ISSN : 0974 - 7451 Volume 6 Issue 3

Environmental Science

An Indian Journal

Trade Science Inc.

Critical Reviews

ESAIJ, 6(3), 2011 [138-147]

A perspective overview on geographic information system

S.Thangadurai*[1], S.Vijaya Chitra[2]

[1]Department of Chemistry, Raja Doraisingam Government Arts College, Govt. of Tamil Nadu, Sivagangai - 630 561, (INDIA)

[2]Department of Geology and Mining, Govt. of Tamil Nadu, Guindy, Chennai - 600 032, (INDIA)

E-mail: drstdurai@yahoo.co.in; drstdurai@gmail.com

Received: 31st March, 2011 ; Accepted: 30th April, 2011

ABSTRACT

Geographic Information System (GIS) is a versatile tool with increased speed due to many available software packages. GIS technology is aptly suited to integrate data in a multidisciplinary geoinvestigations. It is not only speedy but it is cost-effective which is essential for a developing economy like India. GISs have played an extremely important role in vehicle navigation, landslide hazard zonation, health and human services, mining & earth sciences, disaster research, marine, coast & oceans research, defense and intelligence and in e-governance. This paper describes the value of GIS in education and fundamental of geoinformatics also to know how it works and how to select, implement, and manage a GIS. This article will benefit students or scholars who do not have prior knowledge of this system.

KEYWORDS

Databases;
Geosciences;
Information technology;
Education;
Mining.

INTRODUCTION

When Information Technology (IT) fuses with a branch or discipline of science, there is origin of a new branch of science. The fusion of IT with Chemistry is Cheminformatics, the fusion of IT with biology and biotechnology is Bioinformatics. Nowadays a new branch is building. It is the fusion of IT and Geology. This new branch is called Geoinformatics or it can be termed as Geographic Information System (GIS).

Gewin[1] had described that the US Department of Labor identified *geotechnology* as one of the three most important emerging and evolving fields, along with nanotechnology and biotechnology. Job opportunities are growing and diversifying as geospatial technologies prove their value in ever more areas. A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. In common parlance[2], a GIS is a configuration of computer hardware and software specifically designed for the acquisition, maintenance, and use of cartographic data.

The design of a GIS has also kept pace with advances in computer technology. GIS vendors have incorporated object-oriented technology into the user interface design since the 1990s. According to various researcher[3,4], it is very powerful tool for processing, analyzing and integrating spatial data sets. Wright *et al.*[5] have described that GIS is a problem-solving tool. According to him we should become proficient in applying the tool correctly and efficiently. A GIS is most often associated with maps. Campbell *et al*.[4] demonstrated the successful identification of hard rock with feldspar (porphyry)-molybdenum deposits using pre-drilling exploration data and an artificial intelligence program.

Tomlinson[6] provided an early account about the history of GIS and he has also published number of publications on this. Even he has also provided during the 1960s in the early days of the world's first GIS, the Canada Geographic Information System" (CGIS), which had a strong environmental thrust, there was a concern with the analysis of the spatial data sets stored within the GIS. Tomlinson has been known as the "father of GIS," particularly for his use of overlays in promoting the spatial analysis of convergent geographic data.

In the late 1960s and 1970s plethora of researchers[7-9] have done their research on GIS-related work. The year 1962 saw the development of the world's first true operational GIS in Ottawa, Ontario, Canada by the federal Department of Forestry and Rural Development.

The Year 2005 is a very important year for the development of internet GIS. Many significant changes have taken place in this year in terms of new technology, new services, new infrastructures, and new users. The year 2005 will be unforgettable in the history of internet GIS. We hope that at the end of 2010, we might be able to see more internet GIS applications emerged from the thousands of GIServices and become the ONE. Let's wait and see.

REMOTE SENSING (RS) - GIS INTEGRATION

By integrating RS with GIS, an even greater potential for environmental applications is achieved. Ehlers *et al*.[10] and Shelton & Estes[11] took efforts to integrate these technologies. Debate has been focused by numerous geo-scientists[12,13] on different ways the integration may be accomplished. The US military is the first industry to adopt GIS and RS on a large scale.

Yang *et al*.[14] presented an application of GIS technologies for the study of channel migration in the active Yellow River Delta, China. They have also made an attempt to demonstrate the utility of satellite RS integrated with a GIS in investigating channel migration. Chagarlamudi and Plunkett[15] have described about the two new technological tools *viz*. RS and GIS that have emerged to meet this ever-increasing demand for more precise and timelier information. They have also emphasized the need for integration of RS and GIS, is thus inevitable and is rapidly emerging because of the complimentary role played by these technologies in resource management.

The case studies of applications of GIS for surveying and mapping in several new areas recently tried and proved which has been discussed by Datta[16]. Plethora of researchers[17-22] has been worked on various issues using this integration.

GPS – GIS INTEGRATION

GPS is a Global Positioning System. This is a recent device used for identifying the position and movement of objects on the earth surface. It looks like a mobile phone, which capture signals from multiple satellites and provides information on the location of a place, giving details about the latitudes and longitudes. This device is highly useful for defense purpose to find out the location of enemy camps, missing soldiers, aircrafts, etc.

The power of GPS-GIS integration is immense with numerous applications in various fields such as agriculture, environment, defense, natural resources management, health and business etc. Kulkarni and Kamath[23] have developed a real-time GPS-GIS integrated system on an experimental basis using TransCAD as a GIS platform, which is the first and probably only GIS software, designed specifically for use by the transportation professionals to store, display, manage and analyse transportation data.

Harrington[24] had described about the utility of component technologies such as ActiveX that enable GIS and GPS components to be included within the same code. GPS providing enhanced capabilities when integrated with video or digital cameras, with airborne and satellite RS systems and when used in conjunction with GIS.

Pfister[25] have made a detailed review for a discussion of video mapping. Cornelius and Sear[26] have studied on integrating GIS and GPS data has improved environmental characterization, modeling and decision support. Giles and Speed[27] had discussion on emergency management during natural disasters.

Corbley[28], Michelsen[29] and Stevenson & Robins[30] were conducted a detailed study of this integration in archaeological research. Wilson *et al*.[31] carried out a detailed research on water resources utilizing this integration.

The GPS-GIS science, although still in its infancy in India, is the most efficient of all the available ways to achieve this target. We can be fully assured of a smooth ride even on the busiest of the days soon.

GIS DATABASE

A database is a means of storing and sorting data. A GIS is a unique kind of database of the world. In GIS, the database is created to collate and maintain information. The geographical or spatial information has two fundamental components, Firstly, location (position) of the feature (where it is), for example location of a mine, city or a power plant and secondly, the attribute character of the feature (what it is), for example, topographic elevation, or land form type etc. In GIS, the thematic information is stored in data layers, frequently called coverages or maps. A coverage consists of a set of logically related geographic features and their attributes. The attribute data are stored as tables in a data file. The various data are managed and maintained in Data Base Management Systems (DBMS). There are two main kinds of GIS database, one is the Vector based GIS and another one is Raster based GIS.

Vector based GIS

The data for each overlay is stored as a series of points in a database. When these points are projected on the computer screen, they are automatically joined by lines. Each set of points is a "layer" and can be turned on an off, making the layers appear or disappear. The relationships between layers can thus be studied.

Raster based GIS

Each layer is made up of complex set of "pixels" somewhat like the dots in a newspaper photo. Each pixel is individually stored in the computer file, making these files very large. Raster GIS is used for modeling when each pixel is given a value and can be compared with pixels in adjacent layers.

Data model

Plethora of data models has been used for GIS data representation techniques and their implication in spatial data management. Peuquet[32] overviewed an excellent review of this collection. The geodatabase is part of ArcObjects, a collection of thousands of objects, properties, and methods.

Ungerer & Goodchild[33] were made a new implementation using the Component Object Model (COM) technology. Based on the COM technology, ArcObjects provides the foundation for ArcGIS Desktop. ArcGIS and the geodatabase were engineered to support this knowledge-based approach. They enable the creation, use, management, and sharing of all elements of geographic knowledge.

The National Hydrography Dataset program uses the acronym NHDinGEO for their new data in geodatabases. NHD may be setting a precedent for data delivery in the future. As of early 2004, the program's website offers a geodatabase called *NHD_Geo_july3.mdb* as sample data that can be downloaded. The coverage model uses the sub classes of regions and routes to store some of the same feature classes in NHDinGEO. This geodatabase model is replacing the program's coverage model called NHDinARC. Similarly, many commercial sources are providing digital data suitable for use in GISs.

Carlotto[34] had stated that incompatibility might propagate error in GIS and environmental modeling applications. Koch *et al*.[35] have described the advances in CAD and GIS systems have eased data transfer between these systems. According to Levinsohn[36], more important is the need to advance GIS from a computer-aided mapping tool to one that can routinely perform spatio-temporal analyses.

Geochemical data

Geochemical data are often conjunctively used with geological and geophysical data. The data may consist of the distribution of major elements, minor elements, ionic complexes or the relative distribution of some constituents. Geochemical methods have been, by and large, ground based. The technique involves laying of base lines and grid and then sampling of rocks, soil and water followed by their chemical analysis.

Geochemical data management depends on the development of computer hardware and software and is divided into three phases *viz*. the primary phase, the secondary phase and the third phase. In the primary phase, data management is based on file system. In the 1970s in China geochemical data were prepared by files according to different element. In the secondary phase, geochemical database were organized by using DBMS-dBase, Foxbase, FoxPro. These were recognized in the 1980s in Finland, England, US and China etc. DBMS provides conventional data query and management functions in DOS and Windows operating systems.

In the third phase, progress of the Object-Orientation database, the GIS technique and www internet enhance geochemical data application into a new milestone-huge data management, visualizing query and view, data exchange by internet, synthesizing application system of geochemical exploration on GIS-base these were established in 1990s in US, Canada, Australia and China etc.

In terms of geochemical data features, modern computer techniques and object-orientation database characteristics, a high efficiency and valuable geochemical data tool for exploration geochemists is designed to realize visualizing data management, convenient data query and favorable data application. An important application of geochemical data is the assessment of mineral resources in regional scale.

In the early days mineral exploration is the key target. However it is evident that geochemical data can give basic support and many clues for multi-disciplinary research and of multi-purpose application.

GeoMDIS 2000

Regional Geochemical Database and Information System (GeoMDIS 2000) is a software tool for exploration geochemists, which has been developed originally to meet the demand of regional geochemical exploration in China and also to be suitable for application of geochemical exploration in other countries of the world.

GeoMDIS 2000 breaks off the mode of one system managing one regional data and graph. Graph management is on the basis of GIS. Conventional regional geochemistry survey data can be processed and analyzed in this system. All kinds of basic geochemistry thematic map can be generated using GeoMDIS 2000 such as contour map, colorful map, shade map, plan section map, anatomy map and section map etc.

GeoMDIS 2000 can also communicate with other common GIS software in geology and other data disposal software directly. Hence, it is important to choose the suitable software for geochemical data application, in which the functions should include data management, data analysis, and interpretation of geochemical anomalies; geochemical maps generation and data import and export.

GIS SOFTWARE

GIS means of viewing geographic data by using computer software, which visualizes georeferenced data in layers (overlays) and can be used for comparisons and analyses. In modern times, database has become synonymous with computer software designed for input and rapid analysis of data.

The software performs transformation on raster and vector data sometimes of differing datums, grid system, or reference system, into one coherent image. It can also analyse changes over time within a region. Good GIS software can combine the Vector based and Raster based GISs to some extent. *ArcView, Mapinfo, IDRISI,* and *GRASS* are certain examples of this type of software. The market for GIS expanded steadily in the early 1980s, as trade magazines, conferences and professional associations spread the word of its benefits.

Open-source GIS software

Open Source Software (OSS) has been maturing over the last years into robust, well-supported tools whose code base grows exponentially. Open Source GIS is no exception to this trend and it is now able to address the needs of GIS professionals worldwide.

Most OSS GIS products rely on both open communities and private companies for development, integration, technical support and training. Because of the openness of the software, small and medium-size companies can easily provide customized solutions and services. Well-known open source GIS software includes *GRASS GIS, Quantum GIS, MapServer, uDig, OpenJUMP, gvSIG* and many others. In fact, OSS GIS is already widely used in developing countries for education and non-profit projects, but other uses are quickly emerging as local public and private institutions become aware of the potential.

GIS APPLICATIONS

Vehicle navigation

Lange and Gilbert[37] have stated that the Navigation Satellite and Ranging GPS (NAVSTAR GPS) is a constellation of twenty-four dedicated satellites orbiting the Earth at a distance of 12,600 miles that comprise a radio-navigation system permitting accurate determination of locations worldwide, 24-hours a day, in three dimensional *i.e.* latitude, longitude and elevation.

SIMRAN is a developing hardware and software to provide real time train running information to the passengers. It is being developed utilizing the GPS by the Research and Design & Standards Organisation (RDSO), Lucknow, e-Logistics, Chennai and the IIT, Kanpur. Trials are conducted between Allahabad-Kanpur, Kanpur-Lucknow and between Chennai-Bangalore sections.

The major objective of SIMRAN project was to develop technology for continuously tracking of every train for its location, speed and direction of movement. This project was being developed by utilising the GPS.

GIS in disaster research

Disaster researchers to provide rich historical context to disaster investigations increasingly used GIS tools. Disaster researchers[38] have extensively documented the use of GIS in planning for disaster management. For the most part, the use of GIS in disaster research[39] has been for cartographic visualization rather than spatial analysis.

The focus of much disaster research today is on prevention and mitigation. However, technologies and scenarios described here do not hold much promise in helping predict or avert future calamities. They do promise, however, to improve our ability to make more sense of disasters after they occur, and understand how we react individually and collectively as social creatures in times of crises.

However, disaster management poses significant challenges for data collection, monitoring, processing, management, discovery, translation, integration, visualization and communication of information.

According to Varnes[40] the landslide hazard refers to the probability of occurrence of a potentially damaging phenomenon within an area and in a specified time. Brainard *et al*.[41] have used GIS technology for assessing risk in transporting hazardous waste.

Anbazhagan[42] and Pachauri & Pant[43] have carried out a detailed study in the Himalayas for the last few decades, they have proposed plethora of field based hazard zonation studies with manual integration of data. However these approaches have several limitations. However literature[38,42,44] reveals that many attempts have been made around the globe by using different models such as deterministic, statistical, heuristic etc.

Recently, Muthu and Petrou[45] have used ruled based expert system to prepare a landslide alert map using terrain factors and triggering factors. They have also used GIS and terrain factor maps derived from aerial photographs and satellite images in conjunction with field investigations to prepare landslide hazard maps.

Numerous geo-scientists[44,46] have worked in the field of RS and GIS technology and they found that it has become possible to efficiently collect, manipulate and integrate a variety of spatial data, such as geological structural, surface cover and slope characteristics of an area, which can be used for landslide hazard zonation.

Gupta *et al*.[47] and Saha *et al*.[48] have made study on landslide hazard zonation is from a part of the Bhagirathi valley which is in the Himalayas. Verbruggen *et al*.[49] have briefed about Geological Survey of Ireland (GSI), then why and when it has formed the Irish Landslide Working Group (ILWG).

GIS in health and human services

The United States Centers for Disease Control, the world's premier disease-tracking organization, uses GIS to study how toxic substances affect people's health. Authorities in Bangkok[50] are resorting to a GIS to ease the dengue epidemic in the Thai capital. Bangkok governor Apirak Kosayodhin stated that the GIS will help the city find critical epidemic areas and allow authorities to refine their focus in fighting the infections.

Since January 1 2007, there were 3,089 cases of dengue in Bangkok, four of which were fatal. With its capability to store, view and analyze geographical information, especially maps, the GIS is now a technological tool for addressing emergency cases.

The Jansakhya Sthirata Kosh (National Population Stabilization Fund) has undertaken a unique exercise of mapping the existing health facilities[51] in the country right up to the district level. An amalgamation of GIS maps and the Census figures of 2001, the survey gives a picture of each district, its sub-district, prominent towns and urban areas and the distance of each village from the nearest health center. The maps highlight inequities in coverage down to every village to enable resources to be targeted where they are most needed. Veterinary experts[52] are also seriously taking into considering that it is right time that GIS technology should be introduced at the block and district levels for disease forecasting so that the incidence of millions of animals dying of various lethal diseases every year could be brought down.

Geo-scientists should also try to develop a research capability in the use of GIS and spatial analysis in medical geography, specifically in social epidemiological investigations of chronic diseases. Also geo-scientists must shown interest in elucidating the relationships of the prevalence and spatial distribution of heart disease and stroke with underlying socioeconomic structures.

GIS in e-governance

The Indian Institute of Information Technology and Management, Kerala (IIITM-K), an institute under the State government, has announced[53] the launch of the State's first Active Web GIS service in public domain using Free and Open Source Software (FOSS) Technology.

The Jharkhand state principal secretary of IT briefed that governance in Jharkhand is all set to go online[54] even at the grassroots level. He has claimed that we are also trying to use GIS for digital mapping of districts so as to know the exact location of a village. GIS would also be used to calculate how much rainfall an area receives in a year to facilitate irrigation. The Jharkhand government is also trying to put emphasis on water harvesting mapping using GIS in the ground level.

Geospatially enabled e-government functions includes streamlined licensing and approval processes, improved census information, spatial data infrastructure development to serve government, industry and citizen, crime mapping, education, zoning information, property information, public input into resource management and others.

GIS in mining and earth sciences research

GIS enables mineral geologists and mine operators to mine intelligently, efficiently, competitively, safely, and environmentally. The biggest challenge before geoscientists today is to locate mineral deposits. To maintain our economic growth we must continue mining for minerals, and this requires rigorous exploration strategies for new deposits of all types.

Rowan and Bowers[55] have integrated lineament structures derived from Landsat and SAR data with a database for known occurrence in GIS for better interpretation of lineaments for mineral exploration. Bonhan-Carter *et al*.[56] have integrated the geological data sets in GIS for gold investigation.

Bhan *et al*.[57] were commonly used aeromagnetic surveys to aid in the production of geological maps during mineral exploration. Conradsen and Harpoth[58] have successfully used spectral characteristics of limonite for mapping and exploration of hydrothermal deposits.

GIS in marine, coast and oceans research

Rubec[59] had briefed how GIS is being used to support research and management of coastal habitats important to reef fishes. Also he had discussed the issues related to the function of artificial reefs in relation to fish habitat regulations. GIS technology is revolutionizing geographic analyses and has many potential fisheries applications.

The Marine Resources Geographic Information System (MRGIS) is now a comprehensive coast wide GIS database targeted for research and management of Florid's marine fisheries and coastal ecosystems. The locations of coastal habitats and many artificial reefs in Florida have been mapped using GIS and are available to scientists, managers, and to the public.

The Florida Marine Research Institute (FMRI) uses the MRGIS for GIS, RS, and modeling studies that link coastal habitat to marine resources in Florida to support ecosystem management. The FMRI made ArcView shape files available over the internet[60] as part of the Statewide Ocean Resource Inventory (SORI)

A chart is a tool for safe navigation at sea. Satyanarayana[61] overviewed of GIS applications in this environment using a paper chart as database. The main focus of GIS application in marine environment is for navigation at sea. The same data can be used for other non-navigational applications using the chart content as database of marine environment.

GIS in water, wastewater treatment and recycling research

GIS is being used as an integral part of the ground water information management and analysis. RS and GIS coupled with the communication technology plays an important role in generating and disseminating information pertaining to the ground water regime both qualitative and quantitative.

Numerous researchers[62-64] have used RS and GIS techniques for groundwater exploration and identification of artificial recharge sites. Plethora of geo-scientists[65-68] has been used GIS to delineate groundwater potential zone. Srinivasa Rao and Jugran[69] have applied GIS for processing and interpretation of groundwater quality data. GIS has also been considered for multicriteria analysis in resource evaluation. Elkadi *et al.*[70], Shahid *et al.*[71] and Boutt *et al*.[72] have carried out groundwater modeling through the use of GIS.

Kamaraju and Reddy[73] have used GIS to integrate various thematic layers for generation of ground water prospect maps. Recently, with an objective to provide safe drinking water supply to all the habitations across the country, Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development, Govt. of India has embarked upon a major programme of preparing a scientific database using RS and GIS inputs.

Singh *et al*.[74] have evaluated groundwater resources potential in Kurmapalli watershed, Andhra Pradesh, India using GIS technique. In their study area well yield data has been prepared from the monitoring of 438 existing wells. They have also made an attempt to integrate these data through the application of GIS to delineate the groundwater potential zones in hard rock terrain.

Therefore, the utmost need for conservation and efficient use of available water resources data from maps and GIS studies. GIS can integrate administrative policies with available water resources and water use. The enormous data on water resources, Socio economic division and demographics data required for planning can be efficiently led and studied using GIS.

GIS in land, wasteland reclamation and development research

GISs are particularly important to government agencies and other private and public concern dealing with land related information. The evaluation of land use is an important part in land resources investigation.

The analysis of land potentialities using GIS is more efficient method. So it is a more advanced and efficient method in land planning and now being practically used. Noaline Jaga and Sundaram[75] have studied wasteland development using GIS technique. In their study, an attempt has been made to use GIS technique to develop the culturable wastelands which includes upland and degraded forest, occupying more than 70% of wastelands in the Usilampatti block of Usilampatti taluk, Madurai district, Tamilnadu. IDRISI_ GIS software package has been used in their study.

GIS in defense and intelligence

GIS is used for every specialization of the defense industry in many nations around the world. In Dhaka, the capital of Bangladesh[76], the police decided to install the digital surveillance system for traffic management and crime control, setting up a unified control room. Under this " Command, Control and Communication Systems" (C3S) initiative, one hundred and fifty five surveillance cameras will be installed at fifty nine points in the capital, including its nine entrances and exits.

Police officials involved with the project believe the system will provide a centralized command and control system with a new fully digital mobile radio communications system of the tetra (terrestrial trunk radio) communication standard. It will facilitate the law enforces with Automatic Vehicle Location (AVL) system with GIS. There is virtually no end to the range of applications that GIS has found.

GIS in education

GIS technology is one of the hottest new research tools in academia today. It helps people of all ages grasp the ways in which geography matters. It has developed over the last 45 years to a mature discipline that has applications in any area of geosciences. The field has gained so much in importance that the major topics of geoinformatics have to be integrated into geosciences curricula, a few universities have to offer full geoinformatics curricula to satisfy the urgent need for geoinformation specialists.

In addition, a few universities have to offer training for geoinformatics specialists. The first steps have already been made at a variety of universities around the globe. More has to come in order that more experts on geoinformatics are trained that society so urgently needs. GIS is also a tremendous tool for teaching non-science subjects. GIS is a tool not only for students, but for educators and administrators as well.

The process of learning about GIS is itself beneficial to students. For students from elementary through graduate school, GIS engages many learning styles and provides a framework for all types of academic subjects. GIS continues to be a powerful research and presentation tool for both students and faculty at the college and university level. GIS helps students and teachers engage in studies that require and promote critical thinking, integrated learning, and multiple intelligences at any grade level.

The importance of GIS to education is being recognized throughout the world. We could see the current shortage in educated and trained surveyors and GIS professionals as an opportunity for current and future students. The immediate needs of bridging the gap between surveying and GIS is likely to remain until there is more GIS expertise in the surveying profession and GIS users see the need for surveying expertise in building GIS spatial data bases.

The rapid growth of GIS use in society has created a demand for education on the use of GIS in many industries and for research. Perhaps most importantly, GIS helps develop student's critical thinking and problem solving skills so they will become more involved in their community and more responsible global citizens.

CONCLUSION

There have been numerous applications of GIS. There are still many problems that await a solution and therefore we still will see many new developments in GIS. It is powerful and affordable computer hardware and software, the GUI and public digital data have brought GIS to mainstream use. More recently, GIS has been used for crime mapping and analysis, emergency planning, land records management, market analysis and transportation planning.

Geo-scientists should be interested in the development of GIS, their integration with spatial modeling, and their application in the interpretation and understanding of human resource problems. Generally, Geo-scientists and others should come forward to start an initiative into GIS and Society Perspectives on Digital Earth.

The growth of GIS use by law enforcement agencies has created a new demand for GIS professionals in the criminal justice system. There are employment opportunities for GIS specialists in crime analysis, forensics, crime profiling, correction supervision, and courtroom presentation. GIS has also become a job skill that is in demand.

GIS has been recognized as being at the heart of much of the technical requirements of the profession, requiring the training of a new generation of planners. We hope that researchers will keep that date open on their calendars and plan to contribute to the further integration of GIS through interdisciplinary scientific work.

ACKNOWLEDGEMENT

We are very grateful to The Director, Department of Geology and Mining, Govt. of Tamil Nadu, Guindy, Chennai - 32 for providing the necessary facilities.

REFERENCES

[1] V.Gewin; Nature, **427**, 367-377 **(2004)**.
[2] J.Star, J.Estes; in Geographic Information Systems: An Introduction, Englewood Cliffs, NJ: Prentice-Hall, 2-3 **(1990)**.
[3] I.Heywood, S.Cornelius, S.Carver; An Introduction to Geographical Information Systems, Addison Wesley Longman Limited, 279 **(1998)**.
[4] A.N.Campbell, V.F.Hollister, R.V.Dutta, P.E.Hart; Science, **217(4563)**, 927-928 **(1982)**.
[5] D.J.Wright, M.F.Goodchild, J.D.Proctor; Annals of the Association of American Geographers. **87**, 346-362 **(1997)**.

[6] R.F.Tomlinson; The Operational Geographer, **5**, 31-35 **(1984)**.
[7] R.F.Tomlinson; The Canada Geographic Information System, In Foresman op.cit. Chapter 2, 21-32 **(1998)**.
[8] D.Rumsey; Common Place, **3(4)**, 33-34 **(2003)**.
[9] http://www.gisdevelopment.net/technology/gis/techgis_002pf.htm; accessed **(2008)**.
[10] M.Ehlers, G.Edwards, Y.Bedard; Photogrammetric Engineering and Remote Sensing, **55(11)**, 1619-1627 **(1989)**.
[11] R.L.Shelton, J.E.Estes; Geo-Processing, **1(4)**, 395-420 **(1980)**.
[12] J.C.Hinton; Int.J.Geo.Information Sys., **10(7)**, 877-891 **(1996)**.
[13] A.Ade Abiodum; Photogrammetric Engineering & Remote Sensing, **66(6)**, 674-686 **(2000)**.
[14] X.Yang, M.C.J.Damen, A.Van Zuidam; Int.J.Applied Earth Observation and Geoinformation, **1(2)**, 146-157 **(1999)**.
[15] P.Chagarlamudi, G.W.Plunkett; Mapping Applications for Low- cost Remote Sensing and GIS; in ICORG-92 Remote Sensing Applications and GIS Recent Trends. I.V.MuraliKrishna (Ed); Tata McGraw-Hill Publishing Company Ltd., New Delhi, 359-365 **(1992)**.
[16] M.M.Datta; Indian Cartographer, 51-54 **(2003)**.
[17] I.Couloigner, T.Ranchin; Photogrammetric Engineering & Remote Sensing, **66(7)**, 867-874 **(2000)**.
[18] J.E.Dobson, E.A.Bright, P.R.Coleman, R.C.Durfee, B.A.Worley; Photogrammetric Engineering & Remote Sensing, **66(7)**, 849-857 **(2000)**.
[19] M.G.Nogales; GeoInfo Systems, **10(4)**, 24-28 **(2000)**.
[20] T.Pratt; GeoWorld, **13(7)**, 132-136 **(2000)**.
[21] D.A.Quattrochi, J.G.Luvall; GeoInfo Systems, **9(5)**, 26-33 **(1999)**.
[22] K.Thompson; GeoWorld, **12(10)**, 46-48 **(1999)**.
[23] M.N.Kulkarni, M.Kamath; Geospatial Today, **6(3)**, 27-30 **(2007)**.
[24] A.Harrington; GeoWorld, **12(11)**, 26 **(1999)**.
[25] B.Pfister; GeoWorld, **12(10)**, 36-37 **(1999)**.
[26] S.Cornelius, D.Sear; Int.J.Geo.Inf.Sys., **9(4)**, 475-485 **(1995)**.
[27] J.Giles, V.Speed; Geospatial Solutions, **10(6)**, 36-40 **(2000)**.
[28] K.P.Corbley; GeoInfo Systems, **9(6)**, 30-34 **(1999)**.
[29] M.W.Michelsen; GeoWorld, **12(2)**, 54-56 **(1999)**.
[30] M.Stevenson, N.Robins; Planning (American Planning Association), **66(7)**, 10-15 **(2000)**.
[31] J.P.Wilson, H.Mitasova, D.Wright; URISA Journal, **12(2)**, 61-81 **(2000)**.
[32] D.J.Peuquet; Cartographica, **21(4)**, 66-113 **(1984)**.
[33] M.J.Ungerer, M.F.Goodchild; Int.J.Geo.Information Sys., **4**, 369-383 **(2002)**.
[34] M.J.Carlotto; Int.J.Geo.Information Sys., **9(5)**, 621-635 **(1995)**.
[35] M.Koch, S.Greene, L.Thomas; GeoWorld, **12(6)**, 46-50 **(1999)**.
[36] A.Levinsohn; GeoWorld, **13(2)**, 166-173 **(2000)**.
[37] A.Lange, C.Gilbert; Using GPS for GIS Data Capture, in P.A.Longley, M.F.Goodchild, D.J.Maguire, D.W.Rhind, (Eds); Geographical Information System, Principles and Technical Issue. New York, Wiley, **1**, 467-476 **(1999)**.
[38] L.Anselin; Geog.Inform.Sciences, **5(2)**, 67-76 **(1999)**.
[39] N.Dash; Int.J.Mass Emergencies and Disasters, **15(1)**, 135-146 **(1997)**.
[40] D.J.Varnes; Landslide Hazard Zonation: A Review of Principles and Practice. UNESCO, Darantiere, Paris, 61-63 **(1984)**.
[41] J.Brainard, A.Lovett, J.Parfitt; Int.J.Geog.Inform Sys., **10**, 831-849 **(1996)**.
[42] R.Anbazhagan; Eng.Geol., **32**, 269-277 **(1992)**.
[43] A.K.Pachauri, M.Pant; Eng.Geol., **32**, 81-90 **(1992)**.
[44] R.Nagarajan, A.Mukherjee, A.Roy, M.V.Khire; Int.J.Remote Sens., **19(4)**, 573-585 **(1998)**.
[45] K.Muthu, M.Petrou; IEEE Transactions on Geoscience and Remote Sensing, **45(2)**, 522-530 **(2007)**.
[46] R.P.Gupta, B.Cjoshi; Eng.Geol., **28**, 119-131 **(1990)**.
[47] R.P.Gupta, A.K.Saha, M.K.Arora, A.Kumar; Himalayan Geol., **20(2)**, 71-85 **(1999)**.
[48] A.K.Saha, R.P.Gupta, M.K.Arora; Int.J.Remote Sens., **23(2)**, 357-369 **(2002)**.
[49] K.Verbruggen, R.Creighton, X.Pelicer, N.Boylan, M.Long, S.Murphy; Geophysical Research Abstracts, **8**, 08937 **(2006)**.
[50] GIS to Fight Dengue in Bangkok; Geospatial Today, **6(7)**, 13 **(2007)**.
[51] Mapping Health Facilities; Geospatial Today, **6(8)**, 6 **(2007)**.
[52] Veterinary Experts Vouch for GIS; Geospatial Today, **6(11)**, 6 **(2008)**.
[53] http://www.financialexpress.com/news/FOSS-to-drive-Kerala–s-first-e-governance-web-GIS/274632/; accessed **(2009)**.

[54] http://www.telegraphindia.com/1080225/jsp/jharkhand/story_8944258.jsp; accessed **(2009)**.

[55] T.L.Bowers, L.C.Rowan; Photogramm Eng.Remote Sens., **62(12)**, 1379-1385 **(1996)**.

[56] G.F.Bonham-Carter, F.P.Agterberg, D.F.Wright; Photogramm.Eng.Remote Sens., **54**, 1585-1592 **(1988)**.

[57] S.K.Bhan, A.Bhattacharya, P.K.Guha, K.V.Dravidian; Curr.Sci., **61**, 23-24 **(1988)**.

[58] K.Conradsen, O.Harpoth; Econ.Geol., **79**, 1229-1244 **(1984)**.

[59] P.J.Rubec; GIS as a Tool for Research, Management and Placement of Artificial Reef Fisheries. In: Florida Artificial Reef Summit '98, Proceedings of a Conference held 5-7 March 1998 in West Palm Beach, Florida, 112-121 **(1999)**.

[60] C.A.Friel, C.Westlake, R.Hudson, H.Norris, C.A.Fowler; GIS World, **11(1)**, 731-745 **(1999)**.

[61] P.Satyanarayana; Geospatial Today, **6(11)**, 26-29 **(2008)**.

[62] R.M.Teeuw; Hydrogeology Jour., **3(3)**, 21-30 **(1995)**.

[63] A.K.Saraf, P.R.Choudhary; Int.J.Remote Sens, **19(10)**, 1825-1841 **(1998)**.

[64] K.S.R.Murthy; Int.J.Remote Sens, **21(9)**, 1867-1884 **(2000)**.

[65] P.S.Ravi, D.Mishra; J.Indian Soc.Remote Sens, **21(4)**, 217-227 **(1993)**.

[66] J.N.Krishnamurthy, K.Venkatesa, V.Jayaraman, M.Manivel; Int.J.Remote Sens, **17(10)**, 1867-1884 **(1996)**.

[67] S.Shahid, S.K.Nath; Jour.of Spatial Hydrology, **2(1)**, 1-12 **(2001)**.

[68] R.K.Jaiswal, S.Mukherjee, J.Krishnamurthy, R.Saxena; Int.J.Remote Sens, **24(5)**, 993-1008 **(2003)**.

[69] Y.Srinivasa Rao, K.D.Jugran; Hydrogeology Sci.J., **48(5)**, 821-833 **(2003)**.

[70] A.I.Elkadi, A.A.Oloufa, A.A.Eltahan, H.U.Malik; Groundwater, **32(4)**, 617-625 **(1994)**.

[71] S.Shahid, S.K.Nath; Int.J.Remote Sen, **2(1)**, 993-1008 **(2000)**.

[72] D.F.Boutt, D.W.Hyndman, B.C.Pijanowski, D.T.Long; Groundwater, **39(1)**, 24-34 **(2001)**.

[73] M.V.V.Kamaraju, G.S.R.Reddy; India, **34(2)**, 46-48 **(1996)**.

[74] R.K.Prasad, N.C.Mondal, V.S.Singh; J.Geol.Soc. India, **71(5)**, 661-669 **(2008)**.

[75] R.M.Novaline Jaga, A.Sundaram; Wasteland Development Using GIS Technique, in ICORG-92 Remote Sensing Applications and GIS Recent Trends, V.MuraliKrishna (Ed); Tata McGraw-Hill Publishing Company Ltd, New Delhi, 388-394 **(1992)**.

[76] C3S, GIS and Surveillance Cameras for Dhaka; Geospatial Today, **6(7)**, 13 **(2007)**.