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Change in glacial environment of Everest region, Nepal

S. Bajracharya
International Centre for Integrated Mountain Development (ICIMOD); Kathmandu, Nepal

Abstract

The climate variability and global climatic change has brought significant impact on the glacial environment of Everest region. The rapid melting of glaciers had result of reduction of glacier mass with the increase in size of moraine dammed glacial lakes. The merging and expansion of supraglacial lakes at the snout of the valley glacier had formed moraine dammed lakes. Most of these lakes had formed only on the second half of twentieth century as an impact of global warming. The expansion of these lakes leading to the stage of glacial lake outburst floods (GLOF). The Himalaya had experienced at least one catastrophic GLOF event in three to ten years period.

The area of the glaciers in the Everest region is first mapped by ICIMOD in 2001 using the topographic maps published by Survey of India from 1959 to 1982 based on the aerial photographs of 1957 to 1959 and hence referred the data from 1960's. The total area covered by the glaciers in the Everest region was about 482 sq km in 1960's and the glacier area mapped of the region from the satellite was only 473 sq km in 2000. The significant glacier area reduced was noticed from the small glaciers and valley glacier snouts extending down to the low elevation. However the reduction of total area is small but the length of the valley glaciers are retreating at a rate of 10 to 60m/yr in average. The shrinking of glacier mass split the glacier body with the increase in number and decreases in area. The numbering of glaciers was based on the World Glacier Inventory (WGI) methodology. In general, the glaciers are shrinking and retreating faster in the recent decade with the proliferation of moraine dammed lakes, which might pose GLOF danger in future and some of it had already catastrophic outburst event. Hence the lakes which are mapped in the region and identified as potentially dangerous lakes poses different scenario in the present days.

KEY WORDS: glacial environment, glacial lake, Everest, Khumbu Himal

1. Introduction

The Everest region in the Dudh Koshi basin of eastern Nepal is one of the important and largest basins of Nepal in terms of glaciers and glacial lakes, perhaps the most densely glaciated region of eastern Nepal (Bajracharya et al. 2004). The glaciers in the region are extending down to the latitude of 27° 38’ 05” and lowest elevation 4206 masl, however the snout of most of the glaciers are at around 5000 masl. The climate variability and global climatic change has brought significant impact on the high mountainous glacial environment. The glaciers are melting faster than the accumulation resulting negative balance and growing moraine dammed lakes leading to the stage of glacial lake outburst floods (GLOF). Most of these lakes which are accounted from the elevation above 3500 masl had formed only on the second half of twentieth century as an impact of global warming. As a result some of the lakes had breached out to the stable condition and others are growing to the stage of danger condition. Understanding of these glacial environments is an imperative aspect in planning of water resources as well as GLOF disaster management in the region.

2. Glacial Environment

The glaciers and glacial lakes mapped by ICIMOD in 2001 were mainly based on the topographic maps published in 1959 to 1982 by Survey General of India. The potentially dangerous glacial lakes were identified on the basis of different parameter using the temporal satellite images from 1975 to 2000. In the context of global warming and fast retreating glaciers, the moraine dammed lakes are

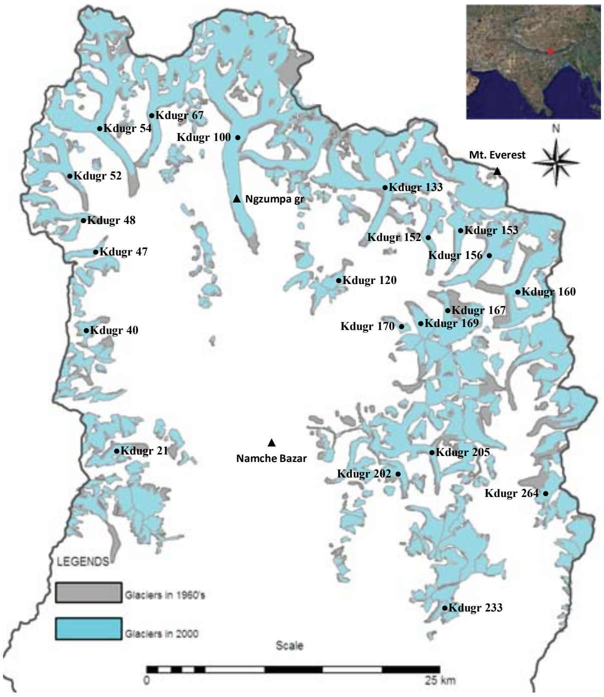
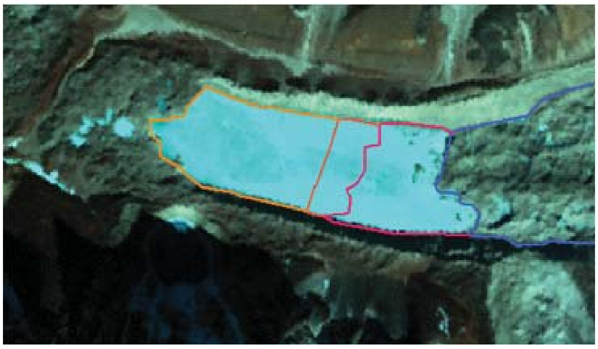
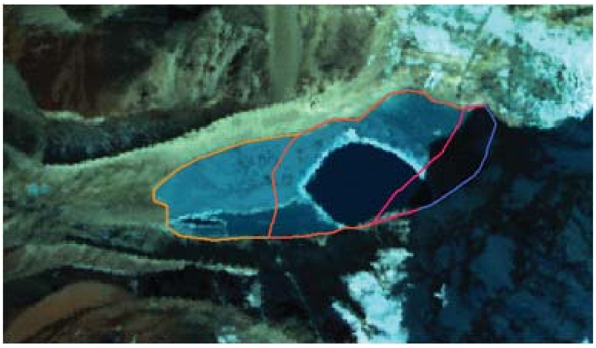


Figure 1: Change of glaciers in Dudh Koshi basin from 1960’s to 2007.



a. Imja Glacier and Tsho



b. Glacier Kdu_gr 262 (Kdu_gl 464) in Hungu Valley

c. Lumding Glacier and Tsho

d. Khumbu Glacier

Figure 2: Some examples of glacier retreat and lake expansion from the Dudh Koshi basin.

growing fast to the stage of potentially dangerous and some of it had GLOF and remain to the stable condition.

2.1. Glaciers

The glaciers mapped in the basin are 278 in number with the total area of 482 sq km and ice reserve of 51 cubic km (Mool et al 2001). The glaciers in the region are distributed in the high mountains from 8850 to 4300 masl. However, the large glaciers extending down to the valley are 40 in number covering more than 70% in area. The Ngojumba, Khumbu, Bhote Koshi and Hongu are the major glaciers in Dudh Koshi basin with the area of 82.61, 45.39, 35.63 and 22.91 sq km respectively. The glacier change mapping were carried out from the satellite images of 1976 (Landsat MSS), 1992 (Landsat TM), 2001 (Landsat etm+) and 2007 (ALOS). Significant change can be seen only in the snout of the valley glaciers (Fig. 1) and some of the examples are shown in the Fig. 2. Due to certain limitations of the remote sensing (such as shadows, poor resolution, etc.), only 24 valley glaciers have been studied to identify their retreat rate. The average minimum glacier retreat rate was 10m/yr; this was observed on the Langdak, W. Lhotse, Lhotse, and Setta glaciers. The fastest retreating glaciers were the Imja and Lumding glaciers with an average rate of 74m per year from 2000 to 2007 (Bajracharya

Figure 3: Change in Imja glacier from 1955 to 2007 (Source: ICIMOD, Alton C Byers, 2007 and Fritz Muller, 1955).

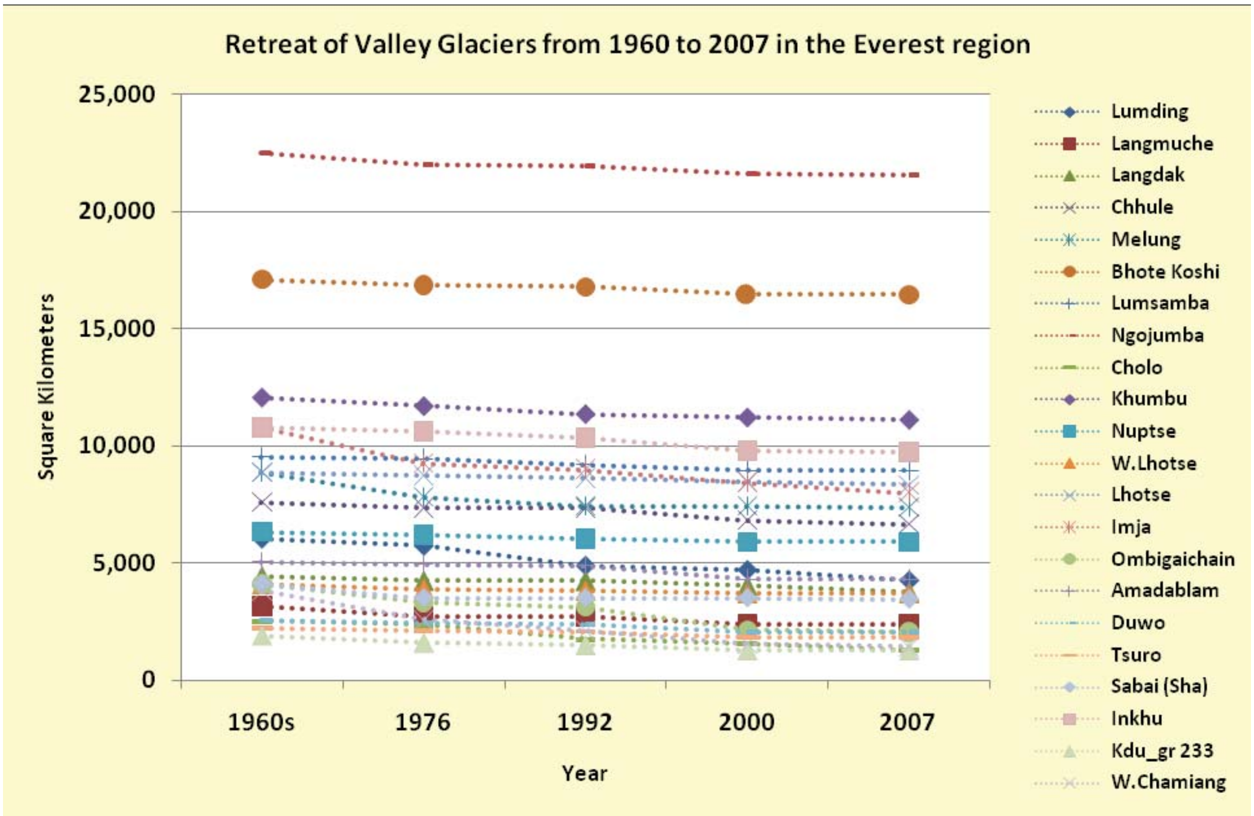


Figure 4: Retreat trend of the valley glaciers in the Everest region from 1960 to 2007.

et al. 2007). Other fast-retreating glaciers are West Chamiang and Ombigaichain. Most of the valley glaciers are shrinking and retreating faster in the recent decade.

The valley glaciers in the Everest region are retreating at a rate of 10 to 60m per year. The fastest retreating glaciers in the region are Imja, Lumding, Ombigaichain and West Chamiang Glaciers. The retreat rate of Imja glacier was found one of the fastest retreating glaciers in the region. Out of the 10.7km long Imja glacier 2.8km had already retreated which can be perceived from the satellite images of 1960. The retreated part of Imja glacier is replaced by the Lake Imja Tsho (Fig. 3). The retreat rate of the glaciers in the region are not uniform for example Imja, Melung and Chhule Glaciers retreated in faster in early 1970s, whereas the Lumding Glacier retreated fast in the period of 1976 to 1992. The Imja, Ombigaichain and Chhule glaciers are retreated faster in the period 1992 to 2000 and the Imja and Lumding Glaciers are retreating faster at present (Fig. 4).

The glaciers snout extension was found down to the elevation from 5300 to 4300 masl. The glacier snout extending at the elevation less than 4800 masl has the retreat rate of less than 30m whereas the glacier snout extending at above the elevation 4800 masl has the glacier retreat rate of 10 to 60m. The glacier retreat rate was perceived high in higher elevation (Fig. 5).

2.2. Glacial lakes

The glacial lakes larger than 0.003 sq km situated above an altitude of 3500 masl are 473 in number in the Dudh Koshi basin. The important lakes in the basin are Lumding Tsho, Dig Tsho, Imja Tsho, Tam Pokhari, Dudh Pokhari, Hungu, Chamiang and others. Bajracharya and Mool, 2005 mapped only 296 lakes from the landsat satellite image of 2001. They found the disappeared lakes were mostly the supraglacial and erosion lakes. Most of the supraglacial lakes are either small in size to map or disappeared. Some of it had transformed to moraine-dammed lakes. The number of glacial lakes had decreased by approximately 37 per cent, while 21 per cent of the lakes associated with the glaciers had increased in size. The increased percentage in surface area is due to the proliferation of moraine dammed lakes. In addition, 34 major glacial lakes are growing and 24 new major lakes have appeared. The newly formed lakes are 15 Moraine-dammed lakes, 5 Supraglacial lakes, 2 Valley lakes and 2 Erosion lakes (Tab. 1). The areas of the major glacial lakes range from 0.021 to 0.848 sq km at altitudes between 4,349 and 5,636 masl.

The fast and continuous retreat of glaciers and growing of glacial lakes highlights the importance of monitoring of glaciers and glacial lakes for the sound management of water resources. However, the study of this phenomenon is a challenge with the limits imposed by the higher altitude, the rarefied atmosphere, the remoteness of many of the locations and the short mapping season.

Based on the satellite images of 2000 and 2007, the main glacial lakes of the basin are monitored by automatic boundaries delineation of the lake using remote sensing techniques. Depending upon the projection of the satellite images the reliability of the data is more than 90%. The growth rate of the lakes from 2000 to 2007 indicates mostly negative value due to the seasonal variation of the lake. The image used for the analysis was from January 2007 during that period most of the lakes at high altitude are frozen and least extended in the years; however some of the lakes like Kdu_gl 71 and Kdu_gl 543 had grown significantly.

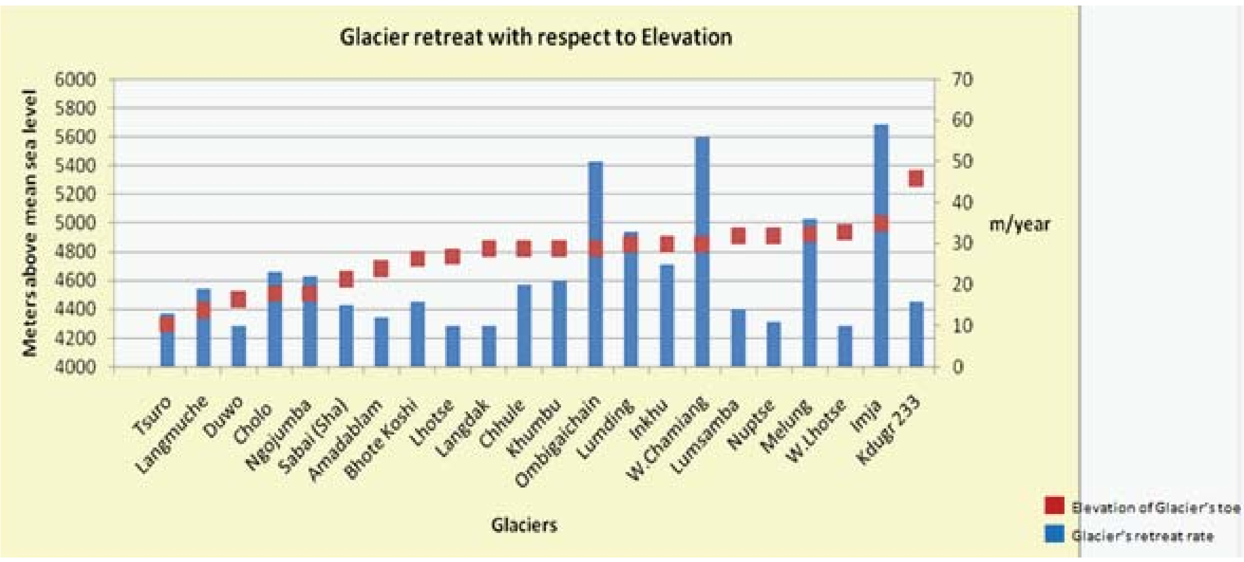


Figure 5: Valley Glaciers retreating with respect to the elevation

1 Disappeared (or less than 50 x 50 sq m) lakes		**245**
	Supraglacial lakes	199
	Erosions lakes	34
	Valley lakes	3
	Moraine-dammed lakes	7
	Cirque	2
2. Converted lakes (from supraglacial to Moraine-dammed Lakes)		**11**
3. New lakes		**24**
	Supraglacial lakes	5
	Erosions lakes	2
	Valley lakes	2
	End moraine-dammed lakes	15
4. Growing lakes		**34**
	Supraglacial lakes	10
	Valley lakes	2
	Moraine-dammed lakes	17
	Blocked lakes	2
	Erosions lakes	3

Table 1: Summary of activity of glacial lakes in the Dudh Koshi sub-basin (1960 –2000).

2.3. Potentially dangerous glacial lakes

A fast retreating of glaciers providing the increased run off and growth of glacial lakes and some of the supraglacial lakes are converted to moraine dammed lakes. The rapid growth of these lakes has the tendency of breaching the weak and unstable loose moraine dam with the catastrophic impact in the downstream valleys. Despite from the numerous glaciers and glacial lakes, the basin contains 12 potentially dangerous glacial lakes, the largest number in any sub-basin of Nepal. All those lakes are dammed by loose and unstable moraine. Among the listed potentially dangerous glacial lakes, three lakes: Kdu_gl 422, 442 and 462 had remained more or less same size; Kdu_gl 444 dried up in 2000 and reappeared in the satellite image of 2007; Kdu_gl 399 (Tam Pokhari) and Kdu_gl 55 (Dig Tsho) already had the outburst event in the past (Tab. 2). The remaining six lakes (Kdu_gl 28, 350, 449, 459, 464 and 466) are growing. The lake Kdu_gl 350 (Imja Tsho) is one of the fastest growing lakes in the Himalaya. Most likely the basin will have another GLOF event in near future.

The potentially dangerous lakes can be categorized in to four groups with respect to the growth rate and GLOF events (Fig. 6):

1- Fast growing lakes e.g. Imja, Lumding, West Chamiang and Kdu_gl 464
2- No remarkable change e.g. Dudh Pokhari, Hungu, East Hungu 1,2 and Kdu_gl 442
3- Dried and reappeared e.g Kdu_gl 444 and
4- With outburst event e.g Dig Tsho and Tam Pokhari

The Lake Kdu_gl 444 is located at 27°48'15"N and 86°56'37"E in the Hungu valley at an altitude of 5,056 masl. The lake area was 112,398 sq m with the average length of 420m when it was identified as a potentially dangerous glacial lake in 2000 (Mool et al. 2001). In the satellite image of 2001 the lake was completely dried or drained and again it appeared in 2007 with the size of 25,376 sq m. The lake is a valley lake and away from the glacier, it could not be a dangerous lake. Compared to the potentially dangerous lakes in the Dudh Koshi basin the area of Lake 444 is very small to include in the list of the potentially dangerous lake hence it can be removed from the list.

The Lake Dig Tsho at location of 27° 52' 25"N and 86° 35' 37"E in the Langmoche valley is at an altitude of 4,365 masl. The lake had an outburst event in 1985. After the outburst the lake area was reduced to 0.3 sq km with maximum depth of less than 10m. The lake is surrounded by thick moraine in two sides and steep sloping Langmoche glacier in western side and lake out let to eastern side. From the analysis of temporal satellite images and field observations show that the extreme end of the lake has reached the steep snout of Langmoche Glacier and there

Lake ID	Name	Altitude (masl)	Length (m)			Area (sq m)			Remark
			1960s	2000	2007	1960s	2000	2007	
Kdu_gl 28	Lumding Tsho	4,85	625	1,95	2,18	104,94	836,77	940,08	Fast growing
Kdu_gl 55	Dig Tsho	4,36	605	1,26	1,26	143,25	375,68	403,04	GLOF on 4 Aug 1985 No danger
Kdu_gl 350	Imja Tsho	5,02	410	1,82	2,03	48,81	848,74	945,66	Fast growing
Kdu_gl 399	Tam Pokhari	4,43	515	925	898	138,85	265,39	255,50	GLOF on 3 Sep 1998
Kdu_gl 422	Dudh Pokhari	4,76	1,12	1,10	1,16	274,30	297,57	316,77	No remarkable change
Kdu_gl 442	Unnamed	5,27	840	1,08	1,08	133,75	194,97	188,56	No remarkable change
Kdu_gl 444	Unnamed	5,06	420	x	235	112,40	x	25,38	Dried/ reappeared No danger
Kdu_gl 449	Hungu	5,18	875	1,05	1,33	198,91	232,84	267,72	Merged with gl 532
Kdu_gl 459	East Hungu 1	5,38	465	982	1,11	78,76	296,89	222,10	Merged with 460
Kdu_gl 462	East Hungu 2	5,48	640	448	459	211,88	178,32	164,10	Area decreasing
Kdu_gl 464	Unnamed	5,21	1,1	1,92	2,25	349,40	783,55	835,13	Growing in size
Kdu_gl 466	W. Chamiang	4,98	125	1,70	1,70	6,45	831,43	852,86	Kdu-gl 465 to 469 merged into one

Table 2: Status of potentially dangerous glacial lakes in Dudh Koshi sub-basin in 2007.

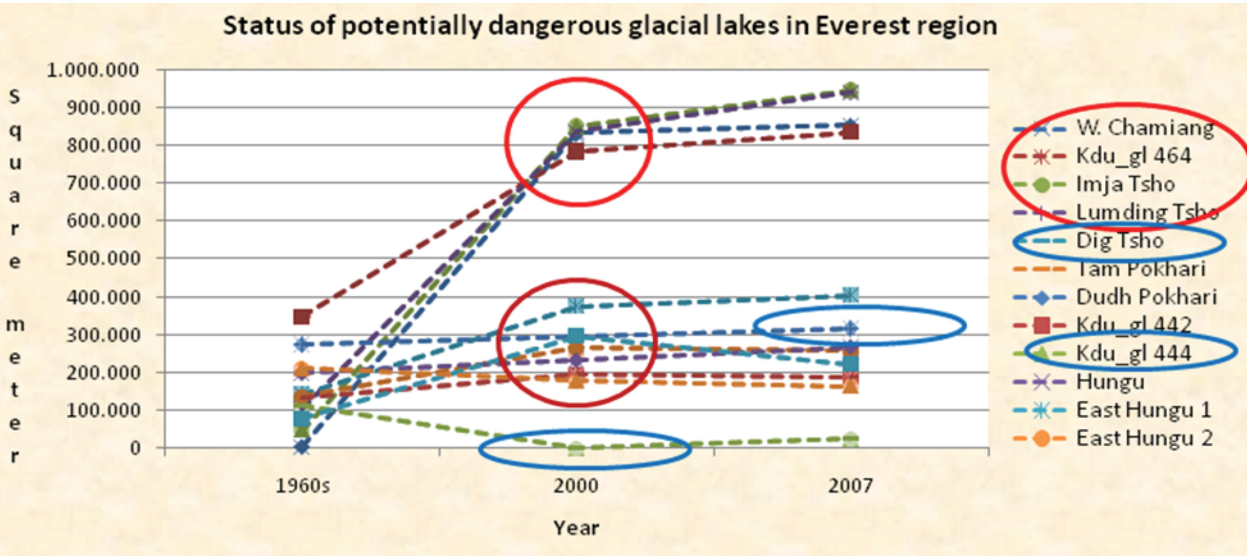


Figure 6: Status of potentially dangerous glacial lakes of Everest region.

is no possibility of further expansion of the lake. The present outlet of the lake is at the same level as the Langmoche river bed (Fig. 7).

From which it can be concluded that Dig Tsho is no longer a potentially dangerous lake as was identified in the 2001 inventory by ICIMOD and UNEP.

4. Conlcusions

a. Dig Tsho Glacial lake in April 2008

b. Outlet of Dig Tsho and Langmoche riverbed

Figure 7: The Lake Dig Tsho is no longer danger as the lake outlet and river bed is at the same level.

The Dudh Koshi basin is the largest glaciated basins in Nepal. The basin consist altogether 278 glaciers and out of which 40 are valley glaciers covering more than 70% in area. In the context of global warming almost all the glaciers snout are retreating at the rate 10 to 59 m/yr. The Imja glacier is one of the fastest glaciers retreating since 2000 at the rate of 74m/year and estimating 100m/yr in coming years.

The fast and continuous retreat of glaciers resulted in the proliferation of 34 major glacial lakes and 24 new at an elevation between 4,349 and 5,636 masl. The basin is already threatened by 12 potentially dangerous glacial lakes however from the field experiences two of it can be removed from the list. The rapid growing glacial lakes may pose danger in future hence the knowledge in growth of glacial lakes enlighten the importance of monitoring of glaciers and glacial lakes for the sound management of water resources and disaster risk reduction. However, the study of this phenomenon is a challenge with the limits imposed by the higher altitude, the rarefied atmosphere, the remoteness of many of the locations and the short mapping season.

References

BAJRACHARYA, S. R., MOOL, P. K. SHRESTHA, B. R., 2007: Impact of climate change on Himalayan glaciers and glacial lakes: case studies on GLOF and associated hazards in Nepal and Bhutan. ICIMOD, Nepal. 119p (http://books.icimod.org/index.php/search/publication/169).

BAJRACHARYA, S.R., MOOL, P.K., 2005: Growth of Hazardous Glacial Lakes in Nepal. Proceedings of the JICA Regional Seminar on Natural Disaster Mitigation and Issues on Technology Transfer in South and Southeast Asia, Sep 30 to 13 Oct 2004, pp 131- 148. Kathmandu: Department of Geology, Tri-Chandra Campus, T U.

BAJRACHARYA, S.R., MOOL, P.K., 2004: Potential Glacial Lake Outburst Floods from Major Glacial Lakes in Nepal in the Event of a Large Earthquake. Proceedings of the seminar and workshop on the Potential for Landslides in Nepal in the Event of a Large Earthquake, held 4-6 August 2004, Kathmandu Nepal, organised by the Mountain Risk Engineering Unit, Tribhuvan University, and University of Durham UK, pp 1-10. Tribhuvan University.

MOOL, P.K., BAJRACHARYA, S.R., AND JOSHI, S. P., 2001: Inventory of glaciers, glacial lakes, and glacial lake outburst flood monitoring and early warning system in the Hindu Kush-Himalayan Region, Nepal. ICIMOD. 364P.

VUICHARD, D., ZIMMERMAN, M., 1987:The 1985 catastrophic drainage of a moraine-dammed lake, Khumbu Himal, Nepal: Cause and consequence'. In Mountain Research and Development, 7(2): 91–110.

Correspondence to:

Samjwal Ratna Bajracharya

GIS Analyst

International Center for Integrated Mountain Development, Kathmandu (ICIMOD)

Mountain Environment and Natural Resources Information Systems (MENRIS)

Khumaltar, Lalitpur

Nepal

Phone: 977-01-4427367

e-mail:sabajracharya@icimod.org