Sectoral GIS - the only Alternative open to Large Developing Countries for Sustainable Land Management

R Siva Kumar* and MD Joshi**

* Joint Director, MO-GSGS, Plot NO 108 (WS), Church Road, New Delhi 11 00 01 India
** Associate Professor, Indian Institute of Technology, Hauz Khas, Delhi 11 00 16 India

1. Abstract

The physiography of India is peculiar in the sense that in the north it contains snow clad Himalayas, in the west the arid desert zone of Rajasthan, the thick rain forest in the north east where the highest rainfall in the world is recorded followed by the 6000 km long coast line of Indian peninsula. India, compared to other countries, poses a number of problems due to the vastness of the area and the diversity of the terrain.

Considering the 5100 sheets on scale 1:50,000 form the basic input data, this alone will be of the order of 50 tera bytes without additional attribute information. It would be preposterous even to suggest that all this data could be stored on a single computer and queried in a similar manner for all areas. The peculiarities of the terrain have to be given serious thought while designing the national topographic database. The characteristics of the desert, snow clad areas and other areas have to be studied.

The deserts and the Himalayan regions of the country account for about 20% of the territory of India. Similarly the coastal zones, gangetic plains and the undulating country in the middle and thick rain forest of the northeast have their own peculiarities. The problems encountered, though not similar, can be handled in a similar manner. In addition, there are about 600 island territories in the Bay of Bengal, Arabian Sea and the Indian Ocean. They form mainly into two groups viz., Andaman & Nicobar and Lakshwadweep islands.

This has led us to distinguish three separate, if not more, databases covering the three regions of India. The attributes of the topographic features for these regions will be naturally different, as are the attribute tables. However, the linkages, input data and the software remain the same. The queries have to be the same in all three databases and the concept should be transparent to the user. The software customization is aimed at achieving total transparency so that the user need not realize which terrain he is accessing till such time the attribute data is shown.

In this paper, the peculiar characteristics of the deserts, and snowcapped areas are discussed and the problems that one encounters while designing a national digital topographic database. The paper conclude with the recommendation that the country be divided into different sectors and Sectoral GIS be applied to obtain a realistic land inventory in support of sustainable Land Management.

2. Introduction

Maps have fascinated man since the days of Ptolemy (Phillimore, 1945) and the quest for geographical information was being satiated by conventional and special purpose maps. The changing scenario in the advancement of electronics and especially computers combined with the satellite sensors of high resolution made it possible to bring this complex and beautiful terrain onto desk tops. A map is a reduced and simplified model of reality, containing geographical information. It is a two dimensional representation of multi-dimensional terrain features on the earth.

In contrast, the geo-information derived from geographical information systems (GIS) is information that can be referenced to a specific location ABOVE, ON or UNDER the surface of the earth. The process of capture, storage, organization, analysis, and representation of dissemination leads us to the topographical data bases and their maintenance and dissemination (Eric de Man, 1987). When compared with Surveying and mapping, it also includes a DATA ANALYSIS phase, requiring that the relationships are established between data entities and data attributes and even between attributes themselves.

This leads to the question regarding the status of these activities in India. No doubt, India has a 100% map cover at a 1:50,000 scale and smaller, a rare privilege even amongst the developed nations (SOI Annual Report , 1992-93). The effort in creating a national topographic database has been limited only to the extent of creating digital data of the existing maps. This onerous task has been taken up by national mapping agencies the world over. In India, besides the map cover, abundant data exists with the state/Central Government departments dealing with Soil, Forestry, Water Resources, Minerals etc. However, the attempts to utilize the tremendous potential of GIS are limited to localized utilities management. The national mapping agency is churning out sphagetti data (unstructured) by converting existing maps into digital data, thus leaving the users to create their own GIS. Considering the availability of a strong conventional topographic data base in the form of maps and highly trained and experienced manpower, India is capable of creating, maintaining, and managing a Digital Topographic data Base for the whole country.

In view of future planning of national development schemes, resource management, environmental monitoring and management as well as strategic planning, a national database is required. The computerized data base should be easily accessible to the users whether government or private agencies

3. Geographical Information and Planning Systems

Urban and rural planning processes in developing countries depend critically on optimum integration of all types of available data. A GIS provides the power of overlaying topographical cadastral, geological, and other land related information, once these data are available in digital form. Very often, each set of information is obtained through scanning of plans, maps, etc. A prime limitation in this process is the incompatibility between the coordinate systems underlying the various types of plans and maps.

This problem is usually counteracted by stretching and deforming the scanned images until the overlays “fit”. A simpler and more controlled procedure consists of geocoding selected features in each of the information layers with differential GPS. The GPS coordinates themselves then provide the necessary integration and unification in the GIS. The resulting Land Information System can serve as the basis for a fiscal cadastre, and thereby contribute to cost recovery through increased tax revenue.

4. Diversity of indian topography

The physiography of India is peculiar in the sense that in the north it is covered by snow clad Himalayas and in the west the arid desert zone of Rajasthan and the thick rain forest in the north east where the highest rainfall in the world is recorded followed by the nearly long coast line of Indian peninsula. India compared to other countries poses a number of problems due to the vastness of the area and the diversity of the terrain.

Considering that over 5100 sheets on scale 1:50,000 form the basic input data, this alone will be of the order of 50 tera bytes without additional attribute information. It would be preposterous even to suggest that all this data can be stored on a single computer and queried in a similar manner for all areas. The peculiarities of the terrain have to be given serious thought while designing the national topographic database. The characteristics of the desert, snow clad areas and other areas are given in succeeding paragraphs.

5. Deserts in India

Every desert has its own peculiar characterstics and even within one desert area there are radical changes from region to region. These changes must be appreciated because they affect the conduct of planning and development. The two kinds of deserts in India are THAR Desert of Rajasthan and the RANN of KUTCH.

Thar Desert of Rajasthan: This desert is a vast arid wasteland, sparsely populated and with little vegetation. It is, however, not so featureless as is generally considered, as it contains sand dunes and hills of weathered rocks. Near the International Border there are high rolling dunes of soft sand; towards the east there are smaller sand dunes and hills of weathered rocks. Here, there are also more areas of stony and gravel wastes (which makes movement by vehicle easier).

Sand Dunes: There are two types of old established dunes in the East which are stationary, and the rolling dunes in the West which are still shifting. The general axial direction of the sand dunes under the prevailing winds is from northeast to southwest. The sand dunes form into a ‘knuckle’ in the northeast that are higher, with ‘fingers’ of dunes running to the southwest. The slopes of the ‘knuckle’ are steeper with loose sand; those of the ‘fingers’ are gradual and can be traversed by vehicle more easily. However, movement of vehicles across dunes and over vast tracks of shifting sand, is extremely difficult. Sand dunes are generally 70-100 meters high and approximately 3-5 kilometers long, with distances between dunes varying from 400 - 1200 meters. Visibility is restricted due to intervening dunes. Desert sand mostly consists of hard mineral grains small enough to be moved by the wind but large enough not to be dispersed as dust. It piles up into definite features. When driven by the wind it settles in sheltered places gradually filling in depressions. When a rock or some other obstruction rises out of the desert, the blown sand accumulates on the leeward side of it where it ultimately consolidates into a streamlined shape. The crest and the long axis of this sand drift will be in the direction of the prevailing wind. On the windward side of an obstacle like a rock or a shrub, a steep sandbank will heap up. On the sheltered side the bank will slope away more generally as a streamlined dune. With the effect of the wind, the dunes in the Thar Desert all run from northeast to southwest.

Rocky Hills: These are up to 100 meters high and 3-5 kilometers long and are composed of weathered rocks and gravel. These provide the main source of road construction material in the area.

Vegetation: Palli is the only desert bush found in THAR. It grows in small clumps and provides additional bearing capacity to the soil. Some stunted trees are found in depressions. These are few and scattered.

The Rann of KUTCH: The RANN of KUTCH consists of a flat sandy, treeless and grassless terrain in which there are islands called ‘bets’. These ‘bets’ are the only topographical features in the RANN. They are comparatively higher areas of ground, and grass, shrubs and sometimes a few stunted trees grow on them. There are other areas called ‘banni’ which have clumps of grass over which movement by vehicles is possible at reduced speed. Some parts of the RANN are water logged throughout the year. There are other areas that are virtually impassable during monsoons. Another peculiarity is that in the RANN there is no habitation at all. A distinctive characteristic of the RANN is the mirage effect that suggests the presence of large areas of water adjacent to the RANN.

6. Himalayan Glaciers

The youngest mountain chain on earth with the loftiest peaks covered with snow in north India is known as *Himalaya.* It seems strange that as late as the year 1847 the occurrence of glaciers in the Himalayas was considered a matter of doubt (Dobhal, 1992). The enormous task of mapping these glaciers defied human endeavour. Over the years, survey of India has built up a good map cover for the region. That has become possible only after the advent of photogrammetry and mapping from space. A *glacier* is a mass of ice that moves slowly and continuously down a mountain valley to a point where the rate of movement is balanced by the melting away of the ice. The *snow line* is the actual limit above which snow lies permanently through the summer. Rocks and stones fallen from the mountainside and carried down on the surface of the glacier are called *Moraine* and a crack in the surface of a glacier is called a *crevasse.* A *bergschrund* is a crevasse separating the moving glacier from the bed of permanent snow above it. A *couloir* is a steep gully on a mountainside, either with or without ice. Small loose stones or shale standing on steep slopes is known as *Scree.* Besides these, there are other ice-forms such as hanging glaciers, ice walls, ice pinnacles, ice caves, Giant Kettle etc., which are commonly depicted on the maps and of significance for planning and analysis. The Himalayan glaciers cover approximately 32,000 sq. km.

7. Rest of the Country

The deserts and the Himalayan regions of the country account for about 20% of the territory of India. Similarly the coastal zones, gangetic plains and the undulating country in the middle and thick rain forest of the northeast have their own peculiarities. The problems encountered, though not similar, can be handled in similar manner. In addition, there are about 600 island territories in the Bay of Bengal, Arabian Sea and the Indian Ocean. They form mainly into two groups viz., Andaman & Nicobar and Lakshwadweep islands.

8. Difficulties in DTDB due to Terrain

The terrain often imposes restrictions on planning and development. Similarly, it does create hurdles in handling digitally the data of the topographic features. One of the major problems faced in handling the desert areas is lack of height information in the form of contours on the existing maps. The height is depicted by the sand dots as a symbol. The relative heights are shown on the maps as 30r, 20r etc. The height is depicted by gradation in the size of the sand dots. Another major problem is the shifting of sand dunes; the terrain information accordingly varies with time. This makes spatial analysis difficult. In addition, details are sparse in the deserts and hydrological features that are relatively insignificant elsewhere have more importance in the deserts. Similarly, the snowclad Himalayas with moving glaciers make the task of creating a DTDB difficult and they have to be handled separately.

9. Sectoral Database and Sectoral GIS

The above discussion leads us to having three separate, if not more, databases covering the three regions of India. The attributes of the topographic features of these regions will be naturally different and so are the attribute tables. However, the linkages, input data and the software remain the same. The queries have to be the same in all three databases and the concept should be transparent to the user. The software customization is aimed at achieving total transparency so that the user need not release which terrain he is accessing till such time the attribute data is presented.

10. Sectoral GIS

Integration of different types of terrain with features peculiar to each is itself a formidable task. No ready-made solution is available for such integration especially in view of the constraints peculiar to the Indian context. Various types of terrain were chosen viz., plains, deserts, snow clad, forest infested. The process of Digital Topographic Data Base was simulated to enable to configure the data base and the features that are required. To overcome the difficulties enunciated above, it was suggested to have a new concept of sectoral GIS for 3 major sectors in India viz., Desert, Snowbound and other areas. The country is divided into 3 sectors and sample sheets for each area were digitized and brought into database for testing and evaluation.

The major problem encountered while dealing with deserts is making the data intelligent. Vectorization of features such as roads, canals etc is not in any way different from similar features in other areas of the country. How to depict sand dunes which are constantly shifting as well as those which are less mobile. The undulation in the terrain as well as the third dimension (height) is depicted by the contours in maps. In the deserts the height information is available only in the form of spot heights and relative heights of dunes. An associated problem is the depiction on conventional maps of graduated sand dots, which is peculiar to the maps of India. Many alternatives for this problem were tried including pseudo contouring but with little success. The better way to depict desert features is by having the raster data in the polygon and adding all the intelligence to that polygon by way of attributes. This leads us to the concept of ‘Real Time Mapping’. The raster data polygon can be swapped for the latest satellite imagery as and when the user wants. This is feasible because the Indian Remote sensing Satellite IRS 1-C has a very short revisit time due to tilting mirror arrangements and thus in future, many satellites will be available to provide data on demand. This is the only way one can get information about deserts in digital domain. However, as per the data model designed by the National Mapping Agency, the sand features appearing on the input documents (maps) have to be digitized as given in the table 1 below.

Table 1.

Feature	FC	FT	LL	L	W	C	Remarks
Ground clear sand	7401	A	56	1	0	37	
Steep face of sand hill	7402	L	56	0	0	37	To be patterned
Sand hill and sand dune as surveyed	7403	L	56	1	0	37	To be patterned
Shifting sand dune	7404	P	56	0	1	37	
Elevated flat sand area	7405	A	56	1	1	37	To be patterned
Conical top of dune	7406	P	56	0	0	37	
Flat sandy area	7407	A	56	0	0	37	

P	**- Point**	**L**	**- Line**	**A**	**Area**
FC	**- Feature Code**	**FT**	**- Feature Type**	**LL**	**- Level**
L	**- Line Code**	**W**	**- Weight Code**	**C**	**- Colour Code**

Similar difficulties are encountered when dealing with the snow clad areas of the Himalays. The glaciers have entirely different properties, the features themselves are peculiar. However, the third dimension is available in the conventional maps and can be accurately portrayed in a digital environment. The data model envisages digitization of high hill features as given in Table 2 below.

Table 2.

Feature	FC	FT	LL	L	W	C	Remarks
Moraine medial	7601	L	59	1	0	0	To be patterned
Moraine lateral	7602	L	59	2	0	0	To be patterned
Moraine terminal	7603	L	59	3	0	0	To be patterned
Rock couloir	7604	A	59	0	0	8	To be patterned
Scree	7605	A	59	1	1	0	To be patterned
Rock fall	7606	A	59	5	1	0	To be patterned
Pass in permanent snow	7607	P	59	0	0	7	
Hanging glacier	7608	A	60	4	0	7	To be patterned
Ice fall	7609	A	60	5	0	7	To be patterned
Crevasses due to uneven bed	7610	L	60	6	0	7	
Crevasses due to movement of ice stream	7611	L	60	7	0	7	
Ice pinnacles	7612	P	60	0	0	7	
Bergschrunds	7613	L	60	0	0	7	
Permanent snow	7614	A	60	1	0	7	
Ice wall	7615	L	60	0	1	7	To be patterned
Glacier stream	7616	L	60	0	2	7	
Glacier lake	7617	A	60	0	2	7	
Ice cave	7618	L	60	0	3	7	
Ice couloir	7619	A	60	3	1	7	
Route over glacier	7620	L	60	1	0	7	To be patterned
Snow cornice	7621	L	60	0	4	7	To be patterned
Giants kettle	7622	A	60	2	0	7	To be patterned

It is recommended that large countries such as India, with diversified topography, go for sectoral GIS as developmental problems will also be different in these areas when compared with other areas. To begin with, we may have 3 sectors that can further grow depending upon the resources available.

When treated as above, the sand features and the snow features did not have anything common with the rest of the country. These areas are also devoid of many cultural details which are in abundance in the other regions such as railways, roads, villages, water points, irigated areas, canals, power lines, telecommunication lines etc. The criteria for development, the kind of development and the infrastructure are also entirely different. Spatial queries evoked null responses due to lack of data of that nature. The following table clearly illustrates mismatches in the queries.

Table 3.

QUERY	NORMAL	DESERT	SNOW	Remarks
Trafficability	Possible	Possible	Possible	Cross-country not possible except in normal areas
Site selection	For all constraints	Limited choice	Limited choice	
Alignments for Roads/Canals	Many alternatives	Limited choice	Limited choice	
Attribute info	Reliable	70% Reliable	30% Reliable	

11. Conclusion

It is imperative that we have an inventory of lands and oceans for effective planning of sustainable land management. Till now, maps have been the only data source. Though maps contain a wealth of information, handling sheets of paper and finding solutions is difficult and GIS is the right answer which affords us an opportunity to view the terrain globally and at the same time yields data at micro level.

Attempting to make a topographic database in digital form for large landmasses may not be practicable and it would be wise to take the route of sectoral GIS that can accommodate the vagaries of the terrain.

12. References

ABLER, R.F., (1987), “The National Science Foundation Centre for Geographical Information and Analysis”, *International Journal of Geographical Information Systems,* 1, pp 303 - 326

BASU, S.K., and GANGULY, P.K., *GIS - A modest beginning, Indian Cartographic,* 13, pp 104 - 108.

BERRY, JOSEPH K., (1993), “Beyond Mapping”, *GIS World Books,* pp ix - x.

De MAN, W.H.E., (1988), “Establishing a geographical information system in relation to its use - A process of strategic choices”, *International Journal of Geographical Information Systems*, Vol 2 No 3, pp 245 - 261.

De MAN, W.H.E., (1984), “Conceptual framework and guidelines for establishing a geographical information systems”, *General information programme and UNISIST, UNESCO, Paris*. Report PGI-84/WS/20. pp 59 - 64.

JANKOWSKI, P., (1995), “Integrating geographical information systems and multiple criteria decision-making methods”, *International Journal of Geographical Information Systems,* Vol 9 No 3, pp. 251 - 274.

JOSHI, M.D., and SIVA KUMAR, R., (1994), “Maintenance of topographic database in India; photogrammetric solutions”, *South African Journal of Surveying and Mapping*. Vol 23, Part 2 (no 138), pp. 85 - 89.

MAGUIRE, D.J., GOODCHILD, M.F., and RHIND, D.W., “Introduction”, *Geographical Information Systems,* Vol 1, pp. 3 - 7

PHILLIMORE, COL R.H., (1945), “Maps of India”, *Historical records of Survey of India, Vol I,* pp 206 - 220

SIVA KUMAR, R., and VACHHER, P.K.,(1996) “GIS - A Dream or Reality”, Remote-Sensing for Environmental Management” pp 123 - 131.

Survey of India, (1992). National Standard for exchange of Digital Vector Data

Survey of India, (1993). *Annual Report 1992 - 93*

Survey of India, (1995). *Maps Published by Survey of India,* July 1995