CHAPTER IV

GIS: A Tool For Synthesizing Inventory, PRA And Other Information Systems

Introduction

Indra Sharan Karki[1]

This introduction provides a general overview of GIS, and how it can be linked with the other methods discussed during the Workshop. The two GIS papers presented at the Workshop are introduced here, and GIS related books and journals are provided for the reader's reference.

WHAT IS GIS?

Geographic Information System (GIS) is a computer based information technology used for capturing, storing, editing, organizing, analyzing, and displaying spatial data in the form of maps. The key integrated components of a GIS are hardware, software, data, procedures, trained staff, and appropriate organizational structure.

In a vector based GIS, geographic features from the earth's surface are represented as three feature types: point, line and polygon. A point (eg. a well, house or settlement, canal intake, or a weir on a canal) is represented by means of a single pair of geographic coordinates. A line (eg. a road, canal, or river) is represented by two or more pairs of geographic coordinates. Similarly, a closed area (eg. irrigated and non-irrigated lands, or rice field) is represented by means of a string of coordinates which close to form an area feature or polygon. All features are given a unique identifier. Spatial features can be represented in a variety of ways depending on scale. For example, viewing a road from far above, it may appear as a line, whereas looking at it from the ground, its width (or area) is also observed. The choice of scale is dictated by required level of details and the final application intended for the data. The structure of data base changes accordingly.

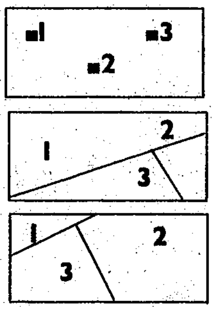
Geographic data, stored in a computer in a GIS format, have the ability to link graphic features with their associated attributes. A common key or identifier existing both in the digital map and data base table links both, as shown in **Figure 1** to create a coverage. This creates a relational and topological database structure. Once this data base is built in a GIS, there is a wide range of capabilities, tools, and functions available. These include spatial analysis, data management, display, and communication of various GIS products e.g. custom maps, plans, visual graphics, etc. among various users.

Conventional tabular inventory is limited, since spatially distributed objects, related to irrigation

Point Features

Line Features

Polygon Features



+

ID	School	Teachers	Students
1	Primary	10	200
2	Middle	10	300
3	High	20	500

Point data base table

+

ID	Trailname	To-traffic	Fm-traffic
1	AA	200	250
2	BB	150	100
3	CC	50	150

Line data base table

+

ID	Type	Kharif yield	Rabi yield
1	A	200	190
2	B	500	250
3	C	400	360

Polygon data base table

FIGURE 1. **In a GIS, feature IDs link digital map with the data base table describing the properties or phenomena.**

HOW IS GIS USED? HOW DOES IT RELATE WITH OTHER METHODS?

Participatory Rural Appraisal (PRA) is one method to collect both qualitative and quantitative information at the grassroots (local) level, that is not discernible from regular records. Since local people's knowledge and experiences are tapped, PRA provides more accurate information about the local area such as spatial distribution of people, their land, and resources. Local people, if reached cooperatively for their contributions, can provide guidance and useful intelligence to a novice map maker attempting to locate features on a map, collect attributes, and even interpret field data. PRA uses a participatory approach to study the local area with the active involvement of local people to collect, correct, and interpret data, and later present this same information to them in various formats. This inventory creates a record of both the qualitative and quantitative characteristics of features including spatial and temporal variations or both, which can be structured into a GIS data base.

GIS is a tool used to store, analyze, and present spatial information collected by various techniques and methods, using a specific approach appropriate to the respective context.

or roads, for example, have limitations to being visualized on a traditional map. However, these data can be reorganized in a GIS to make more useful, visual and problem solving products, by relating the inventory data base with their location on the ground (please see **Figure 3** of the paper **GIS Applications in Irrigation Issues** in this section). Combining various methods and data from many sources, an integrated data base can be maintained in a GIS to address various issues at a micro, meso and macro scales.

A field team can carry a portable GIS to the field, interfaced with a Global Positioning System (for GPS, please see **Text Box 2** in the paper **GIS Applications in Irrigation Issues**) to collect spatial information. Combining technology and indigenous knowledge improves the data quality, increases the contents, and enhances the capabilities of GIS to present information that is more understandable to local people. This in turn, helps them become more aware of their power and potential as problem solvers in terms of their resources, development, and service facilities. GIS, when appropriately applied, can support people directly in a user friendly way.

Figure 2 outlines a procedure to link a variety of information resources and standardize information into a common form. Information systems and data bases derived from various sources and methods are linked through a common location identifier or geo-referencing scheme. This interlinking provides access to in-depth knowledge enabling a user to view the world as a "system" both spatially and in a multi-disciplinary manner.

between the conventional and the GIS approach of structuring data. The benefits offered by GIS are discussed. A Global Positioning System (GPS) to collect location specific data is also introduced. Emphasis is placed on the use of GIS for locating people and their infrastructure.

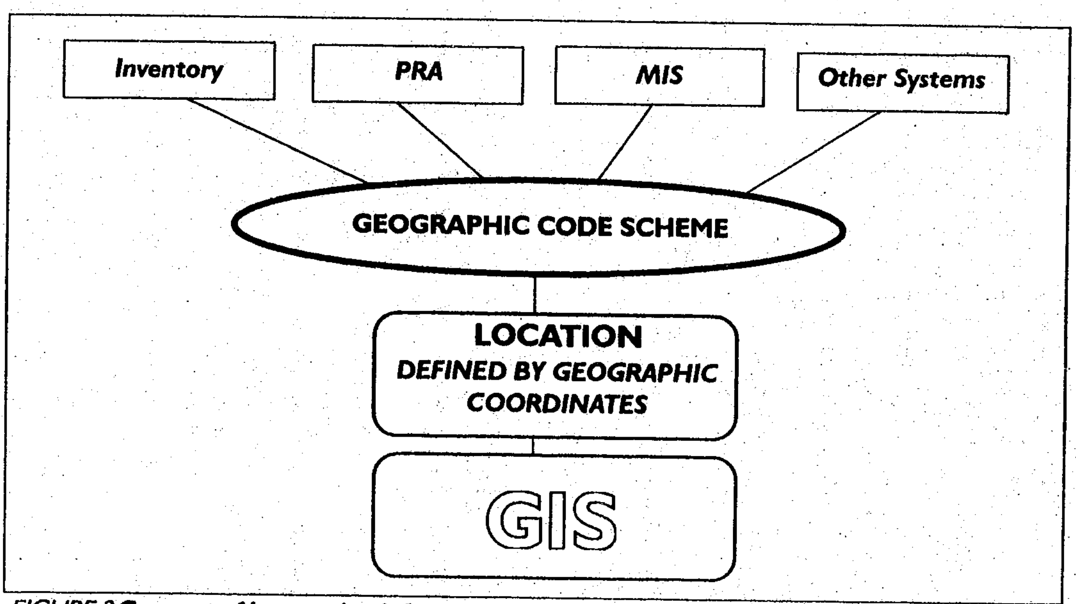


FIGURE 2. **Concept of integrating information systems.**

INTRODUCTION TO PAPERS

Included in this section are two papers that discuss GIS and its application in irrigation and other related fields. Their titles are **GIS Applications in Irrigation Issues** by Indra Sharan Karki and **Use of Statistical and Geographic Analysis in a Farmer-Managed Irrigation System's Study** by Olivia Aubriot.

GIS Applications in Irrigation Issues, introduces the concepts of GIS applications in relation to irrigation issues by, for example, locating irrigation facilities, people, their lands, markets, and relating them with other relevant spatial data. This assists in identifying causes of failure or success of schemes, which are analyzed for effective measures or policies designed to alleviate poverty. The paper also shows clearly how GIS can serve as a guide in making location or site specific decisions. A demarcation is made

In the end, the idea of a multi-participant GIS institution is introduced. Multiple users can network, to share data and facilities in such a way, that it is managed and sustained by the user's contribution.

In her paper, **Use of Statistical and Geographic Analysis in a Farmer-Managed Irrigation System's Study,** Aubriot explains how GIS was used to study the water management dynamics of a Farmer Managed Irrigation System (FMIS) in the hills of Nepal. More specifically, by displaying water-turn and land partitioning, the GIS was used to help understand the origin and evolution of the existing water system. In the study, two simple but important GIS functions were used. The first was to display social and historical information related to water management of the irrigated rice fields on cadastral maps which had been digitized into the computer. Information including lineage organization, population, water-turns of each group, and land partitioning between clans, was linked from a data base to a digital map base. The second function involved GIS analysis and subsequent display of kinship relations among farmers. This paper is an example of how GIS can be used to clarify complex yet subtle social relations, and simplify the analysis of irrigation management in a middle hill society of Nepal.

Since the handling of spatial data is a unique capacity of GIS, special functions such as spatial interpolations techniques based on empirical rules or computation algorithms utilizing probability functions, or regionalized variables are included in some packages. These are often useful to estimate values at points where individual measurements are not taken. These tools are both a curse and boon for a country like Nepal. Boon in the sense that since most places are inaccessible due to rugged topography, the tools provide invaluable means to interpolate data. Curse, however, in the sense that the varying terrain presents extremely unpredictable scale factors affecting the results of any interpolation. Distorting factors such as the terrain should always be considered in the creation of any model.

The Himalayan region is made complicated by the inaccessibility to appropriate resources and a lack of institutional emphasis on field data collection. Measurements of similar features at different locations often results in great variations thus adding to the complexity of the overall situation. While prevailing and ongoing irregularities may be viewed more in light of an emerging appreciation for this spatial *complexity*, it is suggested that more attention be paid to quality data collection first, creating spatially referenced data bases which form the basis for analysis of complex problems and issues.

SUMMARY

GIS is a multi-disciplinary tool that has the capability to integrate data from various sources at different levels of detail and perform both simple displays, as well as complex analyses on spatial data sets. As a result, the GIS user obtains better information and often gains new (geographic) insights that may provide conclusive evidence in support of a hypothesis, or lead studies and further research in new, profitable directions.

GIS can also integrate information systems, and aggregate information at national and sub-national levels as required, to create an information infrastructure for use by decision makers at all levels .

It is possible, with integrated spatial information technologies like GIS, to acquire more detailed data on a micro-scale situation, suitable to support local decision making. This is needed and appropriate for Nepal, a country of extreme variability in its socio-physiographic characteristics. GIS allows for integrated, local-scale problem solving rather than large-scale generalizations--an approach which characterizes the failed centralized approach to development planning of the past. GIS offers a radically new tool for planning, based on sound information resources and a participatory approach which has great potential in the future.

Notes

[1] Sr. Spatial Analyst/GIS Specialist Decentralization Support Project UNDP/NPC GIS Facility, P.O. Box 107, Kathmandu

References

Morgan, Glenn and KC, Indra Sharan. 1990. Developing Decision Support System for Environmental Planning in Nepal's Arun Basin: Premises and Pitfalls of a Geographic Information System Approach. Unpublished paper.

ated attributes, phenomena, property or interest of concern are linked by means of a geo-relational model[3].

Nature of Geographic Information

Any useful information about objects or phenomena over the earth, is geographic information. The "geography" is the location and "information" is an attribute or property associated with a feature on the surface of earth. Text Box # 1 is a list of basic questions that can be investigated using GIS.

1.	Location	Where is it ...?
2.	Condition	What is it ...?
3.	Trend	What has changed ...?
4.	Routing	Which is the best way ...?
5.	Pattern	What is the pattern ...?
6.	Modelling	What if ...?

BOX 1. Basic questions that can be investigated using GIS (after Rhind, 1990).

The distribution of all irrigation systems over a region is a perfect example of geographic information. Similarly, distribution of service centers, transportation and drainage networks describable on maps are all geographic information. Location of the features and their conditions or properties are explicitly defined when they are stored in a GIS.

Sources of Geographic Information

Depending upon the nature, required information over a territory is obtained from:

- Field surveys
  (a) Land surveying to get land information, such as cadastral surveys, engineering surveys, reconnaissance surveys;
  (b) Socioeconomic sample survey questionnaires, census, Participatory Rural Appraisal (PRA) techniques;
- Aerial photographs, satellite imagery and other space and instrument bound data over earth;
- Various institutions or agencies concerned with information.

Global Positioning System (GPS) technology for accurately and rapidly recording the location of phenomena has revolutionized the mapping and data collection procedure, and is becoming popular in recent days (see Text Box 2).

Global Positioning System

Global Positioning System comprises one or more set of hand-held or backpack equipment which receives signals from a number of satellites (Russian - constellation of GLONASS, American - constellation of NAVSTAR) to determine a position (latitude/longitude/altitude) on earth. The receiver is taken to places whose earth coordinates are desired. In this way, any point, line or area feature can be surveyed very quickly in comparison to conventional survey techniques. Their coordinates are recorded systematically which are later downloaded to a computer to post-process and transfer to a GIS. Any associated attributes recorded in the field is linked with the GIS by means of unique identifiers.

Uses of GPS in irrigation or water use inventory

1. To locate feature not identified on photos or maps - such as water sources - tube/dug wells, springs, to locate all engineering facilities such as headwork or canal alignment
2. To collect ground control points for geo-referencing small areas or to map small areas at large scales
3. To locate user groups/settlements, service and market centers
4. To carry out boundary survey of command area, map problem areas such as land plots with seepage problems, crop disease etc.

BOX 2. GPS and survey of irrigation or water use schemes.

Characteristics of a GIS

1. *Data collection and capture:* GIS, in an integrated geographic data collection and capture tools such as GPS and GIS link, aerial photos and imagery, data exchange among systems.

2. *Storage and retrieval:* GIS is an excellent storage and archive means for location specific information. This is a tool to store, or inventory information about surface features of interest. Information for an area can be built up cumulatively as time goes on.

3. *Manipulation:* GIS allows data editing, updating, removing, appending and navigation over and among the data fields.

4. *Analysis:* There are powerful spatial and tabular or statistical analysis tools available in a GIS. A whole range of modeling and spatial data base queries are examples. Various information can be interrelated. This capability provides opportunities to look at any phenomena on the earth surface in relation to other contexts.

5. *Display:* Any data (analysis results or raw) is displayed both on a map and a table. Excellent cartographic capabilities exist within GIS.

We will discuss irrigation development planning by taking an example of irrigation potential area siting. After this, we will discuss the GIS in the context of inventory of irrigation systems. Finally we will discuss how GIS itself can be an approach to a participatory resource information system.

THE PEOPLE AND GIS

Farmers are development targets as well as development agents. For any development to be aimed at them, their location is of fundamental concern in a decentralized approach of development planning.

Referencing information by geographic names was and is by far the most popular method used in information processing. But these names can not be examined in spatial perspective. This is used with non-geographic statistical processing systems. It often becomes impossible to keep track of the names after their number increases, if there is no map associated with it.

The 1991 population census included the place name where the people lived to reference the census information to a particular geographic location[4]. These names can be located on aerial photo based base maps with the help of local people. Involvement of the local people with some training to place their settlements on maps or aerial photographs is a very sensible thing for local development planning. In some cases, use of instruments like Global Positioning System (GPS) receivers are used to create spatially referenced data base of people and their resources, and service centers in some districts of Nepal.

With such a data base, every development program can be examined in relation to the people. Once this is done, the spatial disparities of poverty can be examined in association with the causes, and remedial measures can be devised for poverty alleviation. The mixing of themes such as poverty, farmers or user groups and usefulness of satellite and computer technology, should not be considered to be enigmatic but a benign cause for improving the quality of development planning.

IRRIGATION DEVELOPMENT PLANNING FOR PEOPLE

Which area of the country needs greater attention in terms of investment in development? How should development fund be distributed? Where are priority areas? How many people will benefit from an investment and where are they? Maximum benefits should reach the people when investments are made in development activities. With the use of GIS, and people's data base, it becomes possible to plan development accordingly. To harness the full benefits from a GIS, there is lot to think in advance in terms of

Thomson, M. and Warburton, M. 1985. Uncertainty on a Himalayan Scale. Mountain Research and Development, Vol. 5, No. 2, pp 115 - 135.

Sources of GIS Literature

The following is a list of GIS related books and journals, recommended for further reading:

BOOKS

Burrough, P.A. 1986. Principles of Geographical Information Systems for Land Resources Assessment. Clarendon Press, Oxford.

Aronoff, Stan. 1989. Geographic Information Systems: Management Perspective. WDL Publications, Ottawa, Canada.

Huxold, William E. 1991. An Introduction to Urban Geographic Information Systems. Oxford University Press, New York.

Star, Jeffrey, and Estes, John. 1990. Geographic Information Systems: An Introduction. Prentice Hall, Eaglewood Cliffs, New Jersey.

Maguire, David, Goodchild, Michael F., and Rhind, David W. (Eds.) 1991. Geographical Information Systems. Volume 1: Principles and Volume 2: Applications. Longman Scientific and Technical, Longman Group, UK Ltd., England.

1993 International GIS Source Book: Geographic Information System Technology in 1992. Published by GIS World Inc.

Warnecke, L., Johnson, John M., Marshall, K., and Brown, R.S. 1992. State Geographic Information Activities Compendium. Center for Environment, The Council of State Governments.

Forrest, E., Montgomery, Glenn E., and Juhl, Ginger, M. 1990. Intelligent Infrastructure Workbook: A Management Level Primer on GIS. Automation Newsletter Companies Inc.

Understanding GIS, The Arc/Info Way. 1990. ESRI, Redlands, California.

JOURNALS

Geo Info Systems: Applications of GIS and Related Spatial Information Technologies. Published monthly.

GPS World: News and Applications of Global Positioning System. Published monthly.

GIS World. Published monthly.

International Journal of Geographic Information Systems. Published monthly.

Photogrammetric Engineering and Remote Sensing. Published monthly.