Geographical Information System –As a Media Tool for Promoting Sustainable Development vis-à-vis Environmental Conservation

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Sustainable development vis-à-vis environmental conservation is today recognized as the key to the present and future welfare and survival of the global community. The present day media-dominated world plays a key role in informing the public, influencing public opinion and in setting public agendas. Media is no doubt a powerful tool and multiplier for disseminating knowledge and information, and achieving the goals of sustainable development and environmental conservation. The launching of "Google earth" (www.earth.google.com) – a web based Geographical Information System (GIS) service provider, and the distribution of Free and Open Source Software (FOSS) have fairly democratized the accessibility to the GIS and enhanced its applicability as a powerful media tool. GIS may now not necessarily be considered as a highly sophisticated and specialized system, needing large capital investment for the procurement of hardware and software components, and requiring a great deal of technical and operational skills. The dissemination and usage of resource data from satellites, sharing of maps and other information through the internet and the recent development in the GIS embedded technology, have further revolutionized the way in which information is stored, analyzed, accessed, and disseminated.

There is no doubt that one of the most important prerequisites for sustainable development is the availability of accurate, reliable, up-to-date and standard data on natural and cultural resources of the country. Such data/information

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is required at various levels for different purposes, for example, a tourist who needs to know the location and direction of a tourist spot; demographers need information on the total number, distribution and composition of the population; industrialists need to know the best location to establish an industry; agriculturalists, foresters, soil scientists, environmentalists, policy makers and planners all need data and other vital information to chalk out the development activities and conservation strategies to achieve sustainable development.

Therefore, building a strong, reliable, accurate, and easily accessible micro-level database system should form a major component of decentralization. Such database infrastructure will facilitate participatory planning and decision making at the grass root level. GIS, aided with remote sensing data, Global Positioning System, and other media for information collection and diffusion, can play an effective role in the storage, retrieval, analysis and sharing of data. Its usage can be as simple as providing readers and viewers with maps that give context to the news of a journalist or as complex as creating an earthquake risk zonation model.

The author of this article is highly confident that GIS can play a major role as a media tool for gathering, storing, disseminating, reporting, analysing and sharing of quantitative and qualitative data, and other vital information about the country's natural and cultural resources. This would not only facilitate the process of decentralized planning as an approach to sustainable development vis-à-vis environmental conservation, but would also be an important aid during natural disasters and other emergencies.

Introduction

Conservation of biodiversity and the sustenance of the globe's growing human population is one of the great challenges faced by the present generation. The two are inevitably linked as economic development impinges upon the biota, while at the same time the biosphere provides essential resources for human well being. In this context "Development that meets

the needs of the present without compromising the ability of future generations to meet their own needs",[1] or what is commonly known as 'sustainable development', is seen as the best way to tackle these challenges. The report of the United Nations Conference on Environment and Development[2] suggests the creation of a global mountain database, is vital for launching programmes that contribute to the sustainable development of mountain ecosystems. Some of the major objectives of the programme are to: create and strengthen the communications network and information system; evaluate environmental risks and natural disasters; build an inventory of different forms of soils, forests, water use, and crop, plant and animal genetic resources; identify hazardous areas that are most vulnerable to erosion, floods, landslides, earthquakes, snow avalanches and other natural hazards.

It is a well-accepted principle that appropriate data and information are required to underpin the complex decision-making needed to conserve biodiversity and attain sustainable development. Planning and management to conserve biodiversity must deal with the distribution of these ecological resources through space and time, at a scale commensurate with that imposed on the landscape by human land use and resource extraction.[3] The loss of biodiversity can be considered as a symptom of failure to implement the process of sustainable development and vice-versa. The progress and development of societies are evaluated by

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[1] Bruntland, G. (ed.) 1987: *Our common future*: The World Commission on Environment and Development, Oxford University Press

[2] Agenda 21: Chapter 13, Managing Fragile Ecosystem: Sustainable Mountain Development , Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992. For full details see: http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21chapter13.htm

[3] Brendan G. Mackey: The Role of GIS and Environmental Modeling in the Conservation of Biodiversity. Available from: http://www.sbg.ac.at/geo/idrisi/gis_environmental_modeling/sf_papers/brendan_mackey/mackey_paper.html (Accessed 21 April 2006)

comparing the past with the present condition of the overall social, cultural, economic and environmental standards. Accurate, up-to-date, and reliable data/information about the country's natural and human resources is therefore the prerequisite for analyzing and monitoring the achievements, and for developmental planning. This is where GIS can play an important role as a tool for promoting sustainable development vis-à-vis environmental conservation.

Environmental conservation and sustainable development has been a major aspect of the Five Year Plans in Bhutan, and are also important components of Gross National Happiness (GNH). The Kingdom of Bhutan has received international acclaim for its commitment to the maintenance of her biodiversity and places environmental conservation at the core of development strategy. The vision of happiness, peace and prosperity clearly states that the long commitment to the maintenance of biological diversity and productivity is rooted in the understanding of the importance of forest systems to the survival strategies of remote and isolated communities, beliefs and customs, and understanding of sustainable development.[4] The dynamic leadership of His Majesty and the prevalence of strong traditional values have so far played a crucial role in the preservation of country's rich biodiversity. However, with the ongoing process of decentralization, the responsibilities and powers to maintaining the ecological resources and the overall environment will be vested in local communities, and will also lead to grassroots level planning and management of the resources. A sound database and overall information about the location, quality, and quantity of the country's natural and human resources is therefore the prerequisite for the conservation of biodiversity and for planning for a sustainable future.

[4] Ministry of Planning 1998, RGB, Bhutan 2017: *A Vision for Happiness, Peace and Prosperity*, p. 35

GIS and the Information & Communication Technology (ICT)

The dramatic acceleration in the development and use of information and communication technologies during the last few years has set in motion a worldwide process of transition from the 'industrial' to the 'information society'. Moreover, individuals, groups and communities will need to develop not only new tools of analysis but also very different mentalities and attitudes in order to adapt to the emerging 'new' civilization based on information and knowledge.[5] ICT is a very broad term that includes radio, television, telephone networks, satellite communication and the latest internet system, which can be used as information-handling tools. It is true that these technologies play an important role in gathering, storing, and disseminating information about our environment and resources. However, its use is more for social services, entertainment, and exchange of information, which may not necessarily be related to the environmental conservation or sustainable development. But, the role of GIS as an important component of ICT is already established, and there are ample research and practical applications in various disciplines across different countries to confirm GIS as an analytical device that is especially configured to handle spatial information and/or as an information technology, as a (mass-) media.[6]

The importance of information system has been clearly highlighted in the vision statement, which states that "greater priority must also be accorded to the development of the information system required for decision making and development planning".[7] Christopher B. Faris in his article "Information and Communications Technology and Gross National happiness – Who Serves Whom?" describes the ICT

[5] UNESCO and an Information Society for All.
Available from: http://www.unesco.org/webworld/telematics/gis.htm (Accessed 3 April 2006).

[6] Hans Skov, Petersen, *Defining GIS – Assessment of ScanGIS*. Available from: http://www.scangis.org/scangis2003/papers/31.pdf (Accessed 8 May 2006).

[7] O*p cit,* Ministry of Planning 1998, p.37.

as a powerful engine for accelerating and promoting economic and societal development, preservation of cultural heritage, managing the environment, understanding issues like biodiversity and climatic change, monitoring ecological conditions, and mitigating the effects of natural disasters. His study reveals that the ICT has significant potential to advance Bhutan's progress towards the goal of GNH.[8]

In the past few years, Bhutan has witnessed a rapid growth in the application of ICT. Almost every sector, i.e. government, academia, corporate, non-profit, and non-governmental, are involved in building their respective ICT infrastructure. Many of the technical requirements for the establishment of GIS database already exist in the country, and some of the departments have already procured and started utilizing GIS in their respective fields. However, very little scientifically sound research has been carried out concerning the actual impact of ICT, novel technology required to meeting the developmental needs and methodologies that lead to success or failure of ICT projects. Moreover, the approach in the application of GIS has been somewhat isolated and centralized. An integrated and decentralized information system and a firm policy framework to strengthen the collection, authentication, and sharing of this information, and scientific research will definitely assist in proper planning and conservation of the country's natural resources.

What is GIS?

In its most basic form, GIS refers to computer-based systems for automation, storage, retrieval, analysis, and presentation of geographically related information. It is the ideal tool for extracting the patterns and trends inherent in location-based information. GIS is a technology that manages, analyzes, and

[8] Christopher B. Faris*: Information and Communications Technology and Gross National happiness – Who Serves Whom*? Gross National Happiness and Development, edited by Karma Ura & Karma Galay. CBS, 2004. pp. 140 – 173.

disseminates geographic knowledge.[9]

Peter Burrough defined GIS, as "a powerful set of tools for collection, storing, retrieval at will, transforming, and displaying spatial data from the real world".[10] "A main objective of GIS is to allow the user of the system to interact vicariously with actual or possible phenomena of the real world."[11]

The definition and approach to GIS at the initial stages of its development was initially seen purely as quantitative and data driven technology. It was only during the nineties that the awareness of the social aspects of GIS became more and more articulated. As of today, GIS serves as a main vehicle for communication, and plays a significant role in influencing people's perception of the world. Hrishikesh Samant, the Sr. Associate Editor of *GIS Development*, in his article "The world in a window…Google Earth", describes how web based GIS service has popularized the use of geospatial data, which can be used for a plethora of activities.[12] Its application involves site selection, investment for commercial real estate, architecture/engineering, urban planning, infrastructure maintenance, defense/intelligence, emergency planning, and location context for world events.[13] Google Earth gives the media critical tools for understanding and relating the story in real time. Its services include visual displays of fly-throughs and perspectives for both on-air use and print applications; in-depth earth data including over 100 global

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[9] Bonnie Bracey Sutton: *Geography Matters: GIS*, Available from: http://www.digitaldivide.net/articles/view.php?ArticleID=493 (Accessed 19 Nov 2005)

[10] Burrough, P. 1986: Principles of Geographical Information Systems for Land Resource Assessment. Clarendon Press, Oxford, p. 6

[11] Mark, D.M. 1989. Cognitive Image-Schemata and Geographic Information: relation to the user View and GIS Interface. Proceedings, GIS/LIS '89, Orlando, p. 1.

[12] Hrishikesh Samant, Saurabh Mishra: *The World in a Window…Google Earth*, GIS Development, The Asian GIS monthly, November 2005, vol.9, issue 11, pp. 16-22.

[13] For details see http://earth.google.com/industries.html

cities in high resolution; and valuable data overlays such as the locations of airports and political boundaries.[14] With the launching of 'google earth'[15] and the availability of other internet-based software, GIS as a technology has come to a point in its development where its role as a media tool is a profound feature. GIS can now be considered a media tool that can effectively handle and communicate geographic information to the masses and assist in attaining sustainable development vis-à-vis environmental conservation.

Thus, with the ever expanding use of GIS and mapping-related applications, it becomes increasingly clear that this technology is well established as a strategic element of our information technology infrastructure and subsequently, the decision making process. GIS provides a particularly valuable framework for managing both human and natural activities because it facilitates the integration and analysis of complex data, making it readily accessible to scientists, planners, and the general public. The GIS framework allows the assimilation of physical measurements, analytical methods, and computer models into a uniform system that allows analysis and maintenance of workflows and perpetuates sustainable development. Taken as a whole, GIS is improving our understanding of the natural processes of our planet, at both the micro and macro levels. GIS helps to increase efficiency, reduce costs, and promote better decision-making.[16] Sui and Goodchild in their guest editorial column "GIS as media" provide a very explicit example. They state that the "…latest development in GIS have convinced us of the need for new conceptualizations", and further that "…the complex relationship between GIS and society can be better

[14] For details see http://earth.google.com/media.html

[15] Available from: www.earth.google.com

[16] Jack Dangermond (President, ESRI): *GIS: Helping manage our world*. Available from: http://www.gisdevelopment.net/magazine/years/2005/dec/26_1.htm (Accessed 26 November 2005)

understood if one conceives of GIS as new media". [17]

Components of a GIS

There are four basic components of a GIS. They are:

Hardware: The hardware components of GIS include input, storage, and output devices, such as computer, disk/tape drives, scanner/digitizer, printer/plotter, and Geographical Positioning System (GPS).

Software: Software refers to programmes that manage the functioning of the computer and determine the task it can perform. There are wide ranges of software, which can perform simple cartographic tasks to multiple raster/vector analysis. The choice of the software depends on the type of data to be handled, the purpose to be accomplished, and also the budget allocation.

Database: Database can be generated from existing paper maps, field surveys, satellites images and aerial photographs, sensors, GPS, etc. Advanced GIS software can handle text, tables, graphics, video and most other data formats. The quality of the result that the software and hardware produces depends on the accuracy, relevance, and the overall quality of data that is fed to the computer.

Organizational Setup: The above three components of GIS govern the way in which geographical information can be handled but they do not of themselves guarantee its success. In order to be used effectively, the GIS needs to be placed in an appropriate organizational context. Therefore it is equally important to have a multidisciplinary team of experts, managers, planners, and a strong institutional framework and sound policies to make best use of this technology.

Latest Developments in GIS Technology

GIS offers immense opportunities to all societies and

[17] Sui, D.Z. and Goodchild, M. 2001. GIS as media? Guest editorial. International Journal of Geographical Information Science. Vol. 15, No. 5, 387-390.

individuals as a universal way of accessing and disseminating information. The technology can be easily acquired and adapted with appropriate resource mobilization, and provides immense scope in its utilization and expansion in almost all disciplines. The GIS industry has perhaps experienced three big changes in the recent years, namely: i) GIS awareness ii) new computing technologies for internet, and iii) internet GI Services users and providers. Along with these three big changes, in both academic research and commercial markets, the new pretty face of internet GIS will attract more people to use it and it will transform the way people live, work, and behave.[18]

Embedded GIS

Embedded GIS refers to the geographic data and functionalities embedded into other systems and applications. This could be an application within a web browser, functions embedded within word processing documents and spreadsheets, or mapping provided within applications.[19] A.R. Dasgupta, the distinguished professor in the Bhaskaracharya Institute for Space Applications and Geoinformatics, (Ahmedabad, India) identifies three approaches to embedding technology.

Embedded Applications in GIS

All GIS software provides customization tools to automate GIS functions through scripts. These could also include screen design tools to construct menus to enable a visual interface. The GIS and query functionalities are hidden behind the visual menu system which enables the user to interact with the system and invoke the query functions without knowing the GIS commands.

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[18] Ming-Hsiang Tsou: *Recent evelopments in Internet GIS*. Available from: http://www.gisdevelopment.net/technology/gis/techgis_002.htm (Accessed 5 May 2006)

[19] Jian Kang Wu: *Embedded GIS – An Overview* in GIS Development, February 2006 Vol.10, Issue 2. p.28

GIS Embedded in Applications

The most common example of this kind of embedding is Web GIS. The web browser is used as the interface and HTML and XML extensions are used to serve up GIS content. By adding elements of GPS and communications a very powerful embedded application can be developed. These applications fall under the category of tele-geoprocessing. Vehicle tracking systems have been developed using these technologies.

Device Embedded Geographical Applications

This is the emerging area of development and involves a level of ubiquity already achieved in other IT applications. It calls for a high degree of integration of devices, software and geographical information in to what is termed as 'Portable Spatial Information technologies'.

GIS have become ubiquitous and embedded GIS is the next evolutionary spatially enabled technology for the common people. Embedded GIS have further enhanced the usefulness of the mainstream application and facilitates the integration of spatial information with the IT infrastructure, and makes intelligence about location accessible to more business applications, resulting in better information, and agile decision making.

Another important development in the field of GIS is the Free and Open Source Software (FOSS), i.e. software whose source code is openly accessible, whose ownership may be copyright but which includes collaborative development and/or adoption. FOSS and initiatives have become increasingly popular and dynamic over the past decade. They protect intellectual property through copyright, yet foster sharing, distributed development, bug-fixing, training, support customization, etc. Thus, the freely available internet based GIS software has gained much attention from the geo-informatics community and has created new opportunities

and benefits to a wider audience.[20]

Role of GIS in sustainable development and environmental conservation

GIS plays several different yet complementary roles in relation to sustainable development and environmental conservation. GIS provides a means of converting spatial data into digital form that can then be stored, retrieved, displayed, manipulated, modified, analysed, and reproduced quickly in a new format, available for either visual display or hard copy reproduction.

GIS can be used for constructing models for analyzing trends and identifying factors that affect them and to simulate the effect of a specific process over time for a given scenario. Such models can also be used for environmental impact assessment or for displaying the possible consequences of planning decisions or projects that affect resource use and management.

It can assist policy makers and planners to make appropriate plans for sustainable development, for example, to decide on the best potential sites for growing a certain cash crop, the agricultural planner might use geographic databases combining soils, topography, and rainfall to make an agro-ecological zonation map. Forestry planners can use GIS to monitor the impacts of deforestation and the wildlife manager can use GIS to determine the size and location of animal populations or to determine areas having high food and habitat potential for specific species.

GIS can also be used as a potential media tool for creating awareness related to the country's natural and human resources and biodiversity conservation through

[20] Venkatesh Raghavan: *Free and Open Source Software solutions in GIS* in GIS Development, January 2006, Vol. 10, Issue 1. pp. 22-24. More information about FOSS can be accessed at:
http://www.fsf.org
http://www.opensource.org
www.freegis.org
www.mapserverfoundation.org

environmental education.

GIS provides a platform for individuals and organisations to share and upgrade data and information and facilitate real-time and instant communication network.

Opportunities and Challenges

Over the last decade or so, GIS and related technologies have made remarkable advancements, providing a new dimension for integration and analysis of divergent sources of information. The cost of hardware and software has become less expensive, and since the process of computerization of various institutions in the country is already underway. The emphasis can now be given to software procurement, manpower training and generating geo-spatial database. It is therefore imperative to take necessary steps to building a reliable Geographic Information Infrastructure (GII)[21], which is as important as the building of other infrastructure such as roads or telecommunications.

GIS technologies and applications are evolving in ways to ascertain their prominence in decision-making processes by integrating many disciplines and adding value to them. The information thus processed through GIS-based decision support systems can render useful information and knowledge for sustainable decision-making.[22]

A dearth of credible data and information; poor co-ordination in data and information sharing and exchanging; and the lack of scientific research often hamper decisions on sustainable and equitable development. Studies carried out by the International Centre for Integrated Mountain

[21] GII has been conceived as an environment where - the basic geographic datasets are readily available; existing geographic information are well documented; available geographic information conform to accepted standards; policies encourage sharing and exchange of geographic information; and adequate human and technical resources to maintain and manage geographic information.

[22] GIS for Sustainable Mountain Development op cit.

Development (ICIMOD)[23] in the Hindukush region reveals that the lack of credible data and information and poor regional cooperation in sharing and exchanging data and information as some of the major challenges in sustainable mountain development. Fortunately, Bhutan has so far been able to preserve their natural resources and maintain a healthy environment. This can be largely attributed to the strong traditional values of the Bhutanese society and the dynamic leadership of His Majesty. However, the undergoing process of decentralization will transfer the functions, responsibilities, and powers to maintaining the ecological resources and the overall environment to the local communities. This necessitates proper evaluation and time-to-time monitoring of the resources and creation of a sound information system. "GIS can bolster a community development organization's efforts by enhancing decision-making, resource allocation, and strategic planning functions. In an age when knowledge is power, GIS can offer distinctive tools that enable an organization to gain an edge, provided the organization is willing to make the necessary investment of time and resources to develop a foundation in the GIS basics."[24]

Application of GIS

Mountains have very distinct spatial and temporal expressions and many of our planning and decision-making processes in these areas are often influenced by geographic information. Given the dynamic character of the natural resources that undergo quick changes in the mountain region, there is constant need to update the information and review the dynamic linkages. Geographic information infrastructure provides a unifying framework for integrating

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[23] *GIS for Sustainable Mountain Development*. Available from: http://www.icimod-gis.net/sustain/hkh.php (Accessed 25 Nov. 2005)

[24] Amira Sobeih : Geographic Information Systems (GIS) in Egypt, Available from: http://www.iisd.org/pdf/2005/networks_dev_connection_egypt.pdf (Accessed 8 May 2006).

many different kinds of information for better understanding of mountain ecosystem and supports its functioning and management.[25] Early adopters of GIS included disciplines in the natural sciences, natural resource management, applied technologies, landscape architecture, biology, geography, and geology. Today, its techniques and applications can be widely used in fields such as business, economics, engineering, history, journalism, and public health, among others.

As a digital media tool, GIS integrates disciplines, organizations, work flows, decision-making bodies, plans, and processes. By integrating data, the user has the ability to more clearly understand, conceptualize, model, and visualize what is going on in the world around us or that s/he is analyzing. These tools are especially valuable for persons who deal with budgeting, facilities management, emergency planning, crime analysis, resource allocation, grounds maintenance, and other similar issues where GIS software can offer solutions because of its database interconnectivity, visualization representation, and analysis capabilities that streamline administrative problems.[26]

GIS has attained a multi-disciplinary status and its application leaves virtually no aspect of life untouched. The thrust area basically meant for geographers has been taken over by resource scientists, physicists, computer scientists, electronic engineers, surveyors, and statisticians, apart from the remote sensing application scientists.[27] Saurabh Mishra et al[28] probe into the critical issues and successful applications of GIS and related technologies in the management of three

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[25] Ibid

[26] Geographic Information Systems Software: Digital Media Tool with Uses Across the Curriculum. Available from http://www.bsu.edu/library/article/0,1894,-5572-33424,00.html (Accessed 19 Feb. 2006)

[27] Prithvish Nag and M, Kudrat, 1998: *Digital Remote Sensing*, Concept Publishing Company, New Delhi, p. 200

[28] Saurabh Mishra, Rituparna Sengupta, Tuhina Sinha: *Natural Resource Management*: A critical agenda in GIS Development, Asia Pacific April 2006, vol. 10, issue 4, pp. 16 - 22

important natural resources – water, flora, and fauna, citing case studies carried out in various regions of South Asia. They further conclude that GIS and related technologies have the potential to provide the perfect backdrop for all management decisions by adding greater transparency and accuracy to information. Philip J Burden describes how GIS with its capability for displaying, managing, and modeling spatial data can be utilized throughout the various phases of the disaster cycle, i.e. identification & planning; mitigation; preparedness; response; and recovery.[29] Several instances are observed where GIS is being applied to enhance and facilitate wildlife conservation programmes all over the world.[30] Many countries are already using GIS to plan and implement programs to promote sustainable socio-economic and environmental development. GIS is an important tool that can assist natural resource management initiatives and enable increased public participation in decision-making. The technology, often called mapping software, can be used for a variety of purposes, including resource management, development planning, cartography, and route planning.[31] GIS have advanced into an increasingly important information tool, especially on-line Public Participatory Geographic Information Systems (PPGIS), with the aim to enlarge the level of citizen's involvement and participation in decision-making processes.[32]

GIS aided environmental modeling provides new capabilities for analysing the space/time distribution of

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[29] Philip J Burden: *GIS and Natural Hazard Management*. Available from: http://www.gisdevelopment.net/application/environment/pp/envpp001.htm (Accessed 21 March 2006)

[30] Can GIS save the endangered wildlife? Available from : http://www.gisdevelopment.net/have_a_look/2sept_9sept05.htm (Accessed 8 May 2006)

[31] Amira Sobeih : op cit

[32] Darinka Golubovic Matic, *Geographic Information Systems on the Internet: Sustainable Solution for the Information Society*. Available from: http://www.corp.at/Download/CORP2006_CDRom/archiv/papers2006/CORP2006_GOLUBOVIC.pdf (Accessed 8 May 2006)

ecological phenomena. Habitat modeling, soil erosion modeling, vulnerability modeling, land cover change prediction modeling and so on - all have the common element of deriving new maps of the likely occurrence or magnitude of some phenomenon based on an established relation between existing map layers. Given the importance of this activity, it is not surprising to see that GIS continues to evolve its modeling tools. The latest developments, however, promise to take GIS to dramatic new levels of functionality.

The ICIMOD with its headquarters at Kathmandu is perhaps the most important proponent of GIS in the entire Hindu Kush-Himalayas (HKH), and fosters the establishment of a strong GIS network in the entire region. The article on the ICIMOD website[33] reveals that GIS technology has made significant inroads into the HKH region and clearly demonstrates as to how these technologies have been effectively used to support policy formulation, planning, and management of the natural and human resources for sustainable mountain development. It has also developed diverse ranges of applications and decision support systems suitable for mountain areas at the local, national and regional levels. Some of the important applications and decision support system that ICIMOD has put to use are:

— Landuse/Landcover mapping at the regional level;
— Vegetation monitoring using remote sensing data;
— Sustainable development indicators;
— Inventory of glaciers, glacial lakes and potential impact of glacier lake outburst floods due to global warming;
— Urban and municipal planning;
— Biodiversity mapping and assessment using remote sensing data;
— Water resources management applications;
— Decision support system for national park management;

[33] GIS for Sustainable Mountain Development, Op cit.

— Eco-regional agricultural and landuse planning for mountain ecosystems.

The above applications are mostly related to physical resources, and hold great importance in Bhutan too. Another important area that can help in planning for a sustainable development is the creation of GIS based population census report. The first ever population census survey of Bhutan carried out in 2005, apart from containing the demographic characteristics, also consists of the locational aspects, which was recorded using the Geographical Positioning System (GPS). The compilation of population census data (with its geographical location) in the GIS environment, along with the data on the distribution and utilization of natural resources, and other economic activities can become the base for planning and policy making for a sustainable future of the country.

Decentralization of Information

Bhutan's economy is dominated by agriculture, which accounts for approximately 42 percent of the GDP, and employs 78 percent of the economically active adult population. Forestry shares about 11.2 percent and livestock 9.7 percent of the GDP.[34] This indicates that much of the natural resources are directly or indirectly controlled by the rural masses. The development of the information systems required for more informed decision-making cannot be confined to the national level but should also extend to the *Dzongkhag* (district) level, and eventually even to the *geog* (block) level.[35] While the initiation of *Dzongkhag Yargye Tshogchung* (DYT) in 1981 and the *Geog Yargye Tshogchung* (GYT)[36] in 1991, extends the process of decentralization to the *Geog* level and promotes a participatory approach in the

[34] UNDP, Development Co-operation, Bhutan, 1993 Report. p. 22.
[35] Ministry of Planning RGB, *Op cit*, p. 37.
[36] *ibid*. (Note: DYT refers to District Development Committees, and DYT refers to Block Development Committees).

decision making process, the control over information systems and accessibility to information is highly centralized and institutionalized. Decentralization must not only be seen as having an administrative and planning purpose, but needs to give equal emphasis on the 'decentralization of information'. Therefore, the first level of operation for data entry and collection of information should be based on rural information centers. Respective departments at the *Dzongkhag* level can establish their own GIS divisions to process the data, which can then be used by decision and policy makers to help in planning, implementing, managing, and monitoring public sector developmental activities at various levels. However, there are important issues relating to organizational setup, data classification, policies, and legal framework for data collection, authentication and sharing, privacy and security, right to information etc, which need proper scrutiny and assessment before decentralizing information. Therefore, further research and viability studies needs to be carried out before its actual implementation.

Preliminary Preparation for Setting up GIS

A great deal of careful preparation needs to go into the setting up of a geographical information system. A part of this preparation is finding out what others have done, and becoming acquainted with the enormous literature available. It would be worthwhile to employ a consultant who has recognized experience in the field. A detailed inventory of the existing work situation is essential to create a baseline from which one can anticipate how future data handling needs are likely to develop in order to assess not only current requirements for computerization, but also how the system is likely to grow. The distinction between components that are absolutely essential from the beginning and those that would be helpful but not essential will need to be made in relation to the degree of funding that is available. The type and source of hardware and software and the services they can provide also needs special consideration before deciding to setup a GIS infrastructure so as to ensure its smooth functioning. Most

important of all is a political will to support and encourage the processes of decentralization of information and to formulate policies and standards to promote the development and interconnection of national information infrastructures.

Conclusion

GIS can be effectively used as an important tool for storing, analysing, updating and retrieving data. The increasing use of GIS-based decision support and information systems has rendered useful information and knowledge for sustainable decision-making, resource allocations, and planning functions. Like all other infrastructures, it is also necessary to give due importance to building the nation's information infrastructure, which can best be achieved by decentralizing information systems and formulating firm policies through a dynamic organizational setup. Remote Sensing, GPS, and other associated techniques can serve as important tools for data acquisition, which when fed into the GIS environment can enhance capacities to understand and manage physical and ecological processes. The use of GIS can further reaffirm the role of media to meet the very basic educational, scientific, and cultural needs of people. The strategic importance of the fragile Himalayan eco-system of Bhutan needs to develop locally suited spatial methodologies for environmental conservation and sustainable development. Though the various problems can be generalized at the 'national' level, its solution needs to be realistically 'local' in nature.

The establishment of a GIS-Database and the decentralization of information in the country will definitely assist in planning, managing, monitoring, and disseminating information about natural and human resources, which is a prerequisite for attaining sustainable development vis-à-vis environmental conservation.

> "The application of GIS is limited only by the imagination of those who use it"
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> -Jack Dangermond, President, ESRI.