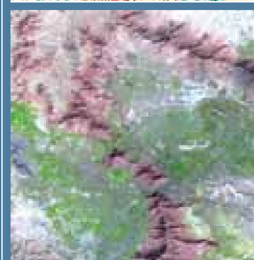
E-conference Report

Mountain GIS: Promoting Geographic Information and Earth Observation Applications for the Sustainable Development of the Hindu Kush-Himalayan Region



Electronic Conference of the Mountain Forum and ICIMOD
(14 – 28 January 2008)

ICIMOD

Mountain Forum

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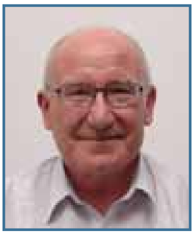
Foreword



In its medium-term action plan (2008-2012), the International Centre for Integrated Mountain Development (ICIMOD) has committed to develop and institutionalise integrated and innovative GI and EO applications for information and knowledge management within ICIMOD and its network of partners to support planning, and decision-making in priority areas such as climate change, water and hazards, and ecosystem services and livelihoods.

The Mountain Environment and Natural Resources Information System (MENRIS) division of ICIMOD has been entrusted with the responsibility to work with other in-house programmes and ICIMOD partners to implement this commitment. This is a very important responsibility and its importance to the Hindu Kush-Himalayan (HKH) region cannot be emphasised enough.

We recognise that there is a dearth of validated facts and figures at a regional scale on some of the priority areas of ICIMOD. The data generated by national and international institutions in the region are partial, fragmented and dispersed. Often different countries use different methods and standards for data collection and analysis. All these hinder proper planning and decision-making for sustainable mountain development of the HKH region.

The Intergovernmental Panel on Climate Change, for instance, has treated the HKH region as a ‘white spot’ due to the lack of data. This is a matter of serious concern, as climate change happens to be one of ICIMOD’s priority areas. Now the question arises: How do we fill in this white spot on the global climatic map? How do we fill in the white spots in other priority areas as well? These are some of the issues we have been grappling with, here at ICIMOD.

Certainly there has to be greater inter-institutional or cross-sectoral transboundary collaboration among the partners to fill in the research or data gaps in these priority areas. The partners need to work or communicate in common languages, using standard metadata protocols, standard map projections and parameters, and interoperable datasets. They need to all do their bit to colour in the white spots until the fuller pictures emerge, until the issues begin to make some sense at the regional scale.

We feel that it is high time we put in place elementary building blocks of the Himalayan Spatial Data Infrastructure to facilitate the acquisition, sharing and build up of geographic information for a broad user base. This is also for us a way to mainstream the concept of Mountain GIS, one of ICIMOD’s trademarks.

The Mountain GIS electronic conference held a year ago (in January 2008) discussed some of these topical issues.

I would like to take this opportunity to congratulate the Mountain Forum (MF) and Mountain Environment and Natural Resources' Information System (MENRIS) Division of ICIMOD for finally bringing out a synthesis of the said electronic conference.

Andreas Schild, PhD
Director General, ICIMOD
Chairperson, Mountain Forum Board of Directors

First, I would like to acknowledge that ICIMOD has done amazing things in the Hindu Kush-Himalayan region – in agriculture, conservation, water resources and land use planning, all the things that matter to the future planning of that region and its societies.

We live in a world that's changing rapidly. Our population is growing. Our planet is warming. We have countless social conflicts underway. We have resource shortages and many countries are faced with loss of biodiversity and security threats. So, we need to forge a future with greater knowledge, with greater awareness; a society which can carry out comprehensive planning to create the future, where we drive more efficiency to create more sustainability in our daily lives. So I would say the world needs a new approach that changes how we see and do things.

Geography is the science that you work with through geographic information system (GIS). It helps us see that there is a whole planet. It helps us see that there is a network of inter-related systems. What we do in this system affects the whole planet. It also provides a framework for allowing us to see how we are a part of the world. It gives us context for understanding what we do.

The geographic approach is a framework for understanding and managing our earth. What you do through GIS is an application of geographic approach. It is about measuring things and modelling processes of geography. It is about storing digital information of what we measure and what we model. It's also applying geographical knowledge to how we plan and design and create our future; how we manage things; how we act; how our footprints affect natural environment and society in general.

GIS is being applied in all kinds of disciplines. ICIMOD's work is exemplary. Many GIS works are often done in isolation but through collaboration with organisations like ICIMOD these can acquire greater meaning because all these separate footprints of activities, if you add them up are in fact affecting the way the region is evolving. That's a pretty bold assertion that in fact GIS becomes an instrument of evolution but I think through your work, through measuring and analysing and taking action in various forms as NGOs or government organisations, it is really changing the outcomes which is very important as a concept and also as a set of workflows because you are actually determining the way it will come out. How you integrate your and the society's values into those models and interpretations is extremely important.

Looking at the future with respect to technology, it is useful to set forth a series of patterns. Firstly, a desktop pattern for GIS where you get some data, do mapping and ad hoc analysis. Second is a server based or a multi-user GIS where there is a shared database with fixed application and people's transactions updated to use each other's data almost dynamically today. Finally there is emerging a new kind of pattern we call a federated pattern where multiple organisations use GIS in a server environment and they use each other's data back and forth. It is a foundation for spatial data infrastructure. A fourth pattern is the pattern of GIS on the web. This is a new pattern. It doesn't replace the desktop pattern but in fact, it fuses with them. It does not replace the server technology or the federated architecture for internet application. This pattern is supportive of collaborative computing where multiple servers can talk with each other and share services. They could be mashed up. It is also interesting because it involves distributive data management, so what we do in Nepal could be shared in India or any other member countries using the web as the connection, but together they can become dynamically integrated as a kind of mosaic. This fourth architecture is built on web service standards and allows for interconnectivity and inter-operablility, and it is integrative and dynamic. Of course it requires web connections and web technology but this is evolving very fast, perhaps not as fast in your region as in Europe and North America but that will come, those investments will happen very naturally.

For the past 40 years, we have created and pioneered GIS technology. We can now see that it is starting to make a small difference. It is certainly changing the way we see things but more than this technology, what is required is that you work in collaboration with each other, sharing your information, working in this ICIMOD kind of network style. I think you are making a commitment to do the difficult work of sharing and collaborating which will make an enormous difference. It will be the framework within which we can apply this new approach and create a more sustainable future.

Jack Dangermond
President, ESRI
(January 2008)

On behalf of UNEP, I would like to congratulate the Head of the MENRIS division of ICIMOD for successfully organising a Mountain GIS e-conference together with the Mountain Forum on "Promoting Geographic Information and Earth Observation Applications for the Sustainable Development of the Hindu Kush-Himalayan region".

I had the privilege to be associated with the establishment of ICIMOD's Mountain Environment Natural Resources' Information System (MENRIS) division. MENRIS-ICIMOD was established as a node in the United Nations Environment Program (UNEP)'s Global Resources Information Database (GRID) network. In the initial years, MENRIS focused on building the capacity of its partner institutions in ICIMOD's regional member countries to promote the use of new GIS and remote sensing technologies in their work. In the subsequent years MENRIS-ICIMOD together with its network of partners worked on applying these tools and applications resulting in numerous publications and databases that have helped inform decision-making for the mountain communities. I am very pleased to see MENRIS-ICIMOD continuing to grow with strong support from both its development partners as well as other institutions across the Hindu Kush-Himalayan region.

The ever growing population pressures and the market forces continue to exact tolls on the natural environment and even more intensely on fragile mountain ecosystems. Human civilisation today faces mega-issues like climate change and globalisation, which will change the dynamics of life support systems as we know them. As we face ever mounting challenges from all directions, we will need to innovate and change our life styles so that they are compatible and in harmony with the natural world around us. This challenge will require better informed decisions. It will, moreover, require all of us to make a collective scientific and technical contribution towards supporting informed decision-making. And I believe that the GIS technology is evolving in ways that ascertain its prominence in decision-making processes by crunching data into critical information by way of indicators, indices and emerging issues.

I am happy to see that ICIMOD and the Mountain Forum have come out with a synthesis of the said electronic conference.

I urge you all to take collective action towards supporting your governments with geo-referenced information that leads to concrete actions on the ground.

Surendra Shrestha
UNEP Regional Director and Representative for Asia and the Pacific (UNEP-ROAP)
(January 2008)

Executive Summary

The Hindu Kush-Himalayan (HKH) region, home to the largest concentration of glaciers outside of the polar region, is the 'water-tower' of Asia. The HKH mountain ecosystem provides life support services to almost a third of humanity. Many mountain issues such as management of water resources, climate change, biodiversity conservation and hazard mitigation are interconnected in nature and, therefore, need to be considered holistically.

The relevance of geographic information (GI) and earth observation (EO) applications in supporting decision-making is being increasingly realised by technical experts, practitioners and policy makers. There is a growing need for generating spatial and temporal data to aid planning, management and policy formulation in the mountain context. The vast diversity of mountain ecosystems, both in terms of biophysical and socio-cultural aspects, makes it extremely difficult to generate data and information and hence, to delineate areas where management and policy can be uniformly applied and compared. In addition, the sets of available and recorded data are often not comparable because of differences in standard, scale and accuracy.

There are primarily three challenges to mainstreaming GIS and RS applications in mountain research and development and these were the sub-themes of the e-conference.

- Sub-theme 1: capacity building and networking to ensure the critical mass of human resources and technical support services,
- Sub-theme 2: establishment of mountain database, tools and methods for creation of an updated information and knowledge base, and
- Sub-theme 3: thematic applications and decision support systems to aid development planning and management.

Recognising the urgency to initiate dialog on these sub-themes, ICIMOD together with the Mountain Forum organised an electronic conference entitled, "Promoting Geographic Information and Earth Observation Applications for the Sustainable Development of the Hindu Kush-Himalayan (HKH) Region" from 14 - 28 January 2008. Altogether 752 participants from 75 countries registered for the conference, out of whom, some 134 participated actively by posting their views on the respective sub-themes and specified issues within each sub-theme. During the course of the moderated e-conference, participants debated many issues and proposed suggestions.

A few of the major points of general agreement that emerged in the course of the e-conference were:

- the universities of the HKH region should step up to meet the rising demand for GI and EO education and training;
- a Himalayan Spatial Data Infrastructure should be implemented through a regional geo-information network with focal points in each HKH country;
- concerted efforts toward bringing datasets, map projections and parameters for the HKH region to common standards should be ramped up;
- GIS should move beyond mapmaking to developing thematic applications and decision support systems to address topical mountain issues such as hazards, climate change and biodiversity;
- 'spatial thinking' should be mainstreamed at a local level using tools such as participatory GIS.

The common thread running through the e-conference was the emerging concept of Mountain GIS, which is one of ICIMOD's trademarks.

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Acronyms and Abbreviations

3D	*Three Dimensional*
ASTER	*Advanced Spaceborne Thermal Emission and Reflection Radiometer*
CDAC	*Centre for Development of Advanced Computing*
CESVI	*Cooperazione e Sviluppo (Cooperation and Development)*
DBMS	*Database Management System*
DEM	*Digital Elevation Model*
DM	*Disaster Management*
DMS	*Disaster Management System*
DSNESS	*Data- Sharing Network of Earth System Science*
DSS	*Decision Support Systems*
DST	*Decision Support Toolbox*
EIA	*Environmental Impact Assessment*
EO	*Earth Observation*
ESRI	*Environmental Systems Research Institute*
Ev-K2-CNR	*Everest - Karakoram- Italian National Research Council (Consiglio Nazionale delle Ricerche)*
FAO	*Food and Agriculture Organisation*
FOSS	*Free Open Source Software*
GEF	*Global Environment Facility*
GEOSS	*Global Earth Observation of System of Systems*
GI	*Geographic Information*
GIS	*Geographic Information System*
GLIMS	*Global Land Ice Measurements from Space*
GPS	*Global Positioning System*
HKH	*Hindu Kush-Himalayas*
HKKH	*Hindu Kush-Karakoram-Himalayas*
ICIMOD	*International Centre for Integrated Mountain Development*
ICT	*Information and Communication Technology*
IGSNRR-CAS	*Institute of Geographic Sciences and Natural Resources Research-Chinese Academy of Sciences*
IIRS	*Indian Institute of Remote Sensing*
INGO	*International Non- Governmental Organisation*
IPCC	*Integovernmental Panel on Climate Change*
ISO/TC	*International Organisation for Standardisation/ Technical Committee*
ISRO	*Indian Space Research Organisation*
IUCN	*International Union for Conservation of Nature*
IWHM	*Integrated Water and Hazard Management*
LandSat TM	*LandSat Thematic Mapper*
LCCS	*Land Cover Classification System*
LGED	*Local Government Engineering Department*
LIDAR	*Light Detection and Ranging*
MENRIS	*Mountain Environment and Natural Resources' Information System*
NDVI	*Normalised Difference Vegetation Index*
NGII	*Nepal Geographic Information Infrastructure*
NGO	*Non- Governmental Organisation*
NIDM	*National Institute of Disaster Management*
NOAA	*National Oceanic and Atmospheric Administration*
NRs.	*Nepali Rupees*
NRSA	*National Remote Sensing Agency*
NSDI	*National Spatial Data Infrastructure*
OGC	*Open Geo-Spatial Consortium*
OOA	*Object Oriented Approach*
P3DM	*Participatory 3-Dimensional Modeling*
PGIS	*Participatory Geograhic Information System*
QNP	*Qomolongma Nature Preserve*
RS	*Remote Sensing*
SAARC	*South Asian Association for Regional Cooperation*
SDI	*Spatial Data Infrastructure*
SDSP	*Scientific Data Sharing Program*
SIC	*Systems International Consulting*
SNP	*Sagarmatha National Park*
SRE	*Satellite Rainfall Estimation*
SRTM	*Shuttle Radar Topography Mission*
UNDP	*United Nations Development Programme*
UNEP	*United Nations Environment Programme*
UNGIWG	*United Nations Geographic Information Working Group*
UN-OCHA	*United Nations Office for the Coordination of Humanitarian Affairs*
UNSDI	*United Nations Spatial Data Infrastructure*
USGS	*United States Geological Survey*
WCPA	*World Commission on Protected Areas*
WFP	*World Food Programme*

1. Introduction

Dhaulagiri Range, Nepal. Photo: Paribesh Pradhan.

Sustainable development of the HKH region requires accurate and reliable databases and geographic information that adequately capture the specific characteristics of mountains both from spatial and temporal dimensions. There is growing recognition by the scientific community of the need for quality databases for better scientific understanding and the need for sharing them among concerned stakeholders *(Rhind 1997)*. One of the major challenges facing the HKH region is limited availability of geo-information and affordable tools and methods for mountain-specific cases. For instance, the Intergovernmental Panel on Climate Change report issued in 2007 treated the HKH region as a 'white spot' *(IPCC 2007)*. There is a need for concerted efforts by relevant stakeholders to bridge the geo-information gap in the HKH region.

Advances in geographic information (GI) and earth observation (EO) technologies

The last decade has witnessed an unprecedented growth and development in earth observation data and applications. Earth observation techniques through remote sensing are proving to be more cost effective than ground-based techniques over large areas. RS data have the benefits of the synoptic view of a large area, which helps in obtaining the proverbial 'bird's eye-view' of the features, especially of inaccessible mountainous terrain. Furthermore, there has been an emergence of high-resolution satellite data in recent years, with greater degree of spatial and temporal variations than ever before. Similarly, Global Positioning System (GPS) technology provides the ability to compute and capture position anywhere on the earth's surface with 24-hour coverage. Systems like Google Earth and Microsoft Virtual World have revolutionised the way we access and visualise satellite-based information seamlessly from local to global levels with unprecedented level of details.

Advances in information and communication technology combined with earth observation technology and geographical analysis and modelling tools are now available to quantify, model, document, and disseminate information on key socioeconomic, environmental, and natural resources conditions and trends. This convergence of information technology (computers, databases, software, networks, especially the Internet), and space science technology (remote sensing, global positioning system, light detection and ranging (LIDAR)) have provided effective and promising tools and methods for dealing with diverse mountain issues. GI systems have emerged as powerful tools for integrating and analysing information from divergent sources and presenting the results in an effective and efficient way. These factors have led to the creation of a suitable context for institutional and technological framework for the use and access of geographic information for improved planning and decision-making.

The roles of GI and EO in sustainable mountain development

In order to capture the opportunities offered by GI technology and applications, the United Nations organisations and several other international and national organisations are playing an important role in embracing a spatial data infrastructure (SDI) framework at the local, national, regional and global levels *(Campbell and Masser 1995)*. Building infrastructure for spatial information is becoming as important as the building of physical infrastructure such as roads and telecommunications infrastructure. SDI has been conceived as an environment where the basic geographic datasets are readily available; existing geographic information is well documented; available geographic information conforms to accepted standards; policies encourage sharing and exchange of geographic information; and adequate human and technical resources are available to maintain and manage geographic information. SDI can be seen as a broad framework having organisational, technical and financial arrangements, necessary to support access to geographic information.

The importance of geo-spatial data infrastructure has been highlighted in UN documents in a global perspective *(UNGIWG 2007)*. The United Nations charters have clearly emphasised in their mandates the application of global spatial data infrastructure and earth observation satellites for humanitarian, poverty, environmental, and disaster applications in a wider scale *(United Nations General Assembly 2004)*. An intergovernmental body, the Global Earth Observation System of Systems (GEOSS), was established in 2005 with a view to promote coordinated efforts to bring the benefits of EO applications for environmental and humanitarian purposes.

Among countries of the HKH region, the status of GI and EO technologies and their applications are diverse and varying in nature. For instance, China and India have their own earth observation satellite systems, while Bangladesh, Nepal and Pakistan established remote sensing data centres in the early 1970s. During the early days, very few applications were concerned with mountain development. GI and EO applications have emerged since the early 1990s as useful tools to aid planning and decision-making for sustainable mountain development. In Bhutan, a major work was initiated to prepare country-wide satellite-based maps for land use planning. With assistance from UNDP, Afghanistan established the Afghanistan Information Management System (AIMS) for GI and EO applications.

ICIMOD established the Mountain Environmental Resources´ Information Systems (MENRIS) division in 1990 to promote the use of geographic information systems (GIS) and remote sensing (RS) technologies and applications for integrated mountain development. The primary objective was to improve environmental and natural resources management and promote sustainable mountain development, by facilitating solutions to common problems and ensuring the communication of results on a compatible GIS platform. MENRIS works as a regional resource centre for the HKH region for the study and application of GI applications and has successfully developed partnerships with key

Himalaya from space. Courtesy: MENRIS-ICIMOD.

international organisations, space agencies, software vendors, and other network of national institutions in the region.

Issues related to GI and EO applications in the mountain context

Geographic information and earth observation applications in mountainous regions present considerable challenges. *Heywood et al. (1994)* observed a common set of issues that are data-related, institutional and technical in nature in the application of GIS in management and research in the mountain context. In the case of the HKH region, there is a need for sustained efforts toward greater utilisation of GI applications *(Shrestha 2007b)* by focusing on three major issues or sub-themes:

- ***Capacity building and networking***
  A qualified and capable human resource is the fundamental component for successful utilisation of GI and EO applications. Although the use of these applications has been advocated to understand various socio-economic and natural processes in the region, it is important that the scientists and planners first understand the technology itself for its appropriate utilisation. GIS is a multidisciplinary tool. Partnerships and networking among different institutions are key to successful capacity building in GIS and EO applications *(Shrestha and Bajracharya 2007)*. Continuing efforts have to be exerted to induce public and private institutions, including the academic sector, to promote in-country teaching and training capacity in GIS and related applications. In particular, universities can play a significant role in formal GI science and education to fill the human resources gap over the longer term. The private sector has an emerging role in providing specific training and services for a growing GI market in the region.

- ***Mountain databases, tools, and methods***
  Data issues related to availability, accessibility, acquisition, management and sharing are prevalent in the region. Specific mountain studies recommend high quality database inputs to minimise errors in computation of the digital elevation model *(Wechsler 2007)*, distance measurement and accurate scale for mountain cartographic mapping *(Cassel-Gintz et al. 2007)*. There are challenges associated with tools and methods of acquisition of cost-effective databases for the mountain region. Furthermore, remoteness poses difficulties in validating the correctness of EO data on the ground. Geo-information in the region is often dispersed, heterogeneous and inaccessible. The demand for good, reliable and standardised data on mountain areas has been clearly established in scientific circles as well as at the levels of national, regional and international organisations. Mountain-specific spatial data infrastructure is, therefore, a prerequisite to the creation of an enabling condition for the use of GI applications in the HKH region *(Shrestha and Bajracharya 2007)*.

- ***Applications and decision support systems***
  The high degree of heterogeneities of mountain areas and the vastly different rates of change in their physical, biological and societal systems, present challenges for GI applications and spatial decision support systems. Compared to the plains, the physical characteristics of mountains are much more complex and need to be analysed incorporating 3-dimensional (3D) features to arrive at an approximate representation of topography, slope and aspect. Challenges also concern upstream-downstream linkages in evaluating mountain ecosystem services, and transboundary and multi-disciplinary applications. Differences in cultures, languages and traditions also pose additional challenges.

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2. Capacity Building and Networking

The availability of a critical mass of trained manpower and effective networking for technical backstopping are a prerequisite for successful deployment of geographic information (GI) and earth observation (EO) tools. In order to build capacity in the HKH region, there is a need to establish institutions and organisations with the requisite infrastructure and expertise as well as strengthen existing ones already working with GI and EO tools for integrated mountain development.

The first sub-theme of the conference - capacity building and networking - identified existing institutions and organisations engaged in capacity building and training on GI and EO applications in the region and beyond, highlighting their good practices and discussing means for replication and upscaling. The sub-theme also examined the need for operationalising a 'geographic information network' in the HKH by involving multiple stakeholders (civil society, private sector and governments). Such a network should foster not only South-South but also North-South dialogue and cooperation.

The participants agreed on the need to ramp up institutional strengthening and networking in developing countries to promote the use of GI and EO applications and decision support systems in the mountain context. This calls for a far greater commitment to investment in education and training in GI and EO sciences and tools at all levels. Capacity building and networking are long term processes as well as resource-consuming tasks, requiring different methodologies and institutional arrangements. Capacity building in particular entails identifying training needs, target groups, methodologies and modes of delivery. It also requires examination of the role and potential of the delivery systems – universities, distance education, e-learning, etc. Networking, on the other hand, entails identifying common objectives, institutions which share these objectives as well as common platforms and tools for sharing good practices and lessons learnt to facilitate replication and upscaling. However, in implementing capacity building and networking, major focus should be to ensure sustainable ways of institutionalising mechanisms for information sharing, delivery, and capacity enhancement.

Need of GI and EO training, target group and the methodology

As GI and EO sciences, which are applied sciences, gain wider usage, there is a growing recognition that competencies are required to understand the decision-making process and institutional set-ups in order to make the connection between the GI and RS technologies and real-world issues. The specificities of the mountains such as limited accessibility, rugged terrain and vast diversity within a short distance demand clarity in outlining the context and composition of what should constitute GI and EO curricula at universities and training institutions.

GI and EO technologies have been deployed in several thematic areas at all levels. There is now an urgency to bridge the gap between tools and applications as well as keep abreast of technological advances. The application of such technologies in mountainous areas requires suitable modifications and innovations, given the mountain specificities. The dynamism of the mountain ecosystems, verticality of the terrain, surface geometry and social and cultural mosaics necessitate a very innovative and adaptive use of GI and EO tools. Therefore, the promotion of GI and EO applications in the mountain context requires special training to address the challenges arising from the mountain specificities themselves.

'Earthquake Vulnerability and Multi-Hazard Risk Assessment: Geo-Spatial Tools for Rehabilitation and Reconstruction Efforts' training, Pakistan.
Photo: Gauri Shanker Dangol.

The most prevalent problem related to capacity development in the HKH region is the lack – often, the absence - of sound infrastructure to facilitate study and research in GI and EO fields. What universities currently provide as GI and EO curricula in developing countries such as Nepal leave much to desire. GI and EO education is still in its infancy in the HKH region. The presence of research and development institutions across the region is sparse and inadequate to bridge the burgeoning knowledge divide. Furthermore, sparsely scattered populations and limited accessibility of mountainous areas do not generate sufficient scale for the private sector to want to provide broadband services or internet connectivity to rural mountain communities. There is, therefore, a need for public investment to develop infrastructure and strengthen institutions for building capacities at all levels.

Given the poverty and education levels obtained in the HKH region, it is a challenge to provide access to computer-based GI and EO technologies and tools to mountain communities. A good majority have never heard terms like 'geographic information' and 'earth observation'. Under such conditions, capacity building in GI and EO technologies demands fresh and innovative approaches. It helps that Google Earth and similar programmes have been mainstreaming 'spatial thinking'. There is a need to mainstream this concept at community level by providing trainings to mountain communities, using participatory tools such as 3-D terrain models, and community/ participatory GIS so that they are able to plan in the management of their natural resources.

Given the multiplicity of stakeholders – mountain communities, students, researchers, practitioners, planners and decision makers, etc - any capacity building initiative must take a host of factors into consideration. The types of training to be provided can range from awareness raising to provision of technical education in a formal setting. The duration can vary from short term for basic level training to long term for focused professional level training. Technical trainings can be tailored to address the needs of the respective target groups. Sensitisation workshops can be held for administrators and decision-makers. Training can be conducted by universities, institutions, or professionals.

ICIMOD GIS training materials.

Mode of delivery: Role of universities, distance education and e-learning

Effective delivery systems are needed to deliver capacity building as it were to a broad range of target groups. However, infrastructure necessary to do that in the HKH region is woefully inadequate. A comprehensive strategy for designing effective delivery systems is needed. Given the demand for GI and EO courses at different levels, a judicious mix of delivery systems - university, distance education and e-learning - needs to be deployed.

GI and EO are highly specialised technical fields, not yet mainstreamed in most academic curricula. The role of the university system as a fundamental delivery system, therefore, retains critical importance. The potential of the university system to churn out qualified personnel in sizeable numbers year after year makes it a particular effective mode of delivery. However, current infrastructure and relevant GI and EO curricula are inadequate in the university system. It is relatively rare, however for universities in the HKH region to offer GI and EO sciences as specialisations or major subjects or electives as specialised courses and trainings.

The concept of 'spatial thinking' needs to be taught at school level education; GI and EO sciences need to be mainstreamed in high school education; specialisations in these subjects need to be offered at Bachelors or even Masters level. This, however, requires a drastic shift in policies with substantial enhancements in funding both from the public funds as well as generous endowments and support from the private sector.

The potential of distance education or of e-learning as a complement or even supplement to formal education in GI and EO sciences needs to be exploited wherever possible. Conventionally, distance education has been imparted by the teacher to the student through couriered materials/cassettes and on rare occasions, telephone conversations. Distant learning or e-learning platforms can be used to teach GI and EO courses, thanks to information and communications technologies (ICTs). Today, capacity building is no longer implemented using just the conventional modes of formal education. Excellent distance learning courses in GIS are now available from institutions like Lund *(www.giscentrum.lu.se/english/index.htm)*, Birkbeck College, University of London *(www.bbk.ac.uk/ggis)* and the UNIGIS Consortium. Short-term professionally oriented courses such as those offered by Pennsylvania State University's World campus and in a related field by *www.statistics.com* are also filling in the gap. Similarly, Salzburg University's capacity building programmes in GI and EO sciences via site-specific, as well as e-learning courses are gaining popularity. If this kind of internet-based learning can be provided in the HKH region in close collaboration with multi-stakeholders (civil society, private sector, and governments), it would go a long way toward addressing capacity building needs.

True, internet use has exploded in the recent past. Moreover, it has been providing an unprecedented opportunity to share and exchange high volumes of data efficiently. The emergence of geo-web applications - inconceivable just a few years ago - is happening, thanks to the growing bandwidth and convergence. The future of GIS will most likely revolve around the web and there has been tremendous growth in this sector lately. An indication of this is the numerous websites that offer various web mapping applications. Even ordinary people, with no formal knowledge or training in GIS, can learn to use them (e.g. Google Map) in their everyday life. In a way, GIS knowledge being fed into mobiles, TV news channels, TV weather news and increasingly at all levels of society. GIS applications are also finding use in environment and development sectors, through these public media.

In addition, the emergence of GeoPortals (e.g. Geography Network) is becoming evident. The Mountain GeoPortal *(http://menris.icimod.net)* has been developed to build, share and disseminate geographic information in the HKH region through a decentralised network of users and providers of geographic information. Such a platform is proving to be an effective means to promote collaboration among various stakeholders in sharing and exchanging geographic information. This portal offers a variety of GIS services (e.g. data, metadata, static and interactive maps, reports, training education, activities and events) and resources in the public domain. Interestingly, the requests for such services are not just limited to the region but well distributed across the globe. The key GI resources that the portal offers are: training and educational resources; e-learning courses such as *GIS for Beginners*; and computer based training manuals; catalogue services including metadata, map and image catalogues - online mapping resources and spatial visualisation - GI data services and application resources. Frameworks such as the Mountain GeoPortal play a key role to support regional spatial data infrastructure in the HKH region by facilitating the sharing, integration and use of geographic information across a broad user-base while giving particular consideration to standardised datasets.

'Application of GeoInformatics for Conservation and Management' training, Myanmar. Photo: Saisab Pradhan.

Glacier mapping exercise during 'Spatial Ananlysis Concepts, Tools and Applications of GeoInformatics for Proctected Area Management' workshop, Nepal.
Photo: Salman Asif Siddiqui.

Thematic GeoPortals are also gaining in popularity. One such example is Conservation GeoPortal *(www.conservationmaps.org)* dedicated to conservation. These thematic portals act as a virtual hub to share and discover map-based information and knowledge within that specific domain. Though there are certain limitations in terms of internet access and speed in the region, things are evolving and changing rapidly.

Such internet-based capacity building programmes have the potential to suit many working professionals and students. These programmes can provide students with cost effective learning tools on GIS/EO based education. Many e-learning processes today are internet-based and can be accessed using the internet as well as through the teacher-student interaction via e-mail, video conferencing, etc. This is a time saving and cost-effective medium. However, the inability of a good majority of the mountain people to access the internet and poor internet connectivity even where they can, will constrain the widespread use of this mode of delivery for some time to come. In this respect, EduSat based outreach programmes and e-learning programmes offer a possible solution and can possibly bridge the gap between the haves and the have-nots.

In addition to the three modes described above, the idea of floating a geographic information network was enthusiastically supported by the participants. A sustained geographic information network could definitely boost the sensitisation of the subject and prove conducive towards knowledge sharing of GI and EO related content. As part of the vision to transform the HKH region into a knowledge society, a Spatial Data Infrastructure (SDI) has to be evolved through a partnership among various agencies that maintain databases in their own field of application, according to specified standards and protocols that facilitate access, integration and networking of databases. As the Mountain Forum and ICIMOD have significant coverage in the region in terms of their networks of members and partners, they could jointly organise such an initiative. In addition, networks such as the International Union for Conservation of Nature (IUCN), World Commission on Protected Areas (WCPA), Mountain Protected Areas Network, the Mountain Partnership with several African countries as members and many projects funded by Global Environment Facility (GEF) and United Nations Development Programme (UNDP) could be tapped to learn and gain from.

Designing and developing GI Science curriculum

Geographic information is fast emerging as a science in its own right, underlying the geographic concepts, applications and systems, taught in degree and GIS certificate programmes at many universities. GIS technology can be used for scientific investigations, resource management, environmental impact assessment, urban planning, cartography, criminology, history, sales, marketing, logistics, etc. GIS is also used for hazard mapping and disaster mitigation, allowing emergency planners to calculate emergency response times in the event of a natural disaster. For a sustained economic and social development, geo-information science, however, has to be integrated into a comprehensive system. This would require large numbers of trained personnel on a permanent basis in the user departments. An effective system in the field of GeoInformatics needs to provide opportunities to develop skills to address technological as well as application needs. Such a process of capacity building can be realised through four different levels of implementation. These are: the elementary or basic level, the secondary level, the graduate level and the professional level.

The elementary level appraisals are realised mainly through supplementary reading and audio-visual aids, whereas the secondary level implementation requires skilled professionals to impart knowledge by story telling, providing classroom materials and making the way clear for the dissemination of the technology. An advanced plan of action will be required at the graduate level. At this level specialised courses for each discipline and projects need to be implemented. Integrated action, based on the methods suggested by national agencies, faculty training programmes, curriculum definitions, syllabi developments, provision of books and educational materials and institutional facilities would lead to the structured implementation of a capacity building programme.

Core groups at the professional level have to be developed at academic centres that can take care of value-based training through short and long-term programmes, self-learning methods and thematic programmes. Institutions with facilities are key contributors to the successful implementation of action plan at the academic or professional level. There is a need for academic courses which provide sufficient background on the technology as well as opportunities for applications in different thematic areas. The scientific concepts need to be supplemented by skills to develop practical applications. Similarly, the institutions in the region, be it in the sector of natural resource management, infrastructure planning or service providing, need to build their own capacities to benefit from these technologies. Generating continuous funds for maintaining GIS labs, retaining trained people, keeping updated in terms of hardware and software are critical concerns that require constant attention in order to ensure sustainability. Neglecting to address these concerns has resulted in failures in many instances. This has been a common occurence in many institutions where donor supported projects introduced such technologies without sufficient capacity building of management and technical staff. Without the realisation of the need for capacity building, the institutions failed to attract funds to sustain the GIS labs ultimately resulting in their collapse.

GI and RS education programmes can be conceptualised in different ways taking into account the content to be taught and the target group. For technology transfer, a fixed structure probably would not work, since the technology itself is in a rapidly changing evolutionary state. The main challenge is to update the stakeholders on the latest developments in GI and EO technologies and tools. In fast developing countries like India, three approaches to capacity building are being followed: the

Project work during the national workshop on 'Application of FAO/UNEP LCCS for the study of Land Cover Dynamics in Central Karakoram National Park', Pakistan. Photo: Salman Asif Siddiqui.

‘hierarchical-ladder', the ‘modular’ and the ‘step-wise' approach. Thus, GIS courses should be made affordable at the school or university level. Efforts must also be explored to facilitate opportunities for researchers to build their capacities through short-term or long-term placement in institutions working in GI and EO fields. Application of GIS should be made mandatory in environmental impact assessments as this would create a demand for including GI and EO chapters in various disciplines that cater to such assessments. While pursuing the task of curriculum design, it is worthwhile to refer to the Association of American Geographers Body of Knowledge (BoK, see *www.ucgis.org)*, which is an excellent resource against which to evaluate courses. By the specification of numerous intended learning objectives over the entire range of the discipline, this in effect provides a route map for GI Science education. Currently, discussions are underway about the 'internationalisation' of the BoK.

Geo-Information and institutional networking

Most of the HKH countries are developing countries with limited resources. It is not surprising, therefore, that there is a dearth of institutions and infrastructure catering to GI and EO sciences. Despite the lack of resources, institutions such as Tribhuvan University and the Kathmandu University in Nepal have been offering courses in GI and EO sciences. The relatively better positioned countries such as India, however, have been able to develop institutions and adequate infrastructure that cater not only to the domestic needs, but also regional needs. Several institutions and universities in India have well developed programmes and they have contributed to making GI and EO sciences much more advanced and state-of-the art, with dedicated programmes like the Disaster Management System (DMS) for managing disasters.

The premier institutions in the GIS field in India are the National Remote Sensing Agency (NRSA), Hyderabad, the Space Application Centre (SAC), Ahmedabad, and the Indian Institute of Remote Sensing (IIRS), Dehradun. IIRS conducts various training programmes on the application of GIS and RS. IIRS presently conducts two courses at Masters level: an M.Sc. Course in GeoInformatics and an M.Sc. Course in Geo-Hazards. Two courses each in Environment Analysis and Disaster Management and Hazard Risk Analysis have also been conducted. The duration of these courses is 18 months and they are conducted in collaboration with the International Institute for Geo-Information Science and Earth Observation (ITC), Netherlands. Similarly, NRSA, Hyderabad offers short-term professional courses for in-service professionals.

Similarly many universities in India are offering undergraduate, post graduate and research courses like M.Sc., M.Tech. and Ph.D. programmes in GeoInformatics as well as remote sensing. Prominent among these institutions are some of the central universities. Several private institutes like Vellore Institute of Technology, GIS Institute, Environmental Systems Research Institute (ESRI), India, Centre for Development of Advanced Computing (CDAC) and similar private organisations also offer various short-term and diploma programmes.

National workshop on ‘Application of FAO/UNEP LCCS for the study of Land Cover Dynamics in SNP Buffer Zone’, Nepal.
Photo: Narendra Bajracharya.

There is also a growing realisation that administrators need to be made aware of the potential of geo-information tools and applications, particularly for disaster mitigation. Keeping this in mind, the National Institute of Disaster Management (NIDM), New Delhi regularly organises awareness generation programmes for administrators and disaster management (DM) professionals, for assisting the DMs at the district level. NIDM also organises technical programmes as well as training-of-trainers programmes at state level for developing pools of trainers at lower levels *(www.nidm.gov.in/forthcoming_program.asp)*.

At the regional level, ICIMOD shines as a beacon of hope. ICIMOD has been recognised as one of the premier centres catering to the needs of the HKH region. ICIMOD has been trying to bridge the gap between the tool and application by designing short-term training programmes that are focused on a particular application area. Such training programmes expose thematic experts to various possibilities of applying the tools in their respective fields. One such example is the recently conducted training on 'Applications of GeoInformatics for Protected Area Management'. This training was undertaken to produce skilled human resources who could utilise GIS tools and methods for accurate and effective monitoring and assessment of the protected areas. The training program enabled the participants to understand the concepts of GIS and remote sensing technologies, database management systems, spatial analysis and the use of spatial analysis techniques for monitoring and assessment of natural resources, conservation and tourism management in protected areas. In addition, the regional training programme created a platform to bring together the professionals involved in protected areas management from ICIMOD's regional member countries for sharing experiences and networking.

The participants pointed out that networking between the government and other institutions in the HKH region has been weak. Against this shortcoming, the recent coming together of a number of universities in the region to form the Himalayan University Consortium to promote mountain science is an encouraging development. Such a consortium can provide an ideal platform for capacity building and networking in the field of Mountain GI-Science too, given the common goal of fostering mountain forestry, mountain risk engineering and sustainable mountain development.

Sustainability concerns

Capacity building initiatives need to be sustainable to meet the growing demands of the region. The need for trained manpower, without doubt, can be best addressed by the university system, as it represents the brightest prospect for continuity and offers the required multiplier effect in producing skilled human resources. It is encouraging to note that a number of universities in the region have stepped forward to offer GI and RS sciences as elective courses. A few universities offer full-fledged degree or diploma courses as well. In addition, there is considerable growth in the private sector offering training courses on GI and EO applications and they too, have an important role to play in providing quality education. It is evident from the increasing number of GIS and RS related companies that the investment in this state-of-the-art technology has increased substantially. It is strategically important (and desirable), therefore, that educational institutions interact with the GIS/RS industry to frame or update the curriculum to produce quality GIS professionals to suit the specific requirements of the GIS industry.

IKONOS Image of SNP, Nepal. Courtesy: MENRIS-ICIMOD.

No capacity building initiative that is only supply driven (through government or donor funding) will succeed and remain sustainable in the long run. Sustainability can never be assured in a supply driven mode. The agenda of human resource development, therefore, has to respond to the market trends, dictated by the professional and business needs.

An ongoing dialogue between the teaching community and practitioners – the effective market - is crucial if sustainability is to be assured. Exchange between the two groups will not only create synergy, but make them both more responsive to market imperatives. Also to attract funding and appreciation from the private and public sectors, a large part of capacity building and networking should deal with critical and emerging issues such as disaster management, watershed management, bio-diversity management, urban planning and increasingly, climate change. Organisations such as IIRS, NRSA and ESRI in India have initiated such thematic modules in their courses. These courses, however, involve full-time participation, thus discouraging working professionals. Opportunities for on-the-job training, particularly through the internet modules should be made accessible.

If GI and EO sciences are to become an integral part of university level curricula, capacity building in the academic sector should not be limited to teaching only but should also be extended to build research capacities. Given the inadequate resources, organisations such as ICIMOD (and the larger GI and EO fraternity) should support and strengthen the process of designing and developing university level GI Science curricula, provide training to university faculty members, facilitate building of GI lab and research capacity within the university, and above all, provide internships to GI and EO students to hone their skills.

Select Quotes from Sub-Theme 1 Discussion

- Our curricula should be “socio-technical”, teaching not just GI/EO skills but also the “information systems” competencies needed to understand decision-making, people and institutions in order to make the connection between the technology and real world sustainable mountain development outcomes.
  - Richard Heeks

- A distance learning programme (such as that offered by Lund University, Sweden) is one of the important sources of capacity building in the field of GI and EO. This kind of internet-based ICT infrastructure and training can be provided in the region in close collaboration with multi-stakeholders (civil society, private sector and government).
  - Rajan Bajracharya

- There should be regular public campaigns to raise awareness about the use and value of GI and EO to our leaders, administrators and education departments.
  - Nakul Chhetri

- Capacity building should entail provision of intensive course or short term training with more emphasis on the practical applications that can be applied on the ground, especially in mountain areas where it is difficult to get reliable and valid data from conventional ground surveying.
  - Getachew Tesfaye Ayehu

- Much of the discussion on capacity building seems to me to have focused on software-driven GIS, which I think may overshadow more fundamental issues like promoting 'spatial thinking' in educational curricula. I would be more concerned about high school and college level students failing to discern and decipher geographical facts and spatial patterns (e.g., physiographic and ecological zones, mountain climate, monsoon, highland-lowland linkages, resource-sink interactions) than specific technical issues, such as not having sufficient training in certain software or lacking human resources in creating robust SDI. I believe, incorporation of some 'spatial analysis' techniques (not necessarily GIS tools) in our high school level general science and geography courses would certainly help sensitise students to solve geographical problems, with or without GIS.
  - Milan Shrestha

- According to a report by a US-based company, Systems International Consulting (SIC), prepared for the electronic and software export promotion council, the GIS exports from India alone touched USD 150 million in the year 2005. The question is: can we produce enough GIS professionals to meet this increasing demand?
  - P.K. Joshi

- There is a need to establish a focal point for the Geographic Information network in each and every participating country of the HKH region. The focal point should be responsible for detailed analysis of GI and EO activities related to mountain development work [in its country].
  - Rafaqat Masroor

Summary

- *Need of training, target group and the methodology* – The unique attributes of mountains such as variability and verticality of the terrain, surface geometry and social and cultural mosaics demand a highly adaptive and sensitive GI and EO technology. This in turn requires a mountain focused perspective and hence, special GI and EO training needs. There is an urgent need for building human resources and infrastructure facilities to ensure the growth of a critical mass of human resources to address the needs of GI and EO application in the mountain context.

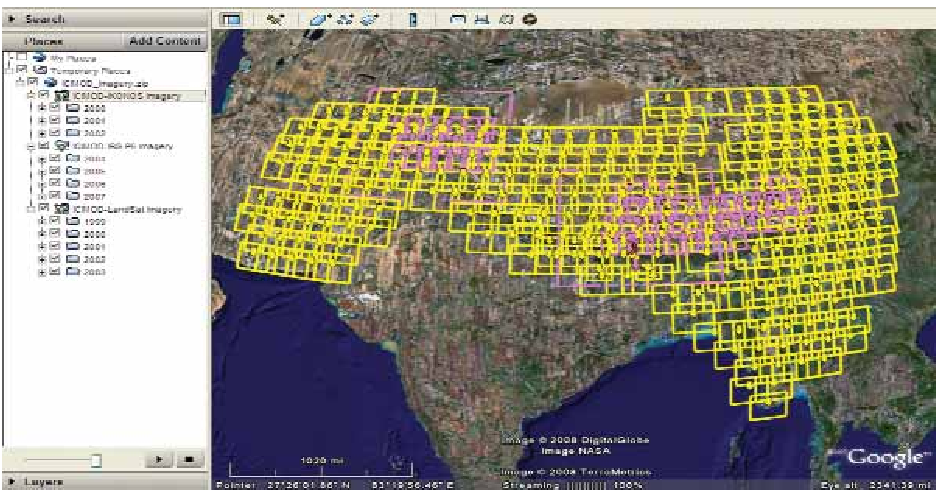
- *Mode of delivery* - Educational programmes need to be conceptualised with tailor made structures and approaches to accommodate the mountain perspective. Universities, distance learning and e-learning were identified unanimously as the major platforms for training. Universities have the potential to bring about the desired surge in human resource development and can also impart a multiplier effect. As a long-term strategy for capacity building and ensuring the growth of the required critical mass, university education promises to be the best platform for teaching GI and EO sciences.

- *Designing and developing GI Science curriculum* – GI and EO applications demand an inter-disciplinary curriculum content to equip students sufficiently for contextual applications. Applications of GI and EO sciences require not only technical capabilities but also a comprehensive understanding of socio-cultural aspects. There is a need, therefore, to design a sufficiently multi-disciplinary curriculum to cater to the varied demands.
- *Geo-Information and institutional networking* - ICIMOD has a good deal of experience in generating and sharing mountain information systems in the HKH region and beyond. The institution should therefore, take a lead in capacity building in GI and EO sciences in the HKH region. In addition, the Himalayan University Consortium would be a good platform for capacity building and networking in the field of Mountain GI Science as it is focused on sustainable mountain development, mountain forestry and mountain risk engineering.
- *Sustainability concerns* - Capacity building initiatives need to be sustainable to meet the growing demands of the region. To ensure sustainability, there is a critical need for enhancing funding to the universities and other research institutions. It is strategically important (and desirable) also, that educational institutions should interact with the GIS/RS industry to frame or update the curriculum to produce quality GIS professionals to suit the specific requirements of the GIS industry.

3. Mountain Databases, Tools and Methods

The second sub-theme of the e-conference focused on mountain databases, tools and methods. Like capacity building and networking, the establishment of mountain databases assumes no less importance in mainstreaming GI and EO applications in mountain development. The participants identified issues and constraints faced by GI and EO professionals in creating and sharing spatial data as well as developing mountain databases in the region. They explored options to address those constraints, including approaches to ensure greater coordination and cooperation among the bilateral and multilateral organisations for sharing spatial data, experiences in analysis, and tools and methods for developing applications for climate change impact monitoring, land use changes and environmental assessments. They also outlined possible roles for civil society, private sector, governments and donors to realise the Hindu Kush-Himalayan Spatial Data Infrastructure (SDI) to support access to and use of geographic information in the region.

Mountain ecosystems are dynamic and susceptible to rapid changes. There is, therefore, a need to update the mountain database periodically for time series analysis as well as to review the dynamic linkages. Proper analysis of mountain problems calls for requirements of multi-scale spatial databases combined with integrated and innovative software tools and methods that are suited to the mountain context. There are challenges associated with tools and methods of acquisition of cost-effective mountain databases. Mountain spatial data infrastructure, spatial visualisation and interactive mapping and common metadata protocol for data sharing were some of the needs expressed by the participants.



Satellite footprints of HKH in Mountain GeoNetwork metadata system.

Spatial data availability and standardisation

Issues of spatial data availability and standardisation dominated the discussion. The fundamental constraint in the region is the limited availability of raw data (e.g. satellite images and topographic sheets), making it difficult to create spatial data. Limited access to datasets of basic parameters related to meteorology in the mountains areas, for instance, is a serious issue because of the lack of collection points, collation or simply cumbersome procedures. Data sharing is often constrained owing to restrictive government regulations. There is often lack of trust between competing researchers and institutions; hence, the reluctance to share data. This holds true not only within a particular country, but also between countries. Researchers often prefer to share relevant information through publications; they are unwilling to share datasets with colleagues within or outside the region, thus hampering database development on wider scales. This is an example of bad practice increasingly at odds with transboundary or regional approaches to addressing mountain issues.

Sadly, the most fundamental hurdle has been limited access to topographic sheets, owing to the government's restrictive map policy. Access to toposheets – especially those of border districts in most countries of the region - is controlled by the government, citing national security concerns. Such toposheets are made available to researchers only after the requisite permissions have been

Internet mapping application with HKKH district boundary in Mountain GeoNetwork.

obtained. Since high resolution satellite imageries of these "geopolitically sensitive" locations can be obtained on the internet (e.g. Google Earth), the logic underlying such restrictions defies understanding. In some instances, institutional restrictions applied to the sharing of analysed spatial data ('finished data') also frustrate researchers who need the data to complete their work.

A welcome development in this regard, particularly with respect to remote sensing data has been the proposal floated by the government of India to allow SAARC countries free access to remote sensing data collected by the various satellites of the Indian Space Research Organisation (ISRO) in the event of major natural disasters in the region. However, since the satellite imaging of the region also involves the security concerns of the neighboring countries, the proposal would be discussed with each nation concerned before the decision is made operational. India has more than half a dozen operational remote sensing satellites in orbit covering the entire SAARC region. The modalities of this decision are being worked out and will be contingent on what exactly the participating countries would share and open up in exchange for having access to ISRO's data. The idea is to use GeoInformatics in risk-mapping, risk assessment and risk monitoring under diverse geographical, socio-economic and cultural settings. Indian experts specifically mentioned how remote sensing images taken even by commercial satellites clearly captured the Tsunami along the eastern coast (2004), Kashmir earthquake (2005) and Bangladesh cyclone 'Sidr' (2007).

Sharing of such data would help not only in assessing the actual damages/sufferings due to disasters but also in improving transparency of relief and rehabilitation administration in the region. Drawing attention to the fact that various regions of the sub-continent are earthquake prone, the government of India stressed the need for sustained scientific research on earthquakes, particularly in the Himalayan region, so as to be able to identify the fault zones and the return period more accurately. While such decisions by governments are extremely supportive, the conditions attached to the decision affecting actual access to the imageries demonstrate the influence of policy and externalities that regulate data sharing, having little to do with actual data generation and analytical processes.

Access to datasets and related information is one of the fundamental constraints in mountain database development. Even when datasets are available, there are other constraints that need to be addressed. A common hurdle often encountered is the adoption of different standards and methods for data collection, preparation and analysis. The lack of common approach results in lots of wasted efforts and resources. As the need to collaborate in transboundary natural resource management continues to arise, the need to coordinate efforts in spatial data collection and standardisation attains criticality.

During data extraction, researchers may use different geo-reference systems invariably leading to inconsistency of extracted data to develop GIS maps. In such cases, a re-standardisation is required by taking references once again, thereby increasing the cost. In countries where SDIs are in advanced stages of implementation, the experience has been that many losses were incurred to bring data to common standards. However, it is frustrating to note that as spatial data collection increasingly becomes cheaper and affordable; many developing countries are slowly amassing spatial datasets that are incompatible. If this situation is allowed to continue, sooner or later, as the need for sharing becomes more apparent, developing countries will painfully incur losses in order to conform to common standards. Spatial information sharing is one of the important factors in the GI and EO applications requiring substantial efforts in the process of data creation. There is, however, a lack of awareness in creating a proper metadata system. It is obvious that standard metadata will help better describe the datasets and also make the metadata interoperable with other systems.

The need for standardisation is aptly exemplified by the issue related to map projection and parameters while using data from various sources. Different organisations have their own customised projections and parameters, which when converted to other map projections encounter 'shifts'. So the questions arise: what are the most appropriate map projections and parameters for the HKH countries? Can these countries agree on standard project parameters for the HKH region? In this regard, participants raised the issue of piling up data with various aspects in a single string.

Metadata on geographic information can facilitate data sharing. The suggestion for the establishment of a metadata compiler and editor in a universally acceptable and accessible format was raised along with interactive teaching methodologies and support to promote them. Some suggested establishing a one-window package for beginners in the form of a portal for learning and sharing/comparing of data inputs. An interesting case highlighted during the discussion was the development of different methodologies and tools for data analysis by different organisations and the failure to share such methodologies among researchers, resulting in duplication and wasted resources. To prevent these, data, methods and tools should not only be shared between bilateral and multilateral organisations but also with community level organisations to harmonise approaches and ensure interoperable datasets.

Spatial data generation in the mountain context is a demanding task both in terms of time and resource requirements. Given the high cost and expertise required, most of the spatial data is generated and prepared by only a few organisations in the region. There is an adage that over 70 percent of the total cost of any GIS based project is incurred in data preparation. It would therefore be logical to have a centralised mechanism in place to collect, prepare, analyse and clear spatial data for client-institutions to avoid duplication and resource wastage. Most of the HKH countries lack such a centralised mechanism – one that is responsible for data standardisation, quality control, maintainance of uniformity on projections, and geo-referencing accuracy for client-institutions that have no expertise or resources. Therefore, data are not easily available to researchers and institutions in the region to produce quality analysis. There is, therefore, a need to operationalise a knowledge sharing network of NGO/INGOs working on mountain issues to generate and share quality spatial information to support each other's work. Toward this end, establishing a Himalayan SDI is a welcome step as suggested by some participants.

Special Feature: Discussion on 'Mountain GIS'

ASTER Image, Myanmar. Courtesy: MENRIS-ICIMOD.

IRS Image, Koshi Tappu, Nepal. Courtesy: MENRIS-ICIMOD.

How is 'Mountain GIS' different from plain GIS? - *David Unwin*

In my experience, the difference is in 'ground truthing'. This is true for two reasons. First, innovative use of light aircraft drones to verify satellite imagery is difficult if not impossible at very high altitudes. More important, with low and dispersed populations and difficult terrain, it is more challenging for humans to verify GIS data on the ground. GIS without ground truthing is not without significant value, but it does reduce the confidence level. Second, governments in general do not collect spatially referenced social, economic and other data beyond defined limits of urban agglomerations. This was starkly evident in two exercises I was involved in: the 'Mountain' chapter of the UN Millennium Biodiversity Assessment, and the World Bank's World Development Report of 2003 on Sustainability, that attempted to assess poverty on a spatial basis and commissioned a background paper I co-authored on mountains. Areas with remote rural poverty (that includes most mountain areas in developing countries) simply lack data. That makes it very challenging to link GIS data with other data that can generate analyses useful for policy making. Each of these reports recommended strongly that governments give priority to spatially-referenced data.

- Jane Pratt

Two significant differences are:

1. The individual's perception/memory of the landscape when not present there.
2. The ability to conceptualise complex polygons in rugged terrain from a 2-dimensional view, and a solution using Google Earth, which not only allows polygon entry on a 3-D view, but also permits rotation of the view during entry to allow points to be placed on "the other side of the mountain".

- Alan J. Thomson

I am writing this in the context of climate change impact studies designed for mountain areas. My concern is about the challenge that the widely varying altitudes (and presumably climatic conditions) of the mountainous areas pose to the design of the impact studies. In contrast, for plain areas, if we consider few areas for studies then the results can be applied to a wide adjoining area with similar climatic conditions. In mountainous areas on short horizontal distances large differences occur in the climatic conditions because of the vertical shifts. So, the estimate of the impact of climate changes under mean conditions in the mountain region may have little meanings since there may be no spot in the region that experiences mean conditions.

- Humaira Sultana

Robert Rhoades stresses the concept of 'verticality' as the only unique mountain specificity (Rhoades, R E (1997). *Pathways towards a sustainable mountain agriculture for the 21st century - The Hindu Kush-Himalayan Experience)*. 'Verticality' is also the one main reason which necessitates a 'mountain specific' GIS. Mountain regions are characterised by their highly variable climates, soil and vegetation patterns and scattered settlements in narrow valleys. Hence, spatial patterns of most of the mountain themes appear as an assortment of patches unlike the neat layers in the plains. There are many complexities in developing GIS databases for the mountains, some of which I would like to highlight below:

- Mountain applications demand fairly large scale data to represent true spatial patterns and generating large scale data is more expensive.
- Digital Elevation Model (DEM) is the fundamental data layer for mountains to bring in the 'verticality' into analysis. Unfortunately unavailability of DEM is a major data gap. The most easily accessible DEM such as Shuttle Radar Topography Mission (SRTM) has large areas missing in the Himalayas.
- Satellite images are the only sources of information for most parts of the HKH which are otherwise highly inaccessible. This has been more remarkable with the emerging high resolution images which provide the details of the variations in the mountains. However, the deep shadows cast by the mountains have always been a major challenge for image analysts.
- Accuracy is another area where the mountains offer more complexities. For example, the 1-meter resolution IKONOS Standard Ortho products have an accuracy of 50-meter CE90 in most locations but may be up to 75-meters in undeveloped areas with high terrain relief e.g., Andes or Himalayan mountain ranges *(IKONOS Imagery Products and Product Guide)*.
- The HKH region has a limited seasonal window for satellite images due to high cloud covers during the monsoon and high snow during the winters. The microwave remote sensing, although penetrates the clouds, adds its own complexities of 'relief displacement' and 'layover effect' which limit its use for the mountains.

Apart from these technical complexities, there is a host of political and socio-economic challenges to be overcome for the GIS community to realise the dream of accurate, accessible, and affordable GIS databases of the HKH region.

- Birendra Bajracharya

'Verticality' feature of mountains (3-D nature to be correct) is what makes Mountain GIS very unique in its concept and conversely makes it cumbersome to implement. The whole concept of 'verticality' is deeply rooted in the work of Humboldt and Carl Troll's work in the Andes, which are further refined by John Murra, Robert Rhoades, Karl Zimmerer and many Alpinists. The main relevant point to Mountain GIS is that mountain societies depend on multiple zones of production (a result of verticality) available within what appears to be a small percentage of land coverage (comparing to plains); however, it also makes graphical and visualisation representation complicated in GIS environments. Some of the recent developments in GIS (e.g., visual nature studio 2) are exciting for Mountain GIS in the sense that they have more sophisticated representation and cognitive capabilities; however, the point remains that it's the analyst (not the software) who is supposed to be more aware of mountain specificity. Similarly, there are a few other interesting cases in which mountain areas require special considerations. Included examples I can think of off-hand are representing the whole concept of social distance vis-à-vis Euclidean distance (rugged terrains separate what seems to be adjacent areas so much apart or seemingly distant villages are more well connected in social distance sense than neighboring villages), using 'buffering' or 'least-cost path' features, and so forth. Hence, I must say there has been some real progress in implementing GIS in the mountain setting and yet we have a long way to go to fairly represent the complex adaptive strategies (and related socio-cultural variations caused by verticality) of mountain societies.

- Milan Shrestha

My reason for the post was to see if standard GIS software, whether open source, free, low cost or fully commercial, is adequate for GIS analysis when we are dealing with mountainous terrains. My question on this is I hope more profound and it has to do with 'verticality' and 'variance'.

First, verticality. All the systems known to me are 'plane' (note the pun with 'plain' here) in that the 'geo' part of their data structure is two dimensional, with height added to give what's been called 2.5 dimensions. If we have significant relative relief, would it not be better to use a full 3D GIS of the sort that a geologist might also use? Does anyone know of applications that have tried to do this?

Second, variance. It's been observed that mountain terrain is typically subject to more rapid change than the plains. One consequence is that to describe it properly we almost certainly will need data (whether grid cells of a raster or polygons, Tobler once called these both 'resolution elements' or 'resels') at a higher spatial resolution than we would in flatter areas. The second is that almost all analytical results will carry with them artifacts of the resolution of the data employed. This is of course well-known in raster GIS, but it applies equally in vector based data structures and I wonder if it will be better or worse in mountain GIS than in plain GIS. Think, for example, of the apparently simple problem of estimating the surface gradient from a DEM. As can easily be confirmed by going into the field with a level, the gradients estimated in the GIS are at best a very rough approximation. This is likely to be the same for almost any quantity of interest and the 'error' must in some way be related to the relationship between the resolution of the 'sampling' and the spatial autocorrelation in that quantity. There are some very tricky analytical issues here that merit further attention.

- David Unwin

Data and image cataloging at MENRIS.

Spatial data challenges in the mountain context

While limited access to data and the need for standardisation are matters of concern, data collection, compilation and analysis in the mountain context require researchers to remain sensitive to the mountain specificities of the HKH region.

Implementing GIS in the mountain context will always be a challenge not only because of specificities such as inaccessibility, marginality and fragility but also because of many technical concerns: shadows in satellite images, 'big holes' in SRTM data, high displacement and tilt factors in aerial photographs, low resolution air photos for mountain areas, multipath signals for global positioning system (GPS) receptions in lower ridges and valleys with steep slopes, and so forth.

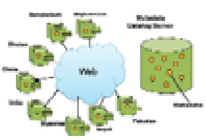
In addition, the lack of data for sparsely populated mountainous areas and the differences in scales and details hamper standardisation of datasets. A case in point: most orthophotos required for the 'accuracy assessment' of land-cover maps (in this instance, for Lamjung in Nepal) were limited to the lower valleys and towns and available only in print version for NRs 1,500/quad. Topographic maps available for the whole district had two different scales: lower valleys had 1:25,000 and the northern part had 1:50,000 scale. Such discrepancies in scale seriously hamper planning. Understanding key features of mountainous areas is essential and influences development planning and execution in much the same way as it would in conducting a GIS based analysis.

Having outlined the specificities of mountains and the need for special attention during data generation and application, it is necessary now to dwell on the sources of data. The first step towards data sharing is to have the information about the availability of the data resources and the owner organisations. This can be obtained by creating a common standard metadata sharing protocol among the different organisations. Using the GeoNetwork open source, ICIMOD is publishing its metadata information through the Mountain GeoPortal. To date, ICIMOD has published more than 2,000 metadata records covering various themes and categories. The future plan is to expand the similar approach in the entire HKH region and build a common standard metadata sharing platform. In the process of developing such a network, ICIMOD has conducted training and helped in installing the GeoNetwork application in some of the HKH member countries. Active member organisations of this network are the Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences (IGSNRR CAS) in the People's Republic of China and Local Government Engineering Department (LGED) in Bangladesh, WWF Pakistan and Survey of Bhutan. Both are serving their metadata information and also expanding the network by further developing local nodes in respective countries.

By the end of 2008, ICIMOD has a plan to set up at least one node organisation in each of its regional member countries. This approach should help to generate an information warehouse in the HKH region and thus contribute toward building the Himalayan Spatial Data Infrastructure in the future. An example of this initiative producing the desired results is the People's Republic of China. The Ministry of Science and Technology of the People's Republic of China launched the Scientific Data Sharing Program (SDSP) in 2003. Nestled within the basic sciences and science frontier area of SDSP, the Data-Sharing Network of Earth System Science (DSNESS) had been set up. DSNESS is maintained by IGSNRR-CAS and has about 14 nodes (one main centre and 13 sub-centres) in various locations of China linked to the data harvesting system between all the nodes. Recently DSNESS has used GeoNetwork open source to publish their metadata in the English language. This has been the result of the collaboration with ICIMOD to build the Mountain GeoNetwork system in the HKH region. To-date, IGSNRR has been serving more than 500 metadata in various categories.

Himalayan spatial data infrastructure (SDI)

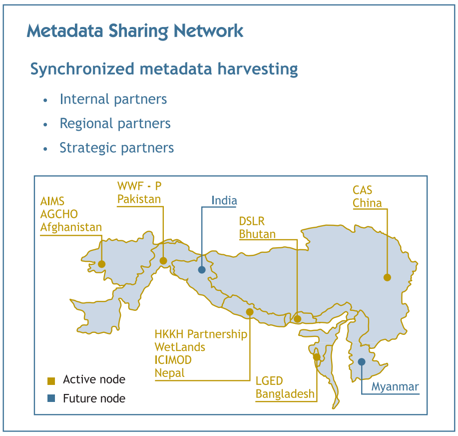
GIS has presently evolved from being a mere planning tool to a healthy scientific discipline in its own right. GI Science has to enrich itself with scientific ingredients. Data management is key to a successful GIS implementation. Data integrity and security are vital since building and maintaining spatial databases can be time consuming and expensive, if not central to the core mission of the organisation. Different platforms and available resources with specific capabilities and standards have been proposed by some participants.



Mountain geo-information network in regional member countries of ICIMOD.

The need for an information sharing network in the HKH region and around the globe is well recognised as a priority. Such a networking for information and data sharing will be beneficial to multiple stakeholders - researchers, decision-makers and even the students for accessing information on their areas of interest. In the process of establishing a network, it is important to emphasise the need and benefits of metadata information through awareness raising and sensitisation. Creating metadata is one of the fundamental imperatives for data sharing mechanism. Standard metadata help to describe the dataset better and also make the metadata interoperable with other systems. In the HKH region, major problems associated with data sharing are the absence of metadata in spatial data preparation, poor inter-organisational coordination, lack of trust between individual authority and the infancy of national level data policy. All these influence the process of data sharing, encourage data duplication and consequently result in wasted resources.

Mountain geography needs special consideration to tackle the problems associated with GI and EO applications. Development of Spatial Data Infrastructures (SDI) at local, national, regional and global levels is a good approach towards promoting joint planning and co-management of natural resources, particularly in regard to transboundary issues. SDIs address barriers to accessibility and interoperability of datasets and applications, hence enabling institutions to share data. In order to capture the opportunities offered by GI technology and applications, the United Nations (UN) organisations and several other international and national organisations are playing an important role in embracing a spatial data infrastructure (SDI) framework at all levels.



National nodes of ICIMOD geo-information network.

SDI has been conceived as an environment where the basic geographic datasets are readily available and existing geographic information conforms to accepted standards. The SDI environment also fosters policies that encourage sharing and exchange of geographic information and encourage conditions that ensure availability of adequate human and technical resources to maintain and manage geographic information. SDI can be seen as a broad framework having institutional, technical and financial arrangements, necessary to support access to geographic information. The development of consistent reusable themes of base cartographic content - known as framework, fundamental, foundation, or core data - is recognised as a common ingredient in the construction of national and regional SDIs to provide common data collection schemes along with the power to bring consistency and synergy between similar systems. Building and working on database infrastructure enhances the ability to treat the data in an object-oriented way, setup rules for data, define relationship and display rules in the model. In short, it closes the gap between a data model and reality .

Numerous participants have highlighted SDI initiatives at the country level of HKH region. National Spatial Data Infrastructure (NSDI) initiated by the Department of Survey has been renamed Nepal Geographic Information Infrastructure (NGII). Being at an initial stage there are certain inconsistencies and wide scope for improvement.

As a part of the vision to transform India into a knowledge society, SDI is evolving in the country through a partnership of various agencies that maintain databases in their own fields of application, according to specified standards and protocols that facilitate access, integration and networking of databases. Similar initiatives have also been taken in the People’s Republic of China.

With the establishment of SDIs in several HKH countries and given the encouraging trend of support witnessed in these countries, it is logical that attempts should be made to link the existing SDIs within the HKH so that a 'Himalayan Spatial Data Infrastructure (SDI)' can emerge. Initiatives on Himalayan SDI should provide a common framework for the geo-spatial standards, specifications and interoperable software systems. There already exist web-based services for accessing data and metadata. ISO/TC 211 - geographic data standard, OpenGIS Consortium - Interface specification for geo-spatial software, ISO 19115 - Spatial metadata standards, are already being applied in the geo-spatial industry. Standard for knowledge management - ISO 13250 Topic Map, or the Unicode standard for coding multi-lingual text and other similar standards must be engineered into the common framework of SDI in an inclusive way by embracing all latest mainstream tools and technologies - service oriented architecture (SOA), XML, X-Query, SQL. Such a framework can also enhance cooperation and networking among the different members within the HKH region and could gradually extend to include members from other mountain regions in the world to share data, information as well as learning, thus fostering a true South-South and North-South cooperation. It is pertinent, perhaps, to highlight here the case of the Hindu Kush-Karakoram-Himalaya (HKKH) Partnership Project initiated in 2006.

The HKKH Partnership Project is a three-year regional initiative aimed at consolidating institutional capacity for systemic planning and management of socio-ecosystems in the HKKH region. Started in July 2006, it is supported by the Italian Cooperation and implemented in partnership by The World Conservation Union (IUCN), ICIMOD, Everest - Karakoram- Italian National Research Council (Ev-K2-CNR) and Cooperazione e Sviluppo (CESVI). This multiscale project is active at regional, national and local levels with a special focus on three protected areas: Sagarmatha (Everest) National Park (SNP) in Nepal, Central Karakoram National Park (CKNP) in Pakistan and Qomolongma Nature Preserve (QNP) in the Tibet Autonomous Region of the People’s Republic of China.

The project will develop methodologies and tools to support ecosystem management based on a systemic approach. A modular Decision Support Toolbox (DST), composed of software and participatory modules, will be a key expected output. The project supports stakeholders in the operational application of the new tools in the local level pilot areas, including the development of management plans. Implementing management oriented research and supporting partnership between national and international research organisations is a core part of the capacity building intervention, which will also feature exchange visits, national and regional training programmes as well as support for higher education. Introduction of international standards for data development and knowledge management will also contribute to develop transboundary cooperation for the management of ecosystems. GIS databases will be developed and included in the applications of DST for these three protected areas.

Activities and experiences of direct relevance for the current discussion theme are:

- Introduction of international standards for data production and land cover mapping in collaboration with the FAO/UNEP Global Land Cover Network Program. The Land Cover Classification System (LCCS) is used to develop LC databases for these three projects' local level sites. Capacity building is carried out through workshops where several national stakeholders have been involved in Nepal and Pakistan.
- Introduction of ISO metadata standards and of the GeoNetwork platform to build a knowledge base and data sharing platform focused on the project areas.
- Development of a data sharing policy based on the idea of custodianship.

Some of these concepts are quite new and evolving, and are being tested in the region. In the process of applying the tools and developing databases, capacity building of related institutions is another activity going on in parallel which will ensure that these applications will get a sustainable way out at the end of the project.

Initiatives like the HKKH Partnership Project can make good contributions to the region in filling the gaps in deployment of GI and EO technologies for mountain causes. As already mentioned, the project is a partnership between IUCN, ICIMOD, Ev-K2-CNR and CESVI, and tries to bring together the comparative advantages of each partner in consolidating the institutional capacities in protected area management in the region. The project builds upon the experiences of ICIMOD in the field of GI/EO and takes it further by applying them in different areas like land cover mapping, sharing spatial metadata and data using GeoNetwork, participatory 3D Modeling, and developing a Decision Support Toolbox which tries to integrate GIS and System Dynamics Modeling. Details can be accessed through the project's web portal *www.hkkhpartnership.org*.

The showcases and postings from ICIMOD have revealed a good start in the creation and wide circulation of metadata of the spatial data archives of the HKH region. Using the GeoNetwork open source, ICIMOD is publishing its metadata information through the Mountain GeoPortal. Such a platform is proving to be an effective means to promote collaboration among various stakeholders in sharing and exchanging geographic information. The Mountain GeoPortal offers a variety of GIS services (e.g. data, metadata, static and interactive maps, reports, training and education, activities and events) and resources on the public domain. Interestingly, the requests for such services are not limited to the region only but well distributed all across the globe from varieties of users.

While establishing SDIs, it is always advisable to learn from established SDIs. In this context, attention should be given to the geo-spatial capacity and interoperability developments of the UN Geographic Information Working Group (UNGIWG) and the recently launched UN Spatial Data Infrastructure (UNSDI) initiative. This initiative has, apart from improving system coherence within the UN system, enhanced capacity building and networking. One of the key capacities in this regard is GeoNetwork, developed by FAO with support from World Food Programme (WFP), UNEP and United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA) and is an open source, international standards-based (ISO, OGC) metadata catalog, used by many stakeholders in the field, including ICIMOD.

Select Quotes from Sub-Theme 2 Discussion

- As the mountain ecosystems are subject to more rapid change than the plains, there is a constant need to update mountain data and databases more frequently as well as to review the dynamic linkages.
  - Krishna Paudel
- It is sad if we have to seek the government's permission to obtain topo sheets. I think all toposheets should be kept on web portal so that anyone can download them as per their needs.
  - Juneaid Nazir Shah
- The first step towards data sharing is to have the information about the availability of the data resources and the owner organisations ("a catalogue holding metadata about available spatial data"). This can be obtained by creating a common standard metadata sharing protocols among the different organisations. The second step is to build the common standard metadata sharing platform in the HKH region. This approach will not only help to generate the huge information warehouse in the HKH region but also contribute toward building the Himalayan Spatial Data Infrastructure.
  - Kiran Shakya
- In arid regions of Africa, there is a lack of databases and tools and there are many constraints such as lack of trust, non cooperation, funding constraints, lack of metadata or data standardisation.
  - Usama Ghazaly
- Data sharing should not be limited to the practice of receiving data, but rather to exchange, revalidate, and use data for the well being of the people.
  - Nakul Chettri
- One main issue that cannot be overlooked is standardisation of data. During data extraction different people use different geo-reference systems that leads to inconsistency of extracted data to develop GIS maps or applications. In that case, the data have to be re-standardised by taking references once again, ultimately increasing cost. Moreover, different organisations collect data independent of each other for their own use. They develop their own methods and tools to analyse data. This approach leads to duplication of work.
  - Deepa Raj Bhandari
- There should be a fixed standard projection parameters for all HKH countries so that we have this sense of uniformity at least in terms of maps. In my opinion this may lead to a decrease in contested border disputes to some extent – at least on maps!
  - Susheel Dongol
- To realise a Hindu Kush-Himalayan Spatial Data Infrastructure (SDI) access to GI all the concerned organisations undertaking or planning research in the region should seek institutional and inter-sectoral collaboration so that they can share the cost of data and its analysis to minimise cost and should also make available this data for future users.
  - Dr. M. A. Khalid
- One of the major obstacles is the cost factor: high resolution satellite imageries are very expensive. The other is their unavailability due to national security or simply political reasons.
  - Bidya Banmali Pradhan


Namche bazaar, SNP, Nepal. Photo: Alton Byers.

Summary

- *Spatial data availability and standardisation* - Spatial data availability and standardisation were the main issues raised throughout the discussion. Limited access to data was identified as the fundamental constraint in database development. In addition, the lack of standardisation made data sharing a formidable challenge and the need for standardisation, particularly of metadata sets, was felt absolutely critical.
- *Spatial data challenges in the mountain context* - 'Verticality' and 'variance' are the major characteristics of the mountains. One consequence is the need of a 'Z' axis or third dimension of the surface with special consideration to depict the mountain terrain. In that case high resolution satellite sensor data or large scale topographic maps are the requirements of the mountain regions.
- *Himalayan spatial data infrastructure (SDI)* - Creating metadata is one of the fundamental starting points of the data sharing mechanism. In the HKH region major problems associated with data sharing can be attributed to lack of metadata, poor inter-organisational coordination and lack of trust between individual authority and infancy of national level data policy. It is recommended that a Himalayan SDI with detail metadata and full capacity sharing mechanism be established.

4. Applications and Decision Support Systems

The third sub-theme of the e-conference focused on thematic applications and decision support systems.

Applications and decision support systems (DSS) of GI and EO are the logical end products of capacity building and database development.

Given the heterogeneity and complexities of mountain ecosystems, GI and EO applications and decision support systems would need to be highly adaptive in order to incorporate the required sensitivity. The relevance of GI and EO applications in sustainable mountain development, especially in disaster preparedness and mitigation and in the evolving context of climate change mitigation and adaptation can be demonstrated when appropriate applications and decision support systems are tailored to mountain situations. In order to elicit discussions on the sub-theme, participants were encouraged to highlight examples of GI and EO applications and decision support systems deployed in the mountain context. They were invited to share their views on mainstreaming geo-information in decision and policy making.

Thematic application

EO is being used in areas where physiography poses a challenge for accurate mapping. Adapting remote sensing data to the mountain context presents difficulties in making data adaptation error free. One of the fundamental challenges in adapting remote sensing data in the Himalayan context is the radiometric distortion caused by the extreme terrain. Experience using ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data suggests that distortion limits the ability to correctly map ground features (not only lithologies), as this is based on unique spectral signatures. The first three ASTER bands have a resolution which is better than the LandSat™ data and may be very useful for diverse applications including snow pack and watershed type studies.

Decision support toolbox software.

Participants also discussed the problems of resolution and scale. Although some work has been done on data manipulation with reference to the HKH region, this has not been widely disseminated or standardised. Cloud cover and snow cover encountered during satellite data acquisition of mountainous terrains pose another difficulty. As the season of data acquisition determines the shadow effect, the summer season is recommended to minimise shadow effect in the case of the HKH region.

The primary challenge for developing thematic applications is attracting funding to carry out large-scale work, and getting experts who can bridge the gap between GI and EO tools and applications, not to mention the challenge of integrating the spatial data in every aspect of planning and decision-making in areas such as biodiversity assessment, risk and vulnerability mapping, census mapping, and climate change monitoring. Sharing experiences and lessons learnt can further strengthen applications and decision support systems.

Although dedicated thematic applications are still in their infancy in the HKH region, there are a few noteworthy examples:

- The 'Biodiversity of Nepal' portal *(www.biodiversityofnepal.net)*: It incorporates a database on biodiversity and related livelihood issues in Nepal and is disseminated through the Mountain GeoPortal framework. The portal provides information on characteristics of all the species found in Nepal and their distribution in different protected areas. The portal also provides tools to query the database either on scientific, common or local names of the species or based on a protected area. Introduction and general information on each protected area is also provided along with the interactive maps.
- The 'Biodiversity Characterisation at Landscape Level' project in India, jointly funded by the

Departments of Space and Biotechnology of the Government of India: Through this project, detailed vegetation cover type, forest fragmentation, disturbance regimes and biodiversity maps of the entire Himalayan region have been prepared. This database is extensively supported by strong field data and ground survey. The highlights of the work can be accessed at *www.bisindia.org* or *www.biospec.org*.

- One initiative supported by the Indian Space Research Organisation (ISRO) explored ecosystem dynamics in northeastern India at regional, selected catchment and watershed levels.

Biodiversity portal of Nepal.

Such projects have helped to develop comprehensive biodiversity databases about the Himalaya.

A discussion on thematic application would be incomplete without mentioning cryosphere mapping, which is a critical application in decision support systems in the area of topical importance, namely climate change. The application of remote sensing technology and of GIS has contributed significantly to cryosphere mapping and monitoring. The European Space Agency (ESA) initiated the GlobGlacier Programme for definition of EO based services for glacier monitoring, integration with state-of-the-art ground-based observations, followed by demonstration, implementation and validation of services for the members of the user group *(http://dup.esrin.esa.it/projects /summaryp98.asp)*.

For the regional to semi-detail monitoring of glacier ice, a GLIMS (Global Land Ice Measurements from Space) project designed to monitor the world's glaciers primarily using data from optical satellite instruments such as ASTER, is a good example *(www.glims.org/*).

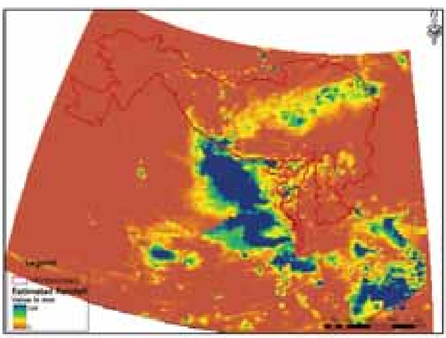
Though not exhaustive, the Atlas of the Cryosphere in the National Snow and Ice Data Centre (NSIDC) *(http://nsidc.org/data/atlas/)*, contains several examples of mapping and monitoring of snow and ice using remote sensing images from the global/synoptic scale like Blue Marble Images to semi-detail scale of individual glaciers items like GLIMS and other programmes. The Blue Marble: Next Generation is a series of images that shows the colour of the earth's surface for each month of the year. *(http://visibleearth.nasa.gov/view_set.php? categoryID=2355)*.


Field monitoring station, Imja Tsho glacial lake, Nepal. Photo: Paribesh Pradhan.

Examples of monthly earth changes in snow and ice cover can be accessed in *http://www.earthobservatory.nasa.gov/Newsroom/BlueMarble/BlueMarble_monthlies.html*. Given the concerns on glacier recession and the implications for water availability, thematic application on cryosphere issues such as those outlined above assume critical relevance not only in monitoring, but also in the critical process of formulating adaptive strategies and mitigation measures.

Potential GLOF simulation model. Courtesy: MENRIS-ICIMOD.

No less important in this context is 'Satellite Rainfall Estimation' (SRE). Accurate rainfall estimation in the region, however, is a challenging task due to intense seasonal rainfall, the scarcity of real time rain gauge data, transboundary issues and the existence of large unpopulated rugged terrain with limited distribution and number of hydro-meteorological observation stations. The distribution of the rain gauge is not sufficient in most cases to provide a detailed perspective on spatial distribution that may be needed for applied modeling techniques. The network of stations is not adequate to accurately capture the highly varied nature of rainfall. The application of remote sensing from space is vital to fill in the gap to some extent. SRE provides information on rainfall occurrence, amount and spatial distribution over the globe and region. It is a significant method for rainfall measurement in addition to the conventional gauge data and provides real time information. By developing the application of SRE, it is expected that more precise, timely and accurate flood and drought forecasting and warnings can be issued. With sufficient lead time, people can be evacuated safely, thereby reducing human casualties and property damage. Therefore, the use of satellite derived quantitative rainfall estimate technology can be crucial for obtaining rainfall pattern that can be used in hydrological models for various applications to produce forecasts of discharge, studies of hydrological cycle, water management planning, flash flood identification, drought monitoring in HKH region, etc. ICIMOD has just concluded a project 'Application of Satellite Rainfall Estimation in the Hindu Kush-Himalaya Region' with technical support from National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS) and financial support from USAID/OFDA. The outcomes of this project will be made available through the following websites: *www.southasianfloods.org* and *www.spacetechnology.icimod.net*.

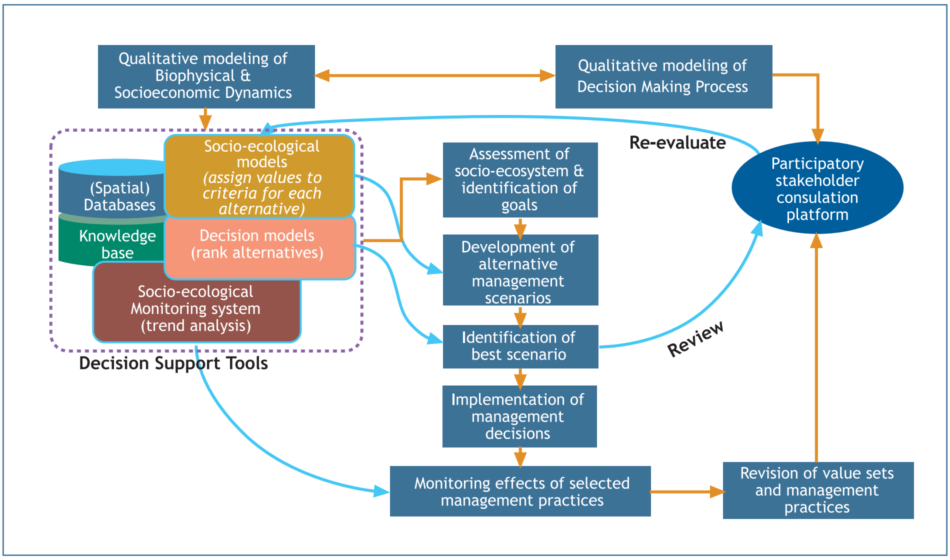


Estimated 24 hours rainfall from NOAA, 2008-263. Courtesy: IWHM-ICIMOD.

Decision support system

Decision makers today need to be able to find good solutions to increasingly complex socio-ecological problems. The complexity of making coherent, integrated, and interdependent ecosystem management decisions demand sound scientific analysis based on reliable data and information. They must be able to anticipate responses and feedback mechanisms at multiple temporal and spatial scales, accounting for biophysical, social and economic considerations. Over the past decades, "interactive computer-based systems that help decision makers utilise data and models to solve unstructured problems" or decision support systems (DSS) have been developed with different forms and capabilities to facilitate this process.

There is a growing interest in implementing decision support systems (DSS). DSS have evolved as multi-component systems that include various combinations of simulation modeling, optimisation techniques, GIS and associated databases and user interface components. GIS application in environmental management is an obvious DSS application, particularly in regard to environmental impact assessment (EIA) and disaster mitigation. The implementation of DSS requires high resolution datasets and makes high demands on the decision rules imposed by the government. EIA procedures may be country-specific but overall procedures are more or less similar the world over. It is important that EIA does not become just another project approval activity. DSS need to focus on areas like land use change (change in vegetation, glacier coverage), town and country development but with equal importance accorded to environmental concerns. Glaciers, which are increasingly prone to climate change, need to be regularly monitored, as they play a vital role in meso- and macro-meteorological dynamics. DSS have been used in disaster risk mitigation and participants provided examples of the applications of such tools at the local level. One such example was from the Neelum valley, Pakistan. An interdisciplinary study of landslides and land use strategies was conducted in Neelum valley, Azad Jammu & Kashmir (AJK), Pakistan. The study involved remote sensing techniques, DEM data, and Normalised Difference Vegetation Index (NDVI) to create a landslide susceptibility model. The study utilised a high-resolution Quickbird image of the study area, followed by a thorough field study mapping land use, economic cost of landslides, vegetation type and risk perceptions of two villages. GIS techniques have also been used to generate flood hazard maps using DEM, incorporating slope, geology, geomorphology and related parameters. DSS have also been used in conservation projects. The Kangchenjunga Landscape project, a transboundary conservation initiative covering Nepal, Sikkim, Darjeeling and western Bhutan, has drawn significantly on GIS applications in mapping corridors to connect isolated protected areas. The project has complimented such applications with community knowledge, experts' knowledge and knowledge from other disciplines such as sociology, conservation authorities and policy makers' views on delineations of conservation corridors *(www.icimod.org/home/projects/projects.contents.php?prid=10)*. In the context of the HKH region, the development of DSS should be considered as a part of a systemic process, which invariably becomes a platform for participatory consultations and analyses resulting in better understanding of the problems and entailing tradeoffs against possible alternatives, as well as a framework for monitoring the socio-ecological dynamics. The DSS should evolve over time and should address the process of decision-making and include the flexibility to review and change assumptions. The generic DSS framework is presented below in a diagram.



Generic DSS framework.


A view of Dig Tsho glacial lake during Eco Everest Expedition 2008. Photo: Paribesh Pradhan.

Community and participatory GIS

The fundamental objective of GI and EO applications and decision support systems is to empower a broad range of stakeholders so that they are able to conduct proper planning and decision-making. Often GI and EO approaches and tools are extremely technocentric, so exclude interactive decision-making involving the very stakeholders that are central to all efforts. A central concern for practitioners has been the search for participatory approaches involving all stakeholders.

Participatory GIS, also known as PGIS, has been developed to address this concern and ensure the active involvement of communities. PGIS uses various tools and the approach ensures the inclusion of community participation in the decision-making process. Community mapping is an excellent example of the application of geo-spatial tool (RS/GIS/GPS with groundtruthing) which is being used at an operational level and in research. Community GIS aims to handle GI and EO by local communities by establishing community GIS centres in rural areas. The concept of PGIS emerged where the geo-spatial technologies were used for community development to empower less privileged communities. PGIS combines a range of geo-spatial information management tools and methods. Participatory 3D modeling (P3DM) is one such method which can be used to represent peoples' knowledge in the physical 3D models. The model is constructed through the active participation of a given community with facilitation by mapping experts and hence derives its name, Participatory 3D Model.

This model can be used as an interactive vehicle for spatial learning, discussion, information exchange, decision-making and advocacy. P3DM integrates participatory resource mapping and spatial information to produce a stand-alone scaled relief model. This type of tool has proved to be user-friendly and relatively accurate. The advantage of P3DM is that it is easier to understand 3D models as compared to other types of maps as it adds a third dimension, which makes it easy for visualisation. With the application of P3DM communities can better plan the management of their natural resources because they have more knowledge about their resources. The P3DM approach allows the villagers to participate in the entire process of 3D model building though it is field intensive and requires much community time. P3DM acts as a visual language and is a powerful medium for easing communication, overcoming the language barrier and creating common ground for discussion. A good example of the application of P3DM is the one recently done by HKKH Partnership for Sagarmatha National Park. The detailed methodology can be found in the document entitled 'Participatory 3D-Modelling for SNP (Nepal) - A Feasibility Study' by HKKH Partnership Project *(*see *Annex 3: Resources)*. Resources related to PGIS and P3DM are available at *www.iapad.org/*. A book entitled 'Participatory 3-Dimensional Modelling: Guiding Principles and Applications' by Giacomo Rambaldi and Jasmin Callosa-Tarr gives detail explanation on PGIS focusing particularly on P3DM.

Particiaptory 3 Dimensional Model (P3DM)

- MENRIS-ICIMOD

Why P3DM?

- An excellent visual aid tangible to everybody
- Participatory tool for collecting and sharing community-based knowledge

Some Applications...

- Supporting traditional knowledge and indigenous people's rights
- Protected area management
- Participatory monitoring and evaluation
- Collaborative research and planning
- Conflict resolution
- Information and education

Tracing contour lines from topographic map

Sheet cutting

The Process...

- Forming the community group
- Identifying the area on topographic map
- Scanning and enlarging the map to desired size, scale and contour interval
- Tracing contour lines on the rubber mat, cutting and layer stacking, fixing with glue and nails
- Drawing and painting the details on 3D model like administrative boundary, roads, rivers, settlements, land use, etc.
- Validating the 3D model by community

Layer stacking

3D model ready for painting

Painting land cover

A complete P3DM

Participants with the model

P3DM by ICIMOD

- Godavari - Tripeni, Lalitpur
- Surkhang VDC, Mustang
- Sagarmatha National Park, Solukhumbu

Gap between knowledge, tools and application

There is a big gap between map-based information and a decision-making culture in the HKH region. The use of GI and EO knowledge, tools and applications has been limited and confined to post disaster management and in sporadic instances, to conservation. This unsatisfactory situation arises because of the limited understanding of the potentials of GI and EO sciences among administrators and decision-makers. The situation, perhaps, has arisen due to the limitation of GI and EO experts in communicating the potentials of their tools and applications in a language comprehensible to administrators and decision-makers. There is a serious mismatch between the design of GIS and the reality of decision-making norms and practices, which results in a significant under use of GIS. For the effective application of GI science, suggestions have been made for the creation of 'hybrids' to bridge the gap between GI sciences and specific thematic application areas. To close this gap is not simply a question of "awareness-raising" - it requires a paradigm shift in approach: a question of either fundamentally rethinking GIS design and use, or engineering a fundamental shift in decision-making culture.

Numerous issues and concerns regarding GI and EO applications have emerged from the discussion. Many of them are unresolved. The participants have suggested the creation of a common platform to discuss these issues to bridge what gaps remain between tools and applications. The platform could be used for sharing good practices that will further strengthen the value of GI and EO applications and decision support systems. In order to mainstream thematic applications and decision support systems into planning and decision-making processes there is a need to interface at three levels:

i. engage with policy makers at the government level through organising sensitisation sessions and user-friendly training workshops so that policy makers are able to use the tools for decision-making and see/feel the 'miracle' of it;

ii. initiate pilot projects with development and conservation agencies to demonstrate the effectiveness of GI and OE tools and approaches;

iii. invest in civil society organisations working in mountain areas and create local and institutional capacities.

Summary

- *Thematic application* - There is a wider horizon for GI and EO applications in the mountain context, such as hazard mapping, land use change, climate change monitoring, and biodiversity assessments. There is a need to go beyond map making to developing thematic applications.
- *Decision support system* - There is an increased need to have better understanding of interrelationships between the different components for integrated mountain development. Integrated and innovative solutions based on modern decision support tools and methods are considered crucial elements for better scientific understanding, supporting policy decisions and devising appropriate development interventions.
- *Community and participatory GIS* - GI and EO approaches and tools are sometimes extremely technocentric and hence, exclude interactive decision-making involving the very stakeholders that are central to all efforts. A central concern for practitioners has been the search for participatory approaches involving all stakeholders. This is where participatory GIS comes in to ensure the active involvement of communities.
- *Gap between knowledge, tools and application* - There is a big gap between map-based information and the decision-making culture. For the effective GI Science application, recommendations have been made for the creation of 'hybrids' to bridge the gap between GI Science and specific thematic application areas. A continuum in knowledge, tools and application has been recommended for the sustainability of the GI Science application in mountainous regions by facilitating a common platform.

Select Quotes from Sub-Theme 3 Discussion

- Sadly GIS is still being used as nothing more than a map making tool. We have not really made use of the application aspects of GIS despite the versatility of the tool. I tend to believe the persons who really apply GIS are specialised professionals in thematic areas (such as geologists, engineers, planners, agriculturists and hydrologists). GIS technicians/specialists as in Bhutan are conversant with GIS but have the problem of bridging the gap between the tool and the application. It is rare to find a professional with a specific background in sound GIS knowledge.
  – *Deo Raj Gurung*
- In my opinion, GI applications especially in mountain areas should focus on a participatory approach to validate results of GIS analysis.
  - Rajesh Thapa
- Effective application of GIS will no doubt - as in the wider information systems field - require within the HKH region the creation of "hybrids": those who are able to bridge the gap between GI Science and specific thematic application areas. The question then becomes, are there training programmes and curricula that are supporting the creation of such hybrids? If not, which HKH institutions will develop such training?
  - Richard Heeks
- We have to move toward a community GIS approach, establish community GIS centres in rural areas and train the locals to handle GI and EO. We have set up a mobile GIS lab for community GIS training.
  - *Mahesh Pathak*
- I am a great advocate of participatory GIS and strongly believe that it is the way forward. However, I feel it is important to highlight a note of caution. As with all maps, they are political and if used incorrectly they can go against the interests of the communities. If used too loosely or not controlled in terms of ownership they can be used to exploit rather than benefit, therefore careful, clear and sensitive planning at the beginning of the project is essential.
  - *Tanya Pascuel*
- There are huge cost implications involved in adopting applications and decision support systems for the mountain context. Accuracy of the system and availability of infrastructure as well as even inputs are in short supply sometimes. There is a lack of consistency in the data required to run the GIS applications.
  - *Ram Charitra Sah*
- As Jack Dangermond points out in his video message, the age of isolated [desktop] GIS applications is past, and more efficient and effective platforms can be achieved through integration across institutional/national boundaries.
  - *Suzanne Slarsky Dael*

5. Conclusions and Recommendations

The world is witnessing a proliferation of GI and EO applications in various disciplines. The vibrant discussion in this e-conference symbolises an increasing use of GIS and related technologies in mountain development related applications. Given the dynamic character of mountains and their spatial heterogeneity, it is apparent from the discussion that mountain areas pose unique challenges in harnessing these technologies. Many participants expressed their appreciation to ICIMOD for its pioneering role in the region in introducing these technologies and reinforced the need for its continuing role as a regional resource centre to promote the usage of GI and EO applications. Undoubtedly, this e-conference has been one of the key milestones in sensitising the stakeholders to the emerging concept of Mountain GIS as well as in addressing some of the pressing challenges. The e-discussion underscored a need to harness potential niches of GI and EO technologies for integrated mountain development giving due consideration to the following facts:

- Mountains are dynamic in nature compared to the plains and they possess distinct temporal and spatial characteristics in a unique socio-cultural setting;
- There is an ever-increasing need for spatial and temporal data for planning and decision-making, and GIS for this matter is increasingly being recognised as a common platform for integrating social, economic and environmental data and information from different sources;
- GIS promotes multidisciplinary approach, which also acts as a crucial element for holistic or systemic planning and management;
- There is a need for a geographic approach to bridge the scientific understanding of complex mountain ecosystems, for instance the issues of climate change, environmental degradation, natural resources management and many others, which require thorough assessment, monitoring, modeling, analysis and dissemination to support informed decision-making.

Major conclusions that can be drawn from the e-conference are as follows:

- There is a dearth of competencies required to understand decision-making, people and institutions to make the connection between GI and EO tools and real world issues in the HKH region;
- The demand for GI and EO courses in the market, especially at university level, is far outstripping the supply in the HKH region because of the exorbitant cost of education, lack of infrastructure and expertise. This mismatch is perhaps the biggest constraint to regional capacity building in GI science to meet the burgeoning industry demand for labour conversant in GI and EO skills as well as geo-information products;
- There are restrictions in some HKH countries with respect to access to topographic sheets of border and sensitive areas. This restriction sometime extends to remote sensing imageries which are made available only in post-disaster situations;
- There is a lack of common standards for metadata, datasets and map and projection parameters for the entire HKH region, which not only leads to lots of duplication and wastage of resources, but also hampers the development of databases and applications, as well as implementation of the Himalayan Spatial Data Infrastructure framework;
- One of the biggest constraints to GIS development in the region is that it is still perceived as nothing more than a map-making tool. Lack of understanding of the full potential of GIS still lingers at all levels; and
- Development of thematic applications and decision support systems to support planning and decision-making for sustainable mountain development is still in its infancy in the HKH region.

Proposed integrated GIS framework.

Recommendations

- An awareness raising campaign on the use of GI and EO systems should be held on GIS Day, supplemented by showcasing of "good practices", organising of talks or interaction programmes, and bringing together of software vendors, private and public institutions offering GI courses or employing GI-trained professionals, as well as students and professionals. It would also help to sensitise political leaders, policymakers, administrators and education departments on the growing relevance of GI and EO applications for planning and decision-making, while lobbying for government support to mainstream GI science in university curricula as well as in planning and policymaking. Institutional strengthening through regular training to staff or training of trainers should be regularised.
- There needs to be greater interaction and collaboration between the institutions offering GI courses and RS/GIS industry to not only frame practical curriculum, but also to produce quality GIS professionals to suit the specific requirements of the said industry.
- Universities in the region need to step up to meet the growing demands for GI science courses. They could start offering regular courses on GI science to full-time students or short professionally oriented courses to working professionals. The education provided should be socio-technical – as opposed to purely technical – so that the learners not only have sufficient background on the technology but are also provided with ample opportunity to learn about people, institutions and policymaking so as to be able to bridge the divide between technology and its application in key thematic areas.
- There is a growing need for accredited distance-learning programmes in the region for students and professionals. These could be offered by universities, research or speciality institutions in the region. The kind of programme being offered by Lund University, Sweden could be replicated and upscaled in the HKH region. Internet-based ICT infrastructure is needed in the region to launch such a programme and could come about through the partnership of multi-stakeholders (private sector, government, civil society) including donors. A consortium of Himalayan universities could be an ideal candidate to offer this kind of programme in the mountain context.
- There should be a greater movement toward using open source GIS at university and professional levels. This would make possible GI education at a lower cost, while at the same time allowing the FOSS community to grow. The big GIS software vendors should be persuaded to promote GI Science by giving away special software packages to a number of universities/institutions for free or at a discounted rate. This is also in the long-term interest of big GIS software vendors.

- There needs to be common standard metadata sharing protocols among different institutions in the HKH region. There also needs to be common map projections and parameters for the region. The datasets need to be brought to common standards so that they are interoperable. Tools and platforms like GeoNetwork can help to manage distributed stores of spatial data through standardised metadata. This is a good way to build a decentralised, multi-participatory, collaborative network to openly share and directly use GI information.
- Institutional and inter-sectoral collaboration needs to be fostered to minimise the costs associated with acquisition or preparation of data and to co-finance joint initiatives. The cost of data acquisition, preparation and analysis should be shared equitably and the data should be made available to the public and future users. A mechanism should be put in place to ensure regular updating, revalidation and adjustment of data and datasets.
- Spatial data infrastructure should be promoted at all levels (local, national, regional and global) to promote a transboundary approach to addressing mountain issues, which are more often than not, transboundary in nature. This would also facilitate joint planning and co-management of natural resources. However, the Himalayan SDI needs to be contextualised to the specificities of the HKH region before it is created and operationalised, since infrastructure has a property of irreversibility once it is in place. Coordination of efforts for developing GIS applications and datasets through regional and national networks is long overdue.
- There needs to be more coordinated lobbying efforts to persuade the government to relax its map policy and make topographic sheets accessible to the public – even of border mountain areas. It no longer makes sense to cite "national security" and restrict access to toposheets in a day and age when Google Earth makes such sensitive information available to the whole world. Also the government should make the pricing policy for toposheet and RS imageries more conducive and affordable for students, researchers and planners of national or local organisations. Access to remote sensing imageries should not be limited to post-disaster situations only.
- Since effective use of GI applications and decision support systems requires a multidisciplinary/ transdisciplinary approach, GI courses offered in formal or informal sectors should be socio-technical in nature, with some courses on community/social informatics as well. There needs to be a push toward creation of 'hybrids'' – those who are able to bridge the gap between the GI science and specific thematic applications and decision support systems.
- As HKH decision-makers do not come from map-based cultures and do not make map-based decisions, there may need to be fundamental rethinking of GIS design and use, and/or engineering a fundamental shift in the decision-making culture.
- Participatory GIS offers lots of scope for validating results of GIS analysis, ground-truthing aerial/RS-obtained data, as well as integrating the perspectives of local communities (local knowledge) in a participatory manner. The main principle behind PGIS is to train local stakeholders to use the GI tools themselves, thereby ensuring their sustainable long term use and only requiring periodic refresher training workshops. Community mapping, mobile GIS lab for community GIS training, GPS and participatory 3-D modeling are some of the tools that should be increasingly used to promote 'spatial thinking' at community level, thereby empowering them to be better managers or custodians of their environments.
- Already the general public in many parts of the world use cell phone, GPS and other internet-based tools to create, share or use geo-spatial information that they think is significant to their community. The challenge now is how to collect this vast untapped geo-spatial information to use productively in one's own work.
- To promote development of thematic applications and decision support systems, there needs to be a forum for showcasing such tools and the impacts they have had, as well as for sharing and discussing good practices and lessons learnt for replicating or up-scaling.

Annex 1. Evaluation Survey Results

Registrations

752 people from 75 countries registered to participate in the Mountain GIS e-conference. The highest numbers of registrations came from Nepal (204), India (90) and Pakistan (89) followed by USA (37), Bangladesh (22) and Canada (17) respectively.

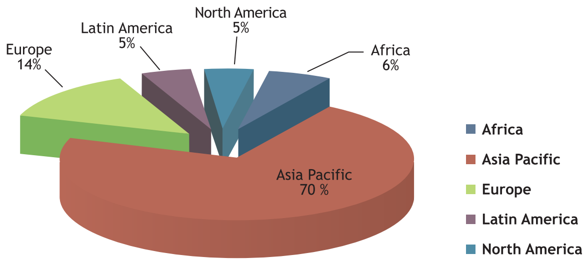
Contributors

Not all those who registered for the e-conference contributed. Of the 752 who registered, only 134 *(see Annex 2: List of Contributors)* contributed one or more postings/messages during the e-conference, thus registering an 'active' participation rate of 18%.

Participation in evaluation survey

66 people out of 752 registered participants responded to the post e-conference evaluation survey, registering a response rate of 9%. Among those who responded to the evaluation survey, 71% were from Asia-Pacific, with Europe coming a distant second with 14% (see Fig. 1).

Fig. 1 Participation by Region in the evaluation survey



Results

The survey asked to rate the following seven components of the e-conference on a scale of 1 to 5 (5=excellent, 4=very good, 3=good, 2=satisfactory and 1=poor); **a.** *Selection of sub-themes/issues posed;* **b.** *Quality of postings/discussions;* **c.** *Quality of moderation;* **d.** *Relevance of the showcases;* **e.** *Usefulness of the papers/presentations;* **f.** *User friendliness of the e-conference website;* **g.** *Overall organisation of the e-conference.*

Fig 2. Average rating per component

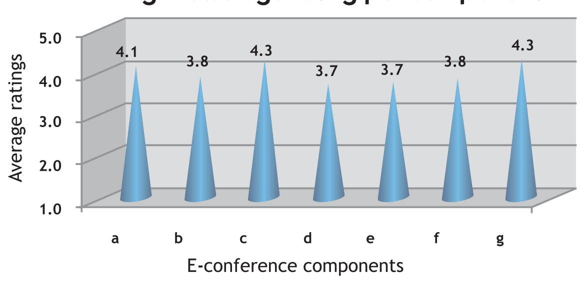


Fig. 2 lists the average rating for each component. The average rating was highest for component **c** *(quality of moderation)* and component **g** *(overall organisation of the e-conference)*, and it was lowest for component **d** *(relevance of the showcases)* and component **e** *(usefulness of the papers/presentations)*. If all components are assigned equal weight, then the overall rating for all of the components (average of averages) is 4 when rounded off. If we take this rating as a "proxy" for the overall rating of the entire e-conference, we can conclude that: the Mountain GIS e-Conference was rated 'Very Good'.

Annex 2: List of Contributors

[Note that this list does not include contributors of GIS resources, namely papers and showcases. Their contributions are separately acknowledged in Annex 3: a & b.]

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Annex 3: Resources

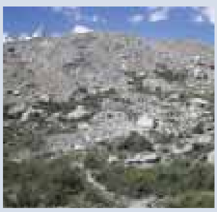
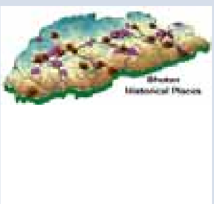
a. Papers *(see: www.mtnforum.org/rs/ec/index.cfm?act=cres&econfid=15)*

- Background Paper - "Promoting Geographic Information and Earth Observation Applications for the Sustainable Development of the Hindu Kush-Himalayan (HKH) Region - *Krishna Poudel*
- Discussion Paper: Mountain GIS e-Conference - *Krishna Poudel*
- Creative Use of Mountain Biodiversity Databases: The Kazbegi Research Agenda of GMBA-DIVERSITAS - *Christian Körner et al.*
- Landslide Mapping of the Everest Region using High Resolution Satellite Images and 3D Visualization - *Birendra Bajracharya and Sagar Bajracharya*
- Estimation of 2002 Extreme Flood over Balkhu River Using NOAA Based Satellite Rainfall and HEC-HMS Hydrological Model, and Assessment of Flood Education of People Living Near the Flood Risk Zone of Balkhu River - *Sagar Bajracharya and Binod Shakya*
- The impact of global warming on the glaciers of the Himalaya - *Samjwal Bajracharya, P. K. Mool and Basanta Shrestha*
- Mountain Tsunamis - *Basanta Shrestha*
- Monitoring/Impact of Wild Fires of the August 2007 in the Mountain Region of Ilia Prefecture (Western Greece) from Web Spatial (no cost) GIS Databases - *George C. Miliaresis*
- Regional Spatial Data Infrastructure (RSDI) for Sustainable Mountain Development in the Hindu Kush-Himalyan (HKH) Region - *Basanta Shrestha and Birendra Bajracharya*
- GIS Education - Experiences from the Hindu Kush-Himalayan (HKH) Region - *Basanta Shrestha and Birendra Bajracharya*
- Geographic Information (GI) for Sustainable Mountain Development in the Hindu Kush-Himalyan (HKH) Region - *Basanta Shrestha*
- Decision Support System for Estimation of Regional Evapotranspiration in arid areas: Application to the Republic of Yemen - *Ayoub Almhab*
- Empowering Local community - GIS in Egypt: Case study for use Google Earth as community based-conservation tool in Gabel Elba Protected Area (GEPA), Egypt - *Usama Mohammed, Ali Dora*
- Hearing a Different Drummer: A new paradigm for the 'keepers of the forest' - *Dr. John Studley*
- Páramo Vegetation Mapping in the Cotopaxi National Park, Ecuador - *Imroz Raihan*
- Community Response to Climatic Hazards in Northern Pakistan - *Ehsan-ul-Haq*
- Mapping the habitat and distribution of western tragopan Tragopan melanocephalus in the Palas Valley, Pakistan using landcover, terrain and field survey data - *Salman Ashraf, Asim Daud, Faisal M. Qamer and Rab Nawaz*
- The Other Side of Development: A Case Study of ACC Cement Factory in Himachal Pradesh (India) - *Dr. Mohinder Slariya*
- GIS Educational Trends - *Basanta Shrestha*
- Forest cover changes in the northern Carpathians in the 20th century: rates, factors and consequences - *Katarzyna Ostapowicz, Joanna Depta, Dominik Kaim, Jacek Kozak, Izabela Sitko, Mateusz Troll*
- Glacial Retreat and Vulnerability Assessment of Glacial Lakes in Himalaya - *Pradeep Mool*
- An Interdisciplinary Approach to Understanding Landslides and Risk Management: A case study from earthquake-affected Kashmir - *Sudmeier-Rieux, K; Qureshi, RA; Peduzzi, P; Jaboyedoff, MJ; Breguet, A; Dubois, J; Jaubert, R; and Cheema, MA*
- Google Earth as a tool for participatory 3-D modelling and elicitation of Traditional Ecological Knowledge (TEK) - *Alan J. Thomson*
- Capacity Building for Integrating GI and EO technologies in Mountain Planning - An Indian

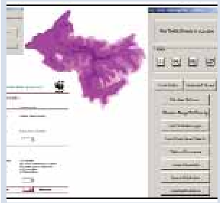
perspective - *Mahendra Sethi*

- Sustainable Agricultural part of an Alternative Livelihood for Ex-poppy Farmers in Myanmar- an example of the Wa Special Region 2 - *Ohnmar Khaing*
- ICIMOD and GIS Capacity Building in Myanmar - *Maung Maung Than*
- Land Use Land Cover (LULC) Mapping in the Mountain Terrain - *Krishna Poudel*
- Conceptual and Methodological Framework for Sustainable Ecosystem Management - *HKKH Partnership Project*
- The HKKH Partnership Project's Decision Support Toolbox for Sustainable Ecosystem Management - *HKKH Partnership Project*
- Metadata Format and Structure - *HKKH Partnership Project*
- Spatial Data Management for Protected Areas - *HKKH Partnership Project*
- Analysis of Future Scenarios for Sagarmatha National Park (Nepal) - Scenario Planning as a Participatory Decision Support Tool - *HKKH Partnership Project*
- Participatory 3D-Modelling for SNP (Nepal) - A Feasibility Study - *HKKH Partnership Project*
- GIS Capacity Building Framework for Sustainable Ecosystem Management - *HKKH Partnership Project*
- Application of FAO/UNEP Land Cover Classification System (LCCS) for study of land cover dynamics in SNPBZ (Nepal) - *HKKH Partnership Project*
- The Current Status of Scientific Data Sharing and Spatial Data Services in China - *Zhu Yunqiang*
- M.Sc. and PG Diploma Courses in GeoInformatics - *P.K. Joshi*

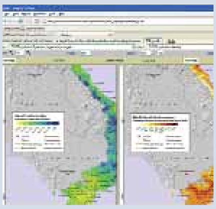
b. Showcases *(see: http://www.mtnforum.org/rs/ec/index.cfm?act=shc&econfid=15)*

	**Geo-Spatial Analysis: Web site, PDF and Book** *- Dr Mike De Smith*		**Glacial advancement and its effect on local community** *- Ali Rehmat Musofer*
	**Capacity Building Project: Environmental Management with GI Science** ***(www.zgis.at/emGIS)*** *- Dr. Shahnawaz*		**Participatory 3 Dimensional Model (P3DM)** *- Govinda Joshi*
	**Conservation Portal: Biodiversity of Nepal** *- Sudip Pradhan*		**Biodiversity of Pakistan: Database and Global networking** *- Rafaqat Masroor*

3-D Visualisation Using Google Earth: Glacial Lake Outburst Flood Hazard Assessment in Sagarmatha
- Lokap Rajbhandari

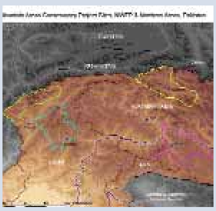


Application of Conservation GIS for Palas Valley, Kohistan District, North West Frontier Province, Pakistan
- Faisal Mueen Qamer

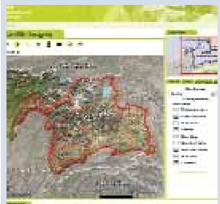


Socioeconomic Atlas of Vietnam
- Bettina Wolfgramm

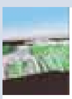
Afghanistan in Maps
- Govinda Joshi



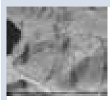
Ecological Mapping and Monitoring for the Mountain Areas Conservancy Project (MACP), Pakistan
- Hammad Gilani



Spatial Information System of the Tajik Pamirs (Pamir Webgis)
- Bettina Wolfgramm

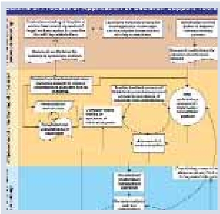


AVI: Flight over mountain terrain (DEM/Colour imagery)
- George Miliaresis

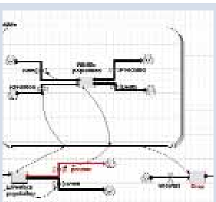


AVI: Flight simulation over mountain terrain
- George Miliaresis

HKKH Partnership: GIS Database Development and Land Cover in Sagarmatha National Park, Nepal
- Bastian Flury



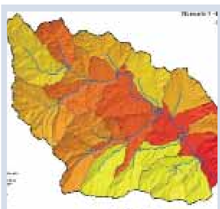
HKKH Partnership: Decision Support Toolbox for Ecosystem Management
- Bastian Flury



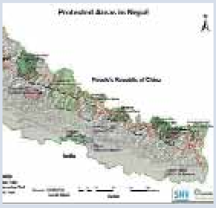
HKKH Partnership: Ecosystem Modelling
- Bastian Flury

HKKH Partnership: Participatory 3D Modelling
- Bastian Flury

Hindu Kush Himalayan (HKH) Region in Maps
- Govinda Joshi



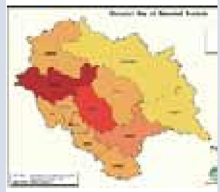
Water Quality Assessment Using GeoInformatics and SWAT Model
- Lokap Rajbhandari



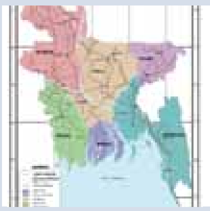
Tourist Attractions in the Proposed Great Himalayan Trail, Nepal
- Govinda Joshi

Inventory of Glaciers and Glacier Lakes
- Pradeep Mool

Spatial 3D Viewer
- Sudip Pradhan



Mapping Himachal Pradesh (India)
- Govinda Joshi

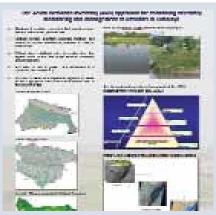


Bangladesh in Maps
- Govinda Joshi

GLOFs in the Sagarmatha Region: Hazard Assessment Using GIS and Hydrodynamic Modeling
- Lokap Rajbhandari

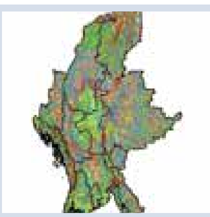
Linguistic Mapping of the HKH Region
- Rajan Bajracharya

Mapping Socioeconomic Indicators in Himalayan Region using GIS (Bhutan)
- Chodok

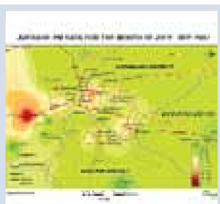


The Asian Wetlands Inventory (AWI) approach for enhancing inventory, monitoring and management of wetlands in Himalaya
- Kabir Uddin

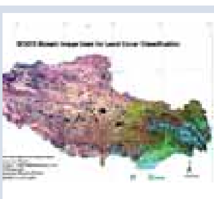
Mountain GeoNetwork
- Kiran Shakya



Myanmar in Maps
- Govinda Joshi

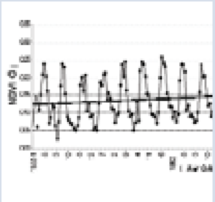


Air Pollution Modeling
- Bidya Pradhan (Banmali)



Land Cover Mapping in Tibet using EOS/MODIS
- Chodok

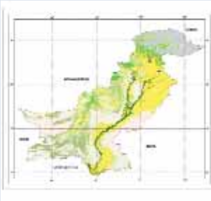
Mapping Socioeconomic Indicators in Himalayan Region using GIS (Nepal)
- Chodok



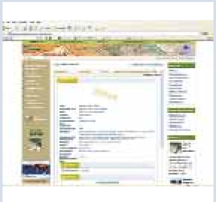
Sensitivity of NDVI to Seasonal and Inter-Annual Climate Conditions in the Lhasa Area, Tibetan Plateau
- *Chodok*

Training Course on Application of GeoInformatics for Integrated Water Resources Management
- *Deo Raj Gurung*

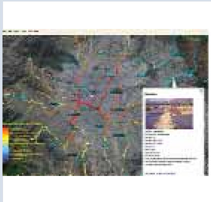
Training course on Application of Geo-Spatial Tools for Disaster Management
- *Deo Raj Gurung*



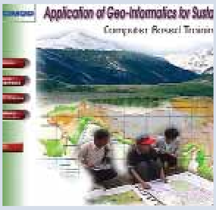
Pakistan in Maps
- *Govinda Joshi*



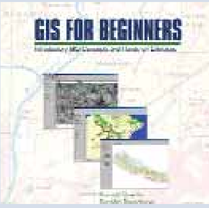
Spatial Data Cataloging System of ICIMOD
- *Govinda Joshi*



Water Quality Classification of the Bagmati River
- *Rajan Bajracharya*



Computer Based Training - Application of GeoInformatics for Sustainable Mountain Development
- *Salman Asif Siddiqui*



GIS for Beginners: Introductory GIS Concepts and Hands-on-Exercises
- *Salman Asif Siddiqui*

Spatial Information at Community Level/ Village Profile: Thailand Case Study
- *Dr Monthip Srirattana Tabuganon*

c. Useful Links

Description	URL
ACADEMIC	
Lund University - distance learning Master's Programme in GIS	*www.giscentrum.lu.se/english/index.htm*
Distance learning courses on GIS in Birkbeck London	*www.bbk.ac.uk/geog/* *www.bbk.ac.uk/gisc/learning/*
Professional development courses in statistics	*www.statistics.com/ourcourses /geostatistics*
US University Consortium for geographic Information Science	*www.ucgis.org/*
Centre for GeoInformatics Asia IT&C, the EU-ASIA Information Technology	*www.zgis.at*

and Communications Programme	*www.sbg.ac.at/zgis/emgis/*
UNIGIS Goa University, India	*www.sbg.ac.at/zgis/unigis/india/index.htm*
GIS Institute, Noida, India	*www.gisinstitute.net/aboutus.asp*
UNIGIS Jahangirnagar University, Savar, Dhaka	*www.unigis.net/ju_dhaka/default.aspx*
SOFT WARE, PORTAL, APPLICATION, METADATA	
FAO-GeoNetwork- The portal to spatial data and information	*www.fao.org/geonetwork*
MENRIS-Mountain GeoPortal	*http://menris.icimod.net/* *http://demo-menris.icimod.org/Default.aspx?mTab=home*
Conservation GeoPortal	*www.conservationmaps.org*
ArcGIS GeoDatabase model	*http://support.esri.com/index.cfm?fa=downloads.dataModels.gateway*
Transboundary Biodiversity initiative	*www.icimod.org/home/projects/projects.content.php?prid=10*
Map Builder	*http://communitymapbuilder.org/*
PROJ.4 - Cartographic Projections Library	*http://trac.osgeo.org/proj/*
GEOS - Geometry Engine, Open Source	*http://trac.osgeo.org/geos/*
OpenEV -software library and application for viewing and analysing raster and vector geo-spatial data	*http://openev.sourceforge.net/*
Map Server is an Open Source development environment for building spatially-enabled internet applications	*http://mapserver.gis.umn.edu/*
SAGA – System for Automated GeoScientific Analyzes- is a hybrid GIS software	*www.saga-gis.uni-goettingen.de/html/index.php*
OSSIM: Open Source Software Image Map	*www.ossim.org*
QGIS: Quantum GIS, is an GIS viewing environment	*http://qgis.org/*
TerraLib: Contain various modules	*www.terralib.org/*
PostGIS: Adds spatial database capabilities to the PostgreSQL	*www.postgresql.org/*
GeoServer: Java (J2EE) implementation of the OpenGIS consortium's Web Feature Server specification	*http://geoserver.org/display/GEOS/Welcome*
Thuban: It is a GIS viewer application in Python	*http://thuban.intevation.org*
JUMP is the 'JUMP Unified Mapping Platform, a visualization and user interface toolkit to solve data integration problem	*www.jump-project.org*
gvSIG: open source tool that utilizes open standards and is platform independent	*www.gvsig.gva.es/*
MapWindow GIS: mapping tool, GIS modelling system and a GIS application programming interface all in one	*www.mapwindow.org*
uDig: Geo-Spatial and a platform through which developers can create new, derived applications	*http://udig.refractions.net*
UTM Grid Zones of the World	*www.dmap.co.uk/utmworld.htm*

GIS development	*www.gisdevelopment.net/*
Panoramio	*www.panoramio.com/map/#lt=27 .575414&ln=84.49313&z=5&k=2&tab=2*
Resources related to PGIS and P3DM	*www.iapad.org/*
Gujarat State Disaster Management	*www.gsdma.org/*
National Snow and Ice Data Centre - The Atlas of the Cryosphere	*http://nsidc.org/data/atlas/*
Visible Earth-MODIS data	*http://visibleearth.nasa.gov/view_set.php? categoryID=2355*
Earth Observatory-example of earth changes in snow and ice cover by month in	*http://earthobservatory.nasa.gov/ Newsroom/BlueMarble/BlueMarble_ monthlies.html*
GLIMS: Global Land Ice Measurements from Space GLIMS: Global Land Ice Measurements from Space Monitoring the World's Changing Glaciers	*www.glims.org/*
ESA-EO based services for glacier monitoring	*http://dup.esrin.esa.it/projects/ summaryp98.asp*
Geological Survey of Canada-Airborne LASER (LiDAR) Terrain Mapping of Glacier Cover	*http://cgc.rncan.gc.ca/glaciology/national /news_e.php*
participatory tool Community Mapping and Its Implications	*http://epress.anu.edu.au/apem/borneo/ mobile_devices/ch05s03.html*
National Weather Services- rainfall estimation data	*www.cpc.ncep.noaa.gov/cgi-bin/RFE-GIS-data.sh*
	www.cpc.ncep.noaa.gov/products/fews/ global/asia/south_asia/
IPWG International Precipitation Working Group	*www.isac.cnr.it/~ipwg/IPWG.html*
PROJECT/NETWORK	
UNGIWG UN Geographic Information Working Group	*www.ungiwg.org/index.htm*
HKKH Partnership	*www.hkkhpartnership.org/*
NEGISS- Nepal Geographic Information system society	*www.negiss.org.np/*
South Asian Floods (SAF) Regional Cooperation for Flood Information Exchange in Hindu Kush-Himalayan Region	*www.southasianfloods.icimod.org*

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Web: http://www.mtnforum.org