1. INTRODUCTION

1.1 The MENRIS Programme at ICIMOD

The Hindu Kush-Himalayan (HKH) Region presents a formidable range of both ecological and development problems that have physical as well as socioeconomic dimensions. Isolated solutions have proved to be counter-productive, since most of the problems are interconnected. Development interventions must, therefore, be formulated and implemented in an integrated manner. An integrated approach to solving the problems needs a strong database. Advances in satellite image processing and computer analysis have made it possible to evolve a realistic, accurate, and uniform database. Geographic Information Systems' (GIS) technology is regarded as a good tool for adapting and disseminating knowledge and experiences from the region, as well as from various other mountain areas, and can be used as an integrated approach to development and environmental management in mountainous regions.

In 1990, the International Centre for Integrated Mountain Development (ICIMOD) established the Mountain Environment and Natural Resources' Information Service (MENRIS) as a resource centre for the HKH Region for the study and application of GIS technology. The objectives of MENRIS are (1) to improve environment and natural resource management and promote sustainable economic growth in mountainous countries, through facilitating the solution of common problems and ensuring the communication of results on a compatible GIS platform; (2) to assist in the promotion of information exchange between interested participating countries of the HKH Region using GIS technology; and (3) to act as a clearing house for existing knowledge of mountain resource management for agencies involved in mountain development.

MENRIS has placed a major emphasis on (1) the establishment of an in-house GIS and remote-sensing (RS) facility; (2) training and capacity building for application of GIS/RS in natural resources' management in each of the regional member countries, including the establishment of national GIS facilities; (3) the build-up of a digital HKH database; (4) networking among member countries, within the region and the sub-region; and (5) computer applications and development.

1.2 The Five Case Studies

MENRIS/ICIMOD, in cooperation with the Gorkha Development Project (GDP) in Nepal, a collaborative project of His Majesty's Government of Nepal and the Federal Republic of Germany, is establishing a Geographic Information System (GIS) for Gorkha District. The scope of the project is to build up a decision support system based on a GIS database with baseline data of the Gorkha District. This will enable decision-makers in Gorkha District as well as the GTZ-supported GDP to (1) better visualise existing natural resources and infrastructure, (2) integrate natural science and socioeconomic data, and (3) use the information thus gained for improved area-specific planning and programme monitoring. A database with baseline data of the Gorkha District had previously been established by MENRIS and was handed over to the GDP (Trapp 1993).

Gorkha District lies in the Western Development Region of Nepal and covers an area of about 3,642sq.km. From south to north the district stretches over a distance of about 100km; in the east-west direction, the length amounts to 60km in the northern part and to approximately 35km in the south (Map 1). The district is divided into 69 Village Development Committees (VDC) — an administrative sub-unit (Map 2) . The study area is a land of extremes - the climates range from subtropical to arctic; the physiography includes fertile alluvial plains below 500masl and very rugged, permanently snow-covered peaks. Major Himalayan ranges are part of the district, namely, Manaslu Himal, Sringi Himal, and Ganesh Himal, with altitudes of 8,162m, 7,138m, and 7,424masl respectively. Bedrock and surficial geology, climate, vegetation, and land use were used as differentiating criteria for the three physiographic regions in the district, i.e., Middle Mountains, High Mountains, and High Himalayas, their areas amounting to 28 per cent, 25 per cent, and 47 per cent respectively (LRMP 1986c).

This volume reports on five case studies and is an effort to address development problems and potentials in the agricultural sector by using GIS technology.

- The assessment of agroclimatic zones in the district was conducted in line with the theory that the zonal approach is regarded to be most suitable for planning development interventions in the agricultural sector in mountainous areas.
- Animal husbandry is an integral part of the agricultural system in Nepal, however, there is a shortage of fodder, limiting the animal productivity. The analysis of the feed situation, i.e., feed supply, feed requirements, and livestock carrying capacity in Gorkha District, was conducted to better understand the spatial relations of the feed deficit problem in the district and to identify smaller units for immediate intervention.
- Horticulture is considered to be an effective tool for reducing environmental degradation and improving the economic situation in mountainous areas. There is great potential for the development of various fruit species in Nepal. The case study assessed the potential of horticultural development and particular fruit crops in Gorkha District, taking into account various parameters, i.e., temperature, land use, aspect, and accessibility to marketing infrastructure.
- The suitability of a location for specific plants and crops is influenced by different parameters, such as temperature, moisture, slope gradient, aspect, and cloud formation, and the interaction between these parameters, including the human factor. The case study, 'Correlation of Land Use with Climatic Factors in Gorkha District', tried to assess the spatial relationship between these parameters, to better understand the environmental system and the use of natural resources in the district.
- In the Nepalese mountains, in particular in Gorkha District, potato cultivation has a high socioeconomic value, either as a staple crop in the high mountain areas or as an important vegetable crop in the mid-hills. Furthermore, marketing and bartering of seed potatoes contribute to household incomes and diversification of diets. In general, potatoes can be grown on all cultivated land. The case study applied GIS technology to the analysis of appropriate locations for potato production during optimal growing periods.

1.3 Mountain Areas and the GIS Concept

Mountain areas present a great challenge for the application of GIS technology due to their diversity, marginality, and strategic importance, as well as their different physical, biological, and societal systems. When compared with the plains in the lowlands, the physical characteristics of the mountain environment are more complex and need to be analysed using a three-dimensional approach/methodology, in order to arrive at an approximate representation of the aspect, slope, and topography of the mountains (Heywood et al. 1994). GIS and Digital Elevation Models (DEM) are used for different types of applications in mountain environments, e.g., regional resource inventory; planning and management; hazard assessment; modelling of the ecology, climate, or hydrology; and geomorphology (sources quoted in Stocks and Heywood 1994).

Data on resources and environment are available. However, these data are often dispersed among many agencies and cannot be quickly compiled for multisectoral, problem-oriented analyses. Thus the ability to respond to the information needs of planners and decision-makers is limited. The strength of GIS technology is its ability to integrate data from various resource disciplines, using a common geographical boundary of reference.

A Geographic Information System (GIS) is a computer-based system capable of holding and using data describing places on the earth's surface. The system is characterised by two forms of data; i.e., attribute data, either statistical or textual, contained in tables, lists, catalogues, etc and geographic information, either spatial or locational, contained in various kinds of maps. Computer technology, for quite some time, has made it possible to manipulate and analyse statistical information. Recent development has facilitated the automation of maps into digital databases and allowed the simultaneous manipulation of both the geo-reference planners to produce a combination of maps and tables that show 'where' and what', and to answer many questions that remained open. This computerised system, known as GIS, can store, manipulate, display, and produce geographic (spatial) information integrated with statistical and textual data; it is becoming one of the most useful and powerful analytical tools for resource planners and managers (FAO 1988).

Database and Techniques

The Geographic Information System software Arc/Info was used to establish the database. The software was used based on an IBM compatible PC platform for data input and digitising. The geographic analysis was carried out on an IBM RISC System/6000™ and AIX™ Operation System; the data are now available on a PC platform. The universal transfer mercator (UTM) system was used for map projection. Gorkha District lies in UTM zone 45 and is based on the Everest spheroid.

The established database of Gorkha District is based mainly on secondary data. The population figures were extracted from the 1991 Census, and all other socioeconomic figures were retrieved from a ward-level baseline survey conducted by GDP. The main references for natural resources and land use were the data and maps published by the Land Resource Mapping Project (LRMP) from 1984 to 1986 (Table 1)

Table 1: Digital Database of Gorkha District

Description	Feature Type	Map scale	Source
Land utilisation	polygon	1:50,000	LRMP 1986
Land system	polygon	1:50,000	LRMP 1986
Land capacity	polygon	1:50,000	LRMP 1986
Elevation contours in 500 feet intervals and spotheights	line and point	1:63,360	ONE INCH maps 1950s
Drainage system	line	1:125,000	SBD 1989
VDC boundaries	polygon	1:25,000 - 1:50,000	HMG 1986
Settlements	point	1:125,000	SBD 1989
Roads and trails	line	1:125,000	SBD 1989
Bridges and fords	point	1:125,000	SBD 1989
Meteorological data	point		HMG
Socioeconomic data	-		HMG, Census 1991 and GDP field survey 1992

Different GIS modules were applied for the spatial analysis. The Arc/Info TIN module was used to create a digital elevation model using embedded on elevation contours of 500 foot intervals and spot heights on a scale of 1:63,360. The analyses of aspect and slope gradient were carried out with the GRID raster GIS method using a 100m x 100m pixel size. Similar agroclimatic zones, horticultural development, correlation of land use with climatic factors, and potato production were assessed using the raster GIS method for technical reasons and an overlay technique for the combination of several spatial data layers (coverages). The GRID module PATHDISTANCE was tested to estimate the accessibility of road infrastructure, cultivated areas, and pasture land.

The data of the study area have been stored in the form of thematic layers (coverages) and related attribute tables, using Arc/Info software. This allows one to retrieve, overlay, and present them in map or tabular form or display them as a three-dimensional view. The data can also be retrieved in spatial format with

WINDOWS-driven Arc/View software on PCs. The data are compiled in subdirectories, or coverages. These coverages include different features such as polygons, lines/arcs and points, as well as the database. The database is either stored in <*coverage name*>\PAT.DBF files (i.e., polygon or point attribute tables) or <*coverage name*>\AAT.DBF files (i.e., arc attribute tables). All data related to areas (e.g., socioeconomic data of VDCs and land use data) are stored in polygon attribute tables; data related to lines (e.g., villages, settlements, and bridges) are stored in point attribute tables. The \PAT.DBF and \AAT.DBF database files can be retrieved and updated in dBASE software (Annex 1).

Data Problems and Limitations

- The data used for the assessment of natural resources were almost 15 years old. The LRMP had already conducted its surveys in the late seventies. Since then land use could have changed, deforestation and degradation of forests could have continued, the conversion of forests into other land use classes could have occurred, agricultural lands on sloping terrain and in valleys could have been lost through natural and man-made causes, and so on. Still, these data are a good base for conducting GIS applications, since the database can be updated using other less labour-intensive technologies, such as remote sensing (RS).
- The data accuracy was limited by the fact that the major features of the database were digitised from maps on different scales and/or maps which were out of date. Natural resource data of the LRMP were retrieved from maps with scales of 1:50,000; contour lines were taken from the ONE INCH maps (scale 1:63,360). Other features, such as roads/trails, rivers, villages/ settlements, and bridges, were extracted from the SBD maps with scales of 1:125,000. The latest updated VDC boundary maps were not available. The maps used were prepared in 1989 without proper reference points; thus, the line features were delineated manually on the topographical sheets of the Indian Survey and only then were they digitised.
- While there are limitations to and lack of data, it is essential that we make the best use of what is available, knowing fully the limitations and responding to needs as we proceed.

1.4 Conclusions

The application of Geographic Information Systems has proved to be a useful and effective tool in the frame of area planning for agricultural development at the district level.

A big advantage of GIS technology is its flexibility. GIS analysis can be carried out by applying different sets of indicators based on adjusted parameters. The system is easy to update, in particular the socioeconomic part. In general, the database can be used for the assessment of different problems and for their solutions. Once a methodology as such is developed, it can be expanded and transferred to other regions with much less effort.

A GIS model tries to describe the reality based on a selected number of parameters. The quality of the model, i.e., the deviation from the reality, needs to be either tested in the field or compared with available secondary sources or other existing models. For Gorkha District, the quality of the model could only be tested in two cases, potato cultivation and agroclimatic zones. Only for potato cultivation do the available sources cover the whole district. The results of the model proved to closely reflect the reality. With regard to agroclimatic zones, a model was developed and compared to an already existing pattern elaborated by the LRMP through non-GIS methodology. The GIS results were different since additional information was used and the methodology used to delineate the zones was also different.

The management and use of the database are now the primary tasks for the future. The first step in this direction was a GIS orientation workshop in Gorkha *bazaar* in April 1995 in which representatives of the local government, various line agencies, and NGOs working in the district participated and results of the case studies were presented. During discussions it was agreed, in general, that the district database should be installed and managed by the local government of Gorkha District. It was envisaged that all agencies should contribute to the information system and have access to it. At present, the district bodies do not have the capability to undertake this task independently. The Gorkha Development Project aims to have staff trained on the subject, and it is planned to establish basic computer facilities for the District Development Committee to manage the database. For proper utilisation of the system, data networking with other agencies, updating of databases, and so on, the local government body needs support to upgrade its institutional skills and knowledge.

It is hoped that these initial exercises using GIS will strengthen local-level planning capacities in the future, as the potentials for more sound decentralised decision-making in local development have been substantially improved through the careful use of GIS technology and available data.