Earth Observation – Taking the pulse of the Himalayas

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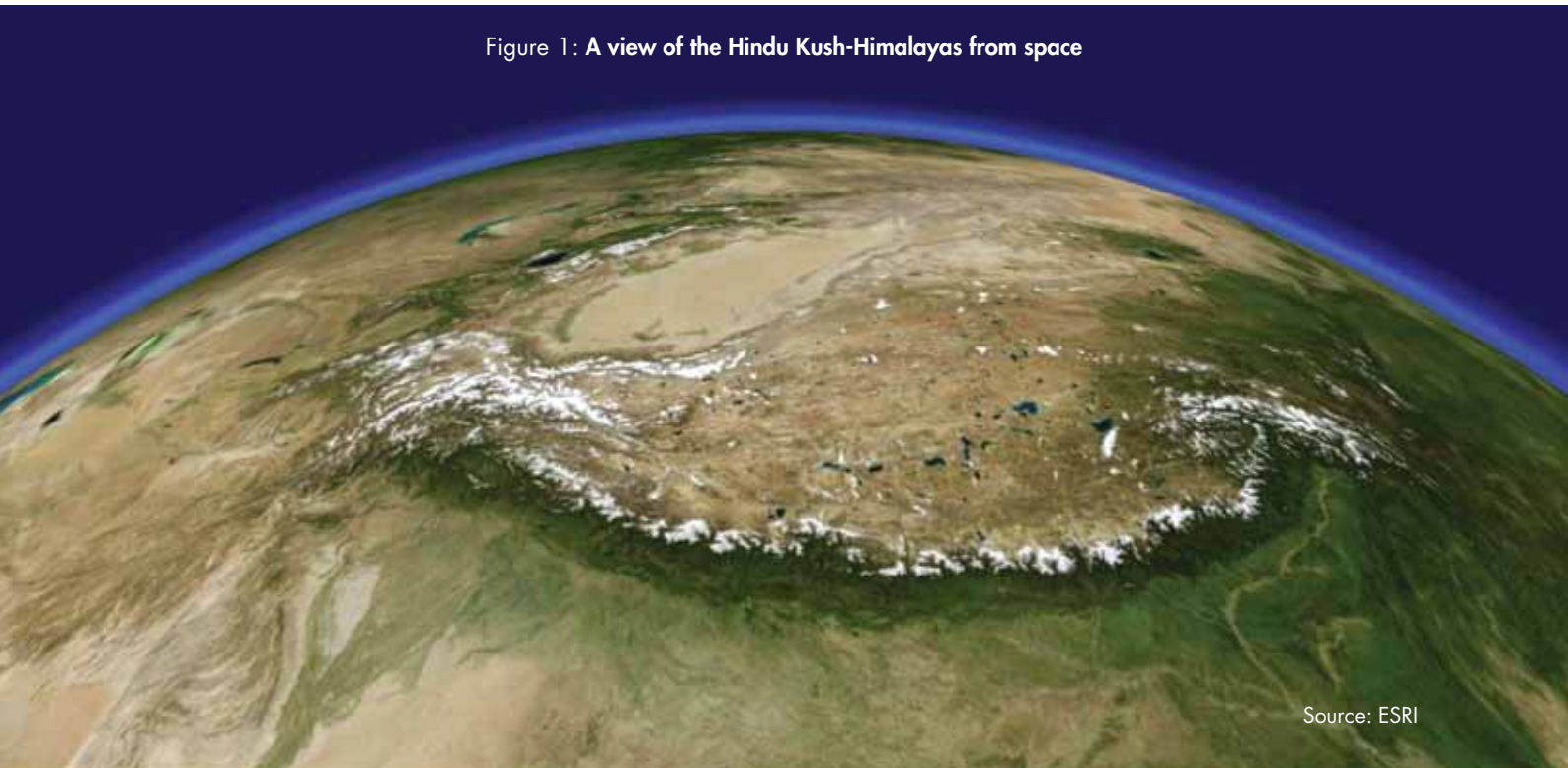
The Hindu Kush-Himalayan (HKH) (Figure 1) region is the youngest, the highest, and one of the most fragile mountain systems in the world. These mountains are the 'water towers' of Asia, providing water not only to the people in the immediate vicinity, but also to more than 1 billion people downstream. 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.

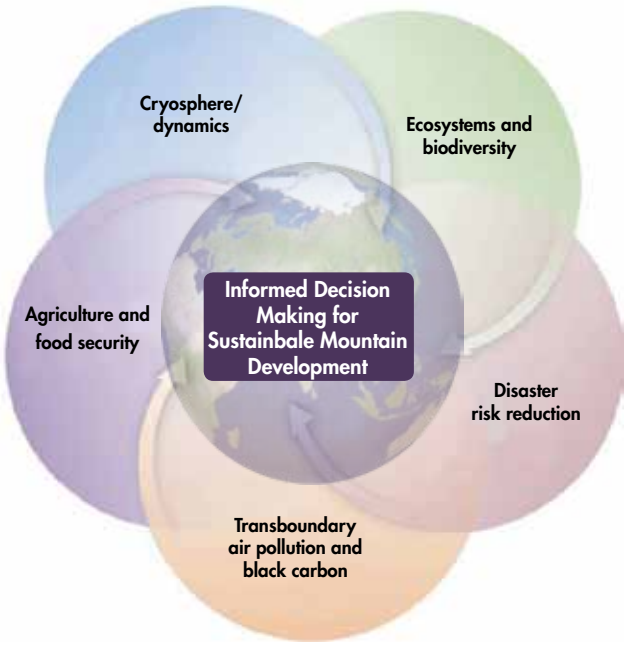
Mountain communities benefiting from Earth observation

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.