

The challenges of mountain environments: Water, natural resources, hazards, desertification and the implications of climate change

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1. Introduction

Mountain ecosystems are a biosphere reserve. They harbor a wide range of significant resources including animals, plants as well as minerals. Mountains are home to about 10 per cent of the global population. A significant high proportion of 25 - 30% directly depends on the resources flowing from mountain regions. Functionally, mountains play a critical role in the environment and economic process of the planet. The great economic importances are the uses of the mountains for forestry, horticulture, mineral extraction, livestock rearing, tourism, and recreation.

Although mountains and uplands constitute about 20 per cent of the earth's surface, it is difficult to find an area not affected by their environment. The most important influence is the hydrological cycle. Mountains act as orthographic barrier to the flow of moisture bearing wind and control the precipitation in the neighboring regions. For example, the Himalayas are fundamental importance to the occurrence of the monsoon in northern India, and of the continental arid conditions in Central Asia. In the upper regions of many mountains large volume of water are stored in the form of ice. Over 90 per cent of the earth's freshwater store is in ice and it is a most valuable natural resource. These provide the necessary melt flows into the rivers during the hot, dry seasons.

Before roads snaked up the mountains, an upland-lowland interaction was based primarily on the convenience of the upland community. The transactions involved the bare essentials. With the increasing population and transport facilities, natural resources and men moved down while the environmental degradation and social ills climbed uphill. Deforestation, land slides, land degradation, desertification, Glacier Lake Outburst Flooding (GLOF) are some of the common environmental issues in the mountain regions. Mountain areas are also more susceptible to natural hazards and disasters, such as avalanches, landslides, debris flow and flashing floods from landslide dam failure. History records of the loss of life from natural disasters show that more than 56 per

cent of the recorded total loss of life in the world is from mountains and adjoining regions. The major challenge that mountain environment face today is the escalation of these issues by atmospheric environmental issue.

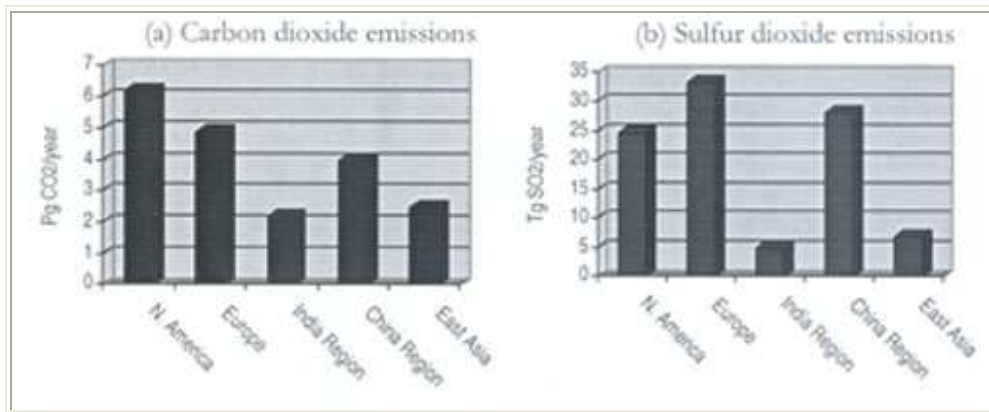


Figure 1: Estimated man-made CO₂ (A) and SO₂ (B) emissions. (India region: Bangladesh, Maldives, Sri Lanka, Myanmar, Nepal, Pakistan; China region: Cambodia, Vietnam, Laos, Mongolia, N-Korea; East Asia: Japan, S- Korea, Indonesia, Malaysia, Philippines, Thailand)
Source: UNEP and C4 (2002)

The emerging issues are impacts of global warming, aerosols and acidifying substances. Atmospheric environmental issues are results of emissions form industrial, transport and domestic sectors. Figure 1 shows emission estimates for carbon dioxide (CO₂) and Sulfur dioxide (SO₂) for different regions.

Mountain systems are more sensitive to climate changes. Small changes in climate can produce significant or larger-scale effects. Specially, the marginal environments are under high stress. Small changes to water availability, floods, drought, landslides and late frosts can have drastic effects on agricultural economy. Climate influence weathering process, erosion, sediment transport, hydrological conditions, rivers and canals. It also affects the type, quantity, quality, and stability of vegetation cover and thereby the biodiversity. This paper attempts to analysis the climate change (including other atmospheric environment issues) and its implications on mountain environment.

2. Climate Change and its Implications

2.1 Global warming

Planet's temperature is determined primarily by the amount of sunlight it receives, the amount of sunlight it reflects, and the extent to which its atmosphere retains heat. When sunlight strikes the earth, it warms the surface, which then radiates the heat as infrared radiation. However, greenhouse gases like CO₂ absorb some of the radiation rather than allowing it to pass through the atmosphere to space. This activity warms the earth in a manner somewhat

similar to the glass panels of a greenhouse, this phenomenon is generally known as the "*greenhouse effect*". Carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxides are most common greenhouse gases.

Since industrialization, human activities have resulted in steadily increasing concentrations of the greenhouse gases in the atmosphere, leading to fears of the enhanced greenhouse effect. Past records suggest that earth has warmed by 0.5 C o during the last century. An analysis of the temperature trend in the Himalaya and its vicinity (Shrestha et al., 1999) shows the temperature changes are higher in the uplands than lowlands (Figure 2).

Figure 2 present the spatial distributions of mean annual temperature trends over the period 1977-94 in Nepal. The mean annual maximum temperature trend distributions show warming in most part of the country. High mean annual temperature increases (greater than 0.06degree centigrade per year) occur in most of the northern belt (the Trans-Himalayan and Himalayan regions and central and western parts of the Middle Mountains). Within the Middle mountain region there are two pockets of anomalously high warming rate (greater than or equal to 0.12 degree centigrade per year): the western Middle Mountain region and the Kathmandu Valley. Most of the Siwalik and the Terai regions show considerably low increasing trends (less than 0.03 degree centigrade per year).

Climate change studies require climate data over long period of time. However, climate data for mountain regions is not complete, and records do not usually extend over long periods of time. The Alps has the longest records, extending for a century. Relatively dense networks exist for the Alps and parts of North America (Don Funnell and Romola Parish, 2001). Elsewhere, problems of access and finance have limited the efficiency of weather stations in places like Himalayas. Barry (1992) tabulated the principal observatories in the mountain regions. Nineteen out of thirty listed are in Europe and none in the Himalayan arc.

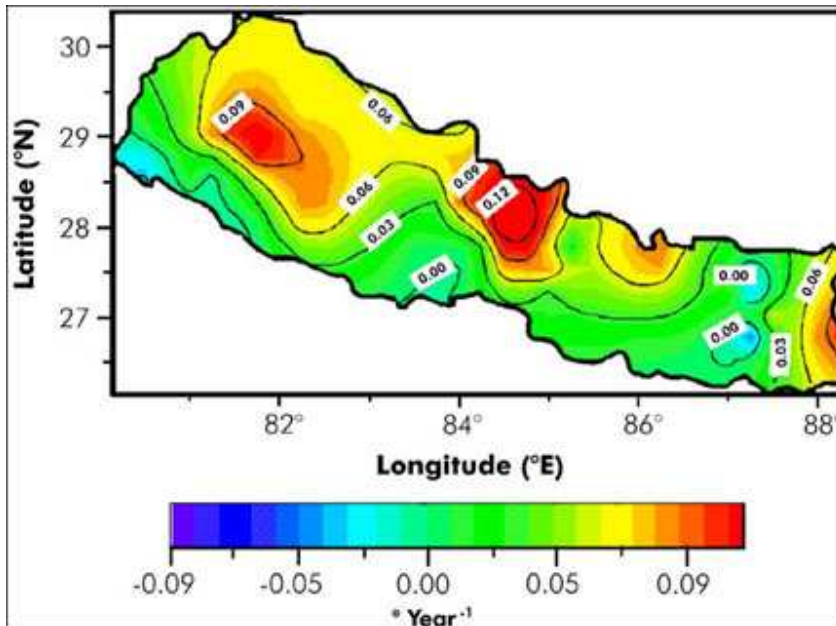


Figure 2: Spatial distribution of annual temperature change trends in Nepal from 1977 to 1994 (Shrestha et al., 1999)

2.2 Haze

A recent international study, the Indian Ocean Experiment (INDOEX) has revealed a brownish haze layer over the Indian Ocean almost 1,000 miles off the coast. Haze impact climate and environment in many different ways. Observational results and climate model studies (UNEP and C4, 2002) shows potentially large impacts of the haze layer in monsoon climate, water stress, agricultural productivity and human health. Its most direct effects include a significant reduction in the solar radiation reaching the surface; a 50 to 100 per cent increase in solar heating of the lower atmosphere; suppression of rain fall; reduction in agricultural productivity; and adverse health effects.



Figure 3: Photograph of the Asian Brown haze approximately 30 km south of Mt.

Everest, taken on March 25. Source: UNEP and C4 (2002)

Aerosols can directly alter the hydrological cycle by suppressing evaporation and rainfall. With respect to the agricultural changes, aerosols can directly impact productivity by shading the vegetation from solar radiation; and indirectly through the induced changes in temperatures and hydrological cycle.

Model simulations (UNEP and C4, 2002) shows that rainfall disruption is surprisingly large (Figure 4). This will be a concern for the mountain environment. Simulations also show Compensated drying during the wintertime over areas northwest of India and over the west Pacific. These precipitation change features are roughly consistent with the recent trend derived from observations.

The studies are very early stages of understanding the impact of haze on the regional climate changes, in particular, how regionally and seasonally concentrated climate forcing terms influence regional and global climate (UNEP and C4, 2002).

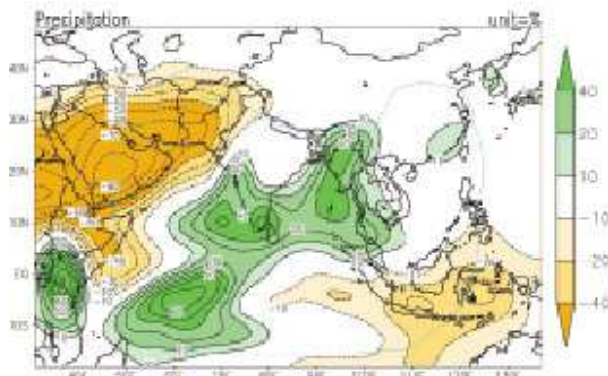


Figure 4: Simulated precipitation change (Jan - Mar) in units of percentage (Source: Chung et al., 2001)

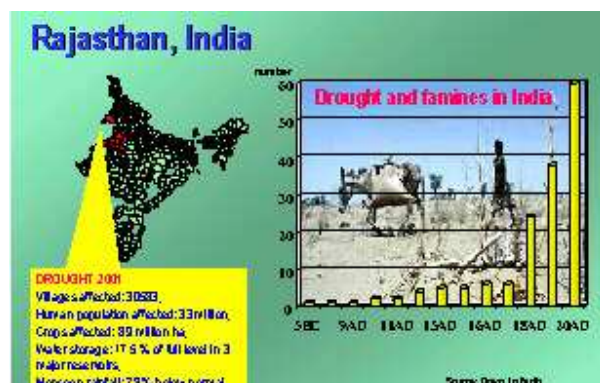


Figure 5: Recorded incidents of drought

Retreating glaciers, low water levels in lakes, worsening floods and decreasing lean season flows in rivers will not only affect mountains.

2.3 Implications on water system and hazards

Mountains are the water towers for the plains below them. The great rivers rise in the mountains. The European mountains, for example, provide about 50 per cent of the water for river systems. About three billion people in China, Southeast Asia, and South Asia are depending on the water towers of the Tibetan plateau.

Due to the climate change there have been major trends in the water system and hazards in recent years. These trends are obvious even to the most casual observers. Unpredicted river flows, and frequent floods, droughts and crop failures are becoming annual events.

Many high altitude lakes are potentially very dangerous. Moraine dams are comparatively weak and can break suddenly, leading to the sudden discharge of huge volumes of water and debris. These events are commonly known as glacial lake outburst floods (GLOFs). They can cause catastrophic flooding downstream, with serious damage to life, property, forests, farms, and infrastructure. In recent years, GLOFs have happened in Nepal, India, Pakistan, Bhutan, and China in the Himalayan region.

There are many examples of GLOFs with catastrophic effects in the Himalayan region. GLOFs occurred in the Lunana area of north-western Bhutan in 1957, 1969, and 1994, causing extensive damage to the Punakha Dzong (a complex that serves as both a religious and an administrative center). Five GLOF events are known to have occurred in Nepal between 1977 and 1998. In August 1985 a GLOF from the Dig Tsho (Langmoche) glacial lake destroyed 14 bridges and caused about US\$ 1.5 million worth of damage to the nearby completed Namche small hydropower plant. Studies have estimated that between 1935 and 1981 another six GLOF events originating from lakes in Tibet caused serious damage along Nepal's Koshi River basin (ICIMOD, 2001).

Due to sudden warming of weather, and snow and ice melting in the mountain areas of eastern Tibet and China, huge rapid landslide dammed the Yigong river on 9 April 2000. The Yigong river is one of the second order tributaries of the Yarlung river (upstream of the Brahmaputra river), after two months, on 10 June 2000, the outburst flood with 50 m high from the landslide dam extended 500 km downstream along the Palong and Yarlung river valleys to the state of Arunachal Pradesh, north-eastern India. The outburst flood and damages were on a scale seldom seen before in the region (Zhu and Li, 2001) (Figure 6)



Figure 6: An overview of erosion and landslides in the Palong river valley (a first order tributary of the Yarlung river) created by the flash flooding from the landslide dam failure on 10 June 2000 in the Yigong river valley, eastern Tibet, China (Photograph by Gary McCue)

In 1999, UNEP (United Nation Environment Program) in collaboration with ICIMOD (International Center for Integrated Mountain Development) took the initiative to document glaciers in Bhutan and Nepal. The study has identified 3,252 glaciers and 2,323 glacial lakes in Nepal and 677 glaciers and 2,674 glacial lakes in Bhutan. On the basis of actively retreating glaciers and other criteria, the potentially dangerous glacial lakes were identified (Figure 7 and 8) using the special and attribute database complemented by multi-temporal remote sensing and evaluation of the active glaciers.

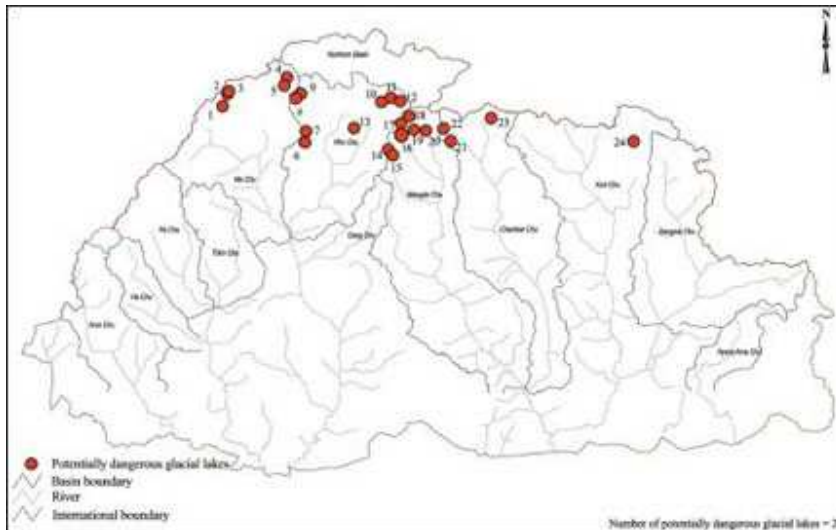


Figure 7: Identified potentially dangerous glacial lakes of Bhutan;
Source: ICIMOD and UNEP (2001)

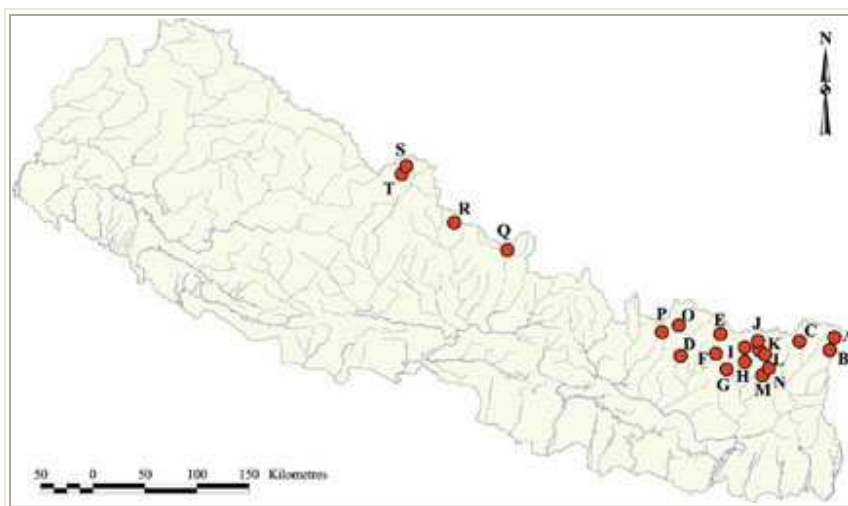


Figure 8: Identified potentially dangerous glacial lakes of Nepal;
Source: ICIMOD and UNEP (2001)

The study also confirm that groups of closely spaced supraglacial lakes of smaller size at glacier tongues merge as time passes and form bigger lakes. Tsho Rolpha Glacier Lake in Nepal, for example, is associated with many supraglacial lakes in the topographic map of 1974. The merging of supraglacial lakes in the Tsho Rolpha Glacial lake has formed a bigger lake in the topographic map of 1981, aerial photograph of 1992, and topographic map of 1996.

Some new lakes of considerable size are also formed at glacier tongues such as the lake at Lower Barun Glacier in Nepal. The lake is not visible in the topographic map published by the Survey of India in 1967. The lake is more

distinct and sufficiently large enough in the topographic map of 1996 published by the Department of Survey, Nepal. These activities of supraglacial lakes are indications that lakes growing rapidly and becoming potentially dangerous.

Apart from the hazards from GLOF, it is also reducing water reserves in the mountains. Therefore in long-term it will lead to lake of water flows in the rivers and thereby leads to drought, crop failure and poverty.

Current study by UNEP and ICIMOD has studied the glaciers in Bhutan and Nepal. However information about glaciers in other areas of Himalaya is still to be studied and documented with the similar methodology used in the Bhutan and Nepal study. It will lead to the development of early warning systems for the Hindu Kush-Himalayan region.



Figure 9: Successive development of the Tsho Rolpa Lake from 1957 to 2000

Source: ICIMOD (2000)

2.4 Implications on desertification

The formal definition of desertification adopted by the United Nations Convention on Desertification is "land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities". Inclusion of climate variation in the definition itself shows the influence of climate change in desertification. In general term desertification is the ability of the land to support the vegetation. Due to the climate change in mountain regions, altitudinal distribution of vegetation is

expected to shift to higher elevations. Some species limited to mountain tops could become extinct. Mountain resources that provide food and fuel for indigenous population may be disrupted in developing countries; recreational industries are also likely to be disrupted.

All agree that Chinese deserts are on the move. Dust storms came to Beijing once every 7 to 8 years in the 19950s', and only every 2 to 3 years in the 1970s'. But by the early 1990s', they were an annual problem.

Asiaweek, October 13, 2000

Deserts are likely to become hotter but not significantly wetter with the impacts of climate change on the water system. With the reduction of water flow from the mountain in the dry season, certainly the deserts will climb up the mountains. Warmer deserts could threaten desert species living near the limit of their heat tolerance. Desertification is more likely to become irreversible if the environment is drier and the land is further degraded through erosion by high intensity precipitations.

3. Existing policy and practices

Most of the national governments have established national institutions for sustainable development to cope with environment challenges. Mountain issues are part and parcel of the national environmental issues and tackled together. In addition, mountain initiatives are now in the process of being increasingly coordinated between countries under transboundary provisions. This is because of the fact that many mountain ranges are divided by national boundaries but their utilities and management involves cross-national links. A good example of this is the activities of ICIMOD in the Hindu-Kush Himalayan region. The center was inaugurated in December 1983 and provides coordinating role in the Hindu-Khus Himalayan region. It has been responsible for initiating research projects and conferences.

Mountain agenda published in 1992 provides recommendations for action that emphasize improving the level of knowledge about mountain systems, encouraging existing mountain communities in their efforts to develop sustainable livelihoods, and to improve international cooperation. Recognizing the challenges of the mountains, mountain areas were given their own special section in the Agenda 21: Chapter 13, under the heading "managing Fragile Ecosystems: sustainable mountain development". FAO was designated as Task Manager for Chapter 13, and there have been a number of significant developments including the publication of a revised policy brief by the Mountain Agenda (1997), along with the detailed studies (Messerli and Ives, 1997). Although the national and international efforts are essential to improve the sustainable management of natural resources in mountain areas, it is also necessary to tackle the emerging challenges from the atmospheric

environmental issues. Since the atmospheric environmental issues are transboundary in nature, it can only be addressed through intergovernmental cooperation. The "Convention on Long-range Transboundary Air Pollution" for Europe, "Malé Declaration on Control and Prevention of Air Pollution and Its Likely of Transboundary Effects for South Asia" for South Asia, and "East Asian Network on Acid Depositions" (EANET) for East Asia are good examples of regional co-operations for tackling the atmospheric environmental issues.

At the international level vigorous response to climate change, involving research, discussions, planning and implementation, was started in 1988 with the establishment of Intergovernmental Panel on Climate Change (IPCC) by UNEP and WHO (World Health Organization). This has resulted in the 1992 Convention on Climate Change and the 1997 Kyoto Protocol. This incorporates legally binding targets for the reductions in emissions of greenhouse gases. In order to meet these targets, a number of flexible mechanisms have also been developed.

4. Recommendations for Actions

Mountain issues cannot be separated from the issues and activities in the lowland area, specially, in the presents of emerging atmospheric environmental issues like climate change. Atmospheric issues will be the major challenge for the mountain and its natural resources in the formidable future. This section recommends some key actions to tackle the Climate change and its implications in the mountain environment.

Scientific studies: A more complete picture of the roles and interactions of greenhouse gases, aerosols and ozone are urgently needed. Problems such as haze, smog, and acid deposition fall under the general category of air pollution. The aerosols and high level ozone that results from rural and urban air pollution are part of the global warming issue since they could induce climate change by altering the radiative balance of the planet. Their presence can also have ecosystem impacts, notably on vegetation. Thus, there is a need to assess the impacts under one common framework.

Early warning systems: In order to cope with the hazards like GLOF, early warning systems could be developed and implemented using a multi-stage approach, multi-temporal data sets, and multi-disciplinary professionals. Focus should first be on the known potentially dangerous hotspots. Monitoring, mitigation, and early warning system program development and implementation involve several phases. Box 1 provides the proposed phases for GLOF monitoring and early warning systems.

Regional cooperation: It can be said that mountain issues cannot be tackled by the mountain community or by individual countries alone. Specially, because of the emerging challenges from the atmospheric environmental issues.

Partnership between the existing institutions and programs on mountain issues and atmospheric environmental declarations is vital to tackle the issues together.

Observatories: Under the framework of regional declarations, observatories could be established not only for air quality monitoring but also meteorological as well as aerosol monitoring in the mountain regions. Together with satellite observations, data from these observatories should provide critical coverage to understand the long-term building up of atmospheric environmental issue like brown haze layer over the South Asia.

Dissemination of Scientific findings: Development and distribution of relevant educational material and information on climate change and its implications on mountain environment and socioeconomic consequences is also vital in order to move the policy cycle.

Box 1

Possible steps for GLOF monitoring, mitigation, and early warning system in Nepal.

(Source: ICIMOD and UNEP, 2001)

- Detailed inventory and development of a spatial and attribute digital database of the glaciers and glacial lakes using reliable medium- to large-scale (1:63,360 to 1:10,000) topographic maps
- Updating of the inventory of glaciers and glacial lakes and identification of potentially dangerous lakes using remote-sensing data such as the Land Observation Satellite (LANDSAT) Thematic Mapper (TM), Indian Remote Sensing Satellite (IRS)1C/D Linear Imaging and Self Scanning Sensor (LISS)3, Système Probatoire d'Observation de la Terre (SPOT) multi-spectral (XS), SPOT panchromatic (PAN) (stereo), and IRS1C/D PAN (stereo) images.
- Semi-detailed to detailed study of the glacial lakes, identification of potentially dangerous lakes and the possible mechanism of a GLOF using aerial photos.
- Annual examination of medium- to high-resolution satellite images, e.g. LANDSAT TM, IRS1D, SPOT, and so on to assess changes in the different parameters of potentially dangerous lakes and the surrounding terrain
- Brief over-flight reconnaissance with small format cameras to view the lakes of concern more closely and to assess their potential for bursting in the near future
- Field reconnaissance to establish clearly the potential for bursting and to evaluate the need for preventative action
- Detailed studies of the potentially dangerous lakes by multi-disciplinary professionals
- Implementation of appropriate mitigation measure(s) in the highly potentially dangerous lakes
- Regular monitoring of the site during and after the appropriate mitigation measure(s) have been carried out
- Development of a telecommunication and radio broadcasting system integrated with on-site installed hydrometeorological, geophysical, and other necessary instruments at lakes of concern and downstream as early warning mechanisms for minimizing the impact of a GLOF
- Interaction/cooperation among all of the related government departments /institutions /agencies /broadcasting media, and others for detailed studies, mitigation activities, and preparedness for possible disasters arising from GLOF events.

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Notes to readers

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