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Development of Geo-Information Infrastructure: Issues in the Hindu Kush-Himlayas

The major problems in data collection and sharing in the region are: lack of coordination and integration in multidisciplinary activities, lack of data, lack of quality standards, and the lack of data-sharing policies. Geo-information infrastructure (GII) is needed to improve access, sharing, integration, and use of geo-information and to support decision-making at different levels. GII provides a platform to develop information policies and institutional, technical, and economic arrangements to enhance the availability of correct, up-to-date and integrated geo-information. However, reengineering of various processes of data collection and data sharing is necessary to support GII.

Background

Natural resource management is a challenging task in the Hindu Kush-Himalayan (HKH) region as a result of poverty, marginality, inaccessibility, and limited understanding of the environment. A thorough knowledge of the resources, of their different uses and evolution, and their linkages with the surrounding environment is necessary for better integrated and sustainable management. With the advances in information technology, geo-information systems (GIS) have emerged as useful tools for decision-making in sustainable development and natural resource management. However, the potential of GIS technologies is underused in the region as a result of the isolated development of databases and absence of a proper framework for information sharing.

The economic activities of the people in the region are centred on small mountain farms. Understanding of the processes involved in these farms at the micro-level is critical for improving the living conditions of the mountain people and the mountain environment. In addition, the practices of these small farmers can aggregate to pose challenges to the tasks of environmental protection and resource management at a much larger scale. Therefore, there is a need to understand the implications and interrelationships of various processes involved in the management of natural resources - both at micro-and macro-levels. The information requirements and the flow of information within a level and between different levels in these processes should be used as a basis for data collection and a data exchange framework. The information should be relevant and easy to access at all levels. The major problems with existing information are that the knowledge of resources and its uses are insufficient; information is dispersed, heterogeneous, and inaccessible; and the available information is not sufficiently relevant in terms of continuity, reliability, and the nature of the parameters.

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ICIMOD's concern has been to strengthen the institutional setting in which decisions can be made and GIS can be used as part of a larger environmental decision-support system. The Mountain Environment and Natural Resources' Information Systems' (MENRIS) Division of ICIMOD serves as a resource centre for the HKH region for the study and application of GIS technology. These broad themes are backed up by establishing networks of nodal agencies and supporting them with hardware and software, training programmes, case studies, and projects. However, there are many challenges in the region which remain as hindrances in the application of GIS technology to the real-world problems. The situation of various factors in the region affects the performance of these activities of ICIMOD in one way or another. These are discussed in detail in the following sections.

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Comments are Welcome

Performance Issues

As the HKH region is data scarce, most activities on natural resource management are focused on the development of databases to support the management process. The efficiency and economy of data collection and the reusability of the databases will enhance the performance of such activities.

Integration of Activities

Proper understanding of the processes involved in the management of different resources is needed for an integrated and coordinated approach in dealing with the diverse issues related to mountain development. The activities on database development are being carried out on a project basis with little focus on generic uses of the data, and this has often resulted in duplication of efforts. There is a need to focus on user/discipline requirements so that the use of data can be optimised. Field-level data collection and regional database development programmes need to be designed in such a way that information can be generated at different levels of aggregation for use in decision-making at the desired level. Again, the lack of data and clear understanding of the processes in the region create difficulties in linking activities at micro-and macro-levels. A multi-level decision-support system (MLDSS) is needed to support the needs for decision-making at different levels and to integrate these activities.

Data

The lack of a consistent and reliable foundation database has been a major hindrance in the development of spatial databases on different themes. The foundation spatial data is defined as *the minimal directly observable or recordable data from which other spatial data are referenced and compiled* (NRC 1995). Geodetic control, ortho-rectified imagery, and a digital terrain model (DTM) are recommended as the critical foundation data. The complexity of mountain areas result from the high spatial variability of altitude resulting in large differences in climate, vegetation, and other natural features within short distances. The lack of a DTM has been a major drawback in the application of GIS in mountainous regions. Although there is a gradual shift to digital technology at the national mapping agencies, the data are not yet available in digital format in the region.

The present attitude of making best use of what is available may not work in the long run as the use of spatial data grows and the applications are targeted to solve real problems rather than to demonstrate the capabilities of GIS technology.

Quality Standards

The quality of the data used in GIS applications is fundamental for the validity of inferences from different analyses. However, quality assurance has been a difficult task as data are compiled from different paper maps, often using different scales and projection systems and produced in different years.

Coordination in Data Generation and Sharing

Many organisations have adopted computers and GIS technology rapidly without proper and sufficient capacity building. However, the transfer of technology should be seen as a multidimensional process which involves selection, acquisition, and appropriate adoption in the context of the political, cultural, social, and economic conditions of the receiving society (Groot et al. 1994). The investments in the technology have not resulted in the expected outputs due to the lack of the necessary data and of a favourable environment for data exchange.

Data-sharing policy - Information on geodetic references and topographic information are restricted in many parts of the region as a result of the conservative data release policies in several of the regional member countries of ICIMOD. Policy makers, users, and producers of data need to become more aware of the benefits of data sharing and policies need to be formulated to facilitate such information exchange.

Standards - Biophysical and socioeconomic data are collected according to logical classification systems. It is only possible to create databases that are useful to a large user group if certain standards exist which are accepted by the users. The standards include methods of referring to objects and of describing data content and quality, data models, and data transfer formats. There are no standards developed for the region for classification systems for themes such as land cover, land use, soil, and biodiversity, nor on matters of data quality, contents, and transfer.

Data-sharing mechanism - There are no formal networks for national or regional data sharing. Data is provided to a user by the particular organisation which holds the data as per request on an ad hoc basis. The process often requires many administrative procedures which are different in different organisations and for different users.

Cost-recovery Mechanism

The nature of digital data is different from that of other economic commodities and its pricing is even more complicated as there are no guiding policies in the region. The national mapping agencies are financed by government funds and the present prices of products are heavily subsidised (Survey Dept. 1998). The activities on geo-information generation and sharing do not have cost recovery mechanisms to ensure sustainability. There are difficulties in continuing the activities when long-term donor support is not available.

Improvement Strategies

Some strategies discussed here to overcome the constraints and drawbacks are discussed in the following, with particular reference to current developmentin the field of geo-informatics and information and communication technologies.

Integration of Multidisciplinary Expertise and Development of Multi-level Decision-support System (MLDSS)

Issues in natural resources and environmental management involve multiple disciplines, different interest groups, and many decision alternatives. Decision-making involves different processes at multiple scales. There are a set of objectives, resources, and constraints at each level and each level has its own set of priorities and scope for decision-making.

With the growing use of GIS, users should take advantage of the developments in the field of multi-level spatial decision-support system (MLSDSS). Spatial decision-support systems (SDSS) are interactive, computer-based systems designed to support users in achieving higher effectiveness while solving semi-structured spatial decision problems. With the existing expertise on the thematic disciplines and information science, an effort should be made to develop an MLSDSS for mountain-specific applications to deal with decision problems at different levels.

Exploitation of the Potentials of Information Technology

The development of new technologies in data acquisition such as *digital photogrammetry* and *automatic feature extraction* techniques should be explored for faster data acquisition since the scarcity of foundation data is a major problem in the region. Mountain areas are difficult to access and *high resolution and multispectral remote sensing techniques* would prove very useful for assessing and monitoring the natural resources in the region.

Developments in *client server* technology, *distributed computing,* and *networking* have opened new opportunities for data sharing when collaborating institutes are geographically distributed. The historic development of the *Internet* technology offers better opportunities for communication and networking. The new developments in *Internet GIS*, have opened up possibilities for disseminating data as well as GIS functionality to users through the World Wide Web (WWW). GIS users should initiate automation of the geo-information sharing process through the use of these enabling technologies. The strategy of exploiting the potentials of IT will introduce new processes in data acquisition and new services for disseminating information. This will prompt a demand for new quality standards and pricing strategies, and reengineering of the related processes.

Partnerships with Collaborating Organisations

Collaborations among the institutions in the region can become a major strategy for the successful implementation of various GIS programmes. These institutions are working on different themes related to environment and natural resource management in different political and organisational setups. Good relationships need to be developed among these institutions and they should work towards building a framework for developing standards for data collection and sharing and start developing local clearing houses. Data collected by different institutions on their respective themes and locations can be aggregated into a seamless regional database if standards are agreed upon and the activities well coordinated. This will demand more active involvement and a greater sharing of responsibilities by all the institutions concerned.

Geo-Information Infrastructure (GII)

Geo-information infrastructure has been conceived as *"the system of sources, network linkages of computer systems, standards and protocols, as well as legal and regulatory elements aimed at facilitating access and use of spatially related data from many different sources to the widest possible group of potential users at affordable costs/prices"* (Groot 1998). GII is needed to improve access, sharing, integration, and use of geo-information to support decision-making at different levels. It provides a platform to develop information policies, and institutional, technical, and economic arrangements to enhance the availability of correct, up-to-date, and integrated geo-information.

GII provides a framework that enables the potential of information technology to be exploited to achieve the goal of integration in natural resource management. However, a certain amount of reengineering is needed for the development of GII at the organisational and regional levels. This can be broadly categorised as reengineering in data acquisition and reengineering in information sharing.

Reengineering in the Data Acquisition Process

The difficulties in integrating existing data from different sources can be solved to some extent by developing a spatial reference system covering the whole region.

Spatial framework for data collection - Developing a spatial framework for data collection will mean first agreeing on the data collection units and specifications for aggregation hierarchies.

Spatial reference system - The difficulties in integrating existing data from different sources can be solved to some extent by developing a spatial reference system covering the whole region. Since the different countries have adopted their own coordinate systems, specifications for transforming the national coordinates into a regional framework are important for compiling regional databases from the local databases. One of the options is to develop specifications for transformation of local reference systems into the World Geodetic System (WGS). One major problem exists, however: projection parameters are regarded as classified information in the regional member countries.

Watersheds as data collection units - Administrative units such as districts and villages have been the basis for data collection for most existing databases. As census data are based on these administrative units, it is a convenient way to compile socioeconomic data. However, integrated area planning demands better understanding of natural processes, and a resource-based approach, using watersheds for example, is suitable for such applications. Watersheds are the natural demarcation for geo-hydrological processes and provide a spatial framework for an aggregation hierarchy using a nested approach. Watershed management units can be used to integrate activities from the smaller hydrological units to large river basins and ecoregions. Collection of data based on watersheds would ensure that the data is complete for a natural system, which may not be true if data is based on administrative units. However, the watershed approach might face problems in dealing with demographic data which have no spatial reference other than the administrative unit. Field data and re-aggregation of census data from a lower level may be necessary in such cases.

Common databases (foundation data) -The lack of availability of basic data has led to duplication of effort in data collection as well as inconsistencies in databases. It is important to develop core databases at regional and local levels which can be used by different applications at various scales. Apart from the foundation data, the other thematic data requirements for most natural resource management processes are soil, geology, meteorology, and land use/land cover. The Terrain Mapping Unit (TMU) approach could be considered as an alternative solution because it contains the inherent data related to soil and geological and lithological aspects of the terrain [Meijerink 1988]. The adoption of a combined watershed approach and TMU concept in data acquisition would provide a basis for different aggregation levels and vertical linkages between these levels.

Data model - A data model is an abstraction of the real world to fulfil the needs of a particular context. The usability of data by different contexts depends on the underlying data model. The model system should correspond to the real-world system more directly to enable use in different applications. The requirements in data content can be different for different applications. Adopting data models based on common concepts and formal modelling techniques such as the geodata model facilitates the use of data by different users for specific purposes.

Reengineering in Information Sharing

Set up a formal data-sharing mechanism - The practice of information sharing on an ad hoc basis creates problems in identifying the existing data, their sources, and the proper path to acquire them. A centralised unit for handling all spatial data exchange activities is needed to enable more structured and coordinated data sharing. Development of metadata is the first step in this direction. 'Metadata' is the comprehensive, systematic, and deductive information about the content, structure, relationships, representation, and use context of the data stored in the underlying database. Metadata are important because they document existing data holdings and facilitate data sharing and reduce the volume of large spatial data sets to a searchable size. Metadata represent a set of characteristics about the data that are normally not contained within the data themselves.

Use IT to setup a network for geo-information sharing - The development in network technology has made it possible to create linkages and easy communications between organisations that are geographically distributed. The reengineering approach proposes developing an electronic network between the various organisations involved in the use of geo-information that are willing to collaborate in sharing this information. The collaboration can work on developing or adapting international standards to suit the local environment. Use of the Internets and Intranet has become quite common in the region, and organisations can benefit from these technologies in developing a network in the field of geo-information sharing. With the developments in geo-information and communication technologies, there are possibilities for many new services that will help in networking and information sharing.

- Catalogue data service - This service would include identifying available and useful data using the metadata.
- Online geo-information request and delivery service - This service would enable users to order readily available geo-information through the Internet and will provide the down loading facility when the necessary conditions for eligibility to acquire the data are fulfilled.
- Online geo-information processing service - The developments in Internet GIS technology have made it possible to provide spatial analysis functions through the Internet. A large portion of the users in the region who do not possess GIS facilities can benefit from online geo-information processing services. This service would include the functions for spatial analyses which the user needs to perform on the data, and only the final results would be downloaded by the user.

System architecture - A conceptual system architecture for GII is shown in Figure 1 in the context of ICIMODs which is working on a *"Systematic exchange of knowledge and experiences through an organised information network"*. MENRIS could initially work as a regional clearing house, which could later be developed as a separate unit within or outside the organisation. Working closely with the ICIMOD's other thematic divisions and the collaborating institutions, MENRIS can take the responsibility of compiling and maintaining the core databases whereas the thematic divisions and the collaborating institutions would be responsible for collecting data in their respective fields.

The system consists of the internal and external environment with MENRIS as the central component. The client or the **front end** contains the graphical user interface for the WWW browser which allows the user to browse the metadata, send requests for the available services, and download the requested data and services. MENRIS plays the **central part** in the system architecture, linking the users to the

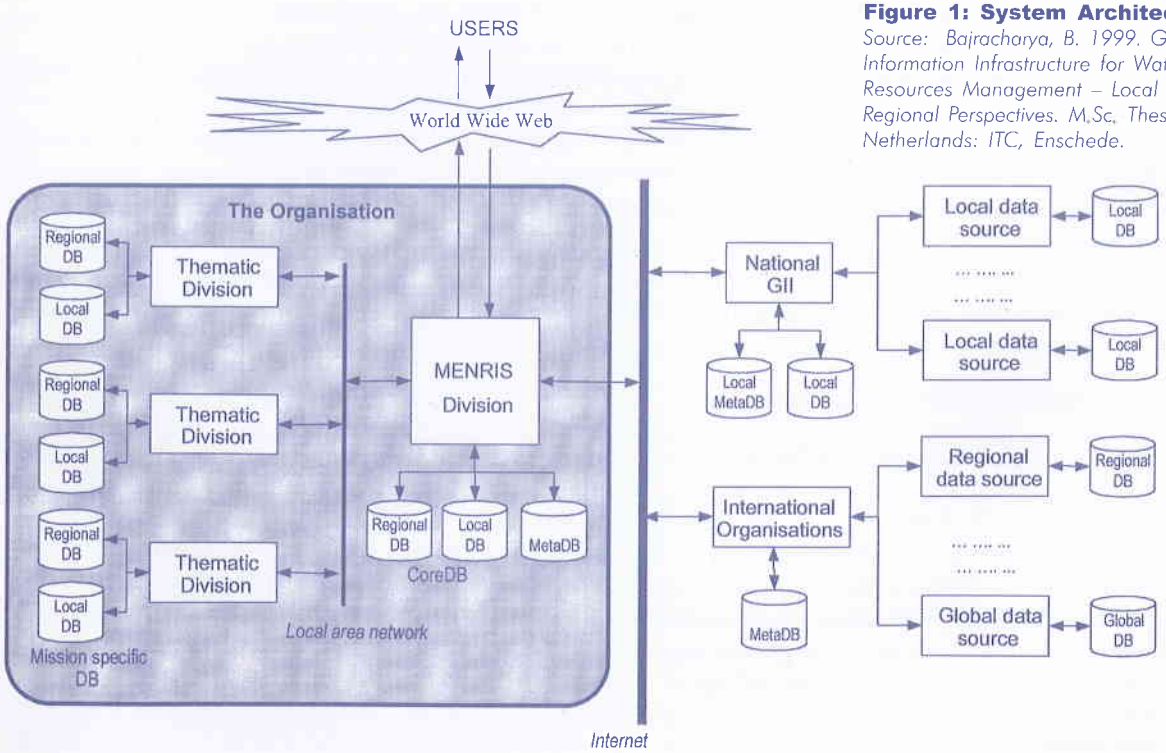

Figure 1: System Architecture
Source: Bajracharya, B. 1999. Geo-Information Infrastructure for Water Resources Management – Local and Regional Perspectives. M.Sc. Thesis, The Netherlands: ITC, Enschede.

various data sources, and providing the requested services. The central part consists of metadata server, web server, application server, and data servers to provide the core local and regional databases.The metadata server stores the information on the available databases and services at MENRIS, at the thematic divisions, and at other national and regional organisations that are accessible through the system. The web server maintains the web page on the WWW, and provides functionality for service requests and delivery through the Internet. The application server provides a data retrieval service, GIS functions, and mapping operations for the databases as required. The data servers store the core databases of the region at local and regional scales.

The thematic divisions are the users and producers of application specific data. They are linked to MENRIS through a local area network or Intranet. They contain of the data servers for local and regional databases on their related themes.

The national and regional data providers **(back end)** are the national and international institutions collaborating with ICIMOD in the task of geo-information development and sharing. These include national and regional GII centres and clearing houses that further link with other data sources. Hence, the system can be visualised as a network of networks.

Conclusion

GII is important to facilitate the sharing of data at both organisational and regional levels. However, reengineering is necessary in various processes of data collection and data sharing to support GII. The use of Internet technology for sharing geo-information, and the introduction of on-line geo-information services, will have a big impact on the application of GIS technology in the region. Development of MLDSS and GII will help in the organisational integration of various activities, between different disciplines, and at different levels. It will facilitate information flow at different decision levels, thus providing better understanding of linkages at micro and macro-scales. Partnership is crucial to the development of GII. Development of national spatial data clearing houses in the regional member countries and networking between these institutions is the foundation to the development of GII at the regional level. ICIMOD can make a major contributions towards the development of a Regional GII in the HKH by assisting the national institutions in the region to establish clearing houses and develop nationwide GIS applications.

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Established in 1983, ICIMOD is dedicated to the cause of poverty alleviation and environmental conservation in the Hindu Kush-Himalayan range of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. ICIMOD is a focal point for documentation and information exchange, training, applied research, and demonstration on a wide range of issues affecting mountain people.

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