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Decadal Change of Glaciers Advance/Retreat in LIKHU KOSI Sub Basin of KOSI River Basin Using Remote Sensing and GIS Techniques

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Abstract: - The study investigates the decadal changes in the ablation area of glaciers within the Likhu Kosi sub-basin of Kosi basin over past two decades using remote sensing and GIS techniques. The main objective is to analyse the trends in ablation area. Landsat satellite images from 2000 and 2020 were processed and analysed for 10 selected glaciers in the Likhu Kosi sub-basin. The results reveal a significant decrease of 122.35 hectares in the ablation area between 2000 and 2020. The initial ablation area in 2000 was measured at 266.86 hectares, which reduced to 144.50 hectares in 2020. The decline in snout area is primarily attributed to the impacts of climate change. The study also highlights the potential of remote sensing and GIS techniques to monitor and understand the impact of climate changes on glaciers. The findings have significant implications for the management of freshwater resources in the region. The reduction in glacial area not only poses risks to the local ecosystem but also increases the potential for flooding and erosion. Consequently, a comprehensive assessment of water levels and volumes is essential for the sustainable management of the freshwater resources in the Likhu Kosi Sub-basin.
Keywords: - Kosi Basin, Likhu Kosi, Landsat-7 & 8, (Advance/Retreat) Ablation, Glaciers, Remote sensing & GIS.

I. INTRODUCTION

Mountain glaciers are massive accumulations of ice that form at high altitudes in mountain ranges across the world. When precipitation exceeds melting, the snow compresses and finally turns to ice. Over time, gravity forces the ice downhill, cutting out valleys and altering the surrounding terrain [1]. They also provide vital sources of freshwater for human populations living downstream and are home to unique ecosystems that support a variety of plant and animal species. However, mountain glaciers are highly sensitive to changes in temperature and precipitation and are currently experiencing rapid melting due to global warming [2]. This melting threatens the stability of local ecosystems and water supplies. Understanding the behaviour of mountain glaciers and their response to changing environmental conditions is therefore critical for predicting and mitigating the impacts of climate change on both local and global scales.

The glacial mass loss rate in High Mountain Asia (HMA) and worldwide average mass loss are comparable, indicating that glacial loss is widespread in this century [3]. According to climate model forecasts based on high emissions scenarios, the HMA would lose around 65% of its ice mass this century, according to the research [4]. Global temperature rise causes glacial retreat, which is an immediate reaction to climate change and alters glacier dynamics and behaviour [5–9]. Global warming has resulted in large-scale glacier retreat all across the planet [10]. As a result, most glaciers in high places such as the Himalayas have receded significantly during the last century, influencing the stream run-off of Himalayan Rivers [11]. According to the inventory of the Kosi basin, the area of glaciers has shrunk by 9.5% (767 km^2) in the previous 40 years, with the south shrinking faster than the north [12]. The Kosi River in the southern Himalayas has received a lot of attention since glaciers have shrunk by 19% in the previous 40 years [13–14]. Kosi basin is divided into seven sub-basins in the Nepal Himalayas, or the southern Himalayas; they are named Indravati, Sun Kosi, Tama Kosi, Likhu Kosi, Dudh Kosi, Arun Kosi, and Tamor Kosi from west to east. The Likhu sub-basin is located between Tama Kosi and Dudh Kosi in Nepal's Kosi basin. Likhu is the Kosi basin's smallest sub-basin. The ten selected glacier inventories of the Likhu Kosi sub-basin decreased from 4310 ha to 3730 ha. The Likhu River is named after the Likhu glacier on the east side of the Likhu Kosi sub-basin. There are no large glacial lakes in this basin, which makes it less vulnerable to the GLOF’s activity than other sub-basins. In this study, 10 glaciers were analysed in advance or retreat, and it was found that all ten glaciers indicated retreat in their ablation area in the past 20 years, from 2000 to 2020.

We used topographic maps and satellite data from Landsat-7 and 8's Enhanced Thematic Mapper Plus and Operational Land Imager (ETM+, OLI) to analyse glacier changes in the Likhu Kosi sub-basin during the years 2000 and 2020. The satellite's capacity to catch huge glacier extents at various wavelengths for large-scale research, Remote Sensing has been recognised as an effective technique for modelling glacier retreat [15]. The combination of remote sensing and GIS has revolutionised our ability to map and monitor Earth's cryosphere and allows us to gather and analyse large amounts of data quickly and accurately. This has led to a better understanding of the behaviour of glaciers and the impact of climate change on these important natural resources [16].

II. STUDY AREA

It lies in the eastern part of Nepal. The Likhu Kosi sub-basin lies in the centre of the Kosi river basin. It covers an area of 108412 [ha] and lies between the longitude and latitude of 86°26'57.601" E 27°49'8.694" N and 86°12'20.218" E 27°15'22.37" N. The sub-basin lies in three districts, namely Ramechhap, Solukhumbu, and Okhaldunga. Annual rainfall increases from 1200 mm to 3550 mm, which progresses from the foothills to the top of the southern slope of the Himalayan range. The Kosi basin lies in the subtropical belt and humid zone; it experiences very hot summers and severe winters.

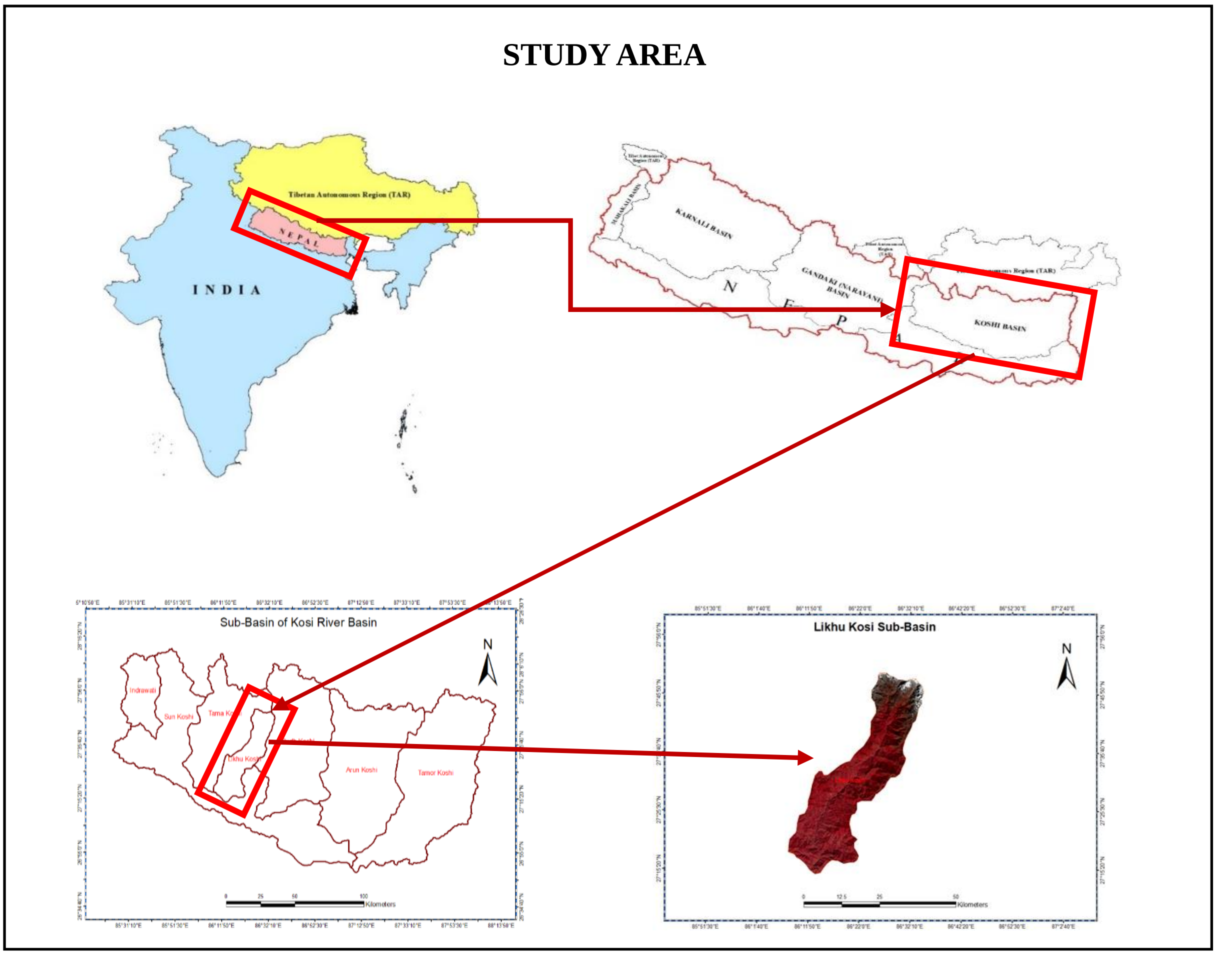

Figure1: Geographical setting of the study area

III. METHODOLOGY

The study utilised Landsat-7 and 8 satellite data from 2000 and 2020 for mapping the boundaries of glaciers in the Likhu Kosi sub-basin. Validation of the glaciers was conducted using 1:50,000 and 1:25,000 scale toposheets produced by the Survey Department of Nepal in 1995, which were georectified. Crossreferencing of the glacier boundary was performed using Google Earth Pro. The maps and statistical data were generated using ArcGIS and Excel applications.

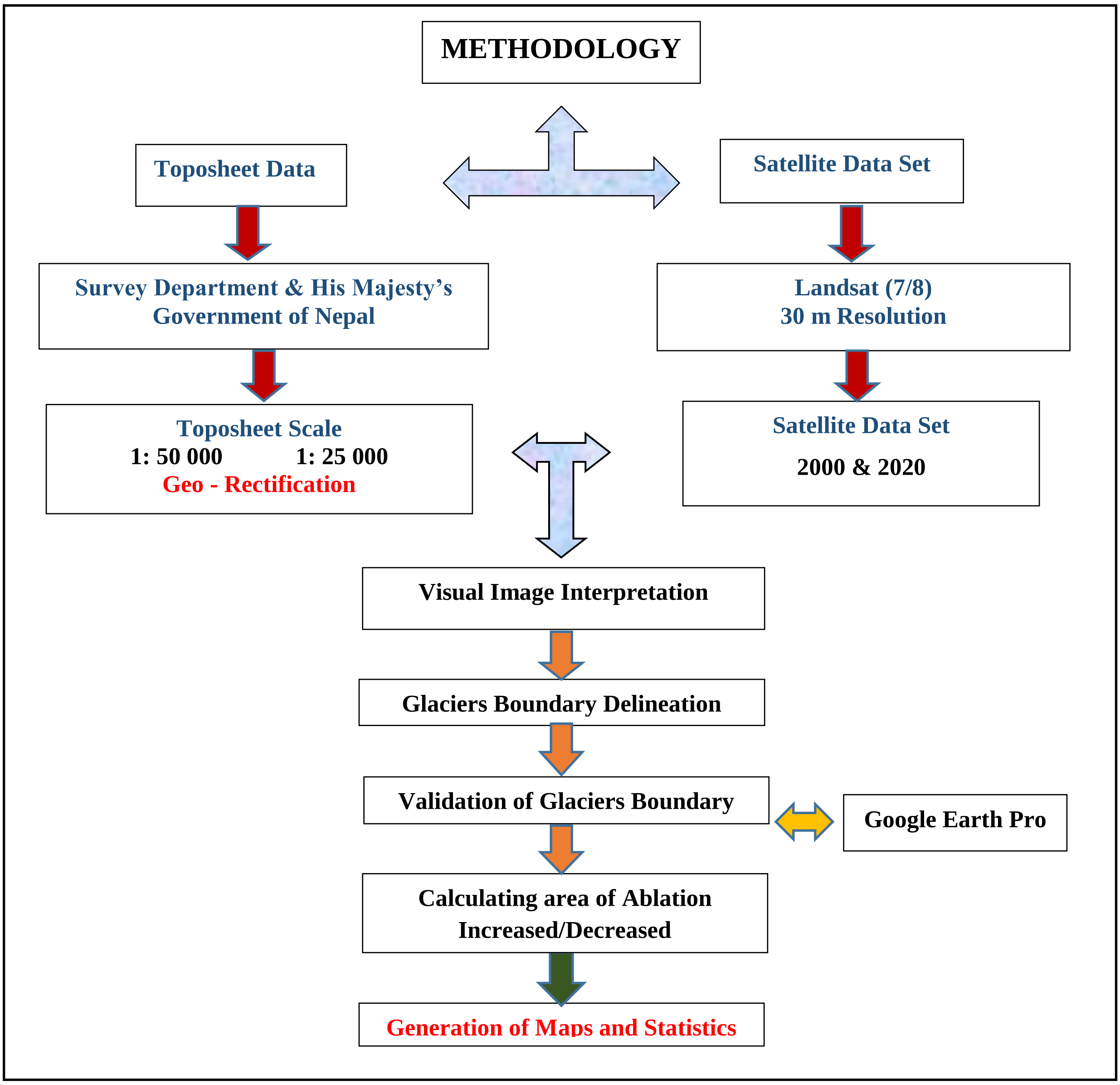

Figure 2: *Block diagram showing methodology used in the study*

IV. DATA

Data used in this study area is Landsat 7 and 8 of the years 2000 and 2020, downloaded from USGS Explorer. Details of satellite data are given in Table 2. The toposheet used in the study area is from the Survey Department of His Majesty's Government of Nepal. Five toposheets of scale 1:50 000 were used in the Barun watershed region. Details of the toposheet are given in table 1.

Table 1: Toposheet data used in the study.

S. No.	Toposheet Name	Toposheet No.	Scale
1.	Gaurishankar Himal	278602	1 : 50 000
2.	Namche Bajar	278603	1 : 50 000
3.	Those	278606	1 : 50 000
4.	Salleri	278607	1 : 50 000
5.	Khiji Phalate	278610	1 : 50 000
6.	Hatdada	278605	1 : 25 000
7.	Dhobi	278609	1 : 25 000
8.	Saghutar	278610	1 : 25 000
9.	Chauki Bhanjyan	278613	1 : 25 000

Table 2: Landsat data used in the study.

Satellite	Sensor	Year	Path/Row	Scene ID
Landsat-7	ETM+	2000-10-30	140/41	ELP140R041_7T20001030
Landsat-8	OLI	2020-11-14	140/41	LC08_L1TP_140041_20201029

V. RESULT

We found that all the glaciers have shown retreat in the ablation area of the Likhu Kosi Sub Basin in the past 20 years. In 2000, the ablation area was 266.8 ha, and in 2020, it was 144.50 ha. The decadal ablation area decreased by 122.35 ha. Glaciers 3, 4, and 6 have drastically changed almost half of the total ablation area.

Table 3: Details of glacier area of 2000 and 2020 and it difference in hectare.

S.No.	BASIN	Sub-Basin	Glacier Name	Area 2000 [ha]	Area 2020 [ha]	Difference in [ha]
1	Kosi	Likhu Kosi	Nil	11.375528	4.727529	6.647999
2			Nil	7.946968	4.432155	3.514813
3			Nil	46.667263	18.472757	28.194506
4			Nil	61.829735	27.650196	34.179539
5			Nil	11.520713	8.996264	2.524449
6			Nil	37.690266	21.552268	16.137998
7			Nil	23.516143	12.193092	11.323051
8			Likhu	32.451892	25.621301	6.830591
9			Nil	18.111378	8.137487	9.973891
10			Nil	15.754217	12.724158	3.030059
TOTAL				266.864103	144.507207	122.356896

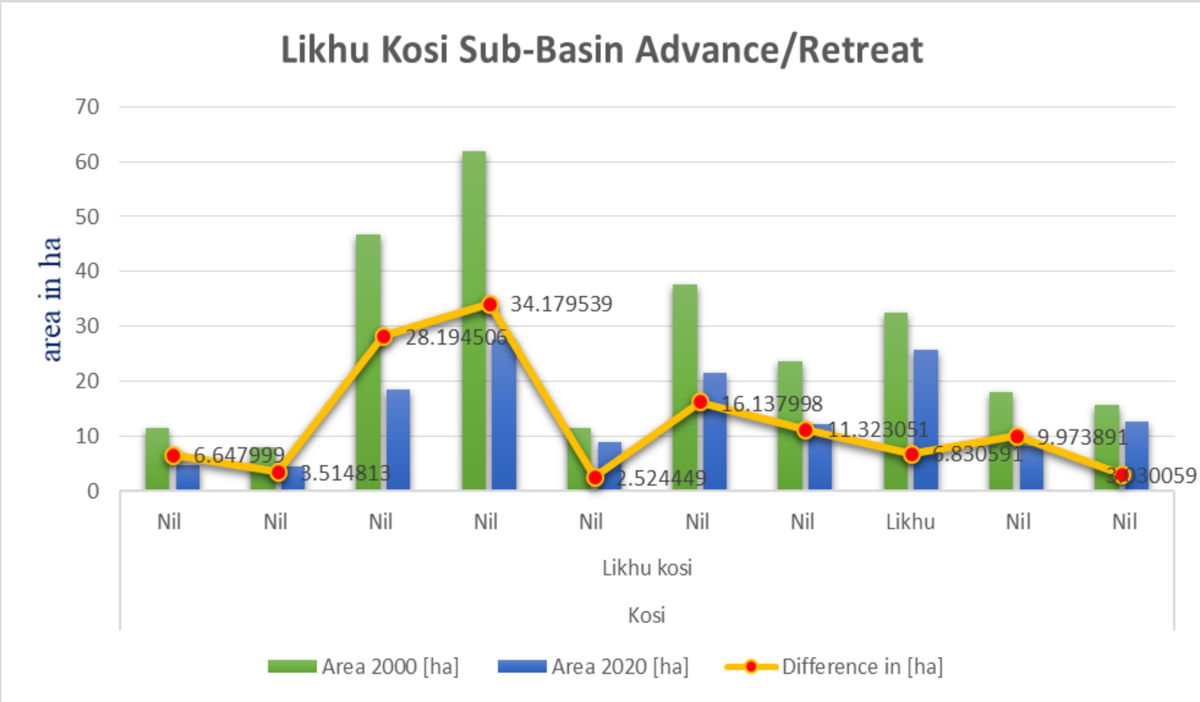

Figure 3: Compound graphical representation of increase/decrease ablation area in 2000 and 2020 and their difference.

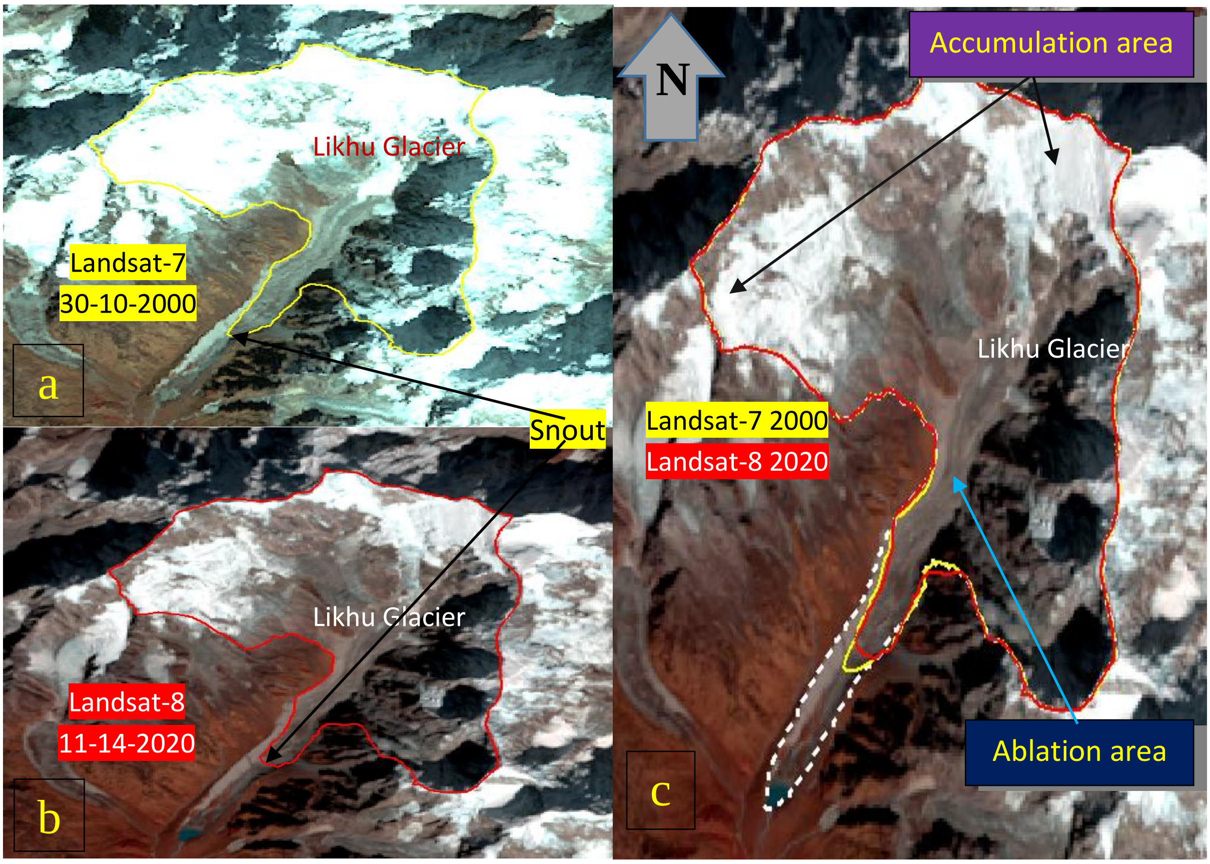

Figure 4: a) Synoptic view of Likhu Glacier of Landsat-7 data of year 2000.b) Synoptic view of Likhu Glacier of Landsat-8 data of year 2020. c) Boundary of glacier super imposed of year 2000 and 2020 and white line show Likhu Glacier Inventory.

VI. CONCLUSION

It was found that the glacier ablation area of Likhu Kosi has shrunk by 122.35 hectares in our study. Findings demonstrate the indisputable influence of climate change on the glaciers studied and highlight their sensitivity to changing climatic circumstances. The observed retreat in the ablation area raises worries regarding the region's freshwater supply in the long run. It advocates for continual monitoring and extensive analyses of water levels and quantities in order to ensure effective and sustainable management of these critical resources. Secondly, the high slope of the ablation is a major component of the region's high ice velocity and increased retreat rates. These extreme climatic fluctuations also have an impact on snow accumulations within the glacier, causing downward movement towards the ablation zones. In many sections of the over Himalayas, the lack of in situ data limits understanding of environmental changes. It has been discovered that the position of the ablation and the rate of retreat are not consistent from year to year. The use of space technology for glacier mapping and monitoring is advantageous for these remote places.

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