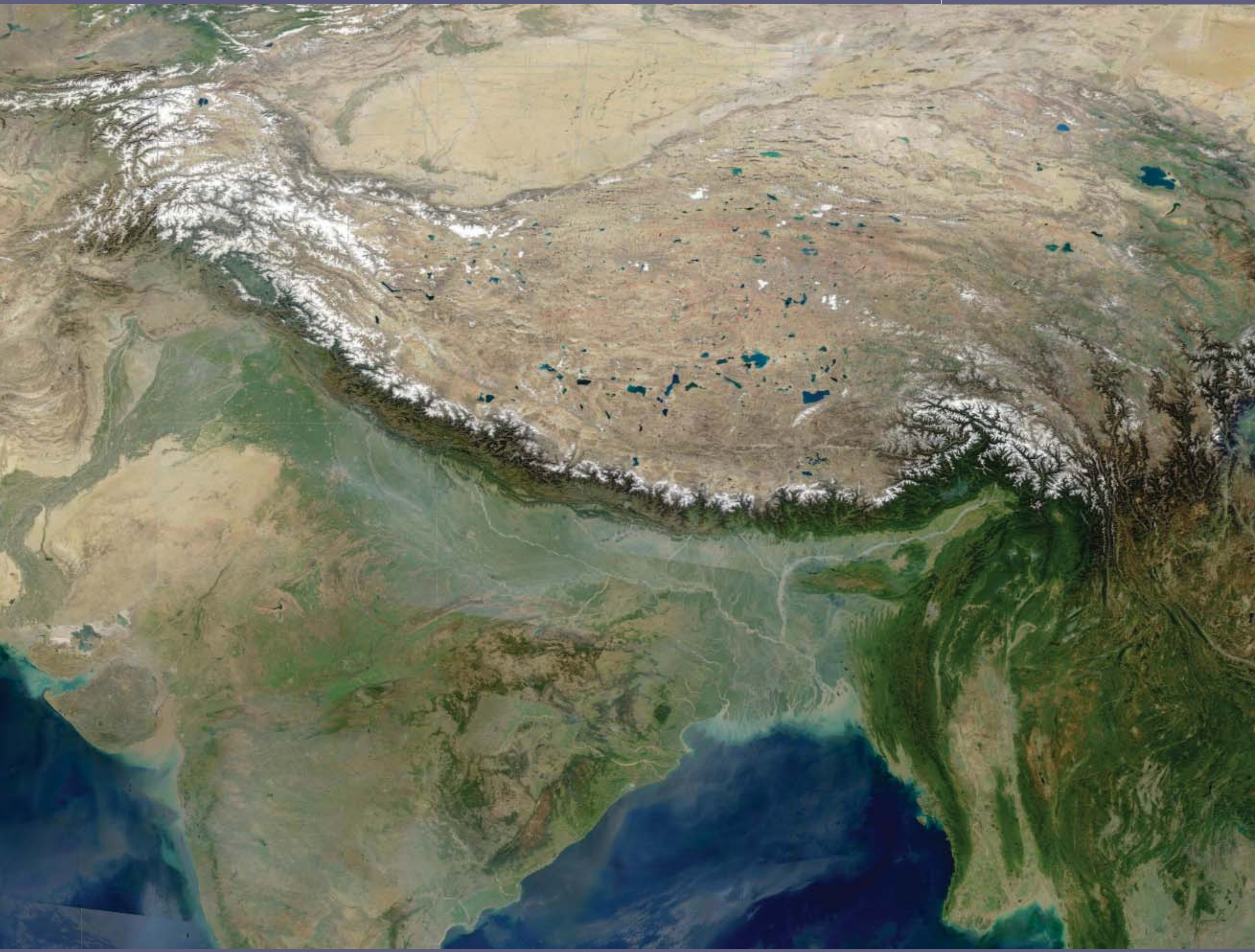
Earth Observation and Climate Change

ICIMOD

FOR MOUNTAINS AND PEOPLE

SUSTAINABLE MOUNTAIN DEVELOPMENT

No. 60 AUTUMN 2011



EARTH OBSERVATION

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Dear Friends of ICIMOD,

This issue constitutes a follow up to the international symposium 'Benefiting from Earth Observation: Bridging the Data Gap for Adaptation to Climate Change in the Hindu Kush-Himalayan Region' organised by ICIMOD in 2010, and coincides with the Climate Summit for a Living Himalayas organised by the Royal Government of Bhutan in November 2011.

ICIMOD has the following grounds for promoting the development of Earth observation.

- Earth observation bears special significance in a mountain environment like the Hindu Kush-Himalayas (HKH) with its remoteness and rugged terrain. It allows a first interpretation and analysis in a situation where in situ analysis is excessively time consuming or impossible. Where good case studies and individual field work have been conducted, Earth observation allows cost effective scaling up and generalisation.
- Geo-coded information based on Earth observation makes it possible to show a complicated situation in an illustrative, graphic way, which can replace long text explanations.

In this context ICIMOD is putting together a comprehensive side event for the Bhutan summit under the title 'Earth Observation and Climate Change in the Eastern Himalayas'. A wide variety of applications showcased at the Bhutan summit are presented in this periodical. The articles demonstrate the practical applications of Earth observation and related technologies for mountain development policies and practices. For instance, satellite observations provide information in near real time about the direction of movement of plumes of smoke from forest fire, or about weekly snow coverage to assess water availability in a catchment. Articles in this issue address the use of Earth observation to assess decadal changes of glaciers, carbon in the community forests of Nepal, cropping systems to support food security, natural disasters such as floods for early warning and response, land cover change, and many more.

ICIMOD partners with regional and international centres of excellence and space agencies to advance the application and practical use of the instruments of Earth observation. We are working with an international network of scientific and research organisations related to geo-information and Earth observation to benefit the HKH region. ICIMOD has become a partner in the Group on Earth Observations (GEO), a voluntary partnership of government and international organizations formed to coordinate information gathered from different space agencies worldwide.

Among many international partnerships, ICIMOD collaborated with the United States Agency for International Development (USAID) and the United States National Aeronautics and Space Administration (NASA) to launch the SERVIR-Himalaya programme in 2010 for improved environmental decision making. Likewise, ICIMOD partnered with the Japan Aerospace Exploration Agency (JAXA) to establish a WINDS (Wideband InterNetworking engineering test and Demonstration Satellite) receiving station for emergency response in disaster situations. ICIMOD plans to increase its satellite receiving capacity and mainstream Earth observation in its strategic programmes.

Our aim is to provide an effective regional platform on Earth observation for mutual sharing and learning among regional experts, scientists, policy makers, students, and researchers, as well as to strengthen regional and international networking so as to customise internationally available knowledge for the region. Wherever possible, ICIMOD works with and through national institutions. We also engage in building national capacities, especially for those of our Regional Member Countries that are weaker in this area.

I hope the present issue on Earth observation gives an engaging overview of these efforts.

Sincerely,

Andreas Schild
November 2011

Earth Observation –

Taking the pulse of the Himalayas

Basanta Shrestha, Division Head, Mountain Environment and Natural Resources Information System (MENRIS), ICIMOD, bshrestha@icimod.org

The Hindu Kush-Himalayan (HKH) (Figure 1) region is the youngest, the highest, and one of the most fragile mountain systems in the world. These mountains are the 'water towers' of Asia, providing water not only to the people in the immediate vicinity, but also to more than 1 billion people downstream. They act as reservoirs of biodiversity, containing all or part of four global biodiversity hotspots. The region is also known for its vast cultural diversity and natural heritage. The mountains of the HKH are particularly exposed to the consequences of climate change and variability, with increased vulnerability and a propensity for disasters of dramatic proportions. Remote sensing satellite data and historical records indicate that the HKH region is particularly sensitive because of pronounced temperature rise, particularly at higher altitudes.

The impacts of climate change on the mountain system are evident in the rapid melting of glaciers, loss of snow cover, changes in vegetation cover, biodiversity loss, erratic weather patterns, and increasing frequency and magnitude of natural disasters. The combination of rapid economic growth, population dynamics, the unsustainable use of natural resources, and globalisation have created unprecedented stress on mountain ecosystems with far reaching implications for socioeconomic development. Many development issues are intrinsically linked to these issues; the livelihoods of mountain people are dependent on the rapid changes in the environment and climatic system. Climate change has focused regional and international attention on the HKH region as one of the most vulnerable ecosystems in the world, with climate change having the potential to severely impact on the social and environmental security of the region.

Figure 1: **A view of the Hindu Kush-Himalayas from space**

Source: ESRI

To meet the challenges posed by climate change, there is a need for comprehensive information about the HKH mountain system and how it is changing over time and space. The effective monitoring of these changes is imperative to provide a scientific basis for informed decision making for adaptation to climate change and sustainable development. Earth observation combined with geographic information systems (GIS) and other related technologies provides the tools to advance understanding of the causes and risks of environmental and climate change to guide planning for adaptation to changes in the region.

Earth observation and climate change in the Hindu Kush-Himalayan region

Mountain systems, with their physical, demographic, cultural, and ecological diversity, present a formidable challenge to the collection and management of data and information. The HKH region is one of the most admired and described, but one of the least studied, monitored, and scientifically understood regions of the world. This has resulted in the characterisation of the HKH as a 'data-deficit' region by the Intergovernmental Panel on Climate Change. There is a high degree of scientific uncertainty about the scale and nature of climate change impacts in the region on a medium and long-term basis. Developing relevant knowledge about what to adapt and how to adapt is of the utmost importance, as climate change is fast becoming the most dominant factor in the sustainable development of mountain areas.

Irrespective of the cause of the climatic changes taking place in the region, these changes needs to be observed, monitored, and understood – and the need for information has never been greater. Decision makers and managers must have access to the information they need, when they need it, and in a format they can use. Earth observation data is proving critical to understanding the causes and effects of climate change. Of the 42 essential climate variables (ECVs) defined by the United Nations Framework Convention on Climate Change (UNFCCC), 26 are directly related to Earth observation. Earth observation plays a central role in understanding the changes taking place in remote and inaccessible areas of mountains and helps us to gain insights into topics of regional significance such as climate change, water and hydrology, biodiversity, natural disasters, and more.

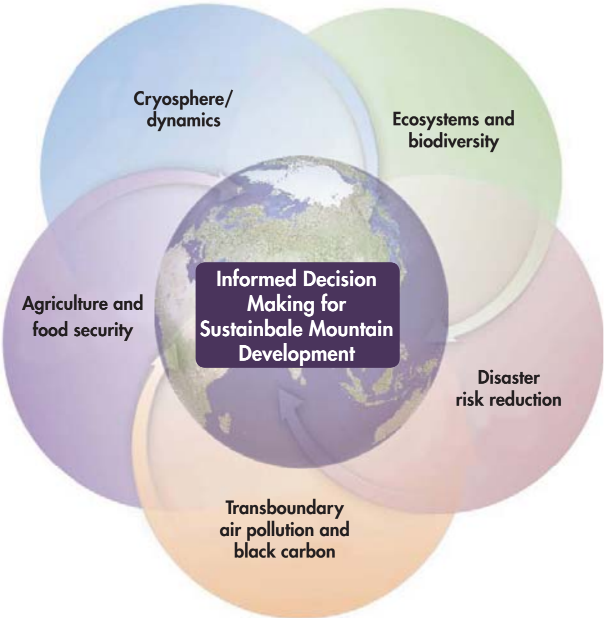
Mountain communities benefiting from Earth observation

ICIMOD is partnering with regional and international partners to understand the dynamics of the cryosphere and its impact on water regimes; assess ecosystem health to ensure that the goods and services provided by mountain ecosystems are intact to protect livelihood options; develop early warning systems for disaster risk reduction; analyse agriculture and food security issues; and monitor transboundary air pollution, among other things. Many of these issues are closely interlinked and interdependent on one another. There is an increased need to obtain better understanding of the interrelationships between the different components of mountain systems by generating spatial and temporal data for planning and management in the context of mountain development. To this end, as part of its role as a regional knowledge centre, ICIMOD is developing a number of strategic interventions to bridge the data gap in the region, create regional and international networks, and develop practical applications.

Mainstreaming Earth observation: linking space to mountain communities

One of the challenges in Earth observation is how to develop integrated and innovative solutions through practical applications to solve the problems of mountain areas. ICIMOD focuses on the following areas (Figure 2).

Figure 2: **ICIMOD's focus areas for application of Earth observation**



Cryosphere dynamics

The impact of climate change on the cryosphere has ramifications at the transboundary level, often with global implications. Increased temperatures and black carbon are the major factors affecting the cryospheric environment, threatening freshwater reserves, and posing increased risks from climate induced hazards to mountain communities and those immediately downstream. ICIMOD is engaged in the mapping and monitoring of the cryosphere at the regional level, providing a significant step towards regional status reporting, which is a prerequisite for the study of climate change and water resources management. ICIMOD's activities in this area include:

- inventorying glaciers and their decadal dynamics;
- snow cover mapping and monitoring;
- monitoring glacial lakes and potential glacial lake outburst flood hazards;
- developing early warning systems for disaster risk reduction;
- hydrological modelling to determine water availability scenarios.

Ecosystems and biodiversity

The HKH region is highly heterogeneous with a wide range of habitats, micro-climates, and ecological conditions. This has resulted in a high level of biodiversity. Planning and management to conserve ecosystems and biodiversity must deal with the distribution of ecological resources in space and time. Information on land cover and its dynamics is required for conservation and management, as a prerequisite for monitoring, and for the modelling of environmental change. With the growing concern about climate change impacts, there is a need to develop methodologies for carbon accounting and monitoring, reporting, and verification (MRV). ICIMOD is using Earth observation and GIS technology to develop:

- a standardised and harmonised time series land cover database to improve our understanding of the dynamics of natural resources;
- a database of species and ecosystems in line with the Global Biodiversity Information Facility (GBIF) and the initiatives of the Group on Earth Observation – Biodiversity Observation Network (GEO-BON);
- methodologies for forest carbon tracking and carbon financing for the benefit of mountain communities;
- a decision support system for protected area management and conservation.

A mountain community using satellite-based information and GIS data in participatory three-dimensional modelling for local-level planning, Bumthang, Bhutan

Disaster risk reduction

The impacts of climate change are already becoming evident in the HKH region in the higher incidence and intensity of natural disasters. The HKH region is among the most vulnerable in the world to natural hazards, particularly those induced by weather and climate, and these often lead to disasters that result in loss of life and property and impede socioeconomic development. Earth observation systems provide information that enables the disaster management community to make critical decisions for preparedness, risk assessment, response, and recovery. ICIMOD is promoting space-based information for disaster preparedness, risk management, and emergency response and is engaged in the following areas:

- multi-hazard risks and vulnerability mapping to minimise the risks due to climate induced disasters;
- rapid response mapping for emergency management and recovery for major disasters;
- remote sensing based forest fire detection and monitoring;
- regional and international cooperation for space-based information for disaster risk reduction.

Agriculture and food security

The HKH mountain system plays a significant role in agriculture and food security in South Asia through water supply, climate and wind regulation, groundwater recharge, and sustaining of wetland ecosystems. The region's capacity for climate monitoring and forecasting for agriculture has an important bearing on food security. For mountain farmers (who are mainly subsistence farmers) depending on marginal agricultural land, advance warning of abrupt changes in rainfall patterns and temperature can mean the difference between a successful harvest and crop failure. Earth observation data, in combination with other types of data, can provide valuable information about environmental conditions, which can have impact on the livelihoods of mountain communities. GIS and remote sensing technologies are helpful in identifying regions experiencing unfavourable crop growing conditions and food supply shortfalls and to determine food insecure areas and populations. ICIMOD is using Earth observation information to develop GIS applications to:

- establish past and recent responses to climate variability and extreme events in agricultural production;
- develop methodologies for modelling biophysical crop suitability;
- develop spatially referenced socioeconomic data to characterise food security and agricultural production;
- support the development of a regional and national food security atlas.

Transboundary air pollution and black carbon

Several of the world's most polluted cities are found in South Asia downstream from the Himalayas. These growing cities produce unacceptably high emissions of health endangering gaseous and particulate matter. Pollution from these cities can affect the entire region due to the unique positioning of the Himalayan mountains and associated atmospheric circulation. Not only do these pollutants impact on human health, they also damage agricultural crops and may increase the melting of the Himalayan glaciers, which are essential to water resources in the region. Earth observation data are becoming increasingly important for the mapping and monitoring of atmospheric aerosol. Advances in satellite Earth observation monitoring capabilities have resulted in the generation of many valuable scientific datasets on local to global scales. ICIMOD is working to provide a regional monitoring and assessment platform and is engaged in the following activities:

- the development of a regional coordinated scheme for the monitoring and assessment of transboundary air pollutants;
- remote sensing and in situ data integration and modelling;
- the monitoring of black carbon and its impact on glaciers and snow;
- research on the effects of transboundary air pollution on human health and agriculture.

Conclusion

Although climate change has focused global attention on the HKH region, our current understanding of mountain ecosystems and their services is limited. Earth observation in combination with field-based measurements is a useful way of generating systematic data on socio-ecological parameters; it has the ability to show us the present situation and track how our mountain system is changing through space and time. Earth observation is becoming increasingly important at global and regional levels, and has significant potential benefits for society. ICIMOD is using Earth observation to link 'space to village' for the benefit of mountain communities. Together with its regional and international partners, ICIMOD is working to provide integrated and innovative Earth observation solutions for informed decision making towards the sustainable development of the region.

Mountain Ecosystems and the Global Earth Observation System of Systems (GEOSS)

Jose Achache, Director, Group on Earth Observation, Switzerland, jachache@geosec.org

Mountain ecosystems are home to about 12 per cent of the world's population and provide a wide range of ecosystem goods and services. However, these goods and services may be in conflict with one another; for instance, the use of forest resources for energy and timber production may lead to a loss of biodiversity. In addition to being under pressure from human activity, mountain ecosystems are vulnerable to global climate change. Mountain glaciers are thought to be rapidly receding, which is seen as compelling evidence of climate change. However, more research and better observation is needed to fully understand the scope of this issue. Sensitive plants and animals that are already specially adapted to a severe environment may have difficulty in adjusting to changing environmental conditions. Because of their remoteness from highly populated and industrialised areas, mountains are considered ideal locations for investigating the impact of climate change on a regional and global scale. The Group on Earth Observations (GEO) supports observation systems that lead to a better understanding of such environmental issues.

GEO is a voluntary partnership of 86 member nations, the European Union, and 61 intergovernmental, international, and regional organisations. The goal of GEO is to coordinate efforts to construct a Global Earth Observation System of Systems (GEOSS) that builds on and adds value to existing Earth observation systems. It addresses critical gaps in current networks, supports their interoperability, and supports the sharing of information. International collaboration is essential for exploiting the potential of Earth observation to support decision making in a complex world. The vision for GEOSS is to realise a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive, and sustained Earth observation and information. ICIMOD joined GEO as a participating member in 2008 and is actively engaged in promoting Earth observation for the benefit of mountain communities in the Hindu Kush-Himalayan (HKH) region.

From observation to understanding, assessments and decision-making

Effective decision making is the key to properly managing mountain ecosystems. GEO works to support decision making by gathering the proper observation data and supporting scientific investigations and assessments. Sustained, long-term observation is the foundation of scientific understanding and assessments, which are essential to support informed decision making. Coordinating the myriad of observation networks around the world is a monumental task. GEO works towards this through nine Societal Benefit Areas (SBAs) that encompass most areas of human activity; these areas are: disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity (Figure 1).

Although GEO works within these societal benefit areas, most environmental issues are cross-cutting and there are many inter-dependencies among the areas. For instance, road and infrastructure construction in mountain regions has an effect on ecosystems, biodiversity, and water storage, and climate change affects all nine societal benefit areas. The monitoring of the goods and services provided by ecosystems is essential to track the status of natural processes and understand their capacity to provide services in the future.

The mountain systems in the HKH region provide essential ecosystem services to more than 1.3 billion people living in the mountains and their downstream river basins. Ecosystem services are defined by the Millennium Ecosystem Assessment (2003) as "the benefits people obtain from ecosystems". However, these services are not fully understood, as many are intangible and do not have an explicit market value. In particular, mountain ecosystem services are not fully captured in markets or valued in monetary terms, and are often marginalised from mainstream development in the plains. These services are taken for granted and do not play a role in policy decisions. In addition, existing policies and practices place demands on mountain ecosystem services, and the cost of conservation adds complexity to valuing these resources. It is important to note that mountain ecosystems not only provide services with a monetary value, but also represent a capital asset. For example, a policy that encourages the conservation of forests and soil in the mountains would result in essential water resources and services for downstream communities.

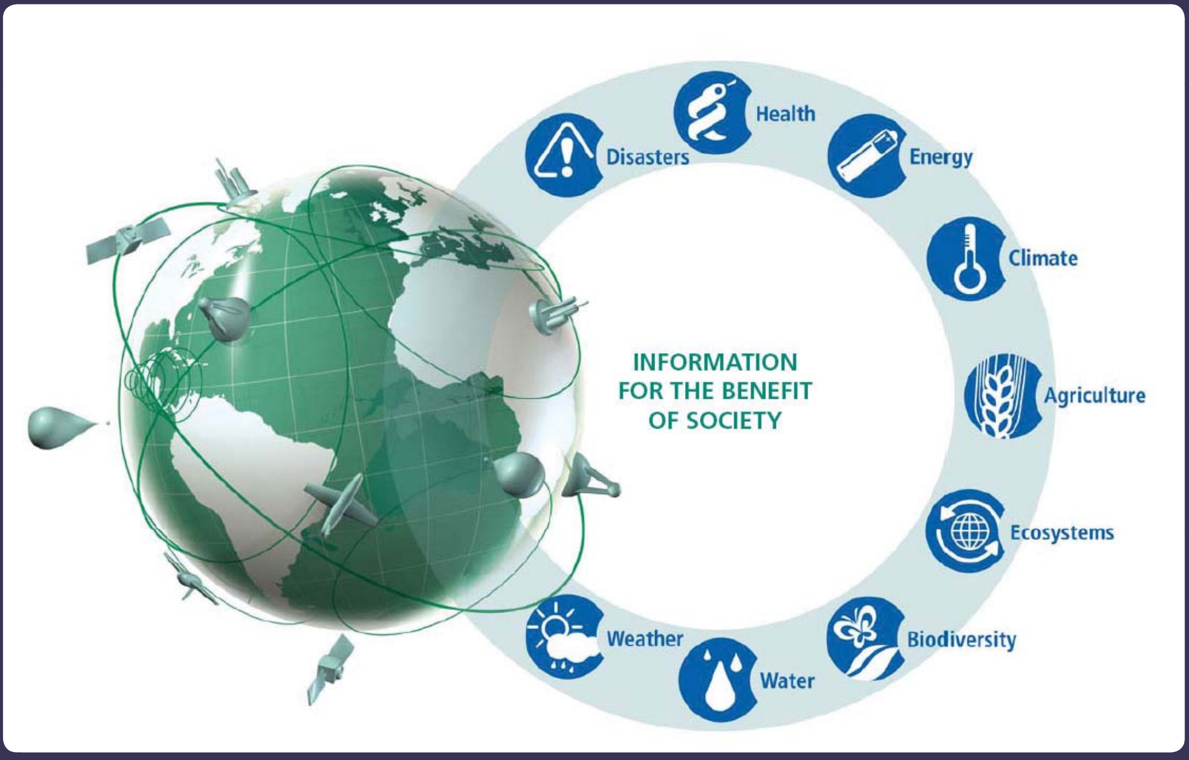
A proper valuation system for mountain ecosystems and their services is essential to guide human activity, but methodological difficulties remain an obstacle to estimating their economic value. The valuation of an ecosystem requires a clear understanding of both the socioecological and economic aspects of its services and of how these are interrelated. The basis for understanding ecosystems lies in supporting continuous, high-quality observation.

GEO is working with regional and sub-regional organisations including ICIMOD. ICIMOD is not only providing an effective platform for fostering regional cooperation, but is also actively engaged in developing Earth observation products and services applicable to key areas of mountain development, namely, integrated water and hazard management, environmental change, and sustainable mountain livelihoods. ICIMOD's collaboration with international partners (which has resulted, for example, in the launching of SERVIR-Himalaya by NASA and the commissioning of the WINDS receiving station by the Japan Aerospace Exploration Agency [JAXA]) provides a good basis for ICIMOD to realise the GEO vision at the sub-regional level.

GEO's web portal (www.geoportal.org) connects to a system of existing portals, providing an entry point to global, regional, and national Earth observation information and services (Figure 2).

I would like to recall the key message of the International Symposium 'Benefitting from Earth Observation: Bridging the Data Gap for Climate Change Adaptation in the HKH Region' convened by ICIMOD, GEO, and other partners in October 2010: "We look forward to a future where Earth observation information, products and

Figure 1: **GEO Societal Benefit Areas**



Source: GEO

services are extensively used in decisions and actions for the benefit of mountain communities in the Hindu Kush-Himalayan region". The International Symposium made the following four key recommendations, and GEO urges its regional and international partners to support ICIMOD in its endeavours to implement these.

- Empower youth to enable them to use Earth observation information for climate action in their communities.
- Foster regional and international cooperation to bridge the data gap in the HKH region and build synergies among national, regional, and global initiatives for integrated approaches and cross-cutting collaborations.
- Provide increased access to, and ensure increased use of, Earth observation for the integrated analysis of emerging mountain development issues.
- Continue regional and international support for sustained capacity building efforts in the HKH region.

One of the tasks under the GEO Work Plan is entitled 'Vulnerability of Mountain Regions' and is conducted through the SHARE (Stations at High Altitude for Research on the Environment) project. SHARE is working to promote continuous scientific observations in key high-mountain regions to contribute to knowledge on regional and global climate change. The specific aims of SHARE are to improve scientific knowledge on climate variability in mountain regions by ensuring the availability of long-term, high-quality data. To meet this goal, a global mountain observation network on atmospheric composition, meteorology and glaciology, hydrology and water resources, biodiversity, and human health has been established. SHARE is also planning activities that include the design of mitigation and adaptation strategies to counter the effects of climate change in mountain regions. SHARE's work has resulted in more than 150 scientific publications since the project began in 2003.

Figure 2: **The GEO web portal, www.geoportal.org**

Earth observation applications and limitations

Many of the observations that are needed to understand mountain ecosystems (field monitoring to track glacier advances and retreats, species observation, and stream gauges) require involved in situ work and a long-term commitment. However, because of the physical demands of reaching high-altitude areas and dealing with risky mountainous terrain, it is difficult to perform regular ground-based surveys. The use of remotely sensed data (both airborne and satellite) provides a great deal of information and improves our ability to monitor mountain ecosystems. Remote sensing satellites are impartial recorders of the story and are useful across different geographic boundaries and scales.

Using satellite data for updating or generating glacier inventories has been explored for many years. For instance, synthetic aperture radar (SAR) interferometry has the ability to measure glacier displacement. However, the topographic relief in mountainous areas makes the use of SAR imagery a challenge. The Gravity Recovery and Climate Experiment (GRACE), a joint partnership between NASA and the German Space Agency DLR, maps variations in the Earth's gravity field. These measurements yield information about the distribution and flow of mass within the Earth. The gravity variations that GRACE studies include runoff and ground water storage on land masses and variations in ice sheets and glaciers.

Airborne laser altimetry systems can measure surface elevation changes (including those of glaciers) with high accuracy. The altimetry system consists of a Global Positioning System (GPS) receiver, a laser, and a gyroscope. The GPS records the position of the plane at regular time intervals as it flies over a glacier, the laser system continually measures the distance between the plane and the glacier surface, and the gyroscope measures the direction in which the laser is pointing. By combining data from these instruments, elevation profiles of the surface of the glacier are created that are accurate to less than a metre.

International Symposium on Earth Observation jointly organised by GEO and ICIMOD in Kathmandu, October 2010

Optical sensors, such as Landsat, SPOT (Système Probatoire d'Observation de la Terre), and CBERS (China-Brazil Earth Resources Satellite), make it possible to monitor several ecosystem parameters. Landsat's nearly four decades of accumulated Earth imagery data provide an historical record that, combined with continuous updates, make it possible to interpret and anticipate changes to the Earth's surface with far greater certainty than ever before.

While Earth observation systems can provide valuable information that cannot be realistically derived from other sources, they do have their limitations. For instance, although Landsat has been operating since 1973 and provides invaluable information on ecosystem characteristics, the ability to detect glacial change from these data is limited by spatial resolution and it is not possible to track many biodiversity indicators from this source. Similarly, many of the other systems are special purpose or short-lived, so their utility for long-term monitoring is limited. Only by using a variety of systems and the recent development of new remote sensing satellites, including in situ observation, can comprehensive monitoring take place – it is towards this that GEOSS is working.

Conclusion

Despite their important contribution, mountains do not receive the attention they deserve in the development agenda, and the importance of the ecosystem services provided by mountains is not properly recognised. GEO supports the initiatives of ICIMOD and others by building the global capacity to integrate Earth observation data and information with data and information from other sources, thereby improving the understanding of mountain systems in order to identify sustainable solutions. It is also necessary to foster linkages and synergy with other mountain regions such as the Alps and the Andes for mutual learning and exchange. GEO, with its global mandate to create a Global Earth Observation System of Systems, is working together with regional and international partners to bridge the existing gaps in observation systems in mountain areas to facilitate the sharing of data and provide decision support tools to a wide variety of users for sustainable mountain development in the HKH and other mountain regions.

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SERVIR: Changing Responses to a Changing Climate

Bart D. Leahy, Senior Technical Writer, SERVIR Coordination Office, Huntsville, Alabama, United States, bartholomew.d.leahy@nasa.gov

Since 2005, the United States Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA) have been providing a collaborative, Internet-based platform for developing nations to access satellite data to respond to environmental challenges. This capacity-building programme now reaches three parts of the world: Mesoamerica, East Africa, and the Hindu Kush-Himalayan (HKH) region. The programme helps countries monitor and respond to the pressing environmental challenges of their region. Regional centres or 'hubs' in Mesoamerica, East Africa, and the HKH are staffed by the host countries, where they integrate and act on real-time or near-real-time information provided by SERVIR.

USAID/NASA cooperation

USAID and NASA recently agreed to expand their joint efforts to overcome international development challenges like climate change. On 25 April 2011, NASA Administrator Charles Bolden and USAID Administrator Rajiv Shah signed a five-year memorandum of understanding at NASA Headquarters. The agreement formalises ongoing agency collaborations that use Earth science data to address developmental challenges and for assistance in disaster mitigation and humanitarian responses. The agreement also encourages NASA and USAID to apply geospatial technologies to solve development challenges affecting the United States and developing countries.

USAID is the lead federal development agency implementing United States development efforts through field-based programmes and projects around the world. NASA has broad experience with Earth science research and the development of Earth science information products and technology applications.

"Through our partnership with NASA, we can apply the latest, cutting-edge technology to deliver meaningful results for people in developing countries in areas like health, food security and water", Shah said. "It is a prime example of our efforts to use the power of science and technology to tackle today's pressing development challenges."

Since 2003, USAID and NASA have worked together to build and expand the SERVIR programme. The programme allows people in developing regions to use Earth observations to address challenges in agriculture, biodiversity conservation, climate change, disaster response, weather forecasting, energy, and health.

SERVIR and climate change monitoring

While providing useful information to respond to immediate needs like hurricanes and landslides, SERVIR also helps host nations respond to long-term problems like climate change. There are already many global climate model outputs; however, the SERVIR platform focuses on regional issues, thereby providing a useful environment for translating such climate projections into potential impacts in sectors such as biodiversity, ecosystems, and water.

USAID-NASA cooperation agreement

Mesoamerica

Much of Mesoamerica consists of tropical or subtropical rainforest with a high level of biodiversity; in an area comprising less than 1 per cent of the Earth's landmass, nearly 8 per cent of the world's terrestrial species can be found. However, this rich biodiversity is very sensitive to climate change.

In 2005, through SERVIR, NASA and the Oak Ridge National Laboratory (under USAID funding) produced the first downscaled climate change data for Central America, providing a much more detailed look at potential local anomalies. In 2008, as part of a USAID Global Development Alliance project, SERVIR's partner in the region, the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) obtained species distribution maps from NatureServe (www.natureserve.org/infonatura) and high-resolution climate data from WorldClim (www.worldclim.org) to identify species-rich areas projected to experience severe climate change. The overall objective is to assess the potential impacts of climate change on the biodiversity of Belize, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama, specifically highlighting critical areas for conservation.

East Africa

East Africa faces several challenges that could be exacerbated by climate change, especially rainfall and flooding. In the Nzoia watershed in the Lake Victoria Basin (Figure 1), SERVIR-East Africa is working with researchers at NASA's Marshall and Goddard Space Flight Centers and the University of Oklahoma to implement and evaluate a higher resolution (approximately 1 km) distributed hydrologic model, the Coupled Routing and Excess STorage (CREST) water balance model. In Lake Victoria Basin, the CREST model uses real-time rainfall data from the Tropical Rainfall Measuring Mission (TRMM) as a boundary condition to map stream flow, evapotranspiration, and soil moisture. For flood forecasting, SERVIR-East Africa is incorporating atmospheric model-based rain forecasts into the CREST model in place of observed TRMM rainfall. Thanks to inputs provided by the Kenyan Meteorological Department (KMD), since late 2010 the CREST model has expanded from a single river basin near Lake Victoria to watersheds in five countries around the lake: Burundi, Kenya, Rwanda, Tanzania, and Uganda. The forecast models provided by KMD, based on the historical experience of local weather forecasters, are more detailed than larger-scale models developed via satellite. These rain forecasts will give decision makers,

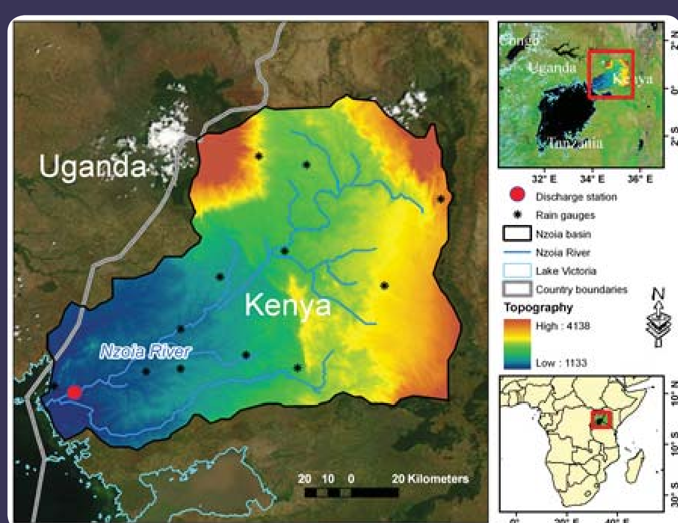
SERVIR-Himalaya regional inception workshop

including the Kenya Ministry of Water Resources, a longer lead time for flood forecasts, allowing more time for preparation and reaction.

Hindu Kush-Himalayas

Following a request from ICIMOD to consider establishing a SERVIR system in the HKH region, USAID and NASA travelled to ICIMOD's headquarters in Kathmandu, Nepal in August 2009. Upon assessing the potential for SERVIR at ICIMOD, the three organisations determined to move forward on plans to establish SERVIR-Himalaya, the third regional SERVIR operational facility, in 2010. SERVIR-Himalaya was inaugurated at ICIMOD in October 2010 in the presence of high-level delegates from ICIMOD's regional member countries and international participants. "Natural and human induced changes in the world have to be measured using all available knowledge resources and

Figure 1: **Mapping topography with a Digital Elevation Model (based on Shuttle Radar Topography Mission data) allows SERVIR scientists to model how water and potential floods move through the Nzoia watershed in the Lake Victoria Basin in East Africa**



SERVIR aims to provide satellite based information in combination with in-situ observations to enable science based decision-making", said Charles Bolden in his keynote speech during the inauguration of SERVIR-Himalaya.

Areas of focus for SERVIR-Himalaya are on developing decision support tools for monitoring snow and glacier melt, georeferencing biodiversity information, improving search and download capability for geospatial data sets covering the Himalayan region, validating national scale land-cover products, disaster response (see Figure 2), and much more.

One specific objective of the ICIMOD/SERVIR hub is to build the capacity of stakeholders in the HKH region to use SERVIR-Himalaya data and decision-support tools for issues related to climate change, ecosystems monitoring, disaster risk assessment, water management, agriculture and food security, transboundary air pollution, and other relevant environmental issues.

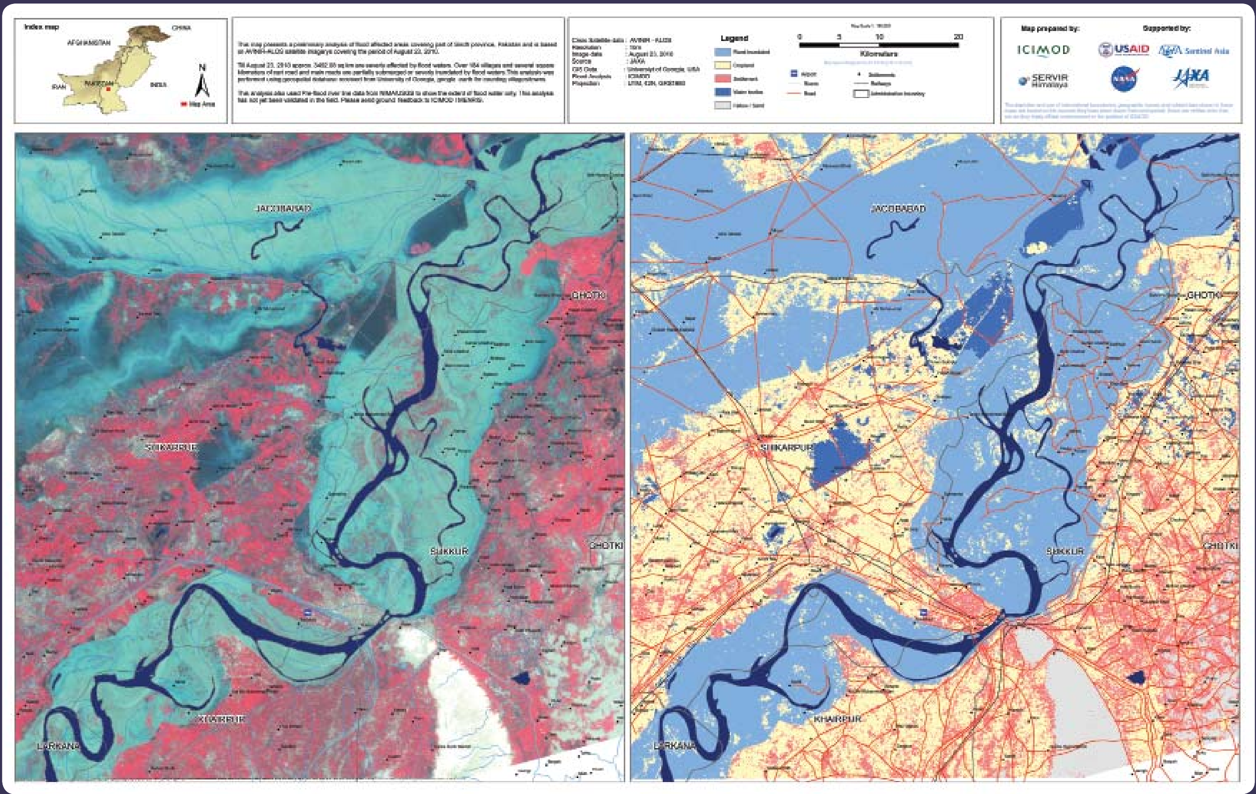
One important issue related to climate change is snow melt and glacier retreat: as the climate gets warmer, snow and glaciers atop the Himalayas melt and shrink, reducing the amount of water flowing into the major watersheds of the HKH region, which includes the regions ten major river basins which sustain more than a billion people downstream. The more data are gathered about the state of Himalayan snow and glaciers on a continuous basis, the better nations fed by these important rivers can manage their water resources. SERVIR and ICIMOD are important partners in long-term environmental policies because they can share the data necessary for ICIMOD's regional member countries to determine the correctness and effectiveness of their policies.

Future of SERVIR

USAID and NASA plan to expand the SERVIR network in the coming years, eventually extending to eight to ten different hubs around the world. Additionally, in the near future, SERVIR will employ an imaging system on the International Space Station, as well as ground-based sensors to capture near real or real-time image data of environmental problems. This broader array of sensors will provide more data in more places for better responses to environmental challenges.

An important side benefit of expanding the SERVIR network is the increased opportunity for international cooperation on issues that benefit society, from environmental management to responding to climate change. This is perhaps the most important effect of bringing space technologies 'down to Earth'.

Figure 2: **Rapid response mapping during Pakistan floods, 2010**



Satellite View of Particulate Pollution in the Hindu Kush-Himalayas

Maheswar Rupakheti, Asian Institute of Technology-United Nations Environment Programme (AIT-UNEP) Regional Resource Centre for Asia and the Pacific, Bangkok, Thailand, maheswar.rupakheti@rrcap.unep.org
Teruyuki Nakajima, Atmosphere and Ocean Research Institute, University of Tokyo, Japan, teruyuki.nakajima@aori.u-tokyo.ac.jp

Atmospheric aerosols are an important factor in climate change in the Hindu Kush-Himalayan region. They alter the Earth's energy budget, primarily by directly scattering and absorbing the incoming solar radiation, indirectly modifying cloud properties. Deposition of light-absorbing particles such as black carbon decreases snow and ice albedo (reflection coefficient). The growing recognition that atmospheric aerosols affect surface temperature and precipitation patterns has created a demand for science-based information. Spaceborne observations are increasingly being used for this purpose.

Figure 1: **MODIS satellite image of large-scale atmospheric brown clouds shrouding the lowlands south of the Himalayas, with a grey veil stretching over the eastern Himalayas, southeastern Nepal, northeastern India, Bangladesh, and the northern Bay of Bengal (1 January 2011)**

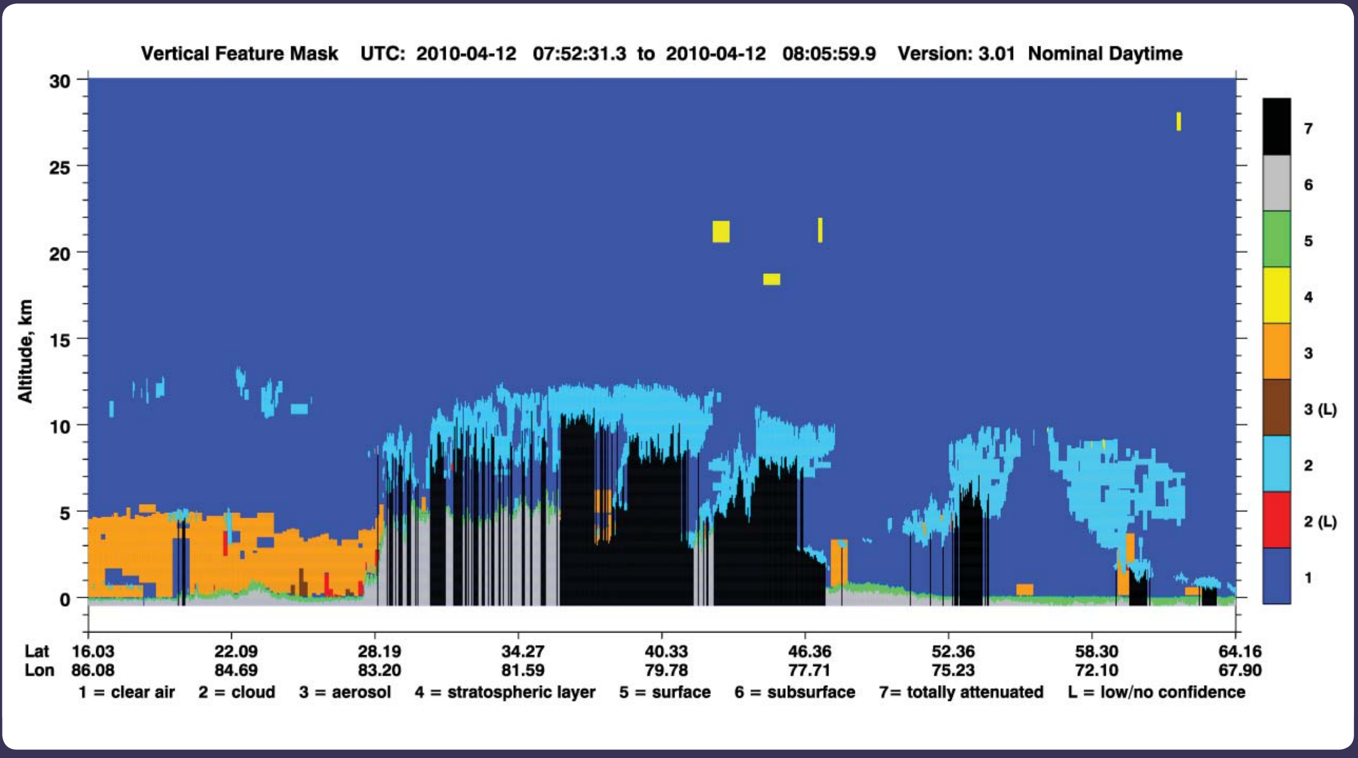
Source: http://modis.gsfc.nasa.gov

A number of much enhanced satellite systems have been developed over the past few decades, which are enabling quantitative analysis of a variety of atmospheric aerosol related parameters (King et al. 1999). As ground-based measurements in the HKH region are extremely difficult and expensive because of the terrain, satellite observations of particulate pollution provide unmatched opportunities for filling in the data gaps to further understanding of climate change in the region and its impacts.

Tracking atmospheric aerosol pollution

The TOMS (Total Ozone Mapping Spectrometer), available since 1978, was not primarily designed to look at aerosols, but it provides excellent observations of elevated smoke or dust layers above the scattering atmosphere. In 1995, satellite-based observations entered an exciting new phase with the launch of GOME (Global Monitoring of Atmospheric Ozone), the first satellite instrument designed specifically to retrieve the composition of trace gases and pollutants in the troposphere. After the pioneering study by weather satellite imager Advanced Very High Resolution Radiometer (AVHRR) (Nakajima and Higurashi 1998), the United States National Aeronautics and Space Administration (NASA) launched POLDER (Polarization and Directionality of the Earth's Reflectances), the first instrument designed for aerosol measurement, in 2000, adding a new dimension to atmospheric aerosol research. Two new instruments, MODIS (Moderate-resolution Imaging Spectroradiometer) and MISR (Multi-angle Imaging Spectroradiometer), which have been in orbit since 2000 as part of the NASA Science Mission Directorate Earth Observing System (EOS), have been providing imagery on large-scale atmospheric aerosol pollution as well as quantitatively monitoring aerosol properties globally, notably aerosol optical depth (AOD). These instruments can even distinguish small pollution particles from coarse sea-salt and dust particles (King et al. 1999; Kaufman et al. 2002). More recently, CALIPSO (Cloud-Aerosol LiDAR and Infrared Pathfinder Satellite Observation) was launched in April 2006 with LiDAR (active sensors) on board. This has made it possible to measure aerosol vertical distributions, providing new insights into the role of clouds and atmospheric aerosols in regulating the Earth's weather, climate, and air quality.

Figure 2: **Aerosol vertical distributions observed by CALIPSO satellite in the Indo-Gangetic plains and HKH mountains; the higher loading of aerosols to the south of the Himalayas is clearly visible (bottom left) (12 April 2010)**



Source: www-calipso.larc.nasa.gov

These recently developed advanced spaceborne sensors enable the quantitative analysis of atmospheric aerosol optical thickness, aerosol size distribution, and single scattering albedo (how reflective or absorbent the atmosphere is due to the presence of aerosol). They are also providing information on the global distribution of, and seasonal and interannual variation in:

- sources of aerosols (e.g., forest fires, wind-blown dust, industrial pollution);
- aerosol loading and optical properties;
- direct radiative forcing (i.e., the change in radiative flux at the top of the atmosphere);
- indirect radiative forcing through the measurement of cloud albedo.

The global distribution of aerosols observed by MODIS led to the discovery of regional plumes of air pollution, known as atmospheric brown clouds (ABCs). As a result of satellite-based observations, the transport of fine particulate pollution is now viewed differently; pollution is now seen as a global, rather than local, phenomenon.

Information from a number of satellites provides crucial data which has enhanced our ability to monitor the state of the atmosphere, led to improved models of pollution dynamics, and helped scientists to predict changes in atmospheric composition with greater confidence. The recent impact of volcanic ash on European aviation is a compelling reminder of the utility of satellite observations in monitoring and understanding the tropospheric constituents of the atmosphere. Satellite observation is also radically changing the field of atmospheric physics and chemistry. The remote observation of the physical and optical properties of aerosols, combined with ground-based measurements, make it possible to study the impacts of aerosols on the climate system. These and other satellite observations have advanced our understanding of the climate system and dramatically improved climate models and climate change projections.

Particulate pollution in the HKH region

South Asia's unique meteorological features and its proximity to regions with high emissions make the Hindu Kush-Himalayan region vulnerable to the impacts of atmospheric aerosols. The long and dry winter, which lasts from November to March, is conducive to the accumulation of air pollutants in much of South and Southeast Asia, leading to the formation of atmospheric brown clouds. Cold, heavy air slides down the southern face of the Himalayas into the lower lands, holding pollution close to the ground. In winter, eastern Pakistan, northern India, much of Nepal, and Bangladesh are regularly plagued by thick air pollution consisting of extremely high levels of particulate matter. Cold air often ends up trapped underneath a layer of warm air, resulting in a temperature inversion and locking pollutants in place. Ambient particulate matter is the most common and significant health hazard in all of the HKH countries. The aerosol vertical distributions in the Indo-Gangetic plains and HKH mountain regions (Figure 2) show a thick layer (up to 5 km from the surface south of the Himalayas) of aerosol pollution in the region.

Recent scientific studies have found that the radiative forcing due to atmospheric aerosols is generally high in many parts of Asia, including the HKH region. The region's contribution to the total emission of air pollutants from HKH countries is minimal, but the aerosol loading in the region is high because of the transport of pollutants from surrounding regions. The high atmospheric concentrations of particulate matter, including black carbon, at high elevations have rapidly increased the amount of black carbon deposition on ice and snow over recent decades, resulting in strong direct and snow-albedo radiative forcing. Because of the high black carbon content in snow and ice and the high level of incident solar radiation, the snow-albedo radiative forcing is estimated to be considerably higher over the Himalayas and Tibetan Plateau than in other snow-covered regions of the world.

Satellite observations of the HKH region are unmatched in providing sufficiently frequent spatial coverage to detect the dynamic nature of the transport of atmospheric pollution across the region. Comprehensive ground-based and airborne measurements are either too expensive or not feasible because of the mountainous terrain. Satellite observation of atmospheric particulate pollution in the region has enabled scientists to fill in previous data gaps, for better understanding of the role of atmospheric circulation, atmospheric aerosol transport, aerosol composition, aerosol deposition on ice and snow, and year-to-year aerosol variability in regional climate change. Daily satellite observations yield continually updated data on atmospheric processes and the state of the atmosphere, which together with ground-based in situ observation enable scientists to predict changes with greater accuracy. This knowledge will support appropriate early warning systems which will ultimately save lives and property in the region.

Haze over the Kathmandu valley, Nepal

Deriving maximum benefit from satellite observations of pollution in the HKH region

The use of satellite observations in the HKH region, including the observation of atmospheric pollutants, is likely to accelerate in the coming years. This will result in an increased ability to predict atmospheric processes in the region through the cross-disciplinary integration of analysis and interpretation, and, ultimately, through a deeper understanding of the dynamic processes that govern pollutant transport, transformation, and removal in the region. It is important to understand the fundamental observations and research behind satellite observations, and to be able to use the satellite data products, which have many practical applications and societal benefits. However, the countries in the HKH region have limited capacity, in terms of infrastructure and workforce, to use satellite data to its maximum potential. However, some programmes have been initiated, notably in China and India, to launch and maintain satellites to study aerosols. The scientific community in the region, although small, is poised to make great progress towards understanding the complexity of atmospheric processes and predicting the effects of aerosols on climate.

Resources are required to maintain the current momentum. A trained workforce of atmospheric scientists and technicians is needed to develop appropriate tools to analyse and interpret satellite observations in the region. Open access to satellite data for the broad scientific community and international collaboration are crucial in training and maintaining such a workforce. In addition, essential infrastructure, such as atmospheric models, computing facilities, and ground networks with long-term data records, is required to validate and maximise the utility of satellite data. Multiple, synergistic observations, including satellite observations and in situ measurements, linked with the best atmospheric models available, should be employed and supported. To study the aerosol distribution, composition, and associated impacts accurately to address the scientific and societal challenges of the future, there is a need for continuous satellite observations, ground-based and in situ measurements, and dedicated field experiments. These need to be integrated with atmospheric models, which are likely to reproduce increasingly realistic pictures of aerosol distribution within and outside the HKH region. This requires national and international support.

We live in interesting times for aerosol research. If current emission trends and policies continue, air pollution will remain a major issue in the region – seriously affecting our climate and health. Satellite observations, ground-based observations, and model simulations of atmospheric pollution in the region would provide a foundation for the development of a regional agreement to control the emission of atmospheric pollutants and mitigate climate change and other effects of pollution. Such an agreement is integral to the sustainable development of the region.

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Understanding the Dynamics of Snow and Glaciers in the Hindu Kush-Himalayan Region

Deo Raj Gurung, Remote Sensing Specialist, MENRIS, ICIMOD, drgurung@icimod.org
Samjwal Ratna Bajracharya, Remote Sensing Specialist, MENRIS, ICIMOD, sabajracharya@icimod.org
Walter Immerzeel, Utrecht University, Utrecht, The Netherlands, W.W.Immerzeel@uu.nl
Anil V. Kulkarni, Divecha Centre for Climate Change, Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bangalore, India, anilkulkarni@caos.iisc.ernet.in

The Hindu Kush-Himalayan (HKH) region is complex and characterised by intricate biophysical and socioeconomic linkages between the upstream and downstream parts of its predominantly transboundary river basins. The cryosphere, in the form of glaciers, snow, permafrost, and seasonally frozen ground, forms a large natural storage system of fresh water important for sustaining the lives of the more than 1 billion people living downstream. The cryosphere and the climate system are linked in numerous ways. The high albedo (reflection coefficient) of snow and ice surfaces is associated with feedback processes and

Snow and glaciers – source of fresh water

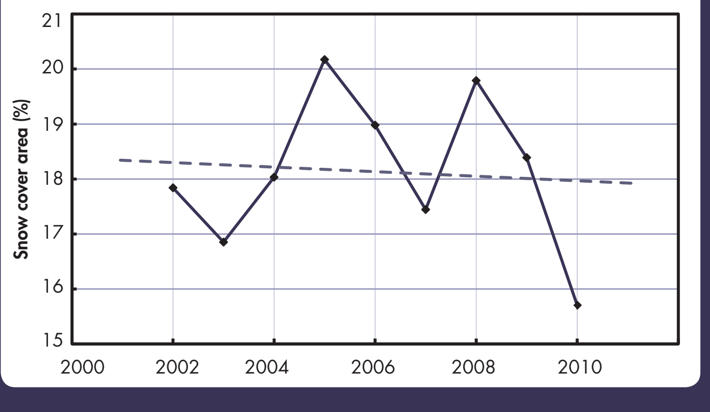
plays a significant role in the global climate. Changes in the cryosphere may have grave consequences for the regional and global climate systems. These changes may have strong social and economic consequences, especially in mountainous regions where economic opportunities such as hydropower, tourism, and agriculture are to a certain degree dependent on the snow and ice melting regimes. The increased melting of snow and glaciers at the headwaters of rivers also increases the risk to infrastructure, particularly when combined with heavy monsoon rainfall.

The cryosphere is thus one of the most important topics in climate science and in climate change impact and adaptation research. The monitoring of all components of the cryosphere is of prime importance in understanding the processes in the cryosphere and the climate system. Without an understanding of the role of the cryosphere, it is not possible to model and predict the variability and future changes of the climate system (Khromova 2010).

Bridging the data gap

To address the data gap pointed out by the Intergovernmental Panel on Climate Change (IPCC 2007), ICIMOD, together with a number of key regional and international partners, undertook a comprehensive study to understand the dynamics of the cryosphere in the HKH region, focusing specifically on two components, snow and glaciers. Remote sensing based observations proved to be critical for the monitoring and assessment of the cryosphere in the HKH region because routine data collection in mountainous regions is often hampered by highly inaccessible terrain and harsh climatic conditions. The study provides a comprehensive account of remote sensing based information, providing homogenous and contiguous datasets at the regional level. A common approach and methodology were used to standardise and harmonise the database in line with international norms, which are a precondition for regional level assessment.

Figure 1: **Average variation in snow cover area in the HKH region, 2002–2010**



Snow

The HKH region has a vast snow-covered area (SCA); the maximum area recorded from 2002 to 2010 was 1.79 million km^2 (42.9% of the total land area). The permanent SCA during this period was 0.18 million km^2 (4.3% of the total land area). The SCA shows strong inter-annual variation (Figure 1). The mean annual SCA ranged from 0.70 million km^2 in 2002 to 0.84 million km^2 in 2005 (Gurung et al. 2011).

A nine-year (2002–2010) analysis of SCA derived from MODIS based standard snow cover products after filtering cloud pixels based on linear regression analysis of annual mean SCA, indicates a positive trend in the western and eastern HKH (Table 1).

Table 1: **Annual snow cover trends in the Hindu Kush-Himalayan region (%)**

Region	Trend
HKH region	-0.05 ± 1.32
Western HKH	+0.02 ± 1.36
Central HKH	-0.40 ± 1.86
Eastern HKH	+0.03 ± 1.55

A map of the spatial trends in SCA shows that this positive trend does not pertain in the central HKH (Figure 2). A seasonal analysis was also performed for the region for the same period. The analysis indicates a consistent negative trend during winter (December to March) across the HKH region. For spring (April to June) and summer (July to September), SCA analysis indicates a negative trend, except in the western HKH region. The trend for autumn (October to November) was negative in the western HKH region while it was positive in the eastern and central HKH (Table 2).

The SCA depletion curve helps in understanding the snow ablation and accumulation cycle, which is important in assessing the contribution of snow melt to the hydrological regimes of river systems. Intra-annual variations in the SCA for the entire HKH region were studied using mean monthly SCA for 2002–2010. Two peaks were observed: one in February and a subsidiary peak in November/December. Immerzeel et al. (2009) observed a similar pattern in the Yangtze and Yellow river basins. SCA depletion curves were also calculated for different elevation bands (<1,000, 1,000–2,000, 3,000–5,000, 5,000–7,000, and >7,000 m) based on mean monthly values for the hydrological year

Figure 2: **Changes in snow cover area in the HKH region and beyond, 2002–2010 (%)**

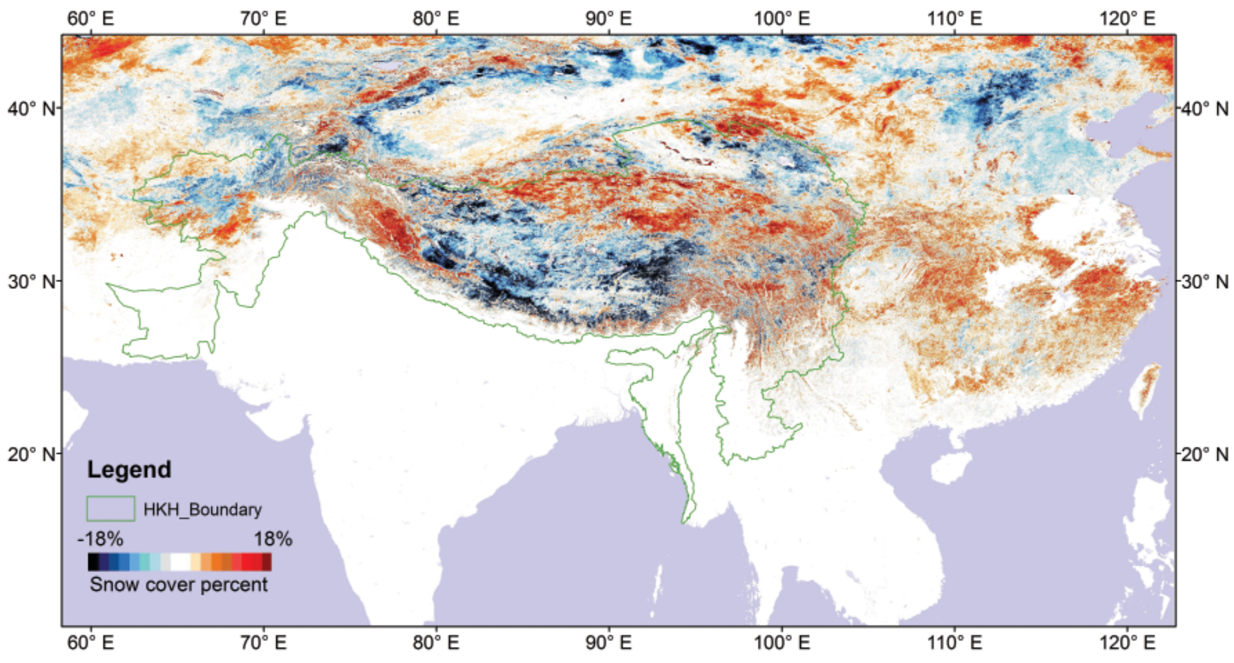


Table 2: **Seasonal snow cover trends in the Hindu Kush-Himalayan region (%)**

Season	HKH region	Western HKH	Central HKH	Eastern HKH
Spring	-0.03 ± 1.28	+0.11 ± 1.83	-0.23 ± 2.46	-0.03 ± 1.06
Summer	-0.01 ± 0.49	+0.16 ± 0.65	-0.20 ± 1.40	-0.04 ± 0.52
Autumn	+0.09 ± 3.97	-0.26 ± 2.81	+0.02 ± 5.74	+0.29 ± 5.32
Winter	-0.16 ± 2.23	-0.02 ± 2.80	-0.84 ± 2.63	-0.01 ± 2.47

2000–2001. The analysis shows delayed snow melt onset with rise in elevation, consistent with observations on the Tibetan Plateau (Pu et al. 2007).

Glaciers

ICIMOD, together with national partners, has recently completed an inventory of glaciers in Afghanistan, Bhutan, China, India, Nepal, Myanmar, and Pakistan (ICIMOD, in preparation). This is the first time that glaciers from Myanmar have been reported. The study is unique as it comprehensively maps both clean ice and debris-covered glaciers for almost the entire HKH region using a consistent methodology. The only exception is China, for which the inventory was done separately, but following a largely similar methodology. The medium-resolution remote sensing data (Landsat and ASTER) were used in the inventory from a single data source with a short acquisition time interval (2005±3 years), and the properties of each glacier were documented in a standardised internationally accepted form. All of the glaciers in the HKH region with a surface area larger than 0.02 km^2 were mapped (Figure 3). A multi-stage approach using both remote sensing and field data was applied for more accurate results. The inventory revealed about 54,000 individual glaciers with a total area of 60,000 km^2 and an estimated 6,100 km^3 of ice reserves in the entire HKH region (Table 3). The stored water in these ice reserves is about four times the annual precipitation. It was found that the average glacier area in the HKH region is 1.10 km^2 (Bajracharya et al. 2010). The highest concentration of glaciers is in the upper Indus basin, and the lowest in the Irrawaddy basin. The largest glacier in the HKH region is the Siachen Glacier in the Indus basin.

Figure 3: **Distribution of glaciers in the Hindu Kush-Himalayan region**

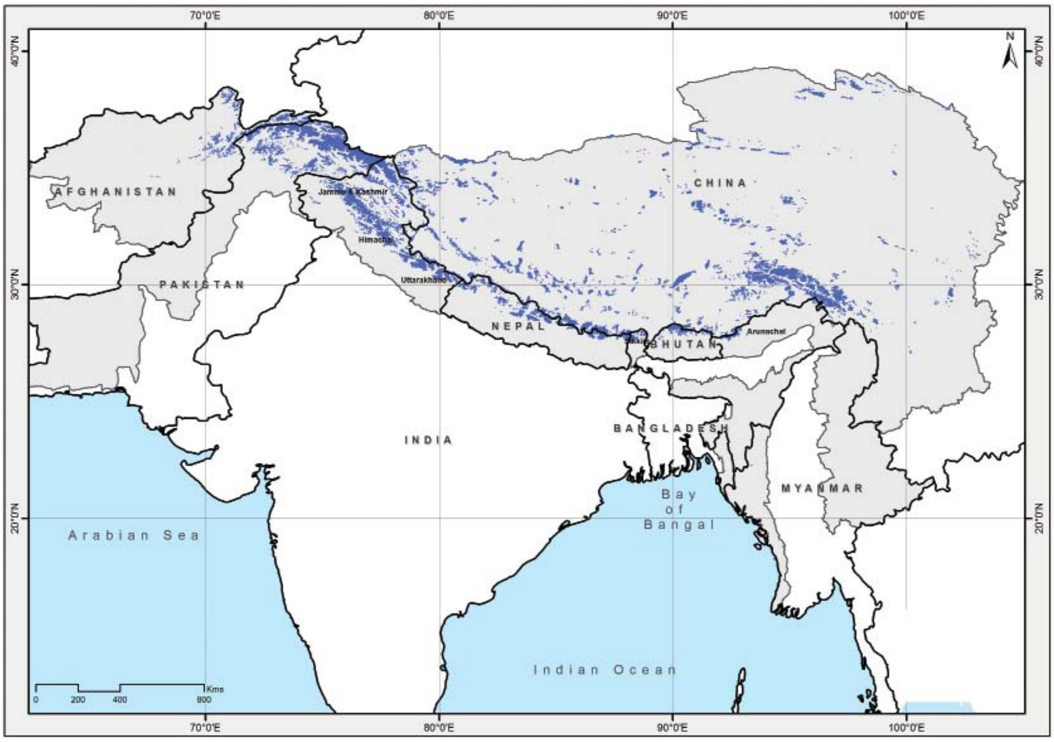


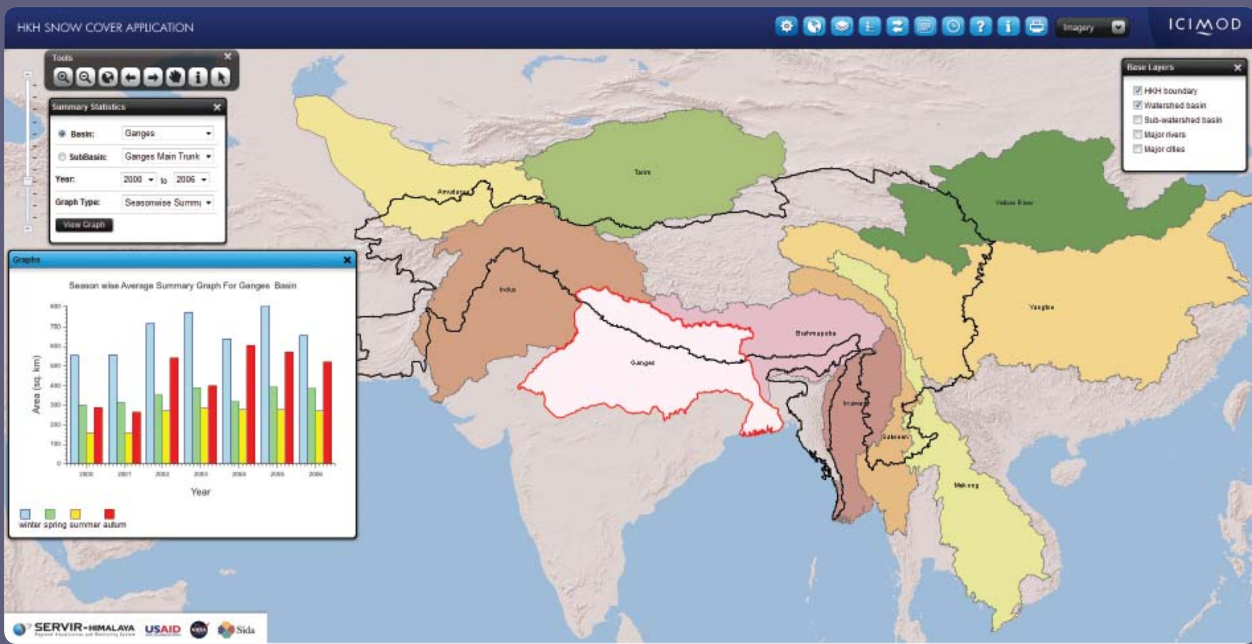
Table 3: **The status of glaciers in Hindu Kush-Himalayan region**

River basin	Number of glaciers	Glacier area (km^2)	Ice reserves (km^3)	Average glacier area (km^2)
Amu Darya	3,277	2,566	162.6	0.8
Indus	18,495	21,193	2696.1	1.2
Ganges	7,963	9,012	793.5	1.1
Brahmaputra	11,497	14,020	1,302.6	1.2
Irrawaddy	133	35	1.3	0.3
Salween	2,113	1,352	87.7	0.6
Mekong	482	235	10.7	0.5
Yangtze	1,661	1,660	121.4	1.0
Yellow	189	137	9.2	0.7
Tarim	1,091	2,310	378.6	2.1
Interior	7,351	7,535	563.1	1.0
HKH total	54,252	60,054	6,126.9	1.1

Cryosphere knowledge hub

The vast amount of data and information collected and the related analyses are disseminated through ICIMOD's Mountain Geoportal (Figure 4). The portal provides essential and unique climate information services on snow and glaciers, as well as information on glacial lakes. The data are accessible to everyone and follow international standards. As a regional knowledge centre, ICIMOD plans to further build this information base on a regular basis by fostering regional cooperation and promoting the sharing and exchange of data and information at the international level.

Figure 4: **Snow cover data in ICIMOD's Mountain Geoportal (www.icimod.org/cryosphere)**



Conclusion

The Himalayan cryosphere, known as the 'water tower of Asia', is under severe threat from global warming, with far-reaching environmental and socioeconomic implications for the region. Understanding of the interplay between climate, the cryosphere, and water availability is at an early stage. Lack of consistent data and information remains a huge challenge in many studies and projects. ICIMOD, together with its regional and international partners, has made a significant leap forward in collecting the necessary baseline information to understand the dynamics of the cryosphere. The information generated will reduce scientific uncertainty and support the formulation of sound policies and programmes at the national and regional levels.

Future work will focus on mapping snow cover and generating glacier inventories at different time intervals. These inventories will make it possible to map changes in glacier areas, to provide continuously updated information on glaciers, and to quantify permafrost areas using climate data and land surface temperature from remote sensing. The final objective is to include all components of the cryosphere.

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Mapping Carbon Stocks in Community Forests of Nepal Using High Spatial Resolution Satellite Images

Yousif Ali Hussin, Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, the Netherlands, hussin@itc.nl
Hammad Gilani, Remote Sensing Analyst, ICIMOD, hgilani@icimod.org

Increases in the concentration of CO_2 and other greenhouse gases in the atmosphere have raised concerns about global warming and climate change. The Intergovernmental Panel on Climate Change (IPCC) reported that the amount of CO_2 in the atmosphere is increasing by 1.4 parts per million (ppm) per year (IPCC 2007). This increase is closely related to human activity. Over the past two decades, most of the anthropogenic emissions of CO_2 into the atmosphere have been from the burning of fossil fuel. An important way of combating global warming is to reduce carbon emissions from deforestation and forest degradation in developing countries. According to Hunt (2009), 1 tonne of carbon stored in trees is the result of the removal of 3.67 tonnes of carbon dioxide from the atmosphere. Thus, the world's forest 'sinks' hold more carbon than the atmosphere. Recognising the importance of forests as carbon sinks, in 2007 the United Nations Framework Convention on Climate Change (UNFCCC) introduced the new mechanism of Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD).

Field measurement of carbon stock

With forests occupying 40 per cent of its territory, Nepal is an important target for REDD projects. In Nepal, deforestation, forest degradation, and forest fragmentation are affecting forest resource based livelihoods. Following serious deforestation in the 1970s, community forestry was introduced for managing Nepal's forest resources. Over 25 per cent of forests in Nepal are now managed by local Community Forest User Groups (CFUGs).

REDD in Nepal

Nepal was one of the first 14 countries selected by the World Bank for assistance under the Forest Carbon Partnership Facility (FCPF), which helps developing countries address global climate issues under the REDD principles. The Government of Nepal has established a three-tiered institutional mechanism for implementing REDD, consisting of the REDD Multi-sectoral, Multi-stakeholder Coordinating and Monitoring Committee as the apex body, the REDD Working Group at the operational level, and the REDD-Forestry and Climate Change Cell as the coordinating entity. All three bodies have been working together to prepare the REDD National Strategy and implementation plan. The REDD Cell, under the Ministry of Forests and Soil Conservation, is implementing REDD readiness activities in Nepal.

Nepal's REDD strategy is that by 2013 and beyond, greenhouse gas emissions resulting from deforestation and forest degradation will be significantly reduced by forest conservation and enhancement, by addressing the livelihood concerns of poor and socially marginalized forest dependent people, and by establishing effective policy, regulatory, and institutional structures for sustainable development of Nepal's forests under the forthcoming new constitutional framework. One of the key pillars of the strategy is to address poverty and enhance the livelihoods of people who depend on forest resources. The strategy also aims to establish a clear link between carbon ownership rights and land tenure, making it a priority to clarify issues of rights to forests during preparation for REDD.

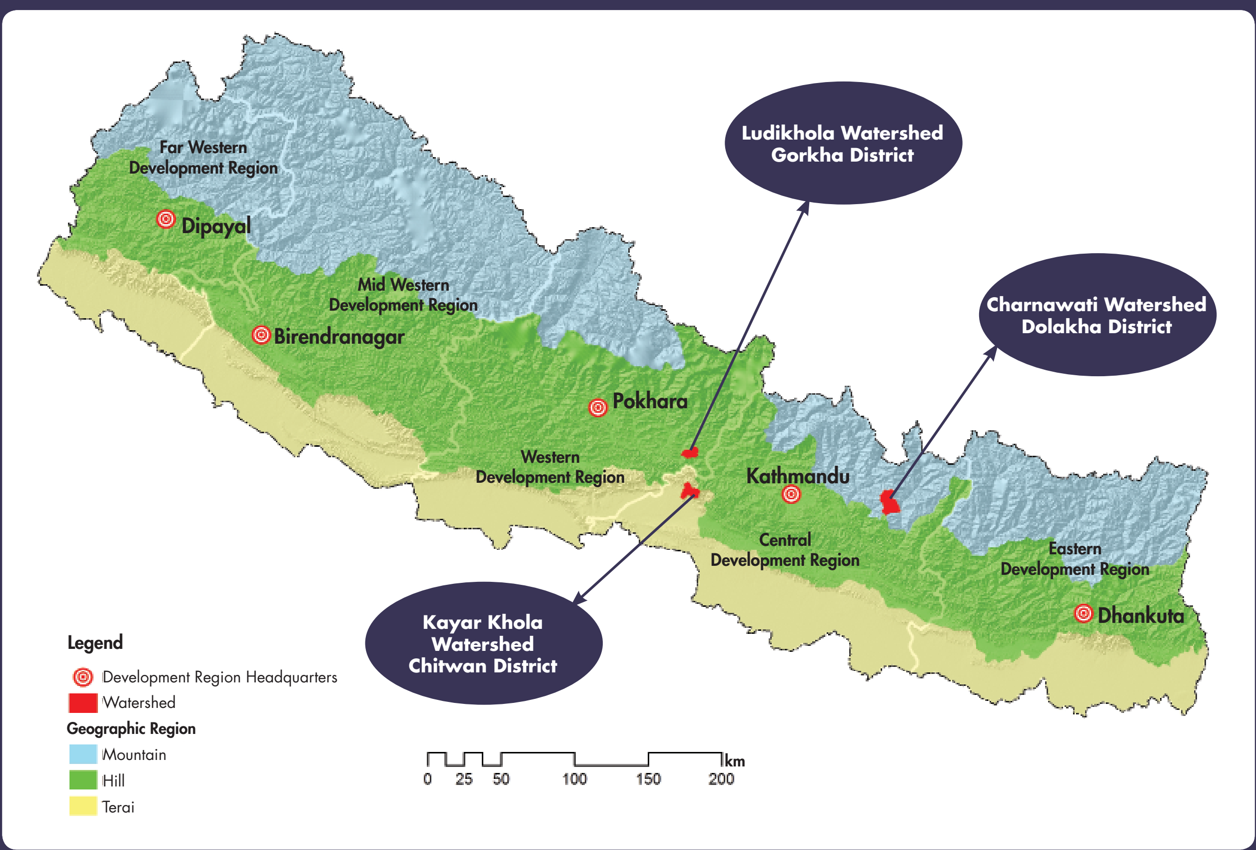
Community mapping of carbon stocks

To support Nepal's REDD activities, ICIMOD, in collaboration with the Federation of Community Forestry User's, Nepal (FECOFUN) and the Asia Network for Sustainable Agriculture and Bioresources (ANSAB), is implementing a project to assist in the design and setting up of a governance and payment system for Nepal's community forest management under REDD. Financed by the Norwegian Agency for Development Cooperation (Norad) under the Climate and Forest Initiative, the project covers over 10,000 ha of community-managed forests in three watersheds (Figure 1) and has an outreach to over 16,000 households with over 89,000 forest-dependent people. It is one of the world's first carbon offset projects involving local communities in monitoring the carbon in their forests and providing the necessary training for them to do so.

Above-ground biomass (AGB) estimation is a key way of quantifying carbon stocks in forests. The carbon stored in the above-ground living biomass of trees is the largest pool of carbon in the world and the most directly affected by deforestation and forest degradation. Accordingly, the estimation of AGB with sufficient accuracy to analyse the amount of carbon stored in a forest is important for emerging mechanisms such as REDD.

The most accurate method for estimating biomass is by cutting the trees and weighing their parts, which is time consuming and expensive for large areas. Instead of this destructive method, the project adopted the use of an allometric equation based on diameter at breast height (DBH), which has proven reasonably accurate and is

Figure 1: **The three watersheds covered under the REDD project**



one of the easiest and least expensive approaches. CFUG members were trained to make the measurements and collect the relevant data.

Verification by remote sensing

At the same time, the project sought to develop a methodology to verify the carbon stock measurements using remote sensing. The advantage of using remote sensing data is that the spatial distribution of forest biomass can be obtained at a reasonable cost and with acceptable accuracy. ICIMOD, together with a group of researchers from the Faculty of Geo-Information Science and Earth Observation (ITC) at the University of Twente in the Netherlands, used high resolution satellite imagery (GeoEye-1 & WorldView-2) together with object based image analysis (OBIA) techniques to delineate and classify crown projection area (CPA) of individual trees for improved AGB estimation (Figure 2). The relationship between stem DBH and the CPA of a tree allows the calculation of AGB using high-resolution optical imagery in which each tree is identifiable.

Three kinds of segmentations (multi-resolution segmentation, region growing segmentation, and valley following segmentation) were performed in three watersheds to assess overall as well as individual accuracies. Nearest neighbour and fuzzy rule classification were applied for tree species classification.

The fieldwork was conducted in the three watersheds by eight Master of Science students from ITC, who produced theses based on the fieldwork (see Box above). The fieldwork was organised and financially supported by ICIMOD.

Overall, 80 per cent accuracy was achieved. Carbon stock maps were produced as the final output (Figure 3).

Topics of Masters Theses Resulting from the Joint Work between the University of Twente (Netherlands) and ICIMOD

- Mapping carbon stock using high-resolution satellite images in sub-tropical forest of Nepal
- Comparison of individual tree crown delineation method for carbon stock estimation using very high-resolution satellite images
- Modeling the relationship between tree canopy projection area and above-ground carbon stock using high-resolution Geo-eye satellite images
- Carbon stock estimation using very high-resolution satellite imagery and individual crown segmentation: A case study of broadleaved and needle leaved forest of Dolakha
- Object based image analysis of Geo-eye VHR data to model above-ground carbon stock in Himalayan mid-hill forests, Nepal
- Assessment of REDD and its effect on the livelihood of local people at CFUGs: A case study of Gorkha, Nepal
- Modeling forest fire behavior and carbon emission in the Ludikhola watershed, Gorkha district, Nepal
- Development of a spatial, dynamic, fuzzy fire risk model for Chitwan district, Nepal

Figure 2: **Crown projection area**

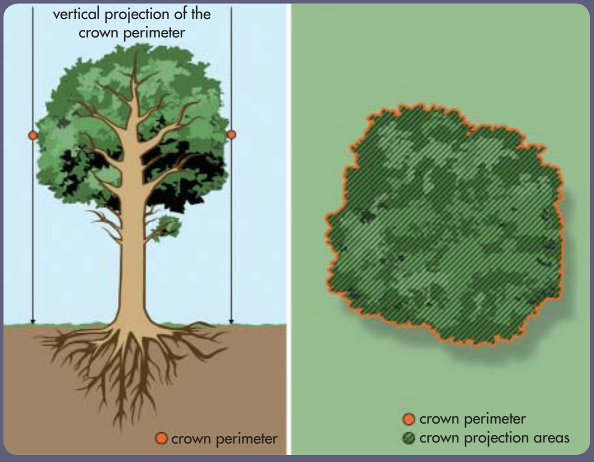
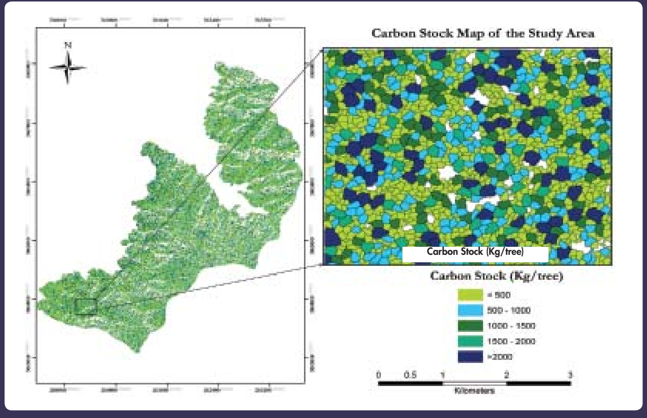


Figure 3: **Map of carbon stock in Chitwan area**



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Space Science for Himalayan Ecosystem Development in India

PS Roy, Director, Indian Institute of Remote Sensing, Indian Space Research Organization (ISRO), Dehradun, India, psr@iirs.gov.in; psroy13@gmail.com
V Jayaraman, Satish Dhawan Professor, ISRO, and Senior Advisor (Space Applications), vjay202@gmail.com

Sustainable development of mountain ecosystems is a challenge in the context of rapid global change. Increased water discharge from melting glaciers associated with increased precipitation, deforestation, grazing, and human disturbances has resulted in increased erosion in the world's mountain regions, including the Hindu Kush-Himalayan (HKH) region. Deforestation, combined with the region's geotectonic composition and precipitation, has resulted in an increased incidence of landslides in most of the Himalayan mountain ranges. As a result, huge amounts of surface soil have been washed into the region's streams and rivers.

In addition, traditional land use is changing quickly in the HKH, influenced by globalisation. Land use intensification is a severe threat to the mountain environment. The Himalayan mountains are particularly susceptible to climate change impacts, which are often coupled with anthropogenic changes to mountain landscapes associated with population changes and economic activities. The region's political and economic marginalisation creates added vulnerability because of the reduced capacity to adapt to such changes. Changes in the bioclimatic envelope will lead to changes in land use regimes and hydrological cycles. Changes in land use and land cover regimes will also affect the tourism industry, which will change the human footprint in the mountains.

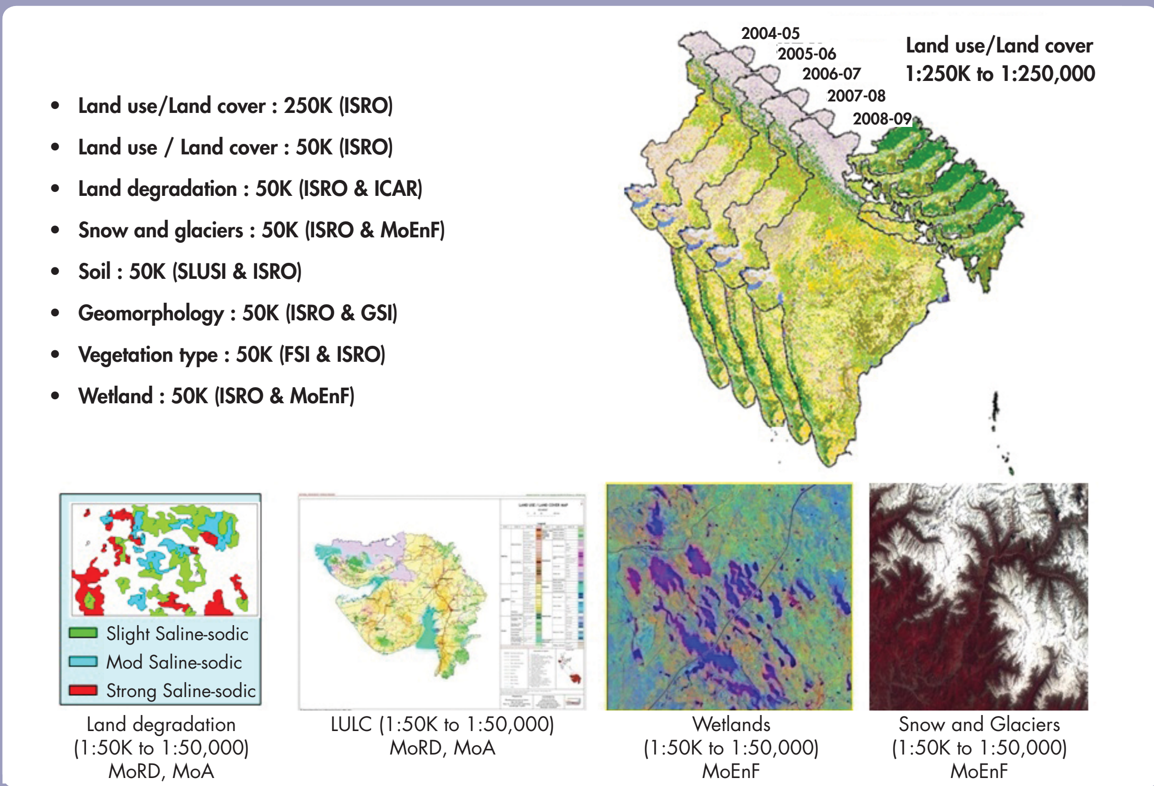
With a vast population dependent on mountain resources for their livelihood, regular monitoring of the landscape is required for proper planning and execution of sustainable development initiatives in the face of a mounting resource crunch. Considering the heterogeneity and spatial variability in mountain ecosystems, space-based satellite remote sensing, with its synoptic and temporal viewing potential, can provide reliable information for planning and decision making.

Space science for sustainable mountain development in India

Remote sensing and geographic information systems (GIS) play an important role in providing spatially explicit information on land, the atmosphere, and the environment. As part of India's national Natural Resources Census, the Indian Space Research Organization (ISRO), in collaboration with other organisations, is generating seven spatial databases on different natural resource themes using space-based inputs (Figure 1). These spatial databases are on land use and land cover at 1:250 and 1:50,000; land degradation; snow and glaciers; soils; geomorphology; vegetation type (Figure 2); and wetlands. The spatial data can be modelled in a GIS environment to predict probable land use and land cover change (Figure 3) (Roy and Roy 2010).

Remote sensing also provides spatial data on aerosol distribution and movement, which can be used to predict the movement of pollutants and their deposition. Integrating satellite remote sensing-based spatial data with global circulation models will help in modelling the nutrient loading on ecosystems. The global coverage of the various space-based platforms permits the availability of temporal data, for example on sea surface temperature changes and climatic processes such as El Niño, that are useful in modelling the impact of

Figure 1: **India's national Natural Resources Census database using space-based inputs**



FSI: Forest Survey of India; GSI: Geological Survey of India; ICAR: Indian Council of Agricultural Research; ISRO: Indian Space Research Organization; LULC: land use and land cover; MoA: Ministry of Agriculture; MoEnF: Ministry of Environment and Forest; MoRD: Ministry of Rural Development; SLUSI: Soil and Land Use Survey of India;

Figure 2: **Vegetation type and land use map of the Indian Himalayas**

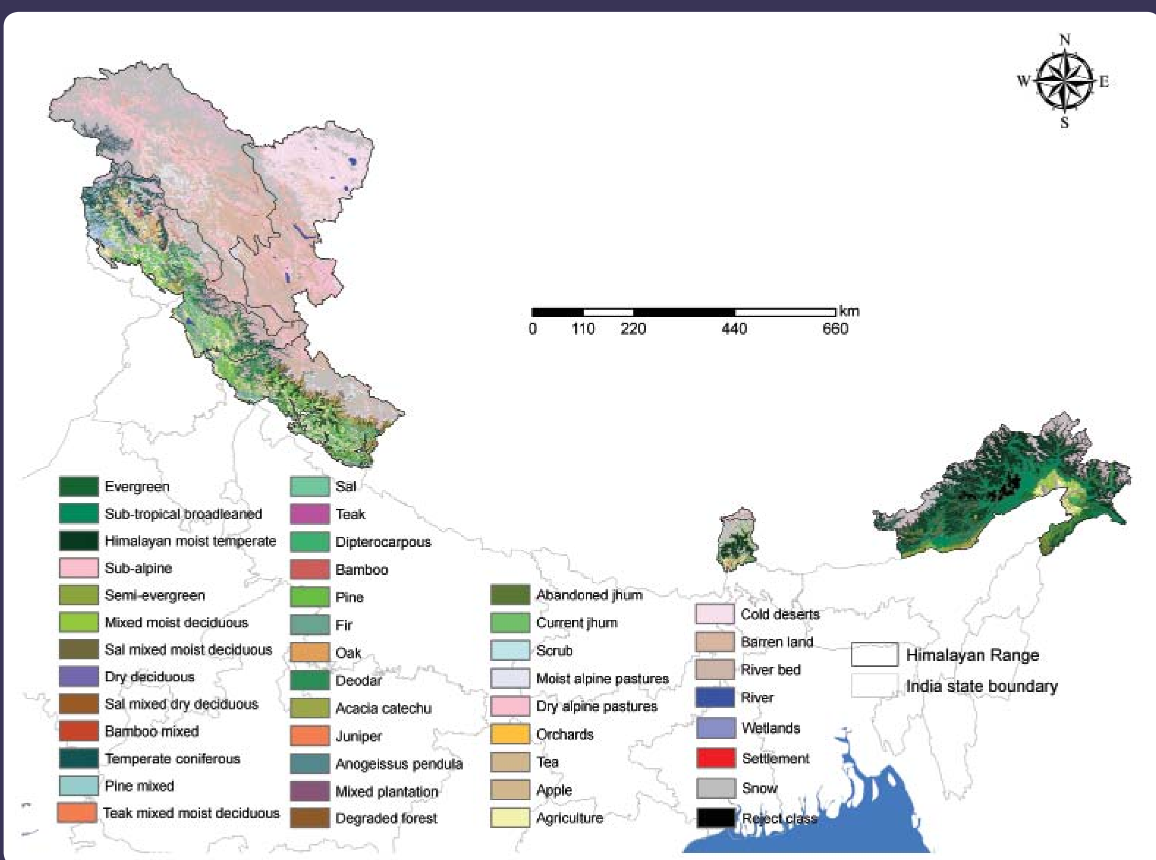
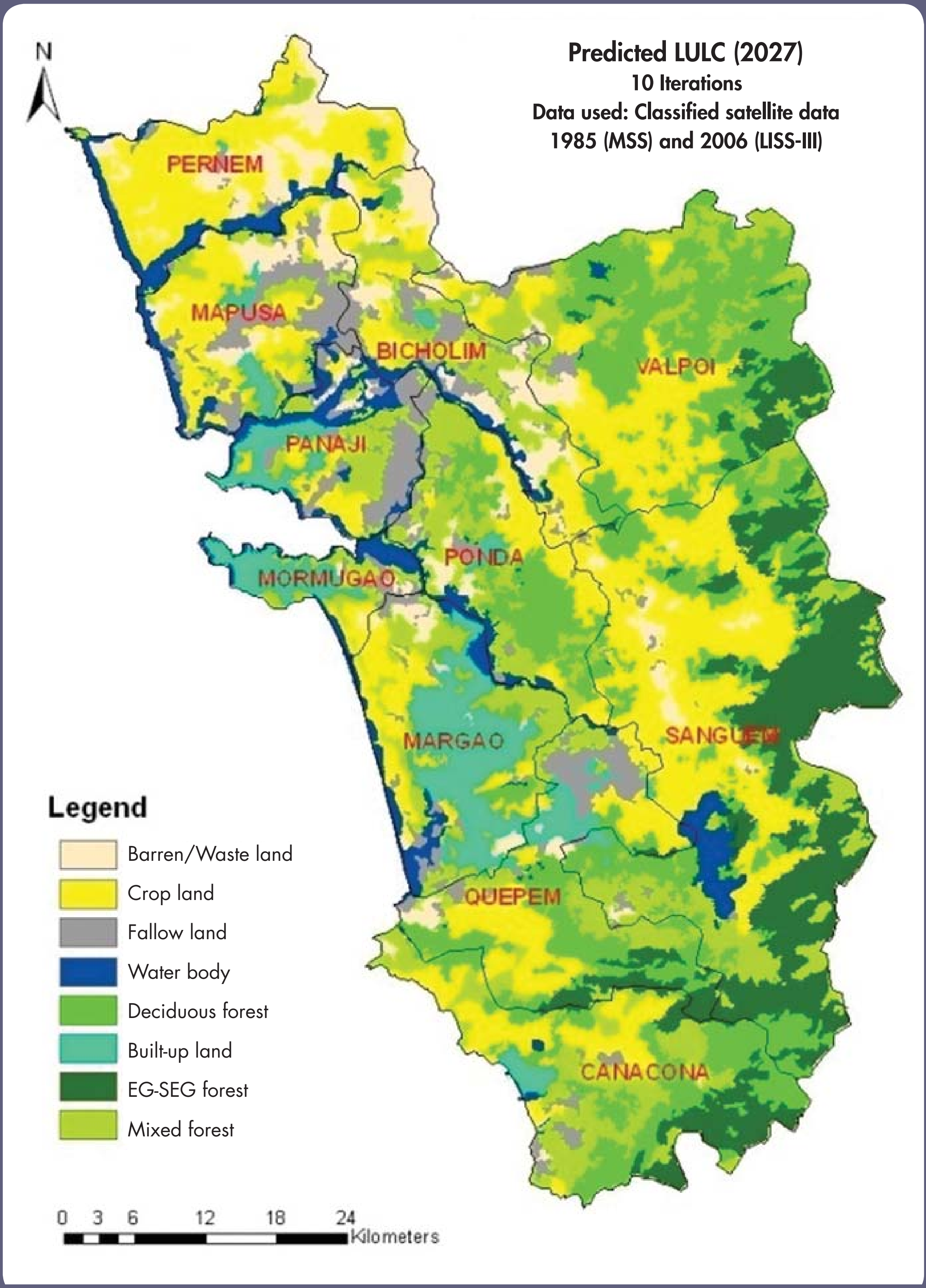


Figure 3: **Modelled land use and land cover map of Goa, India for the year 2027 using agent-based modelling**



Source: Roy and Roy (2010)

ISRO projects using Earth observation systems to support the sustainable development of mountain ecosystems

Project	Sensors used	Contribution
Ongoing		
Landslide hazard zonation	Microwave, LISS III, Cartosat	Identification of potential areas for landslide occurrence
Hydrological modelling	Cartosat, LISS III, LISS I, MSS	Estimates of the total hydrological cycle of a watershed and carrying capacity of a region; input for LULCC
Glacier retreat	Microwave, LISS III, LISS I, MSS	Estimates of dwindling fresh water resources for their sustainable use
NAPCC (Sustaining Himalayan Ecosystem)	SRTM-DEM, ASTER-DEM, LISS III	Decision support tools and information for sustaining the fragile Himalayan ecosystem, targeting food, water, and energy security
Biodiversity characterisation at landscape level	LISS III	Identification of India's biologically rich areas for conservation
Impact of global change on species and habitat transition	LISS III, LISS I, MSS	Generation of probable scenario of species and habitat transition due to global change
LULC dynamics and impact of human dimensions in the river basins	LISS III, LISS I, MSS	Generation of LULC scenario for 2025 and 2050 considering anthropogenic pressures on the major river basins of India
Yearly LULC assessment (1:250,000) as part of Natural Resources Census	AWiFS	Information on annual cropping patterns of rabi, kharif, and zaid along with land cover such as snow
Carbon pool assessment	LISS III,	Identification of potential carbon pool in above-ground and below-ground biomass and soil
Future		
Use of CartoDEM tmodelling probable hydro-electric power generation sites	Cartosat I & II	Identification of the size and scope of hydropower generation capacity in the region for clean energy
Ecological impact assessment of hydro-electric power projects	Cartosat I & II, LISS IV	Estimation of the social and ecological impact of creating major hydro-electric projects
Impact of climate change on tree line shifts	Cartosat, LISS III, LISS I, MSS	Identification of changes in the tree line and in flowering and fruiting of high-altitude flora as a result of climate change
Assisted vegetation regeneration in landslide affected areas	Microwave, LISS IV, Cartosat	Identification of landslide regions to target for vegetation re-growth through assisted regeneration, to prevent further erosion
Early warning system for glacial lake outburst flood	Microwave, LISS IV, Cartosat - DEM, 24x7 videography	Protection of life and property downstream from glacial lakes

Notes: LISS: Linear Imaging Self Scanner; MSS: Multispectral Scanner; NAPCC: National Action Plan for Climate Change; LULC: land use and land cover; LULCC: land use and land cover change

climate change in the spatial domain. With the development of new technologies in light detection and ranging (LIDAR), hyperspectral, and microwave-based sensors, the spatial characterisation of the various facets of climate change and its impacts will become easier, enabling appropriate steps in mitigation.

Geospatial technology has revolutionised the modelling of hydrological runoff from watersheds, and space-based inputs play an important role in this process, mainly in the form of data on temporal land use and land cover. It has been well documented that land use and land cover alteration coupled with climate change can result in substantial changes in hydrological and watershed processes (Bosch and Hewlett 1982; Foley et al. 2004; Gao et al. 2010). It is of utmost importance that probable changes in hydrological regimes as a result of various development activities in mountainous regions be modelled, as these changes could have adverse impact on the livelihoods of more than 3 billion people. The Table shows many examples of how ISRO is using Earth observation systems to promote the sustainable development of the Indian mountain ecosystems.

Outlook

Satellite remote sensing, GIS, satellite positioning systems, and many other technological advances such as broadband connectivity, networking, and enhanced computing capabilities should pave the way for new products and services that can be used in addressing the specific issues facing mountain ecosystems. The Natural Resources Census has done a tremendous amount of work in generating natural resource databases for India using space-based remote sensing inputs. These databases can help in quick estimation of the regions affected by change, and in some cases can help identify probable regions of change.

Countries in the HKH region have started working on their own national adaptation programmes of action to address climate change. The Government of India, for example, has included 'Sustaining Himalayan Ecosystem' as one of the eight missions in its National Action Plan for Climate Change (NAPCC), launched in 2009. In this regard, there is much discussion, including in the Global Earth Observation System of Systems (GEOSS), as to how to integrate satellite-based Earth observation systems and in situ observations to capture essential climate variables in a more quantifiable manner and capture the benefits in climate change adaptation and disaster risk reduction strategies.

Space-based inputs, with their unbiased and synoptic coverage of spatial variability, coupled with their ability to generate a temporal database, provide an indication of the intensity, rate, and extent of the changes taking place in the landscape. With GIS and modelling capabilities, the ability to predict the probable impact of climate change on mountain landscapes greatly increases. Space-based technology is thus an important tool for planning and implementing strategies to address food, water, and energy security in the HKH region (Figure 4).

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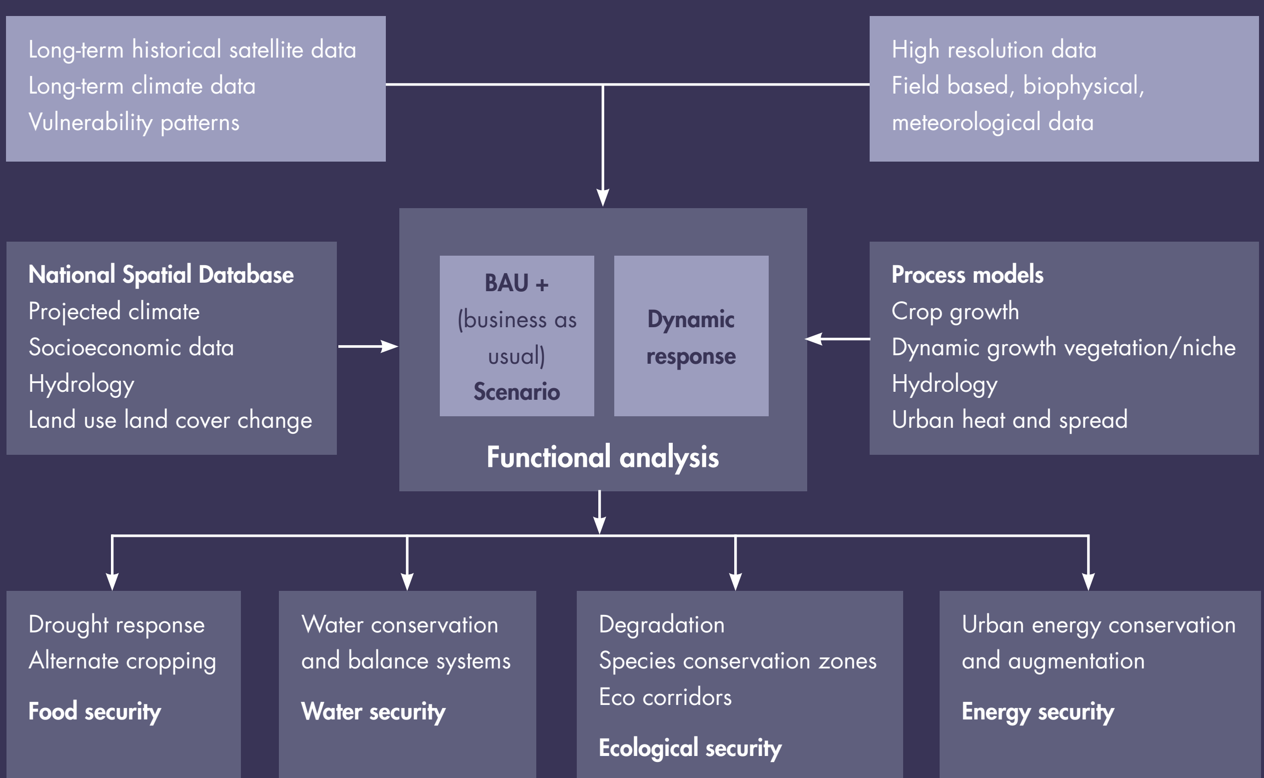
Figure 4: **Space-based inputs to support sustainable development of mountain ecosystems**



Sentinel Asia and ICIMOD

Space-based disaster management support

Kazuya Kaku, Advisor to the Director, Japan Aerospace Exploration Agency, Japan, kaku.kazuya@jaxa.jp
Masaru Arakida, Senior Researcher, Asian Disaster Reduction Center, Japan, ma-arakida@adrc.asia, arakida@adrc.or.jp

Asia has been seriously affected by natural disasters over the last 35 years, the effects of which are exacerbated by its high population levels. The region has sustained 61 per cent of global fatalities associated with such disasters (ADRC 2011).

The Asia-Pacific Regional Space Agency Forum (APRSAF) initiated the Sentinel Asia programme in 2005 to to showcase the value and impact of Earth observation technologies, combined with near real-time Internet dissemination methods and WebGIS mapping tools, for disaster management support in the Asia-Pacific region (Figure 1).

Sentinel Asia aims to improve safety in society through information and communication technology (ICT) as well as space technology, to boost the speed and accuracy of disaster preparedness and early warnings and to minimise the number of victims and socioeconomic losses.

Sentinel Asia is involved in ongoing collaboration with the international community and the Asian Disaster Reduction Center (ADRC). Technical support is provided by the Japan Aerospace Exploration Agency (JAXA). Sentinel Asia receives data from a number of satellites of Asian countries such as India, Japan, Korea, Taiwan, and Thailand. The activities of Sentinel Asia include

Figure 1: **Sentinel Asia website (http://sentinel.tksc.jaxa.jp)**

emergency observation in the case of major disasters such as wildfires, floods, and earthquakes. Sentinel Asia also undertakes capacity building in the use of satellite imagery for disaster management.

International Charter on Space and Major Disasters

The International Charter on Space and Major Disasters is a system for making space satellite data available quickly and free of charge in the event of major disasters. Sentinel Asia and the International Charter for Space and Major Disasters began collaborating in 2009. In the event of a Sentinel Asia emergency observation, the charter can facilitate access to additional satellite resources in disaster-affected areas.

Pakistan flooding, 2010

Activities of Sentinel Asia and ICIMOD in the Hindu Kush-Himalayas

The Hindu Kush-Himalayan (HKH) region is one of the world's disaster hotspots. ICIMOD collaborates with Sentinel Asia as a member of the data analysis node to support space-based disaster management in the Himalayan region. Sentinel Asia provides emergency observation for major disasters in the region such as floods and forest fires. Some of the emergencies observed include the Koshi flooding in Nepal in 2008, flooding in Bhutan in July 2010, and the Pakistan floods in July 2010. In addition, flood and wildfire monitoring products are being developed for the region.

Establishment of WINDS receiving station at ICIMOD

ICIMOD inaugurated a receiving station for JAXA WINDS (Wide-band Interworking Engineering Test and Demonstration Satellites) at its headquarters in Kathmandu in October 2010. WINDS is a super high-speed Internet satellite for emergency response. Its purpose is to ensure steady communication during sudden disasters and to improve communication services in underserved areas. WINDS has the capability to provide quick access to satellite imagery from the Sentinel Asia data providers.

Pakistan floods

Starting in July 2010, the Khyber Pakhtunkhwa province of Pakistan was hit by massive flooding due to monsoon rains. Floodwaters moved south through the Punjab and Sindh provinces, mainly down the Indus River valley. Officials described the flooding in northwestern Pakistan as the worst since 1929. ICIMOD conducted rapid response mapping for the flood-affected areas in the three provinces with the support of Sentinel Asia's partners. The floods were observed and analysed using ALOS, IRS, and FORMOSAT-2 satellite imagery.

Capacity building

To build the capacity of national partners involved in disaster management, ICIMOD and JAXA jointly organised a regional training workshop for ICIMOD's member countries in the first quarter of 2011. The workshop focused on the use of the Sentinel Asia system and on visualising and interpreting satellite data obtained through Sentinel Asia during emergency situations.

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Improving Knowledge of Cropping Systems to Support Food Security

A case study from Nepal

Faisal Mueen Qamer, GIS/Remote Sensing Expert, ICIMOD, Nepal, fqamer@icimod.org
Wataru Takeuchi, Associate Professor, Institute of Industrial Science, University of Tokyo, Japan, wataru@iis.u-tokyo.ac.jp

Agriculture is the most important livelihood activity in the HKH region, providing a substantial proportion of rural income and employment opportunities for its estimated 210 million inhabitants. Around 80 per cent of the population of the HKH is engaged in various land-based activities (Tang and Tulachan 2003).

Agriculture originally evolved from communities' need to feed themselves in a given environment. Given the lack of alternative sources of income, mountain communities have remained essentially agriculture based, and farming systems are the key determinant of household food security. Mountain people often depend on what they grow on their marginal lands for food.

Estimating agricultural output has not been a research priority in the Himalayan region (Aase et al. 2009). However, the dramatic climatic and environmental changes that are taking place in the Himalayas will change the conditions for food production. Local farming practices in the region have been structured around a traditional weather calendar based on a previously undisturbed climate (Vedwan and Rhoades 2001). Any changes in temperature, rainfall, snowfall, and duration of snowfall accumulation will affect crop phenology and production. Together with associated uncertainties, these changes make the local agricultural system highly vulnerable. We need to understand the relationship between crops and climate in today's changing environment in order to estimate local production and understand the consequent responses and adaptive strategies of local people.

Generally, the more subsistence oriented the farming, the more the system is constrained by its biophysical and socioeconomic environment. Remote sensing data, in combination with other types of data, can reveal valuable information about environmental conditions that may affect farmers' livelihoods. Geographic information system (GIS) and remote sensing technologies can help in identifying regions experiencing unfavourable crop growing conditions and food supply shortfalls, and determine food insecure areas and populations (Minamiguchi 2004).

Major world food crop production has been monitored since the mid-1980s. A number of programmes use satellite observations for agricultural monitoring on a regional to global scale; examples include the crop forecasting system maintained by the United States Department of Agriculture (USDA) Foreign Agricultural Service (FAS), and food security monitoring systems such as the Food and Agriculture Organization of the United Nations (FAO) Food Security Global Information and Early Warning System (GIEWS), the United States Agency for International Development (USAID) Famine Early Warning System (FEWS), and the European Union Global Monitoring of Food Security (GMFS).

Agriculture and food security are emerging as pressing issues in the HKH region. In this context, ICIMOD is using Earth observation for improved knowledge on agriculture production systems in the HKH region, specifically to:

- establish past and recent responses to climate variability and extreme events in agricultural production in selected HKH areas;

- customise spatial methods and tools to model biophysical crop suitability in the region;
- develop spatially referenced socioeconomic data to characterise food security and agricultural production; and
- support the development of a regional and national food security atlas.

Case study: Exploring the variability of agricultural patterns in Nepal using hyper-temporal satellite data

ICIMOD and the Institute of Industrial Science, University of Tokyo, Japan are working together to compile crop parameters and phenological trends and to identify drought conditions in agricultural areas of Nepal. Remote sensing is an effective way of monitoring agricultural fields and provides a synoptic view of the results of field practices, which can then be processed to aid agricultural scientist in making meaningful decisions. Remotely sensed green leaf phenology can be used to distinguish the type of land cover and land use change, and has significant applications for the monitoring of agricultural practices. The vegetation indices produced are used to derive a measure that correlates with surface biophysical properties, which facilitates the analysis of large amounts of satellite data, providing valuable spatial and temporal analyses at large scale (Myneni et al. 1995). The fact that vegetation indices are directly related to plant vigour, density, and growth conditions means that they can be used to detect environmental conditions such as drought in semi-arid regions (Li et al. 2004).

In the current study, phenological patterns of agricultural areas were assessed for all of Nepal by analysing time series anomalies in the vegetation index for the period 2001 to 2010. The selected vegetation index was the Normalized Difference Vegetation Index (NDVI) acquired by the moderate resolution sensor MODIS at 16-day time intervals and 250 m spatial resolution, a standard product coded as MOD13Q1. A total of 230 NDVI 16-day composite images were employed in the analysis.

Phenology studies often use a curve-fitting algorithm to analyse the observed datasets. A curve fit simplifies the parameterisation necessary for the identification of metrics such as the start of dry season minima and the amplitude of maxima (e.g., Bradley et al. 2007; Zhang et al. 2003). This study employed Earth Trends Modeler (ETM), which provides an integrated platform for the exploration and analysis of remote sensing time series. While the smoothing and fitting of NDVI and other series data is supported, ETM implements a Seasonal Trend Analysis (STA) method based on harmonic analysis of time series (HANTS), developed by Roerink et al. (2000), which differs significantly from earlier work.

The temporal variability of NDVI in the irrigated areas of the Terai region of Nepal (Figure 1) and rainfed agricultural areas of the middle hills (Figure 2) are analysed throughout the time series. In the Terai region of Nepal there are two annual growing seasons, rabi (spring) and kharif (autumn); whereas in the middle hill areas where agriculture is rainfed there is a single vegetation cycle. No extreme vegetation anomalies are evident from the NDVI graph, except for the effect of a winter drought in 2008–2009.

Figure 3 reflects the monotonic trend, based on the Mann-Kendall Tau test, in all agricultural areas of Nepal. This test measures the degree to which a trend is increasing or decreasing consistently. In a range of -1 to 1, positive values indicate an increasing trend and negative values a declining trend. Much of the western area of the Terai exhibits an increasing NDVI trend, a significant portion

Figure 1: **NDVI time series chart for the irrigated areas of Sunsari district, Terai region, Nepal**

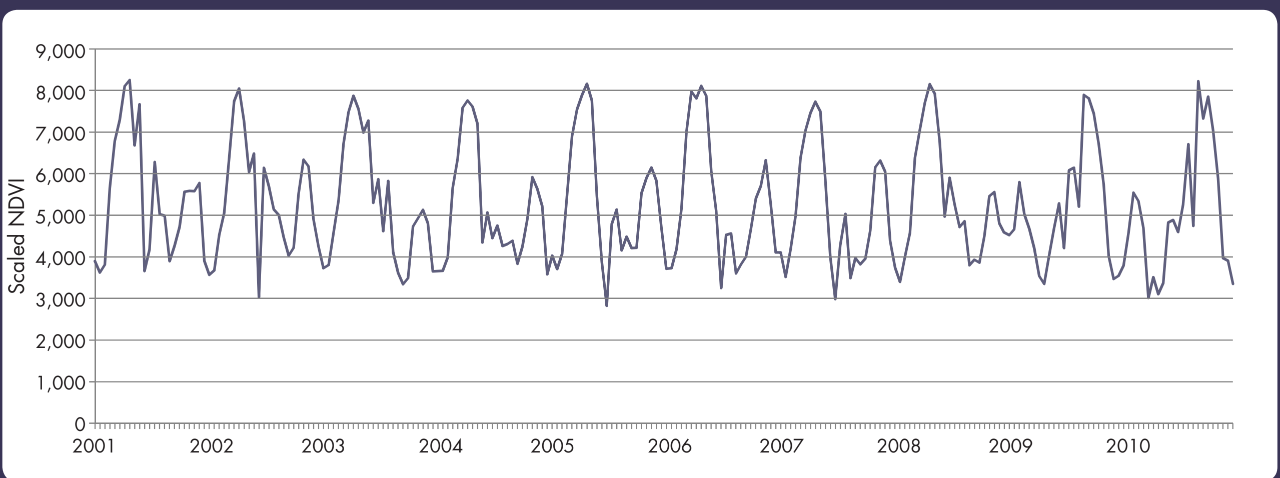


Figure 2: **NDVI time series chart for the rainfed agriculture areas of Kabhre district, middle hills, Nepal**

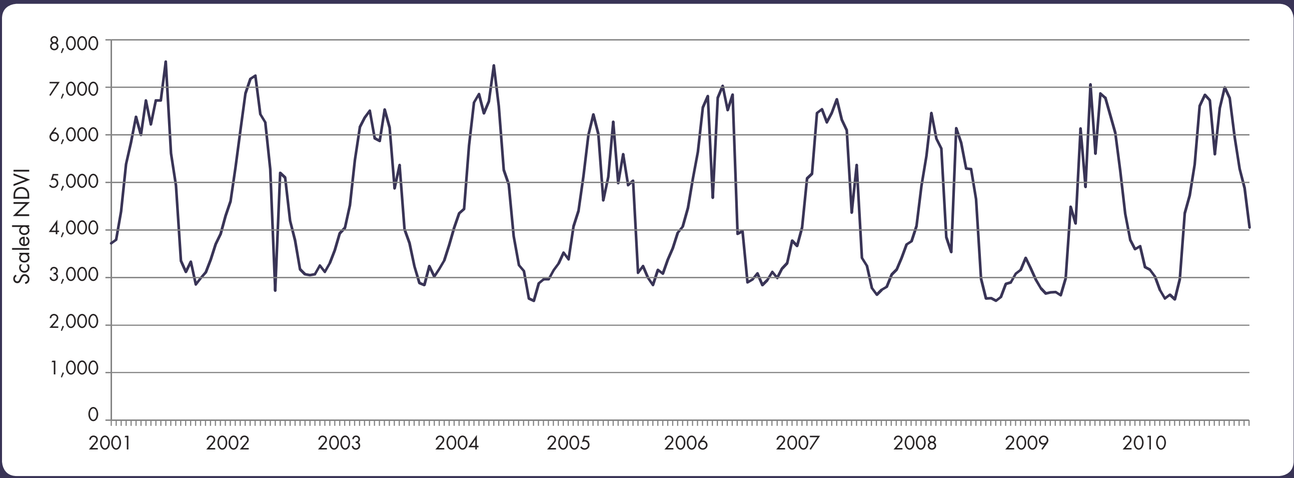


Figure 3: **Mann-Kendall Tau coefficient for trend-adjusted monotonic series of 10 years' NDVI**

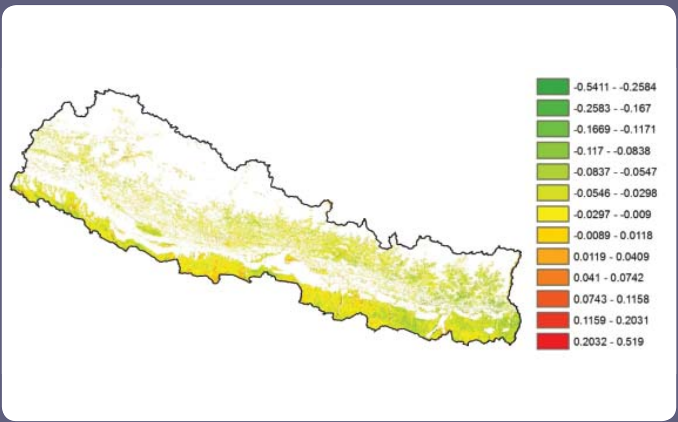
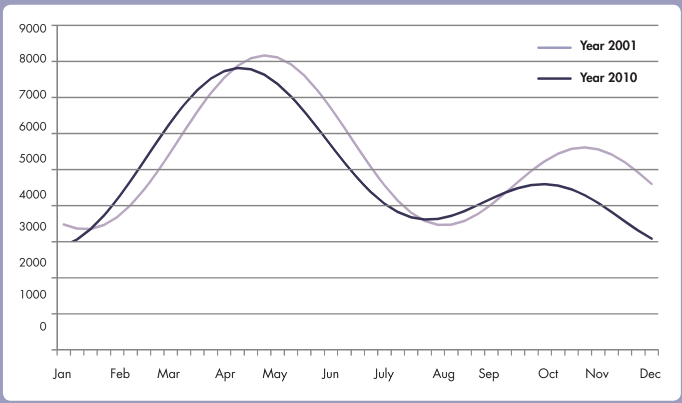


Figure 4: **Fitted seasonal curve in the irrigated areas of the Terai**



shows no change, and the extreme eastern part of the Terai region exhibits a decreasing NDVI trend.

Along with temporal profiles, seasonal trend analysis was performed in representative areas, using two stages of time series analysis to map trends in the shape of the seasonal curve. The results (Figure 4) show that on average spring and autumn both occurred a little earlier in 2010 than in 2001.

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Harmonised Land Cover Understanding natural resources dynamics

Birendra Bajracharya, Senior GIS Specialist, MENRIS, ICIMOD, bbajracharya@icimod.org

Land cover is one of the most important and easily detectable indicators of changes in ecosystems. Land cover links social and physical environments, and changes in land cover can directly impact on biodiversity, and alter ecosystem services and livelihood support systems. Socioeconomic drivers can induce changes in land cover, disrupting the socio-cultural practices and institutions associated with managing natural resources and increasing the vulnerability of people to climate change. Analysis of land cover provides information about landscape patterns and their changes, which is useful in the assessment of human induced drivers and their impacts on the ecosystem. Therefore, land cover assessment and the monitoring of its dynamics are essential to the sustainable management of natural resources, environmental protection, and food security.

Typical land cover types in the mountain landscape

Need for harmonisation

As it has been recognised that information on land cover is a fundamental data layer, many efforts have been made in land cover mapping at global and national levels. Satellite images are the primary data source for both small and large-scale land cover mapping. The availability of satellite images at varying spatial scales and from different sensor types has greatly facilitated these efforts. However, differences in methodology and in the definition of land cover classes have produced land cover maps that are nice to look at, but that generate more ambiguity. Although comparison shows reasonable agreement among the land cover datasets at the global level in terms of total area and general spatial pattern, agreement is limited with regard to the spatial distribution of the individual classes. When we zoom into these global datasets at regional and national scales, the agreement is seen to be significantly decreased in many cases, and the differences in the definition of land cover classes become more prominent.

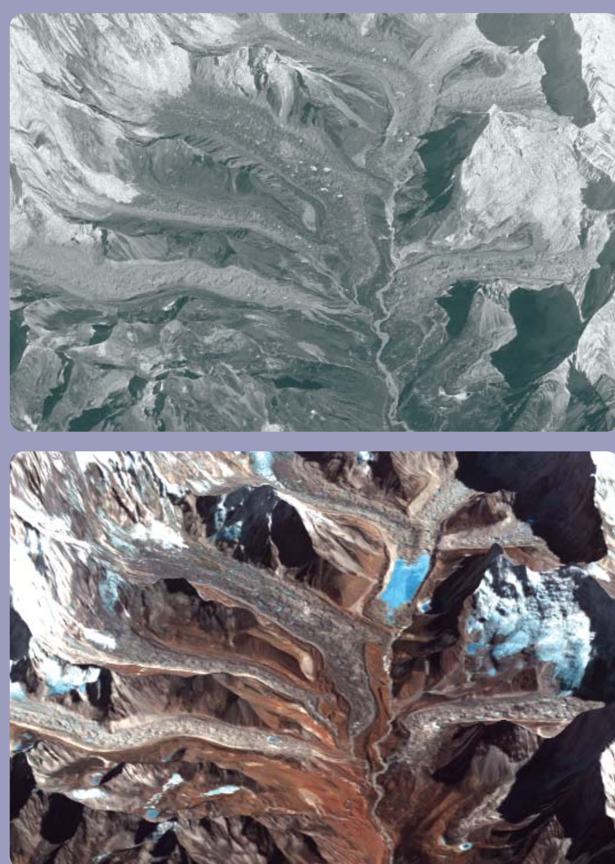
The definition of classes is one of the major issues with land cover databases. A study by the Food and Agriculture Organization of the United Nations/Global Land Cover Network (FAO/GLCN) identified more than 300 definitions of forest worldwide. The land cover classifications vary greatly from one country to another in terms of the definition of classes in addition to differences in spatial disaggregation and resolution. This variability creates challenges in the study of land cover dynamics, as the data available for different time slices are not sufficiently logically and spatially consistent for them to be compared scientifically. The heterogeneity of datasets limits their flexibility and efficiency in serving the multitude of potential applications.

With climate change and the need for homogeneous land cover data across the region for change analysis, the importance of harmonisation has become all the more evident. ICIMOD – which has been preparing land cover maps at national and sub-national (watershed) levels for many years, defining the classes to meet project requirements – collaborated with FAO/GLCN in the Regional Harmonization Programme (RHAP) to build a consensus at the regional level on the development of a harmonised and standardised system of land cover classification. A number of regional and national level workshops were organised involving developers and users of land cover data. Legends were discussed in the national context of each country and then defined using the Land Cover Classification System (LCCS) developed by FAO and the United Nations Development Programme (UNEP). In the LCCS, a land cover class is defined by a set of independent diagnostic attributes or classifiers, and the amount of detail in the description of a land cover feature is linked to the number of classifiers being used. The two-phase design, with the initial dichotomous phase and the modular-hierarchical phase, results in a land cover class defined by a Boolean formula showing each classifier used, a unique number for use in the geographic information systems (GIS), and a name, which can be the standard name as supplied or a user-defined name. The classifiers are categorised as pure land cover classifiers (life form, height, and so forth), environmental attributes (altitude, climate, landform, and so forth), and specific technical attributes (floristic aspect, crop type, and so forth). The process is further facilitated by the LCCS software, which is free and systematically guides users through the steps of defining the legend.

Understanding land cover changes over decades

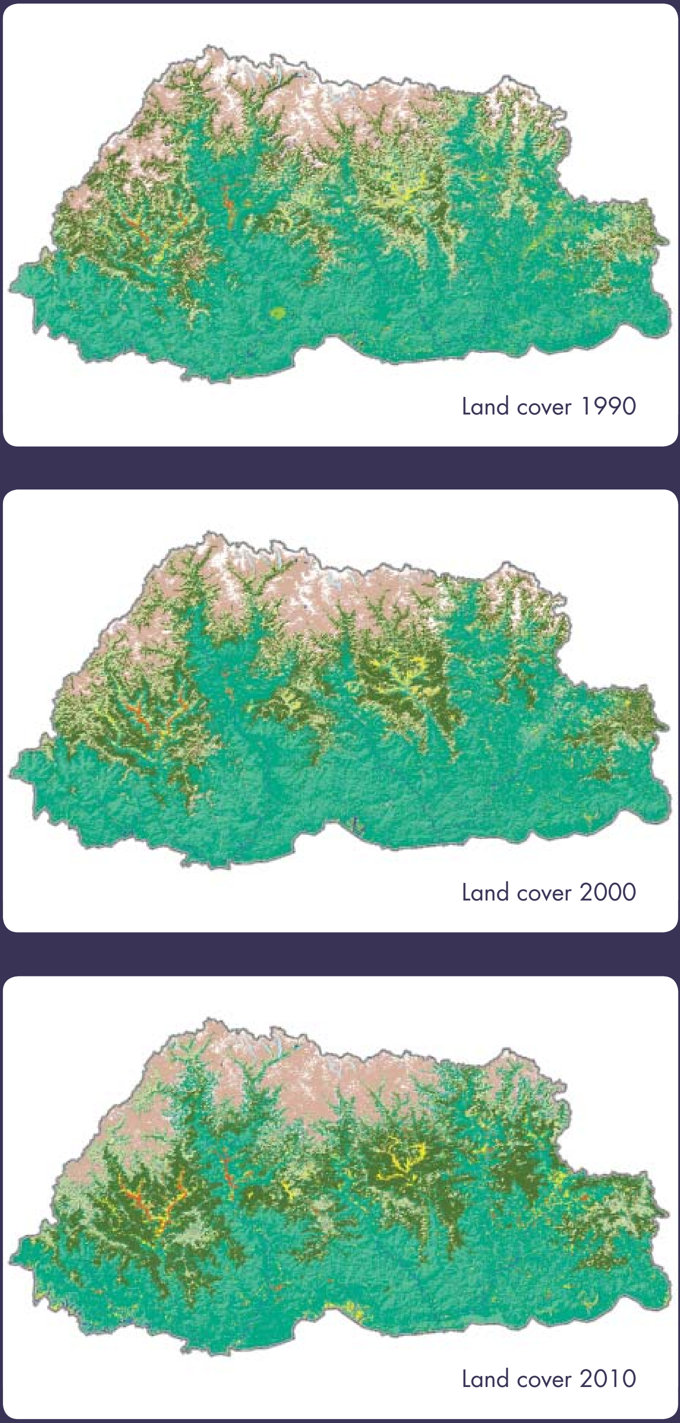
Land cover change study is one of the most common applications of remote sensing. The emerging issues of climate change have made these studies all the more important. It is through the study of historic and recent

Figure 1: **Imja glacier as seen in a Corona image of 15 December 1962 and as ASTER image of 1 February 2006**



satellite data that the retreat of glaciers in the Himalayas was revealed (Figure1). While the changes in the cryosphere show the natural impact of climate change, the changes in vegetation and other land cover at lower altitudes reflect changes because of anthropogenic processes. To understand the overall changes in the Hindu Kush-Himalayas (HKH) over the past decades, ICIMOD initiated the development of land cover data for 1990, 2000, and 2010 using uniform data, legends, and methodology across the countries of the HKH (see Figure 2 for an example). LandSat[TM] images were classified using knowledge classifiers and object based image analysis. Data from previous field studies were used for ground-truthing. Partnerships with national institutions have been a key strategy, and professionals from these institutions with extensive field experience were involved in the classification process. These data will provide spatially explicit insights into the changes that are taking place and help in identifying the key location-specific drivers. Such information will be very useful in investigating socio-cultural and institutional issues and coming up with better policies for climate change adaptation.

Figure 2: **Land cover map of Bhutan at three points in time**



Dissemination of land cover data

The investment in developing time series land cover data is justified by their potential use in a multitude of applications. However, making these data available to a variety of users, from researchers to managers and decision makers at all levels, is vital. ICIMOD has been working under SERVIR-Himalaya, an initiative supported by the United States Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA), to develop web-based tools to provide access to these data in a meaningful and user friendly way. Under this initiative, land cover data for different dates with change maps and statistics in charts and tables will be accessible by district or protected area for intuitive visualisation. Easy access to such information will encourage wider use and the integration of land cover change information into diverse studies related to climate change and adaptations.

Conclusion

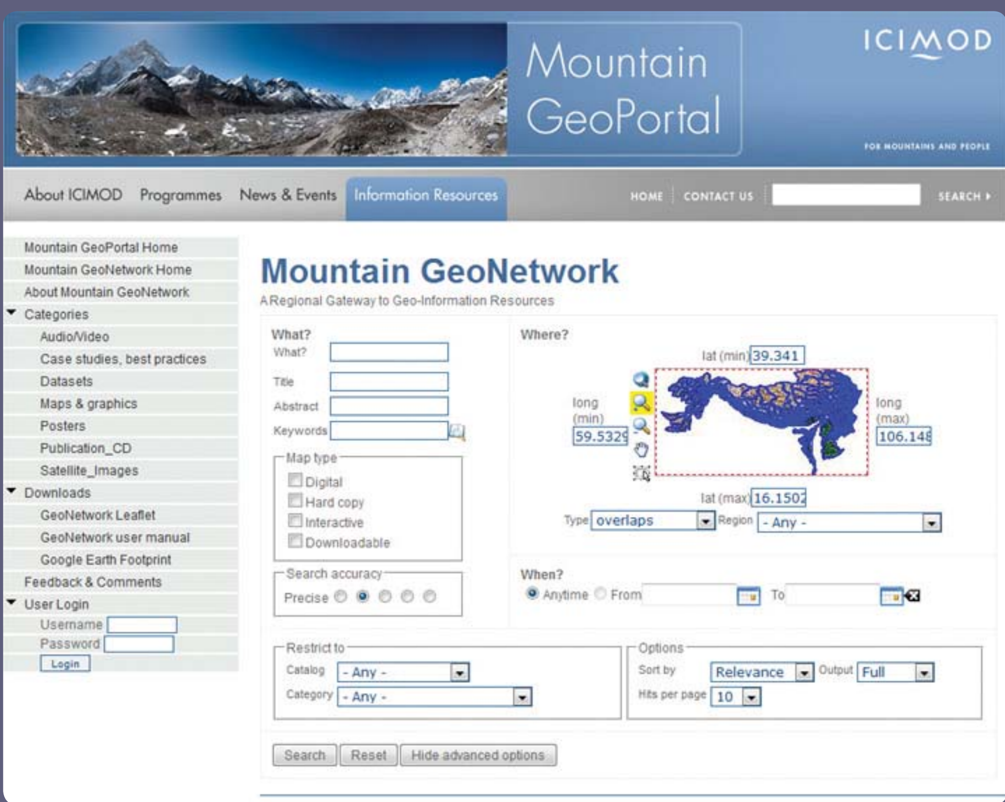
Land use and land cover is evolving as a fundamental source of information for the study of ecosystems. The availability of uniform time series data on land cover over the last two decades will be a great asset for understanding the dynamics and underlying drivers for change. Initiatives for harmonisation and uniform methodology have helped in generating awareness and building consensus among different stakeholders, who will be the ultimate beneficiaries of this information base. A more important step is to make these data easily accessible to all. This will facilitate wide use and provide opportunities to obtain feedback from users for the refinement of the data. These initiatives can be considered as fundamental steps towards creating a better information infrastructure for climate action.

Towards a Regional Geographic Data-Sharing Network in the Himalayas

Zhu Yunqiang, State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhuyq@igsnrr.ac.cn
Rajan Bajracharya, System Analyst, MENRIS, ICIMOD, rbajracharya@icimod.org

Spatial information is assuming greater significance in the fields of climate change, ecosystem assessment, disaster management, and livelihood improvement. However, the availability of such information for mountain regions is limited, because observation networks focused on mountains are few. Even when data are available, access is often difficult because clear data-sharing policies and standards are lacking. Mountain areas need special attention because of their distinct spatial-temporal characteristics and remoteness, and it is often necessary to map information on mountain areas in three dimensions. Furthermore, many issues of mountain development are transboundary in nature. Data and information from different countries need to be harmonised to support integrated analysis for science-based policy and decision making.

Figure 1: **Homepage of the Mountain GeoNetwork (http://geoportal.icimod.org:8080/geonetwork)**



Himalayan Spatial Data Infrastructure (H-SDI)

Spatial data are becoming increasingly important to support policy and decision making in the Hindu Kush-Himalayan (HKH) region. Spatial data infrastructure (SDI) is a framework for organising and managing geographic information, metadata, users, technology, and tools to provide efficient and effective access and use for multiple purposes. SDI is being promoted at the global, regional, and national levels to fill the gaps in data, data standards, and data-sharing protocols to avoid duplication and to facilitate optimal use of spatial information. Himalayan Spatial Data Infrastructure (H-SDI) is an important framework for ICIMOD and its network of partners for data discovery, access, and use. ICIMOD is promoting H-SDI and working with national partners on key components, including the proper definition of data, international standardisation, and appropriate data-sharing mechanisms. These activities have fostered a distributed and decentralised regional data-sharing network. Participation by more partners in ICIMOD's member countries will result in an effective data-sharing network in the region.

Mountain GeoPortal

ICIMOD's Mountain GeoPortal (http://geoportal.icimod.org) is a collaborative effort to build and share geographic resources in the HKH region. The Mountain GeoNetwork (Figure 1) is an open-source metadata management system integrated within the Mountain Geoportal. The Mountain GeoNetwork aims to facilitate the standardisation and sharing of geographic data in the HKH region, forming a virtual community of practice. It is designed so that ownership of data is clearly defined, proprietary rights to databases are protected, and data policy issues are addressed and integrated. The system provides a regional gateway to geo-information resources, contributing to the realisation of one of the key goals of H-SDI.

Earth System Science and the Sharing of Scientific Data in China

Earth system science seeks to integrate various fields of academic study to understand the Earth as a system. It looks at the interaction between the atmosphere, hydrosphere, lithosphere, and biosphere. Therefore, it requires basic datasets for each discipline of earth science, as well as interdisciplinary, multi-scale, and cross-regional datasets. However, in China these data resources are scattered across many different sectors and organisations and are therefore difficult to share to support the study of Earth system science. The consequences include sub-optimal use of data resources and duplicated efforts in the production of data. Therefore, the Ministry of Science and Technology has launched a scientific initiative to share Earth system science data across different organisations.

The Earth system scientific data sharing network has become one of most influential data sharing portals in China (Figure 2). It has one main centre and 14 sub-centres, including five discipline sub-centres, eight regional centres, and one synthesis centre. The network is constructed and operated by the Institute of Geographic Sciences and Natural Resources Research of the Chinese Academy of Sciences, united with more than 40 other institutes and universities. It has been one of nodes of the Mountain GeoNetwork since 2007.

Figure 2: **Homepage of Earth system scientific data sharing network (http://159.226.111.8:8080/geonetwork)**

Way forward

Over the last decade, awareness of SDI has grown considerably in the HKH region. A number of initiatives are already under way to develop national SDIs and other regional data-sharing platforms, such as e-GeoScience to facilitate cooperative research in northeast Asia and the Digital Asia Network initiated by the Japan Aerospace Exploration Agency (JAXA) and Keio University. Several international organisations are promoting scientific data sharing across countries on a regional or global basis, including the World Data Centers (WDC), the World Meteorological Organization (WMO), and the Food and Agriculture Organization of the United Nations (FAO). In the HKH region, ICIMOD's Mountain GeoPortal, as a decentralised network of users and providers of information, is an important step in establishing a regional SDI.

Mountain Biodiversity
Effects of climate change and how to manage them

Eva Spehn, Global Mountain Biodiversity Assessment, Switzerland, gmba@unibas.ch

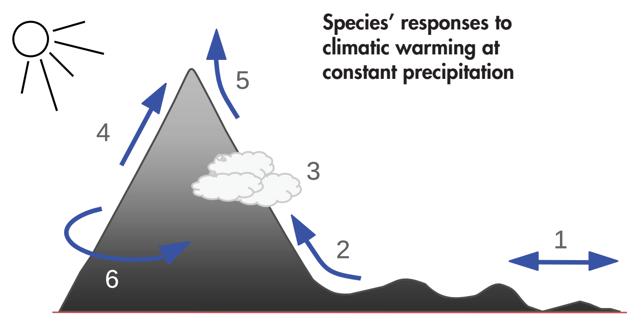
Mountain ecosystems are characterised by steep environmental gradients, including steep gradients of temperature and moisture. They are islands of high-elevation habitats, isolated by the surrounding lowlands. Changes in environmental conditions are especially threatening endemic species that occur in limited areas, such as on mountain peaks. Of these changes, shorter periods of snow cover below the tree line and changes in water availability may be more important drivers of change than temperature change itself. The likely losers from climate warming among plant species in the mountains are late successional species, species with small, restricted populations, and species confined to the summits or the plains; in comparison, ruderal species (weeds), species with large, widespread populations, and mid-slope species are likely to be winners.

Increasing temperatures have caused the early onset of spring activities in plants, such as budburst and flowering. Another widely observed phenomenon is the upward or poleward migration of plant species, which has led to an overall increase in the number of species on mountain summits (see Figure). The migration of species from lower to higher elevations changes species composition and competitive interactions among species, and, in some places, a decrease in cold adapted (subnival and nival) species has been observed. Upward migration in response to anthropogenic climate warming is taking place. Recent studies have demonstrated the upward migration of animal species, such as butterflies and the pine processionary moth, in line with increasing temperatures. As in plant and animal species, huge differences in their reaction to environmental changes have been observed. Interactions among species are also likely to be modified by climate change.

Filling biodiversity data gaps for better decision-making

To improve the forecasting of the effects of climate warming on mountain biodiversity, the quality of predictive models needs to be enhanced. However, available biodiversity data are generally sparse, poorly collected, statistically insufficient, and biased. An alternative is to use the increasingly available geo-referenced species occurrence and natural history databases. The Global Biodiversity Information Facility (GBIF) has catalysed agreements on the standards and protocols required to make datasets compatible and accessible (www.gbif.org). Over 195 million records from over

Schematic presentation of the migration of organisms in response to climatic warming



1 Lowland species lack nearby opportunities to escape from too-warm conditions
2 Foothill species migrate upslope
3 High-elevation species migrate towards summit regions
4 Summit species with no possibility to escape upslope suffer from increasing competition from immigrants from lower elevations
5 Some highland taxa are able to escape short distances by taking advantage of microhabitat diversity in rugged terrain, changing community mosaics at the given elevation

Source: Körner 2009

Rising temperatures are leading to migration of species from lower to higher elevations

8,000 datasets produced by 260 institutions worldwide are now accessible online through the GBIF data portal. Additionally, the Global Mountain Biodiversity Assessment (GMBA) of DIVERSITAS recently launched a thematic mountain portal for GBIF data on mountains (www.mountainbiodiversity.org). This portal allows specific searches of species or taxonomic groups in mountains and their different thermal life belts (e.g., montane, alpine, nival) (Körner et al. 2011), which will help us to understand global mountain biodiversity patterns and inform policy for the protection of mountain biodiversity.

The Hindu Kush-Himalayan (HKH) region is rich in terms of biodiversity resources and ecosystems of global importance. However, available data in the region are sporadic, inaccessible, and not well managed or formatted. Inventory, assessment, and sharing of well-documented biodiversity information from the region is essential to improve the understanding, conservation, and management of these resources. There is an urgent need to fill the geographical and taxonomic data gaps. GMBA recently made a huge plant database of the HKH available at GBIF, the so-called 'Himalayan Upland Plant Database (HUP)' (Dickoré 2011; Nemitz et al. 2012). This database has 164,360 records of approximately 5,562 species collected over 50 years in more than 13 countries (including Afghanistan, Pakistan, Bhutan, China, India, Kazakhstan, Kyrgyzstan, Myanmar, Nepal, Russia, Tajikistan, Turkmenistan, and Uzbekistan).

ICIMOD, in cooperation with GBIF and GMBA, organised a regional workshop and hands-on training at ICIMOD's headquarters in Kathmandu, Nepal in June 2010. The aim of the workshop was to provide a global platform to publish, harvest, and use biodiversity data from the HKH region using international data, metadata standards, and geo-referencing biodiversity data. The workshop brought together 25 participants from ICIMOD's eight regional member countries: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The participants learned about the GBIF infrastructure and framework for primary biodiversity data, discovery, and publishing, and discussed its use in the region. As ICIMOD is the regional node of GBIF, the way forward will be to initiate regional collaboration to develop and share biodiversity information in the region.

Climate information is required to assess ecosystem vulnerability and identify adaptation options (wetland ecosystem, Bhutan)

How to manage climate change impacts and plan for necessary adaptation measures

To protect biodiversity, it is important to identify regions of high biodiversity value (based on data on species and habitats and expert evaluation) and prioritise these areas for conservation. The eight HKH regional member countries are signatories to the Convention on Biological Diversity and are committed to conservation. Towards the immediate protection of globally significant landscapes, these countries have set aside more than 39 per cent of their most biologically rich land. The region now has a total of 488 protected areas, 29 Ramsar Sites, 13 UNESCO World Heritage Sites, and 330 Important Bird Areas.

Climate change is having significant impact on biodiversity and ecosystems, and climate information is required to assess vulnerability and identify adaptation options. Experts on biodiversity and natural resource management recommend the following actions.

- Dialogue between scientists and non-scientists: It is important to organise continuous dialogue between climate scientists and biodiversity/ecosystem scientists to translate climate data into impacts on biodiversity and ecosystem services (i.e., climate services) for the benefit of users.
- Model improvement: We need to improve the representation of the functional role of biodiversity and ecosystem processes in Earth system models.
- Biodiversity monitoring: It is necessary to enhance and integrate biodiversity observing and monitoring activities and systems (such as LTER networks) through support to the Group on Earth Observations Biodiversity Observing Network (GEO BON) using Earth observation and other relevant initiatives.
- Integration of indigenous knowledge: It is important to integrate data and knowledge from indigenous and local communities, including citizen-based observations, about ecosystem responses and approaches to adaptation, in the design and implementation of climate information systems.
- Sharing of information: It is important to facilitate the sharing of information and good practices on ecosystem-based adaptation to climate change.

Approaches in mountains to adapt to climate change

The following guidelines are designed to help natural resources adapt to climate change, with a specific focus on biodiversity and mountain habitats (Baron et al. 2009; Chettri and Worboys 2009).

- Improve protected areas in mountains: Re-evaluate the management goals of protected areas, and ensure the continued protection and appropriate management of existing protected areas. Increase the size of protected areas where possible (e.g., enlarge core protection zones and buffer zones with nature-friendly land uses) and create new protected areas. Protect altitudinal gradients. Cooperate to develop common approaches with adjacent or nearby protected areas.

- Improve ecological connectivity: The safeguarding of latitudinal and altitudinal ecological continuums will be a crucial element in adaptation to changing conditions for many species and populations, mainly in areas where there is an actual or potential tree line and in urbanised areas in the Alps (Scheurer et al. 2008). However, improving ecological connectivity also improves the distribution of diseases, pests, and invasive plants along corridors. Hence, it is not yet clear where connectivity is appropriate, for which taxa, and how ecological connectivity improves biodiversity and ecological persistence.
- Retain permeable landscapes: Enhance existing incentive schemes promoting lower intensity land management and the development of greater landscape heterogeneity. Retain patches of 'semi-natural habitat', especially in urban or intensively used areas.
- Reduce anthropogenic stresses: Minimise localised human-caused disturbances (e.g., fragmentation, nitrogen addition, pollution) that hinder the ability of species or ecosystems to withstand climatic events (Baron et al. 2008, 2009). This can also mean keeping traditional land use in regions where this has been the predominant form of management in order to preserve species diversity and sensitive ecosystems (Theurillat and Guisan 2001).
- Protect key ecosystem features: Manage ecosystems so as to maintain structural characteristics, organisms, or areas that support the overall system, such as keystone organisms. Protect variant forms of a species or ecosystem, so that as the climate changes there may be populations that survive and provide a source for recovery. Maintain or establish more than one example of each ecosystem or population within a managed system, so that if one area is affected by disturbance, replicates in another area may reduce the risk of extinction and provide a source for recolonisation (Baron et al. 2008, 2009). Sustain the variables (e.g., soil resources and the species' pool) that accumulate slowly and provide buffers. Sustain both ecological legacies (e.g., old forest growth, woody debris) and cultural legacies (e.g., people's connection to the land) (Chettri and Worboys 2009).
- Restore ecosystems and species: Rehabilitate ecosystems that have been lost or compromised. Restore or facilitate the recovery of missing keystone species (e.g., wolf, beaver).
- Identify refugia: Use areas that are less affected by climate change than other areas as sources for recovery or as destinations for climate-sensitive migrants and maximise populations of rare and threatened species.
- Relocate: Transplant organisms from one location to another to bypass a barrier (e.g., an urban area). Translocate genotypes, species, and soil invertebrates or microbes, and initiate captive breeding programmes.

In relation to all of these guidelines, the availability of information from Earth observation in combination with in-situ data and flexibility in management approaches will be critical to maintaining biodiversity and ecological resilience in mountains in a changing climate.

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The Way Forward

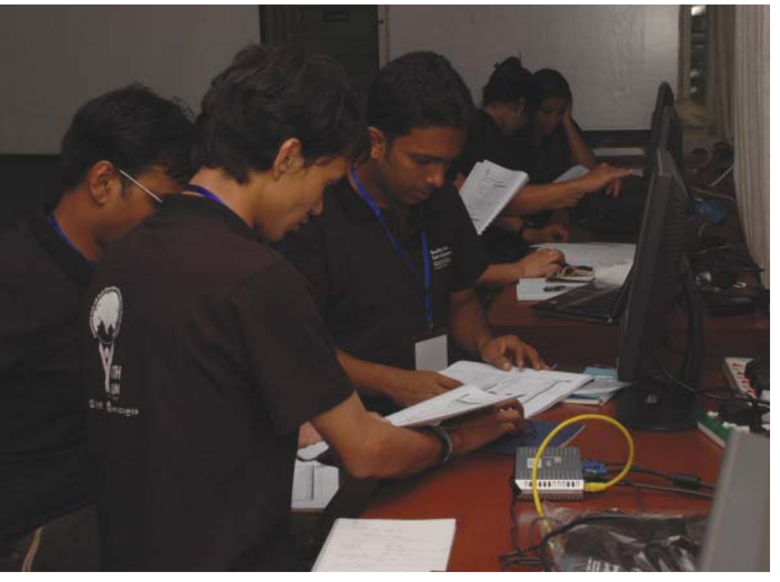
Andreas Schild, Director General, ICIMOD, aschild@icimod.org

Climate change presents a daunting challenge to all of us. It has increased the vulnerability of mountain systems, putting a strain on the resilience of mountain communities and their sustainable development. In the global climate change debate, the Hindu Kush-Himalayan (HKH) region has special significance as a regional 'weather maker'. The region also provides essential ecosystem goods and services, not only to mountain communities, but also to the large populations in transboundary river basins downstream. Mountain communities will need to adapt to the consequences of climate change and increase their resilience. However, our understanding of how to adapt is still at an early stage.

> The size of the Hindu Kush-Himalayas, in terms of extension, altitude, and number of inhabitants affected by climate variability, is in stark contrast with the lack of reliable information and consistent data.

To face the new risks posed by climate change, but also to take advantage of new opportunities, we must enhance our understanding in a scientifically validated way to assess the impacts of climate change so that we can take informed action and plan adaptation measures. However, the data necessary to assess climate change are incomplete.

Training of youth in use of GIS and Earth observation technology



Consequently, the full extent of the linkages among climate change and other drivers of change is not well understood.

Earth observation, combined with geographic information systems (GIS) and related technologies, is proving to be increasingly vital to our understanding of climate change processes, trends, and impacts, and for predicting future scenarios. We need to be able to generate information and scenarios, both on an immediate and long-term basis. ICIMOD is uniquely positioned to capitalise on the emerging dynamics of Earth observation in the region, foster regional cooperation, and tap into increased interest from international space agencies. We need to leverage climate data and information services from remote sensing and in situ measurement to manage climate change to serve the societal needs of mountain communities – in other words, we need to link 'space to village'.

We are in an era of unprecedented technological development, with Earth observation, GIS, the Internet, and the convergence of a myriad of technologies including social media, crowd sourcing, cloud computing, and spatial visualisation. This is creating enormous opportunities to increase our understanding of the state of mountain systems. It is important to enhance regional and national capacity to use these new technologies; to develop a consensus on a common regional approach and methodology; and to put proper institutional mechanisms in place for standardised data sharing and exchange. This will enable us to develop a wide range of decision applications at the national and regional levels for integrated river basin management, landscape conservation and management, early warning for disaster risk reduction, estimating carbon from forest resources, monitoring black carbon from space, analysing agricultural productivity and food security, and much more. Lastly, through the sound framework of the Himalayan Spatial Data Infrastructure (SDI), we need to operationalise climate and environmental information services for improved access to, and use of, Earth observation data and other types of information. This should be done in a format that can be understood and used by policy makers and the public at large. ICIMOD is striving to provide meaningful solutions to help us understand the changes taking place and build resilient mountain communities in the HKH region.

Centre News

China-ICIMOD Day held

China-ICIMOD Day was held on 7 July 2011 in Beijing, China. More than 30 representatives from partner organisations attended the event, held to cement and further the cooperation between China and ICIMOD. Mr Yao Tandong, Director General of the Institute of Tibetan Plateau, chaired the inaugural session. Dr Andreas Schild, Director General of ICIMOD, welcomed the participants and presented the future outlook of ICIMOD programmes, challenges, and opportunities. Mr Cao Jinghua from the International Cooperation Office, Chinese Academy of Sciences, was the guest of honour at the inaugural session. In his inaugural address, Mr Cao highlighted the importance of ICIMOD's mandate and emphasised the need for closer collaboration with Chinese scientists. Dr Wei Fangqiang thanked ICIMOD and the participants on behalf of the Chinese Committee on ICIMOD.

One of the outcomes of China-ICIMOD Day was the presentation of three key proposals to the China Nature Science Foundation. These proposals focused on the Koshi River basin, rangeland carbon potential in the Hindu Kush-Himalayan region, and the Brahmaputra-Salween Landscape Initiative. The presentation of the proposals was followed by discussions. ICIMOD said that it sees positive potential for the three proposals and, together with its Chinese partners, believes that it can contribute in a meaningful way to solving some of the basic issues in the Hindu Kush-Himalayan region.

Farid Ahmad, faahmad@icimod.org

Myanmar-ICIMOD Day held

Myanmar-ICIMOD Day, which was jointly organised by the Forest Department, Ministry of Forestry, and ICIMOD, was held on 24 June 2011 in Nay Pyi Taw, Myanmar. More than 100 people attended the programme including postgraduate students from the Forestry University. The Director General of the Myanmar Forest Department presented the opening remarks, highlighting how the mission of ICIMOD is in line with Myanmar's Forest Policy. He said that Myanmar has been actively collaborating with ICIMOD and hoped that Myanmar-ICIMOD Day would provide an opportunity to scale up ongoing collaborative programmes and identify future priorities and strategic areas. Dr Eklabya Sharma, Director of Programme Operations at ICIMOD, and Mr Basanta Shrestha, Division Head of the Mountain Environment and Natural Resource Information Systems (MENRIS) at ICIMOD, highlighted the role of ICIMOD, its strategic focus, and future possibilities for cooperation with Myanmar.

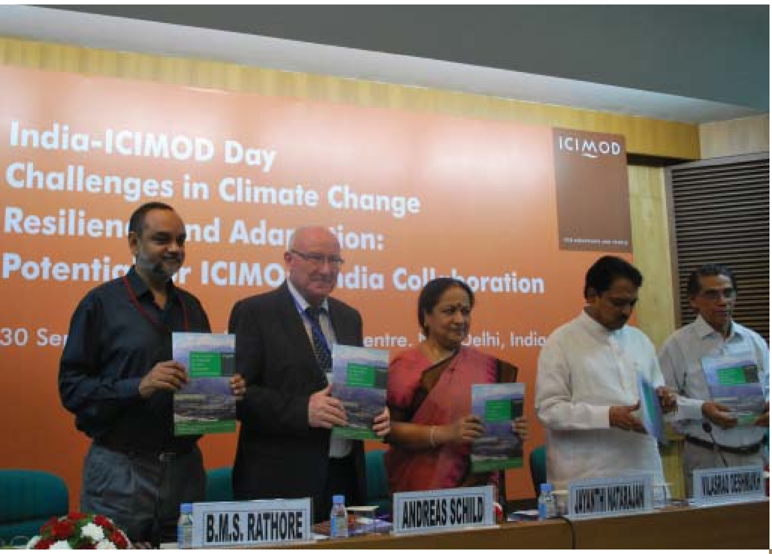
Discussion groups identified three priority areas for future collaboration: biodiversity conservation and management; land cover, REDD, and forest management; and capacity building, training, and exchange.

Farid Ahmad, faahmad@icimod.org

India-ICIMOD Day

The first India-ICIMOD Day was held in New Delhi on 30 September 2011 with the theme 'Challenges in Climate Change Resilience and Adaptation – Potential for collaboration between ICIMOD and India'. More than 90 experts, journalists, academicians, and officials attended the workshop. The event and workshop were inaugurated by Shri Vilasrao Deshmukh, Minister for Science and Technology and Earth Sciences, and Srimati Jayanthi Natarajan, Minister of State (Independent Charge) for Environment and Forests, Government of India. In his welcome address, Dr Andreas Schild expressed his pleasure and satisfaction at co-organising the first India-ICIMOD Day with the Ministry of Environment and Forests and the GB Pant Institute of Himalayan Environment and Development. The presence of the two ministers on the occasion pointed to the significance that India assigns to its partnership with ICIMOD and its recognition of the need to broaden efforts in partnership building.

Shrimati Jayanti Natarajan pointed out that climate change impacts do not respect national boundaries and, hence, any efforts to address climate change issues have to transcend boundaries and be regional



in approach. She pointed out that the Himalayas are the most fragile mountain system, given their geological vulnerability and growing population pressure, which in turn places pressure on Himalayan resources. She drew attention to the rich traditional knowledge and resilience of mountain people and suggested that scientific efforts build upon valuable repository of knowledge by including mountain communities in the partnership. Shrimati Natarajan reiterated India's commitment to ICIMOD, highlighting its recent commitment of USD 1 million to the ICIMOD Foundation as a testimony of the Government of India's support for ICIMOD's efforts.

Shri Vilasrao Deshmukh drew attention to the collaboration between the Ministry of Science and Technology and the Ministry of Environment and Forests in two missions under the National Action Plan on Climate Change: the National Mission on Sustaining Himalayan Ecosystems and the National Mission on Strategic Knowledge. In both these missions, the Minister saw the relevance of a strong partnership with a knowledge centre such as ICIMOD.

The day's events were organised into six plenary sessions. In the introductory session Dr Eklabya Sharma gave an overview of current regional programmes, and Dr Giridhar Kinhal highlighted the importance of India's profile in the HKH region and emphasised the need for an intensive consultation with relevant partners in India in the preparation of ICIMOD's third Mid-Term Action Plan (MTAP). Three technical sessions provided an opportunity for national and ICIMOD experts to deliberate on important issues such as the relevance of the green economy to mountains, the need for further study and research on black carbon and its impacts, and the management of mountain ecosystems to enhance the capacity of mountain people for climate change adaptation. A panel discussion session, chaired by Dr Schild, deliberated on the scope for further strengthening partnerships and networking in India. In the last session, chaired by MM Farooqui, Additional Secretary, Ministry of Environment and Forest, India, Dr Madhav Karki, Deputy Director General of ICIMOD, summed up the conclusions of each session and sketched out the next steps for the India-ICIMOD collaboration in the coming years.

Two new ICIMOD publications, 'Three Decades of India/ICIMOD Collaboration' and 'Green Economy for Sustainable Mountain Development', were also released at the event.

Giridhar Kinhal, gkinhal@icimod.org

International Conference on Green Economy and Sustainable Mountain Development

ICIMOD, in collaboration with the United Nations Environment Programme (UNEP), organised the 'International Conference on Green Economy and Sustainable Mountain Development: Opportunities and Challenges in View of Rio+20' in Kathmandu from 5 to 7 September 2011. This conference brought together about 150 participants from the world's mountain regions, including the Hindu Kush-Himalayas, Central Asia, the Middle East and North Africa, Latin America, North America, and Europe, to discuss and understand the role of mountains in the green economy and to identify the action needed at different levels to promote sustainable mountain development. Dr Ram Baran Yadav, President of the Republic of Nepal, inaugurated the conference and Dr RK Pachauri, Chair of the Intergovernmental Panel on Climate Change (IPCC), delivered the keynote speech.

The conference engaged diverse stakeholders, including international and regional scientists, policy makers, development practitioners, civil society organisations, and the private sector, in mountain development and environmental issues. Participants addressed the role of mountains in the green economy; their upstream-downstream linkages; their contribution to the national, regional, and global economy; and the need for environmental protection. They also discussed emerging challenges and opportunities for promoting sustainable development in the mountains and lowlands.

After three days of deliberations, the participants identified certain priority principles and actions for harnessing the green economy framework to improve the lives of mountain people and to conserve mountain ecosystems to promote sustainable development. The participants put forward a declaration on the green economy and sustainable mountain development and recommended that the Rio+20 conference recognise the contribution of mountain systems to the green economy, sustainable development, and human wellbeing. The declaration set principles and policies for global, regional, and national action in support of sustainable mountain development.

Other key recommendations in the declaration include the incorporation of the value of ecosystem services in national development planning and decision making; the development of a policy framework and global, regional, national, and local mechanisms to compensate and reward mountain communities for the services that they provide; the establishment of favourable conditions for improving markets for mountain ecosystem goods and services; the promotion of international and regional cooperation for knowledge sharing and capacity building to improve the management of globally and regionally significant mountain ecosystems, improving markets for ecosystem services by simplifying the processes prescribed by international instruments and developing methods for the valuation of environmental services; the inclusion of equity concerns in the green economy in mountains; and access to resources and property rights for mountain women, indigenous communities, and marginalised groups. The declaration will feed into major global policy initiatives including the United Nations Conference on Sustainable Development (Rio+20) to be held in Rio de Janeiro, Brazil in June 2012. Read more on this conference at www.icimod.org/gesmd.

Golam Rasul, grasul@icimod.org

Asia-Pacific stakeholders' meeting calls for inclusion of sustainable mountain development agenda in Rio+20

The three-day workshop 'Regional Sharing Workshop on Assessment of Potentials and Opportunities in the Asia Pacific Region for Rio+20', was held at ICIMOD headquarters in Kathmandu from 23 to 25 August 2011. The meeting brought together more than 40 experts from the Hindu Kush-Himalayan (HKH) countries (Afghanistan, Bangladesh, China, India, Myanmar, Nepal, and Pakistan) as well as from the Southeast Asian and Pacific countries (Indonesia, the Philippines, and Papua New Guinea) to share the progress made since the Rio Earth Summit in 1992 and deliberate on the environmental, economic, and social challenges that people living in fragile hilly and mountain ecosystems face in meeting the goals of sustainable development.

The workshop was organised to discuss 14 regional case studies commissioned for the preparation for Rio+20, to synthesise the virtual debate, and to refine a draft regional report prepared for the workshop. A major goal was to identify good practices and missing links and to prioritise environmental issues in the region. The key messages and recommendations of the workshop were presented at the Lucerne World Mountain Conference in Switzerland in October 2011, feeding into the preparatory process for the United Nations Conference on Sustainable Development (Rio+20) in June 2012.

The main conclusions of the workshop were as follows.

- Collaborative efforts are needed to conserve the mountains and enhance regional cooperation.
- Skills in collaborative negotiation and non-adversarial communication help stakeholders resolve resource conflicts, including those with the private sector.
- Decentralised and devolved governance has been effective in various situations, e.g., at state, autonomous council, and district levels.
- Synergy between top-down and bottom-up processes is crucial for sustainable mountain development policy.
- Natural resource management institutions must be strengthened to ensure internal equity and inclusion, and to avoid external exploitation.
- Attention in the HKH and Southeast Asia and Pacific regions, as well as globally, has shifted to the climate change agenda, which is overshadowing economic and social agendas that are equally or more important. A balanced region- and ecosystem-specific, holistic approach and actions are needed to achieve sustainable mountain development.

The conference made the following major recommendations.

- Poverty and governance should be the crucial concerns of stakeholders.
- More emphasis needs to be given to actionable programmes with clear implementation plans and targets.
- The regional report should have a broad audience, including those working to achieve the Millennium Development Goals and adaptation.
- Mountain people should be empowered to participate in the governance of the mountain regions.
- The implementation of political commitments and announced programmes must be monitored by engaging all stakeholders.
- Regional cooperation is the key to achieving sustainable mountain development; mountain countries should have a common platform and position on major issues.
- Although costly, mountain countries must invest in green projects building on already documented success stories, mainstreamed with adaptation and livelihood improvement.

Madhav Karki, mkarki@icimod.org

Road to Rio+20: Mobilising Asia Pacific youth for promoting sustainable mountain development

As the world community takes further steps towards the 2012 United Nations Conference on Sustainable Development, popularly known as Rio+20, awareness is increasing about the role that youth can play in ensuring sustainable development and eradicating poverty through promotion of green economy and low carbon economic activities. In 1992, Agenda 21 identified nine major groups through which all citizens could participate in UN sustainable development activities. As one of these groups, youth around the globe – however diverse in socio-economic, political, and environmental situations – are preparing for this important event

To help mainstream this important group in the Rio+20 processes in the sustainable mountain development context, ICIMOD, through the Asia Pacific Mountain Network (APMN), has organised a series of activities since early 2011. The 'South and Central Asia Regional Virtual Consultation on Youth Perspectives on Rio +20' attracted 550 participants from 38 countries worldwide. Outcomes of this consultation were presented and discussed during the World Leadership Conference 2011 in Singapore and the 'Asia Pacific Youth Forum on Climate Actions and Mountain Issues' organised at ICIMOD headquarters in August 2011. The Youth Forum, attended by 43 young people from 17 Asia Pacific countries, adopted the 'Asia Pacific Youth Declaration on Climate Change and Sustainable Development' and the 'Asia Pacific Youth Position Paper on Rio+20', which are now being used by the Major Group on Children and Youth for Rio+20 debate and have been submitted to Rio+20 Secretariat. These documents were also shared at the 'Regional Sharing Workshop on Assessment of Challenges and Opportunities in the Asia Pacific region for Rio +20' (ICIMOD, 23-25 August 2011), the 'International Conference on Green Economy and Sustainable Mountain Development: Opportunities and Challenges in View of Rio+20' (ICIMOD, 5-7 September 2011) and the United Nations Environment Programme (UNEP) TUNZA Conference 2011 (Indonesia, 26 September to 1 October 2011).

ICIMOD plans to continue similar youth oriented activities to advocate the mountain agenda and mainstream youth in the sustainability debate.

Tek Jung Mahat, tmahat@icimod.org

REDD pilot project and Forest Carbon Trust Fund in Nepal

A pilot project on Reducing Emissions from Deforestation and Forest Degradation (REDD) in three watersheds of Nepal (Charnawati, Kayarkhola, and Ludikhola) has focused on designing and setting up a payment system for sequestering carbon in Nepal's community-managed forests. The project is implemented by ICIMOD together with its partners, the Federation of Community Forestry Users Nepal (FECOFUN) and the Asia Network for

Sustainable Agriculture and Bio-resources (ANSAB), and is financed by the Norwegian Agency for Development Cooperation (Norad) under the Climate and Forest Initiative. The project involves local communities in monitoring carbon and has enabled them to claim rewards for increasing the carbon stocks in their forests. By making real-time REDD+ payments, the Forest Carbon Trust Fund created under the project seeks to explore how governance systems can be adapted to implement performance-based REDD+ at the local level within community forestry settings. Lessons learnt from the pilot project may be applicable to practitioners and policy and decision makers in relation to national REDD+ programmes.

The project is being conducted in three districts (Dolakha, Chitwan, and Gorkha), covering an area over 10,000 ha and involving 105 community-managed forests with approximately 18,000 households and around 90,000 people. Under the pilot project, these forests saw a stock increment of 100,528 tonnes of carbon dioxide between 2010 and 2011. Since these sites are naturally regenerated forests, the increased carbon sequestration meant increased biodiversity richness as well. Funding of USD 100,000 was allocated to the Forest Carbon Trust Fund for 2010/2011. In June 2011, the first payment of USD 95,000 was transferred to the REDD Watershed Network for distribution to the community groups based on their performance in managing and conserving their forests.

The Forest Carbon Trust Fund takes a bottom-up approach. Community forest user groups are responsible for using funds to reduce deforestation and forest degradation, conserve forest carbon stocks, monitor carbon pools, raise awareness and build capacity on REDD, and collect carbon stock data at the community level. The governance mechanism is responsible for validating the carbon stock data from the communities, monitoring and regulating forest management activities, and paying claims based on the increase in forest carbon stock.

The project has been successful in demonstrating that REDD can be implemented at the community level not only for mitigation purposes, but also to enhance ecosystem-based adaptation measures for local

populations that depend largely on forest resources. The project has also demonstrated that local communities can be trained to monitor carbon pools within forests. This is the first time that communities in the Hindu Kush-Himalayan region have received REDD+ payments on an experimental basis.

Bhaskar Singh Karky, bkarky@icimod.org

Highlighting the Critical Role of Mountain Ecosystems for Climate Adaptation and Sustainable Development: Mountain Day at UNFCCC COP 17

4 December 2011 at Durban

ICIMOD, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and the Mountain Partnership Consortium are the main organisers of Mountain Day 2011 at the 17th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COP 17) on 4 December at Durban, South Africa. Mountain Day 2011 will assemble a high-level panel of global leaders, ministers, and scientists to advocate the value and critical role of mountains in climate change adaptation and sustainable development, and to share scientific evidence and examples of challenges and opportunities. The day-long programme will include plenary presentations and discussions, working groups, and panel discussions.

Approximately 90 countries in the world have more than one-quarter of their territory in the mountains. More than 50% of the world's population depends on water sourced from mountains. Mountains also provide high-quality natural products, rich agro-biodiversity, habitats for rare and endangered flora and fauna, and resources for tourism and recreation. However, climate and global changes are having serious impacts on mountain ecosystems and the goods and services they provide for populations both upstream and downstream – in particular water, biodiversity, and atmospheric circulation.

Mountain regions have experienced above-average warming in recent years. This change has had significant implications for mountain ecosystem goods and services, which are especially critical for the livelihoods and survival of poor and indigenous communities. Scenarios of climate change in mountain regions are highly uncertain and poorly understood, with large gaps in knowledge.

There is therefore an urgent need to raise awareness and promote policy actions to ensure that mountain ecosystems continue to fulfil their critical role. Mountain Day will call to the COP 17 delegates and global development partners to press for more concerted long-term actions at the national, regional, and global levels to save vital mountain ecosystems. It is hoped that the knowledge shared and the evidence presented will provide a powerful and convincing message to ensure that UNFCCC deliberations include provisions for protecting mountain systems' integrity for the survival of current and future generations.

Naina Shakya, nshakya@icimod.org

David Molden, incoming Director General

Dr David Molden begins his term as Director General in December 2011, taking over from Dr Andreas Schild.

Dr Molden is a development specialist with more than 30 years of experience in designing, planning, executing, and monitoring programmes on water management, livelihoods, environment, and ecosystem services. He has acquired considerable management experience in a number of positions, including Chief of Party for the United States Agency for International Development (USAID) funded Government of Nepal Irrigation Management Project in Nepal, Chief of Party for a USAID funded water resources strategic research programme in Egypt, and Leader of the multi-institute Comprehensive Assessment of Water Management in Agriculture programme. Prior to joining ICIMOD he was the Deputy Director General for Research at the International Water Management Institute (IWMI) in Sri Lanka. He has worked in several Hindu Kush-Himalayan countries, including China, India, Nepal, and Pakistan, and has experience in projects in the Indus, Ganges, Yellow, Mekong, Yangtze, and Amu and Syr Darya river basins.

Dr Molden was awarded a PhD in Civil Engineering from Colorado State University, United States, in 1987 and has since developed broader interests in integrating social, technical, and environmental aspects of natural resources management. He has contributed to nearly 200 publications including books, refereed journals, research and project report series, and educational materials. He has received many awards including the Consultative Group on International Agricultural Research (CGIAR) Outstanding Scientist award in 2009.

ICIMOD goes 'green'

ICIMOD is going 'green' and more environment friendly by taking simple in-house measures at Headquarters. Three small electric Reva cars have been added to the fleet to reduce the Centre's carbon footprint. Unlike normal vehicles operating on fossil fuel, these cars run on power from inbuilt battery packs which do not emit carbon dioxide. ICIMOD has also installed a solar array of 4.9 KW capacity, comprising 28 mono crystalline photovoltaic PV panels, to capture solar radiation to recharge the electric cars. Options for bigger eco-friendly, low-emission vehicles are also being explored. Waste water generated at Headquarters is recycled to irrigate the garden. ICIMOD has installed a 'constructed wetland' waste water treatment plant on an area of about 54 sq.m for this purpose. The waste water is filtered through the reed beds planted in the constructed wetland. Another eco-friendly initiative within the premises has been the installation of a 10 cu.m biogas plant to recycle vegetation and waste food from the canteen to produce biogas for cooking. The ICIMOD complex has also become a polybag-free zone. The use of eco-friendly bags is now encouraged. Coloured waste bins have been placed within the premises for differentiation of biodegradable, recyclable, and non-recyclable waste.

The ICIMOD Demonstration and Training Centre at Godavari now promotes, among others, solar-based green technologies to provide options for alternative energies to mountain farmers in the Hindu Kush-Himalayas. Such technologies help to reduce fuelwood use for cooking and heating, thus also reducing indoor air pollution. These technologies are appropriate for mountain areas and are also relatively easy to use and maintain. Some of the solar technologies demonstrated at Godavari are solar cookers, solar driers, solar lamps, and solar water purification systems.

Mohan Shrestha, moshrestha@icimod.org

New Regional Board Member

Mr Naba Bikram Kishore Tripura,
Secretary, Ministry of Chittagong Hill Tracts Affairs, Bangladesh

Mr Naba Bikram Kishore Tripura, Secretary, Ministry of Chittagong Hill Tract was nominated as Regional Board Member for Bangladesh to the ICIMOD Board in July 2011. Born in 1956, Mr Tripura obtained his Bachelor of Arts with honours and Master's degree in English literature from Dhaka University. He joined the Bangladesh Civil Service in 1982. He graduated from the Police Academy in 1984 and from the National Defence College in 2005.

Mr Tripura has received a number of awards, most importantly the Samar Padak (War Medal) in 1971 for his participation in the Bangladesh Liberation War; the Commander's Award for Public Service Medal from the United States Department of Defense in 1994 when he served as the Deputy Contingent Commander of the US-led 'Operation Uphold Democracy' in Haiti in 1994; and the United Nations Medal when he served in the United Nations Mission in Haiti in 1995.

In 2009, Mr Tripura led the Bangladesh delegation in negotiations for a Memorandum of Understanding with the United Nations Department of Peacekeeping Operations. He was also a member of the Bangladesh delegation at the Home Secretary level talks held in Delhi in 2008.

From March 2007 to October 2010, Mr Tripura served in the police service as the National Project Director, Police Reform Programme, before joining the Ministry of Foreign Affairs. On 16 June 2011 he was appointed Secretary In-Charge of the Ministry of Chittagong Hill Tracts Affairs, Government of Bangladesh.

Publications authored by Mr Tripura include, among others, 'The Tribal Insurgency in Chittagong Hill Tracts: Background, Evolution and Consequences – an Insider's View', 'Durdeshey' (In Distant Lands), and 'Bangladesher Tripura Janajati' (The Ethnic Tripura Community of Bangladesh), and 'Sardah in Reminisces'.

Mr Tripura has attended many conferences and training courses including the UN Senior Mission Leaders Course at the Swedish National Defence College, Stockholm, Sweden in 2006, and a Senior Crisis Management Course in Washington, DC, USA in 2004. He has also participated in various UN peace missions and knowledge-sharing sessions.

ICIMOD Board of Governors 2011

Regional Board Members

H.E. Raz Mohammad Raz
Deputy Minister of Irrigation and Infrastructure
Ministry of Agriculture, Irrigation and Livestock, Afghanistan

Mr Naba Bikram Kishore Tripura
Secretary, Ministry of Chittagong Hill Tract Affairs
Bangladesh Secretariat, Bangladesh

Mr Sherub Gyaltshen
Secretary, Ministry of Agriculture, Bhutan

Prof. Ding Zhongli
Chairman of CN-ICIMOD
Vice President, Chinese Academy of Sciences, China

Dr Tishya Chatterjee IAS
Chair, ICIMOD Board of Governors
Secretary, Ministry of Environment and Forests, India

Dr Nyi Nyi Kyaw
Deputy Director General, Forest Department
Ministry of Forestry, Myanmar

Mr Deependra Bahadur Kshetry*
Vice Chairman, National Planning Commission, Nepal

Mr Khusro Pervaiz Khan*
Additional Secretary, Economic Affairs Division, Pak Secretariat, Pakistan

Independent Board Members

Dr Lars-Erik Liljelund
Chair, ICIMOD Programme Advisory Committee
Vice Chair, ICIMOD Board of Governors
Chief Executive, The Foundation for Strategic Environmental Research, Sweden

Dr Elke Förster
Environment, Climate Change and Biodiversity
Priority Area Manager
Deutsche Gesellschaft für Intenationale Zusammenarbeit (GIZ), Germany

Dr Amir Muhammed
Rector, National University of Computer and Emerging Sciences, Pakistan

Dr Linxiu Zhang
Professor and Deputy Director, Centre for Chinese Agricultural Policy
Chinese Academy of Sciences (CAS), China

Professor Matthias Winiger
Former Vice Chancellor, Department of Geography, University of Bonn
Germany

Dr Pal Prestrud,
Director, CEO, CICERO, Norway

Dr Christoph Graf
Chair, ICIMOD Support Group
Head, South Asia Department, Federal Department of Foreign Affairs
Swiss Agency for Development and Cooperation (SDC), Switzerland

Dr Andreas Schild
(Ex-officio) Director General, ICIMOD

* Profile will be provided in the next periodical

Outreach activities

'Himalaya – Changing Landscapes' showcased in Japan

The ICIMOD photo exhibition 'Himalaya – Changing Landscapes' was showcased in Yokohama and Tokyo, Japan to raise awareness of climate change and its impacts on mountain people. The exhibition was organised jointly by ICIMOD and the Himalayan Adventure Trust of Japan (HAT-J) and supported by the Embassy of Nepal. It was first shown in Yokohama from 26 to 27 July to coincide with the Third International Forum for Sustainable Asia and the Pacific (ISAP 2011), which was organised by the Institute for Global Environment Strategies (IGES) and United Nations University Institute of Advanced Studies (UNU-IAS). More than 150 forum participants (scientists, research workers, NGO members, and government officials) viewed the photo exhibition. Participants appreciated the clear visualisation of the impact of global warming and the changes in people's lives. The exhibit elicited comments on the difficulty of sustaining local culture with modernisation, and on the pressures of urbanisation on the environment.

The exhibition then travelled to Tokyo, where it ran from 3 to 5 September 2011 as part of the celebrations for the 20th anniversary of HAT-J. About 30 invitees from leading mountaineering federations and clubs and 100 HAT-J members participated in this event. The brochure of the exhibition translated in Japanese was distributed to visitors. The exhibition was an attraction among the attendees at the ceremony. As a result of the exhibition, interest has been expressed by local mountaineering clubs to organise the exhibition in their hometowns to raise awareness about climate change.

Nira Gurung, ngurung@icimod.org

3rd National Conservation Day Celebrated

The 3rd National Conservation Day was organised at the Nepal Academy Hall on 24 September 2011 under the leadership of the Government of Nepal, supported by 10 conservation consortium members including ICIMOD. The Right Honourable Vice President of Nepal, Mr Parmanand Jha, was the Chief Guest and Mr Mohhamad Wakil Musalman, Honourable Minister for Forests and Soil

Conservation, chaired the function. Conservation awards and scholarships were awarded to individuals and organisations that had made a distinct mark in biodiversity conservation in Nepal. Two video films, 'Sacred Himalayan Landscape' and 'Terai Arc Landscape', and six publications were also formally launched.

ICIMOD showcased the 'Promoting Herbal Gardens in Schools' initiative with the first screening of the video in Nepali, 'Vidhyalayama Jadibuti Uddhan', and hosted an information stall containing publications, flyers, and CDs which were distributed among the many participants. An International Year of Forests photo exhibition was also displayed.

National Conservation Day is led by conservation consortium members Bird Conservation Nepal, Environmental Camps for Conservation Awareness, ICIMOD, the International Union for Conservation of Nature, the National Trust for Nature Conservation, the Nepal Forum of Environmental Journalists, The Mountain Institute, Wildlife Conservation Nepal, Wildlife Watch Group, and WWF Nepal, under the leadership of the Ministry of Forests and Soil Conservation, Government of Nepal.

Suman Jaiswal, sjaiswal@icimod.org

Promoting Herbal Gardens in School: Kit Distribution and Video Launch

ICIMOD created the 'Promoting Herbal Gardens in Schools' initiative in 2010 as a part of celebrations for the International Year of Biodiversity. The idea was to involve schoolchildren in creating herbal gardens on their school premises to teach them about the different types of medicinal and aromatic plants, their uses, and their conservation significance. The 'Herbal Garden Kit Distribution and Video Launch' programme was organised by ICIMOD on 26 September 2011 to commence the replication phase of the initiative.

The programme was well attended by participating schools as well as new schools that will replicate the initiative. Also present were representatives of Dabur Nepal, which sponsored the Herbal Garden Kit, and Nepal SBI Bank Limited, which together with Dabur Nepal sponsored the 'Promoting Herbal Gardens in Schools' video film in the Nepali language. The kits, containing some essential garden tools, were handed over to 28 schools. These kits are to be used exclusively by schoolchildren to establish herbal gardens. The representatives of Dabur Nepal and Nepal SBI Bank Limited pledged their continued support and expressed their delight at being part of such a child-focused conservation initiative.

The launch and screening of the video film was an exciting feature of the day's programme. The film highlights the objective behind the initiative, and reflects on the learning experiences of the schools and students, who are now promoting the concept to new schools.

From 2012 onwards, Environmental Camps for Conservation Awareness (ECCA) will be the National Coordinator of this initiative in Nepal. A Memorandum of Understanding was signed to this effect between ICIMOD and ECCA on 22 September 2011. Mr Prachet Shrestha, ECCA Chairman, reiterated ECCA's commitment to strengthen the initiative.

During his opening remarks, Dr Andreas Schild, Director General of ICIMOD, highlighted the need for partnerships among all sectors of society and mentioned that ICIMOD values initiatives in which private-sector organisations are able to join hands. He also said that this initiative has created a platform for young minds to build their capacity and awareness. While ICIMOD hopes that the initiative will gain momentum with many schools across Nepal, it also expects to gradually launch the programme in other regional member countries in the Hindu Kush-Himalayan region.

Bandana Shakya, bshakya@icimod.org

Knowledge Forums 2011

Dr Rajendra Kumar Pachauri, co-recipient of the 2007 Nobel Peace Prize on behalf of the Intergovernmental Panel on Climate Change (IPCC), which he chairs, and Director General of The Energy and Resources Institute (TERI), talked about 'Climate Change in the Himalayas and the Way Forward' at a Knowledge Forum organised by ICIMOD on 4 September 2011.

Dr Pachauri began by shedding light on the history, mandate, and modus operandi of the IPCC. He also said that hundreds of top scientists from around the world are working hard to bring out the Fifth Assessment Report by 2014.

He stated that over the last century, the average global temperature has increased by 0.74OC and the sea level has risen by 17 cm. He attributed this rapid global warming mainly to anthropogenic factors.

He underscored the importance of planned adaptation and the co-benefits arising from mitigation actions aimed at containing global warming through the application of transformational technologies (e.g., the solar lanterns promoted by TERI's 'Lighting a Billion Lights' campaign). He also spoke of the importance of measures such as carbon price signals, regulations, standards, carbon taxes, and the valuation of, and payment for, ecosystem goods and services.

He called on Himalayan countries to join hands to come up with a common programme of action – backed by shared resources – to safeguard the Himalayas.

Professor Veerabhadran Ramanathan of Scripps Institution of Oceanography, University of California, San Diego, United States, known for his pioneering studies on atmospheric brown clouds (ABCs) and the role of black carbon, talked on 'The Extreme Vulnerability of the Himalayan-Tibetan Region to Global Warming and Air Pollution' at ICIMOD on 22 March 2011.

He described the role of black carbon aerosols, produced by the incomplete burning of bio-fuels, in the formation of ABCs over the Himalayan-Tibetan region. He stated that ABCs contribute to overall regional warming, the melting of Himalayan glaciers, reduced sunlight, increased heavy rainfall, and less rain overall. As the atmospheric temperatures rise, more precipitation in the mountains falls as rain and less as snow, leading to an increase in immediate runoff and a decrease in water storage in mountain areas. Black carbon deposited on snow absorbs solar energy, hastening melting. ABCs cause large-scale dimming, reducing crop yields as well as evapotranspiration, thereby contributing to reduced precipitation.

Dr Ramanathan proposed the following pathway to limit global temperature increases to 2°C.

- Reduce CO_2 emissions by 50% by 2050.
- Reduce short-lived warming agents such as black carbon, ozone, and methane by 30% in the next 30 years.
- In the meantime, develop and promote transformational technologies.

He called on all to think globally, assess regionally, act locally, and seek integrated solutions through innovation in science, technology, policy, politics, institutions, and finance.

Ujol Sherchan, usherchan@icimod.org

New appointments at ICIMOD

The list and profiles of ICIMOD staff are posted on the website at www.icimod.org/?q=44

Dr Gopal Singh Rawat,
Deputy Programme Manager and Senior Scientist, Environmental Change and Ecosystem Services
August 2011

Mr Rahul Dabas,
Enterprise Resource Planning (ERP) Coordinator, Administration and Finance
October 2011

Ms Bhavana Syangden,
Programme Associate, SANDEE
June 2011

Workshops, meetings and training events (July – September 2011)

Event	Date	Place
Bhutan Summit Water Regional Meeting	2 – 3 July	Dhaka, Bangladesh
Training Workshop on Mountain Specific Value Chain	6 – 8 July	Shillong, India
ICIMOD-China Day	7 – 8 July	Beijing, China
Bhutan Summit Biodiversity Regional Meeting	11 – 15 July	Bhutan
Land Use Change and Human Health in Eastern Himalayas (ECO-HEALTH) – the Final Project Summary and Dissemination Workshop	20 – 22 July	Kathmandu, Nepal
Writeshop for Preparation of Background Paper for Green Economy and Sustainable Mountain Development Conference	20 – 22 July	Kathmandu, Nepal
Trainers' Training on Beekeeping Management, Quality of Bee Products (Harvesting, Processing, and Value Addition of Honey and Beeswax) and Pollination Management	23 July – 2 August	Kabul, Afghanistan
Photo Exhibition, Himalaya – Changing Landscapes (mobile)	26 – 27 July	Yokohama, Japan
Expert Group Regional Consultative Meeting on Energy Security	28 – 29 July	Kathmandu, Nepal
Asia-Pacific Youth Forum on Climate Actions and Mountain Issues	8 – 12 August	Kathmandu, Nepal
Decision Support Tools and Approaches for Ecosystem Management	8 – 10 August	Chengdu, China
Workshop on Gender and Climate Change	18 August	Kathmandu, Nepal
Authors' Workshop for the Regional Report on Climate Change in the Hindu Kush-Himalayas: State of Current Knowledge	18 – 19 August	Kathmandu, Nepal
Regional Rangeland Management Programme Development and Policy Review Workshop	22 – 23 August	Kathmandu, Nepal
Regional Sharing Workshop on Assessment of Challenges and Opportunities in the Asia Pacific region for Rio +20	23 – 25 August	Kathmandu, Nepal
Workshop on Integration of GIS and Remote Sensing for Range Resource Assessment	24 August	Kathmandu, Nepal
Expedition for Glacier Mass Balance Setup on the Rikha Samba Glacier in the Hidden Valley in Nepal	2 – 18 September	Rikha Samba Glacier, Nepal
Photo Exhibition, Himalaya – Changing Landscapes (mobile)	3 – 5 September	Tokyo, Japan
Knowledge Forum with Dr Rajendra K Pachauri on Climate Change in the Himalayan Region and the Way Forward	4 September	Kathmandu, Nepal
Enhancing Ecotourism as a Tool for Conservation and Sustainable Community Development	5 – 6 September	Thimphu, Bhutan
International Conference on Green Economy and Sustainable Mountain Development: Opportunities and Challenges in View of Rio +20	5 – 7 September	Kathmandu, Nepal
Training on Documentation of Sustainable Land Management Technologies and Approaches using WOCAT Framework	10 – 15 September	Bamyan, Afghanistan
Trainers' Training on Strengthening Honey Production Base and Market Linkages with Special Focus on Beekeeping Management for Honey Production and Pollination; and Harvesting, Processing, Value Addition and Quality of Honey and Other Bee Products	18 – 27 September	Bandarban, Bangladesh
National Conservation Day	24 September	Kathmandu, Nepal
A Knowledge Exchange and Adaptation Partnership Workshop between Hindu Kush-Himalaya-Andes and Central Asian Mountains on Glaciers, Glacial Lakes, Water and Hazard Management and Livelihoods	25 – 28 September	Kathmandu, Nepal
Promoting Herbal Gardens in Schools: Kit Distribution and Video Launch	26 September	Kathmandu, Nepal
India-ICIMOD Day: Challenges in Climate Change Resilience and Adaptation, Potentials for ICIMOD-India Collaboration	30 September	New Delhi, India

News from SANDEE

As South Asia continues to make economic strides, how do we ensure that our measures of growth are accounting for changes in natural assets? The Indian government recently took an important step towards answer this question by appointing an expert group to develop a framework for greening India's national accounts. Chaired by Sir Partha Dasgupta of Cambridge University, other 'SANDEE-ites' who are part of the expert group include Kanchan Chopra, Haripriya Gundimeda, E. Somanathan, and Priya Shyamsundar. SANDEE's work on valuation was disseminated and discussed at the first working group meeting in New Delhi on 22 August.

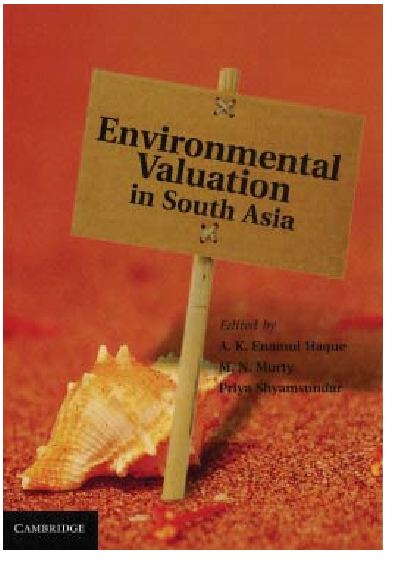
SANDEE's research grants this year focus on the themes of water management, biodiversity conservation, and climate change and migration. SANDEE received 44 pre-proposals earlier this year and approved eight grants. These grants include a collaborative set of studies with East Asia that will focus on estimating the impact of climate change on migration because of changes in agricultural productivity.

During the last quarter, SANDEE published six working papers and six policy briefs, which are outcomes of completed research projects funded by SANDEE. Cambridge University Press also published SANDEE's second book 'Environmental Valuation in South Asia'. This book is a collection of case studies from across South Asia. It showcases different valuation methodologies and a variety of mechanisms to collect and combine environmental data with socioeconomic information to addresses important themes such as ecosystem services, production externalities, health costs, public investments, and so forth. We hope it will be useful to researchers, teachers, and practitioners. The book was officially launched by five vice-chancellors in Dhaka, Bangladesh on 28 September 2011.

SANDEE's under-served areas programme seeks to support parts of the region that need additional assistance. In August, as part of this set of activities, SANDEE organised a research and writing workshop at the North-eastern Hill University (NEHU) in Shillong, India. This workshop provided researchers from the hill areas of northeast India working in the field of environmental and natural resource economics with a valuable opportunity to learn about research writing and methods. During the workshop, key policy concerns in South Asia related to environmental economics and ways to address them through economic research were discussed. The objective of this workshop was to enable researchers and teachers to take their research ideas and develop them into workable research proposals in the field of environment and natural resource economics.

SANDEE

ECONOMICS & THE ENVIRONMENT



Newly published working papers

1. *Transactions Matter but They Hardly Cost: Irrigation Management in the Kathmandu Valley,* by Ram Chandra Bhattarai, WP No. 56–10
2. *User-based Financing of Marine Protection in the Maldives,* by Mohamed Shumais, R. C. Bhatta and Mahadev G. Bhat, WP No. 57–11
3. *Valuing the Recreational Uses of Pakistan's Wetlands: An Application of the Travel Cost Method,* by Ali Dehlavi and Iftikhar Hussain Adil, WP No. 58–11
4. *Rights, Responsibilities and Resources: Examining Community Forestry in South Asia,* by Priya Shyamsundar and Rucha Ghate, WP No. 59–11
5. *Motives for Firms to Adopt Solid Waste Management Controls: The Case of Food Processing Sector in Sri Lanka,* by Udith Jayasinghe and Menuka Udugama, WP No. 60–11
6. *The Welfare Impacts of Leasehold Forestry in Nepal,* by Bishnu Prasad Sharma, WP No. 61–11

(Note: All these publications are available online.)

Anuradha Kafle, Anuradhak@sandeeonline.org

Partnership development (June – October 2011)

Strategic partnership with international organizations

- A partnership was established with the Ev-K2-CNR Committee, Italy for collaboration in areas of mutual interest, especially in the areas of water management, climate change, ecosystem services, and poverty reduction through knowledge sharing.
- An agreement was signed with the Global Observation Research Initiative in Alpine Environments (GLORIA) for the extension and long-term operation of GLORIA observation sites in the HKH region.
- A strategic agreement was entered into with the Stockholm International Water Institute (SIWI), Sweden for collaboration in research on water governance, policy, and participation in policy dialogues.
- For the preparation of climate change scenarios for pilot catchment in the Indus Basin, an agreement was signed with the Swiss Federal Institute of Technology, Zurich.
- An agreement was signed with the World Meteorological Organization (WMO), Switzerland for the rehabilitation of the hydro-meteorological network of Pakistan.
- An agreement was signed with the United Nations Development Programme (UNDP), Nepal for the implementation of a South-South Knowledge Exchange and Writers' Workshop and support to the Government of Nepal's national position paper as part of the Rio+20 preparation process.
- In support of activities related to Rio+20, agreement was signed with the Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN), Peru.
- An agreement was signed with the Stockholm Environment Institute (SEI), Sweden for support of a regional media workshop.
- An agreement was signed with the United States Department of State, United States Embassy, Nepal to host a regional workshop to share knowledge on existing glacier monitoring efforts and develop common methodologies.

Ayushma Rana Basnyat, ayrana@icimod.org
Farid Ahmad, faahmad@icimod.org

Andreas Schild, Director General, ICIMOD, and Agostino Da Polenza, President, Ev-K2-CNR Committee, Italy, signing partnership agreement

Partnerships with regional institutions for programme implementation

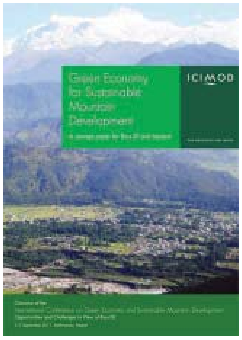
- An agreement was signed with the Ministry of Environment and Forests, Government of Bangladesh to organise and host a regional expert group meeting on water for the Climate Summit for a Living Himalayas – Bhutan 2011 and to produce a regional report from it.
- For the implementation of the project 'Establishment of a Regional Flood Information System in the Hindu Kush-Himalayan Region' (HKH-HYCOS), funded by the Government of Finland, agreement was signed with the Bangladesh Meteorological Department; the Gross National Happiness Commission, Bhutan; the Pakistan Meteorological Department; and the Water and Power Development Authority, Pakistan.
- For the implementation of the three major components of the International Fund for Agricultural Development (IFAD) TAG 1113 project, agreements were signed with the Western Uplands Poverty Alleviation Project, Nepal; the Leasehold Forestry and Livestock Programme, Nepal; the North Eastern Region Community Resource Management Project, India; and the Meghalaya Rural Development Society, India.
- An agreement was signed with Sichuan Grassland Sciences Academy, China for developing an integrated mechanism for combating rangeland desertification in Ruoergai County, Upper Yellow River, China.
- To conduct a land cover change analysis study to assess past changes and present trends in land cover distribution in the mountain areas of Pakistan, an agreement was signed with World Wide Fund Nature (WWF) – Pakistan.
- Under the 'Kailash Sacred Landscape Conservation Initiative' project, agreements were signed with the Central Department of Botany of Tribhuban University, Nepal and the GB Pant Institute of Himalayan Environment and Development, India.
- For designing and setting up a REDD payment mechanism in the community forest management system in Nepal, under the REDD+ project funded by the Norwegian Agency for Development Cooperation (Norad), agreements were signed with the Federation of Community Forestry Users' Nepal (FECOFUN); the Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Nepal; Forest Action, Nepal; and the South Asian Network for Development and Environmental Economics (SANDEE).
- For the assessment of impacts of particulate air pollutants on respiratory health of school children in the Kathmandu valley under the Male' Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia, agreement was signed with Nepal Health Research Council (NHRC), Nepal.
- ICIMOD entered into collaboration with the Institute of Tibetan Plateau Research, Chinese Academy of Science (ITP-CAS) for sharing of information to strengthen databases of the region.
- For monitoring and assessment of changes in glaciers, snow, and glacio-hydrology in the HKH under the 'HKH Cryosphere Monitoring Project', with a special focus on strengthening the capacity of Nepalese organisations, agreement was signed with Kathmandu University, Nepal.
- With the purpose of promoting herbal gardens in schools in Nepal, agreement was signed with Environmental Camps for Conservation Awareness, Nepal.

Ayushma Rana Basnyat, ayrana@icimod.org
Farid Ahmad, faahmad@icimod.org

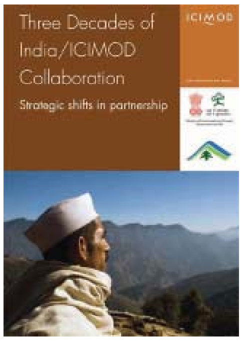
ICIMOD publications

The major documents published by ICIMOD from August to October 2011 are shown below. All publications can be downloaded free-of-charge from **www. icimod.org/publications**. Hard copy publications can be ordered from the Distribution Unit, distri@icimod.org. They can be provided free-of-charge to institutions actively involved in sustainable development of the greater Himalayan region.

General Publications



Green Economy for Sustainable Mountain Development: A concept paper for Rio+20 and beyond



Three Decades of India/ ICIMOD Collaboration: Strategic shifts in partnership

Video

Herbal Garden in Schools, 12 min. (Language: Nepali)

Newsletters

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Sustainable Mountain Development
Periodical publication from the International Centre for Integrated Mountain Development, Kathmandu

LCCN - 00227124

Editorial contact
ICIMOD Publications, info@icimod.org

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Issue coordinator
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Andrea Perlis (Senior editor)
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Photos: Cover - MODIS Satellite Image

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Printed by Hillside Press Pvt. Ltd., Kathmandu, Nepal

International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal
Tel +977-1-5003222 **email** info@icimod.org **web** www.icimod.org