer-based tools for the inventory, analysis and visualization of spatial information. Through their interdisciplinary nature, institutional networking is also facilitated.

Figure 3.1: GIS – Definition

[1] I use the term 'networking' to describe the technology's organizational impacts. Networking is not a GIS component sensu stricto, it has, however, to be regarded as quite vital in conjunction with the introduction of the technology to institutions. The item will be discussed more extensively below.

As general as it is, this definition covers all aspects of the tool: It can be interpreted technically as well as on a broader scale of GIS and society and will be valid throughout my work. These individual components of GIS are outlined below.

Inventory

The extended input domain of a GIS, here called 'inventory', includes the following activities: Data acquisition, data integration and monitoring. Data acquisition is the process of bringing geographical data into a computer compatible format, for instance by digitizing maps, acquiring digital remotely sensed data or registering field observations. Data integration can be defined as the process of assembling data from various sources and different formats into a common system. Through this spatial integration step, the individual data layers are brought in conjunction with each other, thus enhancing substantially their potential. Finally, adding the dimension 'time', we speak of monitoring, the most powerful form of inventory: The repetitive collection, standardization and integration of consistent information over time to detect changes and to predict future trends.

Relevant GIS references related to input and environmental monitoring GIS are: Ashdown and Schaller (1990), Elmehrik et al. (1980), Elsasser and Trachsler (1987), Elsasser and Knoepfel (1990), Rhind (1990b), Spandau et al. (1990), and Simonett (1986).

Analysis

Analysis within Geographic Information Systems has been systematically described by Berry (1987), who defines it as 'map algebra operations' ranging from simple reclassifications, overlays, measurements and neighborhoods to more sophisticated modeling functions. Throughout this paper I distinguish between two levels of GIS analysis: Summary statistics and modeling. The former includes simple operations, such as area calculations, measurements or frequency counts, functions that are generally available in any GIS. The term 'modeling' is used for a more sophisticated mathematical and statistical analysis of spatial data with extended demands on the data and the models. The ability to handle and compare multiple features and their attributes of the same geographical location in one system renders the tool as ideally suited to develop and simulate environmental scenarios, to answer questions of the 'what- if' type. Because of its complex and probabilistic nature, however, modeling is still primarily used in the domain of research institutions.

In my work the term analysis is restricted to its use *within* the GIS: Thus, I will not include graphical analysis, as outlined by Bertin (1981) in this section. This form of information processing relies mainly on output products and will be discussed under 'Visualization'.

Specific literature on GIS analysis and modeling include Berry (1987), Fischer and Nijkamp (1992), Goodchild (1987, 1989, 1991b), Kundert (1989), Nijkamp (1989) and Van Beurden (1992).

Visualization

The visualization part of a Geographic Information System focuses on the translation of spatial data into communicable information.[2] GIS technology allows to visualize geographical information in a variety of forms of maps and graphical products such as sketch maps to be used in the field, portfolio maps to exchange 'quick look' information between planners and scientists or highly communicative maps and graphics used in publications or the mass media. At a more sophisticated level, it is even possible to integrate data from a GIS into multi-media technology and generate animated displays. All these different forms of output products can in general be created with the same data and on the same computer platform, which is an invaluable asset in today's information age demanding versatility and flexibility.

As outlined earlier, I also place graphical analysis under visualization. The basic idea of graphical analysis is to present data in such a way that interrelations become instantly evident: The recipients will be able to directly draw their conclusions from this information. This has the advantage that they are not confronted with pre-fabricated, highly hypothetical results of modeling and analysis steps. And here, Geographic Information Systems offer the possibility to easily visualize raw data available on a standardized base.

The literature to communication of spatial information is quite vast, some relevant sources are Bertin (1981, 1983, 1989), Brunn and Leinbach (1990), Buttenfield and Ganter (1990), ESRI (1991), Grünreich (1992), Kraak (1988), Landfried (1989), Lankhorst (1991), McAbee (1991), Muller (1989), Taylor (1983) and Wellar (1985).

Networking

Networking lies somewhat beyond the more tangible GIS components but its relevance to the field is being increasingly recognized, for instance by Dangermond (1989), De Man (1991), Fisher and De Mers (1989) and also Yeh (1991):

> «GIS capabilities could also have real, meaningful impacts on the organizations through which individuals and institutions carry out their work.» (Dangermond 1989, p. 1)

Networking is a strongly application-oriented component of GIS technology. The tool's potential to integrate information can also lead to institutional integration at various levels. The introduction of GIS into organizations has the power to open up completely new communication channels between practitioners in different sectors or at various hierarchical

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[2] Throughout this publication I will use the terms data and information as introduced by Rosenberg (1987): *Data* as «A representation of facts, concepts or instructions in a formalized manner suitable for communication, interpretation, or processing by human or automatic means.» (p. 144); *Information* as «The meaning that a human being assigns to data by means of the conventions applied to that data.» (p. 289).

levels. Thus, although often hidden, I regard the networking component as central to the application of GIS technology.

Today, the role and the position of the aspects outlined above are widely being discussed: Is GIS mainly an analytical tool, is it a vehicle for the inventory and monitoring of spatial information, is the principal purpose of the technology the visualization of spatial information or is the capability to bring together people, the networking components most relevant aspect? Speaking in general terms, this question can not be answered, since on the one hand, it depends on the individual application case and on the other hand, the breakdown of GIS in its components has to be regarded as somewhat artificial. Thus, instead of indulging merely on speculations now, I will come back to this issue when discussing the potential of Geographic Information Systems for environment and development in chapter 4.

3.2 GIS Developments

After having given a definition of GIS I now want to take a look at the more general aspects and at the literature of the discipline. A comprehensive handbook 'Geographical Information Systems' has been published in 1991 (Maguire, Goodchild and Rhind 1991). General introductions or overviews on GIS offer, among others: Bracken and Webster (1990), Burrough (1986a), Dangermond (1991), Goodchild (1989), Harrison and Dangermond (1987) and Walker and Miller (1990). Besides the scientific 'International Journal of Geographical Information Systems' (Taylor & Francis, London) also a number of application- and business-oriented periodicals exist, such as 'GIS World' (Fort Collins), 'GIS World Europe' (Lemmers) and 'Geo-Informations-Systeme' (Wichmann). Traditional cartographic journals, such as 'Cartographica' (University of Toronto Press), 'Cartography and Geographic Information Systems' (American Congress on Surveying and Mapping) or 'Kartographische Nachrichten' (Kirschbaum Verlag, Bonn) also cover the field of GIS. Relevant scientific papers on GIS research as well as on applications are regularly published in conference proceedings, such as 'Auto Carto', 'EGIS', 'GIS/LIS', 'Symposium on Spatial Data Handling'. Useful articles on scientific and research topics of Geographic Information Systems are Boote (1991), Goodchild (1987, 1991a), NCGIA (1989) and Rhind (1988).

As already indicated in the introduction, the commercial GIS market has seen a boom in the last few years only, with annual growth rates of 25 to 40% (Dangermond 1991). This is mainly due to the tremendous developments of computer technology with rapidly increasing processing speed, storage capacities and general availability of computer hard- and software at progressively lower prices.[3] The basic concepts of GIS have already been de-

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[3] One generally speaks about a doubling of computer performance every second year, thus ten years from now we can expect capabilities ten- to fifty-fold of today's, and this increase will come at even lower prices (Dangermond 1991).

veloped in the 1960ies and early 1970ies, but commercial systems came only into use in the 1980ies and became commonplace very recently.

An issue has always been on where to place Geographic Information Systems among the neighboring scientific disciplines, cartography and remote sensing, as discussed by Fisher and Lindenberg (1989) and NERC (1989). Here, I tend to take a GIS-centered point of view: GIS as an umbrella to the related subjects, integrating cartographic as well as remote sensing principles and information. In my opinion, GIS has distinct integrative and political components, which make it more than just a tool for inventory and monitoring, as it is for instance the case with remote sensing. Today, however, it becomes increasingly difficult to draw clear boundaries between GIS and the related subject areas: One can certainly speak of a «breakdown of traditional frontiers», as also expressed by NERC (1989) in this context.

If one wants to embed the technological aspects of the tool in its human and institutional context, one will have to analyze it at a rather wide angle, as my discussions on environment and development in chapter 2 have already shown. Thus, I will present background material to general geographical and spatial sciences research, aspects of environmental and spatial decision-making, environmental information, information and society, cartographic and graphic concepts before moving to applications of GIS in the environmental domain and in Third World countries.

3.3 GIS, Geography and other Spatial Sciences

Geography as well as other spatial sciences constitute one of the foundations of Geographic Information Systems. Therefore, with the rapid growth of GIS, Geography is now in a more prominent position than it used to be over the last decades. GIS constitutes a tool to apply and experiment with the large amount of spatial theories and models that have been and still are being developed in the various branches of geography, sociology, forestry, biology and other disciplines with spatial components.

It should be evident that by using GIS, it is extremely important to build on spatial science theory rather than merely creating technology-driven applications, as it is often being done. All environmental problems have spatial components, which geography and other disciplines are dealing with in a theoretical as well as in an applied manner. These vast background fields are often being neglected by GIS users, leading to many scientifically inadequate, if not trivial applications. This may even increase with further proliferation of the technology. In my opinion, the idea of GIS as everyone's tool has, despite its attractiveness, certainly scientific limits.[4]

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[4] Also the comparison of GIS to word processors, as often done to outline the tool's future developments, is in my opinion inadequate: Primarily because of the scientific limits outlined above.

I present a list of selected geographical texts, general and applied, which I consider of interest for my work:

An important geography classic is Bunge's 'Theoretical Geography' (1962). Before the existence of the technology, Bunge (1962) has drawn a scientific framework to what we call GIS today under the label 'Metacartography' emphasizing the interrelationships of pre-maps (photographs, cartograms), maps and mathematics. Another relevant older general work is 'Spatial Organization, the Geographer's View of the World' (Abler, Adams and Gould 1971), where, amongst others, spatial decision processes are extensively discussed.

Conducting research in a field 'in fashion' coupled with concrete commercial interests, it is in my opinion relevant to consult opposition literature. Such alternative views are offered in 'Radical Geography' (Peet 1977) and 'New Models in Geography' (Peet and Thrift 1989). Also critical to mainstream geography, Harvey's 'Historical Materialistic Manifesto', points, among others, at the geographers' role as 'eclectic generalists': «Academic geography, as a consequence, posed grand questions but all too frequently trivialized the answers.» (Harvey 1984: p. 4), a risk that is quite evident today with the call for more interdisciplinary work and with GIS being proposed as a solution to many environmental and spatial problems.

Applied geography offers also a vast and widely untapped reservoir of ideas and resources for GIS applications. Human as well as physical geographers have long-standing experience in the field of environment and development, at which we can here only throw a quick glance:

Somehow development oriented are William Bunge's works in Detroit and Montreal (Bunge 1977, Bunge and Bordessa 1975), where the principle of 'Geographic Exploration'[5] is being outlined, which seem to be predetermined to be applied using GIS in a local context. Rapid Rural Appraisal (RRA)[6] another explorative, bottom-up strategy has been applied and described by Carew-Reid and Oli (1991), NPC/IUCN NCS Implementation Program (1992a) and Technische Universität Berlin (1989). Although not purely geographic, Kevin Lynch's ideas expressed in 'Images of the City' (Lynch 1960) are particularly interesting regarding visuali-

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[5] 'Geographic Exploration' is based upon the idea that «Geographers should form expeditions to the poorest and most blighted areas of the country, contributing rather than taking resources, planning with people rather than planning for them, incorporating local people rather than excluding them in an elitist way.» (Peet 1977: p. 14). The principle has been applied by Bunge primarily in poor urban areas in the USA and Canada.

[6] In the context of decentralized development activities, NPC/IUCN NCS Implementation Program (1992a: p. 65) has defined rapid rural appraisal as following: «RRA can be used to describe any of the new methodologies which make use of a multidisciplinary team, working with farmers and community leaders to develop, in a quick yet systematic fashion, a series of hypotheses.»

zation. Other concrete guidelines suited for GIS applications can be found in Carpenter and Harper (1989), Casley and Kumar (1988), Friend (1988), Gares (1989), Hough and Sherpa (1989), Steiner et al. (1988), Stow and Laming (1991) and Wisner (1987) but, as mentioned already above, this list is only the tip of a very large iceberg.

Whether in concrete political processes the spatial sciences get their proper recognition or are not mostly by-passed by economic considerations can also be debated. Davies (1988) has demonstrated that spatial analysis, in the case of Zimbabwe's development planning after independence, has been a 'non-event'. However, particularly since environmental motives are increasingly relevant for political processes, there are enough indicators to prove that spatial sciences gain in importance in development processes.

3.4 Environmental Decision-Making and GIS

One of the central questions this research project elaborates upon is on how Geographic Information Systems can be tied to the political decision-making process for addressing and solving environmental problems. Here, I have come across a peculiar problem reviewing the literature: While references to decision-makers or the decision-making process are commonplace in the GIS context, more concrete information is often lacking:

> «GIS is helping to put geographers very close to the decision-makers.» (ESRI 1989: p. 25)

Chorley (1988: p. 3) recognizes quite rightly that there is still a gap to be filled:

> «The problem is to get the managers and decision-makers to use this (GIS) capability.»

Before outlining the role GIS takes in the context of environmental decision-making, I first will take a look at the general literature of the field. O'Riordan (1976, 1989) treats the subject of environmental decision-making quite extensively, and other important references are Carpenter et al. (1985), Gares (1989), Nijkamp (1989), Rey (1991), Sewell and O'Riordan (1976) and Thompson et al. (1986). From authors of the GIS field, some recent attempts to bridge the gap between the technology and society have been made by Chorley (1988), Chrisman (1987), Coward and Heywood (1991), De Man (1988), De Sède et al. (1992), Despotakis et al. (1992), Fischer and Nijkamp (1992), Fisher and De Mers (1989), Hugentobler (1989), Kusse and Wentholt (1992), Parent and Church (1987), Reitsma (1990), Smith and Honeycutt (1987), UK Department of Environment (1987), Worall (1990) and particularly relevant with regard to my research: Copas and Medyckyj-Scott (1991) and Fedra et al. (1991).

Since the largest environmental problems are caused by an accumulation of small-scale, individual decisions, as also outlined in chapter 2, environmental decision-making is seen by many not as a rational and straightforward task:

> «Despite the attempts by researchers to prove otherwise, decision-making is rarely a conscious rational exercise where key actors can readily be identified and asked to explain how and why they evaluate information and make judgments.» (O'Riordan 1976: p. 244).

The relevance of operations research (OR) and decision support systems (DSS), traditional methods to model decision-making, has by some authors been dismissed in the context of environmental problems, since these techniques are «suitable for supporting structured, operational decision-making only.» (Copas and Medyckyj-Scott 1991: p. 218). Thompson et al. (1986) also disapprove of the use of management science decision-making procedures mainly on the grounds of prevailing uncertainties[7] and that decisions concerning the environment have to be taken between and not inside organizations.

Here, however one has to differentiate: Environmental problems can also be reduced to smaller, manageable levels, and here the application of operational decision methods in the form of decision support systems is quite feasible. The main application fields are the various forms of environmental impact assessment methods (EIA) with well-established procedures and mostly known variables. Examples of such decision support systems are described by Fedra et al. (1991), Despotakis et al. (1992), Kusse and Wentholt (1992) and Reitsma (1990). Fedra et al. (1991) and UNEP (1988b) have included a survey of the various environmental impact assessment procedures: They list Ad hoc, checklist and matrix, overlay, network and diagram, cost-benefit analysis and modeling methods. All these different EIA techniques are suitable for the application of GIS. Most of today's decision support systems, however, still operate with rather simplistic rule bases; also the use of the term 'expert system' is in many cases inappropriate and misleading.[8] The field is still much in an experimental stage, and links to real world decision-making are therefore mostly lacking yet.

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[7] The authors' skepticism is also based on a survey of 'hard', i.e., scientific quantification of fuelwood consumption in Nepal, where the lowest and the highest values varied by a Factor (!) of 67 (Thompson et al. 1986).

[8] The term 'expert system', inducing a flavor of savoir faire, is in my opinion used far too often for quite regular Geographic Information Systems with a decision component; I prefer the more modest but nevertheless accurate label 'decision support system'.

Thus, I distinguish among two general approaches to environmental decision-making with GIS, making use of external and internal, or often referred to as passive and active[9] decision support methods:

Passive Decision Support

The large-scale environmental problems, primarily caused by the accumulation of multiple individual decisions, call for a broader political and educational problem-solving approach. Because the environmental decision-making process can not be rationalized into a readily usable model, structured managerial science methods are not necessarily valid. Concerning Geographic Information Systems, one will have to aim directly at a rather large group of environmental decision-makers, including politicians, planners as well as the general public. These decision-makers require timely, accurate, well presented and communicable information on the environment; it can be well envisaged that, among others, GIS technology will meet this information need.

Active Decision Support

The active or internal decision methods have their principal validity with environmental impact assessments and related planning procedures, which are all to a certain degree operationable. Here, GIS can be applied as decision support systems (DSS), where some decisions, or rather branches of decisions, are taken within the system, implementing readily available and known methodologies.

In the environmental decision-making domain, I consider the passive approach more relevant than the active one; the topic will be discussed with regard to GIS in developing countries in chapter 4 (Figure 4.1). Environmental information in one form or another has been identified as vital to all decision-making domains, I will thus elaborate the topic.

3.5 Environmental Information

In complex and all-encompassing problem areas where solution approaches aim at political processes information has always to be considered as a key issue. With regard to the environment, for instance, in the context of the Group of Seven (G7)[10] summit in London in 1991 a 'Statement on Environmental Information for Decision-makers' has been issued by the International Forum on Environmental Information for the Twenty-First Century, giving the following essentials:

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9 The terminology 'external' and 'internal' is specifically used here with regard to the tool GIS: The official scientific terms are 'passive' and 'active' decision support (Kusse and Wentholt 1992).

10 The world's most important Western industrial nations, Canada, France, Germany, Great Britain, Italy, Japan and the USA constitute the Group of Seven, or short, G7.

> «Public- and private-sector decision-makers at all levels are facing increasingly complex policy and investment choices, many of which require the integration of economic, environmental, social and cultural factors. Scientific, technical and policy information that is timely and accurate, and presented in a comprehensive manner, is essential to the achievement of sound decisions.» (p. 1)

Information in this context has been defined as: «Data, statistics and other quantitative and qualitative materials.» (p. 5)

Concerning GIS and environmental information, I would upgrade this definition with the visual components maps and graphics.

References to the decision-maker's information demand are found throughout the literature:

> «It was recognized that high-level policy and decision makers want simple, repetitive, integrating indicators of resource status and environmental quality.» (Carpenter, Talbot and Mitter 1985: p. 8)

> «The results of evaluation procedures have to be transferred to policy-makers in a manageable and communicable form.» (Nijkamp 1989: p. 206)

> «The ability to handle complex and probabilistic information and visualize the second or third order ramifications of various policy options is obviously an extremely valuable attribute for any decision maker.» (O'Riordan 1976: p. 242)

> «Agencies managing information can help by paying particular attention to the need to present decision-makers and their advisers with relevant information in a comprehensible and usable form, with confidence limits clearly stated.» (IUCN/UNEP/WWF 1991: p. 75)

These references are usually aimed at high-level politicians, the validity of these observations can however easily be extended to administrators and the general public as the individual decision-makers on a day-to-day basis.

Some of the above-outlined information needs pertain to the GIS domain. As mentioned in the introduction, even the Bruntland Report has outlined the need for GIS and space technology, and the IUCN/UNEP/WWF (1991) strategy refers explicitly to information technology and to GIS in order to 'strengthen the knowledge base and make information on environmental matters more accessible'. Also the G7 statement quoted (International Forum on

Environmental Information for the Twenty-First Century 1991), aimed at world leaders, demands nothing less than:

> «Recognizing the spatial nature of all environmental data and information and developing improved methods for presenting the products of Geographical Information Systems (GIS).» (p. 3)

Potential uses of GIS for the proliferation of information have thus clearly been expressed at the highest strategic levels. And here, I am moving closer to the core of my research: What role can Geographic Information Systems play as a tool to meet these information needs? Can GIS be used as a sort of:

> «Uncertainty absorber to simplify information and reduce ambiguity to tolerable levels.» (O'Riordan 1976: p. 242).

These questions will be subject of discussion in chapter 4, in the assessment of the tool's potential.

3.6 Information and Society

To assess communication aspects of spatial information, I want to illuminate the role of and potential large-scale impacts of information in society. References to this topic include Baark (1986), Brunn and Leinbach (1990), Erklärung von Bern (1986), Laudon (1986), National Academy of Engineering (1985) and Wellar (1985). Two principal tendencies have been observed. While some authors assume that the spread of knowledge will lead to a diffusion of power, to more democracy and to the 'erosion of hierarchies' (National Academy of Engineering 1985), others envisage potential negative impacts, which could lead to a centrally controlled 'dossier society' (Laudon 1986). Particularly in Third World countries, central governments could monopolize environmental information. A third group perceives the technology's impacts less important than conventionally expected. Wellar (1985), for example, concluded that the significance of automated cartography to information society was marginal at best. However, since Wellar's publication, the field has dramatically changed and his judgment might be different today.

It is quite difficult to judge the broader implications of Geographic Information Systems on society. However, I want to emphasize that despite the tremendous cumulative effect of information technology as a whole, the weight of one single element, such as GIS, should not be overestimated. The tool's impacts on society and the environment are certainly less than some exponents of the technology tend to believe. Talking about a revolution in the context of GIS and society is certainly an exaggeration, reflecting the commercial success rather than application impacts. After all, we are still far from significant breakthroughs in the handling of today's environmental problems.

Another critical topic is the often discussed 'neutrality' and 'objectivity' of computerized information. These questions have been a prominent issue in conjunction with Forrester and Meadows, the modelers in the late 1960ies and early 1970ies. Then, it has been proclaimed that:

> «Only the computer can 'objectively' work through the maze of interconnected loops and relationships to arrive at 'rational' conclusions; the human mind simplifies and distorts 'reality' to suit its prejudices.» (O'Riordan 1976: p. 15-16)

In conjunction with GIS, similar lines of thought have re-surfaced, stating that information derived from GIS is more objective or transparent than from traditional sources. Here, I agree with the authors taking a negative or at least cautious stand towards self-proclaimed objectivity and neutrality:

> «Maps, like art, are far from being a transparent opening to the world but a particular human way of looking at the world.» (Harley 1989: p. 3)

And in conjunction with GIS:

> «GIS technology is not scientifically objective and value-free.» (Taylor 1991b, p. 71)

GIS technology per se is neither 'neutral' nor 'objective'. In the context of providing information to decision-makers it much rather may well be regarded as a propaganda tool with all negative aspects associated. Only by being aware of this fact allows a meaningful appraisal of the technology and its application. The conclusions for persons involved with the tool has been stated in another context by Harvey (1984: p. 7):

> «Geographers cannot remain neutral, but we can strife towards scientific rigor, integrity and honesty.»

Others have also cited ethical aspects of environmental – and GIS – information, for example the 'confidence limits' in the IUCN/UNEP/WWF (1991) report or statements like «to summarize and interpret ethically in a way to sustain critical examination» by Buttenfield and Ganter (1990: p. 312).

3.7 Cartography and Computer Graphics

The process of transcribing data elements into useful and communicable information within a GIS, mostly relying on cartographic and graphical principles, is quite central to the field. The output from a GIS uses often the form of maps and graphics, and on the other hand cartography has also been one of the driving forces in the development of the technology.

Indispensable contributions in this field are the texts on graphic semiology by Jacques Bertin (1981, 1983, 1989), the 'Outstanding theoretician-practitioner' (Salitchev 1983). The description of the use of visual variables for the graphic transcription of information as well as the use of graphics for decision-making, makes Bertin's work very attractive to the field of GIS:

> «Maps are instruments for decisions as well as communication.» (Bertin 1989: p. 51)

The idea of graphical analysis, using maps as a vehicle for analysis – and not only to communicate messages – has been taken up by many authors in the GIS field, Copas and Medyckyj-Scott (1991: p. 222), for instance are stating that: «Graphics can be seen as decision aids in their own right.»

Board (1981), Grünreich (1992), Muehrcke (1981), Morrison (1989), Muller (1985, 1989), Salitchev (1983) and Taylor (1983, 1986) cover general aspects of traditional as well as automated cartography, which will not be discussed here in detail. It is important, however, to recognize the communicative nature of cartography:

> «The communication of spatial information that cannot be conveyed adequately by verbal or numerical means.» (Board 1981: p. 43)

Adalemo and Balogun (1989), Duru (1986), Freitag (1977, 1980, 1985), Friese and Welsch (1982), Gruber and Kostka (1990), McCall (1991) and Pöhlmann (1986) outline the role of traditional cartography in developing countries. Herzog (1986) looks at cartography and the political decision-making process.

Harley's (1989) critical comments become relevant in conjunction with increased map use in GIS. His conclusions that maps are never «scientific» or «objective» (p. 1), that «all maps strive to frame the message in the context of an audience» (p. 11) and that «behind most cartographers there is a patron» (p. 12) fit well into my elaborations on objectivity and neutrality above.

One serious concern in conjunction with maps and graphics from Geographic Information Systems is the potential of errors and misuse. The credibility of maps, computer maps in particular is still quite high, as Muller (1985: p. 44) has observed: «EDV Karten sind sogar unwiderstehlich, da der Computer ein Aroma der Unfehlbarkeit hinzufügt.»[11] During interactive GIS demos it can be observed that the recipients, stunned by colorful products, may not question the contents any more. Because «New maps are extremely volatile, single purpose and probabilistic», Muller (1989: p. 675) regards all this as nothing less than a «challenge of the integrity of the cartographic discipline».

Buttenfield and Ganter (1990) and McAbee (1991) also extensively discuss aspects of visualization and GIS. The former have developed a classification scheme of graphics commonly used in the context of GIS, comprising of

- ◊ analytical graphics for exploration and inference
- ◊ illustrative graphics for precise representation
- ◊ visual tools for decision-making

The interesting aspects of this scheme are on the one hand the recognition of the analytical qualities of maps and graphics, according to Bertin and others, and on the other hand, the ethical component attached to the 'visual tools for decision making', as cited above. I will come back to this scheme in chapter 4, when assessing the visualization potential of GIS.

With the importance of visualization to GIS in general and the disappearing boundaries between subjects we also have to look beyond cartography and GIS into literature on computer graphics and graphical arts. Overviews are given by Stankowski and Duschek (1989), Stadler (1982), Stauffer (1987), Tufte (1990), Veith (1988) and Wildbur (1989). The field offers enormous potentials which are far from being fully utilized by the GIS community. The same is also true for the use multimedia technologies, which only very recently have found their way into geography and GIS.

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[11] «Automated maps are quite irresistible because the computer adds a flavor of infallibility.»

3.8 Environmental GIS Applications

From the very beginning of the technology's development, GIS has been used for environmental applications. Thus, innumerable publications on the topic exist. A good survey is offered by Ashdown and Schaller (1990); other relevant works are Bächtold et al. (1990), Burrough (1986b), Kienast et al. (1991), Rhind (1990b), Storch (1990) and Van Beurden (1992) just to present an arbitrary selection. The field is vast, and as indicated, it is quite difficult to draw clear boundaries between environmental and non-environmental GIS applications. At a broad level one can use the pyramid developed by Grossmann (1983) and adapted by Ashdown and Schaller (1990) in an ecosystem research context. For my work, I have applied the hierarchical systems method to classify sustainable development strategies and applications, as displayed in Figure 2.3. Here, I have created my own scheme, which is more practice-oriented, to group GIS installations and applications with environmental contents. It is displayed in Figure 3.2:

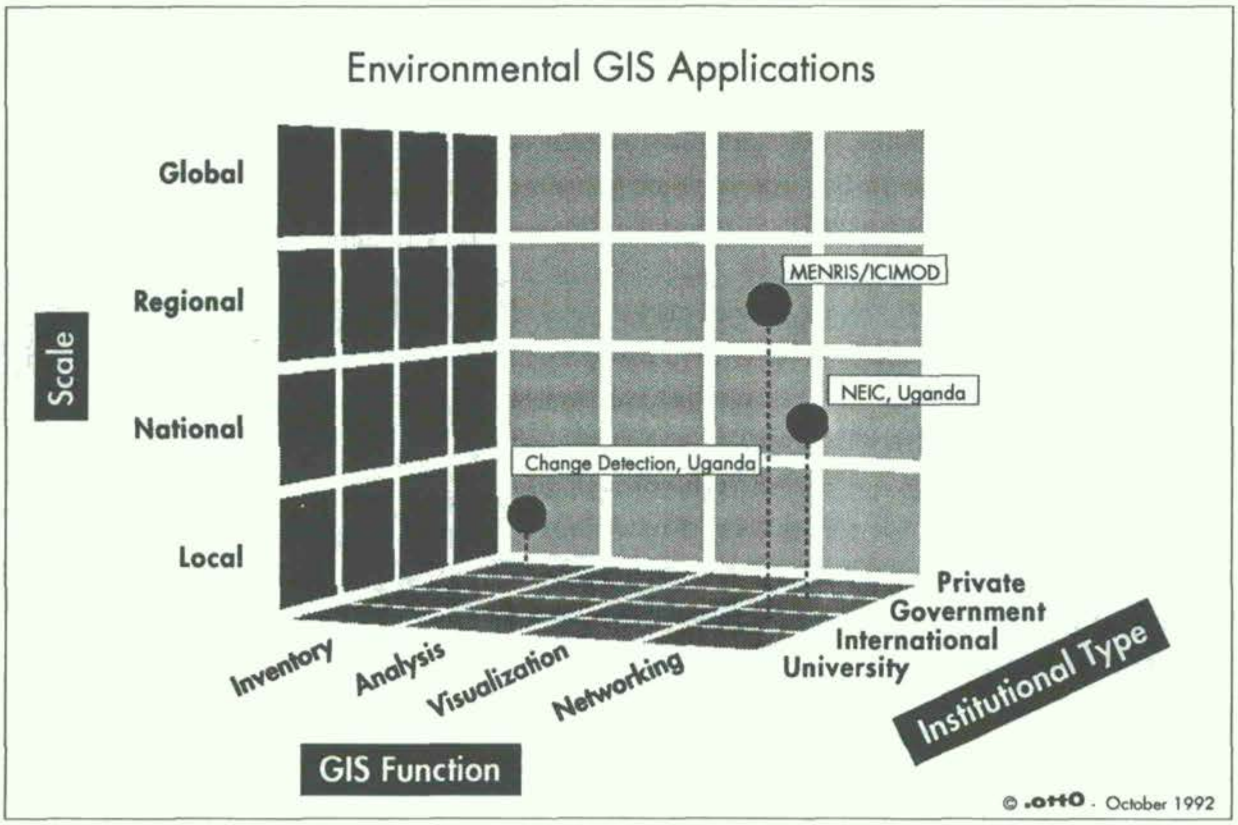

Figure 3.2: Classification of Environmental GIS Applications

My classification according to GIS function is based on the principal emphasis of a GIS site or application project. This is not always easily established, in reality, types are usually mixed, applying multiple functions in parallel. Better discernible are the parameters of institutional type and scale: Institutional type identifying the kind of organization, and scale, besides being a geographical denominator, also indicating the level of abstraction with regard to environmental decision-making. Scale can somehow be regarded as identical, or at least well correlated, with the hierarchical levels by Grossmann (1983; displayed in Figure 2.3: Strategic, dynamic, process and reality).

This scheme will serve as for assessing the potential of GIS technology in developing countries (chapter 4).

3.9 Geographic Information Systems in Developing Countries

With the substantial increase of GIS installations in Third World countries, also the literature on the subject is becoming abundant. It can roughly be subdivided into three groups: Scientific articles, descriptions of applications, and strategies for technology transfer. The descriptive texts are still dominating; very few authors up to now have been looking at the issue at a broader, non-technical scale. This problem will certainly diminish as time goes by: With GIS becoming commonplace and being applied more in developing countries, questions about their true value will become more relevant. So far, the technical problems associated with the tool were too dominant. People working in the field trying to keep the machines running can hardly be expected to venture into questions beyond technology. Thus, in papers on GIS applications in developing countries, the discrepancies between the often elusive general goals and the implementation descriptions dominated by technical terminology, can be quite striking. Another type of relevant literature are the strategic papers on technology transfer issued by international or by aid organizations.

Scientific Articles

Scientific pioneer work has already been conducted by Taylor in Kenya in the 1970ies (Taylor 1980). Of course, this early work is still full of technical details incomprehensible today,[12] however, Taylor never looses sight of the big picture: «I can think of no easier way to convince a regional economist to re-examine his basic premises than to show him a diagram of this type.» (Taylor 1980: p. 77). Taylor has also elaborated on education and training and analyzed the role of the foreign experts (Taylor 1986a, 1986b).

The most recent of Taylor's articles on GIS and developing nations (Taylor 1991a, 1991b) give a comprehensive summary of the developments over the last decade. The essentials of the field has been stated by the author (Taylor 1991b: p. 73) as follows:

> «GIS are a First World technology and their utilization in the Third World will depend, to some extent at least, upon the ways in which technology transfer takes place. If the First World finds new and more politically compelling outlets for its interest, the present nature and scale of that technology transfer may

[12] For instance, data had to be tediously entered on punch-cards, a technology which today has completely disappeared.

change. Thus, to understand GIS in developing nations, it is necessary to understand the challenges and context of development which is itself a constantly changing panorama. This is not primarily a technical problem.»

This is exactly today's prevailing dualism in the field, which is also one of the principal motivations to my work: To place a technical tool in an organizational and political context to create meaningful applications with large-scale impacts, for instance on environmental decision-making.

Taylor (1991b) elaborates extensively on 'top-down' and 'bottom-up' approaches, confirming to some extent observations I have already made in the context of sustainable development and ecosystem research applications (see Figures 2.3 and 3.2): The hierarchical level and scale have to be regarded as quite central parameters to characterize the type of a GIS application. The author has also assigned labels to various organizations in the technology transfer domain, for instance GRID as a 'top-down' operation, AIT as 'bottom-up' and ITC as 'intermediate'. In my opinion, this line of argumentation is not without problems of over-generalization, as one may well envisage mixed types. For instance, a top-down program can still leave niches for local implementations, whereas the appropriateness and financial sustainability, thus outside dependence, of bottom-up GIS projects has in many instances to be questioned.

I do, however, agree with Taylor when he states that GIS technology is often applied in a non-adapted manner, and fully support his call for 'indigenization':

«Ideally, the technology should be 'indigenized' and adapted to the needs and capabilities of the particular situation in which is to be used.» (Taylor 1991b: p. 80).

A special issue of the 'International Journal of Geographical Information Systems' has been dedicated to the topic 'GIS in Developing Countries' (Taylor 1991a). Interesting are here the contributions of Hastings and Clark (1991) on GIS in Africa, Yeh (1991) on the situation in Asia and Yapa (1991) asking whether GIS is an appropriate technology. Similar to my approach, Yeh also (1991) sees the main potential of the technology in conjunction with sustainable development strategies and links its application potential directly to recommendations made in the Bruntland report. Yapa (1991) acknowledges the dualistic nature of GIS technology, on the one hand having a great potential to support rural planning activities, on the other hand still being relatively expensive and difficult to apply in certain areas.

A quite independent and unique line of research is pursued by the East-West Center, focusing primarily on bottom-up, rural GIS applications in Asia: Fox (1991), as in some of his older articles (Fox and Chow 1988, Fox 1989a) is putting emphasis on broader scale issues and quite rightly states that:

«The implementation of this technology is not constrained by technical problems, but by social, economic and political factors.» (Fox 1989a: p. 11)

His rather unorthodox suggestion of moving GIS into the field to work closely with the local population in the context of Rapid Rural Appraisal (RRA) certainly bears potential for the future (Fox and Chow 1988). Particularly in conjunction with sustainable development, decentralized approaches integrating the local population become relevant.[13] Although, of course in a rural context one is more often confronted with the question of the appropriateness of the technology than in a larger, national-scale setup: The relatively high cost of such rural GIS ventures can probably only be supported through heavy external funding, leading to new dependencies and making the true grassroots type of such installations questionable.

Other articles giving a broader scientific valuation of GIS technology in a Third World context are Drummond (1986), International Academy of Environment (1991), GTZ (1991), Meijerink et al. (1988), Specter (1986) and Tveitdal (1989).

Descriptions of Applications

Descriptive articles on Geographic Information Systems applications in Third World countries relevant to my work are those of Chappuis and de Golbéry (1985), linking Bertin's principles to a GIS project in India, and Anker et al. (1986) applying the tool for land evaluation in Zambia. Both put emphasis on the importance of graphical communication:

«In a mostly illiterate environment, graphic communication is a necessity.» (Chappuis and de Golbéry 1985: p. 68)

«A map showing the suitability for growing a particular crop in a country may be a much easier tool for decision-making than long lists of tabulated results.» (Anker et al. 1986: p. 433)

Other articles describing GIS applications in developing countries are EROS Data Center (1988), Fedra et al. (1991), Hardy (1987), Hedberg (1991), Itten et al. (1986), Jampoler and Haack (1989), Krauer (1989), Kundert (1990), Lessard et al. (1989), Nanayakkara et al. (1985), Nkambwe (1991), Rojas et al. (1988), Schmid (1986), Schreier et al. (1989), Simonett et al. (1987), Singh (1989), Turyatunga (1989), Van der Harten (1991), Van Teeffelen (1991) and World Bank (1990).

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[13] Among others, the authors used GIS-like tools for decentralized information collection: «This study sought to demonstrate the utility of CAD software for making sketch maps and to appraise the use of computer-generated sketch maps for conducting rapid rural appraisals» (Fox and Chow 1988: p. 8).

Technology Transfer

Some international organizations and aid agencies, for instance UNEP/GRID, UNITAR, UNSO, USAID, ITC, GTZ and the World Bank for some years have been involved in transferring GIS technology to developing countries. While this is often done in a rather ad hoc, project based manner, the World Bank has elaborated concrete terms of reference for their 'Program of Environment Information Systems in Sub-Saharan Africa' (Falloux 1989, World Bank 1991a, 1991b, 1992b). The aim of the program is to:

> «Help Sub-Saharan countries to set up operational environmental information systems, to meet the priority demands of resource users, planners and decision makers for better renewable resource management.» (World Bank 1991b: p. 1)

The program is linked with the Bank's NEAP activities – described in chapter 2 – in the various sub-saharan countries, principally as an information mechanism for the action plans. The World Bank explicitly uses the term environmental information system (EIS) to emphasize their topic of main concern. The program's framework consists of the following elements for implementing operational environmental information systems:

- ◊ assessment of environmental information requirements
- ◊ assessment of the current situation in the country regarding environmental information
- ◊ elaboration of long-term strategy (15-20 years)
- ◊ identification of appropriate low-cost interventions to be implemented in the short-term
- ◊ initiation of training for both technical staff and decision-makers
- ◊ preparation of the first investment segment (5 years)
- ◊ provision of help to relevant institutions to initiate implementation

The World Bank program has to be considered a top-down, policy-level approach. It is addressed directly at the national government level and thus has considerable effect on general environmental policy developments, such as environmental action plans. It also explicitly leaves space for decentralized efforts, for instance data gathering at lower administrative levels (VIAK 1992). However, how this will work in practice remains to be seen. Despite being aimed at GIS implementations, the program is rather vague on central GIS issues, such as communication. Somehow it is assumed that as soon as Geographic Information Systems are installed, applications and the communication of environmental information will evolve automatically: An attitude not so rare in the international GIS community. Nevertheless, as a broad-level framework, the program has to be regarded as quite viable, above-all because it offers a policy-level treatment of the issue of transferring the technology to developing countries at a national level. For more concrete GIS implementations, guidelines will have to be worked out from case to case. For the National Environmental Information

Center (NEIC) in Uganda, which is being established under the World Bank program, for instance, this work will attempt to bridge the gap between strategy and applications in the frame of the case study discussion in chapter 6.

3.10 UNEP/GRID and UNITAR

UNEP/GRID and UNITAR are two organizations central to GIS developments in the Third World in general and my research in particular. They have relatively long-standing experience in the field. Thus, I will briefly introduce and evaluate the activities of these two bodies.

UNEP

The United Nations Environment Program (UNEP) has been established by the UN General Assembly as a follow-up to the Stockholm conference on the environment in 1972. It is responsible for «coordinating, catalyzing and stimulating environmental action primarily – but not exclusively – within the UN system» (World Resources Institute 1990: p. 15). The organization's main achievements can be seen in the following three areas:

- ◊ UNEP has been quite active and successful in creating global environmental awareness, involving youth, women's groups, industrial leaders and parliamentarians. For instance, the World Environment Day and the Global 500 award have been initiated by UNEP.

- ◊ The organization acts as a catalyst and coordinator of environmental matters above-all throughout the UN system and in certain instances also beyond.

- ◊ Although the program does not directly implement development projects, UNEP does influence development activities through its administration of various trust funds.

Despite being a rather small UN organization[14], UNEP has quite a high profile, particularly since it has initiated the Montreal Protocol on the Protection of the Ozone Layer in 1987 and the Basel Convention on Hazardous Waste in 1989, and because of its leading role at the Earth Summit in Brazil in 1992.

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[14] UNEP's annual budget of US$ 60 million (1988/89) is rather small compared to other UN organizations, such as WHO with US$ 543 million (1988/89), FAO with US$ 437 million (1988/89) or UNESCO with US$ 380 million (1990/91) (Wolfrum 1991).

UNEP/GRID

The Global Resource Information Database (GRID) has been set up in 1985 as a pilot project within the UNEP's Global Environmental Monitoring System (GEMS). After the pilot (1985-1987) and implementation phase (1987-1989), GRID is now operational and has become a UNEP Program Activity Center (PAC) in 1991. Besides a wide range of internal publications (UNEP/GEMS/GRID 1986, 1987a-d, 1988, UNEP/GRID 1990, 1991a-c), GRID's activities have been briefly covered in the scientific literature by Clark, Hastings and Kinnemann (1991), Hastings and Clark (1991) and by Taylor (1991b).

The GRID/PAC with overall policy responsibility is located at UNEP's headquarters in Nairobi, Kenya. Currently there are two UNEP internally funded and staffed regional nodes, Geneva and Nairobi, and a series of other centers of varying status: Sioux Falls (USA), Bangkok (Thailand), Arendal (Norway), Kathmandu (Nepal), Tsukuba (Japan) Warsaw (Poland) and Moscow (Russia). These, together with a range of national cooperating centers, form the GRID network. GRID's broader goals have been summarized as follows (UNEP/GRID 1991c):

> The mission of GRID is:
>
> ◊ To provide timely and reliable georeferenced information; and access to a unique, international Geographical Information System (GIS) service
>
> ◊ To address environmental issues at Global, Regional and National levels
>
> ◊ To bridge the gap between scientific understanding of earth processes, and sound management of the environment.

These goals can be grouped into two principal objective domains: Data and information provision (data assembly and data supply) and technology transfer, as also visualized in Figure 3.3 further below. We can recognize here the dualism technology – applications, which is predominant in the field today. These general goals have been translated into the following activity areas (UNEP/GRID 1991c):

> ◊ Database management, including the acquisition, verification, and dissemination of georeferenced environmental data sets, as well as development of methodologies for handling global data.
>
> ◊ GIS applications, in the form of provision of GIS capabilities and expertise for supporting environmental assessments and solving environmental problems at all scales.

◊ GIS technology transfer, in support to formal training programs, in on-the-job case study applications, and in conjunction with technical assistance programs to strengthen national capabilities.

◊ GRID system development, to ensure that GRID grows to become a useful service within the Earthwatch and the United Nations Environment Program (UNEP).

◊ Meta-database development for improved data documentation, and easy access to the catalog of GRID data holdings.

A schematic diagram of 'How GRID Works' is displayed in Figure 3.3:

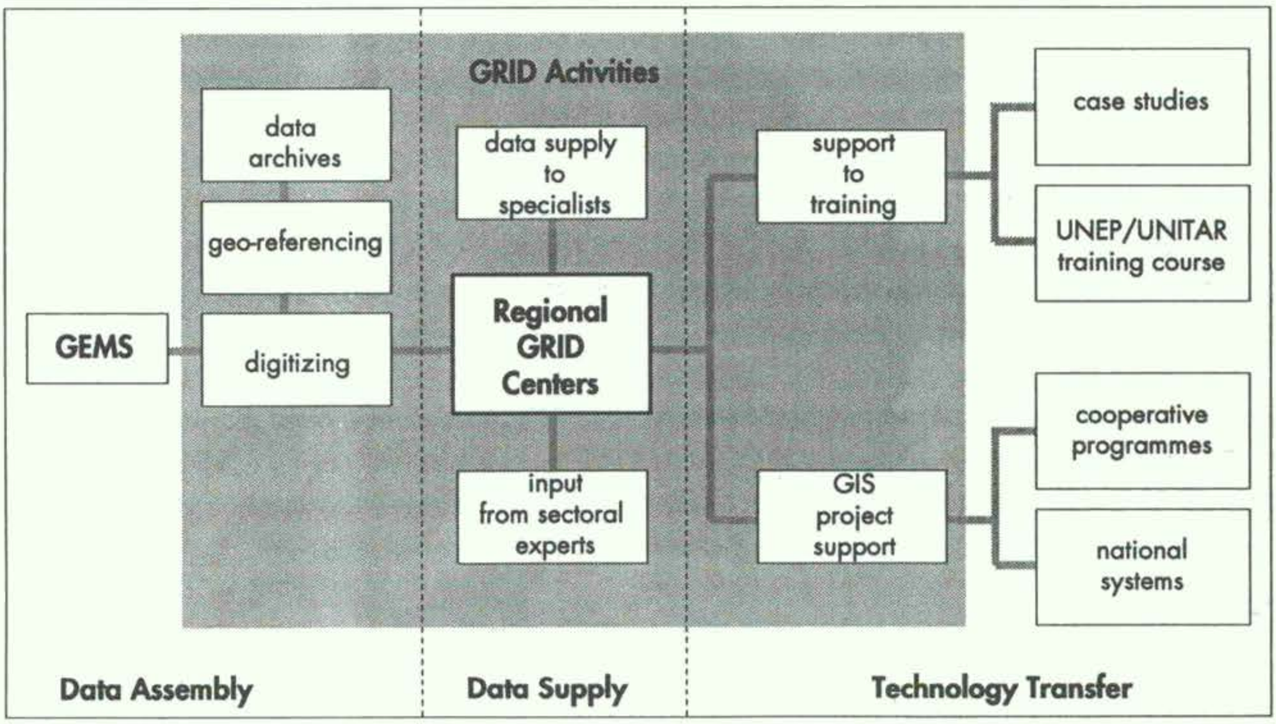

Figure 3.3: How GRID works (Modified from UNEP/GRID 1990)

GRID's strength is, as UNEP's in general, being a catalytic and coordinating body: Through its pioneering efforts in transferring GIS technology to developing countries, the program has created much world-wide interest and spin-off activities. Particularly in the context of national sustainable development strategies, GRID is in an important position; on the one hand to aggregate the national and regional data and strategies to a global synthesis, on the other to provide with GIS a tool to handle the enormous amounts of information accumulating. The GRID network can be regarded as a powerful vehicle to exchange knowledge, coordinate environmental GIS activities internationally and exchange natural resources data. Concerning world-wide data supply, GRID has created an automated cataloging system in the form of a meta-database, accessible on-line for interested information users.

However, I consider GRID's general goals and wide range of activities as probably too all-encompassing and ambitious: Its actions are at times quite *ad hoc* and patchy. This has certainly to do with GRID's position at a global strategic level. In addition, the geographical spread makes coordination rather difficult, many GRID nodes operate rather autonomously. Some nodes, for instance, have clear regional or national information mandates, others being more specialized in technology transfer or global database development. Thus, the program is not really as coherent as it may be expected, which also makes an overall judgment of GRID very difficult. I would term the GRID activities still as experimental, despite the program already being 'operational', because most of its broader goals are still far from fulfillment. Concerning technology transfer, thorough follow-up activities are not really on GRID's agenda, although such activities have to be regarded as a very crucial element in the field of a technology requiring larger scale and long-term investments and consulting activities. On this point I will elaborate more in conjunction with the Uganda GIS in chapter 6. Finally, with respect to its almost insurmountable coordinating and integration tasks, GRID is also just too small an organization with only about 20 professionals working at a few centers around the globe.

UNITAR

The mandate of the United Nations Institute for Training and Research (UNITAR) is to enhance «the effectiveness of the United Nations in achieving the major objectives of the Organization, in particular, the maintenance of peace and security and the promotion of economic and social development» (UNITAR 1992: p. 5). Under the umbrella of 'Economic and social development training programs', the UNITAR European office in Geneva has since 1986 been cooperating with UNEP/GRID in the 'UNEP/UNITAR environmental training programs in Geographic Information Systems for Natural Resource Management'. The training programs have four main goals, which are:

- ◊ To train scientists and planners from developing countries to operate and benefit from GIS technology.
- ◊ To guide trainees through their first GIS application project.
- ◊ To encourage and assist trainees establish GIS information exchange networks in their own countries capable of benefiting from GRID's technology and datasets.
- ◊ To enable trainees to train others within their respective regions in GIS technology.

Besides training, UNITAR pursues thus also technology transfer objectives: Again, an indication of the above-mentioned dualism technology – applications. General references to the program are Azimi (1991) and UNITAR (1990c, 1991 and 1992).

After an initial program at the EPFL in Lausanne and UNEP/GRID in Geneva, the training has now been diversified and decentralized with regional sub-programs in Nairobi, Bangkok and Kathmandu. Training events are of various contents and duration, ranging from one-day sensitization workshops to six-months training courses. To date, UNITAR has trained over 130 professionals from 40 countries from Asia, Africa, Latin America and Eastern Europe (UNITAR 1992).

As a major contribution beyond the diverse training courses and workshops, UNITAR publishes a series of workbooks on GIS related topics. These workbooks contain case study material in the form of digital datasets and written instructions to specific areas, which so far are: 'Change and Time Series Analysis in GIS', 'GIS and Forestry', 'GIS and Coastal Zone Management', and 'GIS and Mountain Ecosystems'. The workbook applications run on IDRISI, a low-cost but quite powerful, raster-based PC software package, whose development at Clark University is also supported by UNITAR (Eastman 1991). The IDRISI development can be regarded as an attempt to make GIS more applicable by being inexpensive and user-friendly.

After some years of experimentation with mixed results,[15] the 'UNEP/UNITAR environmental training programs in Geographic Information Systems for Natural Resource Management' have now matured into well-established institutions. In my opinion, however, two areas will in future need more attention in the UNITAR program: The adaptation of the contents to the local situation and the integration of the training activities into longer term options, above-all formal University education.

UNITAR's claim to pursue a «highly individualized and applied approach» (Azimi 1991: p. 1), has, in the context of workshop duration of a few weeks or months, at least to be questioned. Although UNITAR tends to integrate local data, procedures of applications are generally of a global and mechanistic nature.[16] Also the training's focus on analysis and

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[15] At the beginning, the program was not always able to provide operational GIS hard- and software to their trainees at completion of the training courses. Thus, valuable skills were being lost again and some of the trainees abandoned the field of GIS completely. See also the discussions on Uganda and Nepal.

[16] From a technology point of view it is probably all right to use, for instance, the same soil erosion models word-wide. However, if we really want to adapt GIS to the local conditions, we do not only have to ask whether the used methodology is appropriate but also whether the whole problem area is of relevance. Considerations, which are often ignored in a technology-centered training approach.

modeling could be shifted more towards the visual and communicative aspects of GIS, to get closer to environmental decision-making activities. While in Europe and North America GIS has evolved to an important academic discipline, in the Third World today very few Universities with a GIS curriculum exist. This is an area, where UNITAR could focus more attention upon to enable the long term sustainability of GIS in a country.

Training aspects in general will be discussed in chapter 4, and I will comment UNITAR's concrete involvement with the case studies in Uganda and Nepal in chapters 6 and 7.

GRID and UNITAR are both indisputably pioneers in the field of GIS technology transfer. Their achievements are quite impressive with a large number of cooperating centers and trained professionals world-wide.

My main criticism at both organizations, UNEP/GRID and UNITAR, is their over-emphasis on technology. Instead of playing a part between the technology and its application, both GRID and UNITAR are at times merely vehicles for the uncritical promotion of GIS to developing countries, not always in a well-adapted manner. Responsible for this is surely the novelty of the technology with the need of pilot and experimental work and the global nature of the two institutions. In my opinion, however, the organizations would be able to dedicate more time to environmental concerns and cultural issues, to 'indigenize' (Taylor 1991b) the technology, instead of promoting similar technology-driven solutions worldwide. Here, efforts are already underway[17] and there certainly lays a potential for the future.

[17] Increasingly, activities are being decentralized: GRID is creating regional and national nodes and UNITAR is facilitating regional training programs.

Part Two

MODEL

Part Two: Model

The model on Geographic Information Systems for environment and development has been created applying the Participatory Action Research methodology, as outlined in the introduction. Rather than being a simple cookbook approach easy to execute – as the term 'model' may imply – it is a quite complex conceptual framework on how GIS technology should be implemented and used in developing countries. It is based on scientific literature assessment, systematic qualitative field evaluations and active project participation. The model is intended to serve as a guideline to practitioners in governmental agencies, international organizations and NGOs implementing GIS technology in developing countries.

The all-encompassing 'How should the technology be applied to have an impact on environmental problem-solving' has been split down into two – still quite general – question areas:

◊ What is the **potential** of Geographic Information Systems to contribute to the knowledge and the solution of environmental problems in the Third World?

◊ Which are the **conditions** required for Geographic Information Systems in developing countries to reach their potential?

Accordingly, my assessment will be presented in two chapters, 'Potential' and 'Conditions', which can also be regarded as two levels of abstraction. Thus, chapter 4 'Potential' is a rather broad and generalized evaluation of the GIS tool, attempting to give an answer to the question of what role the technology could take concerning environmental decision-making in developing countries. Chapter 5, 'Conditions', is a more pragmatically oriented framework outlining institutional, financial, professional, training, technical and data issues relevant to the implementation of GIS technology at a national level.

4 Potential

4.1 General Valuation

The evaluation of the background material and the empirical research have lead to two general premises relevant to the valuation of the potential of Geographic Information Systems:

> To become applicable, sustainable development strategies have to be implemented at various hierarchical levels. In developing countries, many efforts are now under way to translate the concept into national policies. In-depth knowledge of the state of the environment is here essential: I consider this as a mandate to aggregate and disseminate information on the country's environment. Thus, my evaluation of the technology's potential is aimed at the national, policy-oriented level: GIS implementations administered by governmental agencies with support from international organizations and NGOs.
>
> Environmental decision-making can only in limited instances be expressed in the form of readily usable models. With the principal environmental problems caused by the accumulation of individual decisions, problem-addressing and problem-solving has in most cases to rely on political and educational processes: The goal is here to have well-informed and sensitized participating actors.

Thus, I see the technology's main potential as a communication interface in the environmental decision-making domain, providing readily usable information to politicians, planners and the general public:

> The main potential of GIS with regard to environment and development is being a communication interface in the political and educational domain: To provide environmental information to politicians, planners and the general public

My model of the tool's potential sets priorities among the various GIS functions: Inventory, analysis, visualization and networking, which have been defined in chapter 3 (Figure 3.1). This approach is certainly closest to the practitioners' mode of operation, and it is also congruent with the general debate on the nature of GIS technology. Other possible methods focusing on the various stages of the environmental decision-making process were not pursued mainly because of the constraints with modeling such processes as outlined above. By dividing GIS in its components, which in reality constitute a rather inseparable whole, I have to work along somewhat artificial boundaries. For instance, visualization and analysis are in reality always dependent on available data, on the inventory domain. I nevertheless assign priorities to these functional components: To accentuate and to outline where the impulses and the motivation should come from. The overall model is displayed in Figure 4.1; I will explain and visualize the details further below.

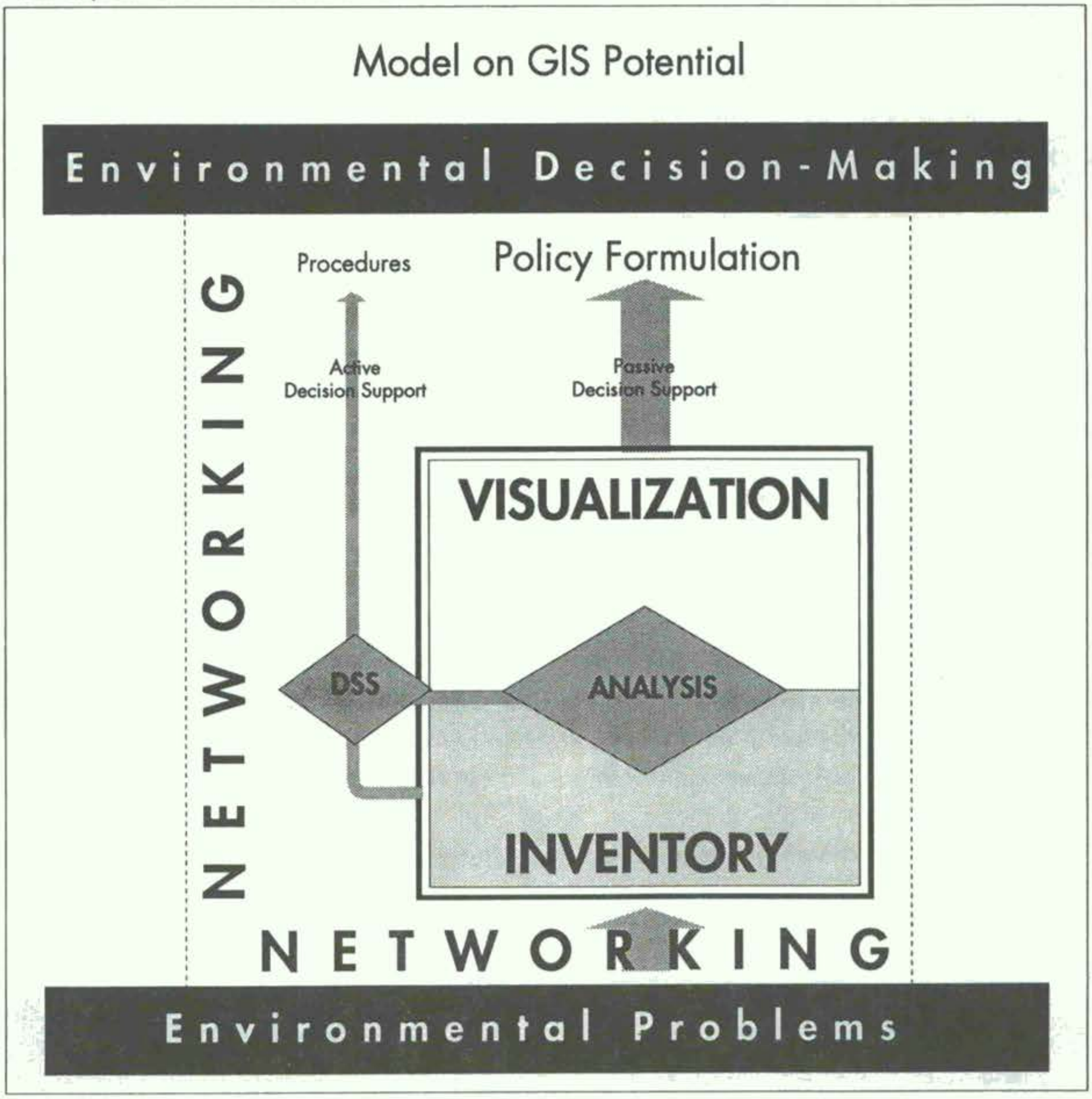

Figure 4.1: Model on GIS Potential

As expressed earlier, in the context of sustainable development strategies in developing countries, I see the tool's main potential in the communication of environmental information. GIS have to be seen as one of many possibilities, having auxiliary character to other means, such as the mass media or traditional educational processes. Figure 4.1 therefore can be considered as open to the left and to the right of the box in the middle visualizing GIS.

Geographic Information Systems already by their nature are a very communicative tool: Highly visual and based on modern technology on the one hand, interdisciplinary, with an enormous potential for opening up communication channels on the other. By regarding GIS primarily as a tool to provide information, I emphasize the communicative aspects of the technology: Networking and visualization. While the networking component can be regarded as the bridging element, creating interfaces between the technology, users and applications, the visualization part constitutes the vehicle of the tool to transcribe the data to communicable information for decision-makers. In addition, a strong inventory base, driven by the communication needs is inevitable to fulfill an information mandate. I do, however, tend to restrict the inventory activities to the basic minimum, as I will elaborate below. Finally, GIS' analytical potential can mainly be seen in the active decision support domain, which, as discussed in chapter 3 and indicated in Figure 4.1, I do not attribute the same importance as passive decision support.

Thus, in my assessment I perceive GIS as an instrument for 'advertising cartography' and 'persuasive communication', as introduced by Harley (1989).[1] Despite some inherently negative associations with these terms – advertisement is not far from propaganda – they are labels coming close to reality. There are certainly positive aspects, too: Creating public and political awareness on environmental problems and the environment in general. Only the consciousness of this advertising potential will allow a realistic and efficient implementation and use of the technology in Third World countries. In my opinion, information users have to be aware that modern technology is not necessarily more objective or transparent than traditional methods but probably a more efficient way to communicate messages.

This information centered view has some drawbacks, the most evident of them being the potential of misuse: GIS and environmental information could become a plaything of the politicians in power, an ideal instrument to promote project activities and to attract development funds. Just because the technology is neither neutral nor objective, it leaves much latitude in the interpretation and visualization of environmental data: Without crossing scientific borders, bias can easily find its way into environmental information as output product from a GIS.[2] This is also the reason to take a rather cautious stand towards analysis and modeling in a political context. By the combination of multiple layers associated with uncertainties, the potential of manipulation increases tremendously. As already indicated

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[1] As already discussed earlier, Harley's article 'Deconstructing the Map' (1989) offers an excellent discussion on the rhetoric aspects of cartography that is also of relevance to GIS.

[2] See also my comments on 'Environmental Decision-Making' in chapter 3, particularly interesting are here Thompson et al. (1986)

above, one of the few ways for information users to meet this potential misuse is to examine any GIS output rather critically; and analysts obviously have to attach an ethical component to their work.

Focusing on communication may also have negative implications on the substance: The oversimplifications of geographical and the environmental aspects, as already outlined in chapter 3, is also evident in Third World countries. Because the information has to be simple, manageable and presented in a comprehensive manner,[3] output from GIS is often extensively generalized to meet these demands. Such products could invoke misleading results, particularly if moved out of their original context: So-called runaway information,[4] usually leaving a lot of space for interpretation, can have rather dubious impacts on the recipients in a political context. Here again, information providers and users will have to find a mode of interaction to mitigate this problem, although in today's fast living information age I do not really see readily available solutions. As indicated in chapter 3, there have been attempts to attach labels of qualitative standards to environmental information, which may however be lost again if the information is being given out.

In my opinion, the danger of monopolizing information is less serious. With a further proliferation of the technology in developing countries, this will become increasingly difficult, since with GIS it is relatively easy to reproduce and disseminate maps, data and statistics. Unofficial data leaks, quite common where information technologies are being applied, can be regarded as a way to evade monopolies.

I now want to elaborate on the role of the individual GIS elements, which I have assigned the priority sequence displayed in Figure 4.1: Networking, visualization, inventory and analysis.

4.2 Networking

I perceive institutional networking as the engine of communication regarding the application of GIS at a policy-level in developing countries. It is, however, the least tangible component of the technology, least visible, thus also rather problematic to describe and to value conclusively. I nevertheless see a tremendous potential in the networking domain of GIS, and it is also the area where we have witnessed the most relevant and most surprising impacts of the technology. Although institutional and hierarchical alignments are hard to change, initial signs, as observed in Uganda and Nepal are encouraging. I will attempt here

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3 Attributes usually associated with environmental information for decision-makers, as also outlined in chapter 3.

4 Runaway information has been extensively discussed by Laudon (1986). It refers to the propagation of information leaving the hands of the authors and thus gain new, unintended meaning.

to put forward a classification of the various networking elements of GIS in developing countries with the potential to cross sectoral, hierarchical and international borders; the list is displayed in Figure 4.2:

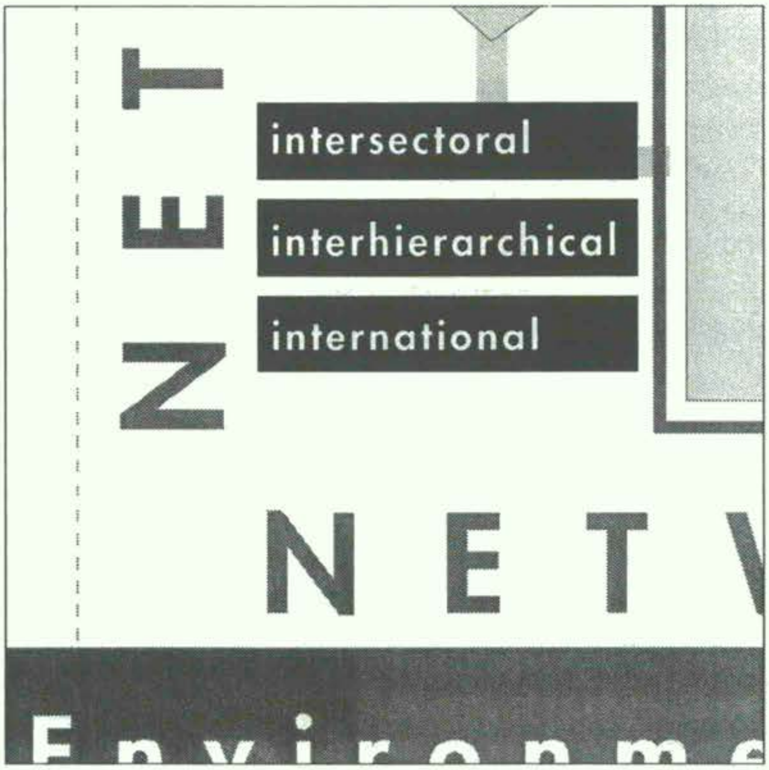

Figure 4.2: Networking Potential of GIS

Intersectoral

Government bureaucracies in Third World countries are usually much more pronounced than elsewhere, with a great number of sub-sectors often not communicating with each other on a professional level. And here, GIS has the potential to open up channels between individuals working in various branches of organizations realizing that many of their activities have a common spatial dimension. The use of the same data as a starting point can lead to cooperation with other areas and on the long run contribute to overcoming sectoral thinking. Particularly regarding the establishment of national environmental strategies, intersectoral cooperation is essential: GIS can be regarded as an integrative, pivotal element in this respect.

Interhierarchical

GIS networking has also the potential to work between the various levels of spatial hierarchies. Here, I envisage the tool to act as an integrator between bottom-up and top-down sustainable development strategies; between local and national scale environmental planning and decision-making activities, as discussed in chapters 2 and 3 (Figures 2.3 and 3.2).

GIS as a communication interface to integrate data and information from various levels, has also the potential for integration at the institutional level, thus also support decentralized planning activities.[5]

The attractiveness of the tool has the potential to create enthusiasm among senior staff in organizations, for instance managers becoming interested in personal GIS use. This certainly can create an intra-organizational dynamism and invoke new forms of interhierarchical communication. Observations made at seminars for high-level government officials in developing countries have so far been interesting, if not positive.[6] How far this trend will go remains to be seen: Today's barrier is primarily the technology still rather difficult to use and requiring a time input usually not available by managers. New developments of making GIS more user-friendly may lead to tomorrow's problems being the lack of scientific understanding, thus maybe an over-simplification of applications, as I have already outlined above and in chapter 3.

International

At the international level, new networking activities through GIS seem to be particularly relevant to Third World countries: Networks in the technology domain to share knowledge and training, in the application domain for data and model exchange may lead to generally improved communication and diminishing of redundancies between the international organizations, development agencies and local government. This is also the GIS function upon which, for instance, the GRID network, with national and regional GIS nodes all over the world, as discussed in chapter 3, is being established.

Generally, the barriers to networking are still tremendous, institutions are not being easily changed. Besides the usual communication obstacles, barriers are of a scientific nature: The limited applicability of spatial data with regard to scale may limit incentives for networking. The transportability of models has also clear limits. I will elaborate more on this in the inventory section. Another relevant aspect is the relative scarcity of GIS installations in developing countries setting clear limits to the networking capabilities. Finally, GIS networking is not a process as automatic as it may here sound: It has to be actively pursued by organizations and individuals working with the tool. I do however regard it as one of the foundations upon which GIS technology can be introduced in developing countries as elsewhere. The potential to create new communication links at a variety of levels is just too attractive to be left untried.

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5 In Uganda, it is envisaged to apply GIS to incorporate district-level information into the development of a National Environmental Action Plan (NEAP). It is expected that this will also enhance the communication links between central and local governmental agencies.

6 UNITAR, for instance has incorporated one- to three-days sensitization workshops into their training activities where senior officials is given the opportunity for hands-on approach to GIS.

An interesting question in this context also is, how the networking activities will develop as GIS is further proliferated. Will they increase because there will be a larger common base as more users, more information and more know-how is available? Or, will the future proliferation of the technology weaken the networking component because everything will then be available in-house and the necessity to share will be much less pronounced than it is today? The answer to these questions will also reveal the general nature of the networking capabilities: Are they only a symptom, linked to today's novelty and relative scarcity of the technology, or do they have a broader, more sustained meaning beyond technology in the application domain? Answers to these questions today can only be speculative today, thus, I will come back to these aspects in chapter 8 (Outlook).

4.3 Visualization

GIS are very visual tools, primarily because of their cartographic base and because of their links to modern information technology, such as computer graphics or multi-media techniques. In developing countries, where printing resources are usually scarce, the potential of GIS to create a whole range of output products in-house makes the tool particularly attractive. When communicating environmental information to different recipients, form and contents can be varied, an invaluable asset in a political and educational context. The relevant elements of the visualization potential of GIS are the highly communicative visuals, illustrative graphics, analytical graphics and user-tailored base maps, as adapted and upgraded from Buttenfield and Ganter (1990) and displayed in Figure 4.3 overleaf.

These GIS output products address different recipients at various environmental decision-making levels. While the highly communicative visuals and the illustrative graphics are in the passive decision support domain, the analytical graphics are a mixed form, potentially to be applied in passive as well as active decision methods. The user-tailored base maps are only marginally decision instruments, representing rather tools for information gathering. The complexity of these elements, concerning their creation with a GIS, decreases towards the bottom of the list. I do, however have to regard the boundaries as flowing, the categories being only indicative.

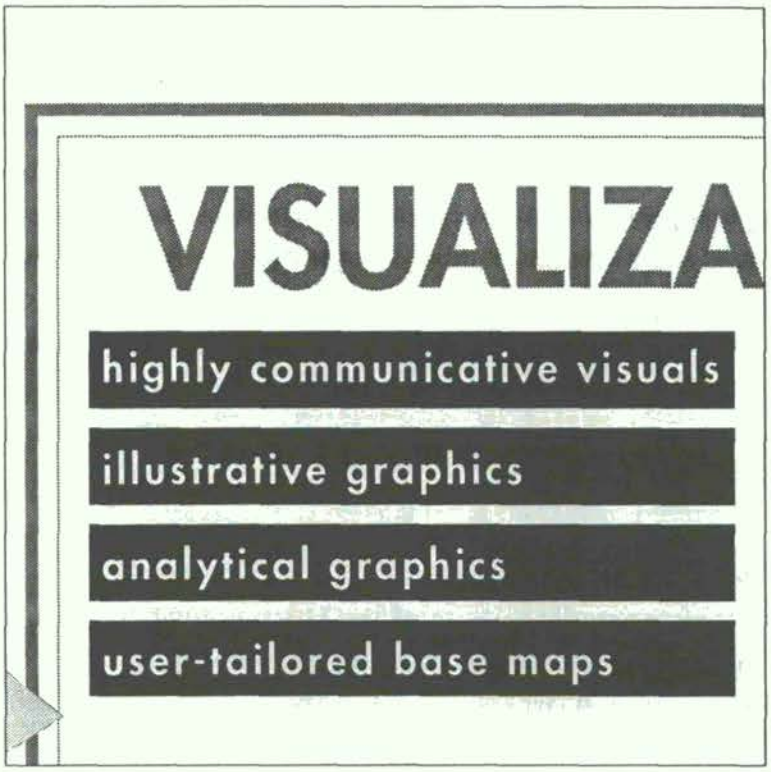

Figure 4.3: Visualization Potential of GIS

Highly communicative visuals

Passive decision support is considered quite relevant for the development of national conservation strategies (see also the discussion in chapter 3 and Figure 4.1). Most prominent are here the 'highly communicative visuals': Maps and graphics on general environmental issues of a country aimed at politicians and the public, also educational tools belong to this category. For instance, a national state-of-the-environment brochure can be counted to this category. This is certainly the most demanding level with data having to be assembled, generalized and visualized into a form allowing widespread propagation. Principal products are here printed brochures and atlases, slides and overheads, films, and, when computers have reached a certain status in a country also interactive demos.[7]

[7] I consider traditional visual products, such as brochures, slides and overheads as more appropriate than computer demos or multi-media shows for the communication of environmental information today: Principally because they still have more credibility with politicians and the public, they are also better transportable and less time-intensive to create than 'modern' information products. In future, this may however change.

Illustrative graphics

The category of illustrative graphics is mainly envisaged for 'less glossy' publications, such as shorter-living reports, scientific papers and project proposals, principally aimed at politicians and a wide audience of professionals in governmental agencies, NGOs and donor organizations. The efforts of creating illustrative graphics can still be regarded as considerable, with a time-intensive visualization step between the GIS data and the final information product.

Analytical graphics

Analytical graphics are defined as simple, but nevertheless communicative maps and diagrams, directly derived from the database. Being brought in conjunction with each other as well as with additional elements of information, they serve planners, analysts and scientists to formulate hypotheses and to reach conclusions on environmental planning questions. Graphical analysis methods, as described in chapter 3 (Bertin 1981, 1983), primarily rely on this type of GIS output product. Here, interactive maps displayed on the screen are probably as important as output on paper: With the principal audience usually having access to GIS, there is no need for extensive product propagation. Thus, this form of output can be considered to belong to both, the passive and active decision support domains. The latter will be relevant in the context of decision support systems discussed in section 4.5 (Analysis).

User-tailored base maps

User-tailored maps on paper as output from a GIS are an important tool for field surveys or census. Such pre-fabricated templates can be used to gather standardized information by people working in the field, also in the context of rapid rural appraisal and geographic exploration methods described in chapter 3. Particularly where base maps are not easily available or hopelessly out of date simple GIS output products are an invaluable asset in the context of formulating and implementing sustainable development strategies locally.

While I attribute Geographic Information Systems an enormous potential in visualizing environmental information, I nevertheless have to highlight some caveats. The emphasis on visual products can have negative, if not misleading, impacts on the recipients as already outlined earlier. Images usually have a much stronger appeal than words or statistics, thus special care has to be taken when visualizing environmental information. The often propagated 'map on the fingertips' also remains a myth. Although visualization software abounds and more recently has become quite user-friendly, cartographic as well as other graphical skills of the users remain essential. Any meaningful output product from a Geographic Information System has usually to be meticulously designed in very time-intensive processes. Then, with the palette of potential output products growing, there are also increasing needs in personnel and hard- and software.

4.4 Inventory

In the model, I have assigned priority to the communication of environmental information over inventory. While in reality, visualization within a GIS is closely interconnected with inventory, I set accents: Inventory will be driven by the communication demand. For the translation of sustainable development into national strategies in Third World countries I envisage GIS technology's potential in the following three inventory areas: Integrated resources base, environmental monitoring and information on hot spots, as visualized in Figure 4.4:

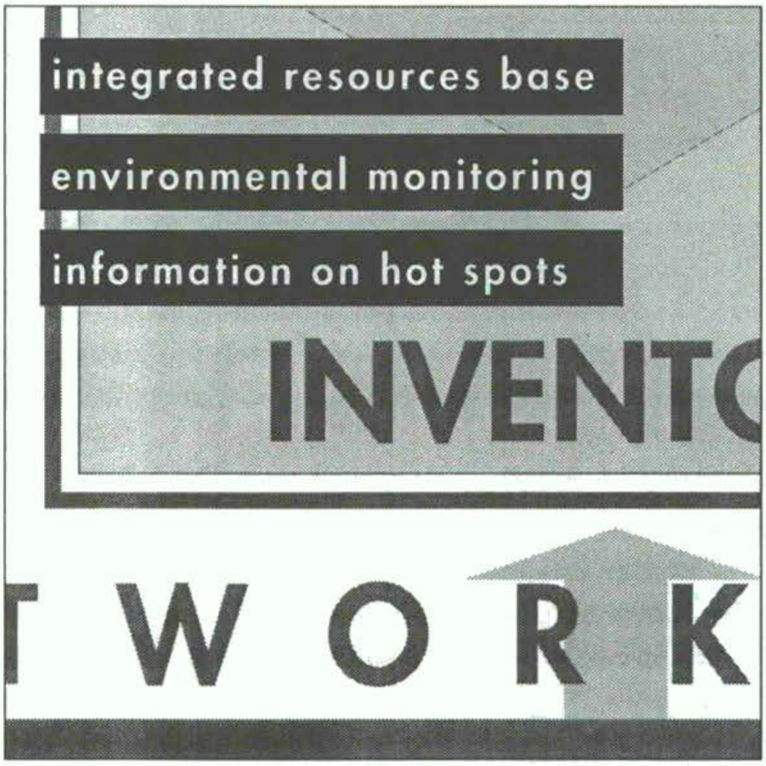

Figure 4.4: Inventory Potential of GIS

All these inventory activities primarily focus on passive and active decision support for the formulation of national environmental policy as well as for general environmental decision-making and educational purposes. Since my approach is aimed towards minimizing primary data acquisition by a national strategic GIS, I emphasize the coordinating functions in the acquisition domain: To formulate needs and issue data standards when larger-scale surveys are being conducted, for instance in the context of a nation-wide land cover mapping project or census activities. Only the collection of data on environmental hot spots,[8] requiring

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[8] Environmental hot spots can be defined as areas with particularly severe environmental problems of national or international importance, such as an endangered forest (e.g. Mabira Forest, Uganda)

quick operational action falls in my opinion under the mandate of a national GIS. Since inventory is very closely related to the data issue, which I will discuss in chapter 5, I will here focus on the main aspects of the function and elaborate on the details further below.

Integrated Resources Base

Principal goal here is to compile a national environmental database from various sources to be able to best meet the information needs for the formulation and implementation of a national environmental strategy. The driving force behind the database creation should be its use rather than available maps and other information. The contents of such a database has to be closely related to a country's principal environmental problems and issues and coupled with standard geographical layers, such as topography, climatic variables and population as the base. A crucial factor is scale, which on the one hand has to support meaningful communication, on the other hand, the complete data coverage of the area of interest, i.e., the whole country, should still be an achievable goal. Thus, in practice, the integrated resource base usually constitutes a compromise between user needs and map and resources available.[9]

There are, however, limits to spatial data integration, some of which I have already indicated above. Although technically feasible, it may be inappropriate on scientific grounds to combine data. Problems can be associated with scale: Only the combination of data of a narrow bandwidth of scales is usually meaningful. In addition, classification schemes and survey methodologies may vary too much to make a unification possible. Another important factor is time: Data search as well as physical data integration are very time-intensive procedures. With the abundance of information, the capabilities of a single GIS can easily be exceeded. Thus, I put emphasis on the networking capacities of the tool and the coordinating and catalyzing functions of a national GIS instead of creating a large database or a larger data acquisition potential in-house.

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or a hazardous waste deposit (e.g. Kilembe Mine, Uganda). The term incorporates also a dimension of political actuality.

[9] As examples of such compromises we can regard the case studies in Uganda and Nepal: In the context of the Uganda case study, to compile a database covering the whole country in a short time period, UNEP/GRID has integrated resource data at a scale of 1:1.5 million. This admittedly very small scale nevertheless has allowed visualizing an environmental cross-section of the country and this base still comprises a valuable stock of the NEIC facility in Kampala. In Nepal, more time and efforts have been put into the creation of a typical district-level database at scales between 1:50,000 and 1:125,000. Because this base has been compiled for one zone (eight districts) only, ways and means have to be found to acquire data at a similar resolution for the whole country. In chapters 6 and 7, I will discuss these case studies more in-depth.

Environmental Monitoring

Some environmental parameters identified as being of national or international importance require the repetitive data collection and integration. Typical national environmental monitoring domains are, among others, air and water quality, forest-cover, and wildlife. Here, the same basic rules apply as with data integration: Behind monitoring there has to be a communication mandate, and a national GIS should restrict itself to coordinating and visualizing functions rather than conduct surveys on its own.

Information on Hot Spots

In my opinion, a relevant political and educational position take the so-called environmental hot spots. Hot spots can on the one hand be regarded as geographical areas requiring special observation, on the other hand, they can also be thematic issues being in the focus of political activities. Thus, hot spots are particularly attractive for a National Environmental Information Center: To make oneself known and to build up credibility and reputation in being able to provide data and information when it is required. This is the domain, where I attribute even a strategic-level GIS facility with the mandate to conduct surveys and to acquire their own data.

Problems with this hot spot inventory domain may arise due to its unpredictability, making it difficult to allocate resources in advance. Thus, the treatment of hot spot information could at times monopolize a GIS site. Above-outlined tendencies for manipulation could also be enhanced, for instance by using GIS to create an environmental hot spot, which in reality does not exist.

Satellite Remote Sensing

Satellite remote sensing – also in the Third World – is a viable source for environmental data. Since it pertains to the inventory domain of a GIS, I want to include here some comments on this issue.

With applications dating back to the early 1970ies, satellite remote sensing has a longer-standing tradition than GIS in developing countries. Thus, Geographic Information Systems are – above-all by practitioners not familiar with the subjects – quite often being considered as being primarily tools for satellite remote sensing. This misunderstanding is partially due to the attractiveness of space technology, and also because the technology is quite aggressively marketed in developing countries.[10] Even though GIS and remote sensing systems are increasingly integrated at a technological level, I nevertheless maintain my hierarchical point of view outlined in chapter 3: Satellite remote sensing being merely one of several data gathering instrument for information systems.

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[10] For instance, the French SPOT image company organizes regular seminars on the use of their products in developing countries, e.g. in Kampala in 1991 (Government of Uganda et al. 1991)

The use of satellite imagery in development projects is quite widespread; a good summary is given by GTZ (1991). The technology's main potential lies in the easy and inexpensive establishment of cartographic bases for large areas.[11] Overview images covering project regions can serve as an excellent planning tool. Due to regular and repetitive data acquisition remote sensing is, and will be in future, when longer time series will be available, also an instrument for environmental monitoring.

In my opinion, however, the value of satellite remote sensing to the solution of environmental problems in developing countries is generally over-rated today. Resource information gathered from satellite imagery is mostly physical, the underlying socio-economic structures being invisible. The thematic spectrum is therefore rather narrow, usually limited to generalized land cover information. This renders the technology applicable only in conjunction with additional ground surveys, which, unfortunately are often neglected due to the widespread belief that remote sensing replace the traditional methods. The dominance of satellite technology in conjunction with GIS in Third World countries has so far impeded the application of other viable and efficient alternatives, such as to link GIS with census activities, ground sampling techniques, surveys in the context of rapid rural appraisal (discussed in chapter 3) and many others. Traditional remote sensing methods – aerial photography – can also be considered as viable alternative to satellite imagery. For a facility providing environmental information, however, the rather high cost (as outlined in the footnote below) limits the applicability of aerial surveys to the project-level, for instance the assessment of environmental 'hot spots'.

4.5 Analysis

As already expressed, I tend to take a cautious stand towards GIS analysis and modeling in a political, sustainable development context. As soon as we move into the more sophisticated spheres of spatial modeling, where multiple layers of information associated with uncertainties are being processed, the results are becoming vague, highly hypothetical and associated with errors beyond scientific error estimation.[12] There are also cultural reservations about some aspects of GIS modeling: The introduction of Geographic Information Systems can support the inappropriate standardization of environmental models. For instance, the same soil erosion models being used world-wide, neglecting local knowledge and prac-

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[11] The cost of mapping land use in semi-detail (1:100,000) is estimated to be less than US$ 15.- per square kilometer, including terrestrial work and cartography. The detailed mapping (1:10,000), using aerial photography would cost US$ 620.- per square kilometer (GTZ 1991).

[12] Assigning confidence limits to data and finding methods for error calculation within a GIS is quite a prominent research topic of the field today. In my opinion, error propagation is however almost inevitable, particularly when information is being separated from its creators, as I have already discussed in the context of runaway information above.

tices, which, in a sustainable development perspective are probably much more appropriate to the solution of environmental problems than global, standardized models.

I nevertheless see some areas of analysis potential, primarily to provide summary statistics and as decision-tools in the active decision support domain, as summarized in Figure 4.5:

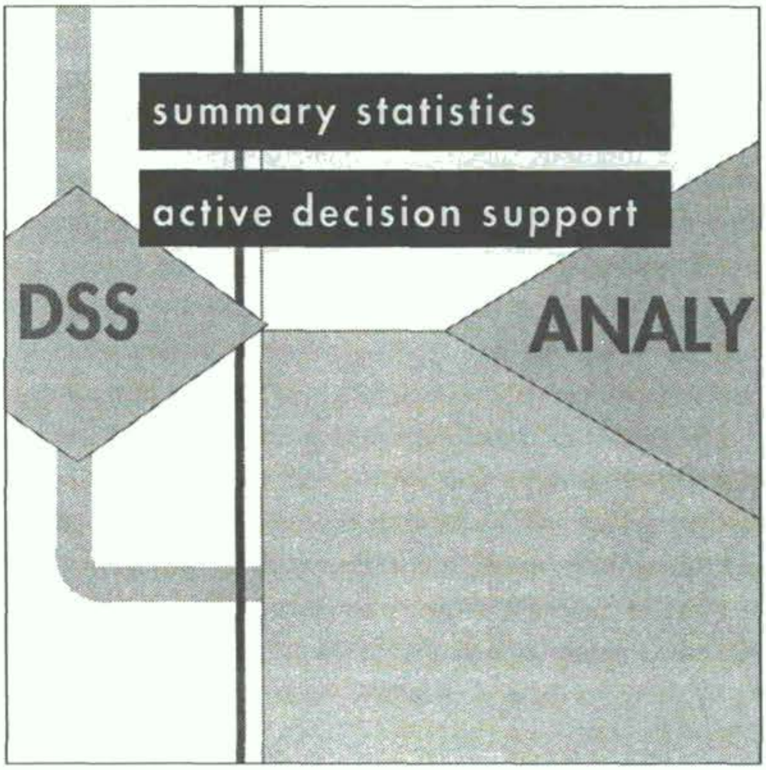

Figure 4.5: Analytical Potential of GIS

Summary Statistics

The most basic analytical capabilities of a GIS: Measurements, frequency counts, summary statistics and simple overlays are probably the most relevant in an environment and development context. Such operations – it could even be discussed if they are actually analytical or just basic GIS functions – clearly support the above-mentioned decision-makers' need of precise information. In developing countries, where, for instance, basic census units undergo frequent changes, the technology's capability to aggregate data is an invaluable asset. Also, simple overlay functions joining various layers of data can have a tremendous information potential.[13]

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[13] For example, in Nepal, land utilization data has been combined with land capability to highlight areas of over-, respectively under utilization.

But by performing simple GIS operations involving several layers of data, there is already a tendency to quantify uncertainties: Derived hard figures might be completely misleading. A point, I have already stressed above.

Active Decision Support

GIS will have a role as decision support systems (DSS) primarily in conjunction with environmental impact assessment methods. As outlined in chapter 3, some applications allow to rationalize decision-making into simple procedures and to integrate into a GIS. Besides the environmental impact assessment (EIA) procedures outlined in chapter 3, other examples suited for DSS may be site selection: For national parks, hazardous waste dumps, areas suitable for growing certain crops. Or, for example for suspension bridge placement in Nepal:[14] Depending primarily on the importance of a trail and basic demographic characteristics of a region, the methodology could be integrated into a GIS, to enable the system to assign site selection priorities automatically.

However, even in these relatively simple cases, the uncertainties are considerable, and I would rather solve the above-outlined suspension bridge selection by graphical analysis: Presenting basic maps and information from a GIS to the responsible planners and administrators and then take the decisions in a team, external to the system.

In my opinion, the biggest assets of decision support systems may be their value to structure processes and thinking in general, rather than actively taking decisions. This would however make it more of an academic than an application-oriented field for the time being, thus not being of central relevance to sustainable development implementations in Third World countries.

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[14] The Nepal main trail and central places study has been described by Griesbaum (1985) and Groeli and Griesbaum (1988).

5 Conditions

5.1 Constraints

Having outlined the potential role I attribute to Geographic Information Systems, I now want to present my guidelines on how the technology could be implemented at the national, policy-oriented level in Third World countries. Through the Participatory Action Research approach I observed GIS facilities over longer time periods and thus gained insight into the prevalent conditions. Also interviews of individuals associated with the sites provided me with relevant information on the GIS' environments. My model can nevertheless not be regarded as a one-to-one copy of what I have seen in the field: The chosen methodology foresees constant feedback from theory, as outlined in the introduction (Figure 1.3). My deliberations therefore are of an independent and stand-alone character, valid beyond the observation cases.

While the potential of GIS discussed in chapter 4 is comparable for developed and developing countries, the gap considerably widens when we look at the conditions for implementing the technology. The principal constraints can be summed up as follows:

Financial and technical dependence
Strong outside funding and technical dependence is common to all Geographic Information Systems implementations in developing countries, a fact that is very unlikely to change soon. After all, GIS is high technology originating in the Western countries.

Isolation and remoteness
The isolation associated with computer technology and GIS installations in developing countries can be considerable. With few users in a region, the exchange of ideas is limited and the networking potential is restrained.[1] Thus, outside dependence may even be more amplified.

Averse working conditions
The day-to-day working conditions in Third World countries are generally much more averse than in Europe or the USA, ranging from inadequate

[1] In early 1992, there was one single GIS installation in the whole of Uganda, while in Switzerland, there were at the same time more than 35 ARC/INFO sites, which is just one of many software systems.

office space, power supply problems to difficulties getting hard- and software supplies locally.[2] In addition, government employees are usually grossly underpaid and have to pursue various activities to earn a living: Absenteeism and lack of motivation are quite often encountered.

These are the circumstances usually met with in the capital cities, not to speak of decentralized systems in district headquarters or other peripheral places.

I now will outline the model on the conditions, elaborating on institutional, financial, professional, training, technology and data aspects of GIS for environment and development.

5.2 Institutional Issues

It is increasingly being recognized that the central problems connected with Geographic Information Systems applications are of institutional rather than technical nature, as already outlined in chapter 3. Despite tremendous developments in computer technology, GIS has not really contributed substantially to the solution of environmental and development problems. Thus, in developing countries the institutional conditions, above-all government bureaucracy, are quickly blamed. In my opinion, however, the technology side can be criticized as well: As some statements cited in the introduction to this publication have shown, GIS at this stage is being oversold. The promotional activities of the technology tend to aim directly at the solution of spatial, environmental and managerial problems, instead of more modestly offering a tool to address, map or maybe analyze spatial distributions. By the nature of environmental problems and decision-making, Geographic Information Systems can not be more than a component in the environmental problem-solving domain, as I have outlined in chapter 4 (Figure 4.1). Although I attribute GIS the potential to have an impact on institutions, I nevertheless tend to pursue a pragmatical approach about the technology's introduction to developing countries: Geographic Information Systems have to be embedded in the existing institutional, organizational and cultural framework, or, as expressed by Taylor (1991b), to be 'indigenized'.

With the principal objective to support policy-level activities – the translation of sustainable development to the national level – I consider the following three broader institutional domains as relevant for the implementation of GIS: 'The National Environmental Information Center' as the core of the activities; the 'Parental Ministry' to host the center; the 'National Steering Committee' and the 'Environmental Information User Group' as umbrella organizations to formulate policy and integrate a broadly defined group of users from sectoral governmental agencies, international development organizations and NGOs .

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[2] In some places, it can be very difficult, if not impossible to find small, from a Western perspective trivial supplies, such as fuses, cables or pens locally, not to speak about larger items. The differences between the individual countries may, however, be quite pronounced.

With the exception of the 'Environmental Information User Group' this model is closely related to the World Bank Program discussed in chapter 3 (World Bank 1991a, 1991b). The general set-up is visualized in Figure 5.1:

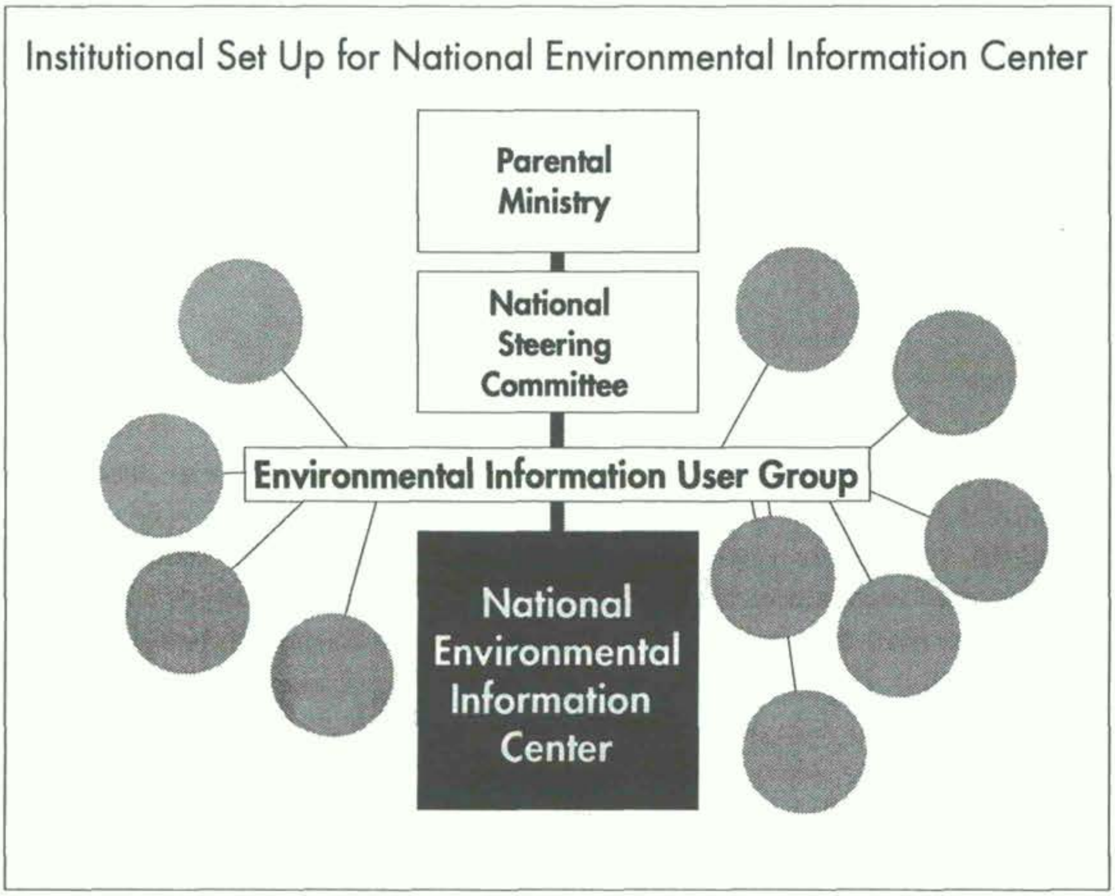

Figure 5.1: Model on Institutional Set-Up

I will start here with the institutional body closest to the subject of my work: The National Environmental Information Center. For this information cell I can put forward explicit guidelines, whereas for the broader institutional context I can only be indicative, if not speculative. I will, nevertheless, also attempt to outline relevant considerations about the technology's broader-scale integration.

The National Environmental Information Center

The model aims at a strong, central GIS facility in a country. Because I regard the communication of environmental information to decision-makers as GIS technology's main potential, I call that cell National Environmental Information Center. This denomination is identical with the institution outlined by the World Bank Program described in chapter 3 (World Bank 1991a, 1991b); in my opinion, it represents an adequate description of the center's function. GIS is assumed to be an integrative component of the information center and does not necessarily have to figure in its name.[3] Concerning national implementations of sustainable development strategies, I envisage the center to be the environmental information branch for the policy development activities.

As already discussed in chapters 2 and 3, such a top-down, centralistic approach is not without controversy. On the one hand, a strong, centrally placed GIS facility, able to fulfill larger-scale tasks is clearly in line with the national policy-formulating objectives as the base of my work. On the other hand, geographically decentralized sites with a specific mandate close to the actual problems and information could also be envisaged. Here, one has to be pragmatic: At this stage, I consider the implementation of the still quite experimental technology at decentralized sites in most developing countries as inappropriate. GIS, being rather sophisticated tools with high financial and manpower demands have the potential to weaken small, decentralized institutions much more than a strong, central site.[4] As already outlined in chapter 3, today the national level is most suitable for implementing GIS in Third World countries, allowing also a certain degree of sustainability.[5] There is evidently also the potential to integrate decentralized, bottom-up models into a central GIS site, for instance by making it generally accessible and supporting decentralized information collection activities.

Due to the multi-hierarchical nature of environmental problems,[6] the issue of centralization and decentralization will always be persistent in the field. Here I consider time as another vital element: Future developments of the technology may be able to correct my conservative view; as soon as GIS will become less experimental and more user-friendly, decentralized GIS options may be much more viable than they are today.

Institutional Placement

Concerning the placement of the National Environmental Information Center within the existing governmental infrastructure, I can only be indicative. Besides the obvious integration into the bodies involved with national environmental policy-formulation, two aspects are relevant to the placement of the GIS center: Autonomy and open access. Autonomy from

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[3] With the future developments envisaged in computer technology, the borders between GIS and information systems in general will disappear anyway. I will elaborate more on this in chapter 8 (Outlook).

[4] GIS, being an experimental technology, requires a considerable time input to operate and may thus, particularly in small organizations, tie up human resources needed elsewhere.

[5] Here, sustainability refers to the capability to survive locally: I consider the chances to generate long-term funds in-country as much greater for a central GIS than for a decentralized site, as also outlined in chapter 3.

[6] See also the discussion on the hierarchical systems method in chapter 2 (Figure 2.3).

the parental organization is important for the networking activities: The GIS facility should be free to independently establish intersectoral and interdisciplinary contacts at the operational level. In addition, autonomy is also envisaged to prevent a single governmental body from monopolizing the facility. Open access, enabling a large group of organizations and individuals making use of the center's services should above-all guarantee the integration of bottom-up and decentralized activities into national policy and support GIS networking at all levels.

Thus, I propose to create the information center as a new institutional cell below the policy body with the mandate to coordinate the formulation and implementation of the national sustainable development policies like NEAP and NCS. The disadvantage of such a new institution would be that existing bodies well suited to host a GIS, such as a national computing center or a country's topographical survey would be bypassed, and therefore existing infrastructure and knowledge would not be made fully use of. Due to the political nature of the information center and its networking mandate, I do, however, value the central placement and its autonomy above the use of existing resources. Regarding the center's information mandate, the line ministries and agencies will nevertheless have a vital position in the steering committee and also conduct specialized data gathering activities.

Despite being attractive regarding to fund management, relative autonomy and easy access to international networks and supplies, the placement of the GIS in an international organization is in my opinion only feasible as a temporary solution. Mainly because it is essential that the environmental information is managed by the government of the respective country: Sovereignty and autonomy has to be valued above practical considerations.

Umbrella Organizations

The proposed umbrella to the National Environmental Information Center consists of two institutions: The steering committee and the inter-sectoral environmental information user group. The steering committee is viewed mainly as the policy-formulation body issuing guidelines on the center's operations and assuming coordination tasks at the political and international levels. Coordination will primarily be necessary for higher-level ministerial co-operation, donor harmonization, education and training. Ideally, this steering group would have an official status, with high-level government endorsement, composed by senior officials from the ministries with an environmental mandate.

The environmental information user group represents another vital element with respect to networking between the ministries at a professional level: It helps to bridge the gap between the technology and its applications. The idea is derived from the highly successful environmental core group concept established in Nepal in the context of the National Conservation Strategy (NCS) developments, which I will discuss in chapter 7 (Carew-Reid 1992). This user group, envisaged to be a highly motivated and competent inter-sectoral working team, is composed of individuals from the environment-related agencies involved with spatial information. Convened on a regular basis in application-specific seminars organized by the center, the user group would be the machinery for extension: To disseminate in-depth knowledge on the potential of the technology to the different ministries and thus give incentives for intersectoral cooperation. The group's activities will hopefully open up channels for data and information exchange, which, on the long run will be the fuel for the national center to run on.

Other networking functions can be taken care of from within the National Environmental Information Center. Here I see the center's role mainly as a forum and a catalyst, with instruments ranging from the above-mentioned seminars, sensitization workshops, demos to more informal contacts to facilitate user integration and GIS applications. These user coordination tasks are another reason for drawing the model around a central and rather autonomous placement as outlined above.

The tasks of the National Environmental Information Center are linked to the technology's potential I have outlined in chapter 4: Collect, analyze, visualize and communicate environmental information to decision-makers and establish networks with organizations and individuals involved with environmental planning and policy development. As outlined above, some functions have been assigned to bodies outside the center: The steering committee and the user group, as also visualized in Figure 5.1. In Figure 5.2 I have outlined the tasks and tools associated with a National Environmental Information Center. Even the most elementary operative Geographic Information System cell encompasses a variety of components: Definitely more than just a computer and someone to run it. There is a threshold in size, below which a GIS facility will not be able to function, certainly not with operational goals, such as addressing, or even solving, environmental problems. Relevant is also the rule of thumb that hardware and software comprise only 20% of a GIS budget, a point I will come back to below, when discussing the individual tools of a national information center.[7]

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[7] Although this rule of thumb is generally accepted, GIS implementations are still made on a hard- and software budgets only, not taking into consideration cost of training, consulting, data etc. Such installations are often not providing the expected results and end up as failures.

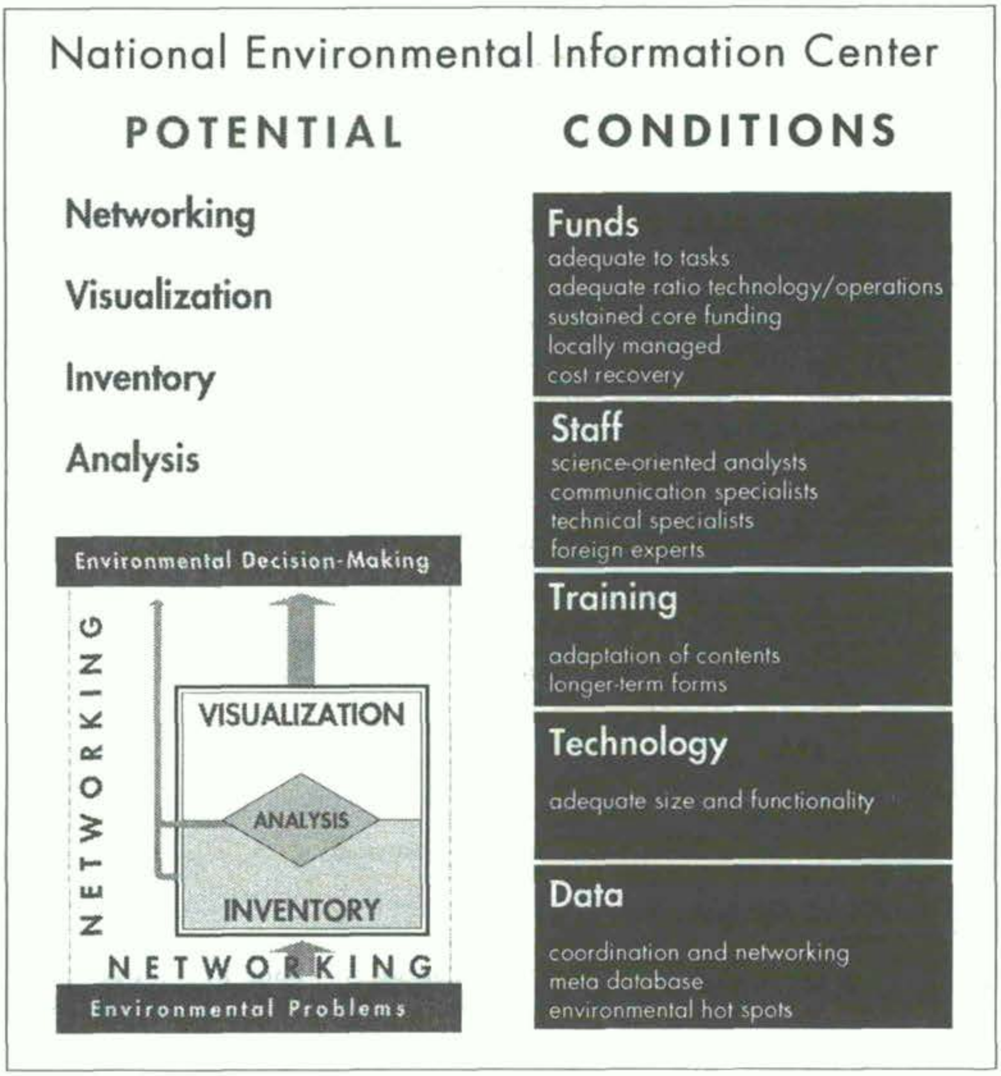

Figure 5.2: Model on Conditions for National Environmental Information Center

5.3 Funding Issues

As I have indicated earlier, the core funds for GIS installations in developing countries are generally coming from outside donors. With the growth of the field, aid agencies are increasingly confronted with the task to spend money on information technology: Considering the current level of uncertainty surrounding GIS this is not at all an easy task. I therefore regard the design of a central GIS facility also as attractive to donors: It offers the opportunity to share the costs among donors, making the investments of a single donor agency in a National Information Center relatively small compared to the potential returns. Having access to a relatively large Geographic Information Systems facility will allow to gain relevant experience in this highly experimental field. Shared facilities can also be considered as vehicles for GIS networking between development organizations, as outlined in chapters 3 and 4.

Five aspects of GIS financing are central to me: Adequate to tasks, Ratio between technology and operational costs, sustained core funding, local fund management and cost recovery.

Adequate to Tasks

Above-all, it should be evident that the funding for a National Environmental Information Center should be adequate to its tasks. Here the gaps are usually considerable: A facility to provide environmental information for national policy formulation has to be of a certain minimum size. If the necessary funds can not be generated, goals and objectives will have to be scaled down to an achievable level: To maintain a certain degree of credibility and to avoid frustration among the organizations and individuals involved with the center.

Adequate Ratio between Technology and Operational Costs

A good indicator to judge a GIS facility's operationability is the rule of the 20:80 ratio between technology and operational cost (Rhind 1991). If hardware and software exceed this 20% limit of the overall budget, it is usually a clear sign that the facility is overstocked with technology and probably not capable to be run efficiently. Above-all personnel, training and consulting but also data, office space, vehicles and extension material are central to any GIS financing in developing countries. If not considered in the information center's budget, failures are predictable.

Sustained Core Funding

In my opinion, core funding of the Information Center, not bound to any concrete projects is vital for sustainability. In the model, one of the center's main potential is being a forum and a catalyst. Activities, which may be rather difficult to express in concrete terms of financing. Thus, my model recommends to provide a National Environmental Information Center to a large extent with core funds rather than tie its financing to project activities. The latter may be attractive to generate funds, they may, however, also weaken the center considerably.

Locally Managed Funds

As a rule, development projects should be locally motivated, therefore also its funds, or at least a large portion of them, should be managed in-country. This certainly also applies to GIS, a field where we have witnessed plenty of what we would call technology-dumps in recent years.[8] Thus, besides local participation in project formulation the local management of GIS funds should be self-evident. Here, I am of course, approaching touchy issues of development: Distrust, mismanagement of funds and corruption. In these issues I do however not consider myself competent enough to elaborate upon.

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[8] As a technology-dump I define development activities providing GIS hardware and software to organizations and users who have not really asked for it and have also not participated in project planning activities.

Cost Recovery

Possibilities of cost-recovery have to be evaluated although most of these revolve around the same sources of funds: Foreign donors. Realistic cost-recovery is probably only possible in a very concrete, project-oriented environment with well-defined deliverables and prices, which is somehow contradictionary to the aim at sustained core financing of the information center. A larger facility, such as a national GIS can also envisage training and consulting as a means to recover costs; here, however an experienced GIS team will be vital for successful operation.

Considering the aim at long-term, environmental benefits and acknowledging the still experimental nature of the technology I take a rather cautious stand towards cost recovery, at least at the current stage of GIS developments in the Third World. I much rather propose the increased sharing of resources and know-how as an alternative to cut down expenditures of the individual donors.

I also have some reservations towards cost-benefit analyses of Geographic Information Systems with environmental components in developing countries: In my opinion, traditional mechanisms are quite limited in assessing factors such as long-term environmental benefits. More recent methods, incorporating environmental costs are very difficult to apply because the impacts of GIS on the environmental problem-solving at this stage are largely unknown.[9]

5.4 Professional Issues

Concerning the staffing of the information center one will have to take into account GIS networking, the integration among the three poles GIS, science and administration, as well as the technology's professional and technical demands. While the former can to a large extent be handled by the facility's management and its umbrella groups, the latter falls into the domain of the GIS core group, the staff present at the center. My deliberations will concentrate on professional issues concerning the GIS staff at the information center close to the technology; with respect to management I can only be indicative.

The political nature and the coordination tasks of the National Environmental Information Center call for a politically oriented management: To be able to integrate the center into existing governmental structures and to make the tools' networking capabilities work best. Management will nevertheless need some experience in GIS, particularly to be able to judge the demands and ramifications of information projects. The management of a Na-

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[9] For instance, even if we can come up with concrete figures on the value of an elephant in Kenya, it will be quite difficult to estimate how much GIS will contribute to save the Kenyan elephants. Thus, the application of GIS in the field of elephant conservation has to be based primarily on assumptions that the technology *may* in future have positive impacts and not on cost-benefit analysis.

tional Environmental Information Center should also have an environment and information-related background. This leads to almost un-fulfillable demands regarding the composition of the management; which, in my opinion can probably only be met by a team divided up along coordination and information tasks.

About the professional staff I can issue more concrete guidelines. The model of an adequately staffed National Environmental Information Center translates considerations outlined above into the three following profiles:

Science-Oriented GIS Analysts

At the core of the facility will be scientists with an understanding of the spatial elements in their fields as well as experienced in using GIS technology. This science-orientation is central in an integrative information processing approach: The analysts will be able to judge the information they are working with and can translate scientist's demands into GIS applications. With computer science or hardware-oriented analysts it is often quite difficult to provide this viable interface between science and GIS.[10]

Communication Specialists

To fulfill the information mandate, the center will also have to be staffed with communication specialists. This group's scope extends beyond the GIS domain, including cartographers, computer graphics specialists, desktop publishers as well as editors. These professionals are relevant for transcribing environmental data into highly communicable information for politicians as well as for the general public. This group has so far been ignored in the context of GIS in developing countries, mainly because the relevance of visualization and communication has not been fully recognized, also because of the widespread belief that with modern technology visualization renders itself automatically.

Technical Specialists

The operation of hardware and software in less than optimal conditions requires computer specialists familiar with the hardware and software to allow a smooth operation of the facility. It will be quite important that the above-outlined analysts and communication specialists will be kept off the day-to-day tasks of running computers.

These profiles represent an ideal model: In reality, an information center will have to be operated with limited staff, some of them likely to be in place through intra-governmental arrangements. It is evident that some professionals will have to fulfill multiple tasks, thus also training of the relevant skills on-the-job will be essential. However, it will be important to fill the profiles outlined above in one way or another.

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10 This has for example been a crucial problem at ICIMOD in Nepal with communication between the technology-oriented GIS analysts and scientists being difficult at times; I will elaborate more on this in chapter 7.

Foreign Experts

An issue of constant debate is whether foreign experts are useful and adequate to work in GIS projects. It is often assumed, that the necessary skills are locally available or can be acquired through training and thus making long-term expatriate staff obsolete.[11] I tend to take here a pragmatic stand: Since GIS is a technology originating in the developed world, Western experts may also work at a National Environmental Information Center. Experienced foreign GIS analysts, for instance, can play an important integrative role as resource persons at the center. For many aspects of operating GIS, such as training and database creation, a continuum of the activities is essential. Thus, an expatriate present at the center for a longer period can contribute much more to the indigenization of the technology than consultants or trainers moving in and out.[12]

5.5 Training Issues

The professional issues are related to training, which with regard to Geographic Information Systems in developing countries has evolved to a field on its own. As outlined in chapter 3, UNITAR in conjunction with UNEP has, for instance, established the 'UNEP/UNITAR environmental training programs in Geographic Information Systems for Natural Resource Management'. I generally accept the importance of such event-focused training activities, do however believe that the relevant issues of continuity, such as motivation, the generation of useful applications and experience are basically un-trainable and have to be developed over longer time periods in sustainable, institution-building processes.

GIS training being an issue with many facets, I can here only concentrate on the trainable aspects. In the model I focus on contents and form, or more direct, on the aspects of what and how should be trained.

Contents

Regarding the contents of training we are again confronted with both: The technology and its application. Should training cover mainly technical aspects, to enable individuals and organizations to use GIS as a tool or should it go beyond, into the various application areas? In my opinion, it is evident that training has to cover both. Thus, with regard to a National Environmental Information Center in a developing country, GIS training will have to be tailored to the concrete tasks evolving around the provision of information: GIS skills, ranging from data input to visualization and problem-oriented application of the tool.

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[11] This is a point quite strongly advocated by the World Bank Program discussed in chapter 3.

[12] As I will discuss in chapter 6, in Uganda, for instance, the presence of a GIS analyst during the whole pilot operations would in our opinion have made a difference in the generation of relevant applications.

Training will primarily have to be adapted to the local conditions. How this can be achieved depends also on the form of the training activities: It is quite evident that longer-term options will have to be preferred to shorter events.

Form

Various forms of GIS training can be envisaged, I distinguish primarily between short- and long-term options. They are outlined – in progressively time-intensive order – and commented below:

Sensitization Events

Such short term events of only a few days are designed to introduce a certain group of people, usually at a senior level, to GIS technology. They can be envisaged to offer hands-on GIS experience, although the potential here is still quite limited. While it is extremely important to make the capabilities of the technology known to a wide group of potential users, it is very difficult that such events not evolve into mere public relations happenings. This is, unfortunately today more often the case than not, also because such workshops are mostly sponsored by private companies.[13] In my opinion, sensitization events should always be organized and held in a pluralistic manner, with broadly based support and with space for controversial discussions: At the National Environmental Information Center for instance in the context of the environmental information user group focusing on an application area rather than technology only.

Training Courses

This is the most common form of GIS training in developing countries today: A group of people is being introduced by professional experts to GIS over a time from two weeks to months. Training is usually held at a national or regional center, depending on the availability of infrastructure, with participants attending full-time. For instance, UNITAR, as outlined in chapter 3, focuses primarily on this workshop model. The main advantage of such training courses is their intensity: The participants are usually fully motivated and able to dedicate much of their time to these activities. In addition, due to their limited duration, such events can be filled with excellent resource persons. As a major drawback of such relatively short courses I consider the limited potential to be adapted to the local situation and the individual trainees.[14] Thus, the events are often of a uniform, technology-centered

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[13] For instance, the SPOT seminar in Kampala already mentioned was held between my two field visits. This lead to a sensitization of my interview partners in the direction that many of them regarded SPOT satellite images as their single most important source of information, regardless of the adequacy to their work.

[14] Adaptation of training requires long-term involvement with the existing conditions in a location by both the trainers and the participants. Therefore, it is in my opinion almost impossible to indigenize training courses of a limited duration: Only long-term forms are a viable alternative.

nature, as I have already discussed in chapter 3, and thus not necessarily well suited for the development of useful applications. At times, such training courses have to be regarded as merely uncritical promotional events. Nevertheless, because of its practical advantages, this model of training will continue to play an important role. It is however relevant to put the individual courses into a longer-term framework, with repetitive activities as well as openness towards long-term alternatives.

On-the-Job Training

For the time being, I consider on-the-job training over a longer period by expert resource persons present at the facility as the most viable and sustainable form of training for a National Environmental Information Center. This model allows not only the adaptation of GIS applications to the local problem areas, it also includes some elements beyond training: For instance longer-term motivation and incentives for self-motivation. As indicated earlier, the continuum of training activities is central, thus I envisage a duration of at least two years. A drawback of this model is that it is almost automatically coupled with expatriate assistance, at least in the beginning of a project. Which, besides being expensive, puts high demands on the resource persons in terms of professional proficiency and the capability to adapt and to integrate.

Establishment of Educational Institutions

As outlined in chapter 3, the necessary educational institutions for a sustained application of GIS technology will have to be established. In developed countries, the Universities should be the most relevant reservoir for skilled GIS professionals, as well as for GIS developments as a whole: A fact that has not yet been taken up in Third World countries. I want to emphasize, that the establishment of GIS curricula at local Universities is of central importance and will have to be taken into account for long-term training. The provision of scholarships for studies abroad can be only a medium-term but nevertheless viable alternative to building capabilities in the country.

It is evident, that all of these training forms are in one way or another relevant: They can also take place in parallel. I do however prefer long-term options rather than training events, primarily to allow the sustained establishment of GIS in a country. Short-term training workshops, in my opinion have always a promotional flavor, which contradicts the long-term goals of a National Environmental Information center.

5.6 Technology Issues

The technology issues up to now have been far too much at the center of the introduction of GIS in developing countries. Fortunately, with GIS becoming more ubiquitous, technological aspects can be moved more into the background. Relevant in my model are above-all considerations of adequacy – the relation between the goals of the National Environmental

Information Center and its hardware and software configuration. Here, because information technology is a field of rapid changes, I will issue only general guidelines:

Adequate Size and Functionality

As already indicated earlier, a central requirement is the approximate ratio of 20:80 between technical and operational costs of a facility. To find a balance here can be an extremely sensitive task: Under- or over-furnished GIS facilities are quite ubiquitous.[15] In terms of functionality, the following considerations can serve as indicators regarding hardware and software:

State-of-the-Art Systems

In the rapidly changing field of computer technology it is vital to furnish a facility with state-of-the-art GIS hard- and software. Given the prevailing conditions in many Third World countries, this may sound inappropriate: However, besides offering a better performance, modern computer equipment is generally easier to operate and less viable to failures, which are both invaluable assets under potentially averse physical conditions in developing countries. State-of-the art technology also comes with more user-friendly integrative tools, for instance in the form of multi-media software, which is in my opinion quite relevant for an information center.

Local Maintenance

Maintenance services for hardware and spare parts should be available in-country. Alternatives, such as experienced hardware personnel on-site or services from abroad may be too expensive.

Commercial and Integrated Software

The National Environmental Information Center should use commercially available GIS software. This guarantees support and updating and allows the access to a user-network with the potential to share new developments. The software should integrate both vector and raster functions, which is now less an issue than it used to be a couple of years ago: Most commercial software systems offer now some way of integration.

Limited Number of Software Packages

A GIS facility can only handle a limited number of different software systems. However, because the National Environmental Information Center is in a quite attractive position to receive software donations from the highly competitive vendors, it might be used as a promotional vehicle. Here, a strict policy on software systems has to be enforced from the beginning not only by the center, but even more so by the steering committee at the national level.

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[15] See also the discussions on Uganda and Nepal in chapters 6 and 7.

Adequate Number of Workplaces

With the envisaged mandates and the designed openness of a National Environmental Information Center, a large number of people should have access to the facility: An adequate number of GIS workplaces will thus be important. As a rule of thumb, I would rate number of workplaces above performance, if this choice has to be made.

Graphics and Desktop Publishing

Because of the information task of the national center, graphical, multi-media and desktop publishing software should be an integrative component of the facility. Such hard- and software is today widely and inexpensively available. For a center operating more sophisticated GIS equipment the integration of such tools into their facility will not pose any additional problems.

Peripherals and Supplies

Standard GIS data input and output peripherals, such as digitizers and plotters should be available in-house. In developing countries it is also vital to do long-term planning for supplies, since such small items are at times rather difficult to get locally.

5.7 Data Issues

The data issues are closely related to the inventory domain discussed earlier. Here my discussion will be on a more concrete level than in chapter 4. The tasks of the National Environmental Information Center will primarily be in the coordination and networking domain, the establishment of a meta database and data acquisition in relation with the environmental issues.

Coordination and Networking

The National Information Center will first have to conceptually define its data integration tasks and then identify and coordinate with potential sources. Concerning these coordination and networking mandates, the steering committee and the user group will be quite vital. For the center it will be relevant to keep the various information channels open, to be able to acquire data and information when necessary. As already outlined in chapter 4, because of the time-intensity of data acquisition tasks I see no other way than cooperative efforts with specialized agencies in order to reach a minimum inventory standard. Actual data to be held at the facility should be constrained to general, nation-wide natural resource layers and specific information on hot spots.

Meta-Database

More important for a center than actually holding the data is to know where to get it, to establish a so called meta-database, a database on data. As in developed countries, also in the Third World the fragmentation of environmental information is quite common, since there are often multiple players involved in environmental projects: Various government agencies, foreign aid organizations, local and foreign scientists as well as the local population create and accumulate a great wealth of environmental data, which are usually never being used in combination with each other. The often cited lack of information in a Third World context is in my opinion a myth; the problem being much rather the lack of an information search and uncoordinated activities. And here, because of the over-abundance of environmental information, a National Environmental Information Center is envisaged to play a key role in the spatially referenced collection of meta-information. Regular distribution of data catalogs through the user group will ensure the spread of this vital meta-information in a country. Considering the relevance of sustainable development to the local, decentralized level, the meta database idea is also relevant for future local information systems. At the 'center' the emphasis will shift to information on information with the actual data being collected and updated in a decentralized fashion.

Environmental Hot Spots

As outlined in chapter 4, only in conjunction with so called environmental hot spots I see a potential of a National information Center to acquire data in-house. The GIS facility has to be ready to fulfill quick data demands in the case of burning issues, for instance natural disasters. Work on such projects can be very attractive and relevant, however, an eye should always be kept on adequacy. Otherwise, an installation could be completely tied up by such requests and degenerate to a procurer of quick information for the politicians in power.

Part Three

CASE STUDIES

Part Three: Case Studies

In the empirical part of this study I will take a closer look at two Geographic Information System installations of national and even regional status: The National Environment Information Center (NEIC) at the Ministry for Environment Protection (MEP) in Kampala, Uganda and the Mountain Environment and Natural Resources Information System (MENRIS) at the International Center for Integrated Mountain Development (ICIMOD) in Kathmandu, Nepal.

The goal of this case study assessment is to provide input to future activities to the cases analyzed, this being in line with the participatory action research methodology described in the introduction (Figure 1.3). I have accompanied the two facilities since their initiation as a consultant working for UNEP/GRID, this personal involvement will be explicitly outlined when discussing the case studies. Modifications of the programs and changes in direction are at time still feasible: Both case examples are at a pilot stage. With GIS being a rather novel technology and the two facilities being of recent date, the experimental character of the study cases has to be acknowledged. Thus, the evaluation of the achievements may be premature but nevertheless relevant to point out trends and make deductions. I do not intend to compare the facilities one to one. Despite commonalties – the same organizations (UNEP/GRID, UNITAR) played a key role in their initiation, the differences in their set-up, objectives, size, staff, hardware and software are too different to allow direct comparison. Above-all, there are significant institutional dissimilarities: NEIC is a national institution in contrast to ICIMOD being an international body.

The evaluation of the case examples is structured according to the overall model: First, I will assess the potential, the broader objectives for implementing GIS technology in the specific institutions, then I will analyze the conditions. Within this general assessment, I also provide an evaluation of the facilities' performance with regard to their own objectives.

The two chapters, 6 (Uganda) and 7 (Nepal) are arranged as follows: A geographical and historical overview and a brief analysis of today's situation is proceeded by a section on environmental problems, issues and policy in the country. The next section provides the project history, the interpreted description of the GIS activities at the facility up to now. At the core of these chapters will be an evaluation analyzing the site's achievements regarding their own objectives and *vis-à-vis* the model. Potential future directions will also be discussed.

6 Uganda

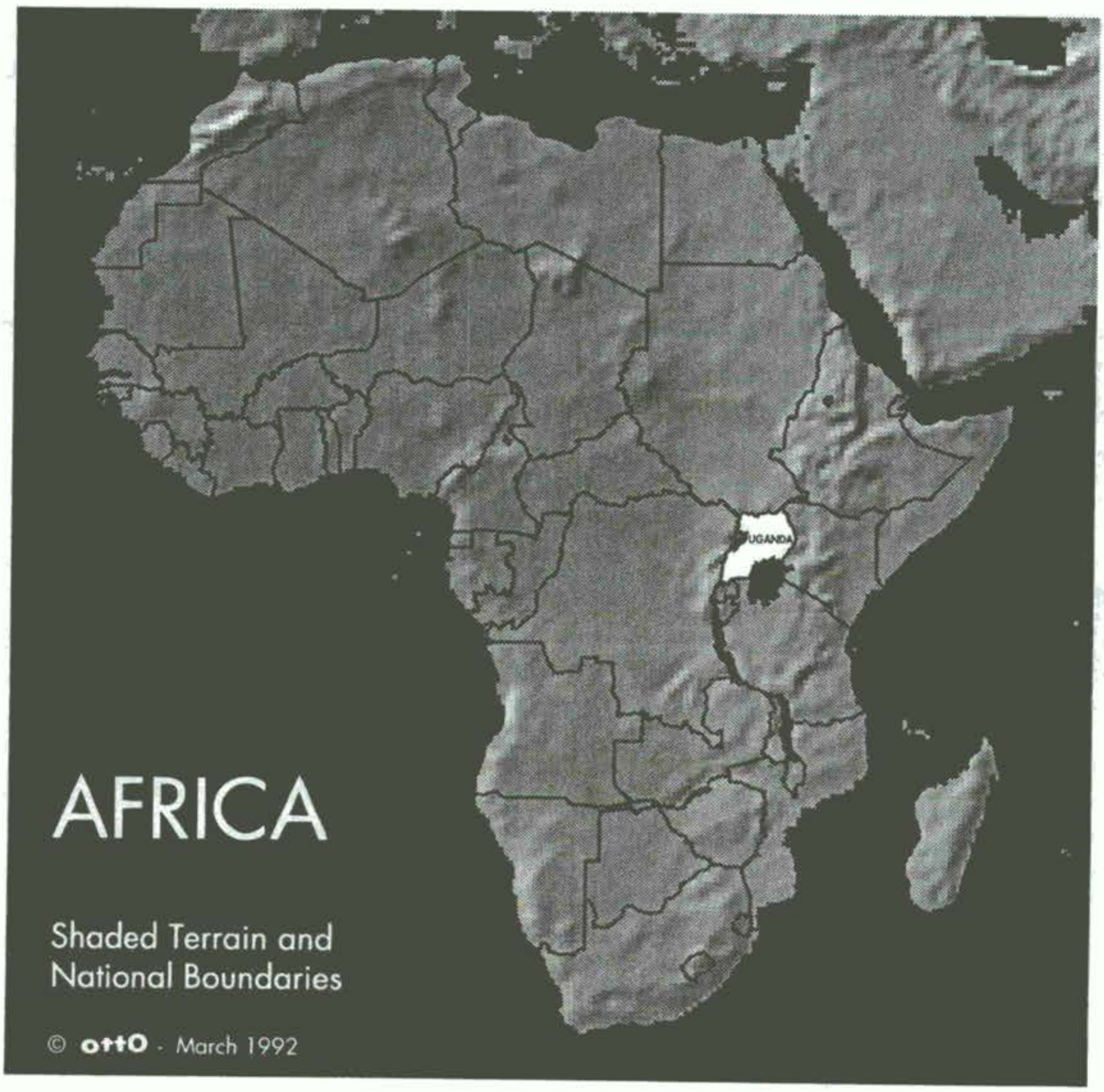

Figure 6.1: Africa

6.1 Geographic and Historic Overview

The Republic of Uganda, is a relatively small, land-locked country in Eastern Africa. About one sixth (38,552 square kilometers) of its area of 240,604 square kilometers is covered by lakes, among them Lake Victoria, one of the World's largest. (Atlas of Uganda; Uganda Department of Lands and Survey 1962).

The current (1991) population is 16.6 million, risen from 4.8 million in 1960. Uganda's high average annual population growth rate of 3.7 % (1985-1990) has not been lowered during the periods of unrest, and it is not expected to decline significantly in the near future. The influence of AIDS on demography remains, however, a widely unknown factor today. According to various scenarios, Uganda's population is expected to reach between 40 and 70 million by the year 2025 (UNEP 1991, World Resources Institute 1992, Statistisches Bundesamt 1991, Turyatunga 1991).

Uganda has a considerable agricultural potential, primarily due to its soils[1] and favorable climate: A bi-modal precipitation regime with rainy seasons in April/May and October/November furnishes the country with adequate moisture. In agro-ecological classifications the largest portions of Uganda are humid, only the Northeast, Karamoja, lies in a semi-arid zone.[2] Agriculture, thus continues to play the dominant role, being the chief source of national income as well as providing an extensive subsistence base. Uganda's export income is almost entirely dependent on coffee, comprising 96.8% of the export revenues in 1988, the rest being cotton (1.1%), tea (0.3%), tobacco (0.2%), maize and beans 0.1% and others 1.5% (Ochieng 1991). Uganda is not very rich in minerals or fossil fuels. The country's only larger mine, the Kilembe copper mine has stopped production due to unrest and unfavorable world market conditions. The abundant water resources render an enormous, widely untapped hydroelectric potential.

Due to the long period of unrest and the weak economy Uganda has to be regarded as one of the world's poorest nations. With a GNP of US$ 250 per capita in 1989 (World Resources Institute 1992) it figures both in the UN group of the Least Developed Countries (LLDC) and the Most Seriously Affected Countries (MSAC).[3]

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[1] More than 75% of the country's soils have been attributed a high productivity potential, as a function of texture, depth, pH, fertility, organic matter, drainage, workability and water holding capacity (UNEP/GEMS/GRID 1987d).

[2] UNEP/GRID adapted a model developed in Kenya to derive agro-ecological zones of Uganda through GIS analysis (UNEP/GEMS/GRID 1987d).

[3] The various groups of developing countries have been outlined in chapter 2.

The 'pearl of Africa' has had a very turbulent recent history. Since its independence from England in 1962 the country has lived through many years of civil strife under several dictatorial governments, such as Milton Obote's and Idi Amin's. More recently, with the seizure of power by the National Resistance Movement (NRM) under Yoweri Museveni in 1986, the situation seems to be getting more stable.

The most recent developments in the country have been extensively discussed in 'Uganda Now: Between Decay and Development' (Hansen and Twaddle 1988) and 'Changing Uganda: The Dilemmas of Structural Adjustment and Revolutionary Change' (Hansen and Twaddle 1991). Other relevant general sources are Statistisches Bundesamt (1991), Berg-Schlosser and Siegler (1988), Hamilton (1982) and the Atlas of Uganda (Department of Lands and Survey, 1962).

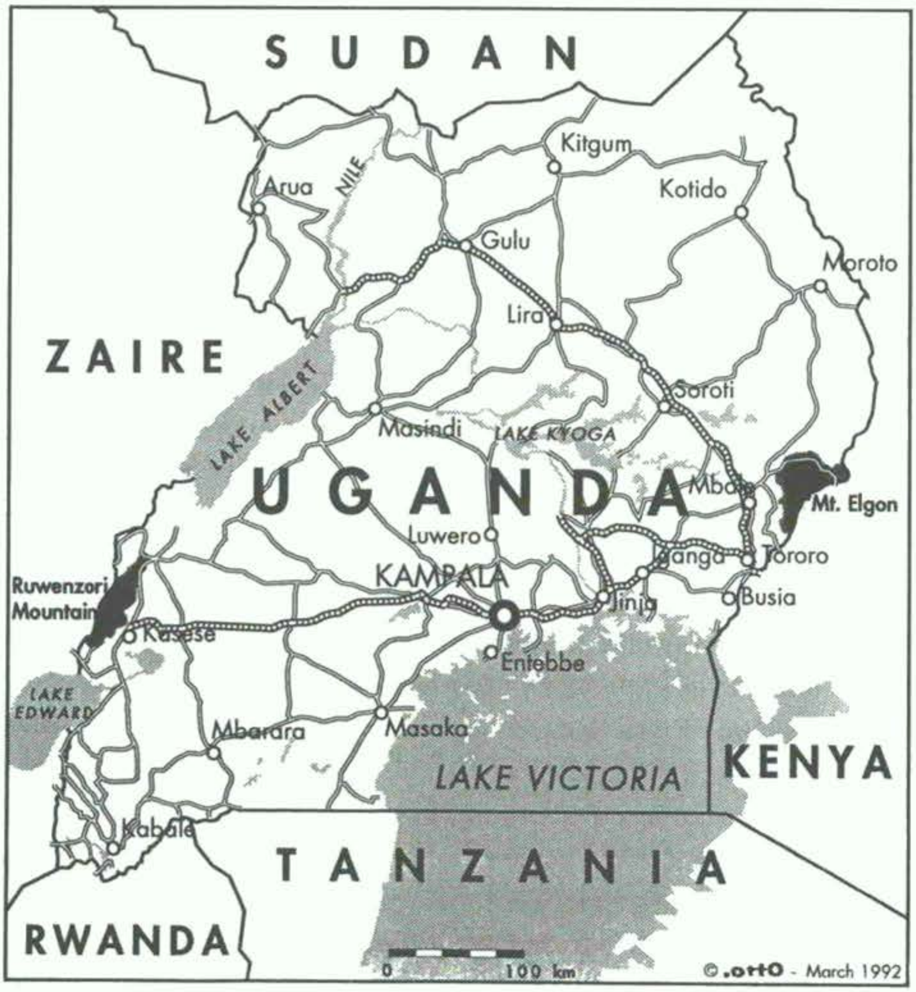

Figure 6.2: Uganda

6.2 The Situation Today

When the NRM assumed power it inherited a nation shattered by years of civil war, with Uganda's economic performance far below other Low Income Sub Saharan Countries and even worse compared with all Low income Developing Countries, as shown in Figure 6.3 (Lateef 1991: p. 24):

Period	1965-73			1973-80			1980-87		
	Uganda	LISSA	LIDC	Uganda	LISSA	LIDC	Uganda	LISSA	LIDC
Annual Growth Rate of GNP per capita	0.7	0.8	3.0	-6.2	-0.6	1.8	-2.4	-2.2	-1.1

LISSA: Low Income Sub Saharan Countries (without Nigeria)
LIDC: Low Income Developing Countries (without China and India)

Figure 6.3: Uganda's Economic Performance 1965-1987 in Comparison

The first item on the NRM agenda was to achieve a certain degree of stability in Uganda. The trends seem to be positive, although the relations with the neighboring countries Kenya, Rwanda and Sudan have been quite tense at times and also the internal conflicts are not entirely resolved yet. A sign of restored stability are the increased development activities starting in the late eighties, with official development assistance having doubled from 1985/86 to 1989/90 (Lateef 1991).[4] This has already left visible traces in the country by booming road and building construction. One aspect which could impede this relative stability, however, is the fact that Uganda's NRM government has come to power through military operations, democratic elections have not been held yet.

Structural and economic adjustment programs are now at the center of Uganda's reconstruction activities:

> «The sustained pursuit of a program of policy reforms that is designed to reduce economic and financial imbalances arising from domestic or external shocks and to address policy deficiencies that are impeding progress towards accelerated economic growth.» (Lateef 1991: p. 20)

Launched in 1987, the Economic Recovery Program under the guidance and assistance of the International Monetary Fund (IMF) is aimed at restoring economic stability, establishing

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4 Average annual Official Development Assistance (ODA) to Uganda 1987-89 has been US$ 349 million, risen from US$ 144 million in 1982-84. ODA expressed as a percentage of the GNP at 7% remained stable during the same period (World Resources Institute 1992).

more realistic relative prices, and initiating the rehabilitation of the country's productive and social infrastructure.

The initial results of the program have been mixed: GDP growth of 6-7 percent per year is contrasted by massive inflation.[5] Increased agricultural output, coffee in particular, has to be seen in the context of dropping world market prices, leading to decreasing Dollar earnings. The value of coffee exports declined by 35% in 1989 as the international coffee agreement collapsed and prices fell dramatically (Slade and Weitz 1991).

The NRM government initially has been very reluctant to accept the IMF reconstruction, still remembering the failure of the 1981 IMF crash program under the Obote regime (Berg-Schlosser and Siegler 1988). Ochieng (1991: p. 59), for instance, has criticized these adjustment programs as:

> «Only capable of producing temporary bouts of positive change ... incapable of stimulating exports to produce enough foreign exchange to fill the gap temporarily being filled by IMF and World Bank funding such that whenever such funding dries up or threatens to dry up, the whole program collapses» and «depending entirely on external funding for their success.»

Others, such as the United Nations Economic Commission for Africa, qualify the programs as altogether misplaced (Ochieng 1991). Nevertheless, these adjustment programs are a reality Uganda has to live with, or as Mugyenyi (1991: p. 74) puts it:

> «In time the NRM has lived with the reality that the IMF is a reflection of the global distribution of power in a contemporary economic system in which Uganda happens to be pretty much at the margin.»

The IMF reconstruction without doubt constitutes the framework to all recent large-scale environmental programs, such as the constitution of the Ministry for Environment Protection (MEP) and the National Environmental Action Plan (NEAP), which are of central interest to my research.

6.3 Environmental Problems, Issues and Policy

In a country highly dependent on its natural resources as a living base, environmental issues have to play a central role. Recently, this has been increasingly expressed through a large variety of publications on the Ugandan environment, which give a good overview of the problems and issues the country faces. Relevant for my work are the Environmental Profile

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[5] Regarding inflation, the latest trends look positive again: 23% in 1989 (Statistisches Bundesamt 1991).

of Uganda (Arid Lands Information Center 1982), the IUCN Environmental Dates Review (IUCN 1986), the UNEP Strategies for Environmental Management (UNEP 1988c), and various reports evolving around the World Bank and USAID assisted National Environmental Action Plan (NEAP) activities, such as Slade and Weitz (1991), Falloux, Talbot and Larson (1991), Kamugasha (1990) and Serageldin (1991). According to these sources, the following environmental problems are being regarded as the most pressing for Uganda:

Deforestation
Heavy encroachment in Uganda's forest reserves, some of which being extremely valuable tropical forests, took place during the period of unrest with virtually no reforestation being done. According to some estimates, many of the countries' forests outside the forest reserves may disappear by the year 2000 if deforestation is to continue at the current rate (Slade and Weitz 1991).

Soil Erosion and Loss of Soil Fertility
Due to migration and population pressure, more and more marginal lands are being cultivated in Uganda; land particularly vulnerable to erosion and nutrient loss. In some parts of Uganda negative impacts are already visible.

Deterioration of Water Resources
Uganda's abundant water resources are threatened to deteriorate due to uncontrolled pollution through human activities. Another problem is the reclamation of swamp lands for agricultural purposes with the long term impact on the water resources largely unknown.

Loss of Wildlife Habitat
Although small in size, Uganda shows a great diversity of plants, animals and ecosystems. However, heavy encroachment took place during the unrest period and is still taking place today. Since 1962, an estimated 78% of Uganda's wildlife habitat has been lost (UNEP 1988).

All these problems also have to be seen in the light of Uganda's rapid population growth. The 1990 population of 18.4 million is predicted to rise to a staggering 53.1 million by the year 2025 (World Resources Institute 1992).

Historically, a large number of different government departments and ministries have been responsible for environmental policy in Uganda. This has not been without coordination problems, thus, in 1986, the Uganda Ministry of Environment Protection (MEP), now incorporated into the expanded Ministry of Water, Energy, Minerals and Environment Protection (MWEMEP), has been established. This ministry's main task is to coordinate the intersectoral environmental issues, mainly the regulation of development activities with an environmental component and the sensitization and education of the general population to prevent future natural resources degradation (VIAK 1992a). The specialized agencies and ministries are still concerned with the exploitation and utilization of the natural resources.

The environmental issues these bodies are confronted with are of a great variety and complexity. Slade and Weitz (1991) have attempted to list them up, admitting that their catalog was far from being exhaustive. I nevertheless want to outline the various groups of these issues below, just to give an overview of their spectrum:

- ◊ Cost of environmental degradation
- ◊ Institutional and policy framework
- ◊ Legal framework
- ◊ Land tenure
- ◊ Ecotourism, national parks and wildlife
- ◊ Information Systems
- ◊ Human resource development, population growth
- ◊ Sustainable agricultural development
- ◊ Water resources

The recognition of 'Information Systems' as an issue of national importance is a fundamental indicator of what role Geographic Information Systems could play concerning Uganda's future environmental activities.

To address these environmental issues in an integrated and coordinated manner the government has recently launched a National Environmental Action Plan (NEAP). The concept of such national, policy-level plans has already been discussed in chapter 2. In the African context, the World Bank has given the following definition:

> «A NEAP is an in-country, demand-driven process based on local participation. It is intended to provide a framework for integrating environmental considerations into a nation's economic and social development.» (Falloux, Talbot and Larson 1991: p. 3)

This is, as a matter of fact, an attempt to transform sustainable development to the national level. By the end of 1990, NEAPs have been completed for Madagascar, Mauritius and Lesotho and were in preparation in Rwanda, Ghana, Guinea and Burkina Faso.[6] Thus,

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[6] NEAP and similar national-level environmental strategies are discussed by Arensberg (1991), who sees their main benefits in increasing general environmental awareness, strengthening environmental policy and instruments, environmentally sounder development projects, development of human resources, strengthening of NGOs and increased donor coordination.

Uganda is among the first African nations accomplishing the NEAP concept The plan is envisaged to cover all environmental issues as comprehensively as possible at various levels. Donors, the World Bank in particular, are supporting the NEAP activities, thus ensuring a large degree of sustainability of the program in the form of funds for the preparation as well as for its implementation.

The principal bodies involved in NEAP activities in Uganda, as outlined by Slade and Weitz (1991) are shown in Figure 6.4 below:

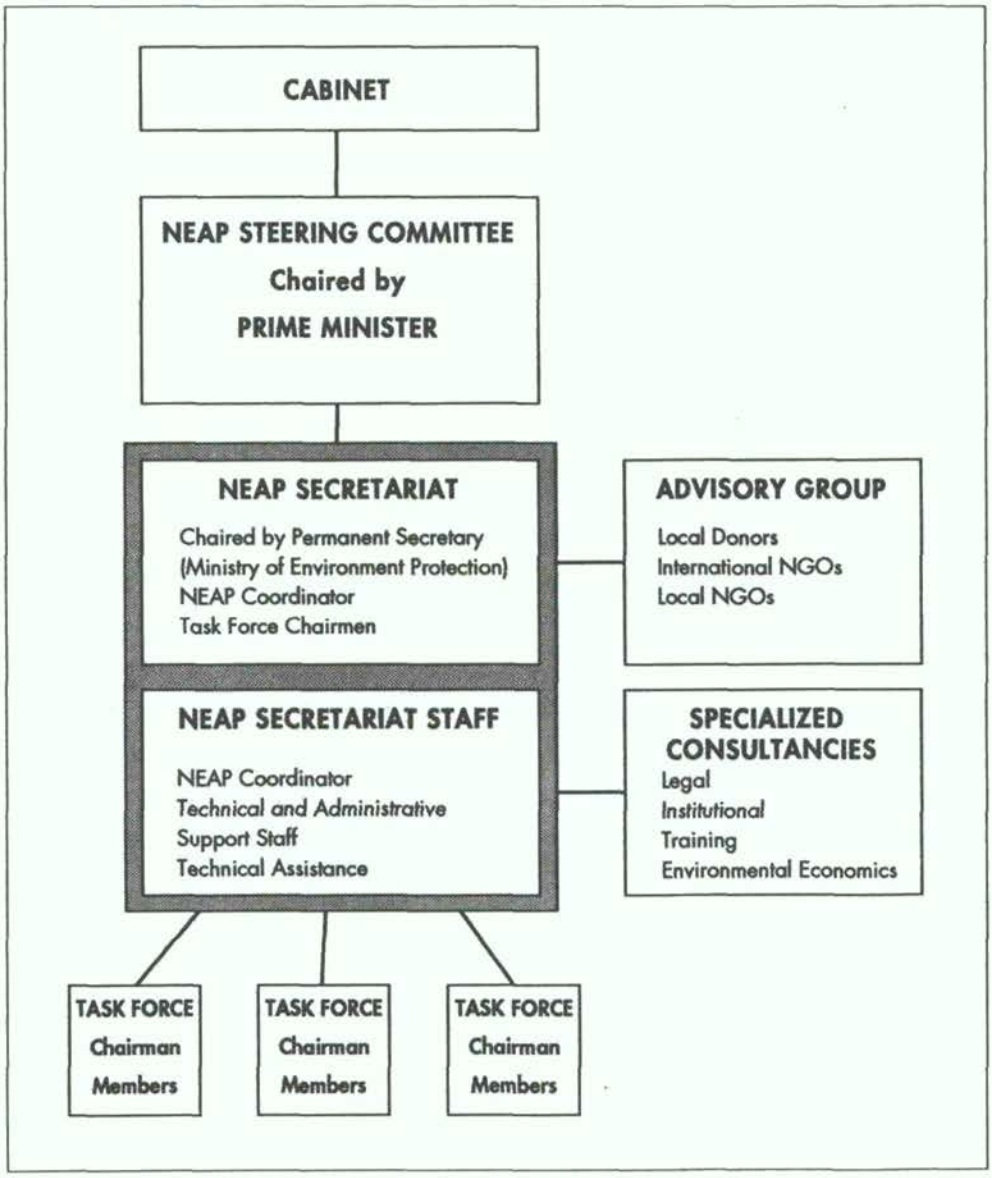

Figure 6.4: Proposed Institutional Setup for National Environment Action Plan (NEAP)
(Modified from Slade and Weitz 1991)

The action plan is to be based on broad participation by local government, central government, NGOs, academia as well as foreign donors. This participatory approach has been extensively discussed by Kamugasha (1990: p. 1), who calls it a «radical departure from present practice». How well participation can be realized in the plan's implementation remains to be seen, after all, the NEAP activities in general have a rather centralistic structure. Activities revolve around the NEAP secretariat, guided by a ministerial-level steering committee which reports directly to the President's cabinet. The steering committee is chaired by the Prime Minister. The secretariat is coordinating and overseeing special task forces, which do the actual work of analyzing environmental problems and look for solutions. Another task of the secretariat is to form links to advisory groups, constituted by donors and NGOs. The task forces are organized subject-oriented and are composed of special consultants and representatives of the respective line agencies.

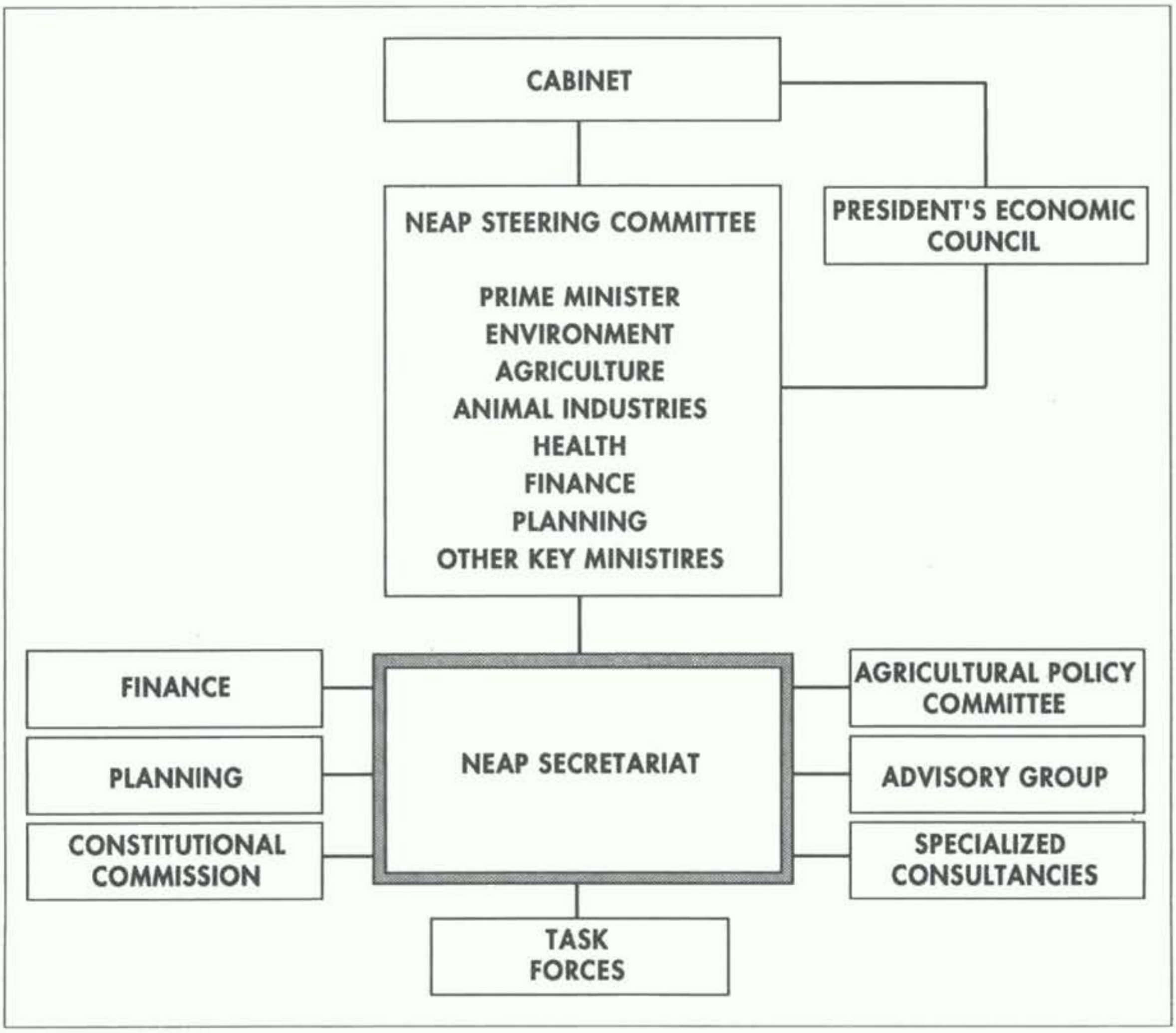

Figure 6.5: Revised Institutional Arrangements for National Environmental Action Plan (NEAP)
(Modified from Slade and Weitz 1991)

Critics of this NEAP point out that key institutions, such as the Ministry of Finance, the President's Economic Council, the Agricultural Policy Committee and the Constitutional Commission have been left out of the principal processes, thus rendering an integration of economic and environmental issues untouched (Slade and Weitz 1991). If these bodies will not be integrated in the process, one is afraid that the chance to make NEAP a real national policy event would be missed. The way as it is, NEAP might just become another rather toothless environmental endeavor, isolated from the mainstream economic development in the country. A proposed revised institutional setup, integrating the main decision-making bodies into the concept and implementation of NEAP is shown in Figure 6.5.

In the context of NEAP, the issue of information has been raised on several occasions: «The lack of an adequate environmental data base and information systems in Uganda leaves the conditions of many areas virtually unknown.» (Slade and Weitz 1991: p. 14). Falloux, Talbot and Larson (1991) have also outlined this lack and, in my opinion even more relevant, the inaccessibility of data and they have taken this fact as a starting point to assign concrete information tasks to NEAP activities:

◊ Restructure existing data and make them accessible to users

◊ Initiate pilot, demand-driven, monitoring and information systems, particularly in mapping and geographic information systems

◊ Prepare substantial investment in this field to meet the national demand for managing the environment

This is also the background to the World Bank Program of Environment Information Systems in Sub-Saharan Africa (World Bank 1991a 1991b) discussed in chapter 3. I maintain that the lack of information should not be over-dramatized. If the NEAP activities are to be based on broad participation, information procurement will not be the main problem. The challenge will much rather be the collation, verification and integration of environmental information and, above-all, to make this information generally available to politicians and planners at various levels as well as the general public. In my opinion, this constitutes the main potential for GIS in conjunction with Uganda's National Environmental Action Plan: «The provision of adequate environmental information and monitoring capabilities should be a component of all NEAPs.» as Falloux, Talbot and Larson (1991: p. 24) have expressed it.

6.4 Geographic Information System Activities

Since 1987 the Uganda Ministry of Environment Protection has been exposed to Geographic Information System technology in the context of the UNEP/GRID case study described below. These activities have grown into the National Environment Information Center (NEIC), which is now being integrated into the NEAP activities as the information segment.

As outlined earlier, on a professional as well as on a research level I have accompanied the Uganda GIS since its initiation in 1987 by UNEP/GRID-Nairobi. The country has been visited on two occasions in that year, mainly to carry out field verifications and to assess the general situation. The first field evaluation of the Uganda GIS for this project has been conducted from November 24 to December 16, 1990 in Kampala and Nairobi. A second field visit in Kampala and in Nairobi took place from November 3 - 14, 1991. Today, I am involved with the Ugandan GIS through contacts to VIAK, the Norwegian consulting company responsible for the GIS operations over the last two years.

Besides this participatory experience I have also relied on written sources: The facility's early development is quite comprehensively documented by Calle Hedberg (Hedberg 1991). Other printed source materials originate mainly from the organizations and individuals involved in the activities, such as UNEP/GEMS/GRID (1987d), Simonett, Turyatunga and Witt (1987), Kalyango et al. (1988), Kalyango (1989), Turyatunga (1989, 1990, 1992), World Bank (1990, 1991a, 1991b, 1992b), UNSO (1990), VIAK (1992a, 1992b), and NEIC (1991). Another relevant information source are the interviews conducted with persons involved with the Uganda GIS during two field visits in 1990 and 1991. On these visits a broad range of people were interviewed: Core NEIC staff (5), external consultants (10) as well as actual GIS and information users (5).[7] The reason that only a small number of users could be integrated in my survey is the fact that the facility is not operational: Real users are thus still nonexistent. I did not consider it as very meaningful to interview the many potential users in the country: The result would have been even more a mixture of wishful thinking, perceptions, myths and the like than it already is, a problem which has already been addressed in the introduction of the publication.

In the discussion I want to extract the general trends from the mass of details encountered during my field research. My goal is to present a synthesis of relevance beyond the individual GIS site. The 'history' of the Uganda GIS site will, therefore, be presented here as concisely as possible. The milestones of the facilities are outlined in Figure 6.6, followed by brief descriptions of the various development steps. The phases are named according to my own interpretation, the terms used are functional descriptions of the stages, serving primar-

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[7] This division in core staff, external consultants and information users has practical reasons: Different levels of familiarity with the facility and with GIS in general required an adaptation in interview detail for each of these groups.

ily as an aid to structure my discussion. They are at times not identical to labels assigned by the organizations involved.

Initiation (August - December 1986)

Memorandum of Understanding (MoU) on environmental cooperation between UNEP and the Government of Uganda leading to the Strategic Resource Planning in Uganda Project (SRPUP)

Meeting between Uganda's President Museveni and UNEP Executive Director Tolba in Kampala (November 1986)

Demonstration Programme (January - June 1987)

UNEP/GRID Uganda GIS case study

Demonstration for high-level politicians of Uganda and other countries; design of a draft project outline (June 1987).

Technology Transfer <Hiatus> (July 1987 - April 1990)

6 months UNITAR training of one MEP staff in Geneva (January - June 1988)

3 months UNITAR training of three MEP staff in Nairobi (July - October 1989)

Pilot Operations (April 1990 - February 1992)

GRID System Installation Kampala (April 1990)

VIAK/World Bank mission to Uganda, Constitution of NEIC

VIAK GIS consultant present (November-December 1990 and May 1991)

'SPOT Seminar' in Kampala (March 1991)

3 months UNITAR training of two NEIC staff in Nairobi (January - April 1991)

'NEIC Workshop' in Kampala (August 1991), sponsored by UNSO

Draft of the Five-Year investment plan, donor search at
Donor's Meeting in Kampala (January 1992).

Figure 6.6: Uganda GIS Activities – Overview

As **initiation** I consider the first formulation of general ideas, leading to the actual start of the program. In the case of the Uganda Geographic Information System this happened to be a top-level meeting between Uganda's President Yoweri Museveni and the Executive Director of UNEP, Mostafa Tolba. The meeting took place in the context of general environmental re-orientation in Uganda. The Government of Uganda and UNEP had previously signed a Memorandum of Understanding (MoU) concerning cooperation in environmental Protection. The MoU initiated the 'Strategic Resource Planning in Uganda Project' (SRPUP), with the main objectives to assess the state of environment in Uganda and to propose mechanisms for monitoring and managing the natural resources in the country. The SRPUP activities are documented by UNEP (1988c). It is quite astonishing, that only half a year after seizing power the Museveni government had already established high-level links to an environmental organization. This clearly demonstrates the new government's positive intentions in this sector and also largely explains the subsequent pioneering role Uganda has taken and is still taking in the field of environment and development, for instance the NEAP activities. The meeting between Museveni and Tolba assigned high priority to the establishment of a natural resources database and resulted in the GRID demonstration program.

The very intensive **demonstration program** included database development, analysis and the demonstration of the technology to various high-level decision-makers from Uganda and other developing countries; it was orchestrated by UNEP/GRID Nairobi. Hedberg even calls this a 'crash' program (Hedberg 1991). This phase involved extensive assistance from groups outside GRID, such as the University of Zürich (Switzerland), Birkbeck College in London (England), NASA's Space Technology Labs (NSTL) in Bay St. Louis (USA) and the Regional Center for Services in Surveying, Mapping and Remote Sensing (RCSSMRS) in Nairobi (Kenya). Although some Ugandan expert consultants were involved in core GIS tasks, the program has to be qualified as completely external to Uganda. Even administration of the technology initially envisaged at the Ministry of Environment Protection in Kampala had to be canceled due to infrastructural constraints. All activities took place outside Uganda, mostly in Nairobi, and knowledge about these activities did not spread deeply into Uganda. The published material, such as UNEP (1987d), Simonett, Turyatunga and Witt (1987) and Kalyango et al. (1988), did not greatly enhance this communication gap, being mainly written for the international community or a scientific audience rather than for Ugandan governmental institutions or NGOs.

During the subsequent **technology transfer phase**, the momentum built up with the intensive and efficient demonstration program went almost back to zero. The phase from the GIS demonstration to Ugandan politicians in Nairobi (June 1987) to the actual GIS installation in Kampala (April 1990) lasted almost three years, an astronomical amount of time considering the urgency and enthusiasm the project was handled with at its initiation. It is therefore not exaggerated to talk about a hiatus: All relevant activities concerning the installation of a national GIS center having ceased during this period. Only some external training activities took place, with three Ugandans – potential employees of the unit to be – being trained in Geneva and in Nairobi. Various factors, better seen today than in 1987, have contributed to this unfortunate discontinuity: Firstly, the search for donors turned out to be much more difficult than anticipated. A potential European Economic Commission (EEC) funded facility was finally not implemented due to bureaucratical constraints (Hedberg 1991). This donor search was definitely not harmonized and supervised properly by the parties involved. Secondly, by mid 1987, Uganda was still struggling with internal and external stability problems, donors were not quite ready to invest in projects in the country. Thirdly, GIS technology was then at an even more experimental stage than it is today, nobody in the development community seemed to be keen on investing in still uncertain ventures.

The next phase, congruent to World Bank phase II (World Bank 1991a) starting with the system installation in Kampala in spring 1990 is entitled **pilot operations**: Demonstration case studies, sensitization, networking, training and experimentation with the system being the principal tasks. During these pilot operations, the support base of the GIS has widened considerably with VIAK, a Norwegian consulting firm, operating with World Bank and NORAD funds as the main executing agency, UNSO and the Karamoja Development Agency (KDA) sponsoring a workshop and the GIS activities in Karamoja, UNITAR being responsible for training and UNEP/GRID providing the equipment and integrating the facility in its global network. The main achievement of this phase has been the formation of NEIC, a semi-autonomous GIS center with its own staff and office space, however still being integrated in Uganda's environmental planning and decision-making machinery through its attachment to MEP. The center has been operating as a project under a steering committee composed by three ministries including MEP. This non-permanent status has nevertheless allowed a large degree of autonomy (VIAK 1992a).[8]

Case study activities have been taken up by the facility during its pilot phase, namely the creation of environmental profiles of Iganga and Karamoja district, the national biomass and wetlands surveys, case studies on national parks and the demonstration of cadastral applications as well as support to various projects outside NEIC, such as banana research and biodiversity studies. All these activities have an explicit networking component with the goal to establish contacts with organizations interested in applying GIS and to attract funds for future operations. Figure 6.7 gives an overview of NEIC's case study activities during the pilot phase also listing the respective cooperating agencies.[9]

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[8] Although the majority of NEIC personnel are from MEP, the center has been designed to be rather autonomous from the environmental ministry. Thus, it also has been physically moved away from MEP in 1991 to its own premises (Morten Sørensen, personal communication).

[9] Some of these activities, above-all the biomass study and the Karamoja profile, are strictly speaking not NEIC projects, they have however been conducted using the NEIC facility. Most recently, the biomass study has acquired their own GIS hardware and software (Ori Okido 1992, Hedberg 1992).

Case Study	Cooperating Agencies
Iganga District Profile	District Development Committee (DDC)
Karamoja District Profile	United Nations Sudano-Sahelian Office (UNSO), Karamoja Office (KO), Karamoja Development Agency (KDA)
Mburu National Park	United States Agency for International Development (USAID), National Parks Authority (NPA)
National Wetlands Inventory	International Union for the Conservation of Nature (IUCN)
National Biomass Study	Ugandan Forest Department, Norwegian Forest Society
Cadastral Pilot Study	Ministry of Lands and Survey

Figure 6.7: NEIC Case Study Activities during Pilot Phase

By the end of the pilot phase relatively little actual Geographic Information System processing on the above-mentioned projects has been done at NEIC. An exception is the National Biomass Study, where nine test areas were interpreted, digitized, analyzed and plotted by the Forest Department with assistance from the Norwegian Forest Society. NEIC's facility has been used to conduct part of these studies. The other case studies have not yet proceeded far beyond the initiation and contacting stage by the end of 1991. The cooperating organizations have however shown considerable interest in NEIC and may contribute to the funding of future operations.

Two widely attended workshops have taken place in Kampala in 1991: The 'National Seminar on Remote Sensing for Natural Resources Management' (SPOT Seminar), in March and the 'Workshop on Natural Resources Management and Geographical Information Systems Development in Uganda' (NEIC workshop), sponsored by UNSO in August. Both workshops were able to attract quite a prominent audience of government staff, professionals from donor agencies and academia as well as representatives from international organizations. These events have been quite extensively documented by VIAK (1992b), the Government of Uganda et al. (1991) and by NEIC (1991).

The pilot phase ended in the design of a project proposal containing a five-year Investment Plan (VIAK 1992a). Despite previous negative experiences it ran into another discontinuity at the end of the pilot phase. With the World Bank funds drying up in February 1992, NEIC had to give up their offices in March 1992.[10] And this happened despite of the fact that the general funding picture looked promising: At a Donor's meeting in Kampala in January 1992, a new main sponsor has been found with DANIDA.

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[10] The closing down of NEIC's offices has also other reasons: In future, NEIC is planned to share premises with NEAP, and the physical conditions at the current site have also been far from ideal (Sørensen 1992).

6.5 Evaluation of Potential

NEIC's broader goals for the pilot operations have been outlined as follows (VIAK 1992a):

- ◊ Play a leading role in the introduction of GIS and RS (Remote Sensing) technologies in the country
- ◊ Provide timely and up-to-date information on natural resources and the environment in general
- ◊ Assume responsibility for meeting user needs for environmental information at district and national levels; support projects and sectors
- ◊ Ensure efficient exchange of intersectoral information.
- ◊ Collaborate with regional and international organizations involved in information collection, analysis and dissemination.

Looking back at the general objectives of previous phases of the Ugandan GIS, we can observe that these have always been more or less the same, undergoing only little variations.

Initially, however, the GRID objectives were more clearly application-oriented; geared towards the creation of an operational database and with Geographic Information Systems analysis leading to tangible results in the country. Then, GRID put progressively emphasis on the demonstration of GIS technology as its main objective, having realized that it was merely impossible to achieve more with the time and resources available and operating from distance. This significant shift from 'real' to 'demo' objectives has also been noticed by Hedberg (1991), who sees in it an explanation to the subsequent failure of the follow-up, with GRID losing interest in the project after having done a successful demonstration job. Ever since, the technology transfer goal has remained the most prominent one, it is not astonishing at all that it figures on top of the catalogue outlined above. How to interpret this is another question. Logically, as time goes by, pure technology transfer objectives should move into the background; in the case of the Ugandan GIS, however, the opposite seems to be the trend. This has certainly to do with the experience that the introduction of the technology to Uganda is progressing much slower than anticipated. In addition, it may also already indicate a sort of resignation, giving up the idea of applying the technology directly in an environmental problem-solving context in the country.

Nevertheless, there are also broader goals concerning substance, the most prominent being

> «To provide timely and up to-date information on natural resources and the environment in general» (VIAK 1992a: p. 3).

This is in harmony with the World Bank Program of Environment Information Systems in Sub-Saharan Africa (World Bank 1991b: p. 1):

> «To meet the priority information demands of resource users, planners and decision-makers for better renewable resource management.»

The other two broader pilot phase objectives can also be put under the general information and networking umbrella (VIAK 1992a: p. 3):

> «To ensure efficient data exchange»

> «To collaborate with other information collection organizations.»

The interviews, although the opinions varied considerably in detail, did not reveal radically different general goals, as the following standard answers show:

> «Improved natural resources management through the supply of information to decision-makers.»

> «Gradual change from sectoral monitoring to central coordination of environmental information.»

Thus, besides the omni-present technology transfer objective the facility is clearly geared towards communication of environmental information to decision-makers, which is quite congruent with my assessment of the technology's potential. Also, GIS networking elements take a prominent position among the envisaged functions.

References to the other relevant GIS components, inventory and analysis, are however lacking. Although the communication implies inventory tasks as well, data collection does not distinctly figure among the more general objectives of NEIC, except in conjunction with co-operation issues. One reason for this is definitely the awareness that Uganda's current inventory tasks surpass the center's capabilities by far. Other organizations – such as the ones identified by an user's survey conducted by NEIC (Turyatunga 1992) – are in this respect able to do a much better job and will sooner or later come up with the required information. Already a variety of data collection activities have been taken up, among them the national change detection project and the national biomass study, which will be discussed under data issues. I nevertheless, particularly in the context of a national environmental information center, would expect the inventory tasks more explicitly mentioned among the general goals of the facility. Otherwise, the center may be relying too heavily on information coming in on an *ad hoc* basis rather than playing an active coordinating part in the inventory domain.

The same is true concerning GIS analysis, which has never been a principal item on the agenda of the Uganda GIS. Here, NEIC has probably learned from the very early stage of the GRID demo program, where modeling has been quite central but did not lead to concrete results. While the UNEP/GRID models were interesting for demonstrating the capabilities of the tool, they did not accomplish much in term of real analysis, mainly because of the resolution of the data and topics, such as climate change, being not necessarily of central interest in Uganda. As an example of an analysis task Figure 6.8 shows agro-ecological suitability of Robusta Coffee, as modeled from precipitation, evaporation and temperature (UNEP/GEMS/GRID 1987d).

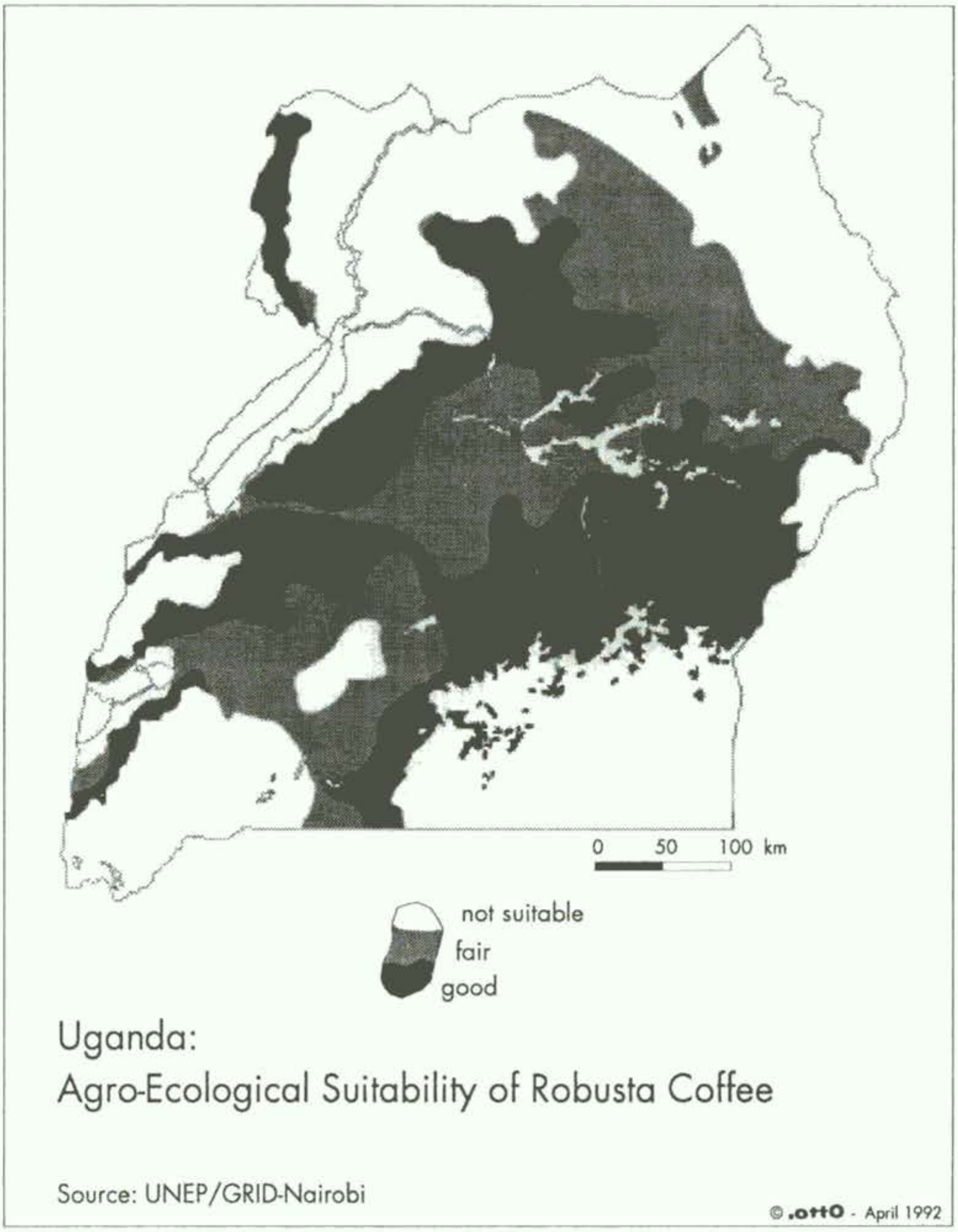

Figure 6.8: Model of Agro-Ecological Suitability of Robusta Coffee in Uganda

The fact that modeling does not have a more prominent position in NEIC is principally in line with my assessment of the tool's potential. Where I would see the main modeling power – in well defined, large scale applications adequately furnished with data – conflicts with the mandates of a national information center are predictable. Despite these reservations, I nevertheless expect something like a policy-level statement from NEIC on spatial analysis.

Concerning the facility's fulfillment of broader goals, two trends can be observed by the end of 1991:

- ◊ Firstly, the Uganda National Environment Information Center, in conjunction with its supporting agencies, has been quite successful in promoting Geographic Information Systems in Uganda. Through various workshops and sensitization programs knowledge about GIS has been proliferated widely into government, donor organizations and academia. The number of systems installed in the country is still insignificant, however, a variety of institutions is planning to acquire the technology or at least to play a part in NEIC's future activities. We thus can surely talk about a success concerning the technology promotion goal of the project. This is not necessarily the merit of NEIC and its background organizations alone, with GIS currently being very much the trend in the development community, the promotion of the technology renders itself almost automatically.

- ◊ Secondly, quite contrasting the successful promotional activities is the poor to non-existent performance of the application side, the actual information level with very little concrete results having been achieved. The facility has not yet been able to supply what could be called timely and up-to-date information to decision-makers. The five-year investment plan (VIAK 1992a) acknowledges this limited performance and links it to the lack of output devices and the lack of facilities. This argumentation, although true, seems to be a little shallow. Simple output hardware could have been purchased without too much expenses, and with some innovative skills NEIC could have produced more output by alternative means, such as photographs off the screen. In my opinion, the reason behind this non-performance is simply the fact that the priority of the pilot operations has been assigned to promotion, 'real' work being postponed to the five-year investment program.

In conjunction with VIAK, NEIC has worked on a five-year investment program (VIAK 1992a). Its more general goals are not significantly different from the pilot activity's, with the introduction of GIS technology in Uganda as the main development objective and the provision of information to a variety of users, such as politicians at the national level, District Development Committees (DDC), projects, schools and the general public (VIAK 1992a: p. 4):

> «It is expected that Uganda will have a large number of decision-makers, planners and others in the country who are sensitized on the capabilities and advantages of using EIS technology. As part of the program, a strong and elaborate user query service will have been established and the ability of the Center to serve the users of natural resources information improved.»

> «In general, GIS/RS technologies will have been employed as tools for the rational management of natural resources and their contribution stimulated the development of a sound environment in Uganda.»

The more detailed immediate objectives, outputs and activities cover more or less the whole spectrum of environmental information, and are rather ambitious (VIAK 1992a). However, as far as the basic GIS functions are concerned, again no specific reference to data input and analysis are made:

i To strengthen and build up capacity of the NEIC. This includes provision of equipment, training and technical assistance.

ii To support the National Environmental Action Plan with its information needs for efficient implementation.

iii To provide a GIS based National State of the Environment for Uganda (biennium), including presentation of historical trends and prognosis for possible future developments.

iv To establish District Environmental Data Bases, and support District Development Committees with relevant information for improved resource management and protection of the environment.

v Provide GIS and RS technology to – and work closely with – the sectors to improve environmental information management at national and district levels.

vi Support information requirements of projects on a cost recovery basis; provide support to information management at national and district levels.

vii Carry out specialized studies aimed at improving the use of GIS/RS in the decision-making process and management of resources in general.

viii Arrange workshops and sensitization drives, addressing information users at technical and managerial levels on the use of environmental information systems for improved resource management and protection of the environment.

ix Provide information about the environment in Uganda to a variety of users, including schools and the general public.

Discussion

I will take these goals of the five-year investment program as a base for the discussion. The number and dimension of the tasks seem to be rather unrealistic in the light of the center's performance so far. The general objectives of the facility will in my opinion have to be streamlined to an achievable level. This to reach tangible immediate results and to allow the establishment of an operational information facility on the long run.

According to my model, emphasis should be put on the following principal objectives:

◊ ***Communication of environmental information to decision-makers***

With this main objective, NEIC's activities could be concentrated, the facility would clearly move in the direction of concrete GIS applications and not merely the promotion of the technology.

Two aspects of this communication mandate will need to be defined more precisely for the concrete Ugandan set-up: The information and the decision-makers.

The ***environmental information*** *could above-all envisaged to be in the form of highly communicative visuals and illustrative graphics. If the users have the capabilities also digital products could be supplied. The center's main focus of attention could be environmental problems of national importance, such as deforestation, loss of wildlife and soil erosion. I would expect NEIC to harmonize information provision with other environmental activities, such as NEAP and current political topics. As the principal source of the information I regard the center's network, i.e. governmental agencies, NGOs and universities organized in the national environmental information user group. NEIC's main processing task could be seen in the area of conversion of spatial data to meaningful, timely, user-tailored and well communicable information.*

*The user community of the center – **the decision-makers** – should in my opinion be defined as broad as possible, including politicians, planners, the media as well as the general public. This is to render the facilities' operations public-oriented, i.e. user-friendly rather than scientific or bureaucratic.*

◊ ***Coordination of environmental data collection activities in the country***

The information goals call for guidelines concerning data collection. In accordance with the model, the inventory mandate should emphasize the center's coordination and networking tasks: To monitor and to harmonize on-going environmental data gathering activities in Uganda and regularly brief users on data availability. As also foreseen by the model, NEIC could be the institution to provide information about environmental information. These meta-database activities are particularly relevant in the light of the difficulties with the establishment of a comprehensive central database with all environmental information on Uganda. Data distribution could concentrate on environmentally relevant layers covering the whole country and on environmental hot spots. All other data, falling under the mandate of specialized agencies, projects and local government, could be stored and updated by the relevant institutions.

◊ ***Establishment of Geographic Information System technology in Uganda***

The obvious technology transfer goal still could figure somewhere on the NEIC agenda, but I'd rather put it into the background to assign more weight to the application objectives. If there is a demand of information provided by GIS, the technology will set foot in the country anyway. If not, this may just prove that the tool is inapplicable, either too expensive, too artificial or too complicated for environmental applications in Uganda. As the most relevant vehicles to promote the technology I consider sensitization workshops and demos to the various interested groups in Uganda: Tasks which are already mastered quite well by NEIC.

6.6 Evaluation of Conditions

The general conditions for establishing GIS technology in Uganda can be regarded as positive: The country is in the process of rehabilitation, and environmental issues are attributed a prominent role as the constitution of MEP and the NEAP activities show. Also, these programs have environmental information in general as well as Geographic Information Systems specifically on their agenda. The reconstruction offers the opportunity to really look for creative solutions. On the other hand, the tasks are huge, surpassing the capabilities and financial means of ministries and aid organizations involved, therefore priorities will have to be set. In addition, the existing technology base in the country is very weak and the general conditions operating GIS are not very favorable.

Institutional Issues

The political situation in Uganda is still quite volatile, with institutional arrangements changing often, as past experiences have shown. This makes it quite difficult to elaborate on the placement of the National GIS center within the larger governmental set up without being speculative.

A center, placed within the Ministry of Environment Protection (MEP) has already been a goal of the GRID demonstration program. And although physically not implemented, it was existing at an organizational level, as the training of MEP staff abroad shows (Figure 6.6). The *de facto* set up; the creation of the National Environment Information Center (NEIC), with a GIS in place, own staff and offices has not taken place until late 1990. The NEIC set-up can be regarded as quite congruent to the model proposed in chapter 5, a central GIS facility of national importance for Uganda. In reality, however, the center is far from fulfilling all the designated tasks, much more emphasis has been put on technology issues and sensitization than on information and data processing. NEIC is nevertheless the address for GIS and environment in Uganda, a status which will grow in importance with future developments, particularly extended activities evolving around NEAP.

NEIC has operated as a project on *ad hoc* arrangements without having a proper legal or institutional status (VIAK 1992a). The center is nevertheless integrated into the governmental activities evolving around environmental decision-making, above-all as designated information tool to the World Bank's NEAP activities. This gives the opportunity to make use of Geographic Information Systems in context with the government's mainstream environmental activities. Although MEP is not a very strong ministry, as also the NEAP activities show,[11] NEIC's placement can nevertheless be regarded as prominent within the governmental structure. Above-all since it is envisaged to be placed under the office of the Prime Minister in future. The center has established important contacts within Ugandan governmental organizations, among others with the Ministry of Lands and Survey, the Ministry of Energy, the Ministry for Planning and Economic Development, the Permanent Secretary of the Office of the Prime Minister, the Forest Department and the Director of National Parks (Turyatunga 1991).

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[11] As discussions earlier in this chapter show, one of Slade and Weitz' (1991) main criticism of the NEAP activities is being based upon the fact that the strong Ugandan ministries are not involved in the plans' set-up.

As outlined in chapter 5, my model supports a centralist design (as NEIC is), mainly because I perceive the decentralized introduction and application of GIS in Uganda with limited financial, technical and personnel resources as premature. Up to now, NEIC has been able to operate quite autonomously[12] and keep a large degree of openness, despite being a centrally placed governmental body. During the pilot operations, anyone interested could contact NEIC directly without bureaucratic obstacles. Probably because up to now the information held within NEIC has been very basic and of limited value. Openness will be another problem if more recent, sensitive and expensive data will be managed by the center. For the center, it will be a challenge to break out of its governmental and NEAP frame to open up alternative, decentralized information channels.

Outside the national government institutions, lines of communication have been established between the center and donor agencies, NGOs, project activities and Makarere University during the pilot phase. These in-country links are not necessarily official, some of them have come up on an *ad hoc* basis through the workshops held in Kampala, common project activities or just by general interest. NEIC is also connected to the UNEP/GRID network, which provides links to other organizations using GIS for environmental applications outside Uganda: A means to overcome the isolation associated with the center's pioneer role in Uganda.

NEIC's steering and coordinating body, primarily designed as a vehicle for intersectoral networking, has not influenced the center's activities significantly during the pilot operations. This was mainly due to the novelty of the facility and the lack of actual GIS networking and processing work being done. A body with the functions of an users group, as outlined in chapter 5, does currently not exist in Uganda.

The five-year investment program continues along the line pursued during the pilot phase, proposing the following organizational structure, visualized in Figure 6.9 below. NEIC is envisaged to be considerably strengthened through an increase in the number of staff and a major hardware and software upgrade. The facility is planned to be internally subdivided along the branches GIS, database and information, primarily in order to pursue its objectives more efficiently.

Externally, the investment plan is proposing a structure with the facility operating under the following umbrella: **The board**, drawn from the natural resources ministries, to develop the policy guidelines and the **technical committee**, composed by collaborating sectors providing the technical guidelines. This proposed set up emphasizes formal aspects much more than contents. Thus, the board and the committee have to be seen as a mechanism to sanction the center's activities rather than formulate policies and provide scientific and techni-

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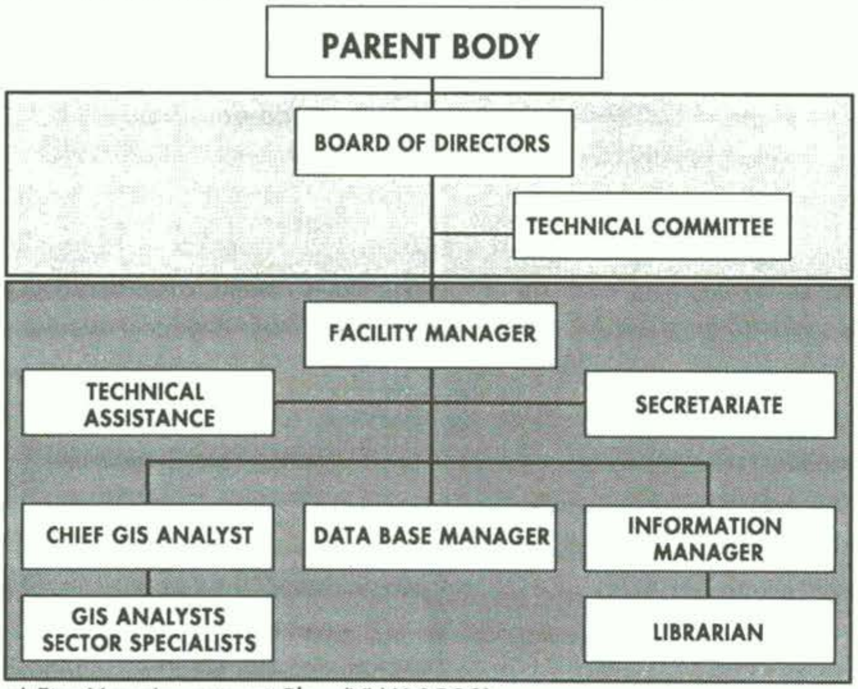
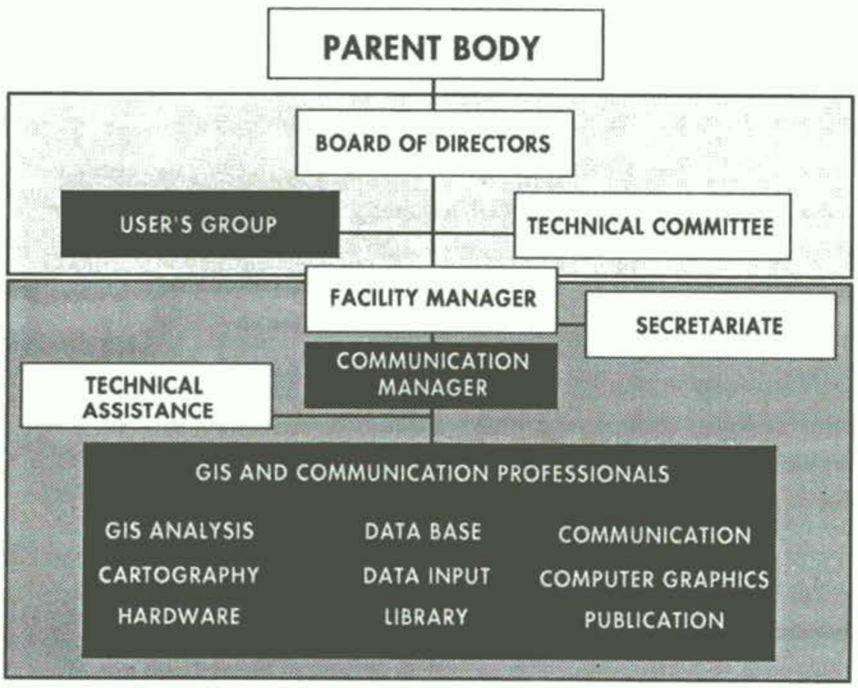
[12] This only with regard to central government control: Concerning finances NEIC has been completely dependent on its donors and the consulting company.

cal input. The center's planned larger scale integration into Uganda's decision-making machinery at this stage is rather vague and will also depend on the NEAP outcome. The office of the Prime Minister as designated 'parent body' (VIAK 1992a) is to ensure a more central placement of NEIC than currently under MEP. This is in harmony with the NEAP activities, which are presided by the Prime Minister, as outlined in Figure 6.3.



a) Five-Year Investment Plan (VIAK 1992)



b) Proposed Modifications

Figure 6.9: Proposed Organizational Set-Up of NEIC.

Discussion

Regarding NEIC's organizational set-up, I generally acknowledge the propositions made in the five-year investment program (VIAK 1992a). Some points, however, could be emphasized and outlined more concretely. For the successful achievement of its objectives, the center should operate under a certain autonomy, above-all financially. It also should be able to maintain a large degree of openness, providing general access to wide range of users. Without meeting these premises, the center's day-to-day operations would be jeopardized, regardless of NEIC's status or its position within the government.

Relevant to the facility's operation are internal as well as external organizational issues. An alternative institutional set-up in line with my model is visualized in Figure 6.9 below the NEIC five-year proposal (VIAK 1992a). My principal modifications are highlighted.

Internally, NEIC's organization could be more clearly streamlined towards information, implying that both GIS and database activities being subordinate to information provision. This mainly to be able to pursue the main information objective more vigorously; to give the center a distinct direction, to honor its name.

Externally, a multi-sectoral users group to be institutionalized on the side of the board of directors and the technical committee – as outlined in the model – could facilitate networking between day-to-day users and between governmental agencies. In addition, downward integration on a political level, e.g. through contacts to the influential national resistance councils and local government in general, could also be an item to be actively pursued by the user group, mainly to open up information channels otherwise inaccessible.

Funding Issues

Concerning finances, the Ugandan GIS has been through many turbulences: An over-funded GRID demonstration program, a three-year hiatus during the technology transfer phase, adequately supported pilot operations and now again a discontinuity mark the facility's history.

The GRID activities can be considered as over-funded primarily because there was no realistic way to sustain the activities after the demonstration: Taking Hedberg's (1991) conservative cost estimate of US$ 160,000 for the GRID case study, a sustained continuation of the program with similar dimensions would have cost more than US$ 300,000 per year without hardware, software or training. Funds, which at that time were just not available. During the technology transfer phase, training alone showed at least a certain degree of continuity, although the usefulness of an expensive training program abroad without any facility back home has to be questioned.

Pilot operation funding, too was not without problems. The core operations have been financed by NORAD through the World Bank and VIAK. Core hardware and software was received as a one shot donation by IBM and ESRI through GRID and has not been significantly upgraded during the pilot phase even though the need has been clearly articulated. A rather insignificant amount of money,[13] has been provided by the Ugandan government for supplies. This relatively complex funding pattern in connection with the remoteness of the Norwegian consultant lead to some problems in Kampala. From a 'field' point of view, as revealed in the interviews, too little money reached ground during this phase, which lead to the negligence of most of the application case study activities.[14] For instance, scheduled field trips had to be canceled due to the lack of money. GIS application consulting activities have been rather patchy, with an in-country presence of a GIS expert of not more than five months consisting of two visits during the pilot operations. More continuity here would certainly have improved NEIC's performance. At least for case study activities and some consulting tasks, in-country fund management would have been more appropriate. Nevertheless, the priority items, such as NEIC's move into their own offices, the workshops, institution building activities and the purchase of an office vehicle have been adequately covered. Also the contacts of the consultant to the center have been well maintained: VIAK representatives visited the facility about ten times during the pilot operations (Sørensen 1992). I nevertheless have to conclude that during the pilot phase an over-proportional amount of money has been spent on promotion and representation, leaving no adequate funding for the GIS application activities.

One reason for this is certainly the general design of the project under the World Bank's terms of reference (World Bank 1991b): The center and with it VIAK, being under constant pressure to secure funds for the continuation of the project, had to dedicate their energies towards self-promotion. Here, the World Bank definitely has to go over their books: In my opinion, a much shorter, 3 to 6 months fund-raising crash program with substantive contents followed-up directly by a sustained-funded long term project would be much more meaningful than a two year pilot operation. In Uganda, valuable time has been lost wit a GIS facility too limited to come up with meaningful application results.

The five-year investment plan (VIAK 1992a) attempts to take corrective actions of some of these shortcomings. The duration of five years will be adequate to build up and consolidate an operational information center and also the funds, in total US$ 2.5 million, seem appro-

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[13] Roughly US $ 14,000 per year (Turyatunga 1991).

[14] One reason for this was also the World Bank's over-estimation of the local fund-raising capabilities for the case studies (Sørensen 1992).

priate. It is not yet clear where the finances will be coming from, most likely they will be provided by DANIDA (Sørensen 1992). The adequate amount of money, however, provides no guarantee against future propagation of mistakes already made during the pilot operations. Again, promotion of the technology is likely to move too much into the foreground by being the principal objective on the five-year agenda. It has also not been clearly stated how the funds will be managed; whether by the center, or again, by a consulting company operating from abroad.

Cost recovery is also being proposed: The strategy aims at steadily increasing targets, starting with 3% (US$ 28,600.-) in the second year up to 15% (US$ 143,000.-) in the fifth year. It is not explicitly mentioned how this will be achieved, proposed has been the selling of cartographic products and the offering of consulting services (Sørensen 1992). Cost recovery has been fervently discussed during the pilot operations, with the World Bank and VIAK going as far as proposing a private company model for NEIC's operation (Falloux 1991, Tveitdal 1991). However, looking at the facility's performance and at the general considerations discussed in chapter 5, the set-up of the center as a private enterprise could at this stage only be sustained at an experimental scale.

Discussion

As indicated above, I consider the proposed sum of US$ 2.5 million as adequate for the financing of the core activities, the set-up and operation of the facility for five years. I see, however, no space for significant reductions, if the center is to operate successfully. GIS need investments above a certain threshold to be able to provide returns. There is also no room for larger projects within the proposed funding pattern: Such activities require in my opinion different funding channels in order not to impede the core operations. Fund management and cost recovery, two financial issues of particular relevance to my model need also special attention in the case of Uganda:

The experiences with the pilot operations call for mechanisms of ***in-country fund management****. Since the project of a National Environmental Information Center is above-all of relevance to Uganda, it would be appropriate to manage the majority of the funds from within the country, preferably by the center itself. If this is considered to be unfeasible, an organization resident in Uganda rather than a consultant abroad, could be designated for the task.*

During the next phase of the program, ***cost recovery*** *is in my opinion only feasible at an experimental level. By the end of the five-year period, the center will certainly be in a much better position to establish guidelines on how funds could be recovered. For the moment, we consider the setting-up of the center as a private enterprise as premature, primarily because with the current performance its economic survival does not seem feasible.*

Professional Issues

In this section I will above-all look at the core staff of NEIC, people which are usually present at the facility. By the end of 1991 NEIC has been operating with the professional staff outlined in Figure 6.10:

Function	Background	GIS training and experience
Manager	Environmental Studies	UNITAR 1988, 1989, VIAK 1990
Analyst	Geographer	UNITAR 1989, MSc Remote Sensing
Analyst	Forester	UNITAR 1989
Analyst/Technician	Surveyor	on-the-job 1990, VIAK 1990, UNITAR 1991
Analyst	Geographer	UNITAR 1991

Figure 6.10: NEIC staff 1991

This staff has been composed on a pragmatical base: All of the employees held government posts, and none of them has had a formal GIS education at the start of the project. The Ugandans involved in the GRID demonstration program, scientists from the various branches relevant to the study, have moved back to their original jobs after the demo in 1987, with the exception of today's facility manager. This is an indicator that at least some continuity could be maintained despite of the 'hiatus' from 1987 to 1990. The group has been complemented by a forester, working as an analyst for the biomass study. An expatriate GIS consultant, employed by VIAK, has been present at the facility for three months in 1990 and two months in 1991. This consultant helped to design the case study activities and provided on the job GIS training to some of the NEIC personnel.

The lack of GIS experience of the group as a whole is evident, with only one analyst having a formal university education in Remote Sensing and Geographic Information Systems (MSc, Bangor, Wales). All others went through UNITAR training courses and two of them received additional training at NEIC by the VIAK consultant and at VIAK in Norway. Probably more severe than the group's limited data processing skills are its inexperience in designing and reviewing projects. This situation certainly has contributed to the weak performance on the application case studies; a lack which could have been bridged by a resident expatriate consultant present during the whole pilot operations. This idea, however, has been dismissed by both the World Bank and VIAK at the beginning of the pilot phase, primarily due to the high cost of expatriate consultants (Sørensen 1992).

The mix of staff, with backgrounds in geography, forestry, environmental science and surveying is biased towards physical sciences but not unusual for the GIS context. NEIC had no social scientists and also no computer specialists employed during the pilot operations. Really lacking, however, are information and communication specialists, absolutely vital to fulfill the information objectives.

Striking, but quite normal for a developing country context is the inadequate payment of the government staff, forcing the individuals to pursue additional enterprises on the side. This is manifested by absenteeism; staff coming to the office in the morning just to disappear half an hour later or not showing up at all. A situation unimaginable in Europe or North America and, needless to say, unacceptable for the performance of an information center. At least some of the personnel have been given special financial incentives by VIAK to avoid the problems outlined (Morten Sørensen 1992). At the moment, I am, however, not able to judge whether these remedies have worked or not.

The five-year investment program foresees corrections of some of the above-mentioned deficiencies. The size of the group will be increased to 8-10 GIS professionals, assisted by an expatriate GIS analyst for 12 months for the first two years and a remote sensing expert for a total of three months. Various other specialists, such as a management expert, an expert in the production of National State of Environment reports, and an expert in the use of socio-economic indicators will also be required for various short term tasks (VIAK 1992a). It is envisaged that through this technical assistance, NEIC will be able to overcome the general lack of experience of its staff.

As already indicated under 'institutional issues', and shown in Figure 6.9 above, VIAK (1992a) envisages the core group to be subdivided into three sections: GIS analysis, database and information, which will be headed by a chief GIS analyst, a database manager and an information manager, hierarchically directly positioned under the facility manager. Three additional GIS analysts and two technicians/digitizers are foreseen to complement the team. The staff is planned to be paid significantly more than average government salaries, mainly to steer against the above-mentioned problem of moonshining and absenteeism.

Discussion

Regarding the professional issues, the investment plan's proposal has to be considered as inadequate, only partially correcting shortcomings of the pilot operations and not taking into account the facility's information goals. Potential alternatives, derived from my model, are discussed below and also illustrated in Figure 6.9. The following additional staff would in my opinion enhance the facility's information and communication tasks considerably:

*A **communication specialist** with knowledge in GIS and with an environmental sciences background directly placed under the facility manager.*

*A variety of other posts in the communication domain – **cartography, graphics, publishing** – to support the information objective. This GIS -*

communication group could be organized as a team of professionals, each one of them being responsible for one or more specialization modules – GIS analysis, data base, communication, cartography, data input, computer graphics, hardware, library, publication – as outlined in Figure 6.9.

A ***computer specialist****, primarily experienced in hardware, to maintain the increasingly growing system installation.*

Continuous technical assistance*, i.e. GIS expert presence for the whole five year period to overcome the still prevailing lack of experience of NEIC's staff. Although the five-year plan already proposes more technical assistance than during previous phases I still consider it being inadequate regarding the facility's goals and the unavailability of experienced Ugandan GIS professionals.*

Training Issues

GIS training has been the one continuum of the Uganda GIS history with staff attending UNITAR training courses in 1988 in Geneva, Switzerland and 1989 and 1991 in Nairobi, Kenya. These UNITAR training courses have offered an intensive introduction to GIS and also some hands-on experience to the trainees. They have, however, to be considered as rather general and standardized, and, since participants from various countries with different backgrounds usually attend, have not been tailored to specific users needs, as outlined in chapter 3. Thus, although evenly distributed over NEIC's history, the UNITAR training has not been smoothly integrated into the facility's other operations: The earlier trainees, for instance had to return to Uganda with no systems available at all, which, of course, lead to the loss of much of the acquired knowledge. More recently, the problem was with the analysts being removed from their job for two months or more to be trained on subjects and systems not necessarily relevant to their day-to-day tasks. Some of them went as far as labeling the training courses in Nairobi «a waste of time». I am far from criticizing UNITAR's training program in this context, the problem lies much rather with course preparation and harmonization – meaningful training case studies could be planned in advance – and follow-up. Then, of course, a remote, general-purpose training course can never substitute for in-house, on-the-job training or a formal GIS education.

The investment program outlines training at various levels: Local computer training courses, in-house GIS training, international training courses and fellowships. The center is also planning to assist Makarere University in creating in-country GIS training capabilities.

Discussion

The five-year investment plan covers all relevant aspects of training, remains however vague on how the various goals could concretely be achieved. In my opinion, NEIC's training objectives could be streamlined to enable a certain degree of fulfillment. Potential solutions are outlined below:

Contents of the training activities could be better harmonized with the information objectives. Thus, besides GIS techniques, training would also cover aspects of ***computer graphics and desktop publishing.***

Considering the training form, more emphasis could be put on ***training on-the-job*** *– making use of the resident GIS expert as a resource person – rather than short-term training events.*

All other activities related to training – special courses abroad, support to the University and scholarships – have in my opinion to be ***directly linked to the facility's needs, capabilities and performance.*** *Thus, only programs well compatible with the rest of NEIC's operations would be pursued.*

Technical Issues

This is the one aspect where we encounter the biggest inadequacies of the Uganda GIS. After the demonstration program on state-of-the-art hardware and software at GRID Nairobi, MEP had to live without any system at all for almost three years. Also during the pilot operations, the one PC based system installed was far inadequate to fulfill the designated tasks; alternate turns had to be taken to provide the various projects at least a minimal amount of system access. In addition, no graphical output devices, not even the simplest type of graphics printer had been installed until the end of 1991.

Due to the limited size of the installation, hardware problems during the pilot operations were controllable, some spare parts, however, had to be procured from abroad. The general situation in Uganda is improving, maintenance, service and spare parts are now locally available, at least in the PC sector.

For the coming five years large scale upgrades have been proposed: Five PC-based GIS workplaces with vector (ARC/INFO) as well as raster (IDRISI, ERDAS) software will be installed at the center. The PC-based systems have been chosen in favor of more powerful workstations because NEIC staff is already experienced in their use and there are currently no workstations at all installed in Uganda (VIAK 1992a). However, the workstation option has been kept open for a later stage (1995). Peripheral devices, such as drum plotters, laser printers, digitizing tables and audiovisual equipment are also planned to be installed.

Discussion

NEIC will be adequately furnished with hard- and software to meet its objectives, in this respect I consider the investment proposal as adequate and in general agree with the outlined set-up. The only point to add would be to designate a part of the system specifically to graphical processing and publishing – as outlined in the model – to allow the required flexibility towards information provision.

Data Issues

The inventory aspects of GIS have played a prominent role in the very early stage of the GRID demonstration program with the development of a comprehensive natural resources database covering the whole of Uganda. Mainly relying on existing printed maps with their roots in the colonial period (Atlas of Uganda 1964 and 1967), GRID nevertheless has also created original data through the interpretation of two landsat mosaics of 1973 and 1986, an example is shown in Figure 6.11 below. The GRID data, in total more than a 100 layers, offer a wealth in thematic information and if regularly updated, these data will remain a valuable stock for NEIC. Despite their rather small scale (1:500,000 - 1:1,500,000), many applications can be envisaged, such as the visualization of general environmental trends or for comprehensive, nation-wide analysis of some of Uganda's natural resources.

During the pilot phase, efforts have been undertaken to put larger scale data into the system. One project is to create environmental profiles at the district-level, another is to build up single thematic national inventories, such as biomass, wetlands and land cover change at scales between 1:50,000 and 1:200,000. Only little has been achieved on the district profiles so far, with only a limited amount of new data having been entered. Projects, actually defined for the pilot operations, such as the Iganga and the Karamoja profiles will have to be carried over into the implementation phase. The progress rate of these projects should serve as a warning to the quite ambitious goal of at least ten district profiles in the next five years.

For the National biomass inventory, nine test areas covering the major urban areas have been interpreted from aerial photography and mapped at a scale of 1:50,000. These data have been digitized on the NEIC system and are used for biomass calculations, testing models and to produce maps. Due to the lack of equipment these maps had to be plotted in Norway.

Although not specifically mentioned in the five-year investment plan, these data gathering activities will be quite relevant to NEIC, some of them furnishing really new, crucial environmental information. The biomass study is planned to be continued using SPOT satellite imagery and covering the whole of Uganda. At this stage it is not yet known how this methodology switch from aerial photography to satellite images will affect the results, preliminary products seem however to be very useful (Hedberg 1992). Also from SPOT satellite images, a generalized national land cover will be derived. Taking the 1:50,000 maps sheets dating from the 1960's as a base, the satellite images will be interpreted according to a simple classification scheme (forest, agriculture, urban, transport, swamp, water). The final product will not only record the current land cover, it is also envisaged to map changes which have taken place since the publication of the topographic maps. As a by-product, a wetland inventory will be derived from the same sources (Mafabi 1991). These national inventories are conducted on a project basis: 'Biomass' by the Forest Department, 'Change Detection' by the Ministry of Lands and Survey and 'Wetlands' by the Ministry of Environment Protection in conjunction with IUCN.

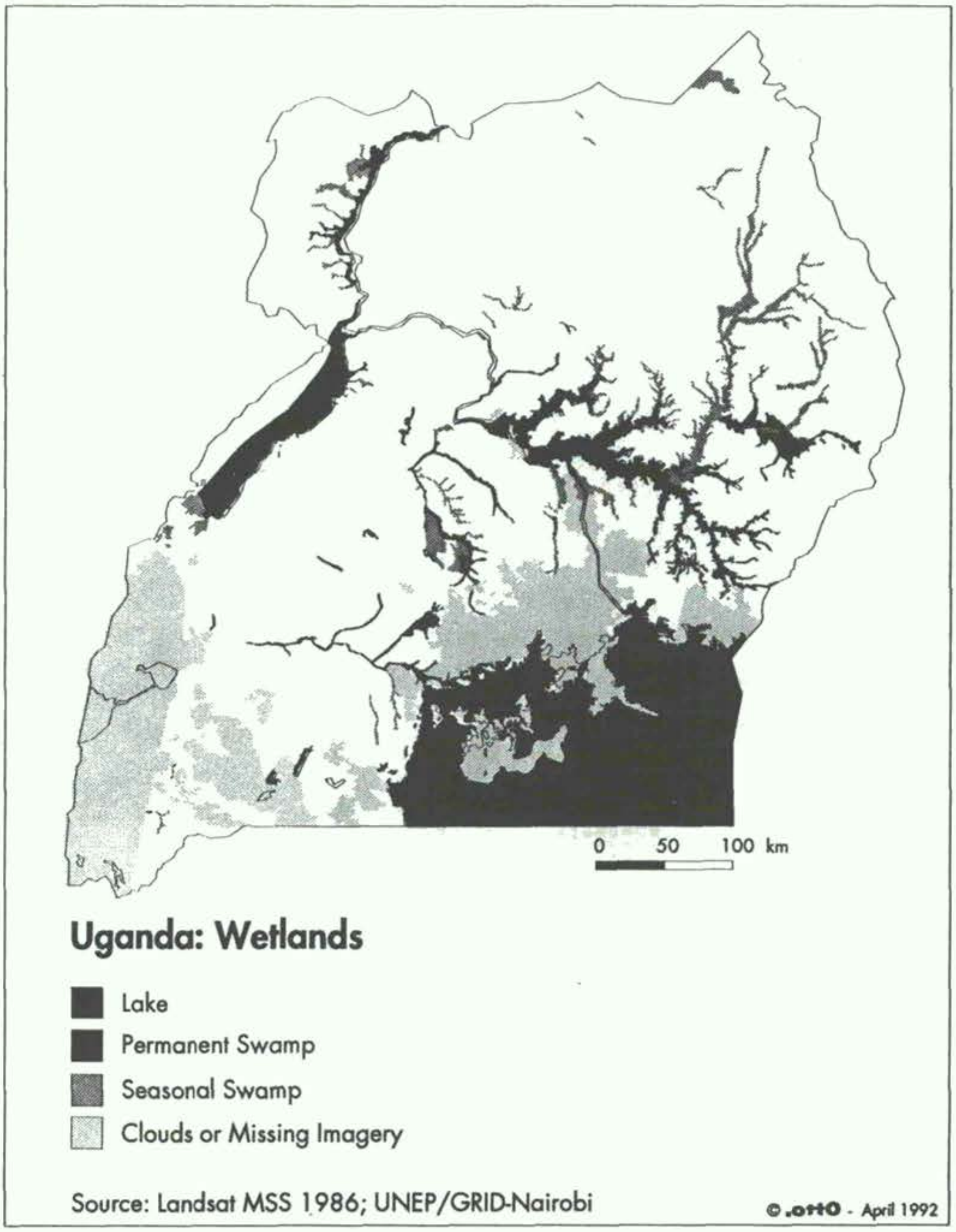

Figure 6.11: Uganda Wetlands (Derived from Landsat mosaics 1973 and 1986)

Discussion

I have already outlined a base for NEIC's data collection activities under 'Potential'. There I have above-all emphasized the center's focus on coordination and meta-database activities. Larger inventory projects are in my opinion better left to specialized bodies and projects, primarily to maintain the center's flexibility for other tasks. My model foresees NEIC to specialize in the acquisition of theme-specific, timely data and information relevant to the political decision-makers and the public. These acquisitions would primarily serve the communication goal, the visualization and distribution of information on environmental issues and hot spots, as outlined in chapter 4.

6.7 Conclusions

The evaluation of Uganda's National Environment Information Center leads to mixed conclusions, not necessarily all positive. Already five years have passed since the initiation of the GRID case study and still no substantial application results have been achieved on-site in Kampala. The pilot activities have primarily focused on promotion and sensitization. Applications, such as information provision to decision-makers and environmental data processing, had secondary priority. The picture of a well functioning information facility as outlined, amongst others, by Falloux (1991), does not quite reflect the reality.

It may, however, be early for such a hard verdict. If we consider the activities up to now as preparatory, the situation might not look at all that negative. The facility has the potential to grow into what it is designed as: The five-year investment plan (VIAK 1992a) already shows some positive starting points. But to make the institution meet its name – National Environmental Information Center – one has to orient it more radically and uncompromisingly towards information communication with all its consequences: Down-scale the technology transfer objective, give the center a certain financial independence, gear it towards communication through a specific organizational set-up and personnel and other actions I have discussed above. At this stage, Geographic Information Systems are still *en vogue* in the development community, their usefulness as a tool, however, can only be proved by successful applications: Uganda seems to be ready for them.

7

Nepal

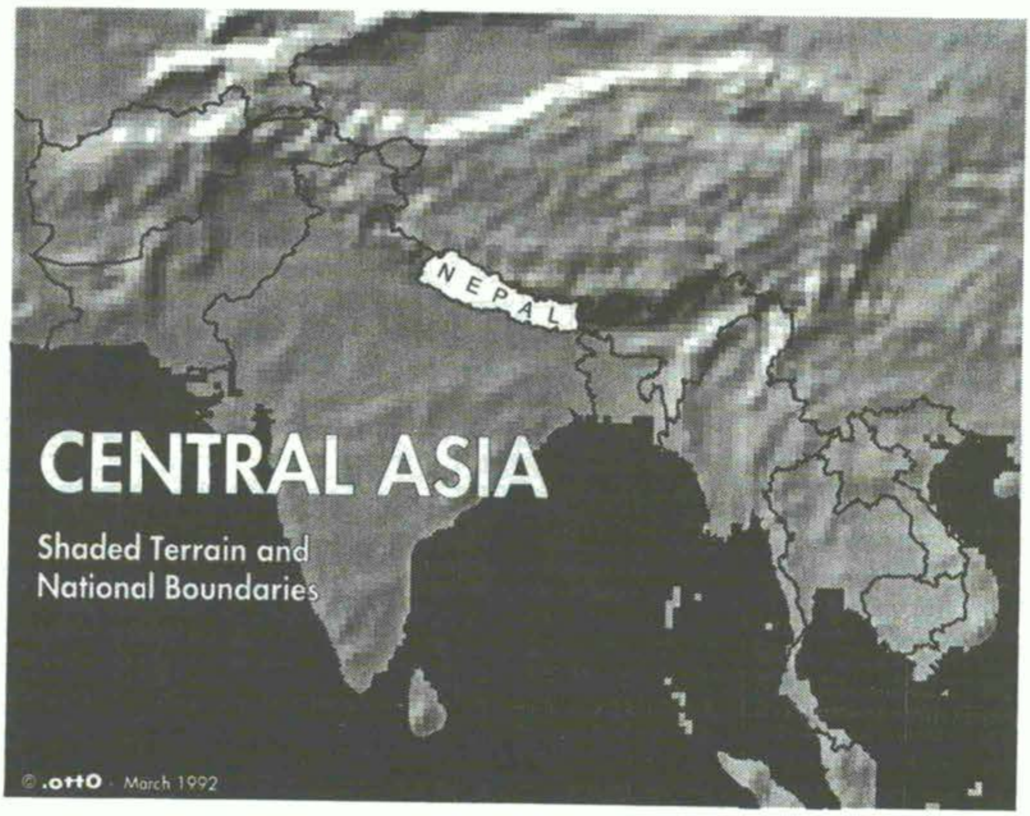

Figure 7.1: Central Asia

7.1 Geographic and Historic Overview

The Kingdom of Nepal is one of the world's model mountain countries. Indeed, 86% of its total area of 147,000 km^2 are considered to be mountainous or hilly with the Tarai plains covering only 14%. Situated on the Himalayan slopes, the country covers a large variety of physiographic zones, ranging from the subtropical Tarai lowlands to the high Himalayan snow and rock deserts. Geo-politically Nepal is in a pivotal position, squeezed between the world powers India and China, without access to the sea. In 1973, King Birendra declared Nepal as a 'Zone of Peace' to emphasize the country's non-alignment. India as the dominating neighbor has, however, never endorsed this declaration (Robert Taylor 1991).

Nepal's population has increased from 8.2 million in 1960 to 19.1 million in 1990, with still less than 10% living in urban areas. Average annual population growth is 2.3%, however, varying considerably depending on geographical location within Nepal. Through migratory movements, the population in the plains (Tarai) is growing much faster than in the hills, so that today only half of Nepal's people are actually living in the hills or mountains (LRMP 1986). By the year 2025, Nepal is expected to have 35 million inhabitants (UNEP 1991, World Resources Institute 1992).

The economy of Nepal is almost entirely based on agriculture, occupying 91% of the nation's labor force and contributing 59% of the merchandise exports and 54% of the GDP (LRMP 1986). The most important food and cash crops are rice and maize, cultivated on more than 90% (Rice: 53%, Maize: 38%) of the country's arable land surface (LRMP 1986, HMG-Nepal/IUCN 1988). Depending on physiographic region, agricultural practices vary considerably. In the hills, rather small subsistence farms prevail, while in the plains the average farm size is bigger and good accessibility allows the cultivation of cash crops besides staple produces. Industry is rather small-scale, absorbing less than 1% of the total labor force. Most important are jute goods, sugar, cigarettes, cement and leather (Robert Taylor 1991).

Nepal's natural beauty and its rich cultural heritage are very attractive for tourism, from 1970 to 1986 nearly two million visitors have come to the country (HMG-Nepal/IUCN 1988). The annual tourist flow has grown from 45,000 in 1970 to 248,000 in 1987. Tourism plays a substantial role in Nepal's economy, having earned 18.5 % (US$ 43 million) of the nation's foreign exchange (HMG-Nepal/IUCN 1988, HMG-Nepal 1989).

Nepal does not have significant exploitable mineral resources: Clay for bricks and ceramics, building stones, limestone for cement, magnesite, talc and a small-scale gem industry. A larger zinc deposit is now being accessed in the Ganesh Himal with government assistance (LRMP 1986). The nation's hydroelectric potential, however, is tremendous. Of an estimated total of 83,000 MW, of which 27,000 MW are considered economically feasible under current conditions, only 161 MW are today installed (HMG-Nepal/IUCN 1988).

Nepal is a rather poor nation and is counted to the UN group of the Least Developed Countries (LLDC). Its GNP per capita of US $ 170 in 1989 (World Resources Institute 1992) is one of the world's lowest. Foreign debt has been increasing from 10% of the GDP in 1980/81 to 33% in 1987/88. Debt servicing is, however, with a rate of 7.8% comparatively low (Statistisches Bundesamt 1989).

Until 1950, Nepal has been ruled for over a century by the powerful Rana dynasty who kept the country more or less secluded from the rest of the world, off-limits to all foreigners. Thus, it has never been colonialized and could preserve much of its cultural heritage. In 1950 constitutional monarchy was established and since then three kings, Tribhuvan, Mahendra and Birendra, have ruled the nation in a progressively autocratic manner. An attempt for democratization with free multi-party elections in 1959 has been aborted in 1960 with the abolishment of political parties. In 1990, however, Nepal's political order has been radically changed through the 'Movement for the Restoration of Human Rights and Democracy'. Widely supported unrests in Kathmandu have lead to the termination of the King's all-encompassing executive, legislative and judiciary powers; the new constitution of November 1990 clearly states that «sovereignty resides in the people» (Shaha 1990). Elections with multi-party participation have been held in May 1991.

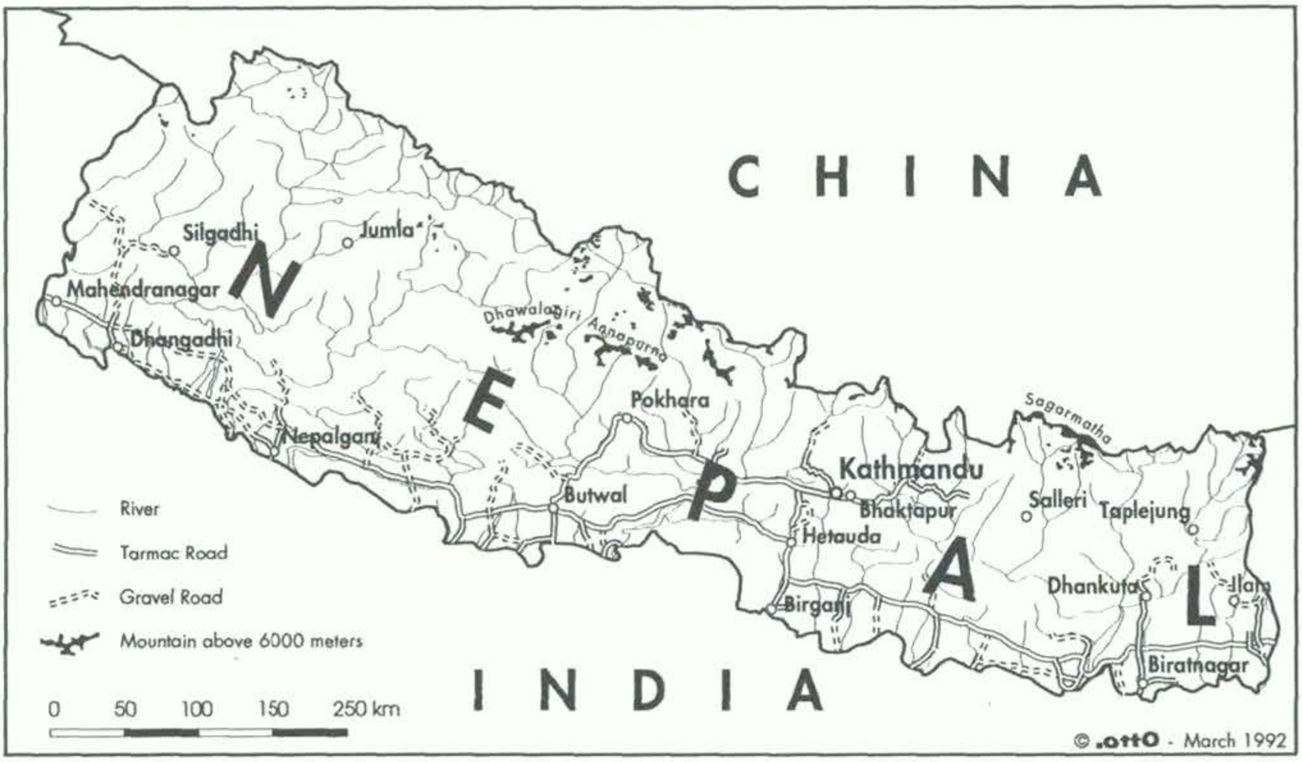

Figure 7.2: Nepal

7.2 The Situation Today

My research on Nepal falls into a period of radical political changes; my reflections on the situation today may thus – particularly with regard to the quite volatile actual political alignments – be valid for a limited time only. From January 1989 to May 1991 Nepal had no less than four government changes with the members of the planning and implementing bodies changing at the same time. The myth of the 'poor but happy' mountain nation has through the recent unrests and the dissolution of the monarchy suffered considerably: Particularly the urban areas face increasingly problems of social disturbance and crime. For the large portion of the population the government changes did not bring the expected economic improvements: In addition to the traditional Gurkha soldiers serving in Commonwealth countries, many Nepali now have to earn their income as laborers in South Korea, Thailand and the Persian Gulf.

For the analysis of Nepal's decision-making process we also have to look at pre-democracy structures, some of which, such as the National Planning Commission still being functional. Until very recently, the King was the center of power in Nepal. With the palace secretariat, a team of technocrats advising him on economic planning and administration, King Birendra had an efficient instrument to use his authorities (Robert Taylor 1991). Since 1975, development planning has been orchestrated by the National Development Council, presided by the King. The council sets the frame for economic development while the National Planning Commission (NPC) formulates and supervises Five-Year development plans. Principal target of the most recent Five-Year plans has been the growth of the GDP; a target which could be met during the Sixth (1980/81 - 1984/85) planning period with a growth rate of 4% per year. In some sectors, such as the non-agrarian industries, however, aimed growth rates could not be achieved. The Seventh plan (1985/86 - 1989/90) is aimed at an annual GDP growth of 4.5% (Statistisches Bundesamt 1989).

For some time, efforts to delegate planning activities to lower, above-all the village (Panchayat) level are underway in Nepal. Specific projects, such as the UNDP project 'Strengthening Decentralized Planning in Nepal', have been established to «enable sub-national level governing bodies to make and implement decentralized planning» (Lundberg 1992). Also the National Conservation Strategy (NCS) activities described below adhere to decentralization concepts.[1]

Development assistance is quite important for Nepal's economy, the country has from 1960 to 1987 received US$ 1.4 billion from individual donor countries, of which Japan, the USA, the UK and Germany have contributed almost 80%. From multi-lateral agencies, Nepal has in the same period received US$ 1.0 billion, 80% coming from the International Develop-

[1] Nepal's administration has to be considered as extremely centralized, it remains to be seen how the recent decentralization activities will develop, or, whether they are not just an example of 'imposed federalism'.

ment Association (IDA), the Asian Development Bank (ADB) and the United Nations (Statistisches Bundesamt 1989). The presence of developing agencies in the country, Kathmandu in particular, is evident and their project activities are innumerous and rather vast. Literature, thus is also over-abundant, some interesting reviews of development activities are given by Basler (1984) and Hagen (1980). Also in HIMAL, the recently founded 'Alternative Bi-Monthly', articles on development and environment in Nepal are being published regularly.

7.3 Environmental Problems, Issues and Policy

The environment in its broader sense plays a central role in many of Nepal's development activities. The country has the reputation of being a model for the most sinister environmental degradation scenarios; most popular are the 'logical' chains of linking deforestation in Nepal to soil erosion and to the devastating floods downstream in Bangladesh. Although the scientific literature clearly rejects such claims (Bruijnzeel and Bremmer 1989), these highland-lowland interactions are nevertheless resurfacing regularly in the media.

The literature on sectoral environmental issues in Nepal being vast, I have concentrated on some recent, comprehensive publications evolving around the National Conservation Strategy (NCS) (HMG-Nepal/IUCN 1988), such as NPC/IUCN NCS Implementation Program (1992a, 1992b), Carew-Reid and Oli (1991) and Arensberg (1991); the Land Resource Mapping Project reports (LRMP 1986) and the ERL study on Natural Resource Management for Sustainable Development (ERL 1988). Other interesting contributions to environmental issues in Nepal are by Thompson, Warburton and Hatley (1986), Ives and Messerli (1989), Basnyet (1989), Bishop (1988), Hough and Sherpa (1989), Kohl (1988), Rowell (1989) and Shrestha (1989).

In any country it is rather difficult to give a comprehensive overview of the environmental problems. This is also the case in Nepal, where the enormous physiographic differences only increase the complexity of the task. I have attempted to roughly outline Nepal's principal environmental problems relying on the above references.

Deforestation and forest degradation

This problem manifests itself through a gradual transformation of forest lands to other uses rather than through cutting down larger forests. This makes it quite difficult to quantify deforestation in Nepal. Although estimates vary considerably one can assume that since 1950 Nepal has lost about half of its forest coverage (Basler 1984). Negative effects, such as fuelwood and fodder shortages are both already marked and predictable.

Exploitation and degradation of arable land and grasslands
Some lands in Nepal are used at the margin of sustainability, leading to declining yields and on the long run also to complete loss for agricultural or pastoral use.

Soil loss through erosive processes
Intensive agricultural and other land utilization practices coupled with physical processes lead to soil erosion and landslides and thus to irreparable damages.

All these environmental problems are linked to the country's principal economic activity, agriculture, and somehow also reflect the widespread poverty in Nepal. Besides resulting from a general over-utilization of resources through population pressure they can partially also be perceived as managerial problems; solution approaches will have to take this into account. These above-listed problems are all rural and physical in nature, but with increasing urbanization undoubtedly urban environmental problems, such as air and water pollution, noise and waste accumulation will also become relevant.

Conservation efforts have a long history in Nepal with the first major initiative, the set-up of a forest office for the protection and the harvest of Tarai forest taking place in 1934. More and more institutions were gradually added, in 1970 the Royal Chitwan National Park in the Tarai and Langtang National Park in the mountains were founded by King Mahendra. Environmental degradation as a problem of national importance was addressed by the Seventh Five-Year Plan, this resulted in 1987 in the establishment of a Division of Environment and Resource Conservation within the National Planning Commission. Increasingly, also NGOs play a significant role in Nepal's conservation efforts, above-all the King Mahendra Trust, UNESCO/MAB and ICIMOD (HMG-Nepal/IUCN 1988).

In general, solution strategies to Nepal's environmental problems tend to move away from central government:

> «Too much reliance has been placed upon government to improve this situation, and insufficient opportunity and responsibility have been given to the users – collectively or individually – to help remedy the problem through personal initiative.» (HMG-Nepal/IUCN 1988: p. 149)

As outlined earlier, planning in general, not only concerning environmental issues is being decentralized in Nepal. For instance, large-scale efforts are now underway, to transfer the management of forests from the central government to communities, to facilitate a sustained use of the resources. Decentralization has also taken into account setting up the National Conservation Strategy (NCS) with regional, district and village committees. During the NCS set-up rural communities have been involved through public meetings and discussion sessions (HMG-Nepal/IUCN 1988, Arensberg 1991).

As elsewhere, it has also been pointed out that resource conservation problems can not be approached on a single-sector basis, the call is for integrated resource management. Another pillar of action is conservation awareness: Through special programs, the broader public will be sensitized to environmental issues, an approach aiming at long-term success (HMG-Nepal/IUCN 1988). A model case of a bottom-up conservation approach is the Annapurna Conservation Area Project (ACAP). The local population is actively involved in the setting up and management of a large conservation area, which gives them the opportunity to generate income, for instance through tourist activities, locally (Hough and Sherpa 1989, Rowell 1989).

In 1988, the Government of Nepal has in conjunction with IUCN issued a National Conservation Strategy for Nepal (HMG-Nepal/IUCN 1988). Being a part of the World Conservation Strategy program it can be regarded as an attempt to implement sustainable development at the national level. The National Conservation Strategy for Nepal has four main objectives, which are to help:

◊ satisfy the basic material, spiritual and cultural needs of the people of Nepal, both present and future generations

◊ ensure the sustainable use of Nepal's land and renewable resources

◊ preserve the biological diversity of Nepal in order to maintain and improve the variety of yields and the quality of crops and livestock, and to maintain the variety of wild species, both plant and animal

◊ maintain essential ecological and life-support systems, such as soil regeneration, nutrient recycling and the protection of water and air.

The sectoral analyses of the conservation strategy give a comprehensive picture on the current status, development objectives, obstacles, constraints and successes concerning the principal conservation issues. These analyses also show how complex the field of conservation and the environment in Nepal is, infringing with virtually all sectors of development. To show the bandwidth of the topic, I just present the sectors discussed in the Conservation Strategy, congruent with Nepal's principal environmental issues (HMG-Nepal, IUCN 1988):

◊ Population and human settlement
◊ Cultural heritage
◊ Conservation awareness
◊ The role of women in resource conservation

- ◊ Drinking water supply and sanitation
- ◊ Agriculture
- ◊ Irrigation
- ◊ Livestock and pasture management
- ◊ Soil conservation and watershed management
- ◊ Forestry
- ◊ Medical plants
- ◊ Biological diversity
- ◊ National parks, protected areas and wildlife conservation
- ◊ Tourism and outdoor recreation
- ◊ Energy development
- ◊ Industrial development
- ◊ Non-renewable resource development and hydrocarbon energy
- ◊ International and regional aspects

The Conservation Action Agenda as final part of the Conservation Strategy gives recommendations on a variety of topics, namely Institutional, Conservation Awareness, Policy, Organization and Administration, Research, Inventory and Directed Studies, Resource Planning, the NCS Vanguard Programs. The NCS document has to be regarded as an intermediate step in a longer-term, institution building process. The implementation phase, starting in 1989 has focused on the establishment of the major policy bodies as visualized in Figure 7.3.

These various institutions have been established in a step by step process, starting with the Environmental Core Group in 1989, the Nepalese Environmental Planning and Protection Council, in 1990, and finally, the Nepalese Environmental Planning and Protection Agency (NEPPA) to be institutionalized in late 1992.[2] These institution building processes can be considered as bottom-up activities, with NEPPA as the core body – the equivalent to an environmental ministry – being established last. The council is to serve as a steering committee to harmonize the activities between the NPC and NEPPA. Quite relevant in this set-up is the core group: A network of senior representatives with environment-related tasks from the sectoral governmental agencies and the National Planning Commission. The group consists of more than fifty members today and forms a vital link between policy formulation and implementation. Above-all through the activities of this core group the Nepalese political institutions have been prepared for the establishment of the key institutions, the 'council' and the 'agency' (Carew-Reid 1992). As outlined in chapter 5, also in the environmental information and GIS domain I regard the foundation of a users group similar to this core group in a country as very relevant, above-all to support GIS networking.

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[2] We use here IUCN terminology to denominate the various bodies, some of these names may, however, not yet be officially used in Nepal.

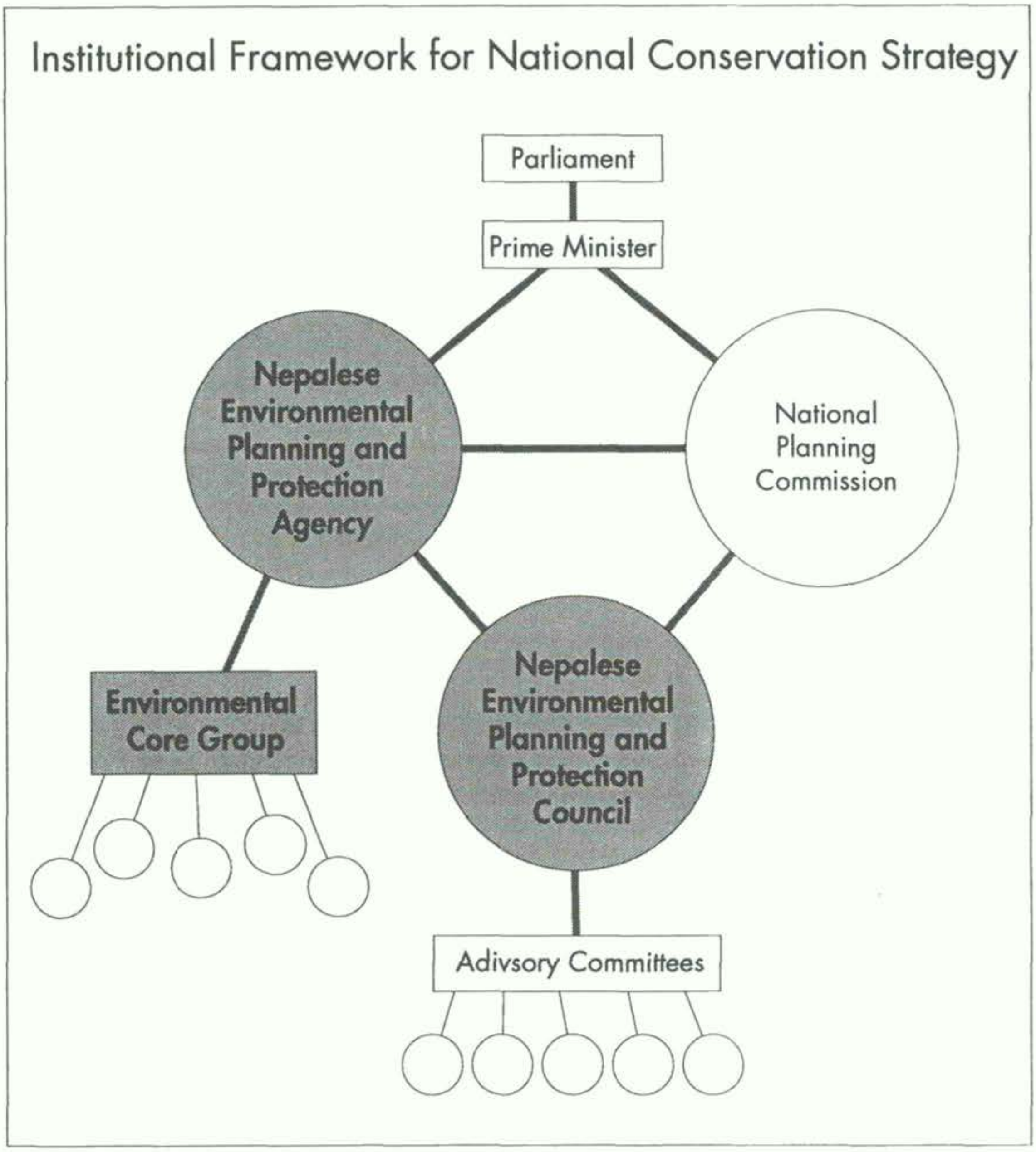

Figure 7.3: Institutional Framework for National Conservation Strategy

All environmental planning activities rely in one way or another on information. In the National Conservation Strategy (HMG-Nepal, IUCN 1988), for instance, we find also references to environmental information which can be perceived as relevant to Geographic Information System developments in the country. On an institutional level, the Nepalese Environmental Planning and Protection Council (see also Figure 7.3), is, among others, responsible for:

- conservation education, training and public information
- research, inventory and directed studies.

Further references to information are made under policy issues with regard to national parks and protected areas, again topics relevant to the GIS domain (HMG-Nepal, IUCN 1988: p.109):

> «For purposes of future park and protected area selection the current broad classification of geographical divisions – the Tarai, inner Tarai, Hills and Mountains – will be refined by taking into account other factors, for example, flora and fauna.»

NCS further mentions:

- ◊ forest surveys
- ◊ identification of areas with critical soil-erosion problems
- ◊ environmental and socio-economic impact statements for large-scale projects
- ◊ assessment of data concerning wildlife and wildlife habitat.

Thus, in the wider sense the need for Geographic Information Systems for environmental applications in Nepal has clearly been articulated. Also in other domains – urban planning, census and surveying – similar needs have been expressed.

7.4 Geographic Information System Activities

My research on the Nepal GIS activities is based on several field visits and active project participation. Preliminary contacts to organizations and individuals in Nepal involved in Geographic Information Systems have been established on visits to Kathmandu representing UNEP/GRID in April 1988, October 1989 and March 1990. The first on-site appraisal of the study case at ICIMOD, using questionnaires developed in the context of my research, has taken place in Kathmandu from March 8 - 24 1991. On a second field visit from September 18 to October 5 1991, depth interviews with GIS users in Nepal were conducted, this field evaluation included a visit of GRID Bangkok also partaking in the Nepal GIS activities.

At various institutions Geographic Information Systems have already been applied in Nepal for quite some time. The National Remote Sensing Center of Nepal has since 1986 been operating a PC-based ERDAS GIS and has conducted various studies applying the technology, for example on the Arun Basin (Malla and Indra 1988) and on Kathmandu Valley in conjunction with George Mason University (Jampoler and Haack 1989). One employee of this facility has been trained by UNITAR and GRID in 1989 in Geneva and UNEP/GRID has taken up informal contacts to the center in 1988. Today, however, the Remote Sensing Center is no longer operational, its staff and equipment being dispersed. The reasons for the center's disintegration seem mainly to be institutional, however, it may partially also be due to the premature implementation of the technology in Nepal. Some of the center's hardware and software components are now integrated to the Forest Resource Information System Development Program, this shows at least a form of continuity (HMG-Nepal 1990; Heinonen and Tokola 1991). The forestry's project objective is to build up a GIS within the Ministry of Forests and Soil conservation, this remote sensing-based system is, however, not yet fully operational. Another endeavor in the forestry sector is the 'Tarai and Siwaliks Forestry IV Project' (World Bank 1991e), but to my knowledge this World Bank project has not yet proceeded beyond the planning phase.

Another institution with long-standing GIS experience is the Integrated Survey Section of the Topographical Survey Branch. As a follow-up to the Land Resources Mapping Project (LRMP) and with collaboration of the University of British Columbia, GIS has above-all been applied for watershed analysis at relatively large scales (1:20,000 - 1:50,000) in the Jhikhu Khola valley east of Kathmandu. (Schmidt 1991, Schreier et al. 1989a, 1989b, Shah et al. 1991, Shrestha and Brown 1991). A PC-based TERRASOFT system has been installed in 1989 at the Topographical Survey Branch and is mainly being used for the on-going work on Jhikhu Khola watershed. This installation is rather research-oriented and experimental, it has nevertheless already produced quite interesting results. The University of Bern, Switzerland, has also been involved in the Jhikhu Khola studies, results have been published by Wymann (1991).

Various efforts have up to now been undertaken to harmonize the various GIS activities in Nepal and put them under a single national umbrella. A GIS under the National Planning Commission at an Environmental and Land Use Resources Center to be constituted was proposed by the National Land Use Planning Project for Nepal in 1987. This idea was recently followed-up in reports published by the Washington-based consulting firm PADCO and UNDP (PADCO 1991, 1992): Reviewing the actual situation, these reports address quite central issues of GIS establishment in Nepal, elaborating on dualisms like institution-based versus project-based GIS or bottom-up versus top-down technology implementations. PADCO (1992) has also put forward a three-phase strategy for future GIS developments in the country. The strategy envisages a distributed GIS network in Nepal with local nodes attached to a central storage facility as long-term goals. The National Planning Commission is attributed coordinating functions, the report also proposes to institutionalize a GIS steering committee under the NPC. The National Computing Center has been identified as the institution to suited to hold a national GIS center and ICIMOD has been attributed training and research functions by PADCO (1991, 1992). Concrete GIS applications are only treated marginally in these reports, although useful applications will be a key element for future GIS developments. Nevertheless, despite at times being over-generalized[3] and rather technology-driven, the strategy gives a good overview of potential future GIS developments in Nepal. A concrete follow-up activity of the PADCO report will be the implementation of a GIS at NPC, some NPC personnel have already been trained in GIS at ICIMOD.

The Mountain Environment Natural Resources Information System (MENRIS), the focus of my discussion, has been initiated in 1989 at the International Center for Integrated Mountain Development (ICIMOD) in Kathmandu. ICIMOD has been established in 1984 with UNESCO, the governments of Germany and Switzerland as its main sponsors. Its goals and objectives have been outlined as follows (ICIMOD 1990a, p. 4):

> «The primary objectives of the Center shall be to help promote the development of an economically and environmentally sound mountain ecosystem and to improve the living standards of mountain populations of the Hindu Kush Himalayan Area which, for the purpose of these Statutes, includes Afghanistan, Bangladesh, Bhutan, China, India, Myanmar (Burma), Nepal and Pakistan.»

Figure 7.4 displays a perspective view of the Himalaya-Hindukush, to emphasize the mountainous character as the principal binding element of the region.

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[3] It is for instance not discussed at all, how local government, such as district headquarters will cope with modern technology to date virtually unknown at this level in Nepal.

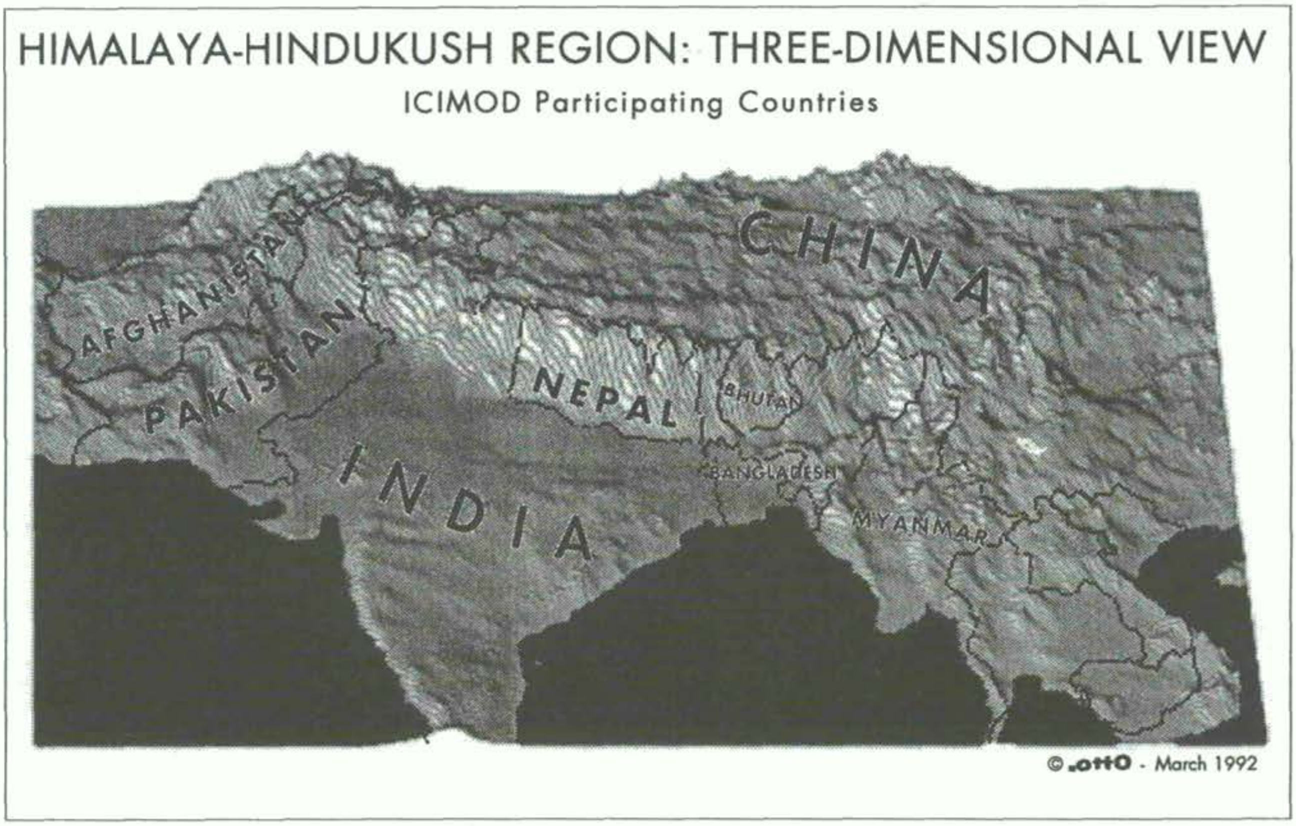

Figure 7.4: Perspective View of the Himalaya-Hindukush Region

The ICIMOD region has to be considered as rather artificial: Historically most of the countries do not really have close ties, not to speak about downright hostilities. Thus, the center faces rather delicate cooperation problems. By being based in Kathmandu it tends also to be Nepal-biased at times, for instance half of ICIMOD's professional staff are of Nepalese origin (ICIMOD Review Panel 1990). A general review of ICIMOD conducted in 1990 – after completion of five years of operation – has lead to the draft of new statutes (ICIMOD 1991f). Changes in direction aim primarily at making ICIMOD a genuinely international organization and thus also widen its base of financial support (ICIMOD 1990b, ICIMOD Review Panel 1990).

ICIMOD puts emphasis on its status as a 'facilitator of development' being neither a research institution nor a traditional development agency. Four main functions, namely being a documentation center, a focal point for problem-solving research, a focal point for training and a consultative center are the base of ICIMOD's activities (ICIMOD 1990a).

Thus, MENRIS is strictly speaking not a Nepalese GIS but it is the largest-scale effort to implement GIS technology in Nepal so far. Printed sources on MENRIS' development are mainly proposals, progress reports and brochures, such as ICIMOD 1991a, 1991b, 1991c, 1991d 1991e, 1992, UNEP/GRID 1991a, 1991b, Simonett 1992, PADCO 1991, 1992 and

UNITAR 1990b. No scientific articles have been published on the facility yet. I have been involved on a professional level in the establishment of MENRIS as a consultant for UNEP/GRID from 1989 to 1991. This allowed me to provide input to the facility's development while conducting my research, thus the term 'action research' evidently applies to this study. MENRIS staff and users have been interviewed on two visits in March and September 1991, my survey included 10 core staff, 5 consultants and 12 users. Despite the quite recent system implementation (mid-1991), some users had already some exposure to GIS technology and contributed substantially to my research.

In Figure 7.5 I have laid out MENRIS' history as concisely as possible, using my own terminology – above-all to be consistent with the chapter on Uganda – to label the various phases.[4] The MENRIS development as a whole has been quite compact, making it difficult to distinguish between the various phases, some of which being extremely brief and others considerably overlapping with my own subdivisions. In official ADB and MENRIS terminology, all activities until the end of 1991 fall under Phase I of the project's development.

A peculiarity of MENRIS is that it has been built upon a dualism still evident today: From the beginning, there were two parallel initiatives to implement GIS technology at ICIMOD: One funded by the Asian Development Bank (ADB), the other by the British Overseas Development Administration (ODA), subsequently referred to as ADB and ODA systems, respectively. Both project proposals have been submitted in early 1989 (ADB 1989, ODA/SWK 1989) offering basic GIS hard- and software, consulting and training, the ODA at a total of UK£ 800,000 (US$ 1,300,000), ADB at US$ 700,000. In substance, the proposals are not considerably different, I do however consider the ODA proposal by being tied to British equipment and services to have a disadvantage: The commercial GIS market today is being dominated by American technology. Because nothing was done either to merge the two initiatives or to give up one of them, both were realized in parallel. Despite later efforts of harmonization, the dualism still persists, particularly in MENRIS' hardware and software set-up. In view of my professional involvement with the ADB project, which today is also ICIMOD's principal GIS, I will dedicate more space to the activities concerning this system.

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[4] The use of this terminology has been outlined in chapter 6 (Uganda).

Initiation (January - October 1989)

Draft of MoU between ICIMOD and ADB to outline technical assistance grant (January 1989).

Meeting of participating groups in the ADB project at ICIMOD, Kathmandu (October 1989).

ODA proposal accepted by ICIMOD.

Demonstration Programme (November 1989 - December 1990)

UNEP/GRID Nepal and Bagmati zone database and demonstration applications November 1989 - December 1990).

3 months UNITAR training course at AIT Bangkok with eight ICIMOD/MENRIS participants (May - August 1990).

Curriculum Development for GIS training at three levels: Research Professionals, Digitizers and Awareness Workshop (August 1990 - September 1991).

Technology Transfer (January - July 1991)

Installation of PC-ARC/INFO software and data input training to cartographers (January).

Transfer of UNEP/GRID Bagmati Zone database and demonstration of applications to MENRIS staff (February - March).

Installation and training on ODA system (PC based, GIST software) by SWK consultants (March - April).

Installation of IBM RISC workstations with ARC/INFO software (June)

Pilot Operations (July - December 1991)

2 weeks ARC/INFO training on IBM RISC by UNITAR/ESRI at ICIMOD (July/August)

MENRIS case study activities in conjuncion with other institutions in Nepal: Service Centre Analysis in Lalitpur, Agro-ecological Zonation in Bagmati, Population Carrying Capacity in Dhading, Mini/Micro Hydroelectrical Potential in Dhading.

4 weeks UNITAR training course at ICIMOD to National Planning Commission and others (September)

Sensitization Workshop Kathmandu (November)

Figure 7.5: MENRIS development – Overview

As initiation of the MENRIS activities I consider the fact-finding ADB mission to Kathmandu in January 1989 opening up the path for future developments. A Memorandum of Understanding, concerning cooperation between ICIMOD and ADB was drafted at the same occasion (ADB 1989). The meeting at ICIMOD in October 1989 convened the executing organi zations of the ADB project: UNEP/GRID, UNITAR and AIT. As an outcome of this meeting MoUs between the participating agencies have been drafted to outline future activities and cooperation.

UNEP/GRID has been assigned responsibility for system design, an initial proposal projected a configuration with IBM RT hardware and vector and raster software. GRID opted for this GIS hardware not necessarily state-of-the-art primarily because of compatibility reasons: The same platform was already installed at other GRID nodes. This design, however, had later to be changed because of hardware constraints: With IBM discontinuing the RT series a new set-up with IBM RISC workstations was proposed.

Another task assigned to GRID was the set-up of the GIS demonstration applications. The study's main objective was to demonstrate the use of GIS for regional planning, above-all at the district level, it was to be conducted at GRID-Geneva, because it was not envisaged to install a GIS at ICIMOD immediately. Relevant maps and other information on the designated case study areas were collected during the constituting meeting.

The responsibility for training was given to UNITAR, a first training course with participants from Nepal was designed to be held at AIT Bangkok in mid-1990.

The ODA project, proposing a full GIS installation on its own including consulting and training was accepted by ICIMOD on the obvious basis that it meant additional hardware, software and human inputs for the center-to-be.

The subsequent **demonstration program** consisted of two principal activities: The UNEP/GRID case study development and the training course at AIT Bangkok.

The GIS application study conducted at GRID Geneva from November 1989 to December 1991 is documented in UNEP/GRID 1991a, 1991b and Simonett 1992; it had the following objectives:

- ◊ Demonstrate the use of Geographic Information System technology for the planning process in Nepal and the establishment of GIS capabilities at ICIMOD

- ◊ Create digital environmental databases with data at different scales and resolutions with emphasis on the district-level

- ◊ Conduct problem-oriented GIS analysis and examine the applicability of the tool at various planning levels ranging from panchayat to national

- ◊ Visualize case study results in the form of maps and graphics

◊ Assist ICIMOD and UNITAR in setting up a curriculum for future GIS training for Himalaya-Hindukush region professionals.

On the Nepalese side, the GRID applications were guided primarily by the Bagmati Task force team at ICIMOD. Scientists from various fields (economy, development planning, forestry, agriculture and environmental management), outlined the design of a district-level database, sketched analysis procedures and formulated their needs for maps and graphics. Further inputs have been provided by other institutions and individuals in Kathmandu: The Topographical Survey Branch on the Land Resources Mapping Project (LRMP) data, the Suspension Bridge Division on their Main Trail and Central Places maps, the UNDP project 'Strengthening Decentralized Planning in Nepal' under the National Planning Commission, IUCN as well as others on a variety of additional issues relevant to environmental planning in Nepal.

GRID assembled the following environmental databases with data at different scales and resolutions, which are described in detail in UNEP/GRID 1991b:

> **Zone-District (Bagmati Zone, 1:50,000 - 1:125,000):** Elevation, Drainage Network, Political Subdivisions, Population Density, Roads and Trails, Suspension Bridges, Central Places with Central Services, Land Utilization, Land Capability.
>
> **National (Nepal, 1: 2,000,000):** Elevation, Drainage Network, Political Subdivisions, Administrative Headquarters, Road Network, Precipitation, Geology, Protected Areas.
>
> **Regional (Himalaya-Hindukush, 1:3,000,000 - 1:5,000,000):** 5-Minute Digital Terrain Model, Drainage Network, National Boundaries, Railway Network.

Upon completion, these databases were transferred to ICIMOD, the National datasets and parts of the Bagmati Zone – Sindhupalchok district – were finished in March 1990 and could be used for the training course in Bangkok. The whole of Bagmati zone was completed in February 1991, the regional datasets in September 1991. As an example of a national dataset, used above-all for visualization and training purposes, the geology coverage is shown in Figure 7.6.

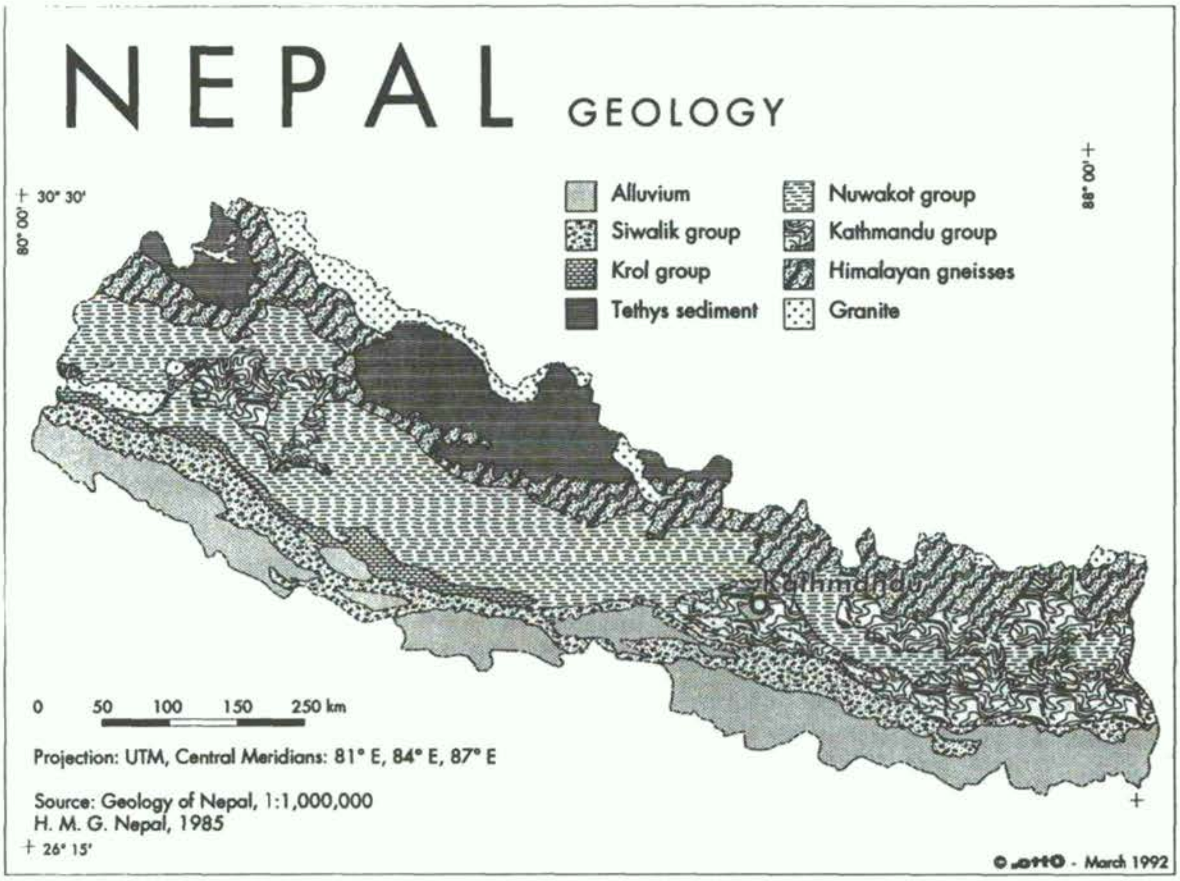

Figure 7.6: Nepal – Geology

Analysis conducted at GRID concentrated on terrain modeling, land resources assessment, population and transport, the results have been presented in Simonett (1992). The analysis remained rather basic and experimental. GRID did not conduct more sophisticated modeling mainly because being too remote from Nepal's day-to-day planning activities and also because artificial models, such as soil erosion or agro-ecological suitability were not considered very meaningful. Satellite Remote Sensing has not been applied by UNEP/GRID since this was supposed to be incorporated into the ODA study.[5] The GRID applications were meant to give an overview of the potential of GIS technology. As an example I want to present here the result of a road and trail network analysis to determine accessibility in Bagmati Zone (Figure 7.7).

[5] ODA consultant Scott, Wilson and Kirkpatrick has acquired satellite images of the Kathmandu Valley and introduced MENRIS staff to remote sensing principles. Currently, there is also a French remote sensing expert stationed at MENRIS (ICIMOD 1992).

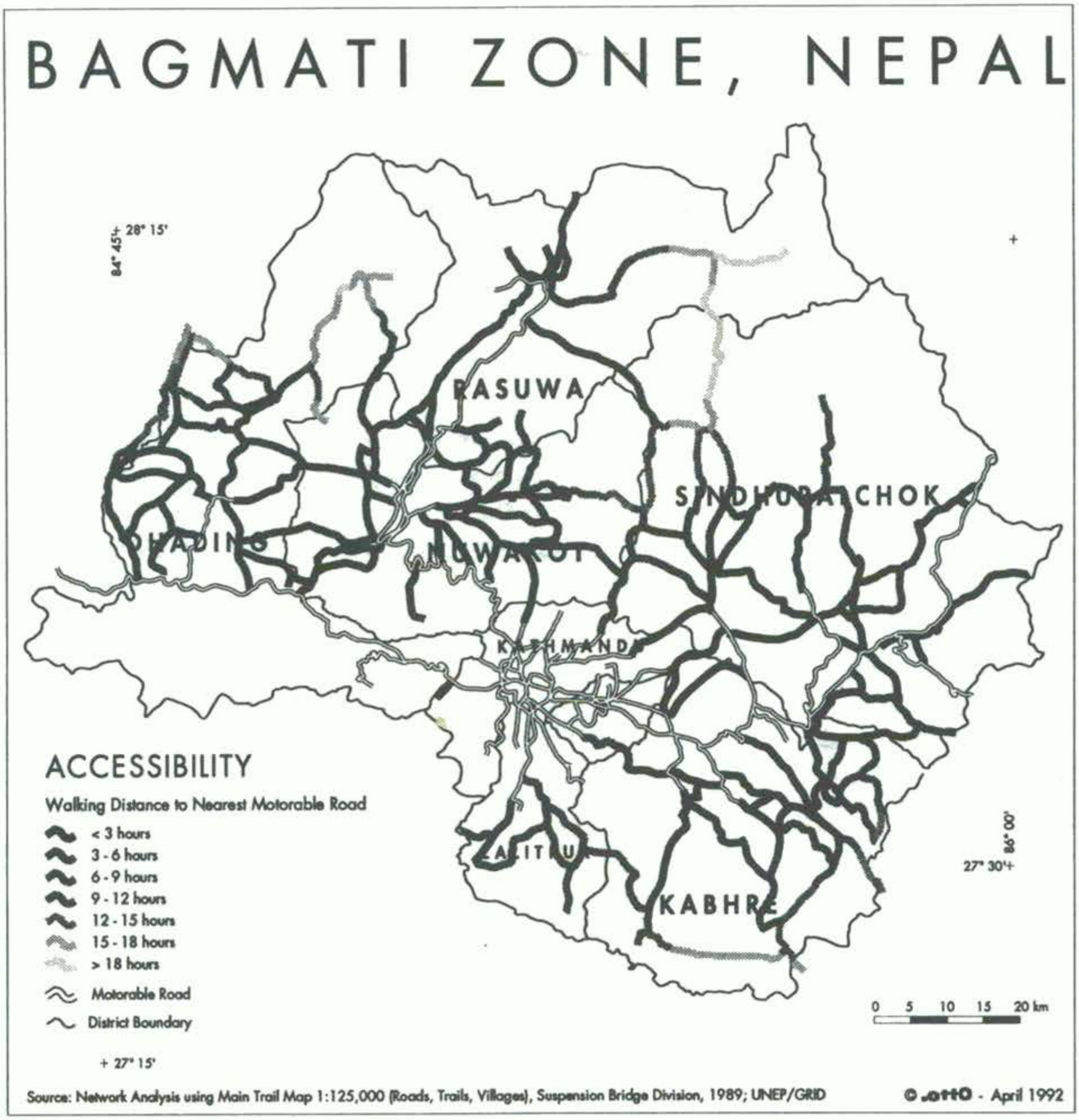

Figure 7.7: Bagmati Zone – Accessibility Model

To demonstrate the communication potential of Geographic Information Systems GRID has visualized results of their case study activities in various forms: Black and white portfolio maps produced with simple laser printer equipment, large format plots and highly communicative slides. The visualization material has been used in ICIMOD's promotional activities, for example in a MENRIS fold-out brochure (ICIMOD 1991d), and MENRIS staff has also been introduced on basic concepts of cartography and visual communication.

GRID's application cases on Nepal have also found their way into ICIMOD's curriculum development as well as to the UNITAR training courses in Bangkok 1990 and Kathmandu

1991. The first training held at AIT Bangkok from May to August 1990 was attended by eight ICIMOD professionals and is documented by UNITAR 1990b. Being the first of its kind, the course was not without organizational problems, and the expectations of the trainees turned out to be too high to be met by a four-month introductory program. Also the contents of the training had not been harmonized well enough between UNITAR, AIT, ICIMOD and GRID. The published results on 'Geographic Information Systems (GIS) for Agro-Ecological Zoning and Zonal Resource Management with a Mountain Perspective' and 'Spatial Planning in Hill Districts: A Case Study of Sindhupalchok District in Nepal' (UNITAR 1990b) show nevertheless significant achievements, considering that the trainees had virtually no previous exposure to GIS technology.

More serious was the fact that due to the change in the hardware design from IBM RT to IBM RISC workstations, no GIS had been installed in Kathmandu until June 1991, the trainees had effectively to return to nothing. The time without system was nevertheless bridged positively: Contacts have been established to other agencies interested in GIS in Nepal to design joint case studies, and MENRIS also started with the compilation of its own three-volume GIS training curriculum for research professionals, digitizers and decision-makers (ICIMOD 1991c).

A first PC-based ARC/INFO was finally installed at ICIMOD in early 1991, I mark this as the start of the **technology transfer** phase. Depending on point of view, all of MENRIS' development activities are in a way related to technology transfer. I use this term in a narrow sense, for the short period of physical transfer, installation and introduction of the hardware and software. The center's cartographers have been trained on this system to be able to meet data input and visualization demands of the group. The Bagmati zone database developed at GRID was also transferred to ICIMOD in February 1991 and introduced to MENRIS staff.

ODA's subcontractor Scott, Wilson and Kirkpatrick (SWK) installed their PC-based (Apricot) system with GIST software at ICIMOD and provided introductory training to MENRIS, principally in applications of remote sensing. One ICIMOD system's engineer has undergone additional training in England. Attempts have been made to harmonize the two platforms, to provide at least physical links between the systems. These, however, have so far not progressed beyond the paper with the systems installed not yet being fully integrated on a functional level. There is currently no operational interface between GIST and ARC/INFO.

With the installation of the IBM RISC workstations with ARC/INFO software in June 1991, MENRIS finally had a very powerful, state-of-the-art Geographic Information System. At this stage, certainly more computer systems than the MENRIS staff could possibly handle.

The **pilot operations** started with the first in-house two-week ARC/INFO training course provided by UNITAR and held by ESRI personnel to MENRIS staff in July - August 1991. This was also to improve the center's staff skills as trainers as the first in-house training course was soon to be held. MENRIS started working on a number of case studies to demonstrate the use of GIS to interested user groups, such as GTZ, UNDP and the National Planning Commission. These case studies were conducted in close relation with the counterpart agencies, some of which are planning to build up their own GIS capabilities. A summary is outlined in Figure 7.8:

Case Study	Cooperating Agencies
Service Center Analysis in Lalitpur	UNDP, National Planning Commission (NPC)
Agro-ecological Zonation in Bagmati	ICIMOD Program I and Program VII
Population Carrying Capacity in Dhading	GTZ, Ministry of Local Development
Mini/Micro Hydroelectrical Potential in Dhading	GTZ, Ministry of Water Resources

Figure 7.8: MENRIS Case Study Activities during Pilot Phase

In September 1991, the first UNITAR/MENRIS professional-level training course with assistance from Clark University (Worchester USA) and GRID was held in Kathmandu. For this event, the PC systems already installed had been upgraded with several IDRISI and ARC/INFO software packages, thus allowing a larger number of trainees, in total eleven, to attend the workshop. On this occasion, the curriculum developed by MENRIS was for the first time being applied: The course served the facility's staff to gain experience as trainers and through the presence of resource persons they could also improve their GIS skills. The eleven trainees originated above-all from Nepalese organizations close to the National Planning Commission (NPC) but on account of the workshop's international nature also two Chinese professionals participated. None of the students had previous exposure to GIS, and their familiarity with computers varied considerably: Only six of the eleven participants had prior experience using computers.[6]

Concluding the pilot operations, a three-day Sensitization Workshop took place in November 1991 at ICIMOD. Participating users were representatives from four ICIMOD countries, namely from Nepal, Bangladesh, China and Pakistan as well as donor agencies with interest in GIS, namely GTZ, UNDP, The World Bank, USAID, DANIDA and FINNIDA. Of the agencies involved in the MENRIS set-up ADB, UNITAR and UNEP/GRID were present. Such workshops are an integrated part on the MENRIS agenda, above-all to promote Geographic Information Systems in the region and to attract funds for future ventures of the center. As indicated earlier, handbooks for all levels of training and sensitization have been compiled by MENRIS staff to accompany their curriculum (ICIMOD 1991c).

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[6] This is another illustration of the problems GIS faces in developing countries.

7.5 Evaluation of Potential

In 1992, MENRIS entered phase 2 of its development, which can also be labeled 'implementation phase'. Despite of this transition, many of the center's operations can still be regarded as experimental. Thus, MENRIS will certainly remain open for changes, new developments will have a chance of being implemented. As a working base for my discussion I use MENRIS' proposals for its phase 2 development (ICIMOD 1991b and 1991e), complemented by knowledge gained through the interviews and my participatory involvement in the facility establishment.

The overall objectives of MENRIS have been defined as follows (ICIMOD 1991b):

- ◊ to improve environment and natural resource management and promote sustainable economic growth in mountain countries through facilitating the solution of common problems and ensuring the communication of results on a compatible GIS platform

- ◊ to assist in the promotion of information exchange between interested participating countries of ICIMOD (IPCs) utilizing GIS technology

- ◊ to act as a clearing house for utilization of existing knowledge in mountain resource management for agencies involved in mountain development.

The formulation of these broader objectives is rather nebulous, particularly with respect to the connecting link between the broader environmental goals and GIS technology. It is quite difficult to interpret these objectives regarding their meaning to GIS, all of them seem to be related to communication: 'communication of results', 'information exchange' and 'clearing house for utilization of existing knowledge' are clear statements pointing in this direction. The first objective has also a problem-solving component: 'Facilitating the solution of common problems'. What exactly this has to do with GIS technology, however, remains in the dark, as already indicated above.

For clarification one has to go further back to the MoU between ICIMOD and ADB (ADB 1989). Here, the main objective has above-all been demonstration and technology-transfer but also communication-oriented:

- ◊ The main objective of the Regional Technical Assistance is to assist ICIMOD to demonstrate how the establishment of a Mountain Environmental and Natural Resources Information Center (MENRIC) could contribute effectively to the organization of an integrated approach to development and environmental management in mountain areas.

The link between GIS and the broader environmental goals have been much more clearly formulated than in the more recent objectives outlined above (ADB 1989):

- ◊ This will be accomplished by assembling, managing and dissemination environment and natural resources data and information, utilizing a Geographic Center (GIS), in a form useful to decision makers and planners for formulation of integrated strategies for sustainable development in the HKH region.

Geared towards information provision to decision-makers and planners, these objectives are fully in line with my general assessment of GIS' potential and it is not quite clear to me why MENRIS has not formulated its broader objectives along similar lines. The interviews did not reveal significantly new goals, they much rather confronted me with even more ambiguity, as the following statements show: «Do the whole regional planning at superspeed» and «Improving the living standards of the people». Rather than being goals, I have to consider such declarations as 'wishful thinking'.

For the phase 1 developments – the demonstration, technology transfer and pilot operations in my terminology – the broad objectives were translated into four program goals (ICIMOD 1991b):

- ◊ Establishment of MENRIS
- ◊ Establishment of a Training Program
- ◊ Facilitate use of MENRIS
- ◊ Initiate establishment of MENRIS Network

These goals are all rather technology-centered, aiming above-all at the set-up of a GIS facility. The strategies do not render account to applications and thus to the GIS functions visualization, analysis or inventory. Here, the persons interviewed were more concrete: Most of them had initially rather high expectations in GIS analysis.[7] These had however to be scaled down as experience revealed more general problems with GIS analysis.

Concerning these institution-building goals, MENRIS is a success: A GIS facility with ten professional staff skilled in the use of the technology and with plenty of operational hardware and software has been established over a relatively short period. As a starting point for the development of a training center, a curriculum has been put forward and a three-volume training manual has also been compiled. Case studies have been conducted in collaboration with a variety of governmental and foreign aid organizations in Nepal and the regional network has at least been initiated. Concrete application results have not yet been real-

[7] For instance, it was initially envisaged to apply GIS models to find 'poverty pockets' in Bagmati zone.

ized; with a system in operation for less than a year only, it is, however premature to expect anything more. Neither has the facility been explicitly geared towards mountain environment and GIS, here I would expect at least a statement giving a definition of the topic, along the lines of the list displayed in Figure 7.9, which has been compiled at a workshop in Geneva by participants from various parts of the world (International Academy of Environment 1991):

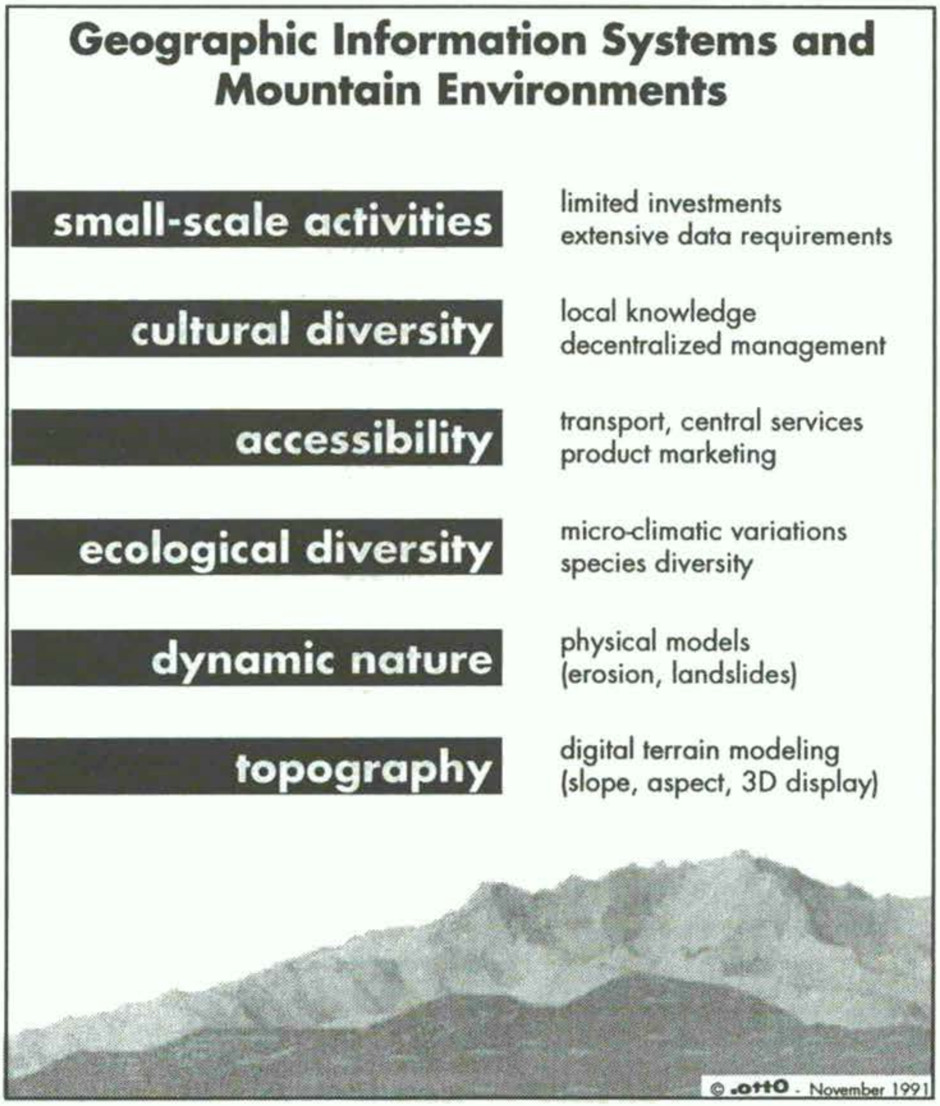

Figure 7.9: GIS and Mountain Environments
(Modified from international Academy of Environment 1991)

This list, being rather general, should be handled with care to avoid a geo-deterministic approach. For instance, economic and cultural factors not necessarily directly linked to mountain environments may be much more relevant for environmental planning. Nevertheless, since MENRIS has mountain environments in its name I would expect something like the above-outlined definition among the facility's objectives.

Without delay, MENRIS has moved into Phase II of its development, covering the period 1992-1995. The broader goals discussed above still have validity and they have been translated into the following concrete program strategies to facilitate phase 2 implementation (ICIMOD 1991b):

Mountain Focus GIS Training Center

◊ continue to improve training curriculum and materials aimed at three groups of audiences

◊ attract and conduct training for all agencies in Mountain development within IPCs

◊ publish training handbook after further external review for wider dissemination

MENRIS Network Establishment

◊ formalize national nodes in the interested participating countries (IPC's)

◊ provide two cycles of training to three groups in the nodal agencies

◊ conduct collaborative case studies with the agencies concerned

◊ provide necessary hardware/software compatible to MENRIS with technical backup

Resource Center

◊ through collaborative case studies gradually build up GIS data base at district level of HKHs

◊ in collaboration with international regional agencies conduct macro level studies of the Region

◊ establish MENRIS as a focal exchange point for all research on GIS on the Mountain area

◊ encourage exchange of public domain data on environment and natural resources within IPCs

◊ disseminate through a newsletter information on research, institutions, developments etc. to interested individuals, agencies and IPCs

Institution building and technology transfer thus clearly seem to dominate MENRIS' further development. For phase 2, only the strategies under 'Resource Center' point towards database creation and information and this at the Himalaya-Hindukush regional level only. While I acknowledge the importance of strong and capable institutions for GIS operations, I nevertheless miss more concrete statements about technology application: There evidently is a danger in the implementation of GIS technology without actually knowing what to do with it. A reason for this is probably ICIMOD's nature as an international institution geared more towards research and coordination than implementation. But still, also at this level the application aspects of Geographic Information Systems should not be moved too far into the background.

Discussion

Being above-all a GIS facility, I would expect MENRIS' broader objectives referring explicitly to Geographic Information Systems. Also environmental goals should be brought in conjunction with the application of the technology to emphasize that not system transfer alone, much rather their application will contribute to the solution of environmental problems. According to the model on GIS, I come up with the following alternative broader goals:

◊ *To improve environmental and natural resource management and promote sustainable economic growth in the Himalaya- Hindukush region, Geographic Information Systems will be applied to meet the environmental information needs of politicians, planners and the general public.*

◊ *Data on relevant environmental problems of the region at various levels and resolutions would be collected, analyzed and put in a highly communicative form for dissemination. A GIS network could be set-up to promote information exchange between interested countries, organizations and individuals in the Himalaya-Hindukush region.*

◊ *ICIMOD/MENRIS could act as the central node of this regional GIS network and serve users' needs concerning environmental information and technical know-how. Mountain environments are considered as the principal thematic issue of the center's operations.*

The regional aspects – applying GIS and building a network in the Himalaya-Hindukush – are considered to be more relevant than the thematical focal point of GIS and mountain environments. ICIMOD could nevertheless put for-

ward a definition of the field of GIS for mountain environments and encourage research on the topic.

The translation of these objectives into achievable strategies would above-all orient the facility towards communication, the aspect my model recognizes as the most relevant in the field of environment and development. MERNRIS' phase 2 strategies could be maintained, but in my opinion, would have to be upgraded with the following components:

- ◊ ***Network establishment:*** *Application elements, above-all concerning the dissemination of environmental information could be added to the now prevailing technology-transfer objectives of the network establishment.*
- ◊ ***Training Center:*** *The training curriculum could be streamlined towards regional and mountain-specific topics and information communication.*
- ◊ ***Information Center:*** *The resource center could be changed into an Information center with emphasis on environmental issues and hot spots in the region. Data collection activities would concentrate on coordination and harmonization and the set-up of a meta-database, only macro-level data would be held by the center in a comprehensive manner.*
- ◊ ***Nepal National GIS node:*** *This could be a new aspect of MENRIS development: Taking into account pragmatical constraints and the wise use of available GIS resources in the country, ICIMOD could temporarily take over certain functions – for instance training – of a Nepal national GIS center. This, however, only until such a center is formally being institutionalized under a Nepalese governmental agency.*

Because of ICIMOD's nature as a 'facilitator of development' rather than an executing agency, technology transfer goals would also in this revised version take a rather prominent position. In my opinion, the center should nevertheless create adequate space for GIS applications. The above-outlined elements will be discussed in-depth under 'Conditions' below.

7.6 Evaluation of Conditions

In my study I am primarily interested in the application of GIS technology in conjunction with environmental decision-making. But ICIMOD is strictly speaking not a political or executing organization. Thus, I will have to include the broader spectrum of MENRIS' activities into my deliberations, above-all the on-going joint projects with implementing organizations in Nepal. After all, MENRIS is currently the only larger GIS installation in Nepal and thus is *de facto* a part of the application of GIS in the Nepalese environmental planning process. What the Himalaya-Hindukush region concerns, it is for the moment too early to judge the facility's impacts, thus, I will here mainly concentrate on Nepal.

The conditions for establishing GIS technology in the country are positive. On a general level, the National Conservation Strategy points out various elements concerning environmental information, which I also can interpret as statements affirming the need for GIS. In addition, the technology has already set foot in Nepal with various organizations having been exposed to it and some efforts to create a National GIS center have also been made. Computers are generally present in the country, the information technology base looks, at least in the Kathmandu valley, encouraging. In the study 'Review of Current Resources for the Establishment of a Geographic Information System in Nepal' also PADCO (1991) sees positive starting points: Dedicated professionals, operational computer facilities – above-all the National Computer Center – and large volumes of available data. Again, there are of course the usual constraints of developing countries associated to day-to-day problems running computers, such as power cuts, inadequate maintenance, lack of personnel and so on, but in Kathmandu these do not surpass the usual. In the periphery, for instance in district headquarters, however, the conditions are much less favorable.

Institutional Issues

I first look at the GIS lab unit, in this case the Mountain Environment Natural Resources Information System (MENRIS) installation at ICIMOD. Although the unit has only very recently been created, it cannot be considered as completely new, since it has grown from an existing institution making use of resources already in place. Initially, there were discussions whether it was appropriate to give ICIMOD'S GIS unit a name on its own and thus add to the already existing confusion with acronyms in international development.

As outlined earlier, the facility becoming fully operational in relatively short time is a success. The main reason for this is above-all MENRIS management which has from the beginning taken the initiative and pursued the program in a straightforward manner, developing achievable strategies and controlling the activities as much as possible. Adequate funds locally managed, competent technical assistance, existing personnel and computer resources were the pillars for the success of MENRIS. Mainly due to these successes, the Phase II proposal envisages no significant changes in the facility's internal organization.

Externally, the situation is more complex. Here, we have to look at the center's placement both within Nepal as well as within the Himalaya-Hindukush region.

Within Nepal, contacts have been established to governmental organizations, NGOs as well as foreign aid agencies mainly through training and case study activities. Regarding environmental decision-making on a national level, relevant in the country today is the National Planning Commission, whose role has been outlined earlier. MENRIS has cooperated with NPC through the UNDP project 'Strengthening Decentralized Planning in Nepal' in the 'Service Center Analysis in Lalitpur' study. Also, the results of other case studies, for instance the agro-ecological zonation of Bagmati zone, will be of relevance to the Planning Commission.[8] Links have also been established to other governmental organizations, such as the Topographical Survey Branch or the Ministry of Forestry and Agriculture.

Of the foreign donor organizations, particularly GTZ plays a vital role in MENRIS' development, through the financing of personnel, case study activities and the purchase of software. To others, DANIDA, FINNIDA and the EEC, at least preliminary contacts have been taken up.

Towards the establishment of a national GIS of Nepal, various efforts have been made, as outlined earlier. MENRIS has a clear stake as a training center, as also outlined by PADCO (1992). Sensitization work has already been conducted and persons associated with the NPC and government ministries have been trained at ICIMOD. Thus, the facility will continue to play a prominent role as a resource in the country. In the context of setting up a Nepal national GIS center it will be important to clearly define ICIMOD's role and position.

Concerning a policy-level GIS umbrella in the country, a national steering committee has been proposed by PADCO (1991), mainly to avoid fragmentation and duplication in governmental and aid organization. Today, this has partially materialized on an *ad hoc* basis in the form of a national GIS interest group under the NPC, above-all to harmonize future GIS projects. PADCO (1992) has recommended to institutionalize this group. A GIS user's group comparable to the NCS core group discussed earlier in this chapter does not yet exist in Nepal. Such a body will in my opinion, however, be quite important for establishing a GIS network in the country.

An illustration of the envisioned international MENRIS network is displayed in Figure 7.10, modified from ICIMOD 1991b. Main links will be with the ICIMOD participating countries (IPC network), the international community through UNEP/GRID and UNITAR (UN network) and to institutions operating in other mountain areas, such as the Alps or the Andes (Mountain network). These networks are currently not functional at all levels. For instance, the IPC member country network connections are in most cases just token units or at a very preliminary stage. Among the first IPC countries to transfer GIS technology are, besides Nepal, China, Bhutan and Bangladesh. Typically, technology transfer from MENRIS will proceed in various stages with training at ICIMOD, application case studies, transfer of GIS hardware and software to a designated institution in the country and local follow-up in training and consulting. It is not quite clear to me how technology transfer from Nepal to

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[8] Because NEPPA (see the discussions earlier in this chapter), the designated environmental ministry, is not yet operational, the NPC still has to be considered as the most relevant environmental policy body in Nepal.

countries with well developed information technology and GIS infrastructure, like India and China, will function. Here, MENRIS will certainly have to work on regional applications as well as on their GIS and mountain environments agenda to have something attractive and unique to offer.

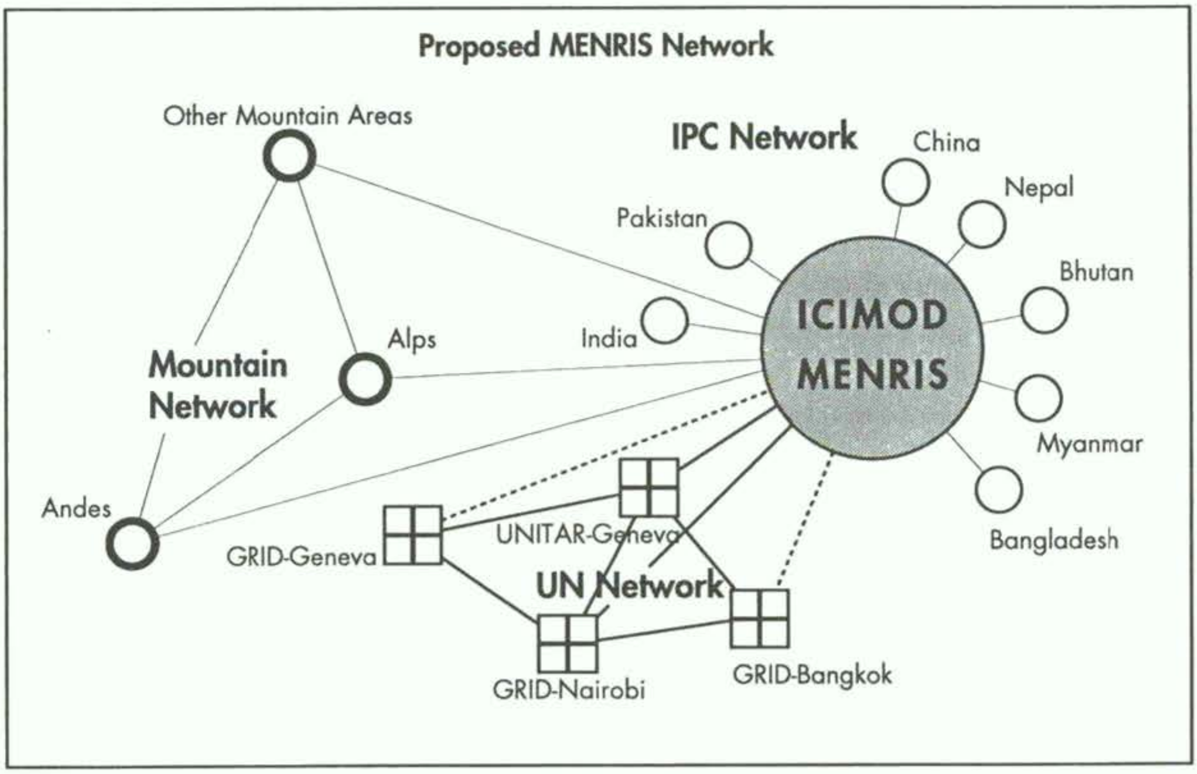

Figure 7.10: The MENRIS Network (Modified from ICIMOD 1991b)

Already well established are the connections to international organizations like UNEP/GRID and UNITAR. Common activities being training and the application consulting of phase 1 and cooperation on a Himalaya-Hindukush database and further training in phase 2. Not much has been happening with the mountain network so far, in my opinion, this is also the area where ICIMOD will have to put forward a scientific base as a starting point. A 'Symposium on High-Mountain Remote Sensing Cartography' held in Schladming, Austria in 1990 with MENRIS participation may be considered as a starting point.

Discussion

MENRIS' internal organization comes close to my model GIS lab, it has also proved to be quite efficient. Even with multiple tasks to be handled by the center, such as training, information and network establishment I would not regard internal organizational changes, for instance subdividing the facility into specialized branches, as meaningful.

Concerning the institutional situation in Nepal, MENRIS should in my opinion take an active part in the set-up of the National Nepalese GIS. The facility could, for instance be attributed the status of a Nepalese GIS training and research node. Such an experimental National GIS center would give national bodies the opportunity to get exposed and experiment with GIS technology and time to constitute themselves. Available GIS equipment and know-how would thus be fully utilized and potentially inefficient competitive situations could be avoided. Relative open access should also be guaranteed at ICIMOD. Principal tasks of this node would be sensitization and training and research as well as the processing and dissemination of environmental information on Nepal. On the long run, a national GIS center should certainly be placed in a true Nepalese organization, for instance under the NPC, or, for environmental purposes under NEPPA.

The international networks could be upgraded with application tasks to become less focused on technology transfer. For instance, environmental information could be exchanged through the IPC network to create 'state of the environment' studies on the Himalaya-Hindukush region on a regular basis. The mountain network could above-all cover scientific aspects of mountain environments and GIS.

Funding Issues

With an overall funding of roughly US$ 1.5 million, the largest portions of which are coming from ADB (US$ 600,000), ODA (US$ 450,000) and ICIMOD (US$ 270,000) the two-year MENRIS initiation phase was adequately financed (ICIMOD 1991b). However, we have to differentiate: The ADB portion was at least partially administered or influenced by ICIMOD and MENRIS, for example the procurement of hardware and software, training as well as application development could be negotiated with ADB, UNITAR and GRID. In contrast, the ODA system has to be regarded as a hardware and software dump upon ICIMOD with only space left to direct the timing but not much of the substance. Thus, although the whole sum of US$ 1.5 million looks large, it is based on restrictions reducing the total value of the system. If ICIMOD could have disposed of all the funds, the system would probably have been built up more efficiently and streamlined more to the center's needs, and the technology set-up would be more homogenous than it is now.

The phase 2 proposal splits the financial requirements into five segments: Personnel, Operation (travel, dissemination, communication, maintenance and upgrade of hardware and software), Training (two annual cycles aimed at three groups of audiences), Network (establishment of national nodes), Resource Center (macro-level study). Including a 20% contingency, the estimated resource need is planned to be between US$ 562,000 in 1992 and US$ 1,092,000 in 1995 (ICIMOD 1991b). These estimates have to be seen as very broad, including areas not necessarily being core tasks of the center, for example the hardware requirements of designated national nodes. I do, however, support this all-encompassing approach with regard to funding because it gives a realistic picture about the real cost of the implementation of GIS technology. The funding base will be rather wide with core staff being covered by ICIMOD, training by the Swiss government through UNITAR and regional database development by UNEP/GRID. Other sources of funds are project budgets from various donors, such as GTZ or ADB. Cost recovery on a small scale base, e.g. to charge for products has not been discussed yet; I would also consider this as premature.

Discussion

I consider MENRIS' financial base as adequate to the tasks, particularly since the facility is very initiative and capable in raising and managing funds.

Professional Issues

The current core staff of MENRIS is displayed in Figure 7.11. This set-up has been constant over the last year, and it is not planned to be changed for phase 2 of the system's development.

Function (Nationality)	Background	GIS training and experience
Coordinator (Nepal)	Computer Applications	
Analyst (Nepal)	Statistics	UNITAR/AIT 1990, 1991
Analyst (India)	Civil Engineer	ditto
Analyst (Myanmar)	Environmental Engineer	ditto
Analyst (Bangladesh)	Water Engineer	ditto
Analyst (Nepal)	Electronic Engineer	ditto, SWK hardware training
Analyst (Germany)	Geographer	ditto
Digitizer (Nepal)	Cartographer	on the job 1991
Digitizer (Nepal)	Cartographer	on the job 1991
Digitizer (India)	Digitizer	UNITAR/AIT 1990

Figure 7.11: MENRIS staff (status end 1991)

The MENRIS professional staff is rather technical and computer sciences-oriented and can at this stage not be regarded as very experienced in Geographic Information Systems. All of the staff acquired their GIS skills quite recently in conjunction with MENRIS set-up mainly through UNITAR and not through a formal GIS education. This lack of expertise manifests itself above-all in conjunction with the judgment of the requirements and constraints of GIS application projects, which is quite relevant when setting up joint studies with other agencies and can lead to an over-optimistic promotion of the technology. This lack of expertise has also been noted by PADCO (1991). The staff composition is international, with the exception of the GTZ person, all originating from the ICIMOD region. It has however to be recognized, that the non-Nepali portion is international only in terms of the staff's citizenship with little relevant connections to the respective home countries.

The center is well staffed with computer specialists, the day-to-day operation of the quite large facility thus poses no problems. Positive is also the integration of cartographers in the operations, knowledge regarding communication of environmental information is thus already present at the facility. With the publication section of ICIMOD, resources potentially relevant to the GIS facility are also available in-house. Scientists with various backgrounds working in other departments of ICIMOD, above-all the Bagmati task force team, have provided input to MENRIS application developments. These contacts have quite clearly demonstrated how delicate the introduction of GIS into a well established institution can be: Through the rather positivistic sensitization on the technology's potential the expectations of the ICIMOD scientists outside MENRIS were initially much greater than after the first hands-on experiences. The potential to alienate some scientists from using GIS was always present during this phase.

The phase 2 proposal foresees no increase in the number of staff, it is however well possible that through project activities MENRIS will be upgraded by external personnel, as it is already the case with the professional from GTZ.

Discussion

In my opinion, GIS experience is a rather crucial element for the facility's future endeavors. Although it is foreseen that the present staff acquire more knowledge on the long run, I would strongly recommend the presence of one or more experienced GIS professionals at the facility for at least the next two years. As envisaged in my model, these analysts could serve as resource persons and provide GIS-specific inputs to all day-to-day project and training activities.

To fulfill the information dissemination tasks, more communication-oriented staff – experienced in computer graphics, desktop publishing and the like – could be attached to the facility. In addition, the links to ICIMOD's publication department could be strengthened considerably through more cooperative projects.

A special program could also be developed to integrate scientists, above-all the ones present at ICIMOD into the GIS operations. To come up with useful GIS applications it would be relevant to have people with scientific rather than technical backgrounds integrated in the activities, primarily to avoid a technology-driven application approach.

Training Issues

The main training events concerning MENRIS, as outlined above have all been in the form of short workshops. Training on-the-job or formal GIS education at universities have so far not played an important role in the facility's development.

I agree with UNITAR that all training efforts have to be seen as a continuum much rather than isolated events (Gold 1992). From this point of view, the problems with the first Bangkok training course are probably balanced in the light of the subsequent training workshops in Kathmandu, particularly because the same people have been involved. One has nevertheless to be careful not to take a short, intensive and successful training course as an indicator: Experience has shown that momentum can fade very quickly *in absentia* of trainers and even more so if follow-ups are lacking. Thus, over-optimism in the capabilities of the students having gone through a workshop, as at times expressed by UNITAR, may not really serve the purpose.[9]

The contents of the training at ICIMOD, as outlined in the manuals (ICIMOD 1991c) has not really been tailored to Nepal, neither to mountain environments in general. It is rather software-driven, thus applicable anywhere in the world. UNITAR has, however, made some efforts at least to use local datasets and the organization is now in conjunction with Clark University in the process of publishing a specialized workbook on GIS and mountain environments, as I have already outlined in chapter 3.

Concerning further training, MENRIS has quite ambitious plans to become a regional training center. The phase 2 proposal (ICIMOD 1991b) envisages two cycles of training for each IPC, aimed at decision-makers, professionals and technicians. This program will principally be orchestrated by MENRIS, the continuation of the UNITAR training is however also secured through a five-year MoU between ICIMOD and UNITAR and sponsored by the Swiss government.

Discussion

Training is the field which on the long run could develop in one of MENRIS' key activities. The following considerations are intended to optimize future training efforts:

◊ *Resource persons present at the facility (indicated under professional issues) could dedicate a large portion of their time to provide on-the-job training for MENRIS personnel and staff working temporarily at the facility. This idea of permanent resource personnel could also be pursued in conjunction with the node establishments in the ICIMOD countries.*

◊ *Training in general and the training manuals in particular could focus more on Himalaya-Hindukush topics and mountain environments than*

[9] Here, I do, however, have to acknowledge the fact that in an international organization context language usually is quite positivistic and flowery and can not always be taken at face value.

they have so far. Communication – visualization, publishing, information dissemination – would have to become an integrative part of training.

◊ *In the continuation of their short-term training workshops, UNITAR could focus more on local and mountain specific topics and add a scientific component to the program by making use of experienced resource persons with special skills concerning the application of GIS in the region.*

◊ *Formal GIS education of staff (scholarships) and the assistance of universities (Tribhuvan University in the case of Nepal) in curriculum development could be integrated into MENRIS' training activities.*

Technical Issues

The MENRIS GIS hard- and software installation is rather large and state-of-the-art, with no vital components lacking. The system consists of a workstation-based data processing unit (2 IBM RISC 6000 workstations with ARC/INFO and SPANS software) and a quite large number of PC-systems (5 IBM PS/2 and 6 Apricot 386 with ARC/INFO, IDRISI and GIST software) for training, digitizing and image processing. Adequate graphical output and input devices, such as plotters and digitizers are also installed at the facility. The systems are connected through a network, on the operational level, however, the connectivity depends on the GIS software and is not guaranteed in all instances. The danger of fragmentation, i.e. weakening the facility by overloading it with systems, is evident. In my opinion, the upper level of software packages and computer systems installed has been reached. The maintenance of these systems has not caused problems so far, mainly due to MENRIS' excellent computer specialists. In addition, ICIMOD as an international organization has no difficulties purchasing computer equipment abroad.

Discussion

ICIMOD is well stocked with GIS devices; harmonization and consolidation rather than upgrades will thus be the most pressing issues in the near future. The MENRIS system set-up could be streamlined and obsolete components be phased out in order not to infringe with valuable personnel resources.

Data Issues

During phase 1 of its development MENRIS has largely relied on the Bagmati zone data acquired by GRID. The various bases have been outlined above, examples are shown in Figure 7.7 and 7.12. There are now efforts underway to consolidate the data holdings; the need to cover the whole of Nepal with a Bagmati-like database has already been articulated. The case study activities have also uncovered new data needs, mainly at scales much larger than the already existing digital databases, 1:50,000 and larger. Such large-scale data gathering activities should, in my opinion, however, be left to special projects.

Considering data, the phase 2 program strategies aim above-all at a district-level base, covering the whole Himalaya-Hindukush region. Besides this quite ambitious goal, no other references to data are made in the proposal. Since data are crucial to the operation of GIS I expect more detailed strategies in this domain, otherwise an opportunistic data gathering approach may be pursued, which would only enhance the already existing problems of fragmentation and duplication.

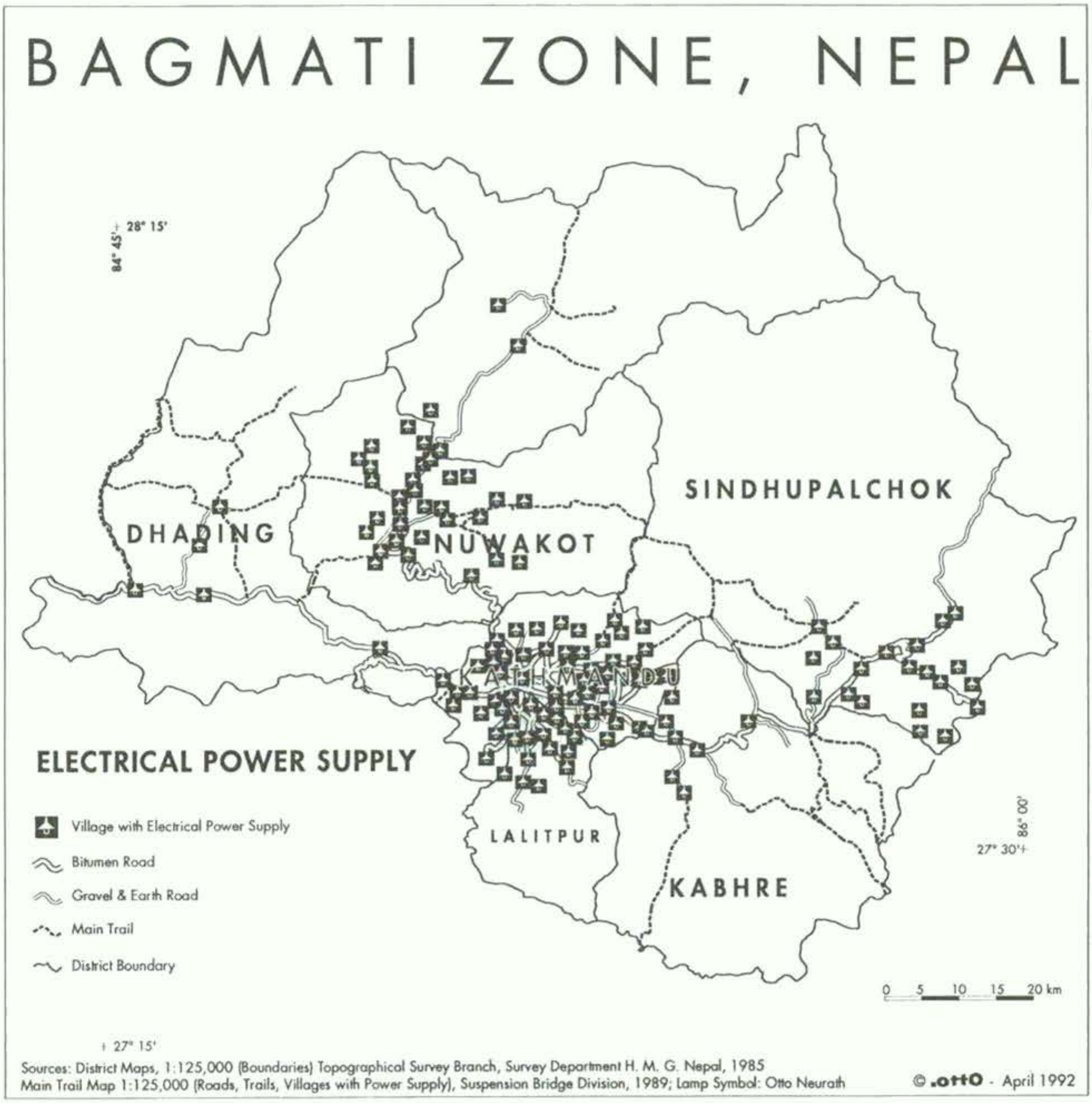

Figure 7.12: Bagmati Zone – Electrical Power Supply

Discussion

Due to its regional, national and even sub-national information mandates, MENRIS should in my opinion streamline its activities in the data domain. I consider the following points of thought as relevant for the facility's data operations:

- *Rather than actually hold large amounts of data MENRIS could focus on information on available data through the creation of a meta database on the region. Thus, the institution would also be in a position to coordinate and harmonize on-going data gathering activities.*

- *The center could build up a small-scale base of regional, natural resources, demographic and other datasets covering the whole Himalaya-Hindukush, this primarily to strengthen its regional application potential.*

- *The center could make resources available to gather timely environmental data on environmental hot spots in an unbueraucratic manner upon demand. This would above-all be required to be able to summarize, visualize and disseminate actual and relevant environmental information.*

- *In conjunction with the Nepal National GIS node to be, efforts could be undertaken to acquire country-wide digital coverage of the principal resource datasets (LRMP, Main trails etc.) in the style of the Bagmati Zone database (UNEP/GRID 1991b), complemented with recent updates of land cover or a high resolution digital terrain model.*

7.7 Conclusions

The review of MENRIS has shown that the key to the successful creation of a GIS facility in a developing country is above-all local initiative coupled with adequate funds managed in-country. It is impressive how in a relatively short period a quite capable GIS center has been built up at ICIMOD.

But, this successful technology transfer also calls for applications of the technology in mountain environments. And this is the aspect where MENRIS now will have to concentrate: Define the application environment and use the tool concretely for data collection, analysis and above-all information tasks regarding environmental issues in the region. This will be important to give the whole program distinct contents.

Due to ICIMOD's regional mandate, technology transfer will still figure very prominently on the MENRIS agenda, here the center will also have to take a lead concerning Nepal, for which the conditions look quite positive at the moment.

8 Evaluation and Outlook

8.1 Evaluation

The project's main objective and motivation has been the comprehensive assessment of Geographic Information Systems applied in the context of the establishment of national sustainable development strategies in developing countries. As outlined in the introduction, intermediate goals have been the theoretical background evaluation, the construction of a model on GIS for environment and development and the assessment of case studies in Uganda and Nepal. In addition, the adaptation and application of Participatory Action Research principles can be regarded as the underlying methodological objective.

I now want to evaluate in a generalized, however personal manner to what degree these objectives have been met and point at areas where future research efforts will have to concentrate:

Overall

The research topic has turned out to be even more complex and volatile than initially assumed. Conflict areas are ubiquitous with dualisms between the technology and its applications, between developed and developing countries and between theory and practice.

Here, it turned out that the most relevant gap today is between the technology and its applications: The issue is to create GIS applications with an impact on the environment. While many approaches aim at technical solutions we tend to see the technology's main potential in a political and educational context. However, a tremendous amount of creative and innovative work needs to be done here to meet some of the high expectations put into GIS. The differences between developed and developing countries, being still minimal regarding the tool's potential, are quite pronounced on the conditions-side: Above-all the financial dependency from donors to operate the rather expensive technology poses problems for the technology's sustainability in a country. This particularly applies to potentially very significant applications of GIS at the local level. Developments in computer technology – the systems will become more user-friendly and cheaper – may bring positive changes. This should, however, not be used as an argument to promote the technology in areas where its sustainability is questionable. The third dualism, between theory and practice, is probably the area with the main potential for improvements, as I will subsequently outline.

Methodology

The Participatory Action Research approach proved to be very useful to the research on a technology transfer issue. GIS as an extremely complex, relatively novel and very application-oriented field requires theoretical work, exploration and longer-term participation. I believe that some of the above-outlined dualisms and conflict areas cannot be adequately approached by traditional means, such as University-based research or consulting: PAR as a strategy seems to offer a viable synthesis.

My work, however, has also revealed methodological limits of this 'in between' approach: For a single research person, Participatory Action Research applied in the GIS domain may be too all-encompassing. Even though I have received much active support by various groups and individuals in the field as well as 'back home' and I also had the opportunity to participate in projects on a longer-term basis, in many areas of research, I had to remain at the surface. This is primarily due to the interdisciplinarity of the field, which certainly requires team efforts to be approached more profoundly. At times, I also found myself pushed back into the role of a consultant, expected to present readily available solutions. A role that I deliberately tried to avoid by choosing a participatory methodology. Here, traditional mechanisms in the development domain seem to be still quite strong, which, in my opinion will have to be overcome to conduct genuinely participatory work.

Future research in the field will have to concentrate even more on interdisciplinary approaches and team efforts. Concerning the increasingly complex environmental problems, it will be imperative to find ways to conduct research in teams involving multiple organizations of different types. Here, we can perceive GIS as a pivotal tool, around which interdisciplinary research can evolve; networking in the research domain. It remains however to be seen how universities and international organizations cope with such future coordination demands in a highly application-oriented field.

Background

In the background part, I have presented a general picture of where to place GIS in a broader environment and development context. By outlining the frame to the research subject, I was able to demonstrate how broad the area surrounding the field of GIS really is and to move out of a purely technological frame. For the creation of this synthesis, I could however not pursue some interesting lines of thought more profoundly, thus the discussions are at times only scratching the surface. Particularly the broader impacts of the technology on politics and society will require more in-depth analysis, and probably are the most relevant future research areas concerning the application of GIS technology.

Model

The transfer of GIS technology, also to the national, policy-building level will certainly increase in the years to come: I consider the conceptual model as a framework for implementing GIS in developing countries, to remove uncertainties in the field and maybe lead to useful applications of the tool. As indicated earlier, the model is not a simple prescription easy to follow, it much rather represents a collection of concepts and guidelines on how the technology should be used to have an impact on the environment in developing countries. The model recognizes above-all the political and educational nature of Geographic Information Systems, thus putting the communication of environmental information at the center. The technology's networking potential, which in more traditional GIS research approaches is often neglected, also assumes central importance. The model clearly acknowledges existing limits of GIS concerning the handling of uncertainties and error, rendering the technology far from being objective or neutral and thus also weakening the technology's analytical potential considerably. My notion of GIS being an advertising instrument may be strong, is however an extremely relevant aspect to judge the technology's potential impacts on the environment in developing countries.

The model is quite general, many areas, for instance the institutional and the training issues would deserve a more profound discussion. With my objective to present a holistic view of the field – a synthesis – this proved however to be impossible. These are certainly aspects where a more interdisciplinary approach within a team of participating researchers would bring improvements. The model is also a product of its time: Having been derived in an action-based process in a field undergoing tremendous changes, it will inevitably need to be updated.

Case Studies

The case studies analyzed in the empirical part of the project still have to be considered as experimental. It may thus be premature to conduct a rigid evaluation at this stage of developments, on the other hand, the facilities are now still open for changes. The facts, opinions and discussions presented on the GIS installations in Nepal and Uganda are above-all of relevance to the organizations and persons actively involved with these case studies. Some of my findings have already found their way into the GIS facilities analyzed. The presentation of the case histories, outlining potential proceedings, as well as mistakes to be avoided, can also be of use to practitioners anywhere working on similar projects beyond Nepal and Uganda. These evaluations have, however, to be considered as the shortest-living part of my work: As the field in general, also the facilities in Uganda and Nepal will be developing rapidly, five years from now we may meet a completely altered picture.

Probably the most striking empirical observation is the fact that both facilities are putting more emphasis on technology-related issues – sensitization and GIS promotion – rather than conducting relevant applications. Despite the fact that the communication of environmental information figures prominently on the agendas of both facilities, astonishingly little has happened in this sector yet. One reason for this is certainly the novelty of the technology as well as the facilities discussed above. But on the other hand, it may already be seen as an indicator that meaningful applications in the environmental domain are not at all as easily conducted as often assumed. Signs, that the technology is currently being oversold are ubiquitous: Particularly the interviews revealed expectations beyond any achievable level, which we could only label as 'wishful thinking'. Here, the GIS centers will have to make great efforts to come up with meaningful application projects to play an active part in the environmental information domain and not just repeat the party lines of the GIS vendors.

It would not be very meaningful to compare the GIS facilities in Uganda and Nepal one-to-one, as it was also never my goal. One aspect, however, the fund management, reveals some striking differences we consider worthwhile repeating here: ICIMOD and MENRIS were from the beginning in a position to manage a considerable portion of the funds themselves and could therefore develop enough initiative for the set-up of a quite impressive GIS facility in a relatively short time period. In contrast, NEIC has never been in a similar position with finances having been controlled by outside institutions during the whole pilot operations. To some extent because of this funding situation NEIC never really managed to get its GIS operations going beyond a modest level. Although it has to be acknowledged that other elements, such as the total amount of project funds and averse operational conditions contributed as well to this unfortunate situation. Generalized as this brief excurse on funds is, it nevertheless bears some truth: As also outlined in the model, local fund management has to be considered as one of the keys to develop local initiative and with it successful and sustainable GIS installations.

Overall, and this has also been my very first motivation to conduct the research on GIS for environment and development, I believe having made a contribution to bridge the gap between theory and practice; between GIS technology and its applications; and, also to the adaptation and application of participatory action research science.

8.2 Outlook

Taking my research as a starting point, I now want to attempt to venture into the future and draw a sketch of GIS for environment and development in the years to come:

The environment will undoubtedly remain a central issue in developing countries. The implementation of sustainable development strategies at the national – and on the long run even more relevant – at the local level will increasingly be pursued. Such longer-term policy formulation efforts will create a continuing demand of environmental information.

In my opinion, also GIS technology will be increasingly applied in the Third World, the question is on how and where. As indicated earlier, due to progress in computer technology, future GIS will have much greater capacities at lower prices than today's systems. They will also be more user-friendly and completely integrated with other components of information technology. These new developments will move the tool much deeper into the various application fields; we will witness a development from experimental to commonplace. Thus, GIS as a subject may even disappear, being submerged in the information domain in general, or, being used as an everyday tool in highly specialized fields.

The decentralized, local use of the technology will certainly grow in importance. The role of a National Environmental Information Center will with this proliferation of GIS be upgraded, mainly with regard to coordination, information and meta database developments. The tool's networking capabilities will remain relevant, they will however be shifted from the technological to the application and the data domain. By the integration of GIS into general information systems, networking will probably include an even wider group of organizations and individuals than today: The mass media and educational institutions will become increasingly important as recipients of information. This as an answer to the question on the general nature of GIS networking I have posed in chapter 4.

The population's awareness of environmental problems will be much more pronounced than it is today, certainly also due to the increased use of information technology, including GIS. This again, may lead to an increased involvement of individuals in political processes regarding the environment and give incentives for environmentally sound resource use. And this may be a starting point for sustainable development.

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Appendix: Questionnaire

I. Evaluation of Potential

1. General

What are the broader objectives of the GIS site regarding environment and development?

Throughout our project we use a four stage GIS model consisting of

- Inventory
- Analysis
- Visualization
- Networking

Your understanding of these terms with regard to facility / project?

Are there additional tasks not covered by this model?

2. Inventory

What are the inventory goals of the GIS facility / project ?

What are the primary data gathering activities?

Sources?

Methods?

Resources?

Have links to large scale future data collection activities (census, base mapping) been taken up or planned?

What secondary data are being integrated into the GIS?

Type	Coverage/Scale	Source	Resources
Maps			
Statistics			
Others			

What is the scope of the physical data entry (digitizing)?

Resources (past-present-future)?

Could the facility draw from existing databases?

3. Analysis

Have spatial models been applied?

- concrete applications
- coverage
- complexity

What potential is attributed to GIS analysis?

- examples

4. Visualization

What are the output products created by the facility/project?

form	contents	weight
user-tailored base maps		
analytical graphics		
illustrative graphics		
highly communicative visuals		
others		

Graphical Analysis

Are these concepts known and applicable in specific situation?

5. Information Use and Networking

Who is using what information for what purpose?

user	information	purpose
self (facility)		
politicians (level)		
planners (level)		
scientists		
NGO's		
international organizations		
media		
'public'		
others		

User's response (readability, availability, usefulness)?

Have the users explicitly been identified and contacted?

Other systems

Are there other GIS sites in the country?

Are these integrated in a national concept?

What is the site's function in relation to other systems?

II. Evaluation of Conditions

1. Organizational Issues

Organizational flow chart of the installation

Position

Why has the installation been positioned as it is?

Advantages/Disadvantages of position, possible improvements?

Degree of 'centrality'

Exposure

How well known is the GIS in the country?

What activities are undertaken to promote the center?

Does the facility have coordinating and catalyzing functions?

Access - Accessibility

Access to decision-makers?

Channels?

Positive?

How accessible is the GIS for the various groups outside?

Access Procedures?

Cost?

Users groups

2. Funding Issues

What	who	amount (past, present, future)
technology (HW,SW)		
operation of facility		
staff		
training		
data		

Adequacy to tasks?

Fund Management?

Cost Recovery?

How could this be achieved?

Comments

3. Professional Issues

Diagram of current staff and their professional background

Evaluation Matrix

skills/positions	tasks	background	status
science-oriented analysts			
communication specialists			
technical specialists			
foreign staff			

Explanations:

4. Training Issues

Evaluation Matrix

topic	objectives	status
Contents		
technology		
applications		
Form		
sensitization		
courses		
on-the-job		
formal - institution building		

What is the training potential in-country outside the facility?

Comments:

5. Technology Issues

Hardware and Software configuration (actual - desired -diagram):

Is the configuration adequate to the tasks?

- Availability of hardware and software in general terms and locally?
- Maintenance?
- Peripherals and supplies?
- Graphics and Desktop Publishing?
- Power supply?

General Remarks and Visions: GIS in the country in five or ten years, function of the facility etc.

Curriculum Vitae

Otto Gaudenz SIMONETT von Andeer und Lohn (GR)

Ich wurde am 29. Juli 1960 in Schiers (GR) geboren. Aufgewachsen bin ich in St. Antönien, Widnau und Chur, wo ich 1980 die Kantonsschule mit der Matuität Typus C abschloss.

Von 1981 bis 1986 studierte ich Geographie (Methodische Fachrichtung) and der Universität Zürich, mit Mathematik, Petrographie, Geschichte und Geologie als Nebenfächer.

Bei folgenden Personen habe ich Vorlesungen besucht:

Geographie: Helga Besler, Kurt Brassel, Conradin Burga, Guido Dorigo, Arthur Dürst, Hans Elsasser, Peter Fitze, Gerhard Furrer, Gian Gensler, Kurt Graf, Thomas Gutermann, Harold Haefner, Klaus Itten, Haruko Kishimoto, Albert Leemann, Daniel Nüesch, Felix Renner, Percy Silva, Dieter Steiner, Pierre Walther, Urs Wiesli, Pinhas Yoeli

Geologie: Ulrich P. Büchi, Volker Dietrich, William Lowrie, Alan Geoffrey Milnes, Walter Oberholzer, John G. Ramsay, Conrad Max Schindler, Pierre Schroeter, Volkmar Trommsdorff, Rudolf Trümpy, Albert Uhr, Walter Wildi

Geschichte: Rudolf von Albertini, Carsten Goehrke, Walter Schaufelberger, Albert Wirz

Informatik: Kurt Bauknecht, Werner Bodmer, Rudolf Marty

Geobotanik: Elias Landolt

Mathematik: Hans Heiner Storrer

Das Geographiestudium habe ich im April 1986 mit der Diplomarbeit «Methoden zur Digitalisierung Geologischer Strukturen» betreut von den Professoren Kurt Brassel (Geographisches Institut der Universität Zürich) und Hans Laubscher (Geologisches Institut der Universität Basel) abgeschlossen.

Seit 1987 arbeite ich als Berater beim Umweltprogramm der Vereinten Nationen (UNEP) in Nairobi und in Genf. Diese praktische Tätigkeit hat mir auch den Anstoss dazu gegeben, die Dissertation «Geographic Information Systems for Environment and Development» bei den Professoren Kurt Brassel und Albert Leemann am Geographischen Institut der Universität Zürich in Angriff zu nehmen. Die Arbeit ist berufsbegleitend entstanden.