Unclassified **ENV/EPOC/GF/SD/RD(2004)6/FINAL**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

07-Feb-2005

English - Or. English

ENVIRONMENT DIRECTORATE
Environment Policy Committee

Global Forum on Sustainable Development

RECENT TRENDS AND POTENTIAL CLIMATE CHANGE IMPACTS ON GLACIER RETREAT/GLACIER LAKES IN NEPAL AND POTENTIAL ADAPTATION MEASURES

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Paris, 11-12 November 2004

JT00178097

ENV/EPOC/GF/SD/RD(2004)6/FINAL
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Madan Lall Shrestha[2], Arun Bhakta Shrestha[3]

Abstract

There is a general consistency among climate models projections on temperature increase in the Himalayan Region. In contrast, projections of precipitation and runoff are not consistent. The observed trends in temperature and precipitation in Nepal are in agreement with the model predictions.

The warming is probably already having its impact on the bio-physical environment of the region. One example of such impact is the widespread deglaciation of the Himalayan glaciers, as suggested by studies on fluctuation of glaciers in the Nepal Himalaya conducted in past decades. Depletion of glaciers and variations in precipitation regime could have serious impacts on the Himalayan hydrology. Runoff data from several hydrological stations, although, does not yet suggest consistent trends. Nevertheless, some indications of increase in the number of flood days and consecutive days of flood events are found. Another important aspect of Himalayan deglaciation is the formation and growth of several glacier lakes and possibility of their outburst floods.

The study finds the water resources sector of Nepal vulnerable to climate change. Serious planning and implementation of adaptation strategies and mitigation options in the sector are urgently needed. Some adaptation measures applicable to the country are suggested.

1. Introduction

Mountainous environments, especially glaciers are considered to be sensitive indicators of climate change (Barry, 1990; Stone, 1992; Beniston, 1994). Several studies in the Himalayas have found that glaciers in the region have retreated considerably in the last two decades (Miller, 1989; Miller and Marston, 1989; Yamada et al., 1992; Kadota et al., 1993). Recent studies have identified the formation and growth of several glacial lakes possibly due to fast retreat of glaciers, which could lead to catastrophic outburst floods (Vuichard and Zimmermann, 1987). It is therefore important to know the present condition of glacier in the Himalaya and their relationship with climatic trends. Unfortunately, such studies are limited in the Himalayan region, mainly due to lack of baseline data. Present report attempts to review

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[1] *Suggested citation:* Shrestha, Madan Lall and Arun Bhakta Shrestha (2004), *Recent Trends and Potential Climate Change Impacts on Glacier Retreat/Glacier Lakes in Nepal and Potential Adaptation Measures,* paper presented at the OECD Global Forum on Sustainable Development: Development and Climate Change, ENV/EPOC/GF/SD/RD(2004)6/FINAL, OECD, Paris.

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The opinions expressed in this paper are those of the individual authors and do not necessarily reflect the views of their organisations or of the OECD.

climate scenarios as projected by climate models. A summary of observation results is also presented. Further this paper reviews glacier fluctuation in Nepal, trends in stream flow and glacier lakes.

2. Results and discussion.

2.1 Climate change projections

Intergovernmental Panel on Climate change (IPCC) provides a comprehensive review of climate models results in terms of temperature and precipitation projections (IPCC, 2002). Atmosphere Ocean Coupled General circulation Models (AOGCM) show greater than average warming in the South Asian Region in summer. There is a general consistency among the models in their output for winter while the agreement is less for summer. The mean temperature increase for the period 2071 to 2100 relative to the period 1961 to 1990 is about 4 ^{o}C for Special Report on Emission Scenario (SRES A2) and about 3 ^{o}C for SRES B2. In contrast, the consistency among models in precipitation predictions, as well as the significance of projected changes are low both for the winter as well as summer seasons.

Organization for Economic Co-operation and Development (OECD) performed assessment of 12 recent general circulation models (OECD, 2003). The best 7 GCMs were run with the SRES B2 scenario. The result also show significant and consistent increase in temperature projected for Nepal for the years 2030, 2050 and 2100 across the various models. This analysis also shows somewhat larger warming in winter months than the summer months. It also agrees with the study on climate change assessment conducted with US country studies programme (Shrestha,1997). The projected change above the baseline average is 1.2 ^{o}C for 2030, 1.7 ^{o}C for 2050 and 3.0 ^{o}C for 2100. This analysis also agrees with the IPCC analysis in the projection of precipitation change, i.e. less significant change and high standard deviation among the model results.

Similar analysis done for Nepal under the National Communication for United Nations Framework convention on Climate Change (UNFCCC) is also in somewhat agreement with IPCC and OECD results (MoPE, 2004).

Model predictions on the effect of climate change on stream flow, varies regionally and between climate scenarios, largely following projected changes in precipitation. In South Asia, HadCM3 shows increase in annual runoff ranging from 0 to150 mm yr^{-1} by the year 2050, relative to average runoff for the period 1961-1990, while the older version, HadCM2 projects decrease of upto 250 mm yr^{-1}. These climate models are unable to highlight the details on seasonal variations in runoff, although it is generally suggested that due to higher evaporation and decrease in glacier mass, the low flows are likely to decrease (IPCC, 2001).

2.2 Observed climatic trends in Nepal

Analyses of observed temperature and precipitation data in Nepal are limited. One of the reasons behind this is the relatively short length of records, about 30 years. From available studies, it has been found that temperatures in Nepal are increasing at a rather high rate. The warming seems to be consistent and continuous after the mid-1970' the average warming over the country in annual average maximum temperature is between 1977 and 1994 was 0.06 ^{o}C yr^{-1} (Shrestha et al., 1999). The warming is found to be more pronounced in the higher altitude regions of Nepal such as middle-mountain and Himalaya, while the warming is significantly lower or even lacking in Terai and Siwalik regions. Further, warming in the winter is more pronounced compared to other season (Table 1). In this sense the trends in observational data is in agreement with projections made by climate models.

Similar analysis on precipitation data does not reveal any significant trends, although precipitation in Nepal is found to be influenced by or correlated to several large scale climatological phenomena, including El Niño (Shrestha et al. 2000).

Warming similar to that observed in Nepal is also observed in Tibetan Plateau. Liu et al. (2002) have shown that in Tibetan Plateau warming is more pronounced in higher altitude stations than in lower ones. In contrast, the widespread area of lowland India does not show significant warming. It is suggested that Himalaya and Tibetan Plateau being elevated regions of the globe, is sensitive to and is affected by climate change.

A study (Shrestha,2004) conducted in the central Nepal clearly indicates the significant increase in extreme rainfall events in the recent decade (1991-2000) by three fold compared to 1971-19980 decade.

2.3 Glacier fluctuation

There are 3252 glaciers in Nepal covering a total area of 5323 sq. km. (ICIMOD/UNEP, 2001; Fig. 1). Since glaciers are excellent indicators of climate change (e.g. Oerlemans, 1989; Oerlemans, 1994), the Nepalese glaciers provide good opportunity to study the impact of global climate change in this region. Unlike in the mid-latitudes, the glacier mainly in Central and Eastern Himalayas are of typical character with accumulation and ablation occurring in the same season during Asian summer monsoon season (June-September). The glaciers of Nepal are important storage of freshwater as they accumulate mass in monsoon and winter at higher altitude and provide melt-water at lower elevations. The melt-water contribution of glacier is particularly important during dry seasons to maintain river flow. The importance of glacier is not limited to Nepal as all rivers flowing through Nepal finally flow into the Ganges. It has been estimated that contribution of Nepalese rivers to the discharge of Ganges is up to 70% during dry seasons (e.g. Alford, 1992). Any significant change in the glacier mass is therefore certain to have impact on water resources in a regional scale.

Glacier study in a regular basis started in Nepal started in early-1970s. Since then several glaciers in Hidden Valley of Dhauligiri Region, Langtang Region, Khumbu Region and Kanchenjunga Region have been studied (Fig. 1). These studies include, topographical survey of the glaciers, mass balance studies and photogrametric study of the terminus location. Some result of the glacier fluctuation studies are presented below.

2.3.1 Shorong Himal

Glacier AX010 in the Shorong Himal (27°42' N, 86°34' E; Fig. 2) is one of the most studied glaciers in Nepal. Changes in glacier terminus area have been monitored intermittently between 1978 and 1995 and every year thereafter until 1999. The aerial extent of the glacier was measured intermittently in 1978, 1996 and 1999 by topographical survey (Fujita, 2001). The changes in the glacier area and terminus retreat are shown in Figure 2. The retreat from 1978 to 1989 was 30 m. the retreat in the terminus position is due to depletion of ice mass in the glacier, which is equivalent to 12 m thinning of the whole glacier surface. Kadota and Ageta (1992) used these results to establish relation between climate and the retreat of the glacier. They applied simple model using climate (temperature and precipitation) data from non-glacierized area (Chialsa and Kathmandu). According to the analysis the surface air temperature around the glacier terminus increased less (0.1 ^{o}C yr^{-1}) than in the non-glacierized area (0.2-0.4 ^{o}C yr^{-1}) or higher effect of temperature increase was off-set by underestimate of winter snowfall during the study period. Kadota et al. (1997) reapplied the model with additional data and found that the retreat after 1989 is much larger than for the period 1978-1989 and derived higher surface temperature at the glacier terminus (4958 m a.s.l.; +1.4 ^{o}C). The study predicted shrinking tendency to continue and accelerate in the future even if climate condition remains unchanged. Recently Galcier AX010 was resurveyed. The results of the the survey showed that the glacier surface is remarkably close to what was predicted by Kadota et al. (1997; Fig. 3). The glacier terminus has further retreated by 14 m after 1999 (Figure 4).

2.3.1 Khumbu Region

Khumbu Glacier is a large debris covered glacier in the Khumbu Region, about 15 km long, which drains mainly from the West Cwm between Mt. Everest and Lohtse. The bare ice zones (ice pinnacles) in the glacier are gradually shrinking (Seko et al., 1998). The surface of the glacier lowered about 10 m throughout the debris-covered ablation area in the period 1978-1995 (Kadota et al. 2000). Indication of slowing down of ice flow was also detected, which means the shrinkage may accelerate even if ablation condition remains unchanged. Naito et al. (2000) developed a model coupling mass balance and flow dynamics of debris covered glaciers and applied it to Khumbu Glacier. The model predicts formation and enlargement of depression in the lower ablation area about 5 km upstream of the terminus. This depression could transform into a glacier lake in future.

Yamada et al., (1992) reviewed terminus fluctuation of seven clean type glaciers in Khumbu for the period 1970's to 1989. Majority of the glaciers have retreated in the range of 30 to 60 m in the observed period.

2.3.2 Langtang Region

In Langtang region the studies mainly concentrated on Yaya glaciers and Lirung glaciers in terms of glacier fluctuation. Yala glacier has been studied in detail. The terminus of Yala glacier was surveyed in 1982 (Ageta et al. 1984). The glacier fluctuation was studied both by photogrametry and ground survey. Fujita et al. (1998) conducted survey of Yala glacier terminus in September 1994, May and October 1996 and found that the retreat rate and surface lowering has accelerated in recent years

Transverse profile of Lirung glacier, with debris covered lower part was surveyed in 1987 and in 1989. There is no major change in the profile, however, photographs taken at different times show clear retreat of the glacier (Fig. 5). There is an indication that the upper steep part and lower flatter part will separate in near future. Data from a station close to the glacier shows that the annual temperature rising at the rate of 0.27 ^{o}C yr^{-1} . However, this is quite high rate and the relatively short record length (1988-2002) may not provide true judgment of the climatic trends prevailing in that region.

2.3.4 Dhaulagiri Region

Rika Samba Glacier (28^{o}50' N 83^{o}30' E) is the most studied glacier in Hidden Valley, Kali Gandaki Basin. The terminus position was surveyed initially in 1974 (Nakawo et al. 1976) and thereafter intermittently in 1994 (Fujita et al. 1997), 1998 and 1999 (Fujita et al. 2001). Photographs taken at different years and topographical survey of the glacier show clear retreating condition of the glacier (Fig. 6,7). The glacier terminus retreated by 200 m in the period between 1974 and 1994 . A study on temperature trends at 7 stations in Kali Gandaki Basin showed warming in average 0.025 ^{o}C per year (Shrestha, 2004).

Besides Rika Samba, glaciers termini altitudes of six other glaciers in the region were measured in 1994 using altimeter and was compared with those found in 1974 (Fujita, 1997). It was found that glacier retreat was a general trend in Hidden Valley.

2.3.5 Kachenjunga Region

Asahi et al. (2000) studied glacier fluctuation in Ghunsa Khola basin of Kanchenjunga area. Based on aerial photo interpretation and field observation he identified clear morphological changes suggesting glacier variation in the region during various stages in the past. From younger to older he classified these stages as, historical stage (around the early part of the 20th century), Little Ice Age, the Holocene, and the late and early sub-stages of the Last Glaciation. Further, a comparison of the 1992 glaciers with those of 1958 in the area revealed that out of 57 glaciers, 50% of them has retreated in the period from 1958 to 1992. Also, 38% of the glaciers were under stationary conditions and 12% were advancing.

2.4 River discharge

More than 6000 rivers and rivulets flow over Nepal. A comprehensive analysis of trends in river flow has not been performed yet. A preliminary analysis of river discharge was carried was. For this, trends in rivers of three categories: large outlet rivers, southern rivers and snow fed rivers were examined (Fig. 8). Among the large rivers, Karnali and Sapta Koshi show decreasing trend although the record of Sapta Koshi is quite short. In contrast another large river, Narayani shows increasing trend. The southern rivers do not show any trend. All of the three snow fed rivers (Kali Gandaki, Dudh Kosii and Tamor) examined here show declining trend in discharge. It is clear that trends observed in the river discharge are neither consistent nor significant in magnitude. It has to be noted the ambiguity is due to short record length and high inter-annual variability in discharge data.

A separate study suggests that the number of flood days and consecutive days of flood events are increasing (Shrestha et al., 2003).

2.5 Glacier lakes and their outburst floods

There are 2315 glacier lakes of varies sizes, the total area of which is 75 sq. km. (ICIMOD/UNEP, 2001; Fig. 1). The formation and growth of glacier lakes is a phenomenon closely related to the deglaciation. Valley glaciers generally contain supra-glacial ponds. These ponds, while increasing in size merge with each other to grow bigger. This process is accelerated by rapid retreat of glaciers. During Little ice Age (1550-1850 AD) the glaciers were much longer than today (Yamada et al., 1998). As the glacier retreat it leaves a large depression, which turns into lakes. The lakes are generally blocked in the front by moraines, which are structurally weak and unstable and undergo constant changes due to slope failures, slumping, etc. and possess the danger of catastrophic failure, causing glacier lake outburst floods (GLOFs). Principally, a moraine dam may break by the action of some external trigger or self-destruction. A huge displacement wave generated by rockslide or snow/ ice avalanche from glacier terminus into the lake may cause the water to overtop the moraines, create a large breach and eventually cause the dam failure (Ives, 1986). Earthquakes may also be one of the factors triggering dam break depending upon its magnitude, location and characteristics. Self-destruction is caused by the failure of the dam slope and seepage from the natural drainage network of the dam.

A GLOF is characterized by a sudden release of a huge amount of lake water, which in turn would rush down along the stream channel downstream in the form of dangerous flood waves. These floods waves comprise of water mixed with morainic materials and cause devastating consequences for downstream riparian communities, hydropower stations and other infrastructure. The severity of flood wave depends upon the amount of water released, debris load and on basin characteristics of the watershed. Discharge rates of such floods are typically several thousand cubic meters per second.

The record of past disastrous GLOF event in Nepal is shown in Table 2. Although GLOF event is not new in Nepal, it has attracted the attention of the scientific community and government only when a disastrous GLOF occurred at Dig Tsho Glacier Lake on 4 August 1985 in the Langmoche valley of Khumbu region in eastern Nepal 1985 (Ives, 1986; Yamada, 1998). It had caused serious damage to the nearly completed Namche Hydropower Project, washed away big area of cultivated land, bridges, houses including livestock and inhabitants along its path downstream. The flood waves lasting for about 4 hours released about 6 to 10 million cubic meter of water (Ives, 1986). Since then, His Majesty's Government of Nepal (HMGN) has considered GLOF as a threat to the development of water resources of the country and has given attention to GLOF studies.

Tsho Rolpa is the largest glacier lake in Nepal occupying an area of 1.76 km^2. This lake was in the form of a cluster of small supra-glacier ponds in the late-1950, which merged and grew to its present stage (Fig. 9). Based on rapid growth of the lake, rapid degradation of terminal and lateral moraines holding lake water, melting of fossil ice inside the moraine, seepage of lake water from end moraine, and rapid ice calving from glacier terminus these studies suggested high risk of GLOF from Tsho Rolpa Lake. This is the only lake in Nepal, where some mitigation work and early warning scheme has been implemented (Rana et al., 2000; Shrestha et al., 2001). Realizing the imminent of GLOF from Tsho Rolpa a GLOF risk reduction project was initiated in 1998. This included cutting of an open channel through the end moraine to lower the water level by 3 m. The other glacier lakes listed a dangerous are Imja, Lower Barun and Thulagi Lakes. ICIMOD/UNEP (2001) identified altogether 20 lakes in Nepal as potential dangerous lakes (Table 3), although many of these need field verification.

Mitigation work is extremely expensive and it is not possible to implement mitigation work in all dangerous lakes. Moreover, mitigation work cannot completely exclude possibility of GLOF. It is certain that GLOF will have strong negative impact on the development efforts of Nepal, especially in the water resources sector.

2.6 Adaptation and mitigation measures

While the discharge records do not show concrete evidence of impact of climate change, it is rational to plan ahead in case impact does occur in the future. Some generic adaptation may also be applicable for Nepal. They include: proper management of the water resources system; promotion of indigenous and sustainable technologies, etc. But for the case of Nepal some specific "no regret" adaptation measures may be proposed.

1. Storage system: Majority of the water resources system, especially hydropower system are based on run-off-the-river scheme. These schemes are particularly vulnerable to changes in river flow. One way to cope with this problem is to develop storage type water resources system. This will enable to store excess runoff water and use them during dry seasons.

2. Integrated approach: This measure complement the measure mentioned above. Integrated water resources management is best implemented with storage system. It is easier to cope with the impact of climate change as the direct risk is distributed among different sectors.

3. Flexibility in operation: The water resources schemes can be designed with certain flexibility in operation. For example, hydropower with flexible head will operate better under climate change scenarios. Power stations with multiple smaller units operate better under changed runoff conditions compared to few larger units. Same principle can be applicable for irrigation schemes also.

4. Larger rivers compared to smaller rivers: Larger rivers have more sustained flow and the inter-annual variability is less. It is therefore better to shift area of project areas to larger rivers. Larger rivers have greater capacity to allow large floods as GLOF. This measure will certainly have some cost implication as construction in large river demands more infrastructures.

5. Design consideration specific to GLOF: A water resource scheme can be design with specific consideration to GLOF. The powerhouse can be designed under ground, which has more

protection against GLOF. The tailrace may be adequately protected against flood wave. The storage may be design to cater excessive sediment deposition due to GLOF debris.

6. Early warning and protection system: As GLOF and rainfall-runoff floods are imminent to occur, early warning systems are inevitable. Appropriate early warning systems have to be developed along rivers those are likely to experience floods. In addition to warning systems flood shelters, escape routes, emergency supply systems, rescue systems have to be adequately developed.

7. Flood protection measures: Flood protection embankments may be necessary in some areas, especially in low lying Terai.

8. Draining of potentially dangerous glacier lakes: timely draining of dangerous glacier lakes is the best way to avoid GLOF. There are several ways to drain lakes. In Nepal there is the experience of lowering Tsho Rolpa Lake by 3 m. This measure, although is the most effective, has a very high cost implication.

3. Summary and conclusion

Climate Model results are highly variable concerning projections for the south Asian region. The projections on temperature change is more or less consistent and significant with projected mean temperature increase of 1.2 and 3 ^{o}C by 2050 and 2100 and 2.3 to 4.3 ^{o}C at 2CO_2. Overall increase in precipitation is projected; the magnitude of change is low. Change in runoff projections generally follows precipitation although highly it is variable with model.

Observed trends in temperature generally agree with climate model results and show significant warming in last decades. More warming is observed in high altitudes compared to low land. No significant trend is found in precipitation except in the central Nepal. Both temperature and precipitation are found to be related to large scale climatological phenomenon.

There is an overwhelming evidence of deglaciation in the Himalayas. As glaciers are important source of water to the rivers of Nepal as well as India especially during dry seasons, widespread deglaciation is certain to have an impact of regional scale. Preliminary analysis of river flow data, however, does not show any consistent trend. This could be due to rather short length of discharge records. As runoff variation is directly related to glacier condition, continued deglaciation is certain to have impact on runoff in the future. However the variation in runoff is dependent on the stage of deglaciation. In the initial stage there is an increase in discharge due to accelerated melting. Later, as the ice-mass is depleted the flow is likely to decline. It is not yet clear which stage of deglaciation we are currently in. It is therefore wise to prepare for the worse. Furthermore, it is obvious that GLOF is a problem to water resource development. It is timely to make vulnerability assessment of different development sectors and devise Adaptation Plans. Some "no regret" adaptation measures may be implemented in the near future.

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ANNEX

Figure 1. **Map showing locations of different areas of glacier study**

The background map shows glaciers and glaciers lakes of Nepal according to ICIMOD/UNEP (2001).

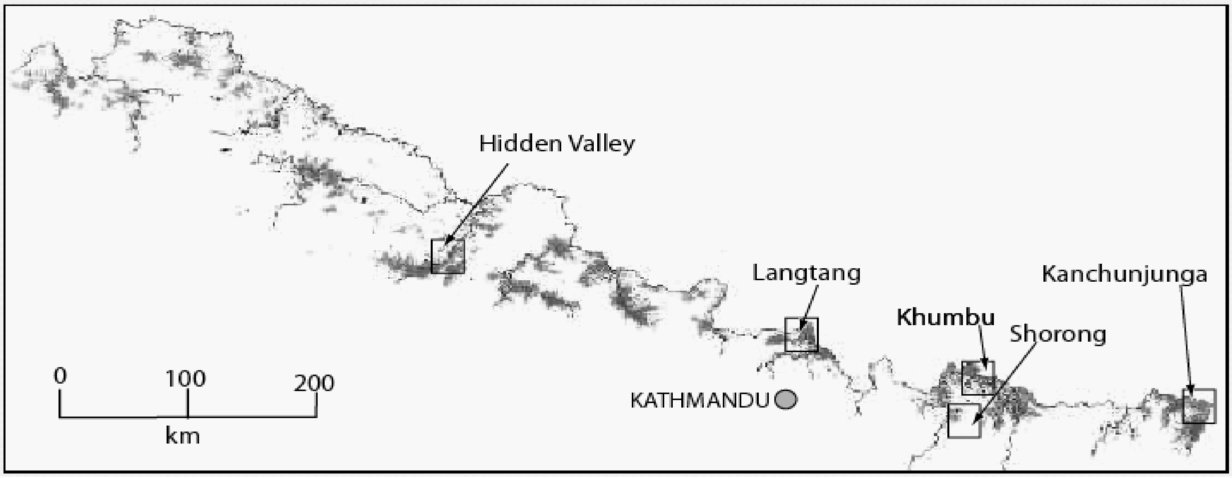

Figure 2. **Retreat of glacier AX010**

Top: Map showing the changes in the glacier area. Bottom: The changes in the glacier area and the rate of terminus retreat.

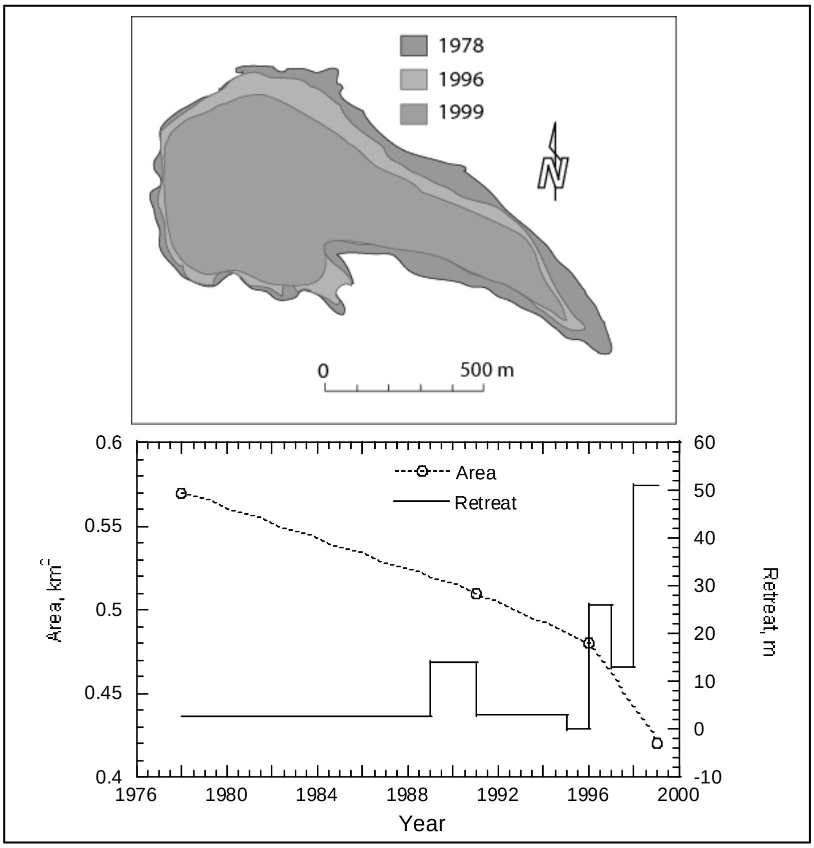

Figure 2. **Comparison between the glacier profile predicted by Kadota et al. (1997) and the survey of summer 2004.**

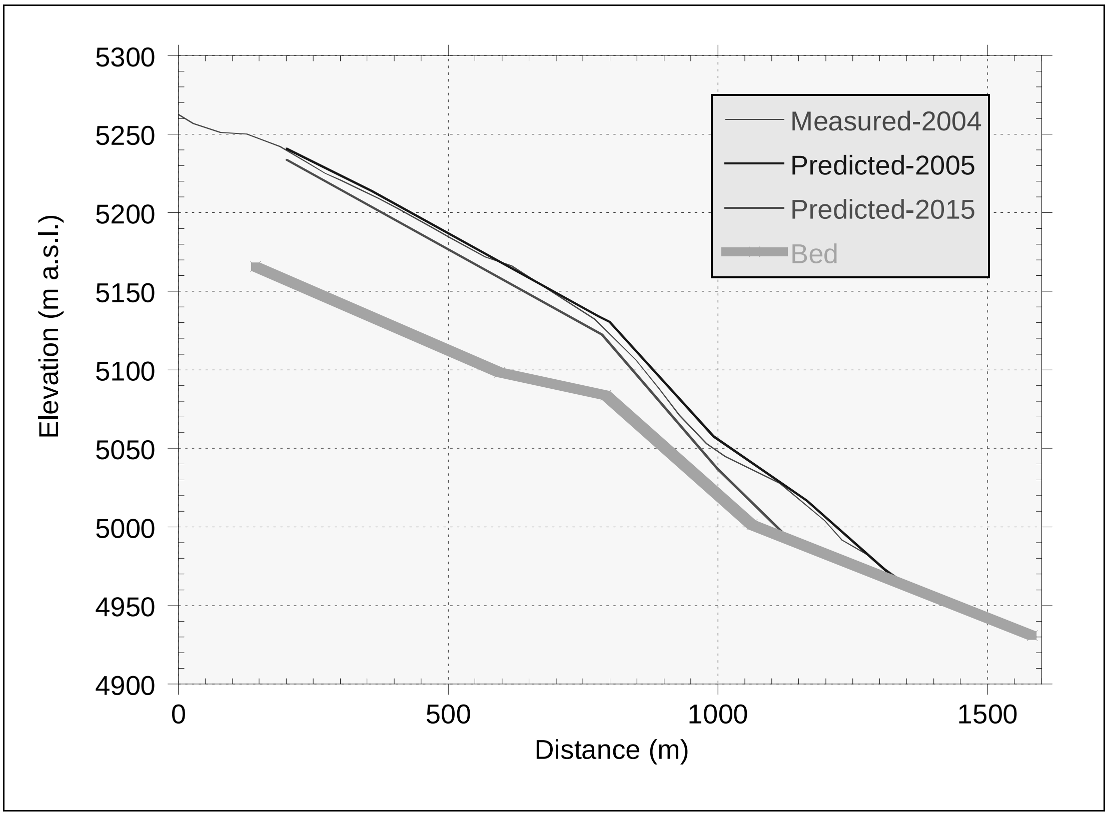

Figure 4. **Changes in glacier AX010**

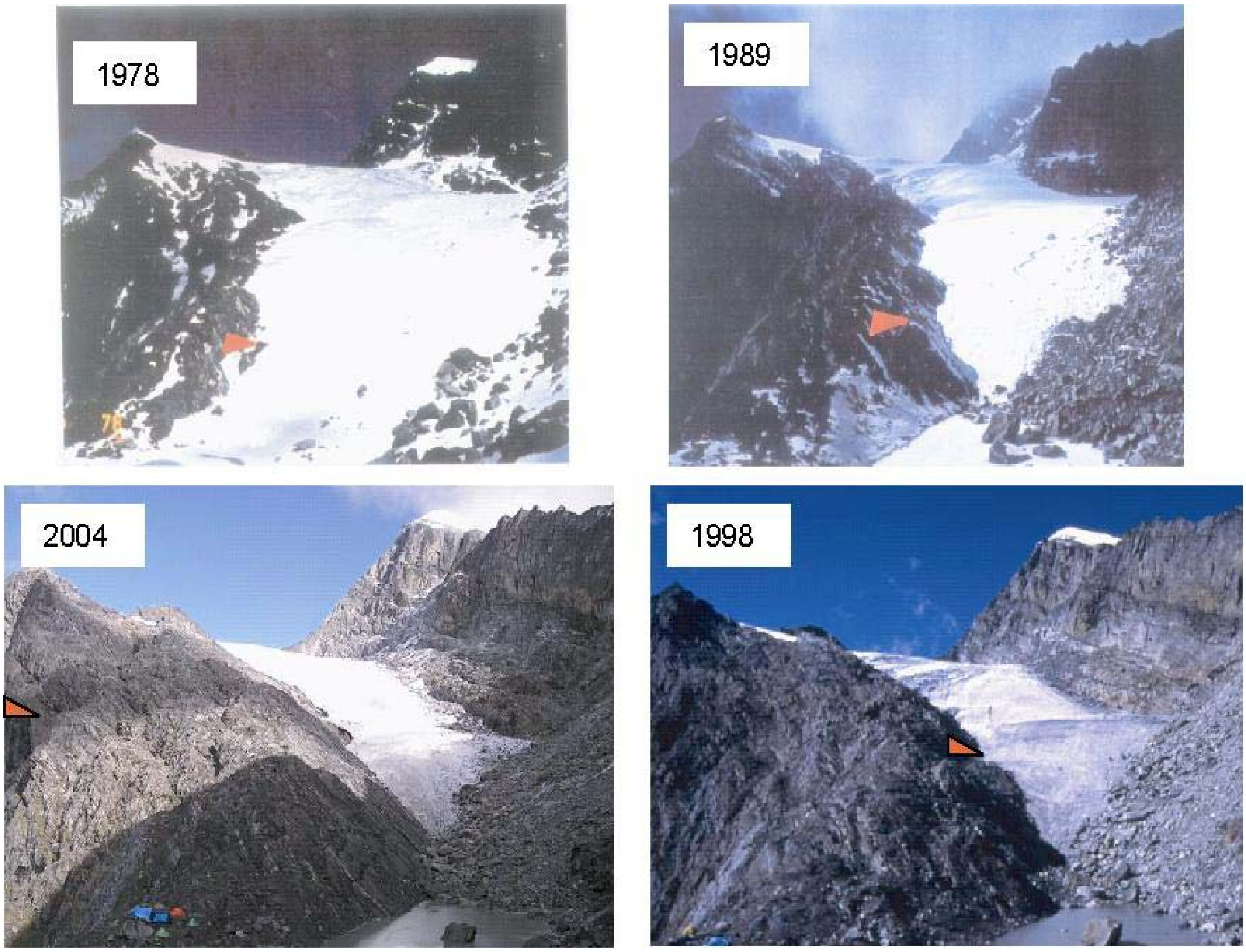

Figure 5. **Lirung Glacier in a. 1985 and b. 2002**

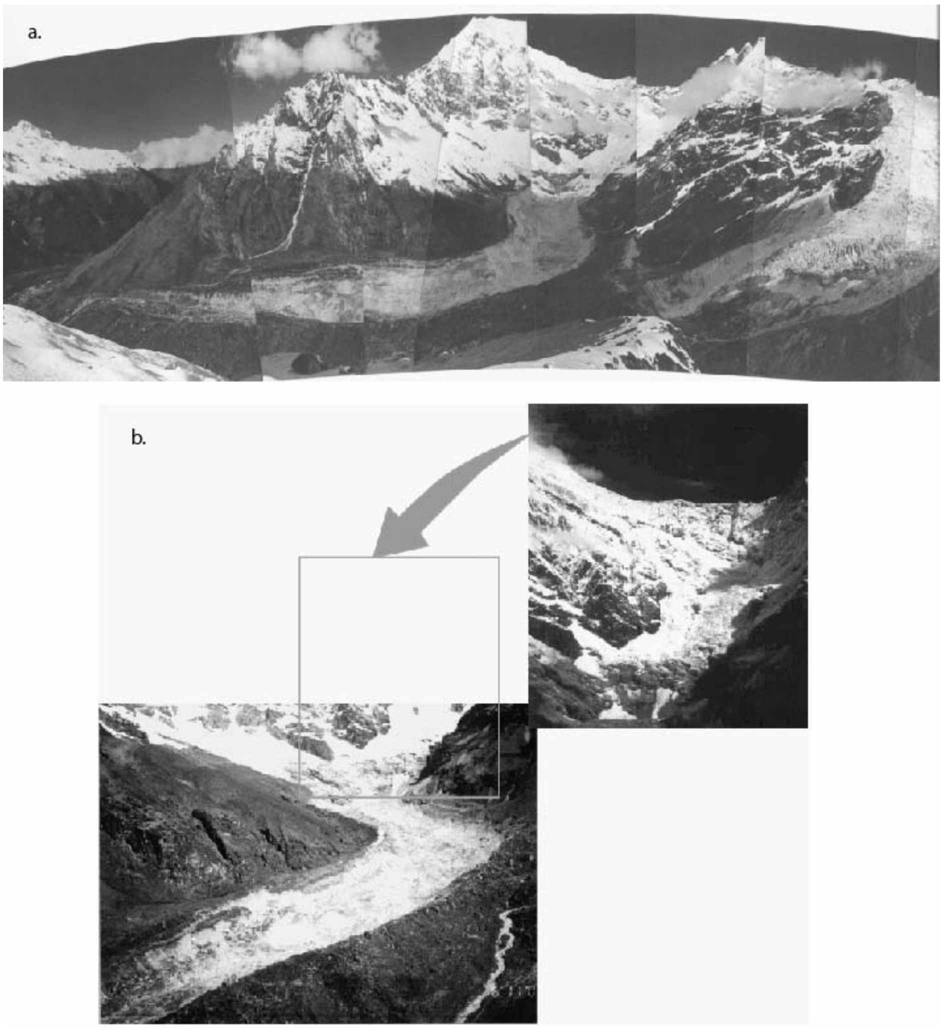

Figure 6. **Terminus position changes of Rika Samba Glacier**

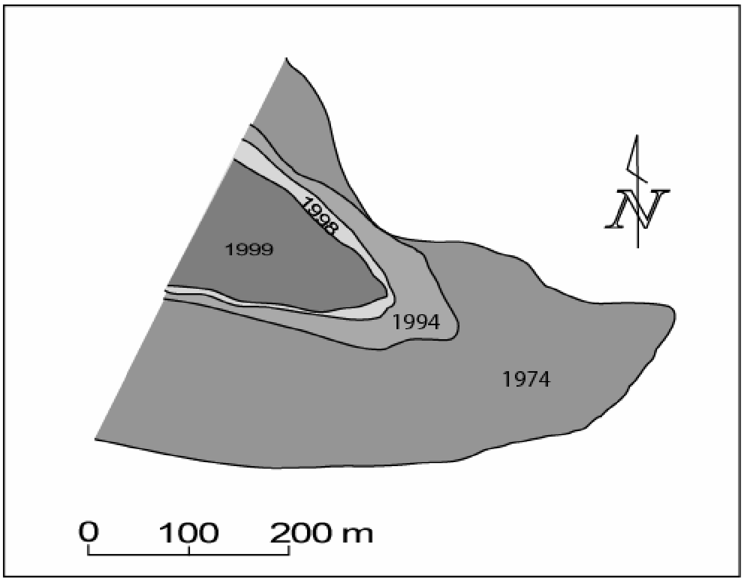

Figure7. **Rika Samba Glacier in a. 1974 and b. 1994**

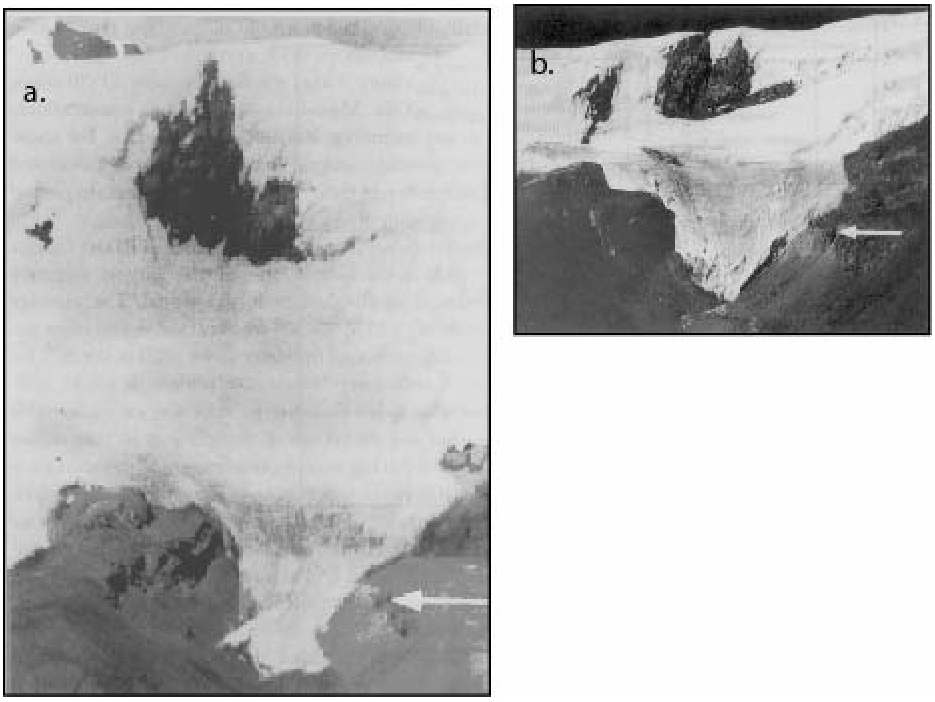

Figure 8. **Discharge data of selected rivers**

Top row: Large rivers; middle row: southern rivers; and bottom row: snowfed rivers.

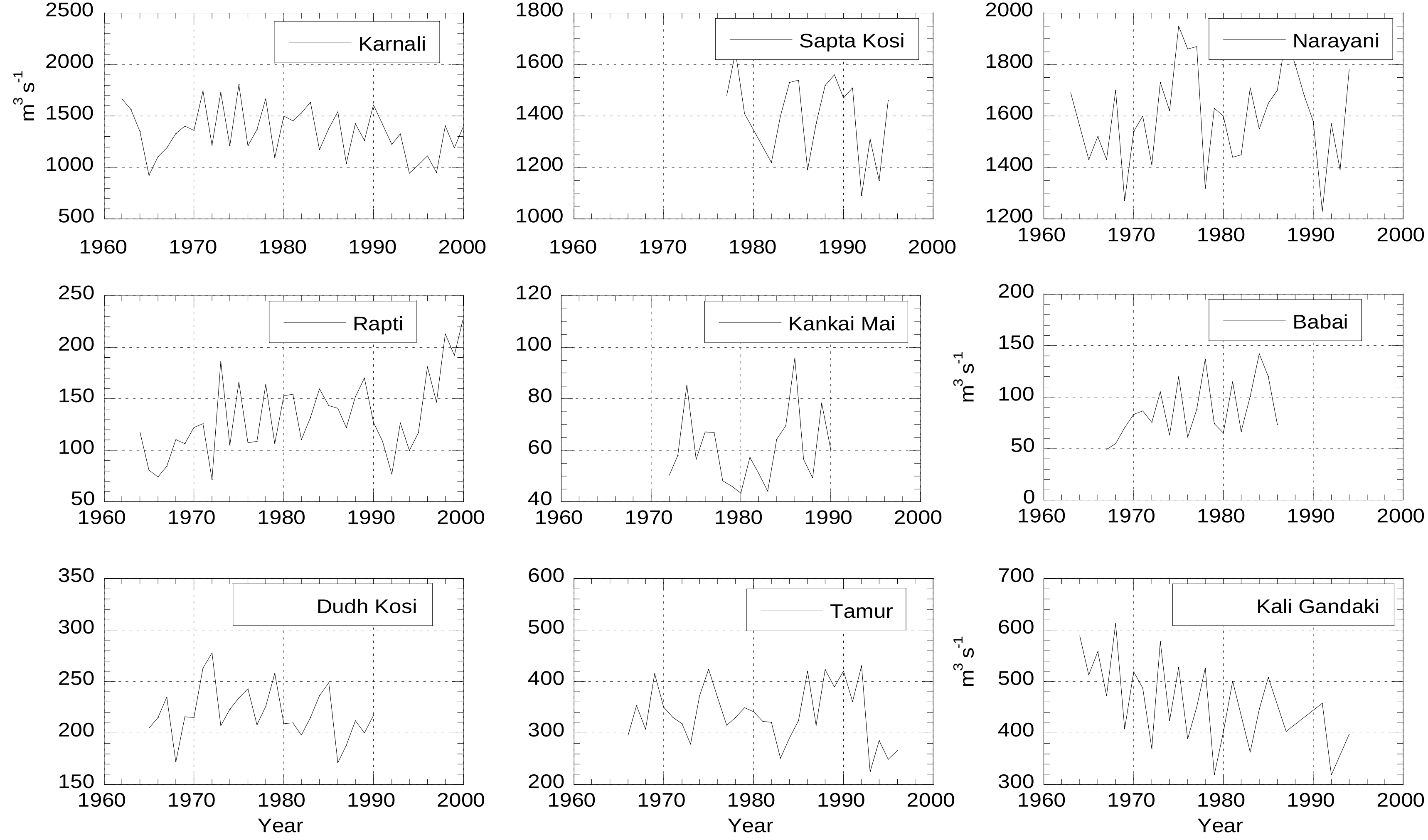

Figure 9. **Growth of Tsho Rolpa glacier lake from late 1950s to 2002**

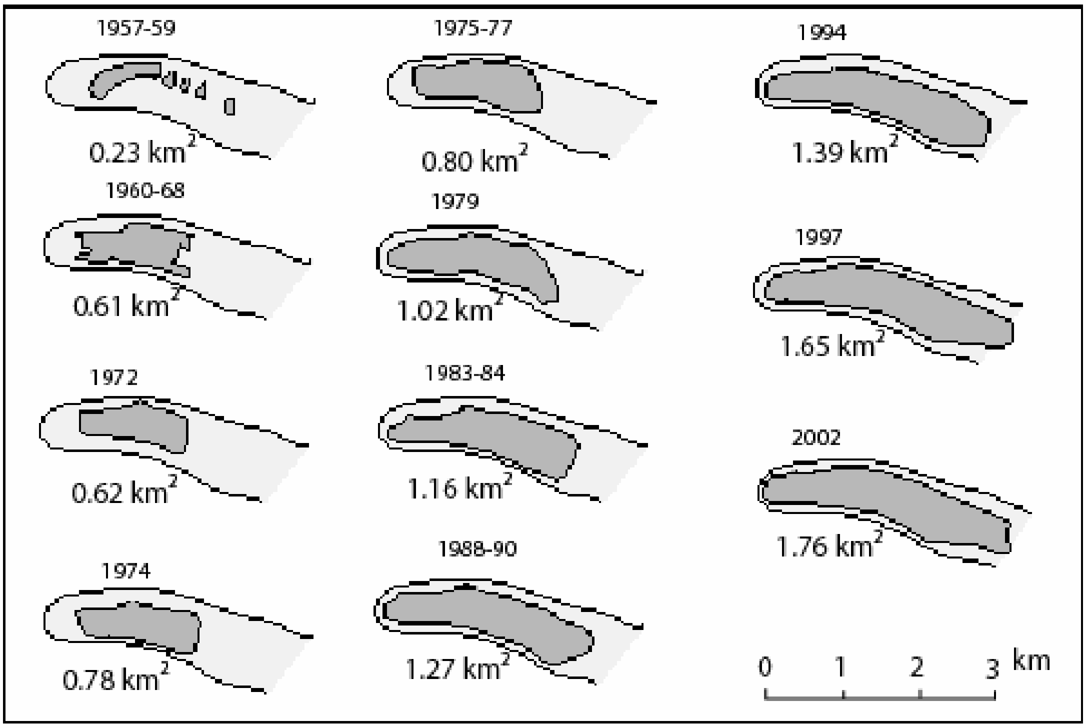

Table 1. **Regional mean temperature trends for the period 1977-94 (°C per year)**

Regions	Seasonal				Annual
	Winter Dec-Feb	Pre-monsoon Mar-May	Monsoon Jun-Sep	Post-monsoon Oct-Nov	Jan-Dec
Trans-Himalaya	0.12	0.01	0.11	0.10	0.09
Himalaya	0.09	0.05	0.06	0.08	0.06
Middle Mountains	0.06	0.05	0.06	0.09	0.08
Siwalik	0.02	0.01	0.02	0.08	0.04
Terai	0.01	0.00	0.01	0.07	0.04
All-Nepal	0.06	0.03	0.051	0.08	0.06

Table 2. **List of GLOF events recorded in Nepal**

Date	River Basin	Name of Lake
450 years ago	Seti Khola	Machhapuchhare
Aug-1935	Sun Koshi	Taraco, Tibet
21-Sep-1964	Arun	Gelaipco, Tibet
1964	Sun Kosi	Zhangzangbo, Tibet
1964	Trishuli	Longda, Tibet
1968	Arun	Ayaco, Tibet
1969	Arun	Ayaco, Tibet
1970	Arun	Ayaco, Tibet
3-Sep-1977	Dudh Koshi	Nare, Tibet
June-23-1980	Tamur	Nagmapokhari, Nepal
11-Jul-1981	Sun Koshi	Zhangzangbo, Tibet
27-Aug-1982	Arun	Jinco, Tibet
4-Aug-1985	Dudh Koshi	Dig Tsho, Nepal
12-Jul-1991	Tama Koshi	Chubung, Nepal
3-Sep-1998	Dudh Koshi	Sabai Tsho, Nepal

Table 3. **Potentially dangerous glacial lakes of Nepal**

Lake name	Sub-basin	Latitude	Longitude	Altitude (m asl)
Nagma Pokhari	Tamor	27° 52.10'	87° 52.02'	4,907
unnamed	Tamor	27° 48.83'	87° 45.09'	4,876
Lower Barun	Arun	27° 45.31'	87° 06.31'	4,550
Lumding Tsho	Dudh	27° 46.51'	86° 37.53'	4,846
Imja Tsho	Dudh	27° 54.00'	86° 55.40'	5,023
Tam Pokhari	Dudh	27° 44.33'	86° 50.76'	4,431
Dudh Pokhari	Dudh	27° 41.21'	86° 51.68'	4,760
Unnamed	Dudh	27° 47.70'	86° 54.81'	5,266
Unnamed	Dudh	27° 48.23'	86° 56.61'	5,056
Hungu	Dudh	27° 50.17'	86° 56.26'	5,181
East Hungu 1	Dudh	27° 47.92'	86° 57.95'	5,379
East Hungu 2	Dudh	27° 48.30'	86° 58.65'	5,483
Unnamed	Dudh	27° 46.86'	86° 57.22'	5,205
West Chamjang	Dudh	27° 45.24'	86° 57.33'	4,983
Dig Tsho	Dudh	27° 52.41'	86° 36.61'	4,364
Tsho Rolpa	Tama	27° 52.03'	86° 28.41'	4,556
Unnamed	Budhi	28° 35.79'	84° 38.09'	3,590
Thulagi	Marsyangdi	28° 29.69'	84° 29.01'	3,825
Unnamed	Kali	29° 2.76'	83° 40.52'	5,419
Unnamed	Kali	29° 12.79'	83° 41.79'	5,452

Source: Modified after ICIMOD 2001.