GLACIAL AND HIGH-ALTITUDE LAKE INVENTORY OF KARGIL, LADAKH

G.B. Pant National Institute of Himalayan Environment
Ladakh Regional Centre | Leh – 194 101, Ladakh UT

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Reviewers:
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2. Dr. Lavkush Kumar Patel, Scientist-D, Centre for Cryosphere and Climate Change Studies, National Institute of Hydrology, Roorkee - 247667, Uttarakhand.

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3. Mr. Jikmat Stanzin, Research Scholar, G.B. Pant National Institute of Himalayan Environment, Ladakh Regional Centre, Leh – 194101, Ladakh UT

GLACIAL AND HIGH-ALTITUDE LAKE INVENTORY OF KARGIL, LADAKH

G.B. Pant National Institute of Himalayan Environment
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EXECUTIVE SUMMARY

High-mountain areas are considered to be among the most active regions of the earth from the perspective of lake formation, evolution, and draining. A glacial lake, characterized by its significant water volume, exists in association with a glacier. These lakes are formed beneath, besides, and next to glaciers, or on top of them. These lakes are created by the movement and melting of glaciers, which are themselves affected by climate change. The lakes are often impounded by unstable barriers like ice or loose rocks. If these barriers break, they can trigger massive floods called glacial lake outburst floods (GLOFs), causing major destruction. The specific shape and features of the land around the lake primarily regulates formation and sustenance of such lakes. With increasing glaciers melt, GLOFs are becoming a growing concern in the mountainous areas around the world. Thus, it is imperative to regularly map and analyze various lake characteristics to understand any potential hazards originating from them.

The Kargil district, one of the two districts of the Ladakh Union Territory of India, is nestled within the Zanskar and Karakoram ranges of western Indian Himalaya, and is amongst the most glacierized areas within the country. In this region, though the human settlements are scarce, they are primarily distributed near the glacierized areas. Therefore, depleting glaciers and increasing possibilities of the formation of new glacial lakes pose serious threat to local communities in terms of water availability and potential GLOF hazards. In view of this, the present study aims at generating a comprehensive and updated inventory of glacial and high-altitude lakes in the Kargil district of Ladakh UT, with a systematic analysis of their types and topographic attributes. With the analysis of recent Sentinel-2 MSI imagery (2022), a total of 355 glacier and high-altitude lakes in the Kargil district were identified, encompassing an area of 4.8 ± 1.2 km^2. These lakes are divided into four classes mainly based on their relationship with the glaciers as: proglacial/periglacial lakes away from the glaciers (PGLA), proglacial/periglacial lakes in contact with glaciers (PGLC), supraglacial lakes (SGL), and other lakes (OL). Results revealed that, though PGLCs are comparatively low in number (85), they occupy the largest area share of 60% in total glacial lakes covering an area of 2.88 ± 0.7 km^2. The PGLAs are 138 in number and occupy the second largest area of 0.9 ± 0.2 km^2. A large number (103) of SGLs are found with an area coverage of 0.32 ± 0.07 km^2. The OLs are limited in number (29) and cover 0.6 ± 0.1 km^2 of area. The lake sizes range from 0.0004 km^2 to 0.579 km^2 with an average lake area of 0.013 km^2, indicating that the lakes in the region are small in size and are in an early development stage. The mean elevation for all the lakes is 4605 m asl, and notably ~21% of lakes are predominantly oriented in a southward direction. The majority of lakes are situated on slopes with a gradient ranging from 2-8°, reflecting their potential to grow in size. Results also confirm that about 88% of lakes are situated within the permafrost zone. From the analysis, it can be concluded that the glaciated areas in the Kargil region are dominated by a large number of PGLCs and SGLs, which are likely to expand in the future. In addition, thawing permafrost poses further prospect of lake-instability, resulting a serious threat to the communities living in immediate proximity to such lakes. Findings of this book provide valuable insights on different types of glacial lakes in Kargil. Moreover, cues on vulnerable lakes within the region having potential for GLOFs, requiring further investigation are also provided. Therefore, it is envisaged that information provided in this book would be essential for making informed decisions to minimize flood related disasters within the region.

FOREWORD

Shri Kacho Mohammad Feroz
Hon'ble Executive Councilor
(I&FC/ PHE/Tourism/KDA / ZDA/Urban Dev/Revenue/ CAD/Fisheries)
LAHDC-Kargil

सत्यमेव जयते

Ladakh Autonomous Hill Development Council, Kargil
Union Territory of Ladakh

The Kargil district of Ladakh Union Territory is characterised by arid climate and sparse population. However, the region has a weath of large number of glaciers and snow-covered areas supporting water demand in the downstream. For centuries, the people of Kargil have flourished in this unique environment, with their lives intertwined with this rich snow and glacier wealth. The impact of global climate change has led to rapid glacier decline over the high-mountains of Kargil leading to formation and growth of various glacial lakes. These growing lakes coupled with permafrost thawing pose serious threat in the form of glacial lake outburst floods (GLOF). When the natural dams holding these lakes fail, GLOF can unleash torrents of water, causing devastations downstream. Therefore, a clear understanding of these dynamic features is of utmost importance.

In this context, I am pleased to introduce this book on "Glacial and High-Altitude Lakes of Kargil, Ladakh", compiled by the researchers of G.B. Pant National Institute of Himalayan Environment, which presents a systematic study on the glacial and high-altitude lakes in the Kargil region of Ladakh. This book lucidly and concisely represents various aspects of the glacial lakes such as their types, sizes, distribution, topographic attributes, etc. The statistics on lake-typologies, their distribution and association with permafrost of this region are eye-opening, highlighting the extent of the glacial lake phenomenon and their potential risks. As we face the challenges of climate change, knowledge is power, and this book is a valuable document for anyone who cares about sustainable future of the Trans Himalaya.

I compliment the entire team of authors for carrying out this task diligently. I do hope that the regular and repeat monitoring of glaciated terrain within the region would be continued.

(K.M. Feroz)

FOREWORD

Shri Brij Mohan Sharma, *IFS*
PCCF and CWLW
UT of Ladakh

सत्यमेव जयते

केंद्र शासित प्रदेश लदाख का प्रशासन
Administration of Union Territory of Ladakh

The Ladakh Union Territory amasses about 50% of the glacier-wealth of the country. These glaciers, shaped over thousands of years, are the lifelines for the communities residing in this arid landscape. They form vital water reservoirs, feeding almost all regional streams, and support critical habitat for a unique array of flora and fauna. The peculiarity of the region is that, though it is sparsely inhabited, majority of the settlements are located in the proximity of glaciers. Undoubtedly, the high-mountain systems are among the most sensitive environments to climate change. As the climate change accelerates the glacier changes, different types of high mountain lakes form, evolve and, given the appropriate trigger, pose serious threat of glacial lake outburst floods (GLOFs).

Better knowledge of the distribution and topographic characteristics of lakes and an understanding of the associated processes are of great scientific importance and have the potential to help in effective hazard analysis and risk management related to GLOFs.

It is my privilege to introduce the book titled "Glacial and High-Altitude Lakes of Kargil, Ladakh", meticulously compiled by the researchers of the G.B. Pant National Institute of Himalayan Environment. This book provides simplified and invaluable scientific insights into the classification, distribution, and characteristics of glacial lakes in the Kargil district. I am certain that the statistics presented in this book will empower planners, policymakers and other stakeholders for informed decision-making towards mitigating the GLOF-risks and will trigger more relevant studies.

I congratulate the entire team of GB Pant NIHE-Ladakh, for their dedicated and meticulous efforts in compiling and bringing out this important document.

(B.M. Sharma)

PREFACE

Kargil, one of the two districts of the Ladakh Union Territory of India, is nestled within the Zanskar and Karakoram ranges of western Indian Himalaya. The district represents picturesque landscape, remote passes and high elevation mountain ranges often surrounded by glaciers supporting downstream water demand. As climate change accelerates, the pace of glacier retreat, rapid formation and development of glacial lakes poses serious threat to local communities. The risk of glacial lake outburst floods (GLOFs) looms large, endangering the lives and livelihoods of those residing in the downstream. This requires systematic understanding of various types of glacial lakes, their states and other important attributes. To suffice this knowledge gap, this book highlights glacial and high-altitude lakes of Kargil District, Ladakh, subsequently, provides details of 355 glacial and high-altitude lakes present within the region that encompass a total area of 4.8 km^2. Detailed insights on various types of lakes, their updated state, topographic characteristics and their association with the permafrost are also discussed. The book emphasizes that the glaciated areas in Kargil are occupied by 85 numbers of proglacial and 103 numbers of supraglacial lakes which are sensitive in nature and likely to expand in the future as glaciers continue to retreat. The book also highlights that around 88% of the total lakes of this region are within the permafrost zone resulting enhanced vulnerability of the region. The overall findings presented in the book are crucial to understand unique features of glacial lakes in the region and are essential for informed decision-making processes to minimize possible hazards associated with these dynamic water bodies. Therefore, it is anticipated that information provided in this book would be beneficial for combating GLOF related disasters, and instigate further studies in this direction.

Prof. (Dr.) Sunil Nautiyal
Alexander von Humboldt Fellow
Director, GBPNIHE

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GLACIAL AND HIGH-ALTITUDE LAKE INVENTORY OF KARGIL, LADAKH

1. INTRODUCTION

A glacial lake is a body of water that originates from a glacier. It typically forms at the foot of a glacier, but may form on, in, or under it (National Snow and Ice Data Center (NSIDC); https://nsidc.org). These formations are a result of glacial activity, when a glacier erodes the land, it leaves depressions. As the climate changes and the glacier melts, these depressions fill with water forming lakes (Bolch et al., 2019; Ives, 2012; Mal et al., 2021; Nie et al., 2017; Raj and Kumar, 2016; Zhang et al., 2015). These lakes are typically found in high-altitude regions within glacial and periglacial environments (Ahmed et al., 2021; Bhambri et al., 2018; Kääb et al., 2005; Shukla et al., 2018).

Glacial lakes come into existence as meltwater collects in glacier troughs, originating from a complex interplay of glaciological processes that include snow and ice accumulation, glacial melting, and the inflow of meltwater and precipitation (Hewitt, 2014; Pienitz et al., 2008; Sakai et al., 2002 ; Schmidt et al., 2020). The meltwater originating from glaciers often contained by natural barriers like terminal moraines or ice which leads to pondage and eventual lake formation (Reynolds, 2000; Sakai and Fujita, 2010; Westoby et al., 2014). Movement and erosion of glaciers, sculpting the surrounding terrain with depressions, grooves, and moraines play a crucial role in lake development (Murtaza et al., 2021; Sakai and Fujita, 2010). Glacial lake also develop when the void created by glacier retreat are filled by the meltwater (Sakai, 2012). In summary, formation conditions of glacial lakes are closely linked with glacier feedback mechanisms, glacier movement, ice melt, and the broader hydrological systems (Ahmed et al., 2021; Gupta et al., 2022; Mal et al., 2020; Westoby et al., 2014; Worni et al., 2013).

Sakai, (2012) highlighted that glacial lakes tend to form over low sloping (<2° slope) and low moving (< 10 m/y) debris-covered glacier tongues under prevailing negative mass balance regimes. Reynolds (2000) suggested that on debris-covered glaciers with slope >2°, large supraglacial lakes may form, while slope between 2° and 6° facilitates development of supraglacial ponds of a sufficiently large area. However, these may be transient in nature. Quincey et al. (2009) and Benn et al. (2012) noted that surface lowering, particularly in the upper and middle ablation area, is a key factor contributing to lake formation. Earlier, formation of supraglacial ponds and the commencement of calving at the glacial lake was also attributed (Kirkbride, 1993) to lowering of the glacier surface. Suzuki et al., (2007) estimated thermal resistance of debris-covered glaciers and observed that glaciers with relatively thin debris layers tend to develop glacial lakes at their snout.

Regarding classification, Bhambri et al., (2018) suggested that glacial lakes can be categorized into four main types: (i) Moraine-Dammed Lakes: lakes formed behind ridges of glacial till (moraines) created by glacier movement. They can be classified as end-moraine, lateral moraine, or recessional moraine-dammed lakes, depending on their location and the glacier's history, (ii) Ice-Dammed Lakes: lakes resulted from glacier blockages that obstruct rivers and create lake formations. Supraglacial ponds can also contribute to the formation of these lakes under certain conditions, (iii) Glacier Erosion Lakes: lakes carved out by glacial erosion processes in depressions, including cirque

lakes formed in steep, armchair-shaped hollows, and glacier trough valley lakes created by glacier movement over areas with alternating hard and soft bedrock layers, and (iv) Other Lakes: lakes formed independently of glacier processes and resulted from blockages by rock falls, debris flows, landslides, and even human activities. This category also includes man-made lakes. Glacial lakes can also be classified based on their location and relationship with respect to the mother glacier as proglacial lakes, supraglacial lakes and periglacial lakes. As the glacier gradually retreats, it creates depressions in its wake, which then become filled with meltwater, giving rise to what are known as proglacial lakes. The key characteristic distinguishing these lakes is their close association with the terminus or end of the glacier. Supraglacial lakes form on the surface of the glacier. They form due to the accumulation of meltwater gathering on the glacier's surface. These lakes are temporary in nature and can experience fluctuations in size and shape, influenced by the glacier's movement and the ongoing processes of melting. Periglacial lakes typically originate from the melting of ice within the spaces between the glacier body and the adjacent side walls. Their characteristics can vary, influenced by the surrounding terrain (Shukla et al., 2018).

Glacial lakes usually form behind moraine or ice 'dams' (Emmer et al., 2014; Frey et al., 2010a). The moraine walls are formed by sediments, stones/pebbles and sand deposits left by melting glaciers which holds the water body (Benn and Evans, 2010). These moraines are structurally weak and undergo constant changes (Emmer and Vilímek, 2013; Huggel et al., 2004). Owing to the inherent instability of such dams, the potential of sudden outbursts/breaches becomes high. The phenomenon, constituting a sudden discharge of a huge volume of water from such glacial lakes is known as Glacial Lake Outburst Floods (GLOFs). GLOFs are described as 'low frequency, high magnitude events' and can lead to discharge of millions of cubic meters of water and debris within a short span (e.g. in a few hours) and can cause catastrophic devastation and flooding in downstream areas (Costa and Schuster, 1988; Emmer and Vilímek, 2013). The outburst can be triggered by various factors or their combinations such as an earthquake, avalanche, landslide, over-topping, rock-fall, slope failure etc. or due to inability of the moraine dam itself to hold the water as it crosses the retention threshold. The sudden flooding can cause serious damage to life, livestock, forests, ecosystems, property, agriculture and the livelihoods of mountain communities heavily reliant on mountain ecosystems for sustenance, as well as precious socio-economic infrastructure like roads, bridges, hydro-power, electricity and communications networks. The overall consequences can so severe that they can induce forced migration and undermine the already meagre sources of livelihood of mountain people and downstream communities.

Throughout the last century, GLOFs have had a profound and tragic impact on communities worldwide. Approximately 32,000 people died in Peru due to these floods. They have also claimed at least 7 lives in Iceland, 393 in the European Alps, 5,745 in South America, and 6,300 in central Asia (Carrivick and Tweed, 2019). The 1994 Lugge Tsho event brought severe devastation to downstream villages, including Chozoz, Thanza, Tenchey, and Punkha in Bhutan (Watanbe and Rothacher, 1996). GLOFs have also left their mark in regions like the Tibetan Himalaya, Karakoram Himalaya (as seen in the Ghulkin GLOF of 1981), and the Nepal Himalaya (with events like Dig Tsho in 1985 and Tampokhari in 1998), leading to substantial loss of both lives and property (Richardson and Quincey, 2009; Vuichard and Zimmermann, 1987; Xu, 1988).

The Himalaya, with roughly 15% of its land area covered by glaciers, stand as the world's largest ice repository outside the Polar Regions (Azam et al., 2021; Bolch et al., 2012; Brun et al., 2017). This extensive expanse exhibits a diverse landscape characterized by varying climates, topographies, and glacial features. According to recent research, the Himalaya are one of the locations most vulnerable to the effects of climate change (Gosavi et al., 2020; Bolch et al., 2012; Negi et al., 2012;Fujita, 2008; Meier et al., 2005). Consequently, this vulnerability has led to the proliferation of glacial and high-altitude lakes (Gardelle et al., 2011; Kargel et al., 2005; Zhang et al., 2015). The rapid growth of these glacial lakes in the region poses a significant threat to local communities. The Himalaya have about 9,000 glacial lakes, and nearly 200 of them could be dangerous (Ahmed et al., 2021; Ives, 2012).

Over the past seven decades, the region has witnessed the occurrence of approximately 40 documented GLOF events, leading to substantial losses in human lives, property, infrastructure, agriculture, and forests. (Ahmed et al., 2021; Ives, 2012; Mool, 2001; Shukla et al., 2018). For instance, Sikkim recently confronted a GLOF when continuous rainfall led to the partial rupture of the South Lhonak Lake, situated at an elevation of 5182 m asl in the state's northwest (Kashyap and Behera, 2024). The Chorabari GLOF event in 2013 resulted in extensive damage (Allen et al., 2016; Das et al., 2015; Rafiq et al., 2019). Similarly, in 1929, an Ice-dammed lake outburst in the Shyok basin of Ladakh impacted approximately 48 villages (Ahmed et al., 2021). Recently, in trans-Himalayan region of Ladakh, a catastrophic GLOF inundated Gya Village, during the night of August 6-7, 2014. This calamity was triggered by the failure of a moraine-dammed lake associated with the Gya Glacier, located 14 km upstream and 75 km from the main Leh town (Majeed et al., 2020; Schmidt et al., 2020; Schmidt and Nüsser, 2017). Notably, Ahmed et al., (2021) summarized that the regions of Jammu and Kashmir and Ladakh are susceptible to large number of potential hotspots for GLOFs. Moreover, Zhang et al., (2015) projected more glacial lake development and expansion in the western Himalaya particularly in Ladakh as compared to central and eastern Himalaya. This makes detailed and updated study of glacial lakes in Ladakh region imperative.

Ladakh, Union territory (UT) comprises two districts: Leh and Kargil. Both the districts are characterized by large glaciated area (Hussain et al., 2023). However, the glaciers in Kargil district are, in general, large in size and their ablation areas (glacier tongue) is characterize by heavy debris cover (Frey et al., 2012; Mir et al., 2018). The rate of mass loss is also higher in Kargil district as compared to Leh (Mandal et al., 2023). These conditions make glaciers in Kargil district more conducive for glacial lake development. However, updated comprehensive inventory of glacial and high-altitude lakes and systematic topographic analysis of these lakes in terms of size, shape, slope, aspect and altitude is not available in Kargil district. Considering this, the present study aims to conduct a comprehensive mapping of glacial and high-altitude lakes in the Kargil district. The major objectives of this study are to (a) generate a comprehensive inventory of glacial and high-altitude lakes in the Kargil district of Ladakh UT, and (b) assess the various morphological and topographical characteristics of each documented lake.

Through this research, we aim to contribute to our understanding of glacial lakes in the Ladakh region, providing essential data for informed decision-making related to prevention and migration of the glacial lake related hazards.

2. STUDY AREA

Kargil, the second-largest town in Ladakh, is one of the two districts in the Ladakh region, surrounded by the Ladakh, Zanskar, and Greater Himalayan Mountain ranges. Kargil district covers an area of approximately 14,036 km^2 and is located between 30 to 35° North latitude and 75 to 77° East longitude (Figure 1). This region is distinctive due to its elevated terrain, which ranges from 2545 to 7089 m above sea level (asl). Politically, it is surrounded by Baramullah, Srinagar, and Doda districts of Union Territory of Jammu and Kashmir in the South-West, Leh District in the East, Lahaul and Spiti district of the Himachal Pradesh in the South, and Pakistan in the North-West. The district includes four high-level natural valleys: the Suru Valley, Drass Valley, Indus Valley, and Upper Sindh Valley of Kanji Nallah Valley. Zojila and Fotulla passes, at 3567 and 4192 m asl, serve as gateways for Kashmir Valley and Leh district entry into Kargil.

Kargil is characterized by its high rocky mountains, arid desert landscapes, and abundant snowfall during the winter months and limited natural vegetation (Gupta and Arora, 2017; Kumar et al., 2022). Precipitation is minimal (primarily in the form of snow), the average annual precipitation is around 318 mm, with the driest month being November, receiving only 6 mm of precipitation (Das and Meher, 2019; Mann et al., 2022). March is the wettest month, with an average of 82 mm of precipitation (Kumar et al., 2022; Shukla et al., 2020). Kargil experiences

rainfall on approximately 162 days each year, making up 44.5% of the annual calendar (Ahmad et al., 2019; Machiwal et al., 2017). The region receives an annual snowfall of approximately 10 cm, with regular snowfall amounts ranging from 2 to 5 meters (Jain et al., 2007; Koul et al., 2016). The diurnal and seasonal temperature fluctuations range from -48°C in winter to +35°C in summer and average annual temperature is 8.6 °C (Ahmad et al., 2019; Behera et al., 2014; Mann et al., 2022). The coldest months are January and February when temperatures drop below freezing, accompanied by snowfall (Shaheen et al., 2013). Such temperature and precipitation conditions make the region a cold desert. Irrigation mainly relies on channels from glacier-melted snow (Le Masson and Nair, 2012). The study region is largely barren with limited forest cover (Behera et al., 2014).

The 2011 census of India recorded a population of 1,40,802 souls in Kargil district, with 77,785 males and 63,017 females (https://kargil.nic.in). The majority of the population resided in rural areas (88.4%). The study area includes Kargil town, 127 inhabited villages, and 2 uninhabited villages, with settlement patterns that differ from traditional compact villages. It is administratively divided into 12 Niabats (administrative units in the state): Drass, Kargil, Shargole, Chiktan, TSG, G.M.Pore, Sankoo, Taisuru, Padum, Lungnaq, Cha, and Zangla. The district is further subdivided into four Sub-Divisions: Kargil, Zanskar, Sankoo, and Shakar-Chiktan, with seven Tehsils: Drass, Kargil, Shargole, Shakar-Chiktan, Sankoo, Taisuru, and Zanskar (Bloeria, 2021). Kargil administrative structure differs from other districts in India due to the Ladakh Autonomous Hill Development Council (LAHDC), instituted in 2003. The LAHDC consists of 30 members or councilors, with 26 being elected and 4 nominated. The Deputy Commissioner Kargil serves as the administrative head and Chief Executive Officer of the Hill Council, responsible for law and order.

Kargil district is home to a multitude of glacial lakes. Glaciers and glacial lakes play a vital role in the lives of the local people, providing a source of irrigation for agriculture, hydropower generation, and drinking water. However, these lakes also pose a significant threat due to their potential for catastrophic GLOFs. The downstream communities nestled along the river primary tributaries are particularly vulnerable to the devastating consequences of such events. Their close proximity to the source of these glacial lakes and their reliance on the glacier-fed water further amplify the risk of disaster.

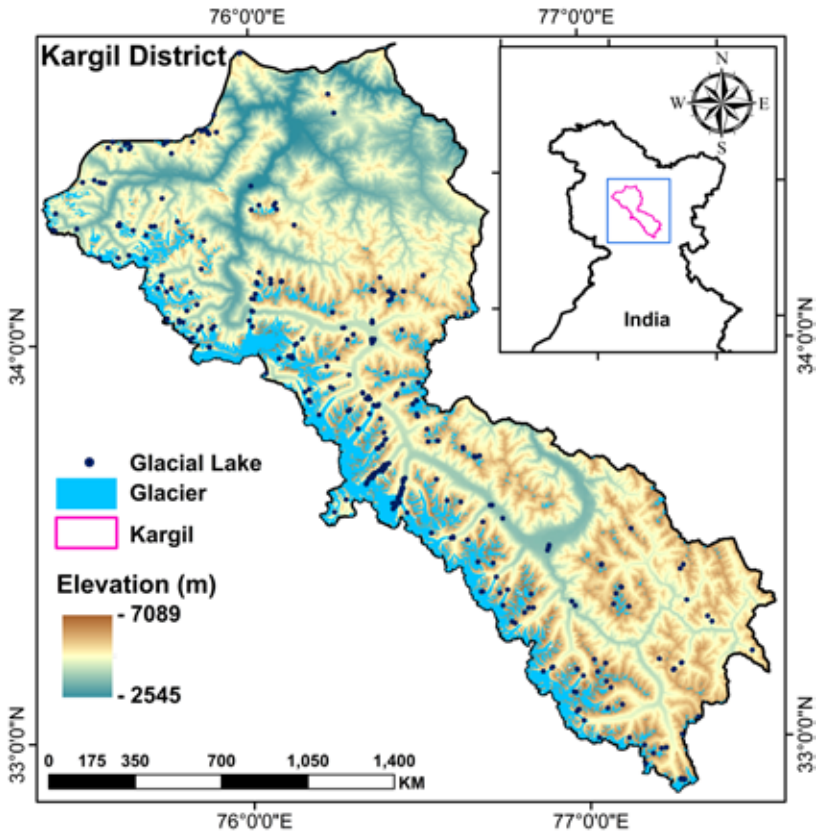


Figure 1. Location map of the Kargil district. This image utilizes the SRTM DEM as its backdrop, upon which glacier polygons derived from the GLIMS RGI 7.0 inventory are overlaid.

3. DATASET USED

This study utilized Sentinel-2 MultiSpectral Instrument (MSI) satellite imagery to map glacial lakes within the Kargil region acquired from the European Space Agency (https://browser.dataspace.copernicus.eu). The MSI satellite images were opted due to their advantageous features, such as adequate spatial resolution of 10 meters and a substantial ground coverage area of 110*110 km^2. The satellite images employed in this study were captured for the month of September 2022, chosen due to minimal cloud and snow cover presence. Topographic data for the study area such as slope, aspect, and elevation, were derived from the Shuttle Radar Topographic Mission Digital Elevation Model Version-3 (SRTM DEM-v3). This SRTM DEM-v3 having spatial resolution of 30 meters, was acquired from the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). The details of dataset used in this study is given in Table 1. Additionally, the RGI 7.0 glacier inventory served as our reference for mapping the glacial lakes, ensuring the precision and uniformity of our analysis (http://glims.colorado.edu/glacierdata/).

Table 1. List of satellite data used to map the glacial and high-altitude lakes in the Kargil, Ladakh. MSI = MultiSpectral Instrument, SRTM DEM-v3 = Shuttle Radar Topographic Mission Digital Elevation Model Version-3.

Platform and sensor	Scene ID	Resolution (m)	Date of acquisition
Sentinel 2 MSI	L2A_T43SFU_ A028917_20220919T054631	10	19-09-2022
Sentinel 2 MSI	L2A_T43SFS_ A028917_20220919T054631	10	19-09-2022
Sentinel 2 MSI	L2A_T43SET_ A028917_20220919T054631	10	19-09-2022
Sentinel 2 MSI	L2A_T43SFT_ A028917_20220919T054631	10	19-09-2022
Sentinel 2 MSI	L2A_T43SEU_ A028917_20220919T054631	10	19-09-2022
Sentinel 2 MSI	L2A_T43SGT_ A037568_20220901T053903	10	01-09-2022
Sentinel 2 MSI	L2A_T43SGS_ A037568_20220901T053903	10	01-09-2022
SRTM DEM-v3		**30**	**February 2000**

4. METHODOLOGY

The 10-meter bands of Sentinel-2 MSI including Blue (B), Green (G), Red (R), and Near-Infrared (NIR), were harnessed for the precise mapping of glacial and high-altitude lakes. Previously several approaches have been employed to delineate glacial lakes from satellite images such as manual mapping (e.g., Bhambri et al., 2018; Zhang et al., 2015), supervised and unsupervised classification methods (Zhang et al., 2022; Nautiyal et al., 2022; Zhang et al., 2020), normalized techniques, including the Normalized Difference Water Index (Huggel et al., 2002; Li and Sheng, 2012; Worni et al., 2013) and object-oriented mapping (Nie et al., 2017, 2013). Particularly, automatic lake delineation approached from optical and radar images are well-introduced (Huggel et al., 2002; Mergili et al., 2013; Nie et al., 2013; Raj et al., 2016; Mal et al., 2020; Zhang et al., 2022) and have proved to be advantageous in reducing interpretational biases. However, misclassification owing to spectral mixing is recognized to be a major challenge in the delineation of small features such as supraglacial ponds (Zhang et al., 2015) requiring

rigorous manual editing (Mergili et al., 2013). Therefore, a hybrid approach is preferred in the present study to delineate the lake boundaries. This involves firstly automatic delineation of all the lakes using band ratio (Green/NIR) method as outlined in Gardelle et al. (2011) (Figure 2). Different thresholds were tried to arrive at optimum value to differentiate the water bodies. The variation in the threshold can be attributed to the tonal differences exhibited by the lakes. Shallow, deep, and turbid lakes, among other variations, contribute to the tonal diversity observed in the imagery, necessitating a dynamic threshold (0.9 to 1.8) to effectively capture these distinct features. Setting an initial low threshold (1.1) was intentional, which resulted in the overestimation of lake areas, considering dark and very light image pixels. Consequently, we conducted systematic manual post-editing for each mapped lake to account for the misclassifications owing to shadows, clouds and threshold value (Mergili et al., 2013) (Figure 2). While editing, lake boundary lines were digitized along the pixel boundaries to keep consistency with automatic mapping (Shukla et al., 2018). Notably, manual editing can sometimes produce results that might vary from one interpreter to another and can be hard to reproduce (Nie et al., 2017; Zhang et al., 2015). Therefore, to minimize individual biases, the present study involves a single and sole interpreter responsible for mapping as well as editing all the glacial lakes (Nie et al., 2017; Paul et al., 2015).

Present study considered all mapped feature as a lake if it consisted of at least four pixels or covered an area of about 0.0004 km^2 on the surface. This is in contrast to previous studies by Chen et al., (2021, 2007) and Wang et al., (2015) which filtered lakes, considering only those larger than 0.02 km^2 and the National Remote Sensing Centre (NRSC) which considered lakes with a minimum size of ≥ 0.0025 km^2 (Rao et al., 2023). To classify the lakes, schema proposed by Mergili et al. (2013), Gardelle et al. (2011) and Shukla et al. (2018) was followed. The lakes were grouped into four main classes: supraglacial lakes (SGL), proglacial or periglacial lakes in direct contact with the glacier (PGLC), proglacial or periglacial lakes located away from the glacier (PGLA, based on proximity to the glacier), and other lakes (OL) (Shukla et al., 2018). For the PGLA category, a 2.5 kilometer buffer zone

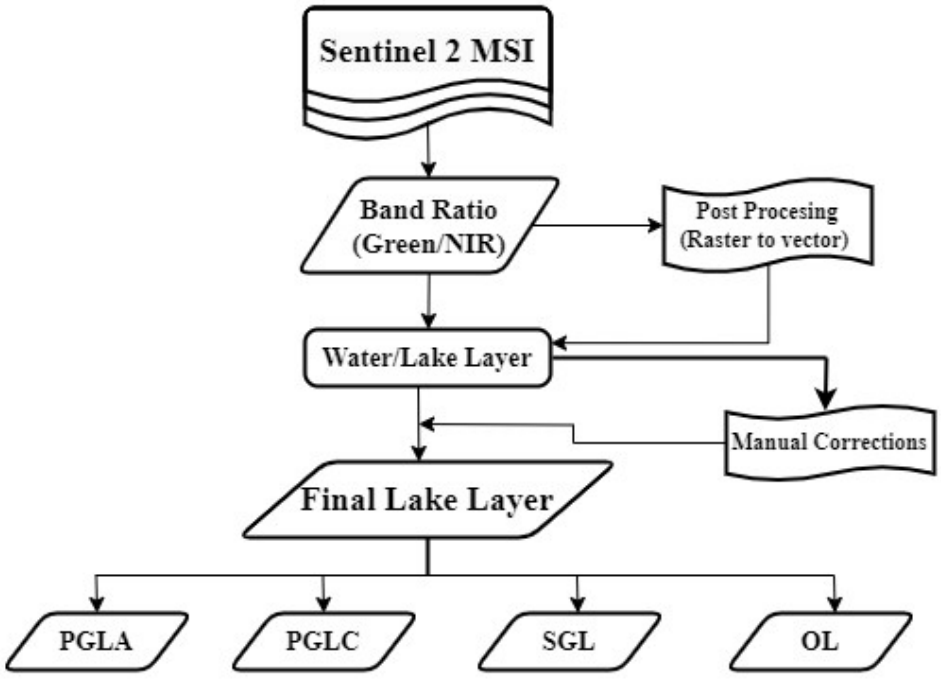


Figure 2. Flowchart showing the methodology employed for mapping the glacial lakes. PGLC is pro/peri glacial lakes in contact with glaciers; PGLA is pro/peri glacial lakes away from glacier; SGL is supraglacial lakes and OL is other high-altitude lakes.

from the glacier boundaries was generated, assuming that lakes within this buffer distance had formed due to glacial processes (Fujita, 2008; Gardelle et al., 2011; Shukla et al., 2018). The OL category includes all other high-altitude lakes in the study area that do not fit into the first three categories.

Information of the each and every lake is stored in a shapefile format, containing details such as Serial Number, Lake ID, Lake Type, Area (km^2), Perimeter (m), Elevation (m asl), Slope (deg.), Aspect and locational coordinates (Latitude/Longitude) (Appendix-I). The unique ID of each lake was assigned based on its central location (centroid), following a method recommended by the Global Land Ice Measurements from Space (GLIMS) (https://www.glims.org/MapsAndDocs/assets/GLIMSID_fromPointfile_ArcGISscript_Jiskoot.pdf).

4.1 Uncertainty Estimation

The uncertainty estimation is crucial to substantiate the results derived from the remote sensing data. The accuracy of glacial lake mapping is influenced by various factors, including the quality of satellite imagery, the precision of digitization procedures, the complexity of the terrain, the choice of threshold values, and the expertise of the analysts (Gardelle et al., 2011; Xin Wang et al., 2013) . Therefore, due care was taken to minimize the potential errors at each step. Satellite imageries were chosen for the ablation period with minimal snow and cloud cover, ensuring optimal visibility. To address the terrain complexity, enhance precision of digitization procedures and minimize the error due to analyst biases, a sole analyst with five years of experience in digitization processes and good understanding of the study area terrain was engaged. Threshold values for band ratios were carefully finalized through rigorous trial and error method considering image-specific characteristics combined with values recommend in literature (Ahmed et al., 2021; Gardelle et al., 2011; Mitkari et al., 2017; Paul et al., 2016). Further, verification involved manual inspection of each and every lake to eliminate potential errors, securing the overall reliability of the glacial lake inventory. Finally, the residual uncertainty in lake measurements attributable to image resolution was quantified using techniques established in previous research (Fujita, 2008; Gardelle et al., 2011; Salerno et al., 2012; Wang et al., 2013). Image resolution is a critical factor affecting the accuracy of lake measurements obtained from remote sensing imagery. As the resolution improves, finer details of the lake surface become distinguishable, leading to more precise measurements. However, even with high-resolution imagery, an inherent uncertainty remains due to the pixelation of the lake surface. This uncertainty stems from the possibility that the actual lake boundary may not align perfectly with pixel boundaries, resulting in errors in lake area and perimeter measurements.

It is assumed that the lake margin is mapped with an error of ±1 pixel along its perimeter. Therefore, inside and outside buffers of 10 m size (equal to the spatial resolution of the unitized imageries) were created around the glacial lake boundaries and their differences were calculated and divided by the lake area to calculate the uncertainty quotient in percentage. The percentage measures how much the area of a glacial lake is overestimated or underestimated. The estimated uncertainty ranges from 18.5% to 384.5%. This relatively high uncertainty is mainly because of the presence of significant number of small glacial lakes in the study area where almost all the pixels are treated as boundary pixels contributing in error estimation. However, this uncertainty is theoretical and can be considered indicative because manual adjustments were made to each and every lake to ensure that mapped boundaries adhere precisely to actual lake boundaries, particularly in the case of small lakes. Finally, to calculate the uncertainty judiciously, the mapped lakes were classified into three categories based on their sizes i.e., 0.0004 to 0.01 km^2, ≥0.01 to 0.1 km^2 and ≥ 0.1 km^2. The average uncertainties for these classes are 167.53, 39.38, and 24.87%, respectively showing larger uncertainties for the smaller lakes. However, larger lakes have uncertainties comparable to previous estimates (Mal et al., 2020; Shukla et al., 2018; Nie et al., 2018; Worni et al., 2013) and can be said representative for all the lakes. Hence, an uncertainty quotient of 24.87% is considered here for all the lakes mapped in the present study.

5. RESULTS

The results reveal a total of 355 glacial and high-altitude lakes in the Kargil district region, encompassing an area of 4.8 ± 1.2 km^2 in 2022 (Appendix-I). The lake sizes range from 0.0004 km^2 to 0.579 km^2 (Figure 3a), with an average lake area of 0.013 km^2. The Shapiro-Wilk normality test at 95% confidence level indicates that the lake sizes deviate significantly from a normal distribution (Figure 3b). Instead, it exhibits substantial skewness by a factor of 8.198, which characterizes a right-skewed distribution (Figure 3b). Among 355 identified lakes, approximately 82% (n=293) are less than 0.01 km^2 in size, collectively covering an area of 0.82 ± 0.2 km^2. Thus, these smaller lakes contribute only ~18% to the overall lake area. Conversely, only ~2% of the lakes (n=7) have areas ≥ 0.1 km^2 and account for about 52% of the total lake area. This highlights a significant disparity in lake size distribution, with a small number of large lakes contributing substantially to the total lake area. Class-wise analysis reveals that PGLCs are comparatively low in number (85) but occupy the largest area share of 60% in total glacial lakes covering an area of 2.88 ± 0.7 km^2 (Figure 4). PGLAs are 138 in number and occupy the second largest area of 0.9 ± 0.2 km^2. There are large number (103) of SGLs with an area coverage of 0.32 ± 0.07 km^2. OLs are limited in number (29) and cover 0.6 ± 0.1 km^2 of area (Table 2).

The topographic analysis of the study includes elevation (Figure 1), slope (Figure 5a) and aspect (Figure 5b) characteristics of the mapped lakes (Figure 6). The mean altitude of all the lakes is 4604 m (asl). Further, to assess the altitudinal distribution of lakes, 500 m altitude bins were generated using the SRTM DEM. Results reveal that the majority of lakes, numbering 237, are confined within the altitude range of 4000-5000 m asl, covering a substantial proportion of ~84% (4 km^2) of the total area (Figure 6a). Within this range, lakes in the 4000-4500 m asl altitude range cover majority (~68%) of the area (n= 118; area = 3.87 km^2). The lakes in the 4500-5000 m altitude bin count 118 collectively covering 18% (0.83km^2) of the total area. This concentration is attributed to the favorable conditions prevalent in this elevation range across the Hindu Kush, Karakoram, and Himalayan ranges (Ashraf et al., 2017; Nie et al., 2017; Zhang et al., 2015; Worni et al., 2013). At 4000-5000 m asl altitude bin, the prevailing temperature creates an optimal environment where glacial ice melts faster than it accumulates, leading to the formation of water bodies. Lower elevations, being generally warmer, experience rapid melting but also increased evaporation, while higher altitudes are too cold for significant melting (Ashraf et al., 2017; Frey et al., 2010b; Sakai, 2012; Zhang et al., 2022). Topographically, this range often features cirques and depressions carved by glacial action, acting as natural basins for accumulating the meltwater. As glaciers retreat, they leave behind debris called moraines. These moraines can act like dams, blocking the flow of melting ice and forming new lakes. These dams are particularly common in the 4000-4500 m asl altitude bin (Sakai, 2012; Sakai and Fujita, 2010). These general findings by previous studies are in line with the observed altitudinal distribution of lakes in the present study. Additionally, lakes below 4000 m asl and above 5500 m asl have significantly lower counts and areas. Only 34 lakes are observed below 4000 m asl (i.e. 3500-4000 m asl altitude bin) covering an area of (0.19 km^2; ~4% of the total area) while 81 lakes in the altitude bin of 5000-5500 m asl range covering 0.52 km^2 of area. Only 2 lakes are located above 5500 having a minimal total area of 0.002 km^2. Category-wise, below 4000 m asl, lake distribution shows 11 PGLA, six PGLC, four SGL, and 13 OL. The 4000-4500 altitude bin shows 30 PGLA, 16 PGLC, 64 SGL, and eight OL. Within the 4500-5000 m asl m asl altitude bin, there are 60 PGLA, 27 PGLC, 24 SGL, and 6 OL. The 5000-5500 m asl bin consists of 38 PGLA, 30 PGLC, 11 SGL, and one OL. Altitudes above 5500 m asl exhibit only two PGLC with no counts of PGLA, SGL and OL (Figure 6d). Interestingly, the number of SGLs decreases with increasing elevation. This reduction in SGLs with higher elevation can be attributed to the general colder temperature limiting their formation and sustenance owing to increased freezing, reduced melting, and the prevalence of snow cover, creating an environment less conducive to the presence of these lakes.

Figure 6b displays the distribution of lakes based on their slope along with their corresponding area. Slope significantly influences the distribution of glacial lakes, revealing distinct patterns in their dimensional characteristics and abundance. Lakes with gentle slopes (≤ 4°) are scarce, covering only 3.8% (0.18 km^2) of the total area, yet accounting for 12.4% (n= 44) of the count. However, the slope range 4-8° contains largest cover of glacial lakes (2.53 km^2 52.6%) with a count of 133. Relatively steeper slopes (≥ 8°) also host substantial area (2 km^2; 40.6%) and count (n= 178) of glacial lakes. Overall, the results reveal a complex relationship wherein gentle slopes tend to support larger, stable lakes, and surprisingly, steeper slopes also show a significant increase in both lake count and total area. This is probably because of sudden increase in slope in the mountainous terrain of the study region and unintended inclusion of pixels at lake borders showing steep slopes. Nevertheless, the mean slope of SGLs is 7.44° affirming their formation at gently sloping glacier tongues. PGLCs have a mean slope of 12.68° impounded behind steep moraines. In contrast, PGLAs and OLs, occupy moderate slopes of 8.45° and 9.91°, respectively. Grasping these slope-type relationships is critical for managing water resources and assessing glacial lake hazards.

Further, lakes with slopes less than 2° have a count of 7 lakes and cover a total area of 0.01 km^2 and have five PGLA, one SGL, and one OL. In the 2-4° slope range, there are 37 lakes, encompassing an area of 0.17 km^2 and there are 15 PGLA, two PGLC, 16 SGL, and four OL. The 4-6° slope range consists of 66 lakes with a cumulative area of 0.90 km^2 which comprises 26 PGLA, 8 PGLC, 25 SGL, and seven OL. Lakes in the 6-8° slope range number 67 includes 30 PGLA, seven PGLC, 24 SGL, and four OL, covering a larger area of 1.62 km^2. The 8-10° slope range has 22 PGLA, 12 PGLC, 19 SGL, and one OL includes total 54 lakes with a total area of 0.75 km^2. Moving to higher slopes, the 10-12° range has 32 lakes covering 0.25 km^2 and there are 15 PGLA, 8 PGLC, six SGL, and three OL, while the 12-14° slope range comprises 25 lakes with an area of 0.10 km^2 and this range includes 8 PGLA, 10 PGLC, six SGL, and one OL. Lakes with slopes greater than 14° account for 67 and have a total area of 0.89 km^2 consist of 18 PGLA, 35 PGLC, seven SGL, and seven OL (Figure 6e). This comprehensive distribution provides insights into the varied occurrence of lake types across different slope categories in the inventory.

Figure 6c presents the relationship between aspect and the distribution of glacial lakes. The statistics reveal a dominance of south-facing lakes, covering a substantial area of 1.25 km^2 (26%; n=75). The southeast and southwest aspects are occupied by approximately 30% (area= 1.43 km^2; n= 58) and 10 % (area= 0.48 km^2; n=47) of total area of lakes. East and west aspects each cover 22% (area=1.06 km^2; n=58) and 5.4% (area=0.26 km^2; n=34) of total lake's area. In contrast, north and northwest aspects host fewer lakes (10 and 32) and cover smaller areas (0.01 km^2 and 0.08 km^2). This pattern is consistent with previous studies (Garg et al., 2017; Shukla et al., 2018), indicating that relatively higher solar radiation on western and southern slopes facilitates snow and ice melt, thereby supporting the development and expansion of various glacial lakes as meltwater accumulates in depressions or behind natural barriers. Additionally, SGLs tend to develop over southern (and related directions) aspects which can again be attributed to higher solar radiation at these slopes which influences glacier melt driving SGL formation and their distribution. Proglacial lakes (including PGLC and PGLA) exhibit a more even distribution across aspects, indicating their higher dependence on topographical setting than on melt water supply. OLs are sparse across all aspects, suggesting low influence of slope direction on their formation and distribution. Highest concentration of glacial lakes, particularly SGLs (in combination with PGLCs), in southern aspects indicates that these lakes have high potential to grow in size and may become hazardous

Table 2. Glacial lakes distributions in the Kargil district, Ladakh

S.No.	Lake type	Total number	Total area (km^2)	Mean area (km^2)	Area percentage (%)	Mean elevation (m)	Mean slope (°)
1	PGLA	138	0.9	0.007	18.75	4679	8.45
2	PGLC	85	2.88	0.034	60	4757	12.68
3	SGL	103	0.32	0.003	6.67	4484	7.44
4	OL	29	0.6	0.02	12.5	4129	9.91

in nature. Understanding the precise role of aspect, solar radiation, and glacier dynamics in shaping the size and stability of these SGLs and PGLCs remains crucial for effective hazard mitigation and resource management in the Kargil region.

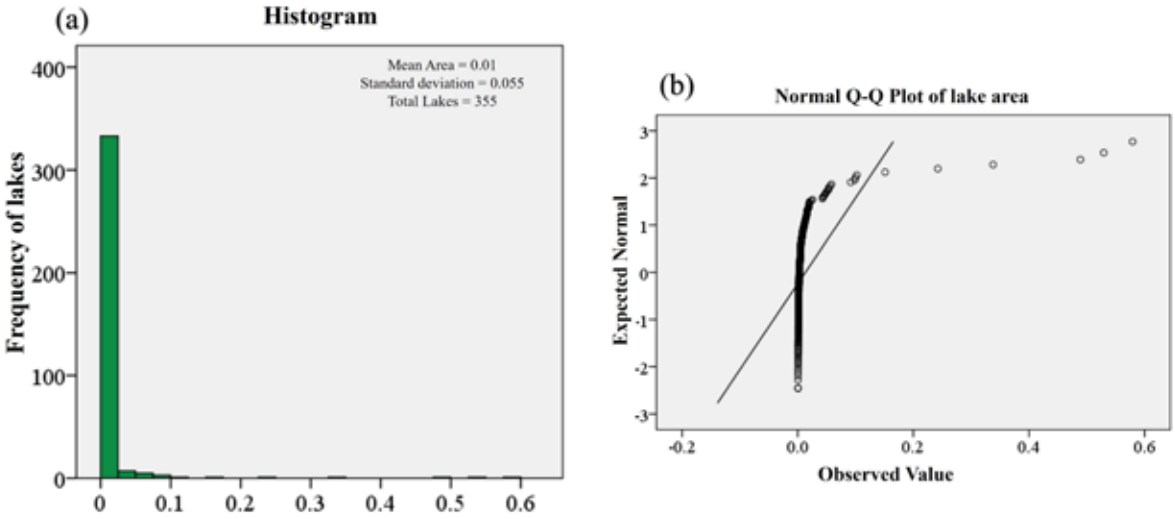


Figure 3. Panel (a): frequency distribution of lake areas in the study area highlighting the predominance of small lakes. Panel (b): Normal Q-Q plot of lake areas using the Shapiro-Wilk distribution test. The plot reveals a significant deviation from normality, indicating that the lake area distribution is not normally distributed.

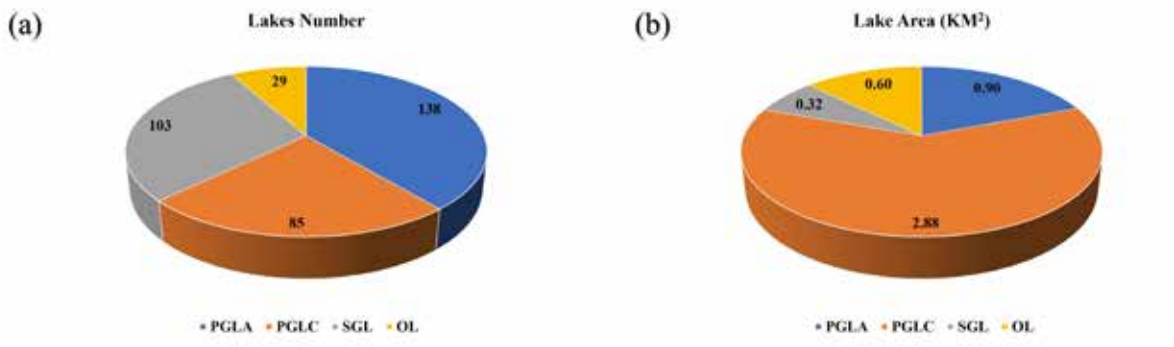


Figure 4. Panel (a) displays the count of glacial lakes in different categories (viz. proglacial lakes in contact with glaciers (PGLC), proglacial lakes away from glacier (PGLA), supraglacial lakes (SGL) and other high-altitude lakes (OL)) in Kargil district, while Panel (b) shows the area of lakes in each category.

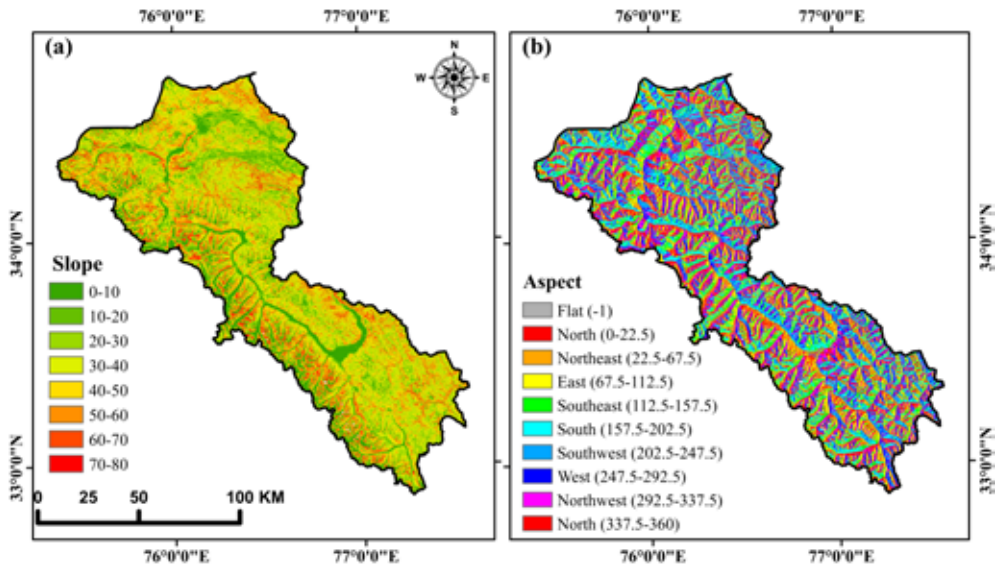
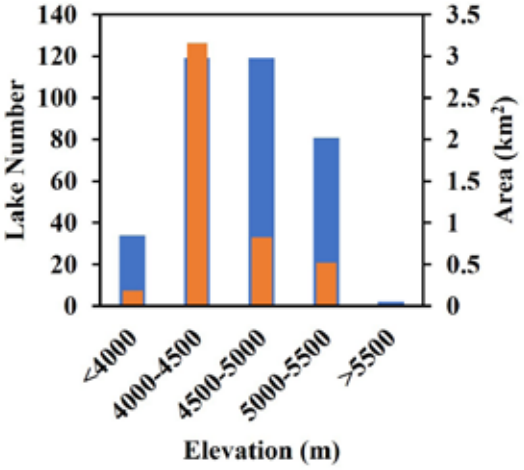
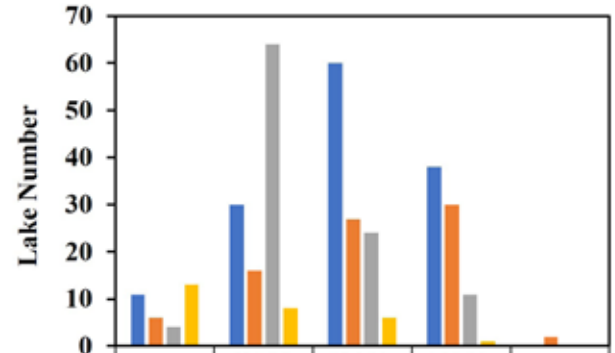
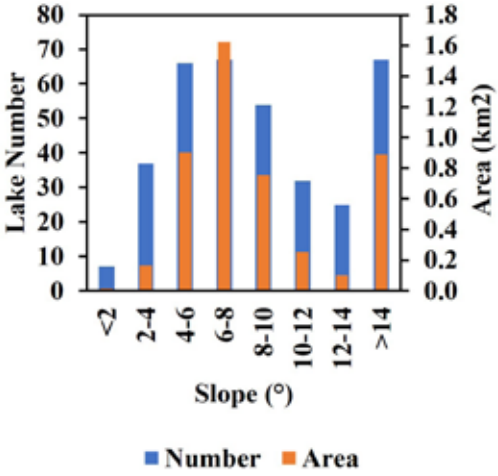


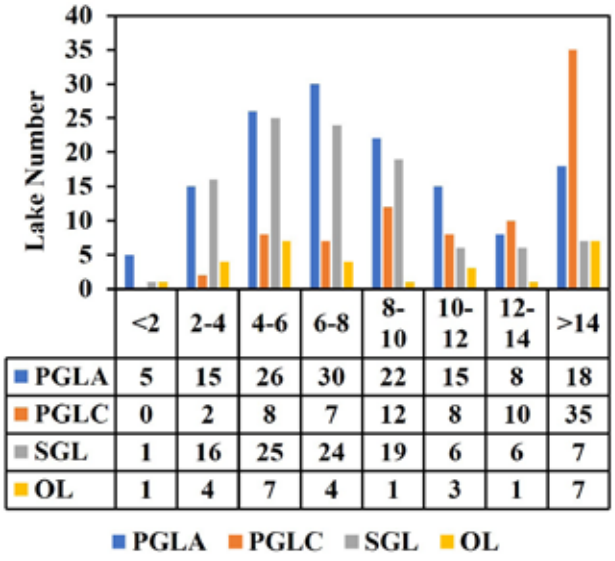
Figure 5. Slope (Penel a) and aspect (Panel b) maps of the Kargil district, Ladakh UT generated from SRTM DEM.



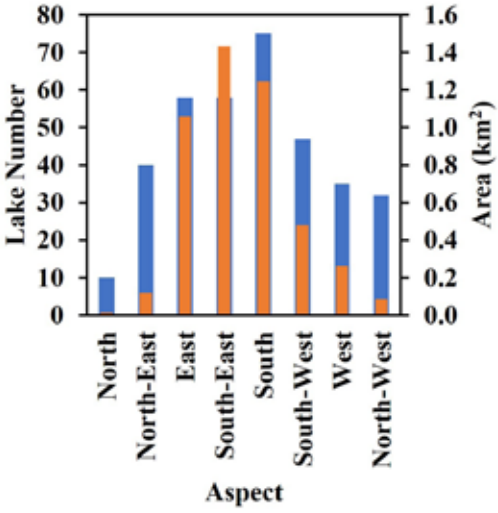


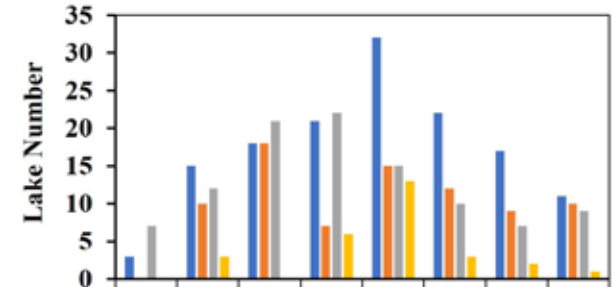
	<4000	4000-4500	4500-5000	5000-5500	>5500
PGLA	11	30	60	38	0
PGLC	6	16	27	30	2
SGL	4	64	24	11	0
OL	13	8	6	1	0





	<2	2-4	4-6	6-8	8-10	10-12	12-14	>14
PGLA	5	15	26	30	22	15	8	18
PGLC	0	2	8	7	12	8	10	35
SGL	1	16	25	24	19	6	6	7
OL	1	4	7	4	1	3	1	7





	North	North-East	East	South-East	South	South-West	West	North-West
PGLA	3	15	18	21	32	22	17	11
PGLC	0	10	18	7	15	12	9	10
SGL	7	12	21	22	15	10	7	9
OL	0	3	0	6	13	3	2	1

Figure 6. Frequency distribution and area (km²) of glacial lake inventory based on their various altitudinal ranges (Panel a), Slope (Panel b), and Aspect classes (Panel c). Area and distribution of glacial lake areas and their classification (PGLC, PGLA, SGL, OL) across various altitudinal ranges (Panel d), Slope ranges (Panel e), and aspect classes (f).

6. DISCUSSION

6.1 Regional context

The study presents a comprehensive inventory for "glacial and high-altitude lakes" in the Kargil region using Sentinel-2 MSI images for the year 2022. The findings reveal that there are a total of 355 glacial and high-altitude lakes in the Kargil region covering an area of 4.8 ± 1.2 km^2. A recent study conducted by the National Remote Sensing Centre (NRSC, Rao et al., 2023) identified a total of 307 glacial lakes in the Kargil region with a total area of 951.12 (ha) for the period 2016-2021. This difference in number and area of the lakes from the present study can be ascribed to variations in data sources, time frame, interpretation biases and methodological approaches employed in both the studies. The present study also acknowledges that certain limitations could have resulted in the omission of some glacial lakes from the mapping process. These limitations include: a) snow or clouds concealing the glacial lakes; b) glacial lakes being frozen over; and c) glacial lakes being shaded by mountains (Rao et al., 2023).

There have been credible reports of lake expansion in the western Himalaya including Ladakh during the last two three decades (Zhang et al., 2015; Gupta et al., 2022; Nie et al., 2017). Though the number and area of current glacial lakes are low in the Ladakh Himalaya, they are likely to increase in the future. Zheng et al. (2021) projected a comparatively higher expansion of glacial lakes in Ladakh region during the 21st century than the eastern Himalaya, and by the year 2100, the GLOF hazard levels in the Indus River Basin are anticipated to reach their peak. This is because the saturation point is reached in the eastern Himalaya, meaning that there is limited space for new lakes to form or for existing lakes to expand further. On the other hand, Ladakh glaciers have started melting with an apparent end of Karakoram anomaly (Hugonnet et al., 2021) and there is a large scope of new lake formation (Zheng et al., 2021). Zheng et al. (2021) stressed that in the third pole region including the Indus River basin, the overall number of lakes classified to have high or very high-risk levels is expected to increase rapidly (Zheng et al., 2021).

Furian et al., (2022) presents projections for the development of glacial lakes in High Mountain Asia (HMA) until 2100. They estimated that the glacial lake area in the entire region will grow by 474 to 833 km^2. This represents an increase in lake area of approximately 120% to 210% compared to 2018. Additionally, the lake volume is expected to increase by 22.8 km^3 to 39.7 km^3, indicating a potential increase of approximately 585% to 1,000%. They accentuated for the urgent need of more localized, in-depth studies to enable local communities to adapt to emerging challenges from growing glacial lakes and improve sustainable development in the HMA. Recently, Zhang et al., (2023) reported a substantial rise in proglacial lakes, indicating a 47% increase in number, a 33% expansion in area, and a 42% growth in volume within the greater Himalayan region from 2000 to 2020.

Our study aligns with these findings, revealing that proglacial lakes constitute the majority, with 223 out of 355 lakes identified in the Kargil region. Notably, the prevalence of proglacial lakes, which are directly fed by glaciers and possess huge potential to grow, raises concerns about potential hazards to downstream communities. Studying these dynamic water bodies provides crucial data for predicting the future behavior and potential impacts of the entire Himalayan glacial lake system.

6.2 Glacial lakes formation conditions

The formation of glacial lakes in the Ladakh region is intricately linked to several key factors. Negative mass balance regime, low velocity, presence of debris cover and gentle slopes are some of the prerequisite for the glacial lake formation (Sakai 2012; Sakai and Fujita, 2010). In the Kargil district, there are 2219 number of glaciers covering a total area of 1661 km^2. About 13% of glaciers (n= 284) have debris at their ablation zone amounting a total debris cover of 165 km^2 of the glacierized area (Herreid and Pellicciotti, 2020). The debris is often distributed unevenly on the glaciers (Anderson and Anderson, 2018), causing heterogenous melting and creating depressions that eventually fill with water (Sakai, 2012; Sakai and Fujita, 2010). Notably, the average slope of debris-covered glacier tongues in the Kargil region is ~10° which promotes water retention on the glacier surface. Also, there have been ample reports of glacier depletion in the Kargil district as well as

glacier velocity slowdown in recent decades (Garg et al., 2022; Soheb et al., 2022 Dehecq et al., 2018; Shukla et al., 2020; Frey et al., 2012; Mandal et al., 2024; Abdullah et al., 2020). These conducive conditions have probably led to the development of large number of glacial lakes in study region. Moreover, comparatively low altitude of the glaciers in the study region contributes to the formation of glacial lakes (Frey et al., 2010b; Salerno et al., 2016, 2012), as evidenced by our finding which reveal largest concentration of lakes (3.87 km²; n=119) in the 4000-4500 m asl altitude bin. At lower altitudes, the temperatures are higher, causing glaciers to melt more rapidly and leading to the formation of glacial lakes (Frey et al., 2010b). Ashraf et al. (2017), also reported higher concentration of lakes in the altitude bin of 4000-4500 m asl in the in the Hindu Kush, Karakoram, and Himalayan ranges. Furthermore, our study revealed that the maximum number of lakes, in total 177, and covering an area of 2.18 km², are formed in the slope gradient range of 2-8° (Appendix-I). The gentle slopes allow meltwater retention, which can then accumulate behind moraines or ice dams to form glacial lakes (Schmidt et al., 2020). In combination, dynamic interplay between glacial processes and the unique geographical characteristics of the region plays a crucial role in the formation of glacial lakes in the study region.

6.3 Permafrost and glacial lake occurrence

The relationship between glacial lakes and permafrost is intertwined through hydrological dynamics and shared environmental vulnerabilities (Shukla et al., 2018). Glacial lakes, often formed by the melting of glaciers, interact with permafrost in regions where the frozen ground is present (Mergili et al., 2013). The presumption of a particular permafrost influence arises from the high altitudes of many lakes, suggesting potential effects on both the stability of the dams themselves and the adjacent slopes and rock walls (Mergili et al., 2013). The topography of permafrost areas, shaped by glacial processes, influences the formation and characteristics of these lakes. Changes in permafrost conditions, such as thawing, can impact the stability of lake surroundings, contributing to the potential for GLOFs (Haeberli et al., 2017; Harris and Murton, 2005). Moreover, as permafrost thaws due to climate change, it can also destabilize glaciers, potentially leading to the formation of new glacial lakes (Kääb et al., 2005).

Owing to the absence of any comprehensive permafrost studies in the Ladakh region, present study utilizes global datasets on potential permafrost distribution (Gruber, 2012) to investigate any potential correlation between the presence of glacial lakes and the concentration of permafrost (Figure 7). To analyze the probability of occurrence of permafrost and the spatial arrangement of glacial lakes in the study area quantitatively, the Permafrost Zonation Index (PZI) range of 0–1 was divided into five sub-categories (Table 3). The lowest value indicates permafrost in very favorable conditions, while the highest values suggest permafrost occurrence in almost all conditions (Figure 7). Figure 8 shows the spatial distribution of each glacial lake type across specific PZI classes while Table 3 contains the corresponding statistics. Results reveal that more than 88% of the lakes (n=311) are situated within the permafrost zone. About 43% of lakes are situation in zones where the permafrost has high probability to exist in almost all conditions (PZI valve >0.4). Notably, a substantial concentration of Proglacial (PGLA) lakes, accounting for about 40% (n=122), is observed within the PZI. This observation is highly certain, as permafrost provides an ideal environment for the formation and persistence of proglacial lakes (Haeberli et al., 2017; Kääb et al., 2005). Furthermore, current study identifies that a large number of lakes are located in the <0.2 PZI zone, totaling n=131 (Table 3). Glacial lakes are more prevalent in this zone due to permafrost thawing, discontinuity, and shallowness, creating depressions that can be filled with water and form lakes. Overall, the close association of existing glacial lakes with the permafrost adds to their sensitivity to climate change.

Table 3. Distribution of different glacial lake types (viz. proglacial lakes in contact with glaciers (PGLC), proglacial lakes away from glacier (PGLA), supraglacial lakes (SGL) and other high-altitude lakes (OL)) in different sub-classes of Permafrost Zonation Index (PZI) in the Kargil region.

Permafrost Zonation Index class → / Lake Type ↓	<0.2	0.2-0.4	0.4-0.6	0.6-0.8	>0.8
PGLA	35	13	23	37	14
PGLC	22	7	5	29	12
SGL	65	8	9	8	6
OL	9	1	6	2	0
Total Lakes	131	29	43	76	32

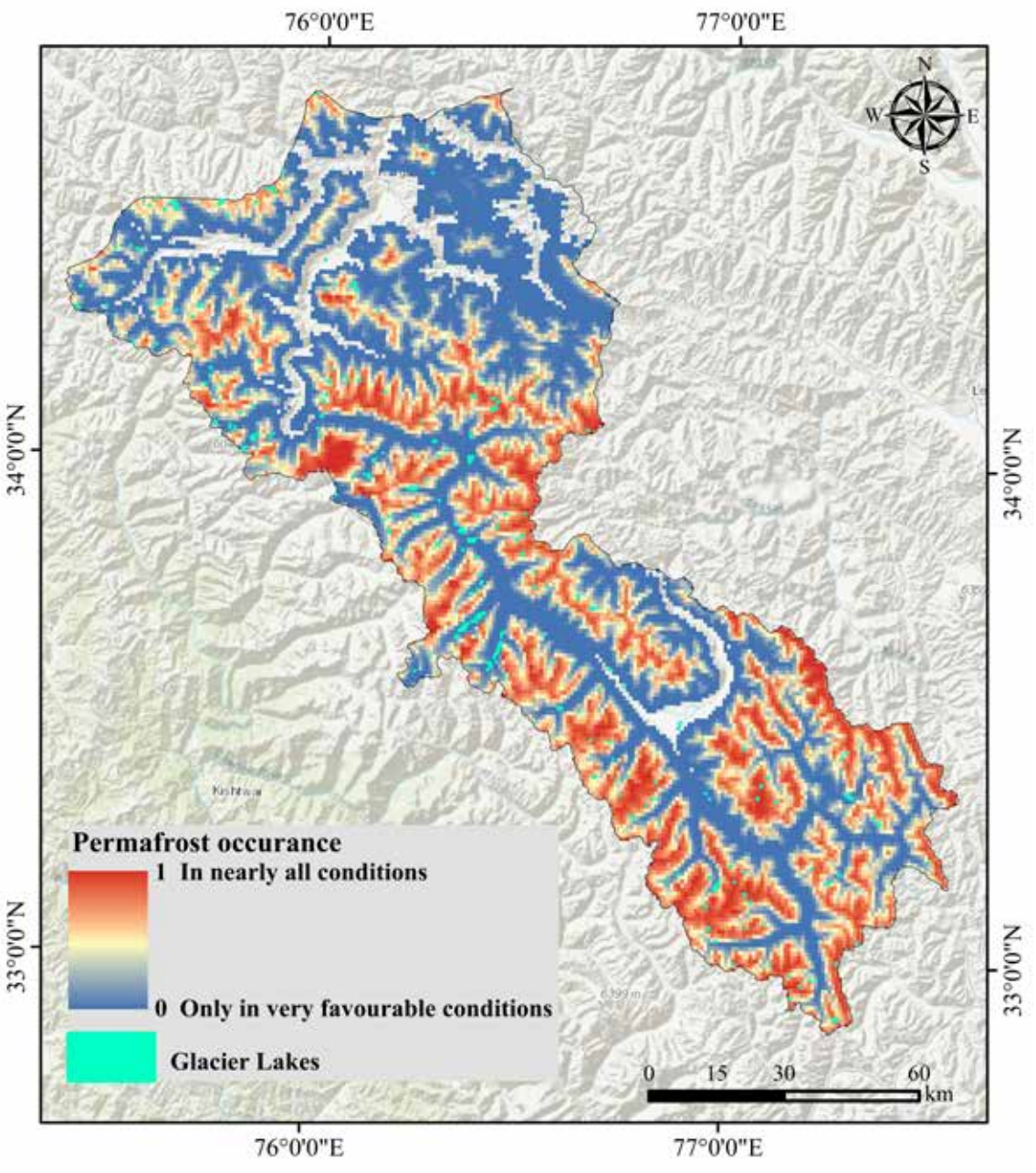


Figure 7. Presence of permafrost within the region, shown by the Permafrost Zonation Index (PZI), and the distribution of the glacial lakes. Permafrost Zonation Index data sourced from Gruber, (2012).

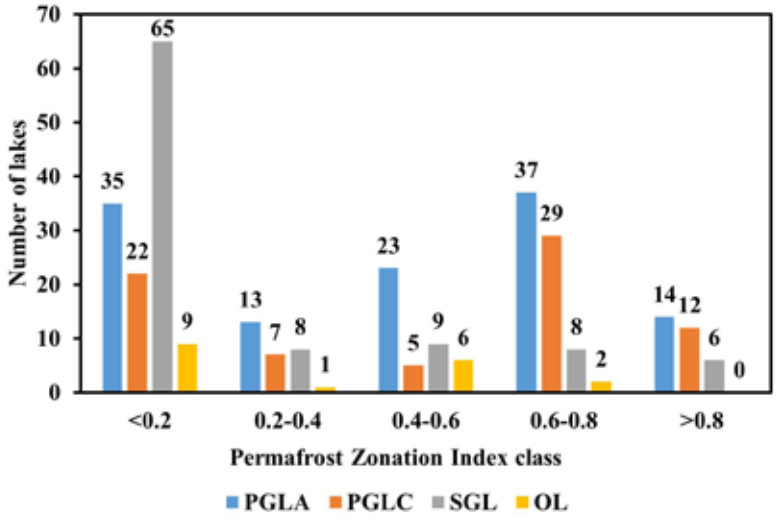


Figure 8. Relationship between glacial lake area and permafrost zonation index (PZI) in the Kargil region, Western Himalayas.

7. CONCLUSION & RECOMMENDATIONS

This study presents a comprehensive inventory of glacial and high-altitude lakes in the Kargil district of Ladakh and systematically analyzes their types and topographic attributes. With the analysis of recent Sentinel-2 MSI imageries (2022), a total of 355 glacier and high-altitude lakes were identified in the Kargil district, encompassing an area of 4.8 ± 1.2 km^2. The lake classification reveals that though PGLCs are comparatively low in number (85), they occupy the largest area share of 60% in total glacial lakes covering an area of 2.88 ± 0.7 km^2. PGLAs are 138 in number and occupy the second largest area of 0.9 ± 0.2 km^2. There are large number (103) of SGLs with an area coverage of 0.32 ± 0.07 km^2. OLs are limited in number (29) and cover 0.6 ± 0.1 km^2 of area. The lake sizes range from 0.0004 km^2 to 0.579 km^2 with an average lake area of 0.013 km^2 suggesting that the lakes in the region are small in size and are in their initial phase of development. The mean elevation of the lakes is 4604 m and notably, ~21% of them predominantly oriented in the southward direction indicating their exposure to higher solar radiation. The majority of lakes are situated on slopes with a gradient ranging 2-8° which reflects their potential to grow in size. Sustained glacier recession and consequent velocity decrease in the study region further exacerbate the lake formation and development processes. Also, ~88% of the lakes (n=311) are found to be situated within the permafrost zone with ~43% of lakes located in the zone where permafrost has high probability to exist in almost all conditions. This permafrost association adds to the instability of the lakes. Further, the analysis reveals that the glaciated area in Kargil region is dominated by the large number of PGLCs and SGLs which are likely to expand in future posing serious threat to the communities living in immediate proximities to the glaciers. Overall, the present study provides a reliable base line data on lakes dimensions, spatial distribution, topographic characteristics and their association with the permafrost in the Kargil district. This baseline data will provide a valuable foundation for future research and management efforts related to glacial lakes in the area. Towards mitigation efforts, it is important to prioritize vulnerability assessments, especially for larger PGLCs, in order to thoroughly understand the potential risks associated with glacial lakes in the Kargil district. Additionally, an in-depth investigation into factors influencing lake growth, such as meltwater input and glacier dynamics, is essential for anticipating changes and mitigating potential hazards. The development of targeted risk reduction strategies for GLOF-prone lakes can minimize the risks substantially. In summary, this research contributes to our understanding of glacial lakes in the Kargil district of the Ladakh region, providing essential data for informed decision-making in order to minimize the glacial lake related hazards.

References

Abdullah, T., Romshoo, S.A. and Rashid, I., 2020. The satellite observed glacier mass changes over the Upper Indus Basin during 2000–2012. Scientific reports, 10(1), p.14285.

Ahmad, L., Parvaze, S., Sheraz Mahdi, S., Kanth, R.H., 2019. Climate Scenario in Cold Arid Region and its Future Prediction, in: Sheraz Mahdi, Syed (Ed.), Climate Change and Agriculture in India: Impact and Adaptation. Springer International Publishing, Cham, pp. 239–250. https://doi.org/10.1007/978-3-319-90086-5_19

Ahmed, R., Wani, G.F., Ahmad, S.T., Sahana, M., Singh, H., Ahmed, P., 2021. A Review of Glacial Lake Expansion and Associated Glacial Lake Outburst Floods in the Himalayan Region. Earth Syst. Environ. 5, 695–708. https://doi.org/10.1007/s41748-021-00230-9

Allen, S.K., Rastner, P., Arora, M., Huggel, C., Stoffel, M., 2016. Lake outburst and debris flow disaster at Kedarnath, June 2013: hydrometeorological triggering and topographic predisposition. Landslides 13, 1479–1491. https://doi.org/10.1007/s10346-015-0584-3

Anderson, L.S., Anderson, R.S., 2018. Debris thickness patterns on debris-covered glaciers. Geomorphology 311, 1–12. https://doi.org/10.1016/j.geomorph.2018.03.014

Ashraf, A., Naz, R., Iqbal, M.B., 2017. Altitudinal dynamics of glacial lakes under changing climate in the Hindu Kush, Karakoram, and Himalaya ranges. Geomorphology 283, 72–79. https://doi.org/10.1016/j.geomorph.2017.01.033

Azam, Mohd.F., Kargel, J.S., Shea, J.M., Nepal, S., Haritashya, U.K., Srivastava, S., Maussion, F., Qazi, N., Chevallier, P., Dimri, A.P., Kulkarni, A.V., Cogley, J.G., Bahuguna, I., 2021. Glaciohydrology of the Himalaya-Karakoram. Science 373, eabf3668. https://doi.org/10.1126/science.abf3668

Behera, M.D., Matin, S., Roy, P.S., 2014. Biodiversity of Kargil Cold Desert in the Ladakh Himalaya, in: Nakano, S.-I., Yahara, T., Nakashizuka, T. (Eds.), Integrative Observations and Assessments, Ecological Research Monographs. Springer Japan, Tokyo, pp. 253–274. https://doi.org/10.1007/978-4-431-54783-9_13

Benn, D.I., Bolch, T., Hands, K., Gulley, J., Luckman, A., Nicholson, L.I., Quincey, D., Thompson, S., Toumi, R., Wiseman, S., 2012. Response of debris-covered glaciers in the Mount Everest region to recent warming, and implications for outburst flood hazards. Earth-Sci. Rev. 114, 156–174. https://doi.org/10.1016/j.earscirev.2012.03.008

Benn, D.I., Evans, D.J.A., 2010. Glaciers & glaciation, 2nd ed. ed. Hodder education, London.

Bhambri, R., Mishra, A., Kumar, A., Anil, G., 2018. Glacier lake inventory of Himachal Pradesh. Himalayan Geol. Himal. Geol. 39, 1–32.

Bloeria, S.S., 2021. Ladakh in the twentieth century, 1. published in India. ed. Vij Books India Pvt Ltd, New Delhi, (India).

Bolch, T., Kulkarni, A., Kääb, A., Huggel, C., Paul, F., Cogley, J.G., Frey, H., Kargel, J.S., Fujita, K., Scheel, M., Bajracharya, S., Stoffel, M., 2012. The State and Fate of Himalayan Glaciers. Science 336, 310–314. https://doi.org/10.1126/science.1215828

Bolch, T., Shea, J.M., Liu, S., Azam, M.F., Gao, Y., Gruber, S., Immerzeel, W.W., Kulkarni, A.V., Li, H., Tahir, A.A., Zhang, G., Zhang, Y., 2019. Status and change of the cryosphere in the extended Hindu Kush Himalaya region, in: The Hindu Kush Himalaya Assessment. Springer, pp. 209–255.

Brun, F., Berthier, E., Wagnon, P., Kääb, A., Treichler, D., 2017. A spatially resolved estimate of High Mountain Asia glacier mass balances from 2000 to 2016. Nat. Geosci. 10, 668–673. https://doi.org/10.1038/ngeo2999

Carrivick, J.L., Tweed, F.S., 2019. A review of glacier outburst floods in Iceland and Greenland with a megafloods perspective. Earth-Sci. Rev. 196, 102876. https://doi.org/10.1016/j.earscirev.2019.102876

Chen, F., Zhang, M., Guo, H., Allen, S., Kargel, J.S., Haritashya, U.K., Watson, C.S., 2021. Annual 30 m dataset for glacial lakes in High Mountain Asia from 2008 to 2017. Earth Syst. Sci. Data 13, 741–766. https://doi.org/10.5194/essd-13-741-2021

Chen, X., Cui, P., Li, Y., Yang, Z., Qi, Y., 2007. Changes in glacial lakes and glaciers of post-1986 in the Poiqu River basin, Nyalam, Xizang (Tibet). Geomorphology 88, 298–311.

https://doi.org/10.1016/j.geomorph.2006.11.012

Costa, J.E., Schuster, R.L., 1988. The formation and failure of natural dams. Geol. Soc. Am. Bull. 100, 1054–1068. https://doi.org/10.1130/0016-7606(1988)100<1054:TFAFON>2.3.CO;2

Das, L., Meher, J.K., 2019. Drivers of climate over the Western Himalayan region of India: A review. Earth-Sci. Rev. 198, 102935. https://doi.org/10.1016/j.earscirev.2019.102935

Das, S., Kar, N.S., Bandyopadhyay, S., 2015. Glacial lake outburst flood at Kedarnath, Indian Himalaya: a study using digital elevation models and satellite images. Nat. Hazards 77, 769–786. https://doi.org/10.1007/s11069-015-1629-6

Emmer, A., Vilímek, V., 2013. Review Article: Lake and breach hazard assessment for moraine-dammed lakes: an example from the Cordillera Blanca (Peru). Nat. Hazards Earth Syst. Sci. 13, 1551–1565. https://doi.org/10.5194/nhess-13-1551-2013

Emmer, A., Vilímek, V., Klimeš, J., Cochachin, A., 2014. Glacier Retreat, Lakes Development and Associated Natural Hazards in Cordilera Blanca, Peru, in: Shan, W., Guo, Y., Wang, F., Marui, H., Strom, A. (Eds.), Landslides in Cold Regions in the Context of Climate Change, Environmental Science and Engineering. Springer International Publishing, Cham, pp. 231–252. https://doi.org/10.1007/978-3-319-00867-7_17

Frey, H., Haeberli, W., Linsbauer, A., Huggel, C., Paul, F., 2010a. A multi-level strategy for anticipating future glacier lake formation and associated hazard potentials. Nat. Hazards Earth Syst. Sci. 10, 339–352. https://doi.org/10.5194/nhess-10-339-2010

Frey, H., Haeberli, W., Linsbauer, A., Huggel, C., Paul, F., 2010b. A multi-level strategy for anticipating future glacier lake formation and associated hazard potentials. Nat. Hazards Earth Syst. Sci. 10, 339–352. https://doi.org/10.5194/nhess-10-339-2010

Frey, H., Paul, F., Strozzi, T., 2012. Compilation of a glacier inventory for the western Himalayas from satellite data: methods, challenges, and results. Remote Sens. Environ. 124, 832–843. https://doi.org/10.1016/j.rse.2012.06.020

frey, M.J., Glasser, N.F., Brasington, J., Hambrey, M.J., Quincey, D.J., Reynolds, J.M., 2014. Modelling outburst floods from moraine-dammed glacial lakes. Earth-Sci. Rev. 134, 137–159. https://doi.org/10.1016/j.earscirev.2014.03.009

Fujita, K., 2008. Effect of precipitation seasonality on climatic sensitivity of glacier mass balance. Earth Planet. Sci. Lett. 276, 14–19. https://doi.org/10.1016/j.epsl.2008.08.028

Furian, W., Maussion, F., Schneider, C., 2022. Projected 21st-Century Glacial Lake Evolution in High Mountain Asia. Front. Earth Sci. 10, 821798. https://doi.org/10.3389/feart.2022.821798

Gardelle, J., Arnaud, Y., Berthier, E., 2011. Contrasted evolution of glacial lakes along the Hindu Kush Himalaya mountain range between 1990 and 2009. Glob. Planet. Change 75, 47–55. https://doi.org/10.1016/j.gloplacha.2010.10.003

Garg, P.K., Shukla, A., Jasrotia, A.S., 2017. Influence of topography on glacier changes in the central Himalaya, India. Glob. Planet. Change 155, 196–212. https://doi.org/10.1016/j.gloplacha.2017.07.007

Gosavi, V. E., Mukerjee, S., Kumar, K., Kumar, R., & Tiwari, A. (2020). Water resources of Indian Himalayan Region (IHR): a synthesis in the context of climate change. Environ We Int J Sci Technol, 15, 81-89.

Gruber, S., 2012. Derivation and analysis of a high-resolution estimate of global permafrost zonation. The Cryosphere 6, 221–233. https://doi.org/10.5194/tc-6-221-2012

Gupta, A., Maheshwari, R., Sweta, Guru, N., Rao, B.S., Raju, P.V., Rao, V.V., 2022. Updated Glacial Lake Inventory of Indus River Basin based on High-Resolution Indian Remote Sensing Satellite Data. J. Indian Soc. Remote Sens. 50, 73–98. https://doi.org/10.1007/s12524-021-01452-0

Gupta, R.D., Arora, S., 2017. Characteristics of the soils of Ladakh region of Jammu and Kashmir. J. Soil Water Conserv. 16, 260. https://doi.org/10.5958/2455-7145.2017.00037.6

Haeberli, W., Schaub, Y., Huggel, C., 2017. Increasing risks related to landslides from degrading permafrost into new lakes in de-glaciating mountain ranges. Geomorphology 293, 405–417. https://doi.org/10.1016/j.geomorph.2016.02.009

Harris, C., Murton, J.B., 2005. Interactions between glaciers and permafrost: an introduction. Geol. Soc. Lond. Spec. Publ. 242, 1–9. https://doi.org/10.1144/GSL.SP.2005.242.01.01

Herreid, S., Pellicciotti, F., 2020. The state of rock debris covering Earth's glaciers. Nat. Geosci. 13, 621–627. https://doi.org/10.1038/s41561-020-0615-0

Hewitt, K., 2014. The Regional Context, in: Glaciers of the Karakoram Himalaya, Advances in Asian Human-Environmental Research. Springer Netherlands, Dordrecht, pp. 1–35. https://doi.org/10.1007/978-94-007-6311-1_1

Huggel, C., Haeberli, W., Kääb, A., Bieri, D., Richardson, S., 2004. An assessment procedure for glacial hazards in the Swiss Alps. Can. Geotech. J. 41, 1068–1083. https://doi.org/10.1139/t04-053

Huggel, C., Kääb, A., Haeberli, W., Teysseire, P., Paul, F., 2002. Remote sensing based assessment of hazards from glacier lake outbursts: a case study in the Swiss Alps. Can. Geotech. J. 39, 316–330. https://doi.org/10.1139/t01-099

Hugonnet, R., McNabb, R., Berthier, E., Menounos, B., Nuth, C., Girod, L., Farinotti, D., Huss, M., Dussaillant, I., Brun, F., Kääb, A., 2021. Accelerated global glacier mass loss in the early twenty-first century. Nature 592, 726–731. https://doi.org/10.1038/s41586-021-03436-z.

Hussain, A., Schmidt, S., Nüsser, M., 2023. Dynamics of Mountain Urbanisation: Evidence from the Trans-Himalayan Town of Kargil, Ladakh, India. Land 12, 920. https://doi.org/10.3390/land12040920

Ives, J.D., 2012. Environmental change and challenge in the Himalaya. A historical perspective. Pirineos 167, 29–68. https://doi.org/10.3989/Pirineos.2012.167003

Jain, S.K., Agarwal, P.K., Singh, V.P., 2007. Physical Environment of India, in: Hydrology and Water Resources of India, Water Science and Technology Library. Springer Netherlands, Dordrecht, pp. 3–62. https://doi.org/10.1007/1-4020-5180-8_1

Kääb, A., Reynolds, J.M., Haeberli, W., 2005. Glacier and Permafrost Hazards in High Mountains, in: Huber, U.M., Bugmann, H.K.M., Reasoner, M.A. (Eds.), Global Change and Mountain Regions, Advances in Global Change Research. Springer Netherlands, Dordrecht, pp. 225–234. https://doi.org/10.1007/1-4020-3508-X_23

Kargel, J.S., Abrams, M.J., Bishop, M.P., Bush, A., Hamilton, G., Jiskoot, H., Kääb, A., Kieffer, H.H., Lee, E.M., Paul, F., Rau, F., Raup, B., Shroder, J.F., Soltesz, D., Stainforth, D., Stearns, L., Wessels, R., 2005. Multispectral imaging contributions to global land ice measurements from space. Remote Sens. Environ. 99, 187–219. https://doi.org/10.1016/j.rse.2005.07.004

Kashyap, A., Behera, M.D., 2024. Excess topography and outburst flood: Geomorphic imprint of October 2023 extreme flood event in the Teesta catchment of Eastern Himalayas. Global and Planetary Change 104540. https://doi.org/10.1016/j.gloplacha.2024.104540

Koul, M.N., Bahuguna, I.M., Ajai, Rajawat, A.S., Ali, S., Koul, S., 2016. Glacier Area Change over Past 50 Years to Stable Phase in Drass Valley, Ladakh Himalaya (India). Am. J. Clim. Change 05, 88–102. https://doi.org/10.4236/ajcc.2016.51010

Kumar, A., Devrani, R., Srivastava, A.P., 2022. Landscapes and Paleoclimate of the Ladakh Himalaya, in: Pandey, M., Pandey, P.C., Ray, Y., Arora, A., Jawak, S.D., Shukla, U.K. (Eds.), Advances in Remote Sensing Technology and the Three Poles. Wiley, pp. 308–320. https://doi.org/10.1002/9781119787754.ch21

Le Masson, V., Nair, K., 2012. Chapter 5 Does Climate Modeling Help when Studying Adaptation to Environmental Changes? The Case of Ladakh, India, in: Lamadrid, A., Kelman, I. (Eds.), Community, Environment and Disaster Risk Management. Emerald Group Publishing Limited, pp. 75–94. https://doi.org/10.1108/S2040-7262(2012)0000011011

Li, J., Sheng, Y., 2012. An automated scheme for glacial lake dynamics mapping using Landsat imagery and digital elevation models: a case study in the Himalayas. Int. J. Remote Sens. 33, 5194–5213. https://doi.org/10.1080/01431161.2012.657370

Machiwal, D., Dayal, D., Kumar, S., 2017. Long-term rainfall trends and change points in hot and cold arid regions of India. Hydrol. Sci. J. 62, 1050–1066. https://doi.org/10.1080/02626667.2017.1303705

Majeed, Z., Mukhtar, M.A., Mir, R.A., Kumar, P., Krishna, K., 2020. Sonapani Glacier Recession over a Century from 1906–2016, Chandra Basin, Himachal Himalaya. J. Geol. Soc. India 95, 36–44. https://doi.org/10.1007/

s12594-020-1384-5

Mal, S., Allen, S.K., Frey, H., Huggel, C., Dimri, A.P., 2021. Sectorwise Assessment of Glacial Lake Outburst Flood Danger in the Indian Himalayan Region. Mt. Res. Dev. 41. https://doi.org/10.1659/MRD-JOURNAL-D-20-00043.1

Mal, S., Kumar, A., Bhambri, R., Schickhoff, U., Singh, R.B., 2020. Inventory and Spatial Distribution of Glacial Lakes in Arunachal Pradesh, Eastern Himalaya, India. J. Geol. Soc. India 96, 609–615. https://doi.org/10.1007/s12594-020-1610-1

Mandal, A., Vishwakarma, B.D., Angchuk, T., Azam, M.F., Garg, P.K., Soheb, M., 2023. Glacier mass balance and its climatic and non-climatic drivers in the Ladakh region during 2000-2021 from remote sensing data (other). oral. https://doi.org/10.5194/egusphere-egu23-6319

Mann, Rohit, Gupta, A., Sharma, S., Saini, D., Koul, M., Mann, Rahul, 2022. Time-Series Trend Analysis of Precipitation and Temperature over Ladakh, India (preprint). In Review. https://doi.org/10.21203/rs.3.rs-2213673/v1

Meier, M.F., Bahr, D.B., Dyurgerov, M.B., Pfeffer, W.T., 2005. Comment on "The potential for sea level rise: New estimates from glacier and ice cap area and volume distribution" by S. C. B. Raper and R. J. Braithwaite. Geophys. Res. Lett. 32, 2005GL023319. https://doi.org/10.1029/2005GL023319

Mergili, M., Müller, J.P., Schneider, J.F., 2013. Spatio-temporal development of high-mountain lakes in the headwaters of the Amu Darya River (Central Asia). Glob. Planet. Change 107, 13–24. https://doi.org/10.1016/j.gloplacha.2013.04.001

Mir, R.A., Jain, S.K., Lohani, A.K., Saraf, A.K., 2018. Glacier recession and glacial lake outburst flood studies in Zanskar basin, western Himalaya. J. Hydrol. 564, 376–396. https://doi.org/10.1016/j.jhydrol.2018.05.031

Mitkari, K.V., Arora, M.K., Tiwari, R.K., 2017. Extraction of Glacial Lakes in Gangotri Glacier Using Object-Based Image Analysis. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 1–9. https://doi.org/10.1109/JSTARS.2017.2727506

Mool, P.K., 2001. Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Floods. Int. Cent. Integr. Mt. Dev.

Murtaza, K.O., Dar, R.A., Paul, O.J., Bhat, N.A., Romshoo, S.A., 2021. Glacial geomorphology and recent glacial recession of the Harmukh Range, NW Himalaya. Quat. Int. 575–576, 236–248. https://doi.org/10.1016/j.quaint.2020.08.044

Nautiyal, S., Goswami, M., Prakash, S., Rao, K. S., Maikhuri, R. K., Saxena, K. G. & Banerjee, S. (2022). Spatio-temporal variations of geo-climatic environment in a high-altitude landscape of Central Himalaya: An assessment from the perspective of vulnerability of glacial lakes. Natural Hazards Research, 2(4), 343-362.

Negi, G. C. S., Samal, P. K., Kuniyal, J. C., Kothyari, B. P., Sharma, R. K., & Dhyani, P. P. (2012). Impact of climate change on the western Himalayan mountain ecosystems: an overview. Tropical ecology, 53(3), 345-356.

Nie, Y., Liu, Q., Liu, S., 2013. Glacial Lake Expansion in the Central Himalayas by Landsat Images, 1990–2010. PLoS ONE 8, e83973. https://doi.org/10.1371/journal.pone.0083973

Nie, Y., Sheng, Y., Liu, Q., Liu, L., Liu, S., Zhang, Y., Song, C., 2017. A regional-scale assessment of Himalayan glacial lake changes using satellite observations from 1990 to 2015. Remote Sens. Environ. 189, 1–13. https://doi.org/10.1016/j.rse.2016.11.008

Paul, F., Bolch, T., Kääb, A., Nagler, T., Nuth, C., Scharrer, K., Shepherd, A., Strozzi, T., Ticconi, F., Bhambri, R., Berthier, E., Bevan, S., Gourmelen, N., Heid, T., Jeong, S., Kunz, M., Lauknes, T.R., Luckman, A., Merryman Boncori, J.P., Moholdt, G., Muir, A., Neelmeijer, J., Rankl, M., VanLooy, J., Van Niel, T., 2015. The glaciers climate change initiative: Methods for creating glacier area, elevation change and velocity products. Remote Sens. Environ. 162, 408–426. https://doi.org/10.1016/j.rse.2013.07.043

Paul, F., Winsvold, S., Kääb, A., Nagler, T., Schwaizer, G., 2016. Glacier Remote Sensing Using Sentinel-2. Part II: Mapping Glacier Extents and Surface Facies, and Comparison to Landsat 8. Remote Sens. 8, 575. https://doi.org/10.3390/rs8070575

Pienitz, R., Doran, P.T., Lamoureux, S.F., 2008. Origin and geomorphology of lakes in the polar regions. Polar lakes and rivers: limnology of Arctic and Antarctic aquatic ecosystems 25–41.

Quincey, D.J., Luckman, A., Benn, D., 2009. Quantification

of Everest region glacier velocities between 1992 and 2002, using satellite radar interferometry and feature tracking. J. Glaciol. 55, 596–606. https://doi.org/10.3189/002214309789470987

Rafiq, M., Romshoo, S.A., Mishra, A.K., Jalal, F., 2019. Modelling Chorabari Lake outburst flood, Kedarnath, India. J. Mt. Sci. 16, 64–76. https://doi.org/10.1007/s11629-018-4972-8

Raj, K.B.G., Kumar, K.V., 2016. Inventory of Glacial Lakes and its Evolution in Uttarakhand Himalaya Using Time Series Satellite Data. J. Indian Soc. Remote Sens. 44, 959–976. https://doi.org/10.1007/s12524-016-0560-y

Rao, B.S., Sweta, Maheshwari, R., Raju, P.V., Rao, V.V., Joshi, S., Arivoli, E., Roy, P., 2023. Glacial Lake Atlas of Indian Himalayan River Basins. Natl. Remote Sens. Cent. ISRO Dep. Space Gov. India Hyderabad - 500 037 Telangana Indi 1–211.

Reynolds, J.M., 2000. On the formation of supraglacial lakes on debris-covered glaciers, in: IAHS-AISH Publication. Presented at the Debris-covered glaciers (Seattle WA, 13-15 September 2000), pp. 153–161.

Richardson, S.D., Quincey, D.J., 2009. Glacier outburst floods from Ghulkin Glacier, upper Hunza Valley, Pakistan, in: Geophysical Research Abstracts. Presented at the EGU General Assembly 2009.

Sakai, A., 2012. Glacial Lakes in the Himalayas: A Review on Formation and Expansion Processes. Glob. Environ. Res. 16, 23–30.

Sakai, A., Fujita, K., 2010. Formation conditions of supraglacial lakes on debris-covered glaciers in the Himalaya. J. Glaciol. 56, 177–181. https://doi.org/10.3189/002214310791190785

Sakai, A., Nakawo, M., Fujita, K., 2002. Distribution Characteristics and Energy Balance of Ice Cliffs on Debris-covered Glaciers, Nepal Himalaya. Arct. Antarct. Alp. Res. 34, 12–19. https://doi.org/10.1080/15230430.2002.12003463

Salerno, F., Rogora, M., Balestrini, R., Lami, A., Tartari, G.A., Thakuri, S., Godone, D., Freppaz, M., Tartari, G., 2016. Glacier Melting Increases the Solute Concentrations of Himalayan Glacial Lakes. Environ. Sci. Technol. 50, 9150–9160. https://doi.org/10.1021/acs.est.6b02735

Salerno, F., Thakuri, S., D'Agata, C., Smiraglia, C., Manfredi, E.C., Viviano, G., Tartari, G., 2012. Glacial lake distribution in the Mount Everest region: Uncertainty of measurement and conditions of formation. Glob. Planet. Change 92–93, 30–39. https://doi.org/10.1016/j.gloplacha.2012.04.001

Schmidt, S., Nüsser, M., 2017. Changes of High Altitude Glaciers in the Trans-Himalaya of Ladakh over the Past Five Decades (1969–2016). Geosciences 7, 27. https://doi.org/10.3390/geosciences7020027

Schmidt, S., Nüsser, M., Baghel, R., Dame, J., 2020. Cryosphere hazards in Ladakh: the 2014 Gya glacial lake outburst flood and its implications for risk assessment. Nat. Hazards 104, 2071–2095. https://doi.org/10.1007/s11069-020-04262-8

Shaheen, F.A., Wani, M.H., Wani, S.A., Norphel, C., 2013. Climate Change Impact in Cold Arid Desert of North–Western Himalaya: Community Based Adaptations and Mitigations, in: Nautiyal, S., Rao, K.S., Kaechele, H., Raju, K.V., Schaldach, R. (Eds.), Knowledge Systems of Societies for Adaptation and Mitigation of Impacts of Climate Change, Environmental Science and Engineering. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 239–256. https://doi.org/10.1007/978-3-642-36143-2_15

Shukla, A., Garg, P.K., Srivastava, S., 2018. Evolution of Glacial and High-Altitude Lakes in the Sikkim, Eastern Himalaya Over the Past Four Decades (1975–2017). Front. Environ. Sci. 6, 81. https://doi.org/10.3389/fenvs.2018.00081

Shukla, A., Garg, S., Mehta, M., Kumar, V., Shukla, U.K., 2020. Temporal inventory of glaciers in the Suru sub-basin, western Himalaya: impacts of regional climate variability. Earth Syst. Sci. Data 12, 1245–1265. https://doi.org/10.5194/essd-12-1245-2020

Vuichard, D., Zimmermann, M., 1987. The 1985 Catastrophic Drainage of a Moraine-Dammed Lake, Khumbu Himal, Nepal: Cause and Consequences. Mt. Res. Dev. 7, 91. https://doi.org/10.2307/3673305

Wang, W., Xiang, Y., Gao, Y., Lu, A., Yao, T., 2015. Rapid expansion of glacial lakes caused by climate and glacier retreat in the Central Himalayas. Hydrol. Process. 29, 859–874. https://doi.org/10.1002/hyp.10199

Wang, Xin, Ding, Y., Liu, S., Jiang, L., Wu, K., Jiang, Z., Guo, W., 2013. Changes of glacial lakes and implications

in Tian Shan, central Asia, based on remote sensing data from 1990 to 2010. Environ. Res. Lett. 8, 044052. https://doi.org/10.1088/1748-9326/8/4/044052

Wang, Xu, Siegert, F., Zhou, A., Franke, J., 2013. Glacier and glacial lake changes and their relationship in the context of climate change, Central Tibetan Plateau 1972–2010. Glob. Planet. Change 111, 246–257. https://doi.org/10.1016/j.gloplacha.2013.09.011

Watanbe, T., Rothacher, D., 1996. The 1994 Lugge Tsho Glacial Lake Outburst Flood, Bhutan Himalaya. Mt. Res. Dev. 16, 77. https://doi.org/10.2307/3673897

Worni, R., Huggel, C., Stoffel, M., 2013. Glacial lakes in the Indian Himalayas — From an area-wide glacial lake inventory to on-site and modeling based risk assessment of critical glacial lakes. Sci. Total Environ. 468–469, S71–S84. https://doi.org/10.1016/j.scitotenv.2012.11.043

Xu, D., 1988. Characteristics of debris flow caused by outburst of glacial lake in Boqu river, Xizang, China, 1981. GeoJournal 17. https://doi.org/10.1007/BF00209443

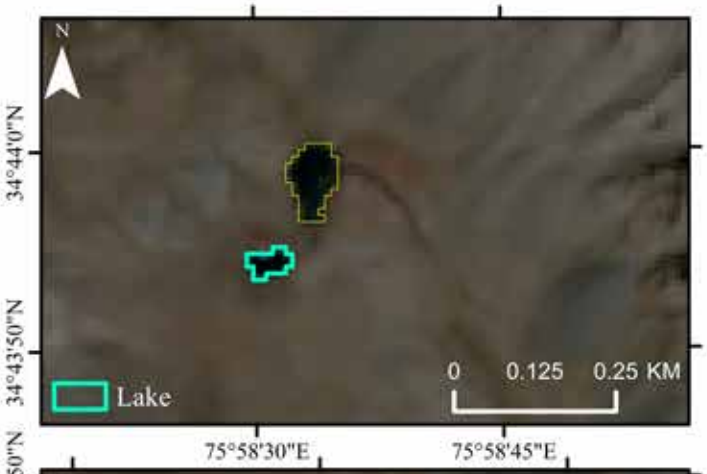
Zhang, G., Bolch, T., Yao, T., Rounce, D.R., Chen, W., Veh, G., King, O., Allen, S.K., Wang, M., Wang, W., 2023. Underestimated mass loss from lake-terminating glaciers in the greater Himalaya. Nat. Geosci. 16, 333–338. https://doi.org/10.1038/s41561-023-01150-1

Zhang, G., Yao, T., Xie, H., Wang, W., Yang, W., 2015. An inventory of glacial lakes in the Third Pole region and their changes in response to global warming. Glob. Planet. Change 131, 148–157. https://doi.org/10.1016/j.gloplacha.2015.05.013

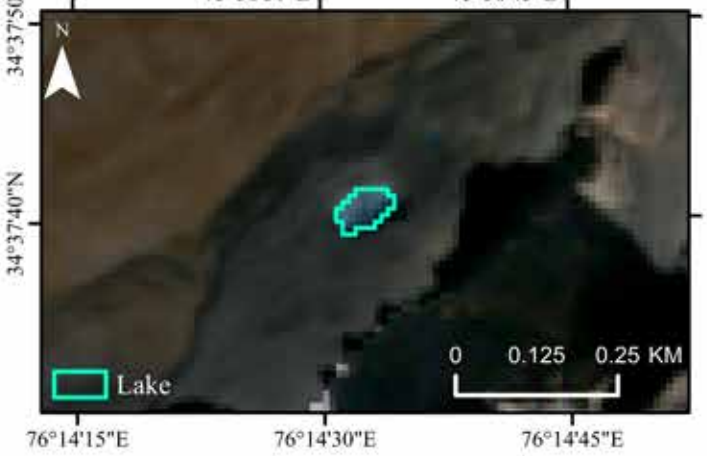
Zhang, Y., Gu, J., Liu, S., Wang, X., Jiang, Z., Wei, J., Zheng, Y., 2022. Spatial pattern of the debris-cover effect and its role in the Hindu Kush-Pamir-Karakoram-Himalaya glaciers. J. Hydrol. 615, 128613. https://doi.org/10.1016/j.jhydrol.2022.128613

Zheng, G., Allen, S.K., Bao, A., Ballesteros-Cánovas, J.A., Huss, M., Zhang, G., Li, J., Yuan, Y., Jiang, L., Yu, T., Chen, W., Stoffel, M., 2021. Increasing risk of glacial lake outburst floods from future Third Pole deglaciation. Nat. Clim. Change 11, 411–417. https://doi.org/10.1038/s41558-021-01028-3

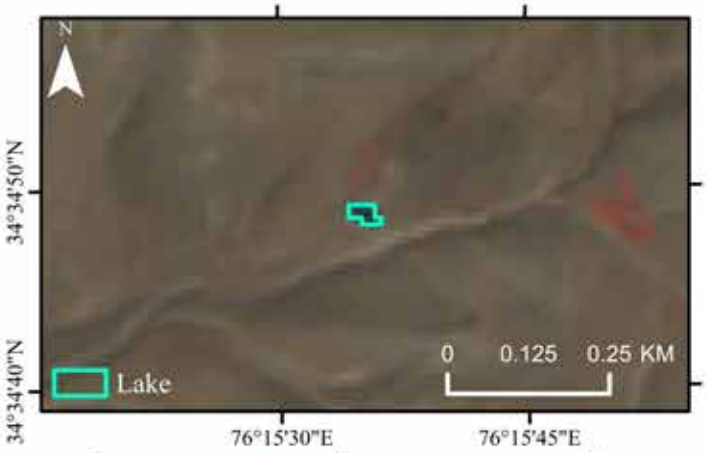
Appendix-I



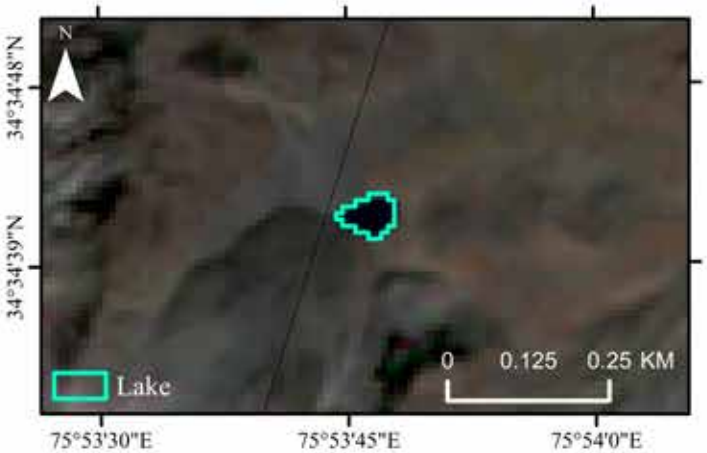
Lake ID	GL284025E34732N
Lake Type	OL
Area (m²)	2313
Perimeter (m)	241
Elevation(m asl)	4739
Slope (deg.)	4.12°
Aspect	South-East
Lat/Long	34.7318°/75.9752°



Lake ID	GL283758E34628N
Lake Type	OL
Area (m2)	4201
Perimeter (m)	320
Elevation(m asl)	4637
Slope (deg.)	7.34°
Aspect	South-West
Lat/Long	34.6279°/76.2423°

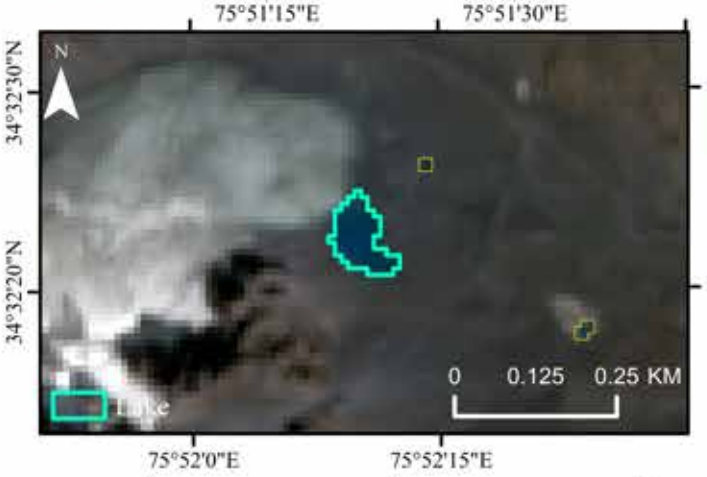


Lake ID	GL283740E34580N
Lake Type	OL
Area (m2)	1117
Perimeter (m)	162
Elevation(m asl)	3755
Slope (deg.)	12.98°
Aspect	South-West
Lat/Long	34.5802°/76.2597°

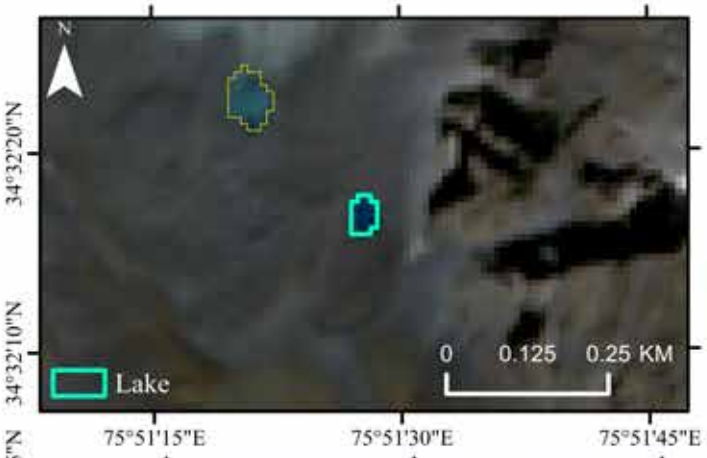


Lake ID	GL284104E34578N
Lake Type	PGLA
Area (m2)	4100
Perimeter (m)	323
Elevation(m asl)	4664
Slope (deg.)	12.03°
Aspect	South-West
Lat/Long	34.5782°/75.8962°

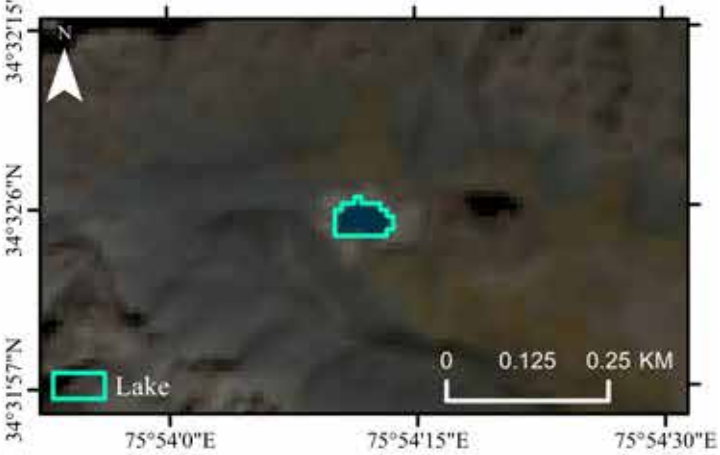
Lake ID	GL284144E34540N
Lake Type	PGLC
Area (m²)	4901
Perimeter (m)	341
Elevation(m asl)	4905
Slope (deg.)	13.38°
Aspect	South-West
Lat/Long	34.5396°/75.8558°



Lake ID	GL284130E34540N
Lake Type	PGLC
Area (m2)	7709
Perimeter (m)	500
Elevation(m asl)	4838
Slope (deg.)	14.84°
Aspect	East
Lat/Long	34.5396°/75.8695°



Lake ID	GL284142E34538N
Lake Type	PGLA
Area (m2)	2104
Perimeter (m)	200
Elevation(m asl)	4915
Slope (deg.)	8.69°
Aspect	South-West
Lat/Long	34.538°/75.8577°



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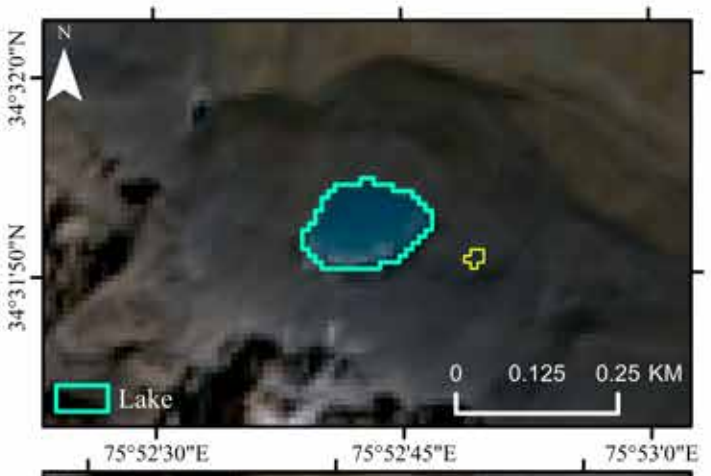
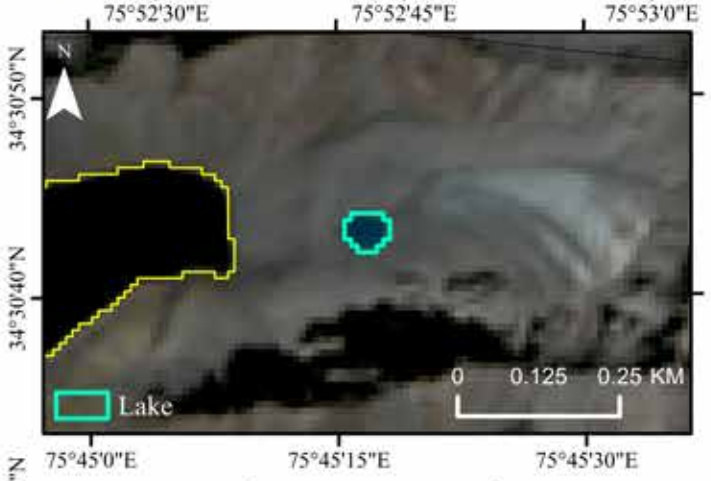
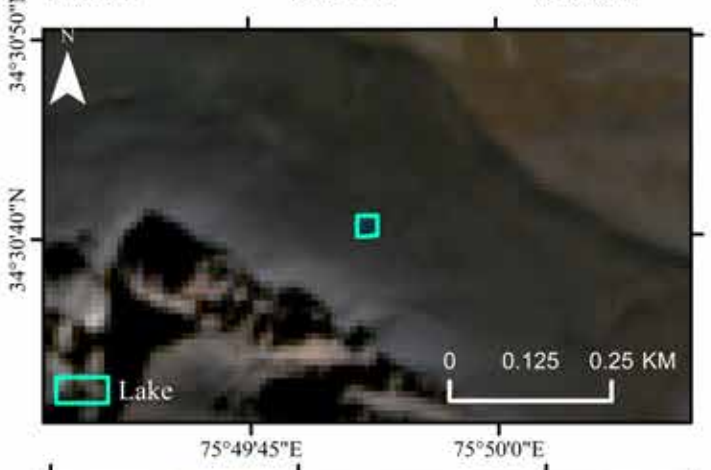
Lake Type	OL
Area (m2)	4110
Perimeter (m)	302
Elevation(m asl)	4773
Slope (deg.)	5.17°
Aspect	South-East
Lat/Long	34.5348°/75.9032°



Lake ID	GL284122E34531N
Lake Type	PGLA
Area (m^2)	20100
Perimeter (m)	680
Elevation(m asl)	4741
Slope (deg.)	8.62°
Aspect	South-East
Lat/Long	34.5312°/75.8785°

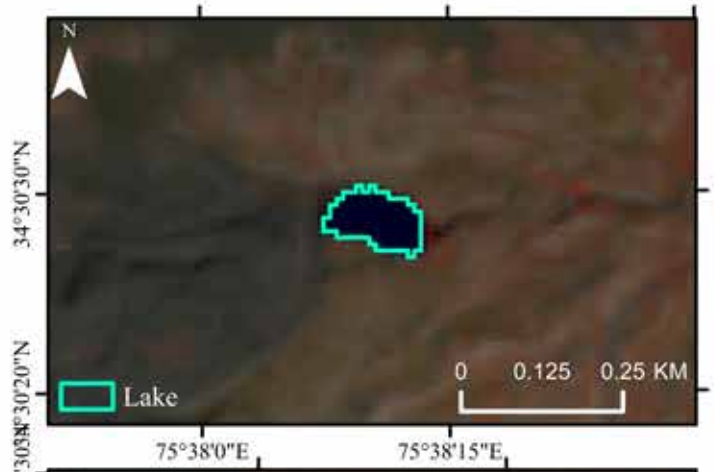


Lake ID	GL284245E34512N
Lake Type	PGLC
Area (m2)	3400
Perimeter (m)	260
Elevation(m asl)	4746
Slope (deg.)	15.71°
Aspect	North-West
Lat/Long	34.512°/75.7546°

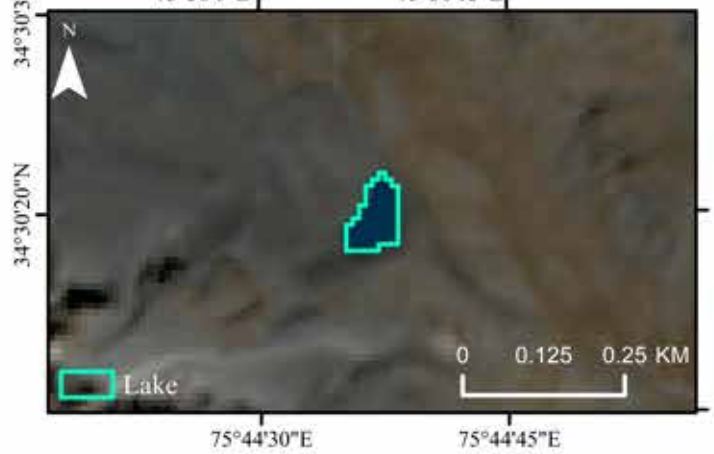


Lake ID	GL284169E34511N
Lake Type	PGLA
Area (m2)	981
Perimeter (m)	127
Elevation(m asl)	4723
Slope (deg.)	6.73°
Aspect	East
Lat/Long	34.5113°/75.8311°

Lake ID	GL284411E34512N
Lake Type	SGL
Area (m2)	2005
Perimeter (m)	201
Elevation(m asl)	4682
Slope (deg.)	9.55°
Aspect	North-West
Lat/Long	34.5121°/75.5886°



Lake ID	GL284364E34508N
Lake Type	PGLA
Area (m²)	10617
Perimeter (m)	546
Elevation(m asl)	4360
Slope (deg.)	8.65°
Aspect	South
Lat/Long	34.5079°/75.6363°



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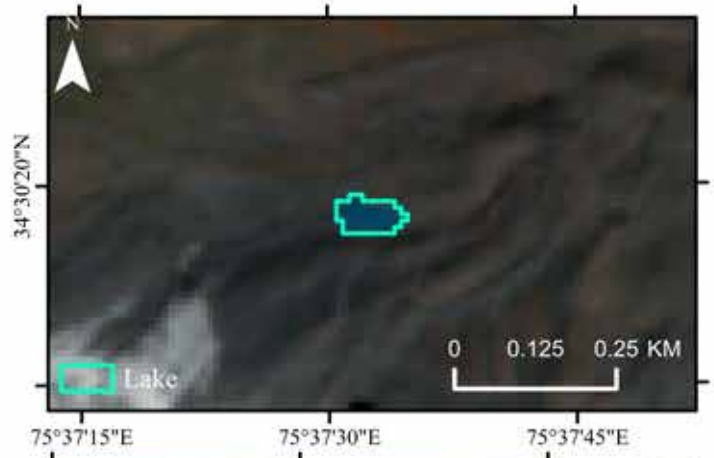
Lake Type	PGLA
Area (m2)	6703
Perimeter (m)	400
Elevation(m asl)	4549
Slope (deg.)	3.6°
Aspect	South-East
Lat/Long	34.5055°/75.7436°



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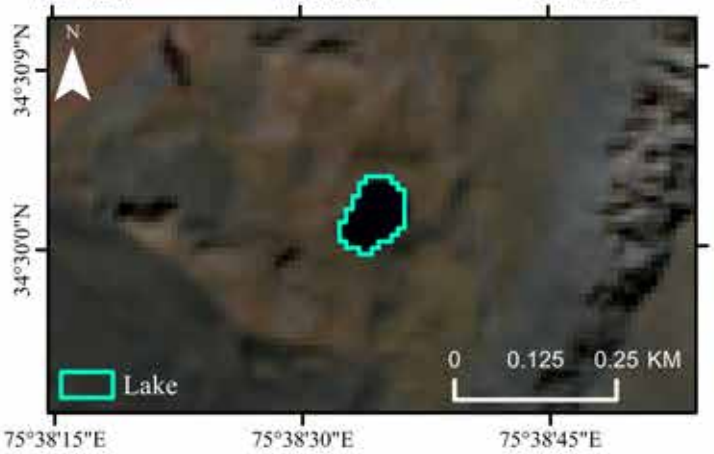
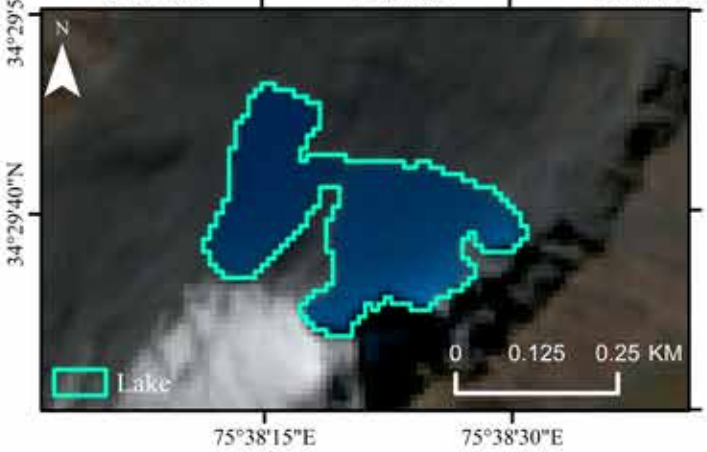
Lake Type	PGLA
Area (m2)	4899
Perimeter (m)	341
Elevation(m asl)	4419
Slope (deg.)	12.35°
Aspect	South
Lat/Long	34.5051°/75.6257°

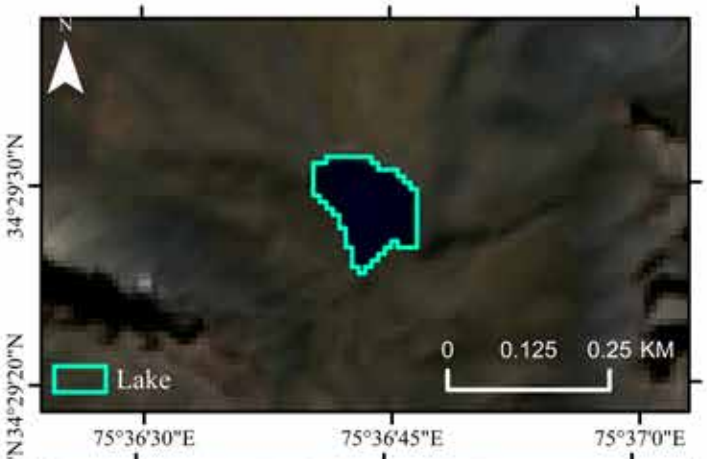


Lake ID	GL284357E34500N
Lake Type	PGLA
Area (m2)	8502
Perimeter (m)	443
Elevation(m asl)	4517
Slope (deg.)	8.76°
Aspect	West
Lat/Long	34.5005°/75.6429°

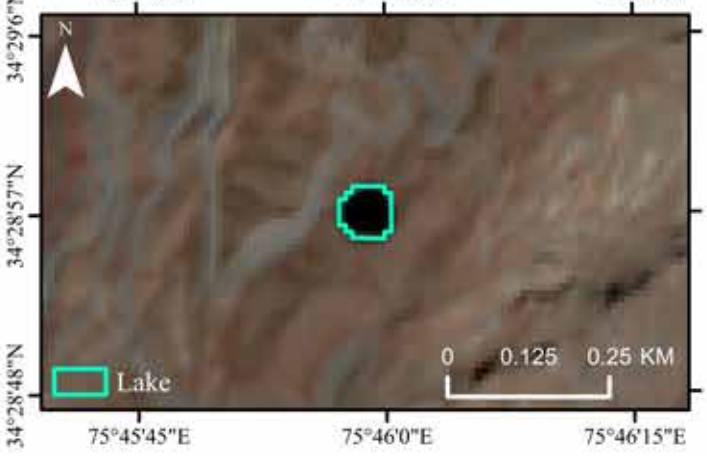
Lake ID	GL284426E34498N
Lake Type	PGLC
Area (m^2)	4105
Perimeter (m)	280
Elevation(m asl)	4570
Slope (deg.)	9.52°
Aspect	East
Lat/Long	34.498°/75.5744°



Lake ID	GL284361E34494N
Lake Type	PGLC
Area (m2)	91635
Perimeter (m)	2461
Elevation(m asl)	4599
Slope (deg.)	15.97°
Aspect	South-West
Lat/Long	34.4944°/75.639°



Lake ID	GL284388E34491N
Lake Type	PGLA
Area (m2)	18618
Perimeter (m)	703
Elevation(m asl)	4655
Slope (deg.)	7.49°
Aspect	South
Lat/Long	34.4914°/75.6121°



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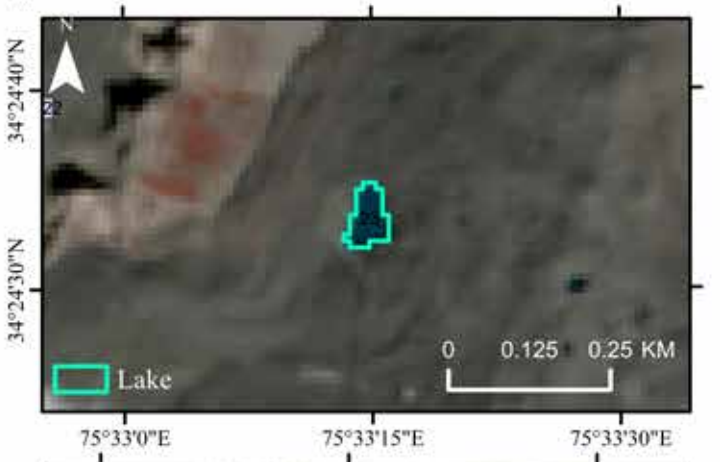
Lake Type	OL
Area (m2)	5601
Perimeter (m)	320
Elevation(m asl)	4300
Slope (deg.)	7.73°
Aspect	South
Lat/Long	34.4825°/75.7663°

Lake ID	GL284468E34416N
Lake Type	SGL
Area (m²)	803
Perimeter (m)	140
Elevation(m asl)	4279
Slope (deg.)	17.74°
Aspect	South-East
Lat/Long	34.4163°/75.5322°

Lake ID	GL284452E34411N
Lake Type	SGL
Area (m2)	1815
Perimeter (m)	221
Elevation(m asl)	4318
Slope (deg.)	4.84°
Aspect	North-West
Lat/Long	34.411°/75.5485°



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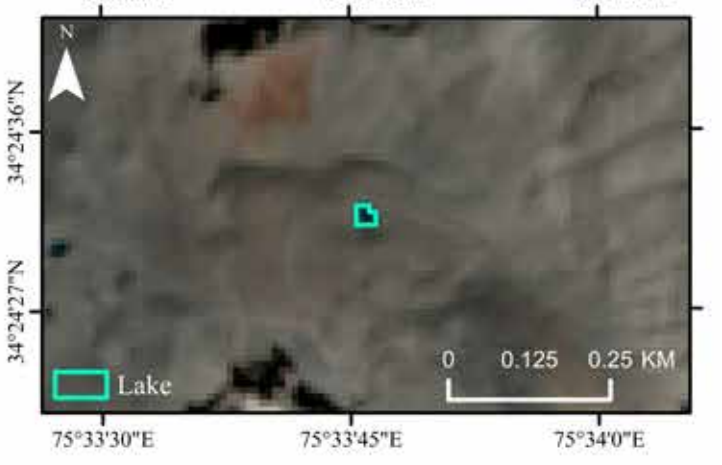
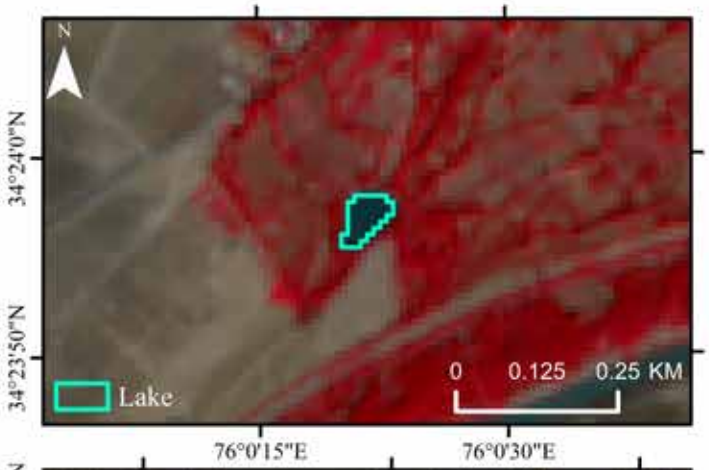
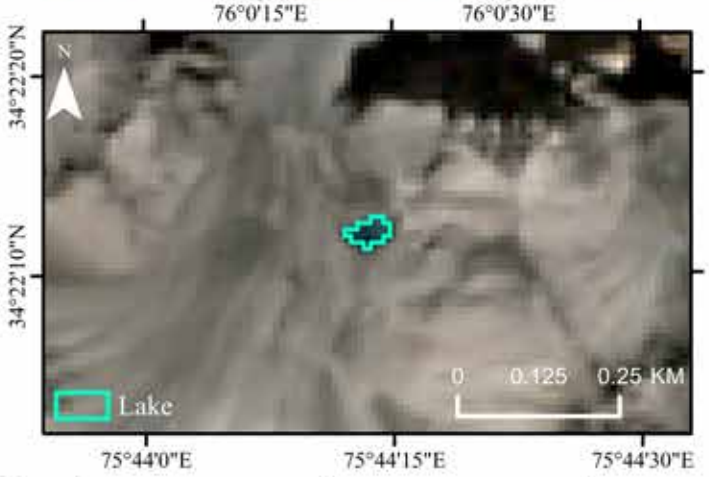
Lake Type	SGL
Area (m2)	4602
Perimeter (m)	340
Elevation(m asl)	4305
Slope (deg.)	7.73°
Aspect	East
Lat/Long	34.4093°/75.5541°



Lake ID	GL284437E34409N
Lake Type	PGLA
Area (m2)	804
Perimeter (m)	121
Elevation(m asl)	4378
Slope (deg.)	7.11°
Aspect	North
Lat/Long	34.4088°/75.5628°



Lake ID	GL283994E34399N
Lake Type	OL
Area (m²)	4101
Perimeter (m)	320
Elevation(m asl)	2846
Slope (deg.)	5.04°
Aspect	South-East
Lat/Long	34.3991°/76.0059°



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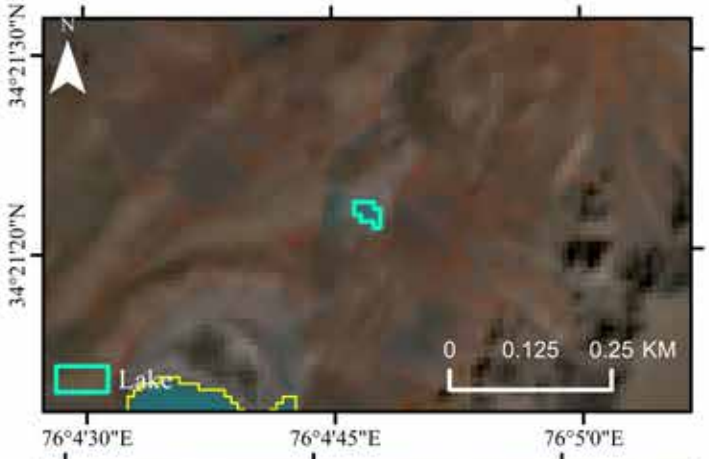
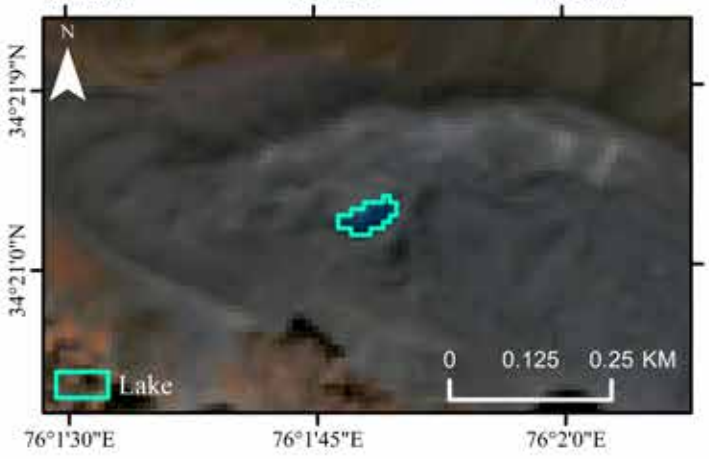
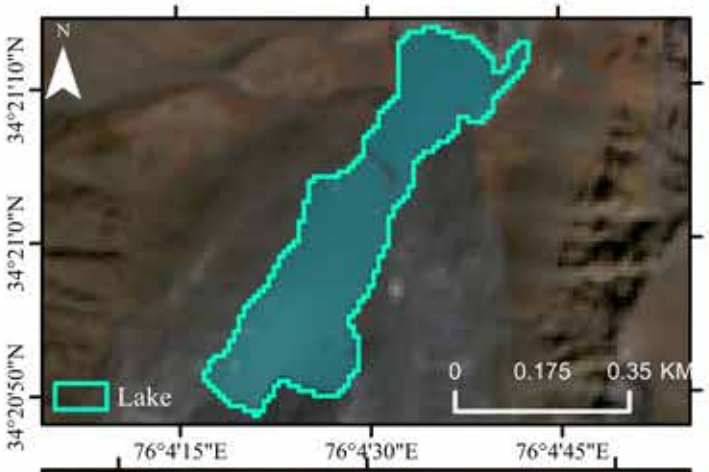
Lake Type	OL
Area (m2)	2003
Perimeter (m)	240
Elevation(m asl)	4693
Slope (deg.)	11.59°
Aspect	West
Lat/Long	34.37°/75.7371°



Lake ID	GL283920E34356N
Lake Type	PGLA
Area (m2)	1108
Perimeter (m)	161
Elevation(m asl)	4397
Slope (deg.)	6.28°
Aspect	North-West
Lat/Long	34.3561°/76.0797°



Lake ID	GL283970E34351N
Lake Type	PGLC
Area (m2)	3103
Perimeter (m)	300
Elevation(m asl)	4318
Slope (deg.)	15.89°
Aspect	North-West
Lat/Long	34.3507°/76.03°



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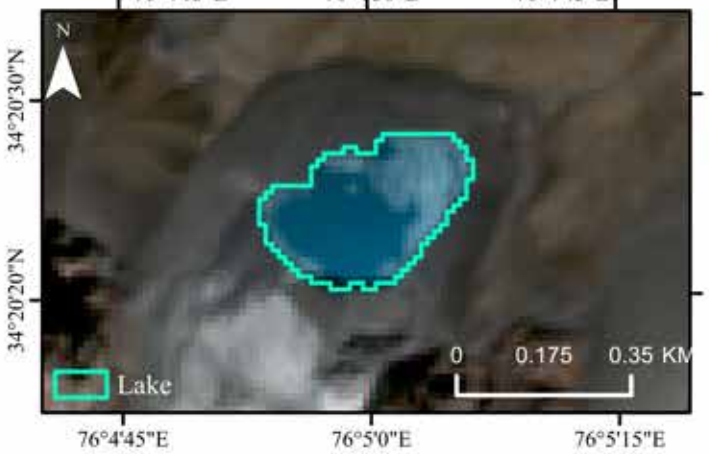
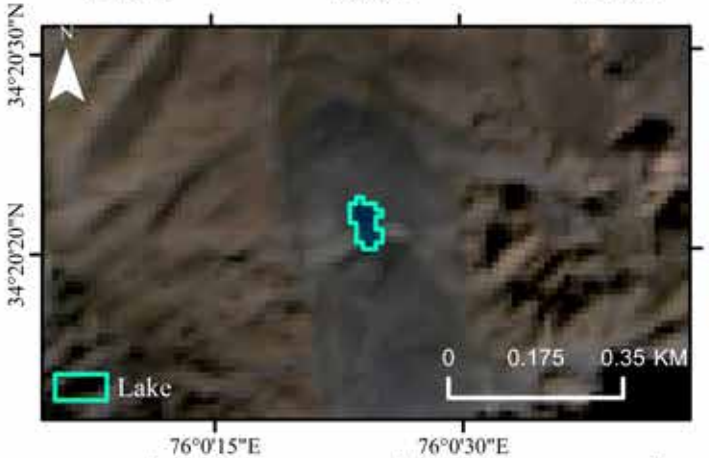
Lake Type	PGLC
Area (m²)	151200
Perimeter (m)	3100
Elevation(m asl)	4428
Slope (deg.)	8.32°
Aspect	South
Lat/Long	34.3502°/76.0747°



Lake ID	GL283917E34340N
Lake Type	PGLC
Area (m2)	53499
Perimeter (m)	1180
Elevation(m asl)	4644
Slope (deg.)	16.2°
Aspect	East
Lat/Long	34.3401°/76.0833°



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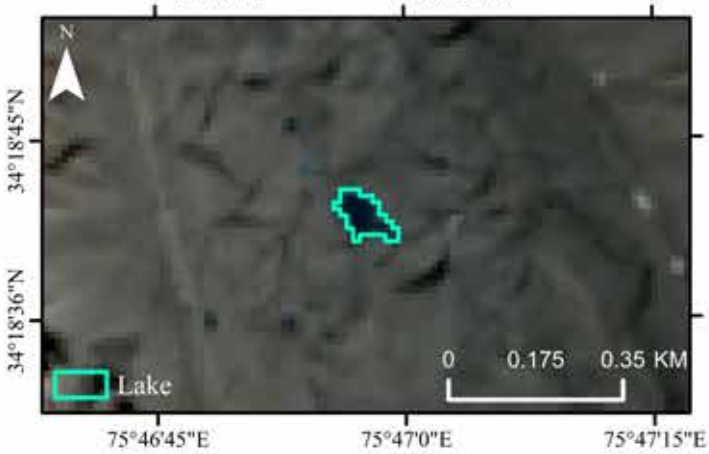
Lake Type	OL
Area (m2)	2698
Perimeter (m)	280
Elevation(m asl)	4732
Slope (deg.)	20.92°
Aspect	North-West
Lat/Long	34.3393°/76.0067°



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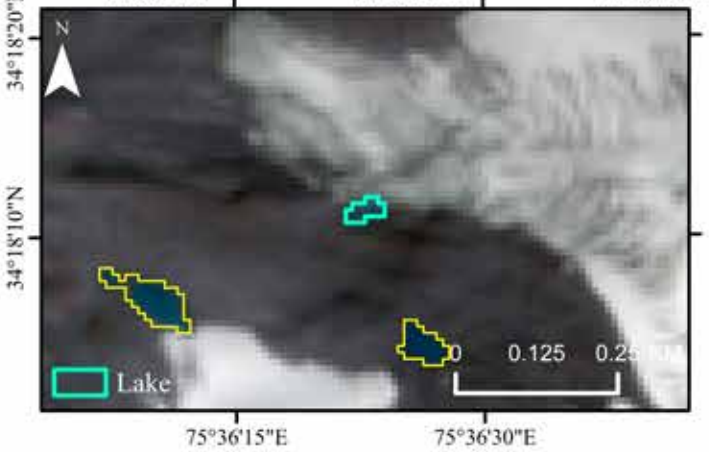
Lake Type	SGL
Area (m2)	4435
Perimeter (m)	381
Elevation(m asl)	4464
Slope (deg.)	4.44°
Aspect	East
Lat/Long	34.3114°/75.7827°

Lake ID	GL284392E34308N
Lake Type	PGLC
Area (m^2)	1500
Perimeter (m)	181
Elevation(m asl)	4680
Slope (deg.)	12.17°
Aspect	South
Lat/Long	34.3079°/75.6077°



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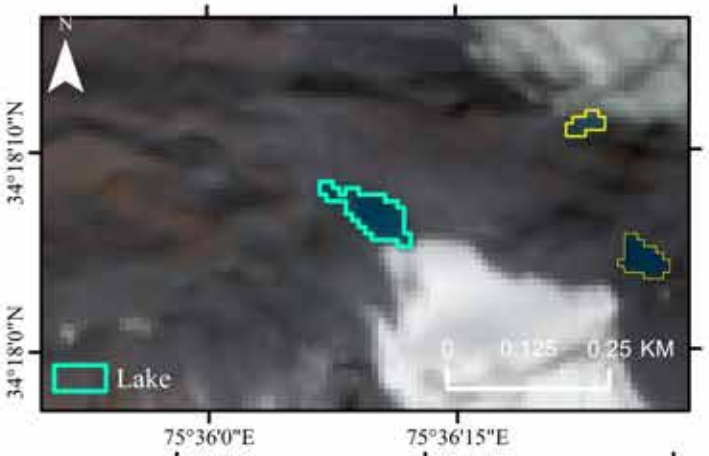
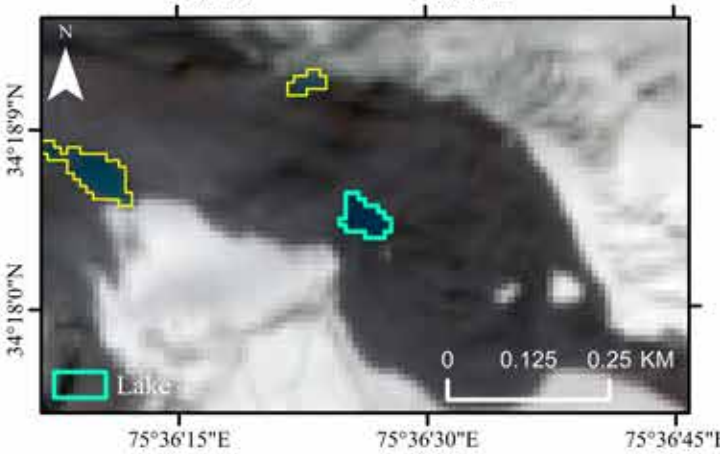
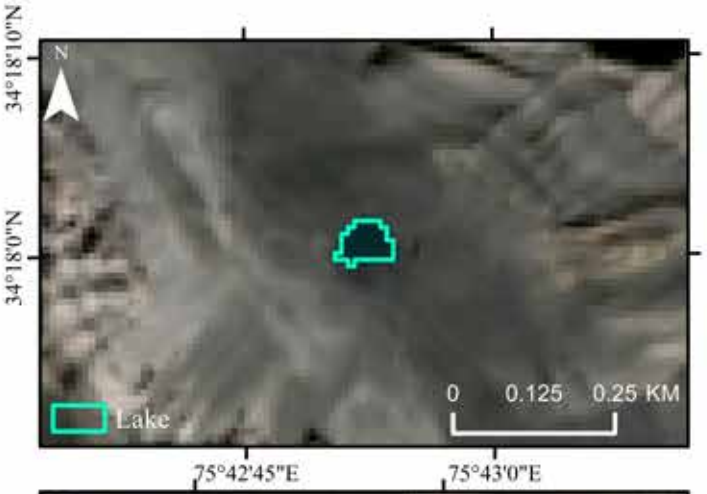
Lake Type	SGL
Area (m2)	1599
Perimeter (m)	200
Elevation(m asl)	4611
Slope (deg.)	11.23°
Aspect	South-West
Lat/Long	34.3031°/75.6063°



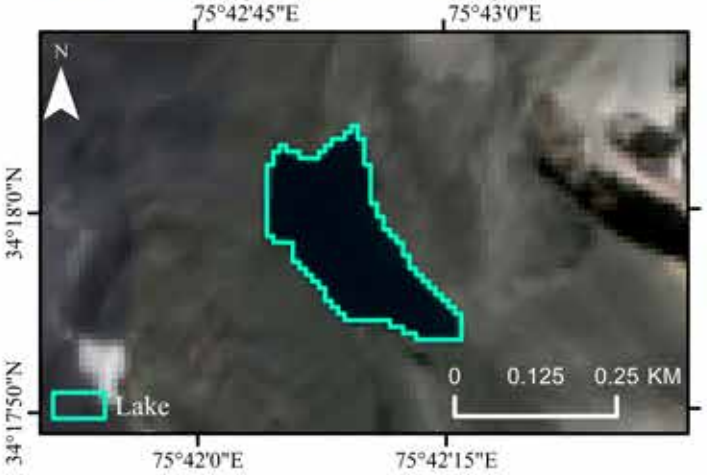
Lake ID	GL284397E34302N
Lake Type	PGLC
Area (m2)	6207
Perimeter (m)	503
Elevation(m asl)	4574
Slope (deg.)	27.91°
Aspect	South-West
Lat/Long	34.3019°/75.6027°



Lake ID	GL284393E34301N
Lake Type	SGL
Area (m2)	3399
Perimeter (m)	300
Elevation(m asl)	4639
Slope (deg.)	12.96°
Aspect	North-West
Lat/Long	34.3013°/75.6073°

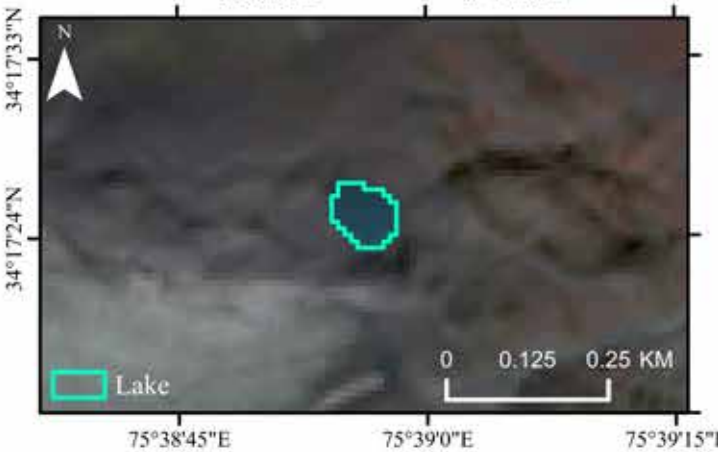


Lake ID	GL284286E34300N
Lake Type	PGLA
Area (m²)	4303
Perimeter (m)	320
Elevation(m asl)	4556
Slope (deg.)	10.07°
Aspect	South-West
Lat/Long	34.3002°/75.7145°



Lake ID	GL284297E34300N
Lake Type	PGLC
Area (m2)	48040
Perimeter (m)	1302
Elevation(m asl)	4595
Slope (deg.)	9.65°
Aspect	South
Lat/Long	34.2996°/75.7026°

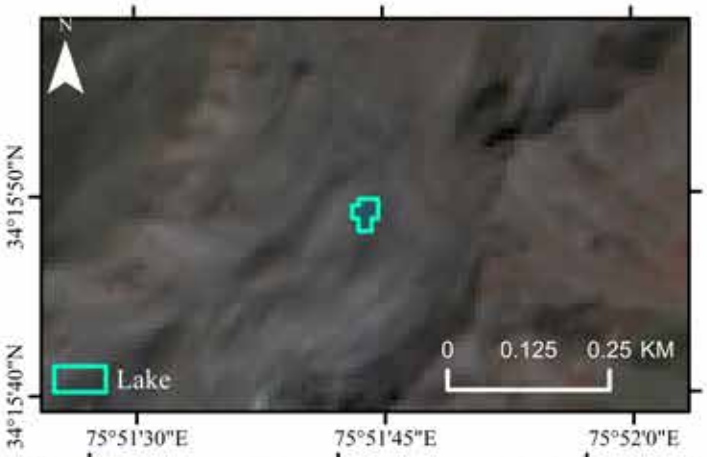
Lake ID	GL284594E34293N
Lake Type	OL
Area (m2)	18726
Perimeter (m)	782
Elevation(m asl)	4218
Slope (deg.)	14.45°
Aspect	South
Lat/Long	34.2929°/75.4058°



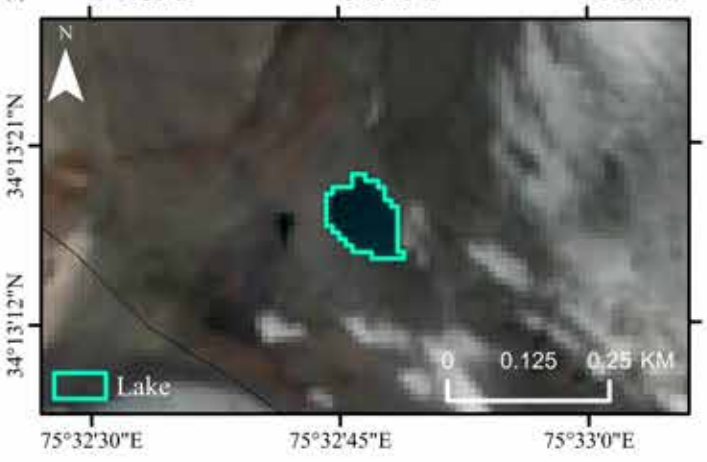
Lake ID	GL284351E34290N
Lake Type	PGLC
Area (m2)	7702
Perimeter (m)	401
Elevation(m asl)	4479
Slope (deg.)	20.91°
Aspect	East
Lat/Long	34.2903°/75.649°

Lake ID	GL284312E34278N
Lake Type	SGL
Area (m^2)	1401
Perimeter (m)	200
Elevation(m asl)	4801
Slope (deg.)	15.55°
Aspect	South-West
Lat/Long	34.2778°/75.6876°

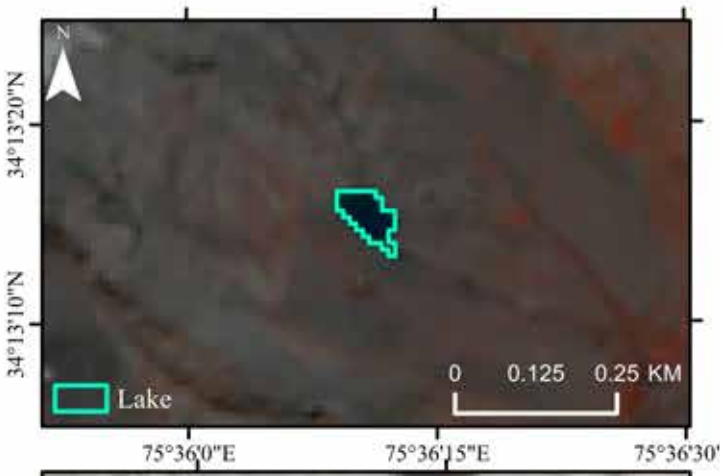
Lake ID	GL284174E34273N
Lake Type	SGL
Area (m2)	1703
Perimeter (m)	221
Elevation(m asl)	4883
Slope (deg.)	3.85°
Aspect	South-East
Lat/Long	34.2732°/75.826°



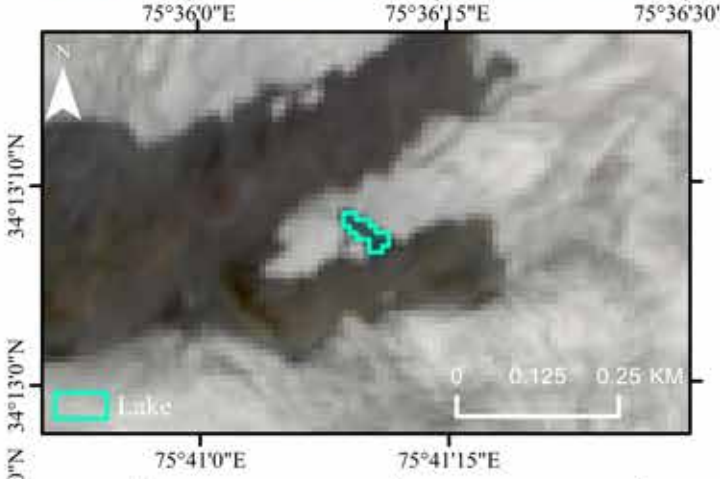
Lake ID	GL284138E34264N
Lake Type	SGL
Area (m2)	1503
Perimeter (m)	180
Elevation(m asl)	4849
Slope (deg.)	3.88°
Aspect	South-East
Lat/Long	34.2636°/75.8622°



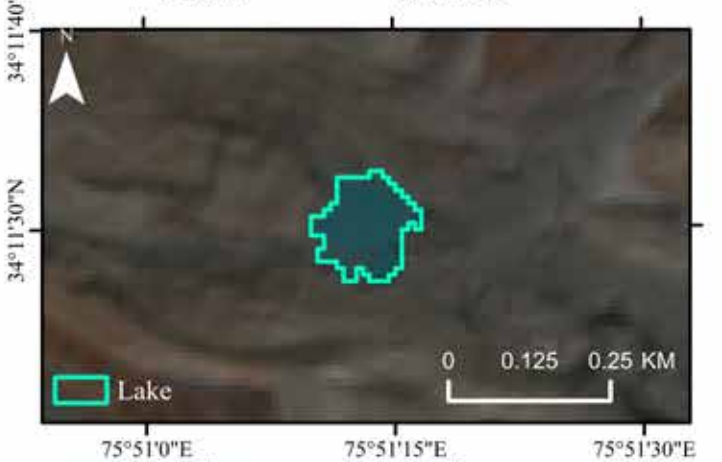
Lake ID	GL284454E34222N
Lake Type	SGL
Area (m2)	10506
Perimeter (m)	501
Elevation(m asl)	4455
Slope (deg.)	6.94°
Aspect	South-East
Lat/Long	34.2215°/75.5462°



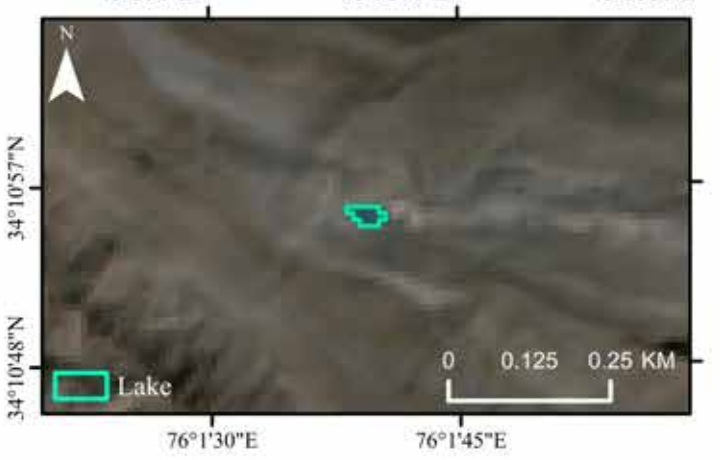
Lake ID	GL284397E34221N
Lake Type	PGLA
Area (m²)	5116
Perimeter (m)	400
Elevation(m asl)	4453
Slope (deg.)	6.16°
Aspect	South-East
Lat/Long	34.2209°/75.603°



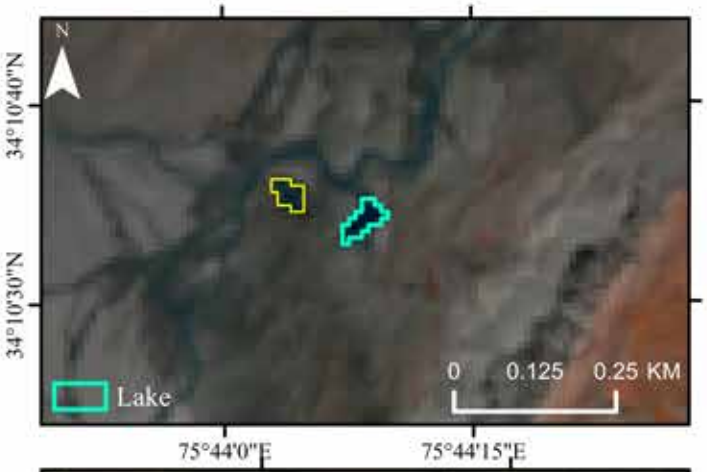
Lake ID	GL284314E34219N
Lake Type	PGLC
Area (m2)	2001
Perimeter (m)	260
Elevation(m asl)	4799
Slope (deg.)	13.18°
Aspect	South
Lat/Long	34.2188°/75.6861°



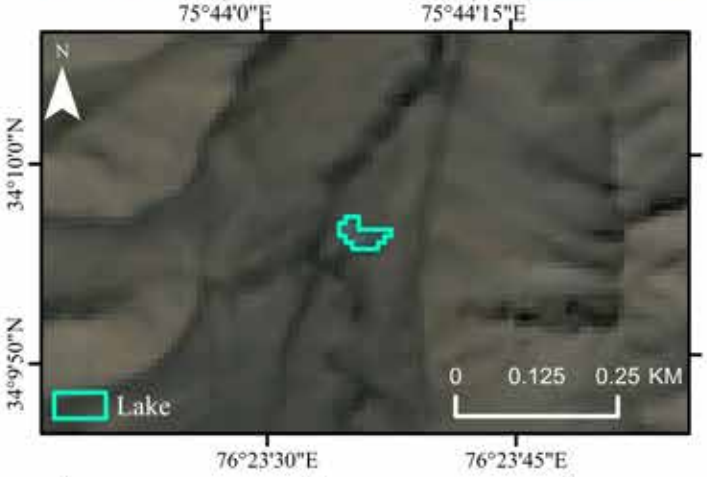
Lake ID	GL284146E34192N
Lake Type	PGLA
Area (m2)	18711
Perimeter (m)	763
Elevation(m asl)	4605
Slope (deg.)	8.23°
Aspect	South
Lat/Long	34.1917°/75.8537°



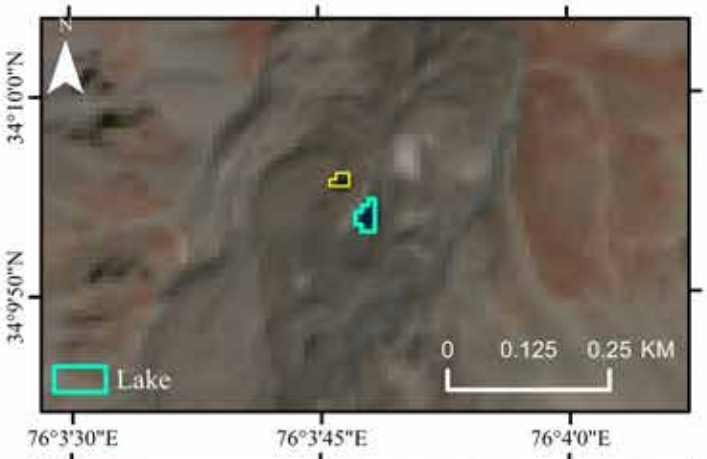
Lake ID	GL283972E34182N
Lake Type	PGLA
Area (m2)	1302
Perimeter (m)	181
Elevation(m asl)	4856
Slope (deg.)	7.3°
Aspect	North
Lat/Long	34.1821°/76.0276°



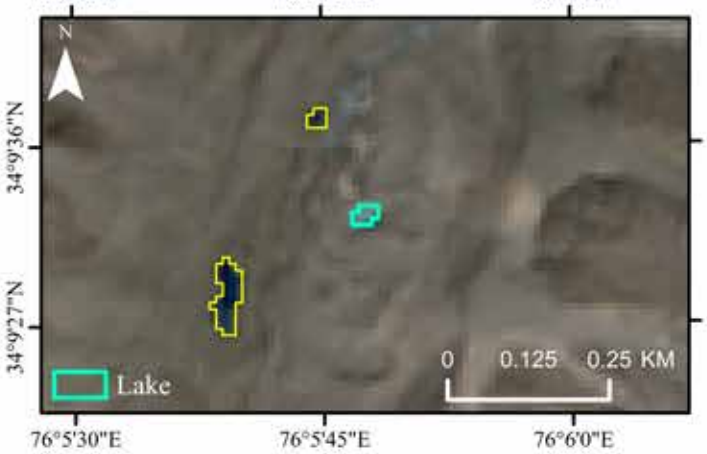
Lake ID	GL284264E34176N
Lake Type	PGLC
Area (m^2)	2301
Perimeter (m)	280
Elevation(m asl)	3880
Slope (deg.)	17.37°
Aspect	North-East
Lat/Long	34.1761°/75.7357°



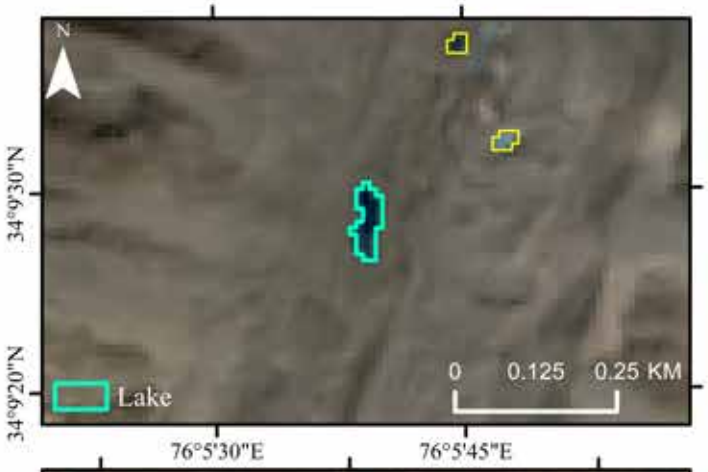
Lake ID	GL283607E34166N
Lake Type	PGLA
Area (m2)	2305
Perimeter (m)	260
Elevation(m asl)	4845
Slope (deg.)	8.46°
Aspect	East
Lat/Long	34.1656°/76.3933°



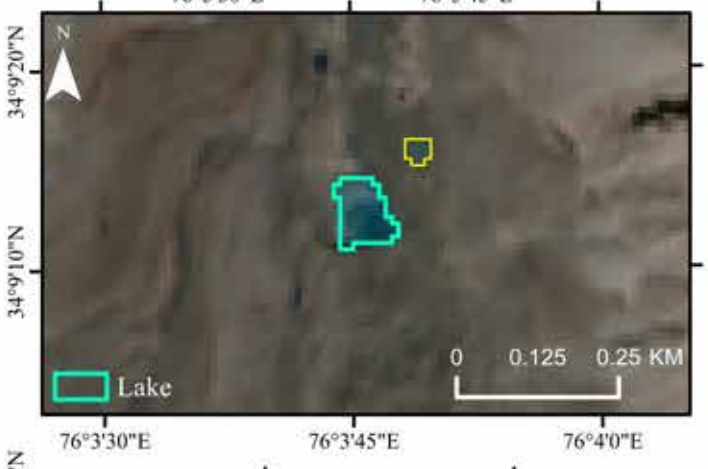
Lake ID	GL283937E34165N
Lake Type	PGLA
Area (m2)	1112
Perimeter (m)	161
Elevation(m asl)	4506
Slope (deg.)	11.33°
Aspect	North-East
Lat/Long	34.165°/76.0633°



Lake ID	GL283904E34159N
Lake Type	PGLA
Area (m2)	1000
Perimeter (m)	141
Elevation(m asl)	4769
Slope (deg.)	13.43°
Aspect	West
Lat/Long	34.159°/76.0965°

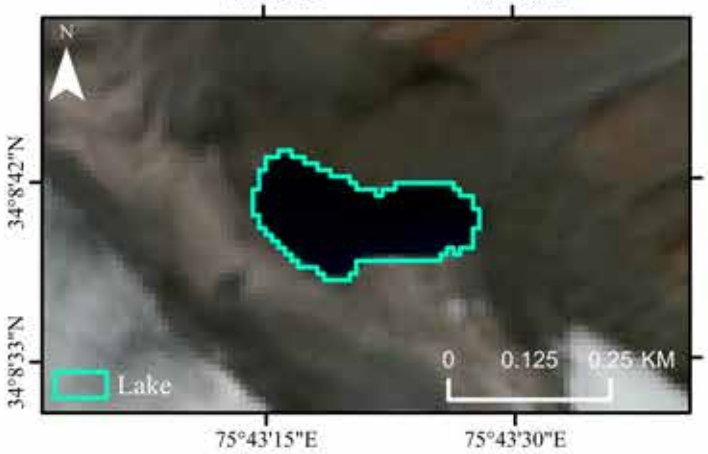


Lake ID	GL283906E34158N
Lake Type	PGLA
Area (m²)	3704
Perimeter (m)	361
Elevation(m asl)	4762
Slope (deg.)	5.73°
Aspect	North-East
Lat/Long	34.1579°/76.0942°



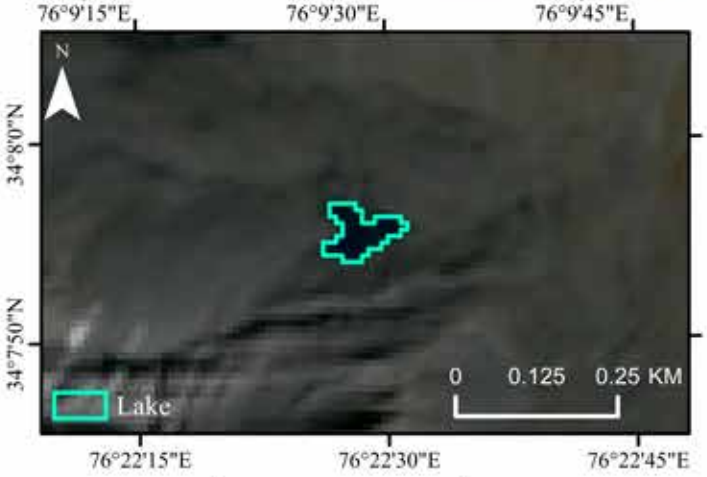
Lake ID	GL283937E34154N
Lake Type	PGLC
Area (m2)	7599
Perimeter (m)	420
Elevation(m asl)	4636
Slope (deg.)	10.9°
Aspect	North-East
Lat/Long	34.1535°/76.0627°

Lake ID	GL283978E34153N
Lake Type	PGLC
Area (m2)	2401
Perimeter (m)	240
Elevation(m asl)	4918
Slope (deg.)	17.49°
Aspect	North-East
Lat/Long	34.153°/76.0224°



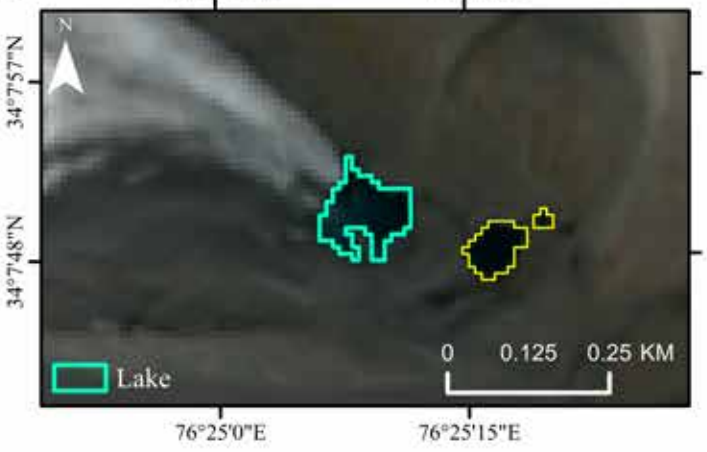
Lake ID	GL284278E34144N
Lake Type	PGLC
Area (m2)	42822
Perimeter (m)	1162
Elevation(m asl)	4578
Slope (deg.)	15.71°
Aspect	South-West
Lat/Long	34.1445°/75.7224°

Lake ID	GL283841E34138N
Lake Type	PGLA
Area (m^2)	1901
Perimeter (m)	220
Elevation(m asl)	5215
Slope (deg.)	9.69°
Aspect	North-East
Lat/Long	34.1382°/76.1589°

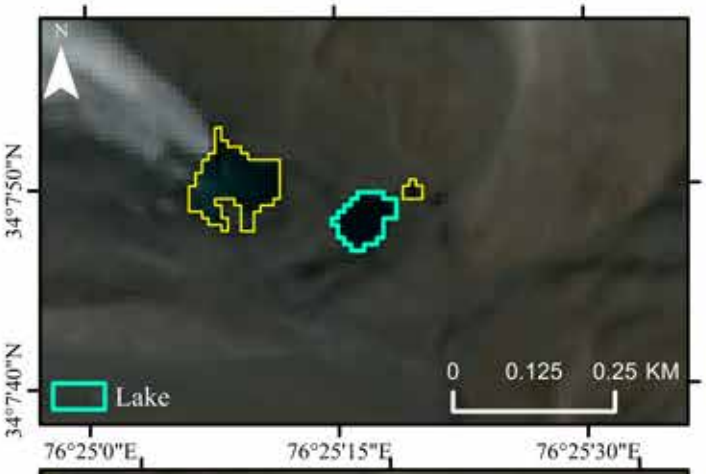


Lake ID	GL283626E34132N
Lake Type	PGLA
Area (m2)	6314
Perimeter (m)	501
Elevation(m asl)	4927
Slope (deg.)	14.09°
Aspect	North-East
Lat/Long	34.132°/76.3745°

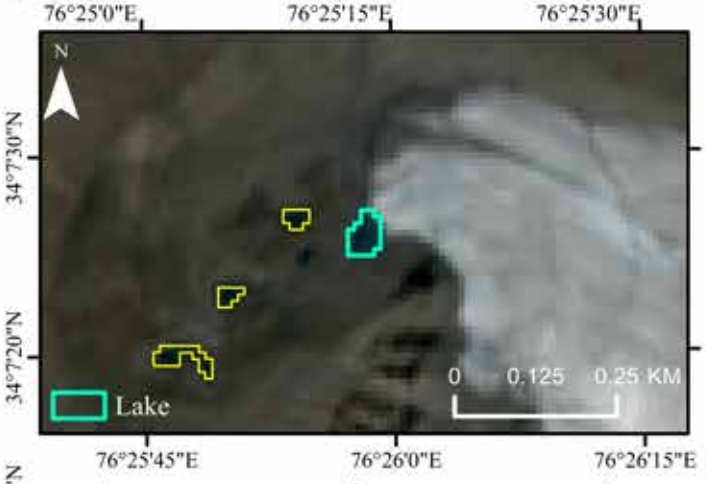
Lake ID	GL283535E34130N
Lake Type	PGLA
Area (m2)	902
Perimeter (m)	140
Elevation(m asl)	4862
Slope (deg.)	4.59°
Aspect	West
Lat/Long	34.1304°/76.4649°



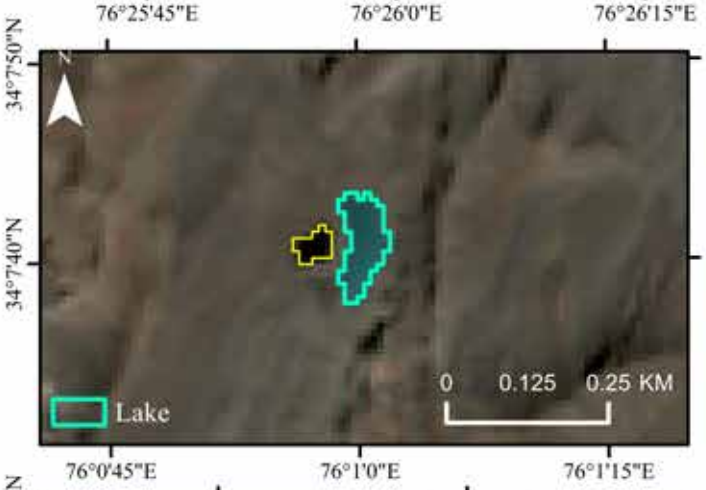
Lake ID	GL283581E34131N
Lake Type	PGLC
Area (m2)	12314
Perimeter (m)	741
Elevation(m asl)	5166
Slope (deg.)	12.15°
Aspect	South-East
Lat/Long	34.1306°/76.4191°



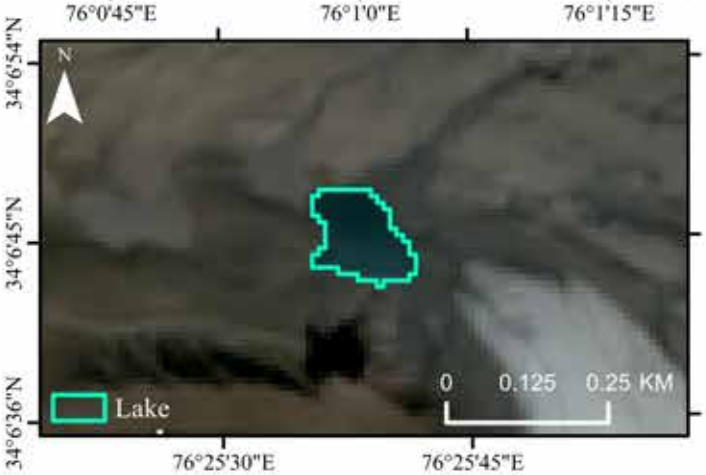
Lake ID	GL283579E34130N
Lake Type	PGLA
Area (m²)	5721
Perimeter (m)	380
Elevation(m asl)	5146
Slope (deg.)	14.2°
Aspect	South
Lat/Long	34.1301°/76.4213°



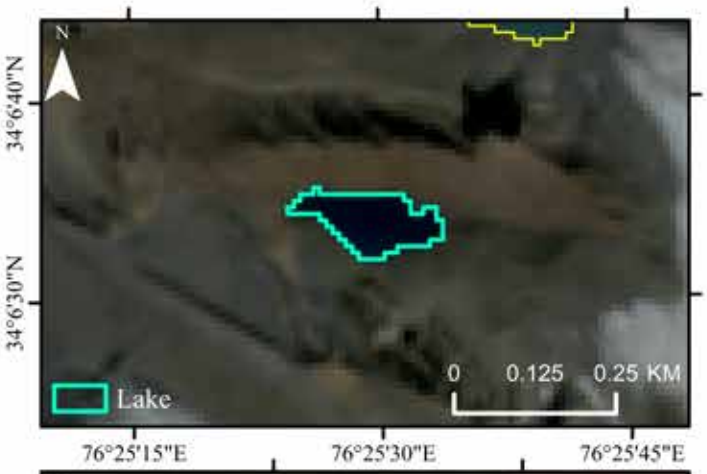
Lake ID	GL283567E34124N
Lake Type	PGLC
Area (m2)	2808
Perimeter (m)	241
Elevation(m asl)	5117
Slope (deg.)	21.73°
Aspect	West
Lat/Long	34.1239°/76.4328°



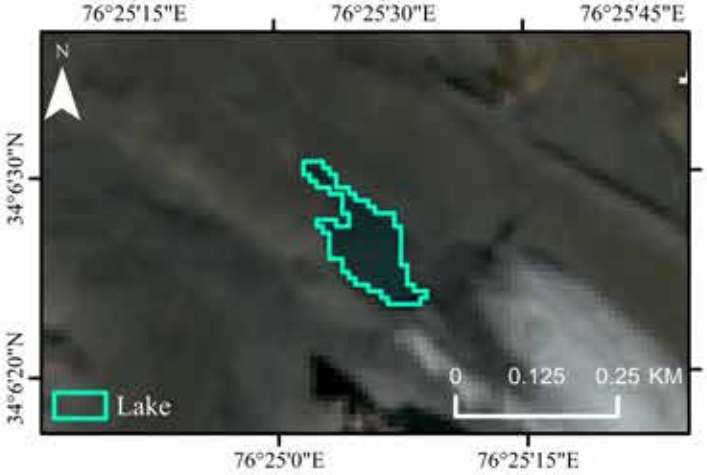
Lake ID	GL283983E34128N
Lake Type	PGLA
Area (m2)	8705
Perimeter (m)	560
Elevation(m asl)	4788
Slope (deg.)	22.04°
Aspect	West
Lat/Long	34.128°/76.0167°



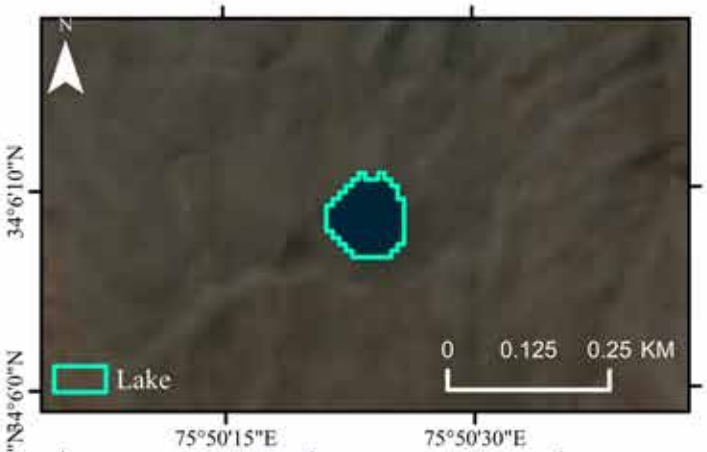
Lake ID	GL283573E34112N
Lake Type	PGLC
Area (m2)	16511
Perimeter (m)	661
Elevation(m asl)	4944
Slope (deg.)	18.01°
Aspect	West
Lat/Long	34.1125°/76.4273°



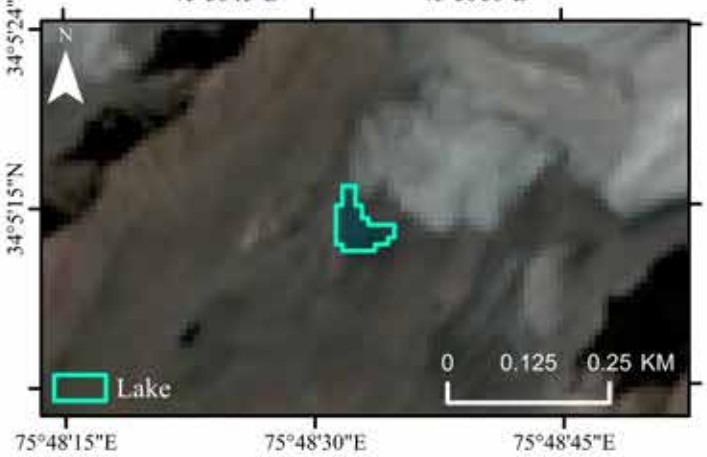
Lake ID	GL283575E34109N
Lake Type	PGLC
Area (m²)	14915
Perimeter (m)	721
Elevation(m asl)	5005
Slope (deg.)	14.73°
Aspect	South-West
Lat/Long	34.1094°/76.4248°



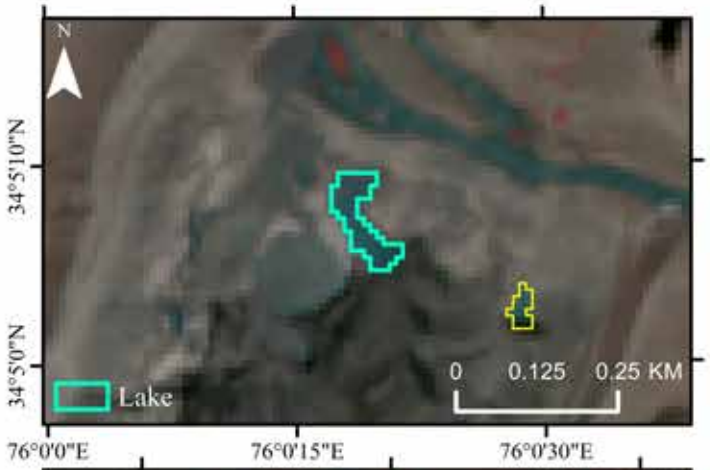
Lake ID	GL283582E34107N
Lake Type	PGLC
Area (m2)	15708
Perimeter (m)	941
Elevation(m asl)	4953
Slope (deg.)	14.91°
Aspect	North-West
Lat/Long	34.1074°/76.4181°



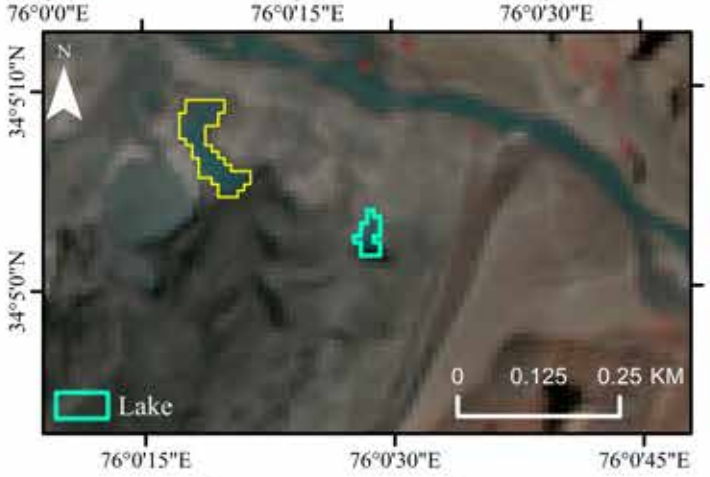
Lake ID	GL284160E34102N
Lake Type	PGLA
Area (m2)	11905
Perimeter (m)	521
Elevation(m asl)	4715
Slope (deg.)	8.5°
Aspect	South
Lat/Long	34.1024°/75.8399°



Lake ID	GL284191E34087N
Lake Type	PGLC
Area (m2)	5002
Perimeter (m)	380
Elevation(m asl)	4804
Slope (deg.)	15.78°
Aspect	South
Lat/Long	34.0872°/75.8091°

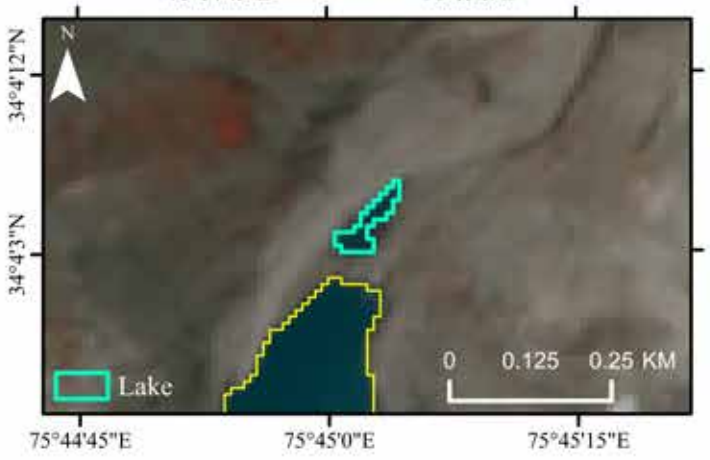


Lake ID	GL283995E34085N
Lake Type	PGLC
Area (m^2)	7204
Perimeter (m)	580
Elevation(m asl)	3604
Slope (deg.)	18.06°
Aspect	East
Lat/Long	34.0853°/76.0053°

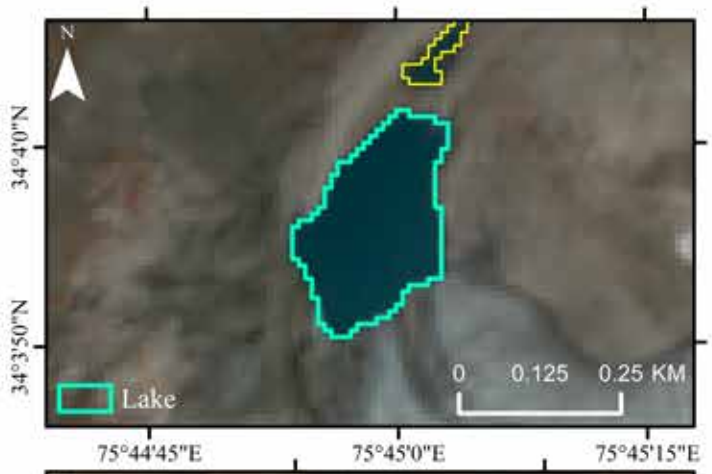


Lake ID	GL283992E34084N
Lake Type	PGLC
Area (m2)	1801
Perimeter (m)	242
Elevation(m asl)	3615
Slope (deg.)	10.09°
Aspect	North-East
Lat/Long	34.0841°/76.0079°

Lake ID	GL283752E34080N
Lake Type	PGLC
Area (m2)	1801
Perimeter (m)	200
Elevation(m asl)	5241
Slope (deg.)	14.63°
Aspect	South-East
Lat/Long	34.0798°/76.2483°

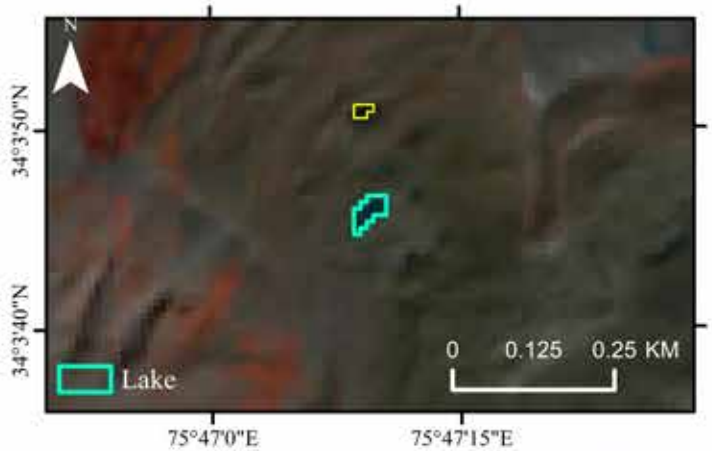


Lake ID	GL284249E34068N
Lake Type	PGLC
Area (m2)	3717
Perimeter (m)	439
Elevation(m asl)	4527
Slope (deg.)	4.6°
Aspect	South-West
Lat/Long	34.0679°/75.7507°

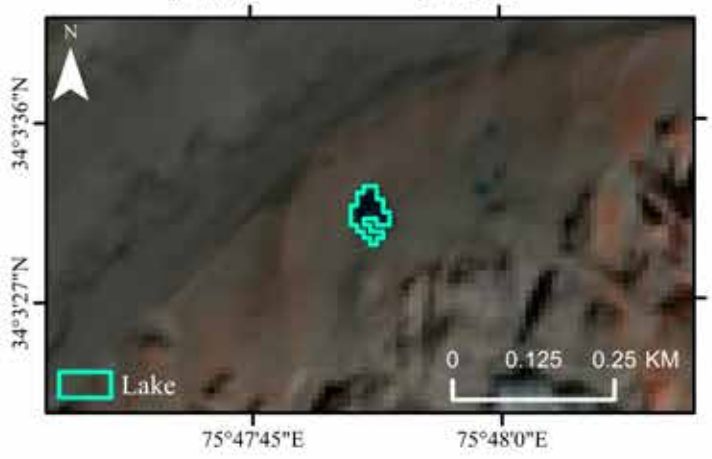


Lake ID	GL284250E34066N
Lake Type	PGLC
Area (m^2)	53503
Perimeter (m)	1200
Elevation(m asl)	4549
Slope (deg.)	8.9°
Aspect	South-West
Lat/Long	34.0655°/75.7496°

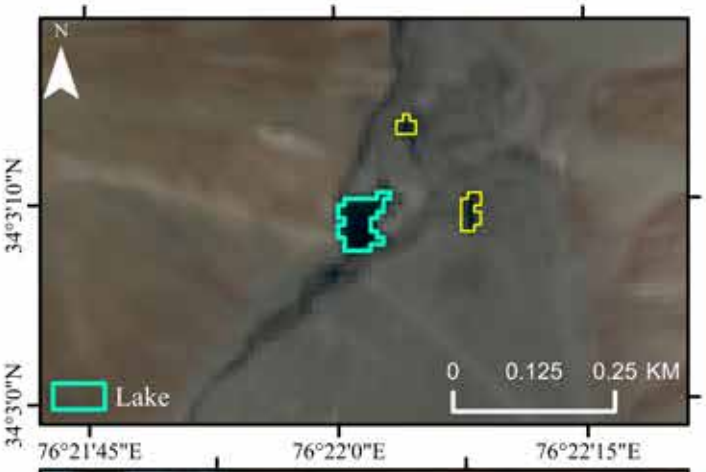
Lake ID	GL283632E34058N
Lake Type	OL
Area (m2)	4903
Perimeter (m)	340
Elevation(m asl)	4000
Slope (deg.)	4.74°
Aspect	South
Lat/Long	34.058°/76.3679°



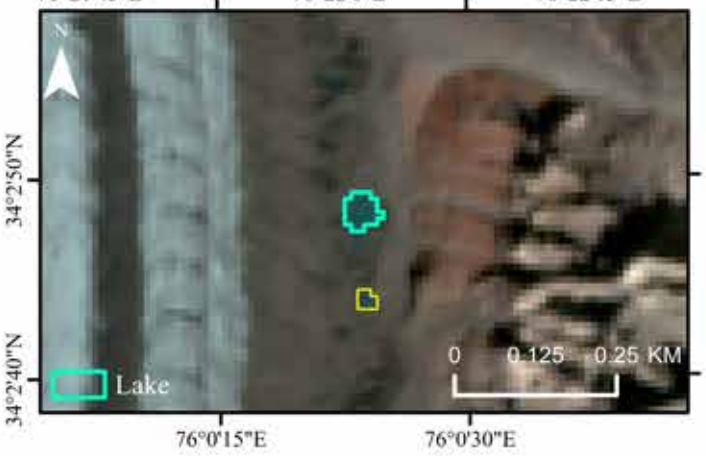
Lake ID	GL284214E34063N
Lake Type	PGLA
Area (m2)	1798
Perimeter (m)	220
Elevation(m asl)	4135
Slope (deg.)	4.01°
Aspect	West
Lat/Long	34.0627°/75.7859°



Lake ID	GL284202E34059N
Lake Type	PGLC
Area (m2)	3016
Perimeter (m)	381
Elevation(m asl)	4111
Slope (deg.)	10.84°
Aspect	East
Lat/Long	34.0587°/75.7978°

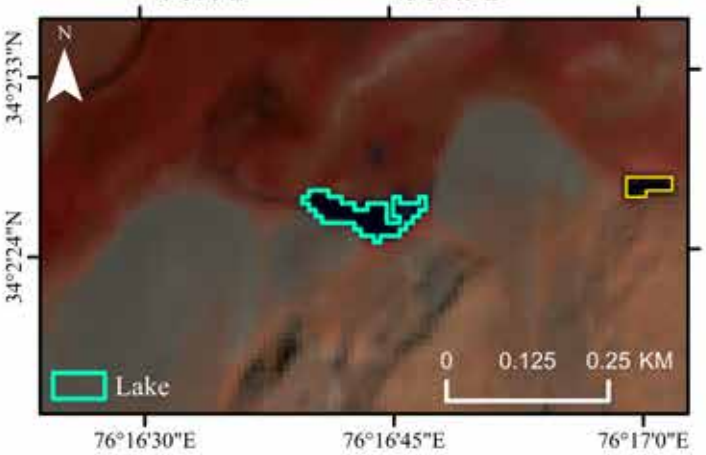


Lake ID	GL283633E34052N
Lake Type	OL
Area (m^2)	4605
Perimeter (m)	400
Elevation(m asl)	3995
Slope (deg.)	2.61°
Aspect	South-West
Lat/Long	34.0525°/76.367°



Lake ID	GL283994E34047N
Lake Type	SGL
Area (m2)	2604
Perimeter (m)	240
Elevation(m asl)	4323
Slope (deg.)	4.15°
Aspect	South-East
Lat/Long	34.0467°/76.0065°

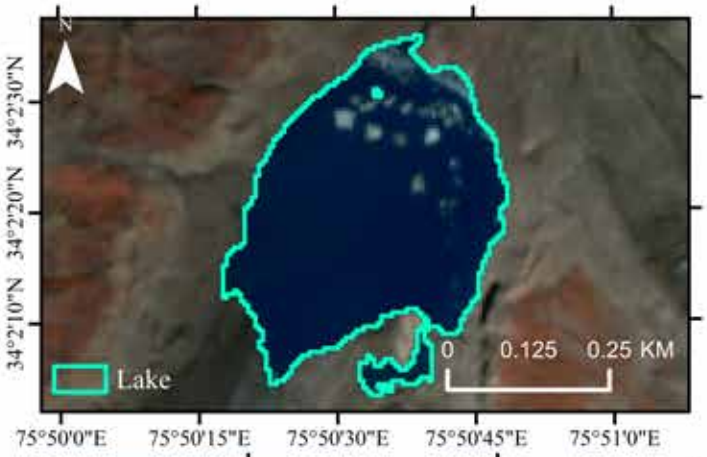
Lake ID	GL284147E34048N
Lake Type	PGLC
Area (m2)	4512
Perimeter (m)	300
Elevation(m asl)	3982
Slope (deg.)	5.75°
Aspect	West
Lat/Long	34.0477°/75.8528°



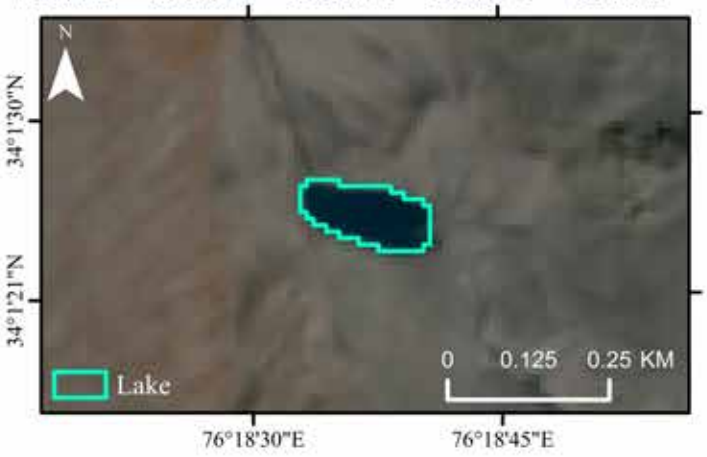
Lake ID	GL283721E34040N
Lake Type	OL
Area (m2)	6847
Perimeter (m)	683
Elevation(m asl)	3952
Slope (deg.)	6.76°
Aspect	South
Lat/Long	34.0405°/76.2787°

Lake ID	GL284116E34041N
Lake Type	SGL
Area (m²)	1507
Perimeter (m)	181
Elevation(m asl)	4455
Slope (deg.)	5.78°
Aspect	South-West
Lat/Long	34.0414°/75.884°

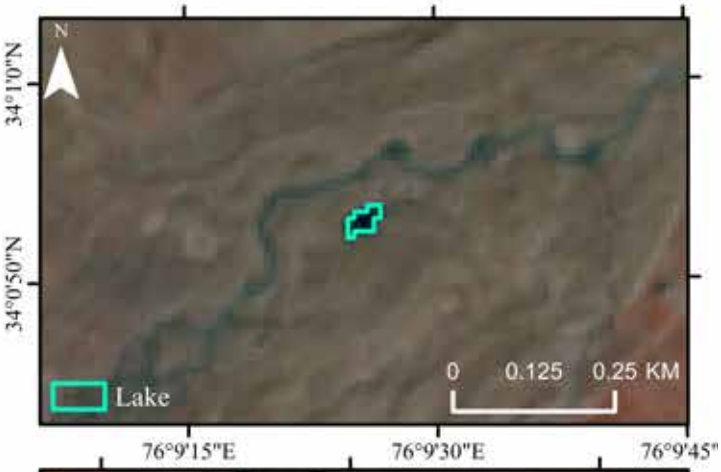
Lake ID	GL283543E34034N
Lake Type	PGLA
Area (m2)	1703
Perimeter (m)	200
Elevation(m asl)	4840
Slope (deg.)	16.7°
Aspect	West
Lat/Long	34.0341°/76.4569°



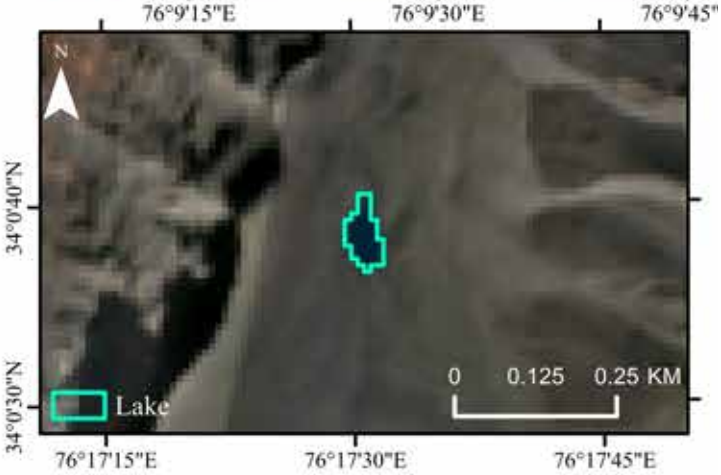
Lake ID	GL284157E34039N
Lake Type	PGLC
Area (m2)	488825
Perimeter (m)	4942
Elevation(m asl)	4073
Slope (deg.)	6.86°
Aspect	South-East
Lat/Long	34.0388°/75.8427°



Lake ID	GL283690E34024N
Lake Type	PGLA
Area (m2)	15905
Perimeter (m)	621
Elevation(m asl)	4709
Slope (deg.)	7.62°
Aspect	South-East
Lat/Long	34.0236°/76.3103°



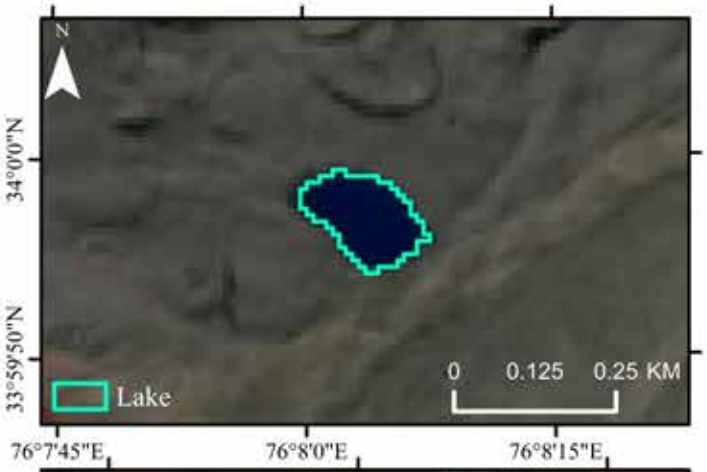
Lake ID	GL283843E34015N
Lake Type	OL
Area (m^2)	1506
Perimeter (m)	200
Elevation(m asl)	4018
Slope (deg.)	5.53°
Aspect	South-East
Lat/Long	34.0147°/76.1571°



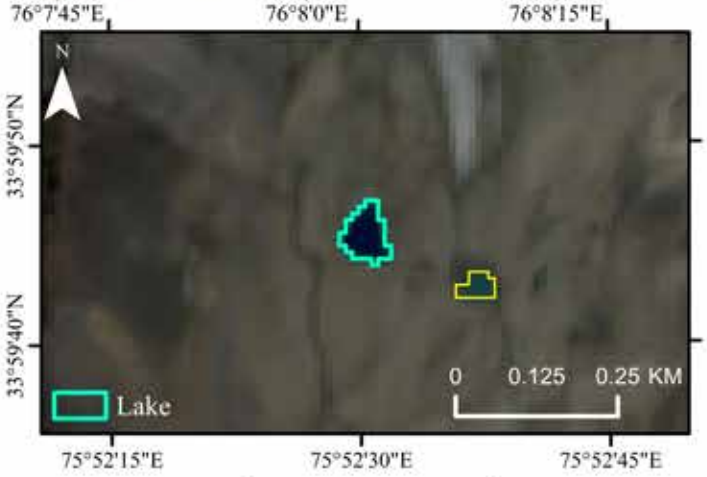
Lake ID	GL283708E34011N
Lake Type	PGLA
Area (m2)	4504
Perimeter (m)	360
Elevation(m asl)	4938
Slope (deg.)	7.37°
Aspect	South-West
Lat/Long	34.0107°/76.2918°

Lake ID	GL284181E34015N
Lake Type	PGLC
Area (m2)	99622
Perimeter (m)	1883
Elevation(m asl)	4383
Slope (deg.)	9.39°
Aspect	West
Lat/Long	34.0148°/75.8187°

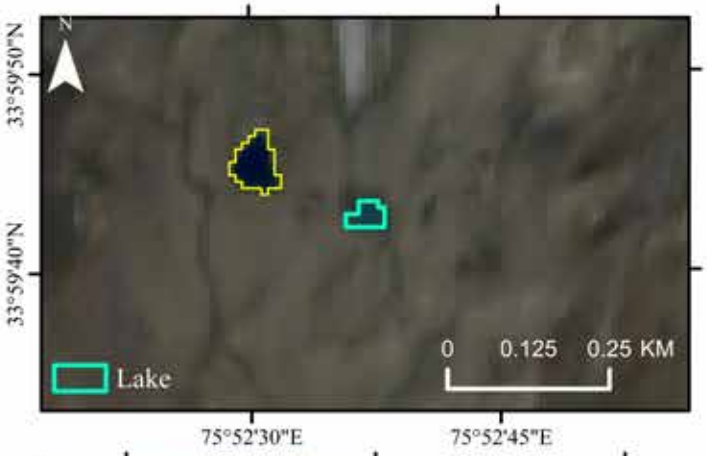
Lake ID	GL283860E34002N
Lake Type	PGLA
Area (m2)	1295
Perimeter (m)	180
Elevation(m asl)	4159
Slope (deg.)	6.31°
Aspect	South-East
Lat/Long	34.0022°/76.1399°



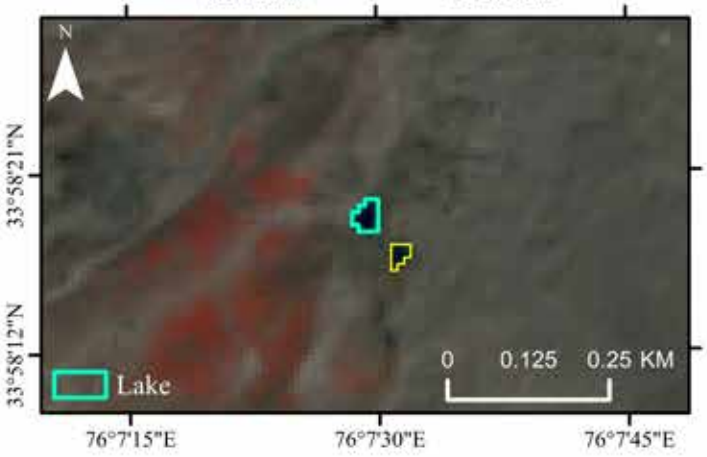
Lake ID	GL283866E33999N
Lake Type	PGLC
Area (m^2)	18610
Perimeter (m)	721
Elevation(m asl)	4211
Slope (deg.)	7.85°
Aspect	South-East
Lat/Long	33.9991°/76.1343°



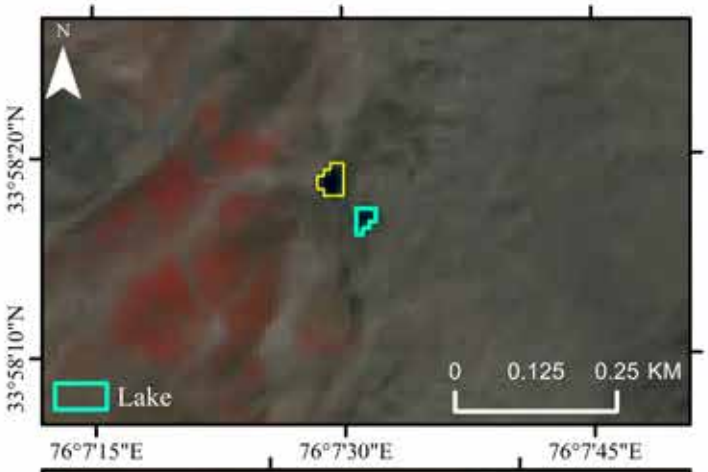
Lake ID	GL284125E33996N
Lake Type	PGLC
Area (m2)	4917
Perimeter (m)	360
Elevation(m asl)	4816
Slope (deg.)	15.66°
Aspect	South
Lat/Long	33.9959°/75.8751°



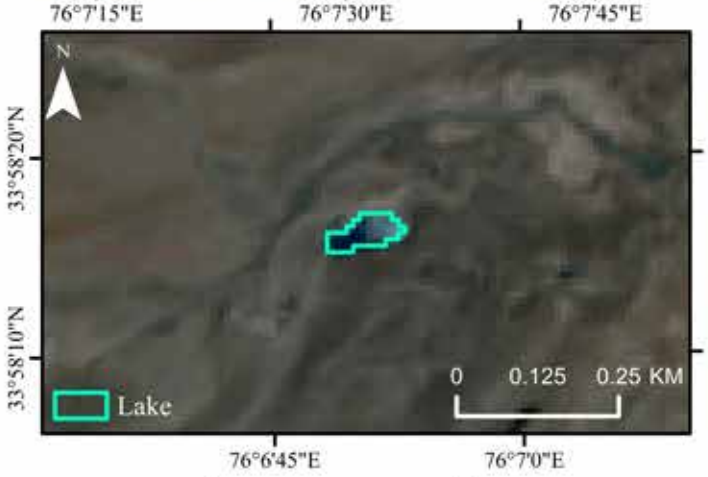
Lake ID	GL284123E33995N
Lake Type	PGLC
Area (m2)	1903
Perimeter (m)	200
Elevation(m asl)	4799
Slope (deg.)	9.97°
Aspect	South
Lat/Long	33.9952°/75.8769°



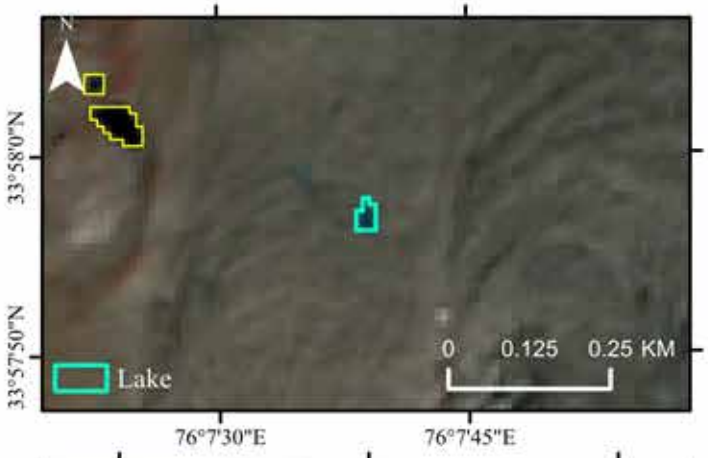
Lake ID	GL283875E33972N
Lake Type	PGLA
Area (m2)	1606
Perimeter (m)	180
Elevation(m asl)	4397
Slope (deg.)	1.95°
Aspect	West
Lat/Long	33.9719°/76.1248°



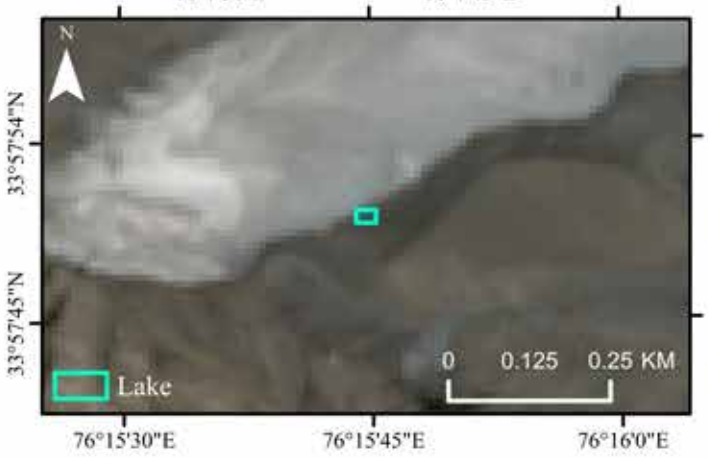
Lake ID	GL283875E33971N
Lake Type	PGLA
Area (m²)	902
Perimeter (m)	140
Elevation(m asl)	4394
Slope (deg.)	6.19°
Aspect	South-East
Lat/Long	33.9713°/76.1253°



Lake ID	GL283886E33971N
Lake Type	PGLC
Area (m2)	4502
Perimeter (m)	361
Elevation(m asl)	4442
Slope (deg.)	4.83°
Aspect	East
Lat/Long	33.9711°/76.114°

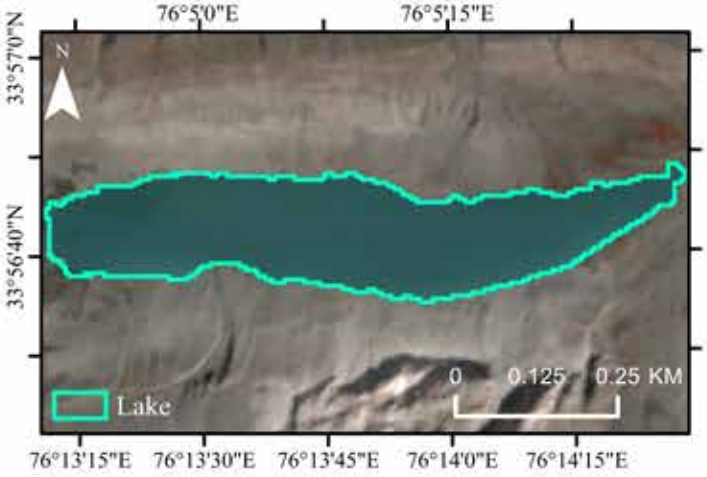


Lake ID	GL283873E33966N
Lake Type	SGL
Area (m2)	1202
Perimeter (m)	162
Elevation(m asl)	4427
Slope (deg.)	4.76°
Aspect	East
Lat/Long	33.9658°/76.1274°

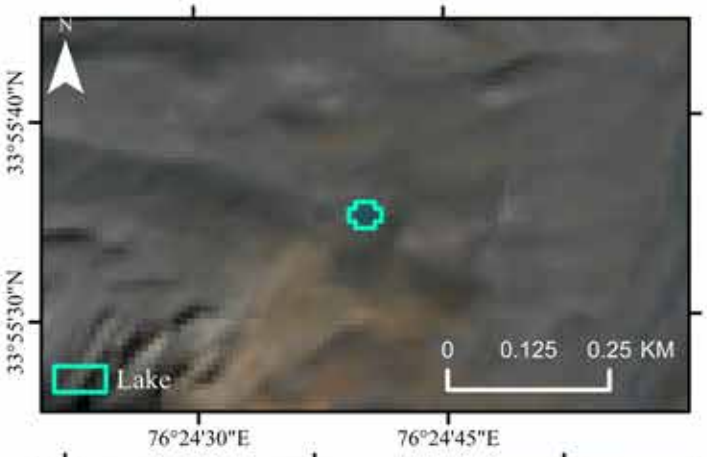


Lake ID	GL283738E33964N
Lake Type	SGL
Area (m2)	608
Perimeter (m)	102
Elevation(m asl)	5337
Slope (deg.)	12.25°
Aspect	South
Lat/Long	33.9639°/76.2624°

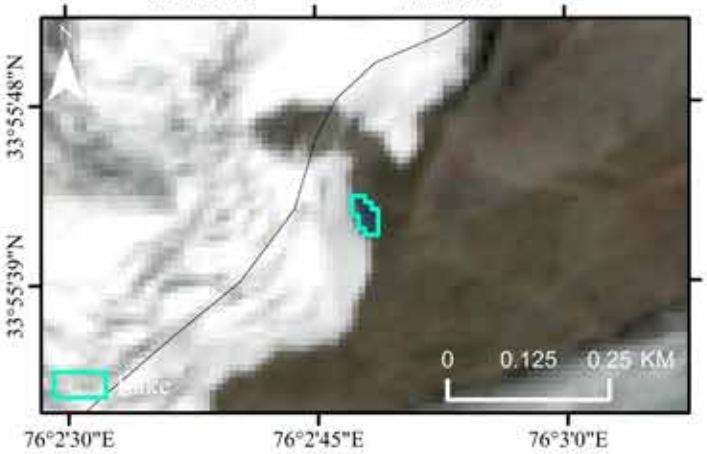
Lake ID	GL283914E33965N
Lake Type	SGL
Area (m^2)	3803
Perimeter (m)	320
Elevation(m asl)	4893
Slope (deg.)	13.95°
Aspect	East
Lat/Long	33.9652°/76.0861°



Lake ID	GL283770E33945N
Lake Type	PGLC
Area (m2)	529303
Perimeter (m)	5442
Elevation(m asl)	4358
Slope (deg.)	7.53°
Aspect	South-East
Lat/Long	33.9451°/76.2297°



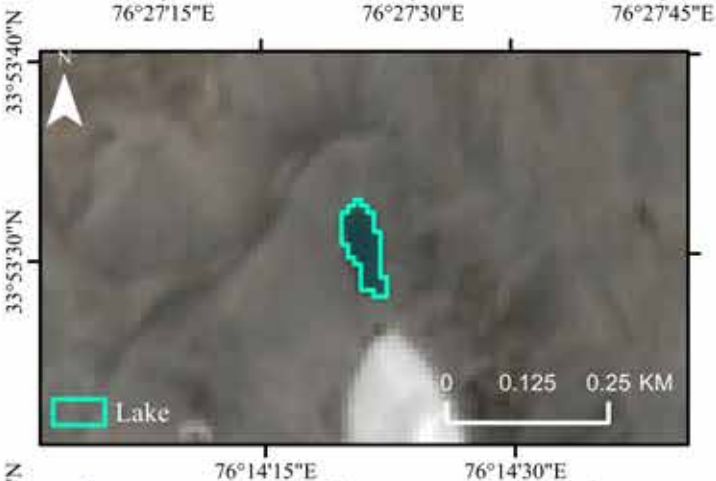
Lake ID	GL283589E33926N
Lake Type	PGLA
Area (m2)	1600
Perimeter (m)	180
Elevation(m asl)	4991
Slope (deg.)	11.26°
Aspect	North-West
Lat/Long	33.9264°/76.4111°



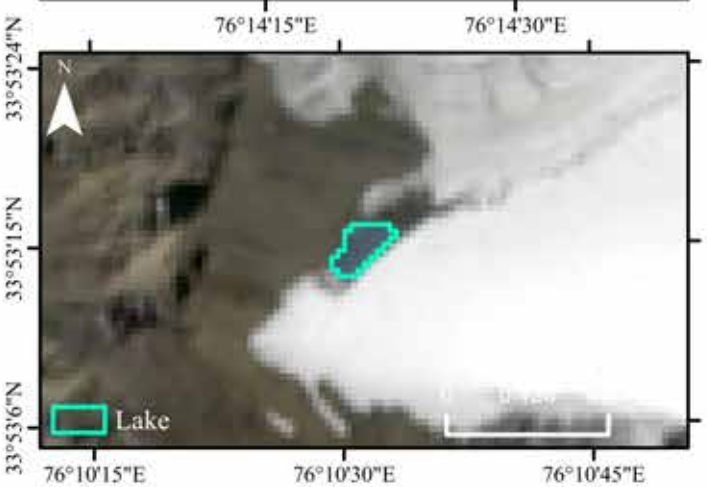
Lake ID	GL283953E33928N
Lake Type	PGLC
Area (m2)	1702
Perimeter (m)	200
Elevation(m asl)	4835
Slope (deg.)	23.08°
Aspect	North-East
Lat/Long	33.9284°/76.0466°

Lake ID	GL283496E33901N
Lake Type	SGL
Area (m²)	800
Perimeter (m)	160
Elevation(m asl)	5174
Slope (deg.)	7.85°
Aspect	North-West
Lat/Long	33.9007°/76.5039°

Lake ID	GL283542E33898N
Lake Type	PGLA
Area (m2)	4100
Perimeter (m)	300
Elevation(m asl)	4883
Slope (deg.)	12.88°
Aspect	West
Lat/Long	33.8975°/76.4576°



Lake ID	GL283761E33892N
Lake Type	PGLC
Area (m2)	6096
Perimeter (m)	440
Elevation(m asl)	4766
Slope (deg.)	12.26°
Aspect	West
Lat/Long	33.8918°/76.2391°

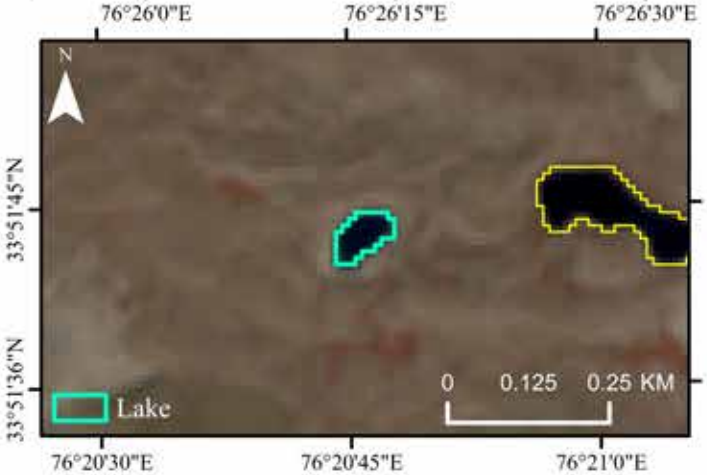


Lake ID	GL283825E33888N
Lake Type	SGL
Area (m2)	4701
Perimeter (m)	360
Elevation(m asl)	5050
Slope (deg.)	6.25°
Aspect	South-East
Lat/Long	33.8875°/76.1753°

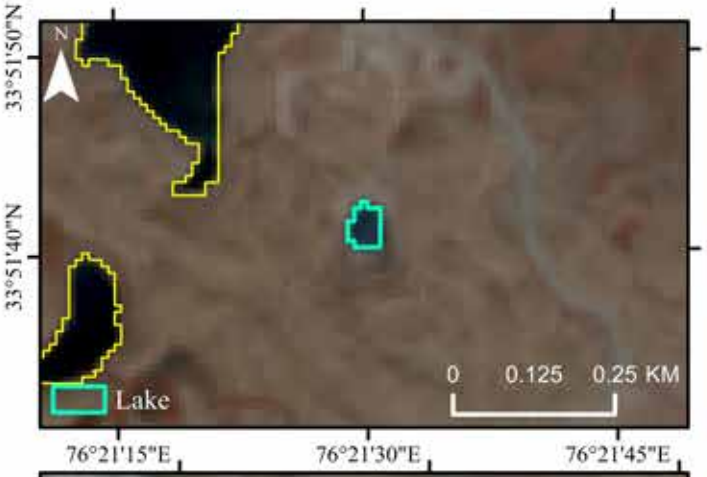
Lake ID	GL283837E33880N
Lake Type	SGL
Area (m²)	2104
Perimeter (m)	240
Elevation(m asl)	4424
Slope (deg.)	8.92°
Aspect	North-East
Lat/Long	33.8804°/76.1627°

Lake ID	GL283561E33874N
Lake Type	PGLA
Area (m2)	1503
Perimeter (m)	181
Elevation(m asl)	4956
Slope (deg.)	3.94°
Aspect	South-West
Lat/Long	33.8738°/76.4391°

Lake ID	GL283563E33870N
Lake Type	PGLC
Area (m2)	1499
Perimeter (m)	180
Elevation(m asl)	4977
Slope (deg.)	13.58°
Aspect	South
Lat/Long	33.8697°/76.437°

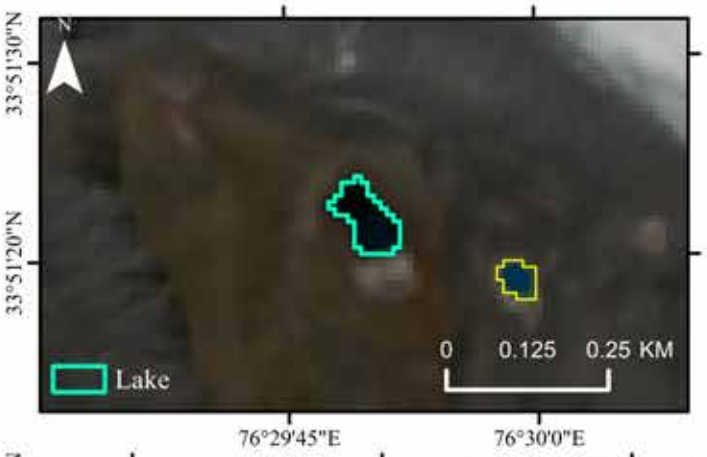


Lake ID	GL283654E33862N
Lake Type	PGLA
Area (m2)	4895
Perimeter (m)	339
Elevation(m asl)	4463
Slope (deg.)	4.59°
Aspect	South
Lat/Long	33.8621°/76.346°

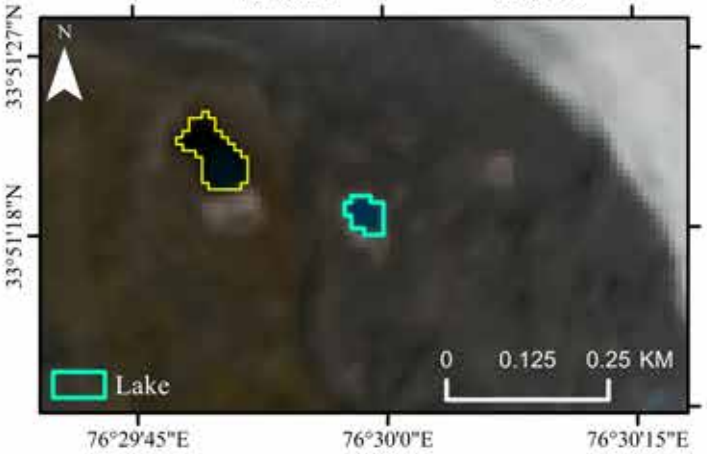


Lake ID	GL283642E33862N
Lake Type	PGLA
Area (m^2)	2804
Perimeter (m)	241
Elevation(m asl)	4430
Slope (deg.)	1.71°
Aspect	East
Lat/Long	33.8615°/76.3583°

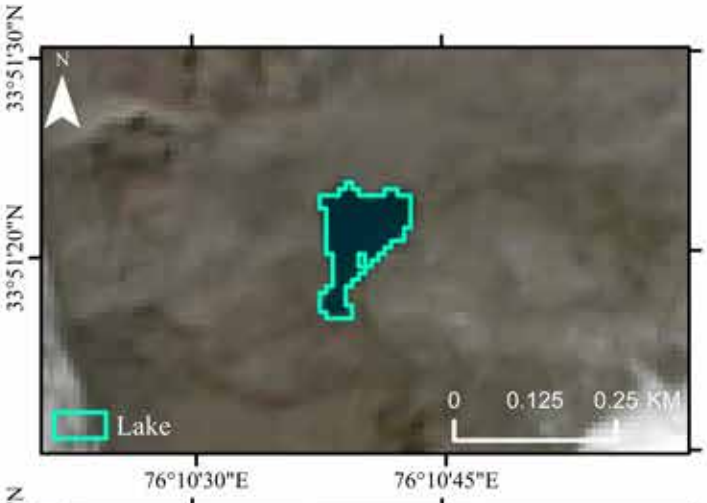
Lake ID	GL283826E33861N
Lake Type	PGLA
Area (m2)	4404
Perimeter (m)	321
Elevation(m asl)	4575
Slope (deg.)	7.85°
Aspect	South-West
Lat/Long	33.8607°/76.1739°



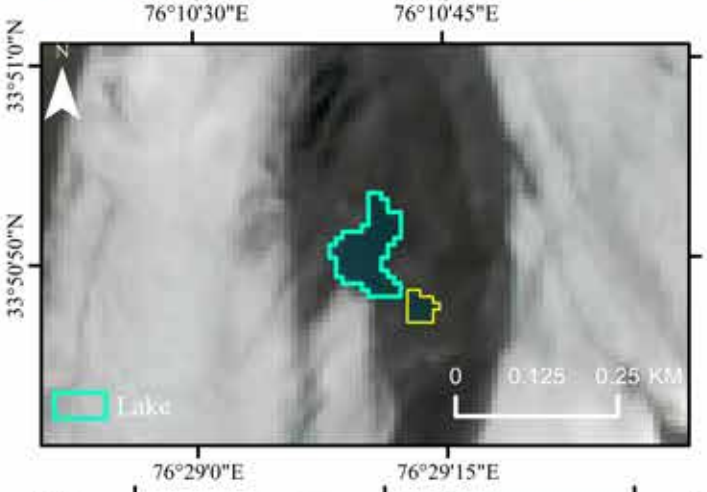
Lake ID	GL283503E33856N
Lake Type	PGLA
Area (m2)	7141
Perimeter (m)	461
Elevation(m asl)	5036
Slope (deg.)	2.82°
Aspect	South
Lat/Long	33.8561°/76.4971°



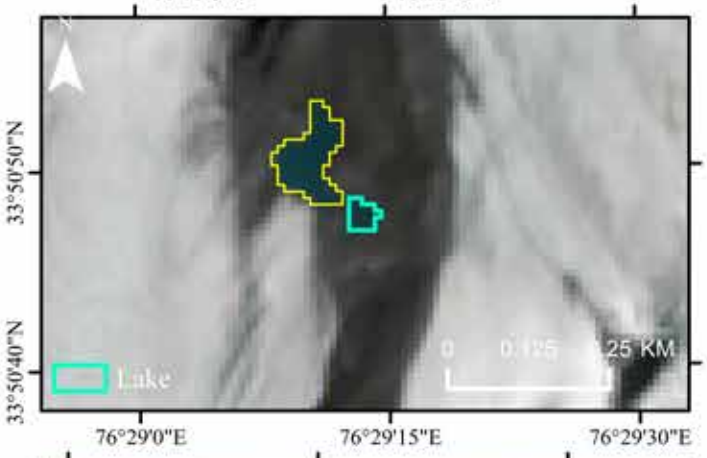
Lake ID	GL283500E33855N
Lake Type	PGLA
Area (m2)	2803
Perimeter (m)	241
Elevation(m asl)	5035
Slope (deg.)	1.92°
Aspect	South-East
Lat/Long	33.8552°/76.4996°



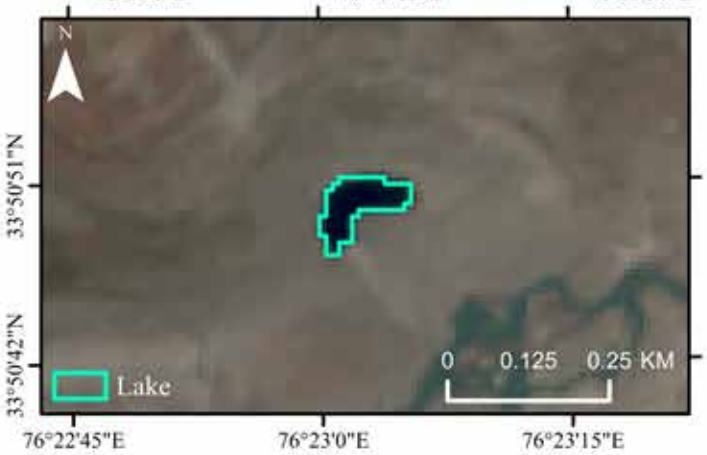
Lake ID	GL283822E33856N
Lake Type	PGLA
Area (m^2)	15896
Perimeter (m)	839
Elevation(m asl)	4735
Slope (deg.)	7.63°
Aspect	South-West
Lat/Long	33.8558°/76.1777°



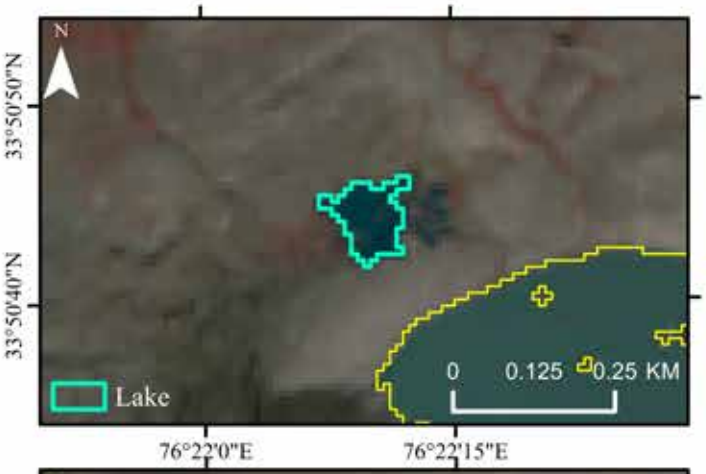
Lake ID	GL283514E33847N
Lake Type	PGLC
Area (m2)	10094
Perimeter (m)	600
Elevation(m asl)	5033
Slope (deg.)	12°
Aspect	North-East
Lat/Long	33.8474°/76.4862°



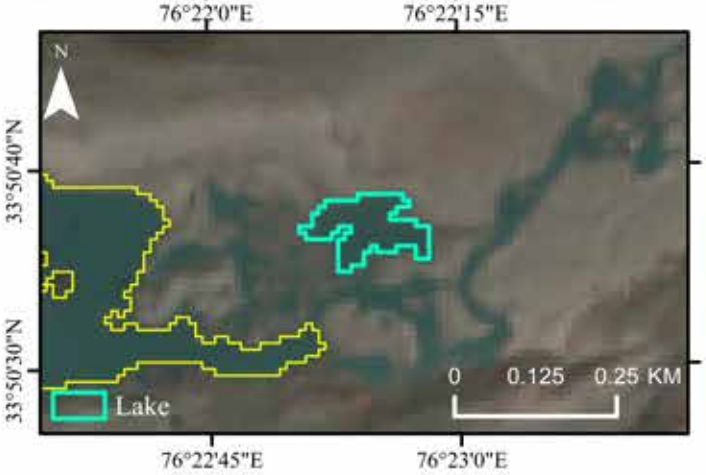
Lake ID	GL283513E33847N
Lake Type	PGLC
Area (m2)	1899
Perimeter (m)	200
Elevation(m asl)	5016
Slope (deg.)	16.5°
Aspect	East
Lat/Long	33.8466°/76.487°



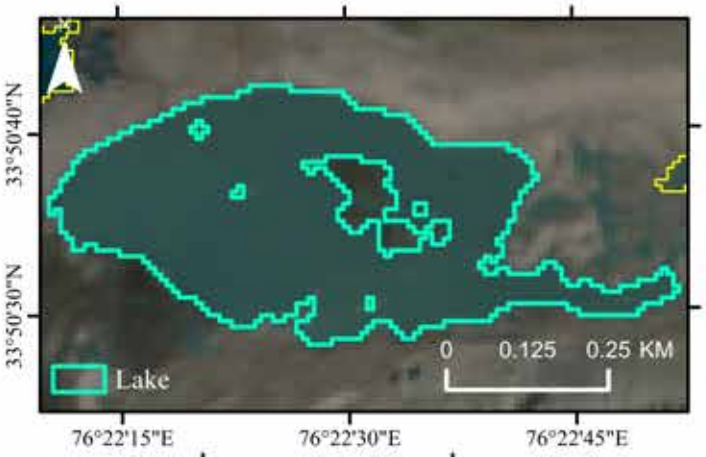
Lake ID	GL283616E33847N
Lake Type	PGLA
Area (m2)	8537
Perimeter (m)	522
Elevation(m asl)	4055
Slope (deg.)	2.21°
Aspect	South
Lat/Long	33.8472°/76.3839°



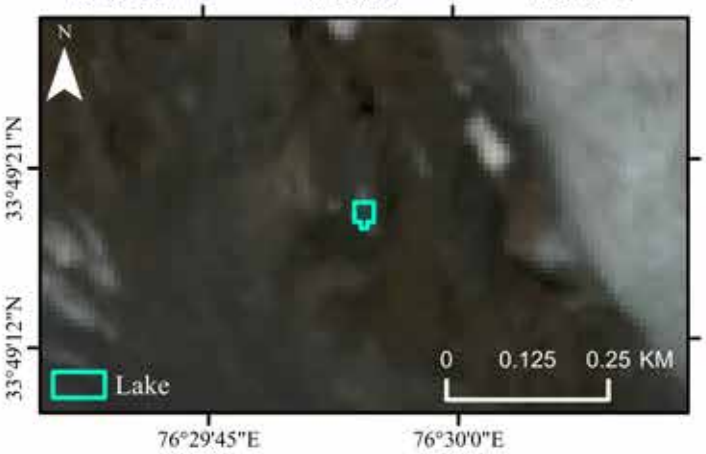
Lake ID	GL283631E33846N
Lake Type	PGLC
Area (m²)	10305
Perimeter (m)	662
Elevation(m asl)	4110
Slope (deg.)	9.59°
Aspect	North-East
Lat/Long	33.8456°/76.3694°



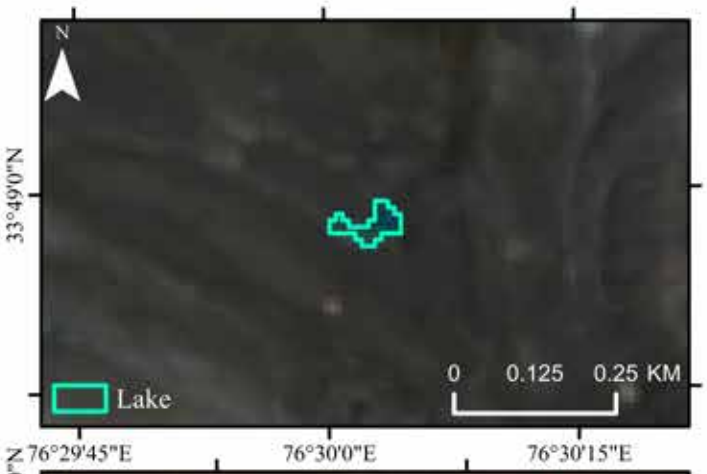
Lake ID	GL283618E33844N
Lake Type	PGLC
Area (m2)	13119
Perimeter (m)	839
Elevation(m asl)	4059
Slope (deg.)	2.54°
Aspect	South
Lat/Long	33.8436°/76.3818°



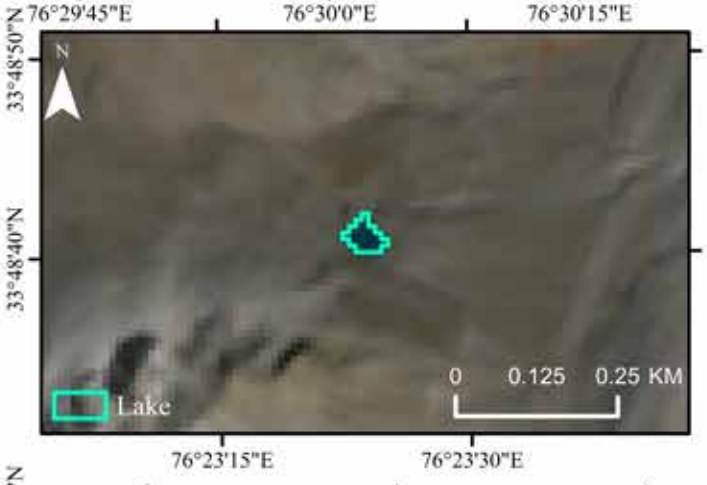
Lake ID	GL283626E33843N
Lake Type	PGLC
Area (m2)	242338
Perimeter (m)	5161
Elevation(m asl)	4096
Slope (deg.)	7.59°
Aspect	East
Lat/Long	33.8431°/76.3744°



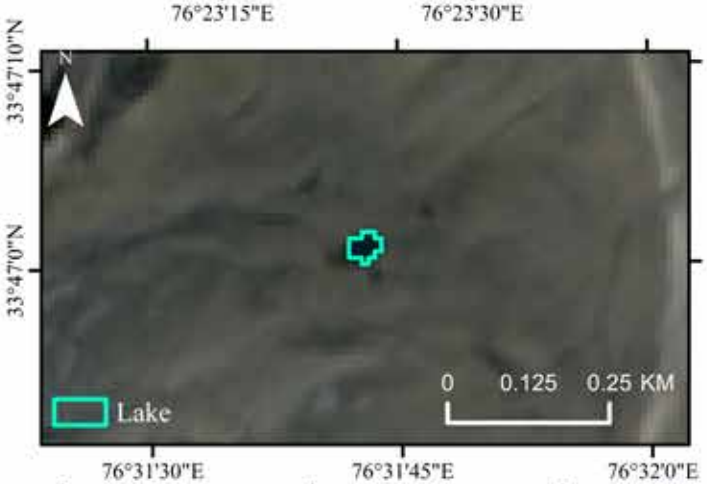
Lake ID	GL283502E33822N
Lake Type	PGLA
Area (m2)	1002
Perimeter (m)	140
Elevation(m asl)	5197
Slope (deg.)	20.03°
Aspect	South-West
Lat/Long	33.8218°/76.4984°



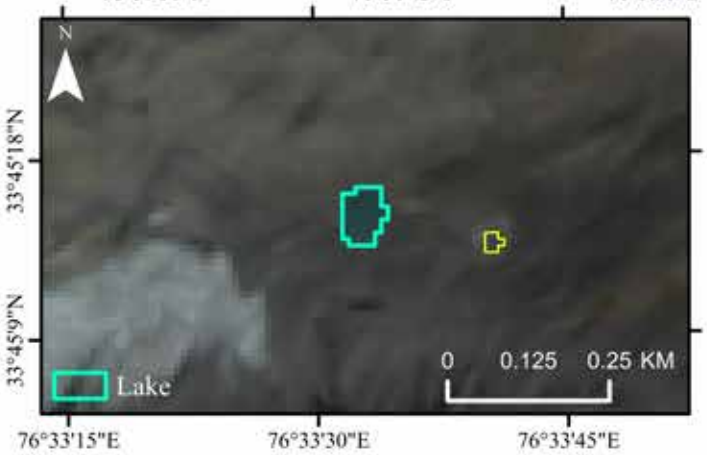
Lake ID	GL283499E33816N
Lake Type	PGLA
Area (m^2)	3512
Perimeter (m)	401
Elevation(m asl)	5019
Slope (deg.)	5.2°
Aspect	South-West
Lat/Long	33.8162°/76.5007°



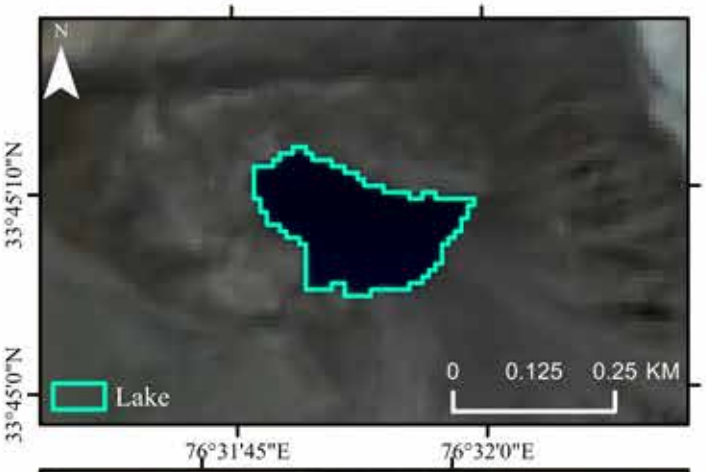
Lake ID	GL283610E33811N
Lake Type	PGLA
Area (m2)	2305
Perimeter (m)	260
Elevation(m asl)	4932
Slope (deg.)	2.9°
Aspect	West
Lat/Long	33.8114°/76.3899°



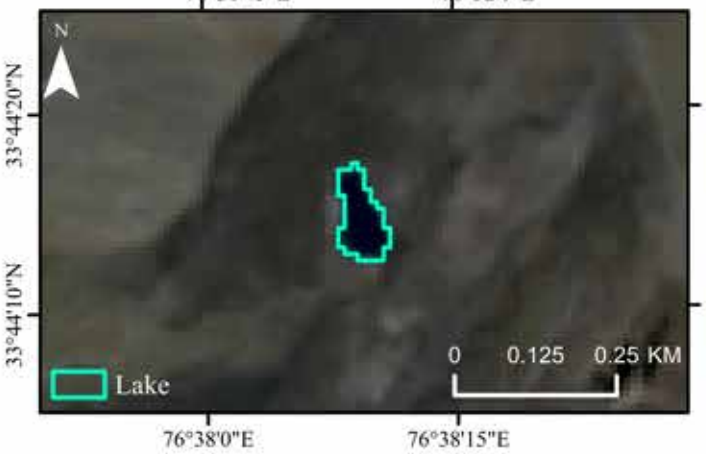
Lake ID	GL283472E33784N
Lake Type	PGLA
Area (m2)	1702
Perimeter (m)	200
Elevation(m asl)	5065
Slope (deg.)	2.39°
Aspect	South-East
Lat/Long	33.7836°/76.5285°



Lake ID	GL283441E33754N
Lake Type	PGLA
Area (m2)	5108
Perimeter (m)	321
Elevation(m asl)	5025
Slope (deg.)	9.57°
Aspect	South-East
Lat/Long	33.7542°/76.5591°

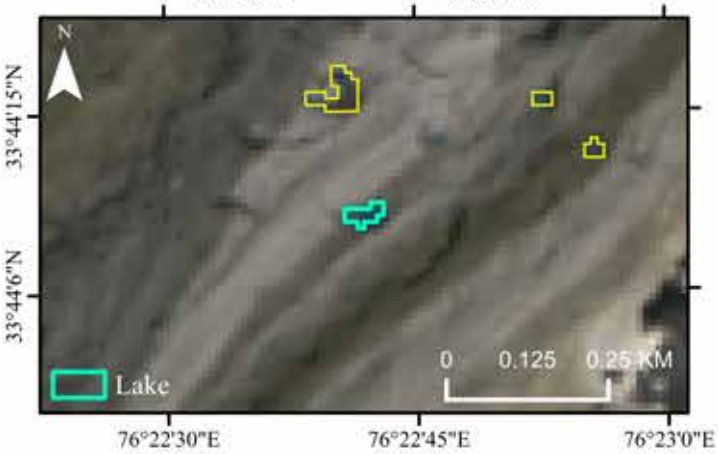


Lake ID	GL283469E33752N
Lake Type	PGLA
Area (m^2)	45015
Perimeter (m)	1182
Elevation(m asl)	5052
Slope (deg.)	8.1°
Aspect	South
Lat/Long	33.7523°/76.5311°



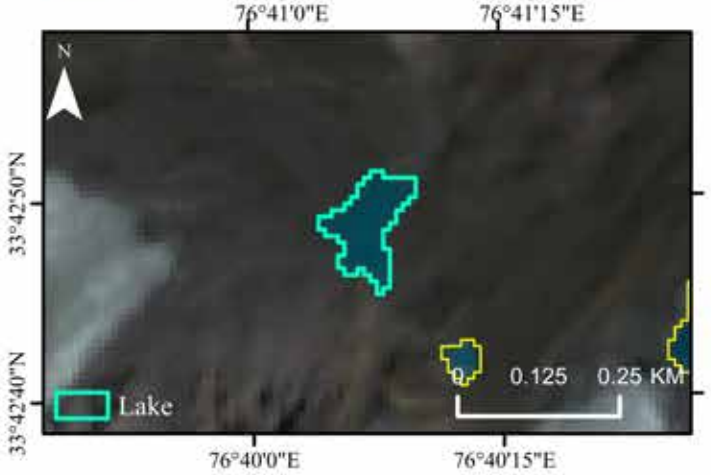
Lake ID	GL283364E33737N
Lake Type	PGLA
Area (m2)	7906
Perimeter (m)	480
Elevation(m asl)	5000
Slope (deg.)	3.77°
Aspect	South
Lat/Long	33.7374°/76.6359°

Lake ID	GL283619E33738N
Lake Type	SGL
Area (m2)	605
Perimeter (m)	100
Elevation(m asl)	4621
Slope (deg.)	6.38°
Aspect	North
Lat/Long	33.7377°/76.3812°

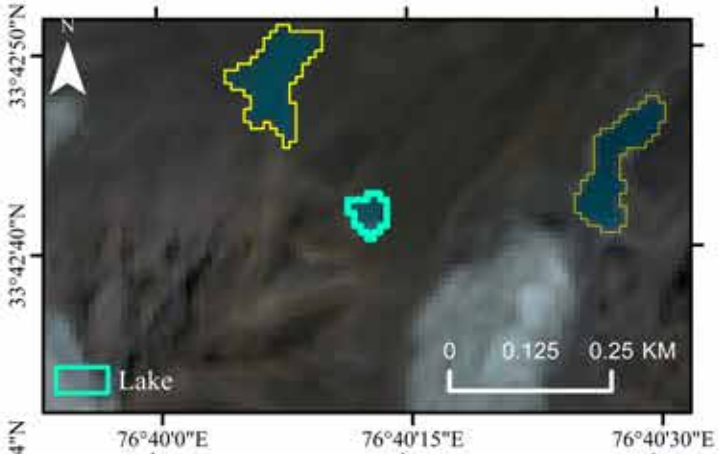


Lake ID	GL283622E33736N
Lake Type	SGL
Area (m2)	1403
Perimeter (m)	201
Elevation(m asl)	4656
Slope (deg.)	7.59°
Aspect	East
Lat/Long	33.7361°/76.3783°

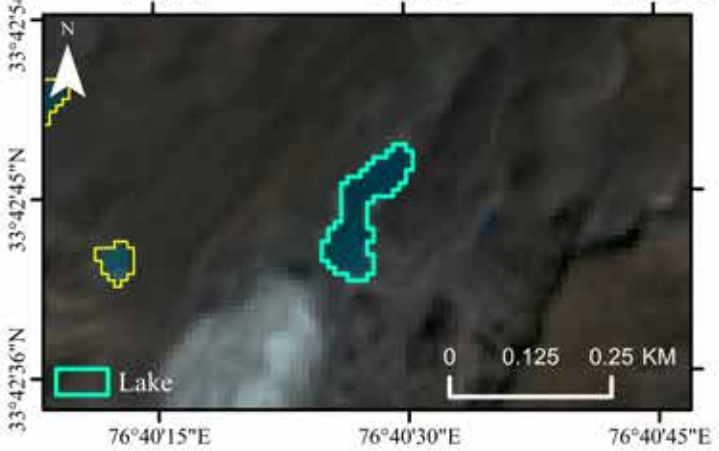
Lake ID	GL283315E33715N
Lake Type	PGLA
Area (m²)	1203
Perimeter (m)	161
Elevation(m asl)	4949
Slope (deg.)	5.31°
Aspect	North-East
Lat/Long	33.7148°/76.6848°



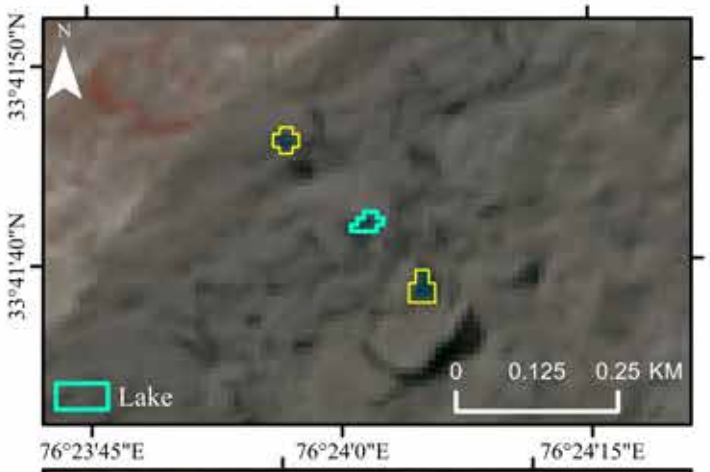
Lake ID	GL283331E33714N
Lake Type	PGLC
Area (m2)	13601
Perimeter (m)	740
Elevation(m asl)	5148
Slope (deg.)	8.31°
Aspect	South-West
Lat/Long	33.7135°/76.6686°



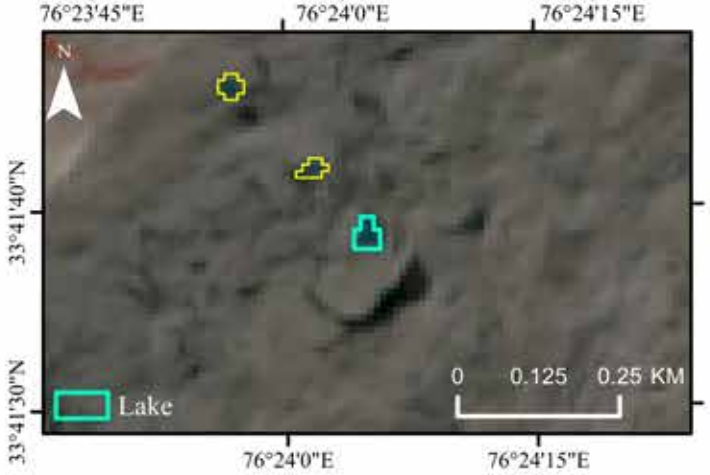
Lake ID	GL283330E33712N
Lake Type	PCLC
Area (m2)	2804
Perimeter (m)	261
Elevation(m asl)	5186
Slope (deg.)	8.89°
Aspect	East
Lat/Long	33.7116°/76.6701°



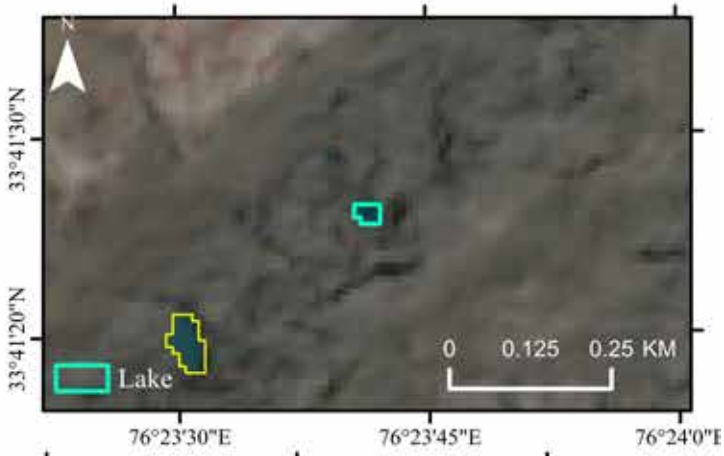
Lake ID	GL283326E33712N
Lake Type	PGLC
Area (m2)	12600
Perimeter (m)	740
Elevation(m asl)	5095
Slope (deg.)	15.24°
Aspect	South-West
Lat/Long	33.7122°/76.6742°



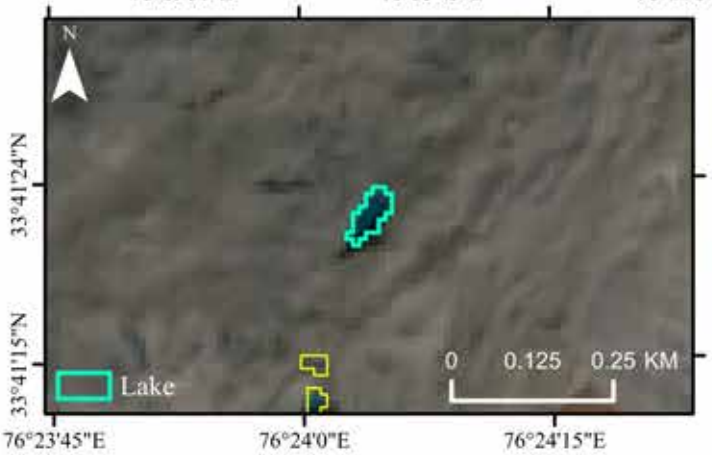
Lake ID	GL283600E33695N
Lake Type	SGL
Area (m^2)	1012
Perimeter (m)	161
Elevation(m asl)	4168
Slope (deg.)	12.73°
Aspect	North-East
Lat/Long	33.695°/76.4004°



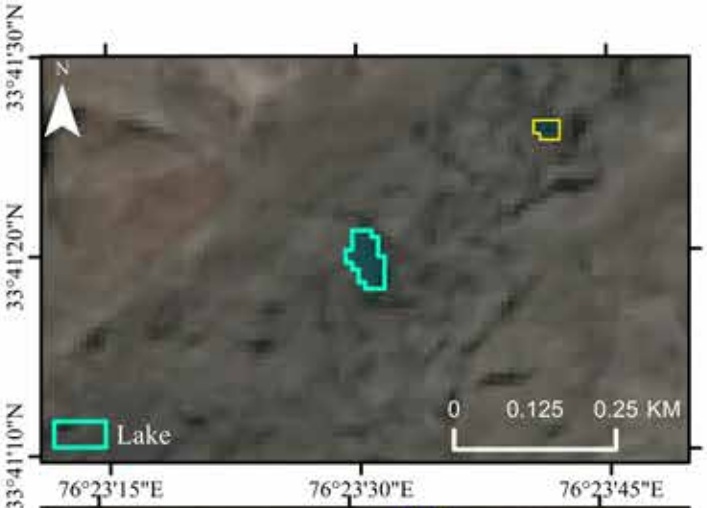
Lake ID	GL283599E33694N
Lake Type	SGL
Area (m2)	1601
Perimeter (m)	181
Elevation(m asl)	4169
Slope (deg.)	13.11°
Aspect	South-West
Lat/Long	33.6941°/76.4013°



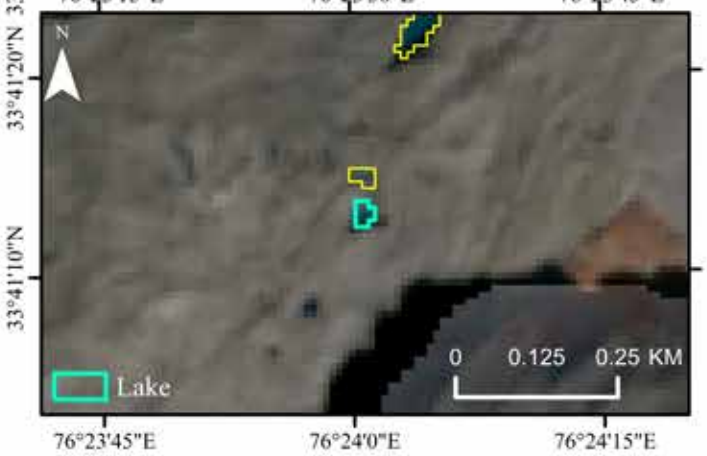
Lake ID	GL283605E33691N
Lake Type	SGL
Area (m2)	1096
Perimeter (m)	141
Elevation(m asl)	4202
Slope (deg.)	7.52°
Aspect	North-East
Lat/Long	33.6906°/76.3948°



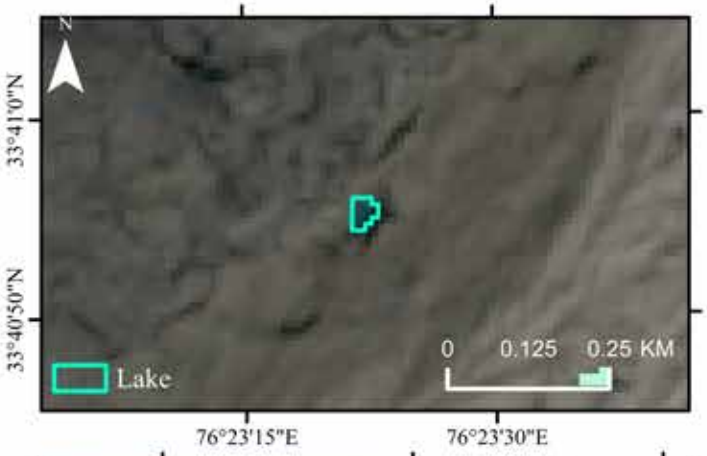
Lake ID	GL283599E33690N
Lake Type	SGL
Area (m2)	3209
Perimeter (m)	320
Elevation(m asl)	4197
Slope (deg.)	8.36°
Aspect	South-East
Lat/Long	33.6895°/76.4011°



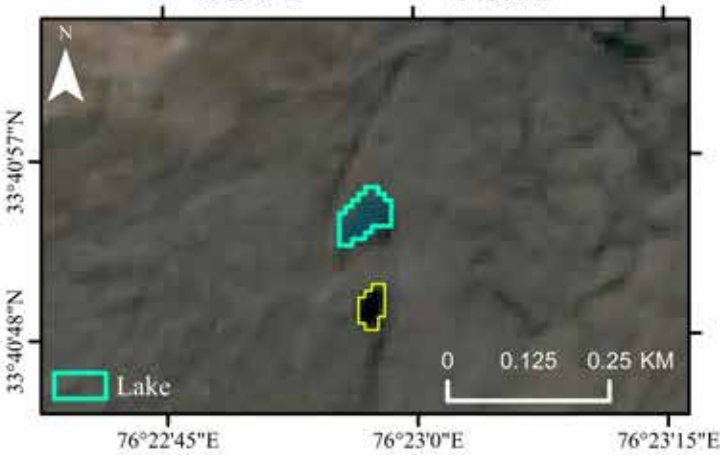
Lake ID	GL283608E33689N
Lake Type	SGL
Area (m^2)	3804
Perimeter (m)	301
Elevation(m asl)	4231
Slope (deg.)	4.68°
Aspect	South-East
Lat/Long	33.6888°/76.3918°



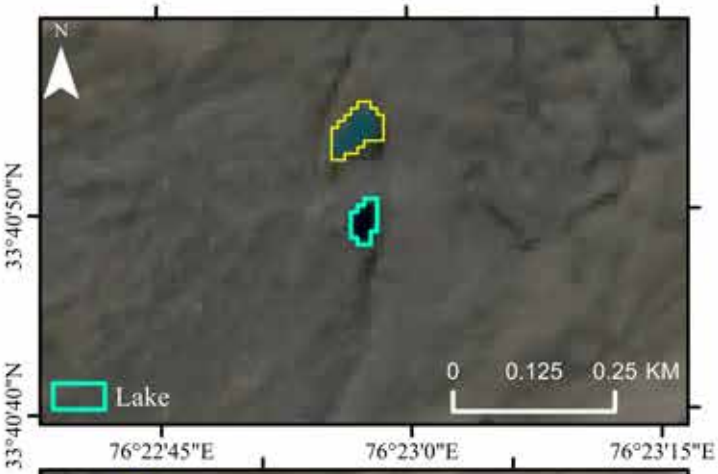
Lake ID	GL283600E33687N
Lake Type	SGL
Area (m2)	1006
Perimeter (m)	141
Elevation(m asl)	4214
Slope (deg.)	3.78°
Aspect	South-West
Lat/Long	33.6869°/76.4001°



Lake ID	GL283611E33682N
Lake Type	SGL
Area (m2)	1609
Perimeter (m)	182
Elevation(m asl)	4287
Slope (deg.)	5.6°
Aspect	South-West
Lat/Long	33.682°/76.3894°

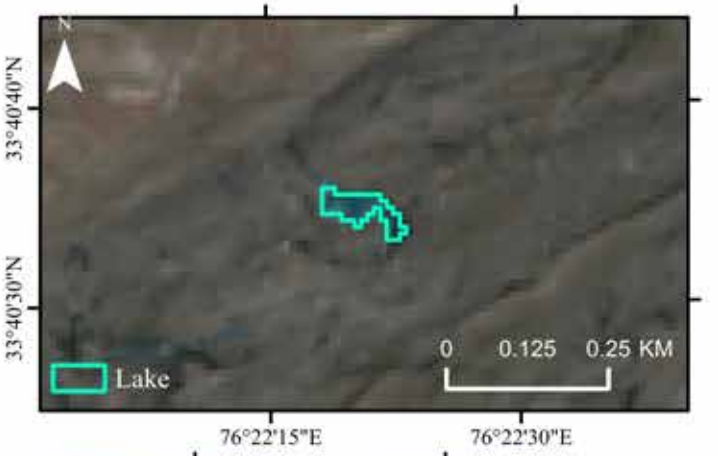


Lake ID	GL283618E33682N
Lake Type	SGL
Area (m2)	4604
Perimeter (m)	340
Elevation(m asl)	4309
Slope (deg.)	11.7°
Aspect	South-East
Lat/Long	33.6817°/76.3824°

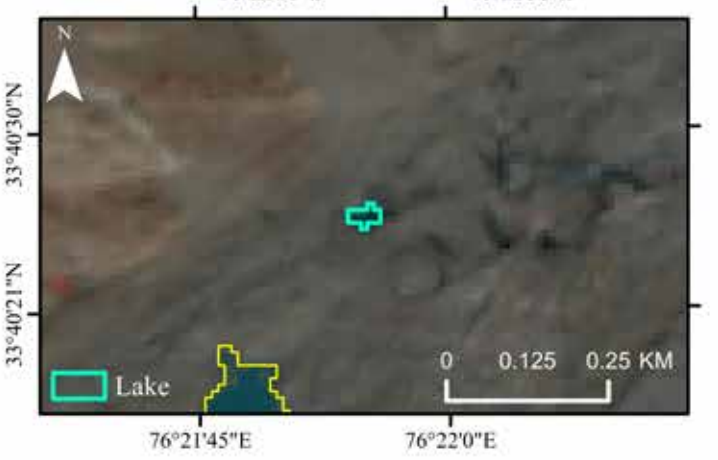


Lake ID	GL283618E33680N
Lake Type	SGL
Area (m^2)	2239
Perimeter (m)	221
Elevation(m asl)	4306
Slope (deg.)	9.99°
Aspect	North-East
Lat/Long	33.6804°/76.3825°

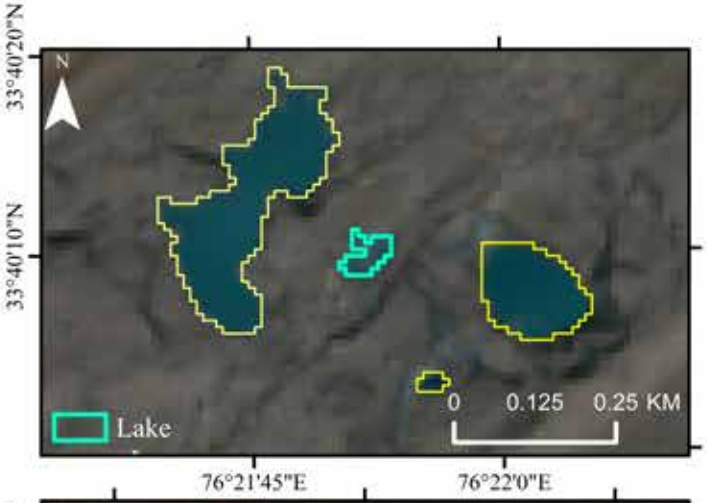
Lake ID	GL283607E33680N
Lake Type	SGL
Area (m2)	1198
Perimeter (m)	160
Elevation(m asl)	4281
Slope (deg.)	2.41°
Aspect	East
Lat/Long	33.6796°/76.3933°



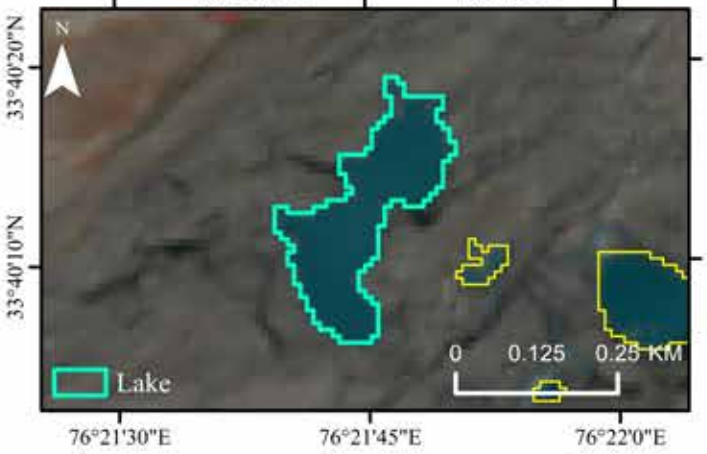
Lake ID	GL283628E33676N
Lake Type	SGL
Area (m2)	4608
Perimeter (m)	479
Elevation(m asl)	4371
Slope (deg.)	4.57°
Aspect	East
Lat/Long	33.6763°/76.3723°



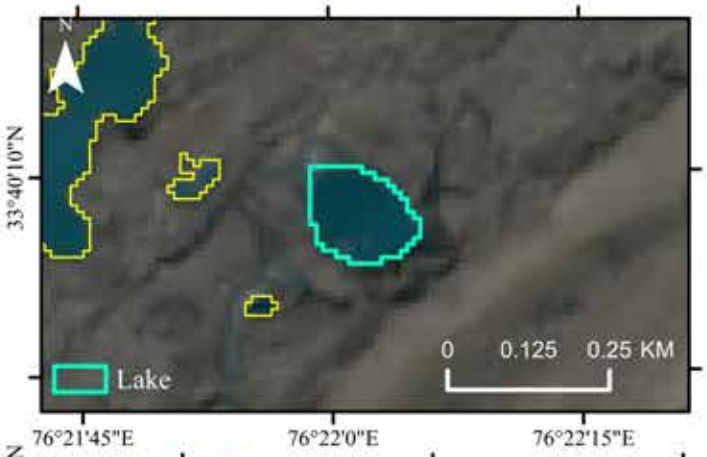
Lake ID	GL283635E33674N
Lake Type	SGL
Area (m2)	1199
Perimeter (m)	180
Elevation(m asl)	4403
Slope (deg.)	6.13°
Aspect	South-East
Lat/Long	33.6738°/76.3652°



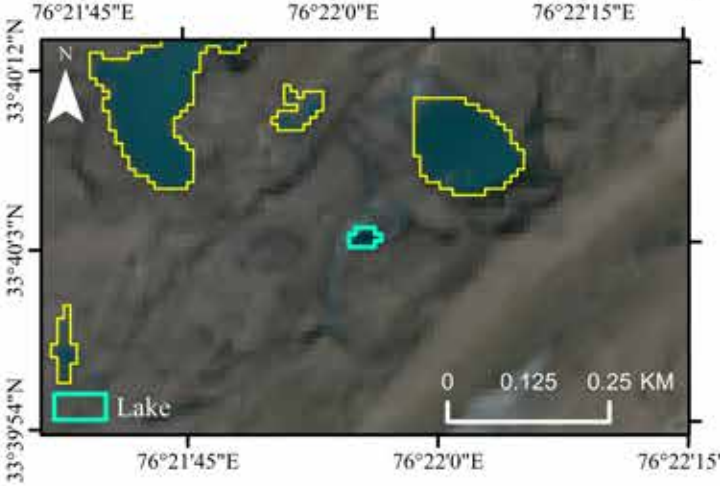
Lake ID	GL283636E33669N
Lake Type	SGL
Area (m^2)	3214
Perimeter (m)	362
Elevation(m asl)	4408
Slope (deg.)	3.25°
Aspect	South
Lat/Long	33.6694°/76.3644°



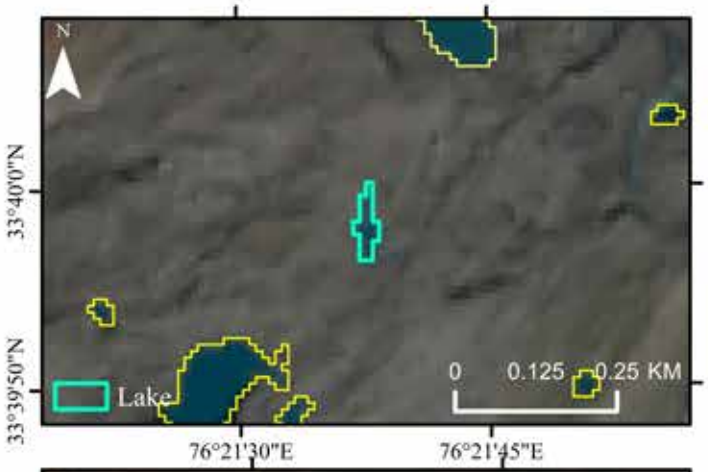
Lake ID	GL283638E33670N
Lake Type	SGL
Area (m2)	46204
Perimeter (m)	1581
Elevation(m asl)	4423
Slope (deg.)	6.31°
Aspect	South-East
Lat/Long	33.6701°/76.3624°



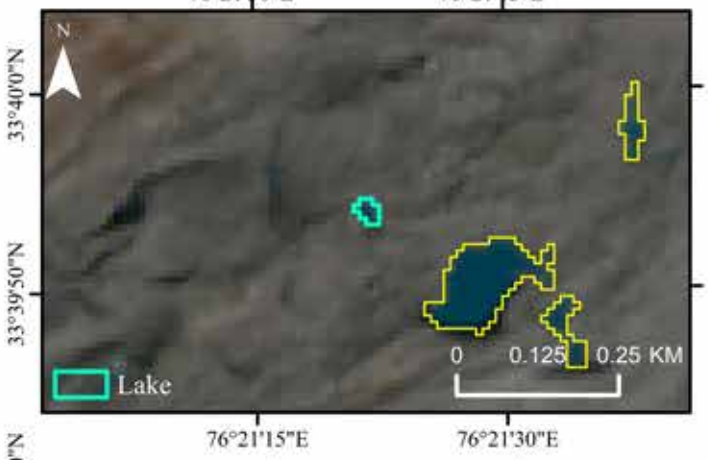
Lake ID	GL283633E33669N
Lake Type	SGL
Area (m2)	19503
Perimeter (m)	640
Elevation(m asl)	4407
Slope (deg.)	10.95°
Aspect	South
Lat/Long	33.6689°/76.3671°



Lake ID	GL283635E33668N
Lake Type	SGL
Area (m2)	1202
Perimeter (m)	160
Elevation(m asl)	4414
Slope (deg.)	3.59°
Aspect	South
Lat/Long	33.6676°/76.3654°

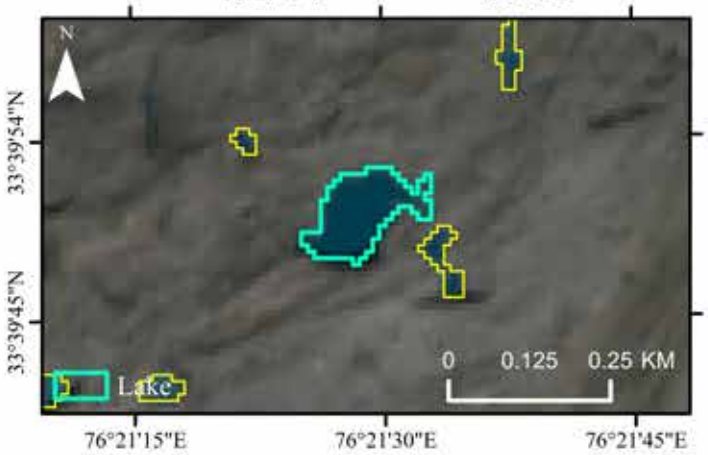


Lake ID	GL283640E33666N
Lake Type	SGL
Area (m^2)	2704
Perimeter (m)	321
Elevation(m asl)	4443
Slope (deg.)	7.23°
Aspect	North-East
Lat/Long	33.6661°/76.3604°

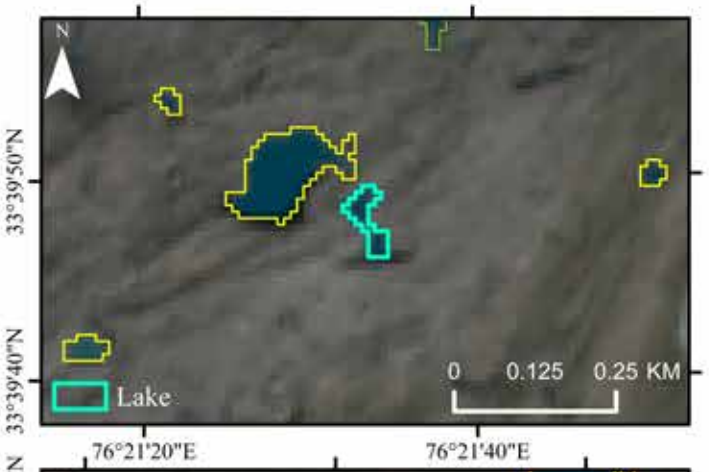


Lake ID	GL283644E33665N
Lake Type	SGL
Area (m2)	1107
Perimeter (m)	160
Elevation(m asl)	4459
Slope (deg.)	4.45°
Aspect	North
Lat/Long	33.665°/76.356°

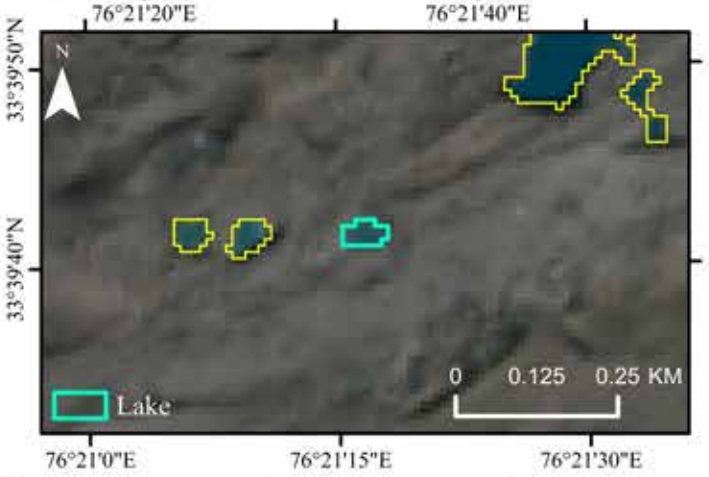
Lake ID	GL283636E33664N
Lake Type	SGL
Area (m2)	1310
Perimeter (m)	162
Elevation(m asl)	4450
Slope (deg.)	2.91°
Aspect	South
Lat/Long	33.6639°/76.364°



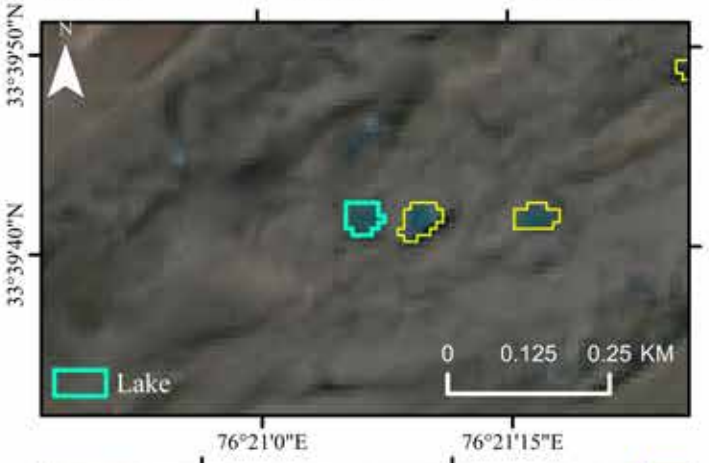
Lake ID	GL283642E33664N
Lake Type	SGL
Area (m2)	16311
Perimeter (m)	821
Elevation(m asl)	4457
Slope (deg.)	4.98°
Aspect	East
Lat/Long	33.664°/76.3579°



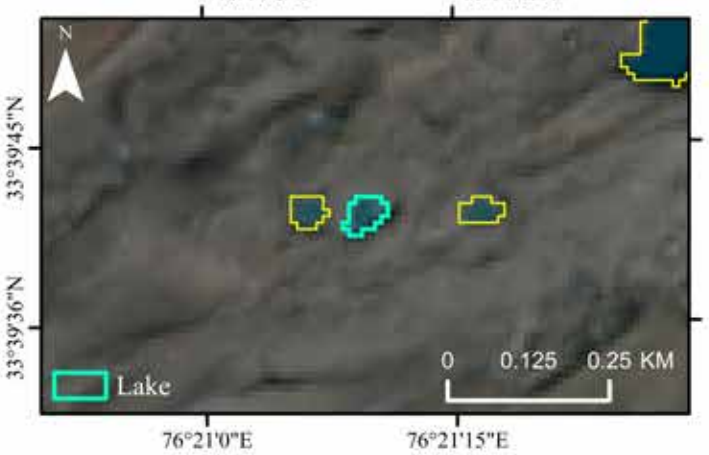
Lake ID	GL283641E33663N
Lake Type	SGL
Area (m^2)	3307
Perimeter (m)	401
Elevation(m asl)	4446
Slope (deg.)	7.81°
Aspect	North-East
Lat/Long	33.6633°/76.3593°



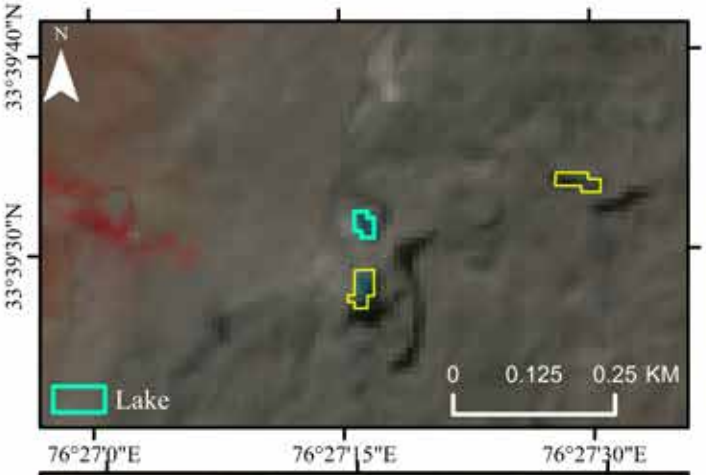
Lake ID	GL283645E33662N
Lake Type	SGL
Area (m2)	2303
Perimeter (m)	221
Elevation(m asl)	4473
Slope (deg.)	15.38°
Aspect	South-East
Lat/Long	33.6615°/76.3546°



Lake ID	GL283648E33662N
Lake Type	SGL
Area (m2)	2407
Perimeter (m)	221
Elevation(m asl)	4484
Slope (deg.)	9°
Aspect	North-East
Lat/Long	33.6616°/76.3517°

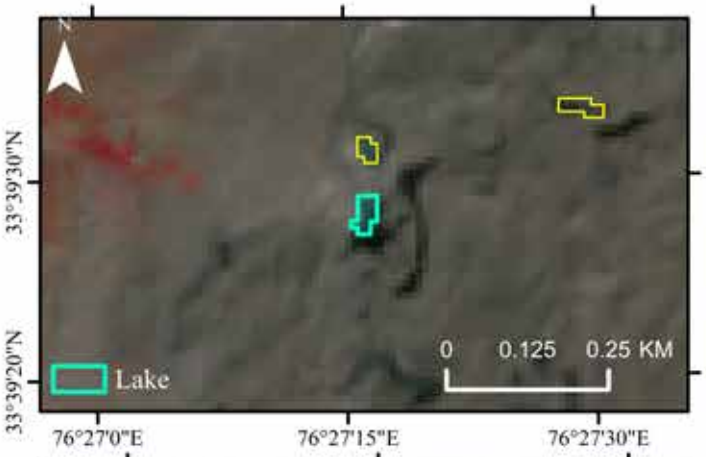


Lake ID	GL283647E33662N
Lake Type	SGL
Area (m2)	2800
Perimeter (m)	260
Elevation(m asl)	4478
Slope (deg.)	14.52°
Aspect	North
Lat/Long	33.6615°/76.3526°

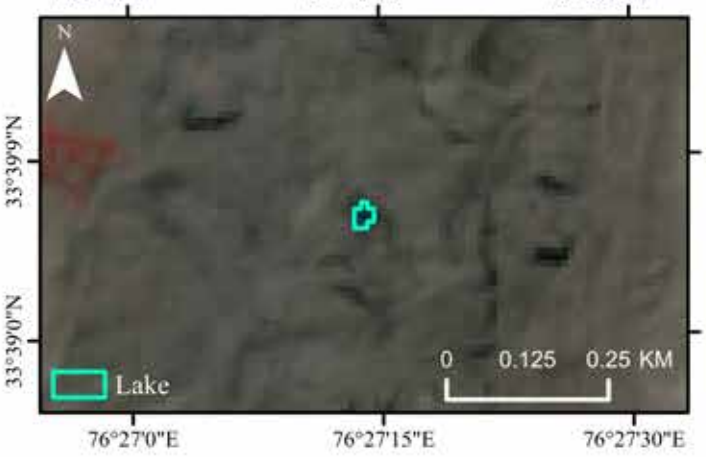


Lake ID	GL283546E33659N
Lake Type	SGL
Area (m^2)	1013
Perimeter (m)	141
Elevation(m asl)	3982
Slope (deg.)	11.21°
Aspect	North-West
Lat/Long	33.6587°/76.4545°

Lake ID	GL283446E33657N
Lake Type	PGLA
Area (m2)	5227
Perimeter (m)	462
Elevation(m asl)	4905
Slope (deg.)	13.51°
Aspect	North-West
Lat/Long	33.6574°/76.5542°

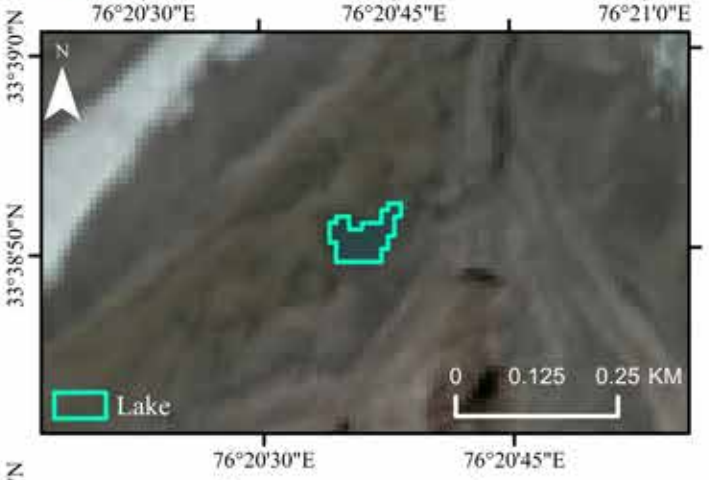


Lake ID	GL283546E33658N
Lake Type	SGL
Area (m2)	1675
Perimeter (m)	199
Elevation(m asl)	3994
Slope (deg.)	6.05°
Aspect	East
Lat/Long	33.6578°/76.4545°

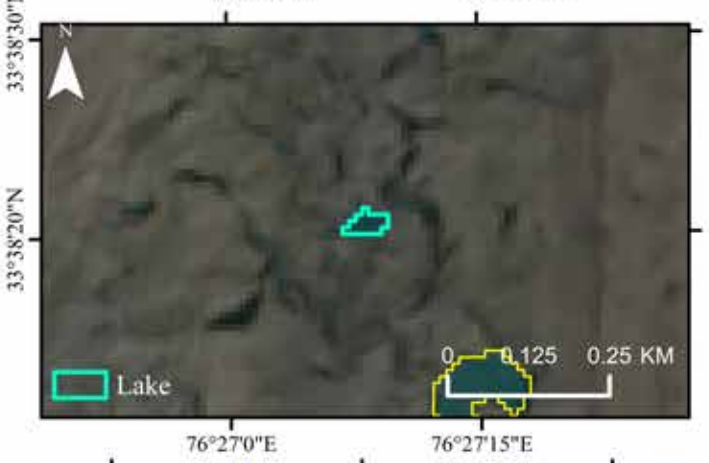


Lake ID	GL283546E33652N
Lake Type	SGL
Area (m2)	906
Perimeter (m)	140
Elevation(m asl)	4074
Slope (deg.)	3.09°
Aspect	East
Lat/Long	33.6517°/76.4538°

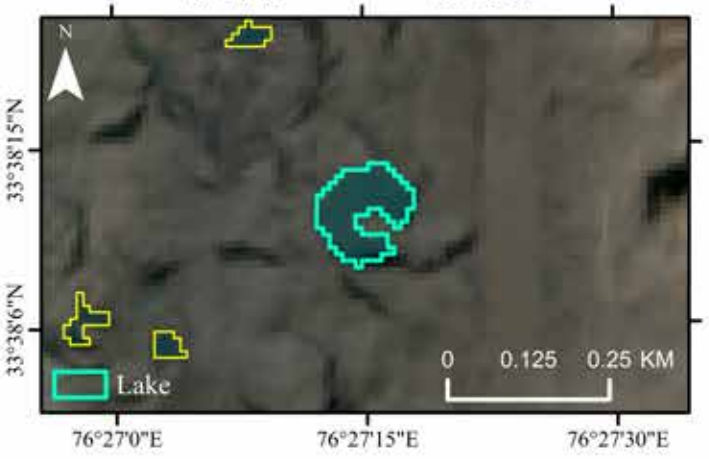
Lake ID	GL283655E33652N
Lake Type	SGL
Area (m²)	1613
Perimeter (m)	201
Elevation(m asl)	4533
Slope (deg.)	2.2°
Aspect	South-East
Lat/Long	33.6515°/76.3454°



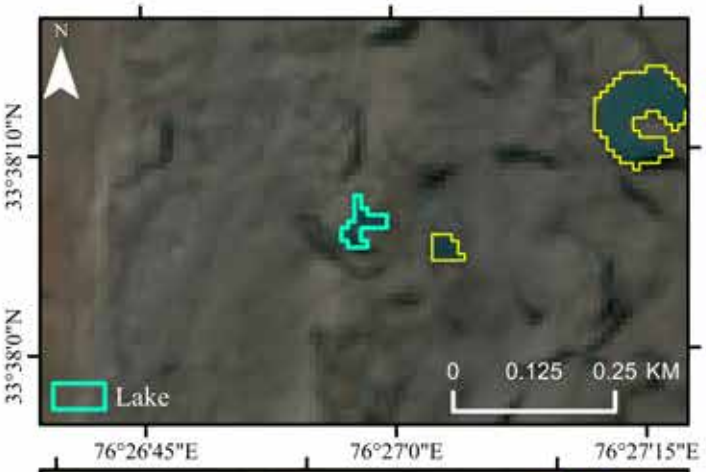
Lake ID	GL283657E33647N
Lake Type	SGL
Area (m2)	5824
Perimeter (m)	442
Elevation(m asl)	4556
Slope (deg.)	6.47°
Aspect	East
Lat/Long	33.6474°/76.3433°



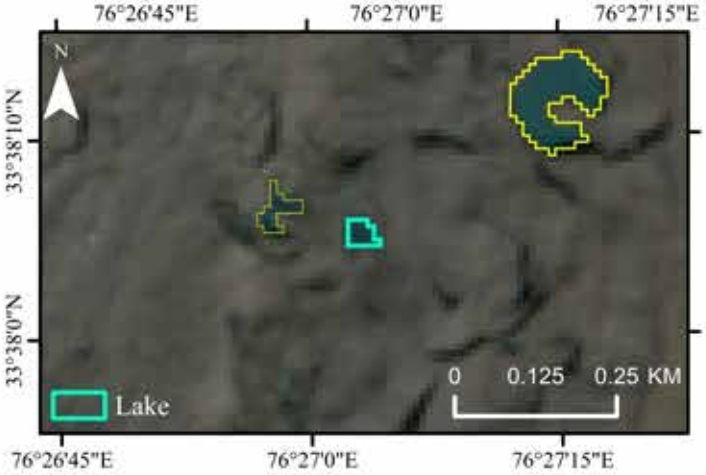
Lake ID	GL283548E33639N
Lake Type	SGL
Area (m2)	1811
Perimeter (m)	221
Elevation(m asl)	4197
Slope (deg.)	3.23°
Aspect	South
Lat/Long	33.639°/76.4523°



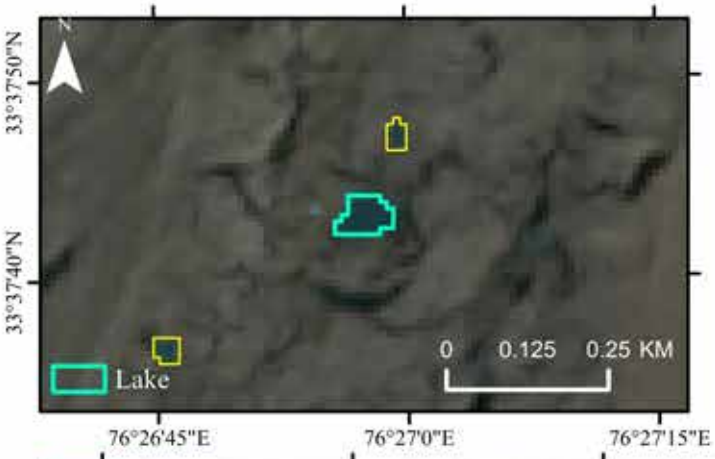
Lake ID	GL283546E33637N
Lake Type	SGL
Area (m2)	14489
Perimeter (m)	801
Elevation(m asl)	4195
Slope (deg.)	7.13°
Aspect	South
Lat/Long	33.6366°/76.4541°



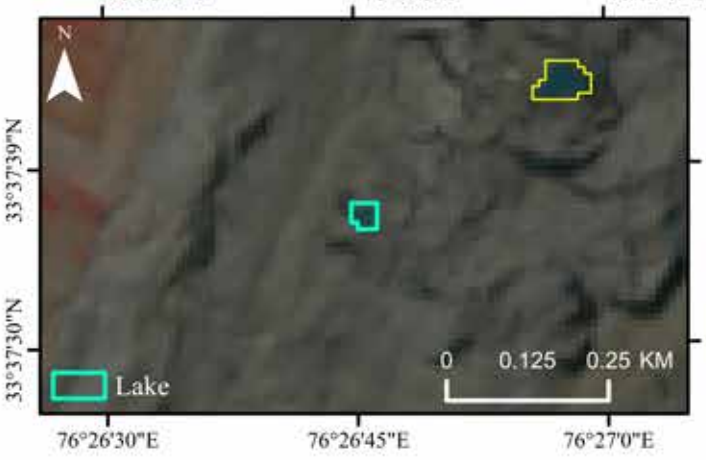
Lake ID	GL283551E33635N
Lake Type	SGL
Area (m^2)	2411
Perimeter (m)	321
Elevation(m asl)	4220
Slope (deg.)	7.58°
Aspect	North-East
Lat/Long	33.6351°/76.4494°



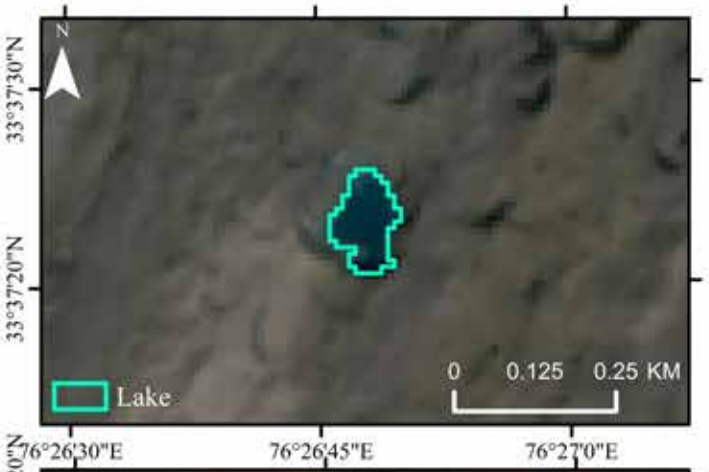
Lake ID	GL283549E33635N
Lake Type	SGL
Area (m2)	1602
Perimeter (m)	182
Elevation(m asl)	4230
Slope (deg.)	8.75°
Aspect	South-West
Lat/Long	33.6348°/76.4508°



Lake ID	GL283551E33629N
Lake Type	SGL
Area (m2)	4202
Perimeter (m)	300
Elevation(m asl)	4271
Slope (deg.)	8.11°
Aspect	South-East
Lat/Long	33.6286°/76.4493°

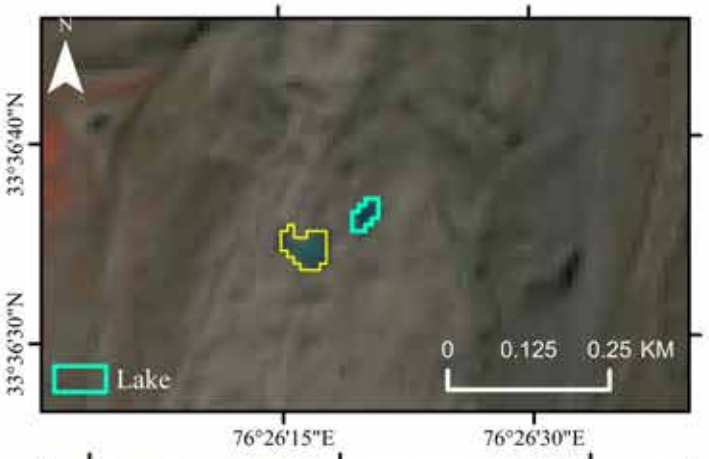


Lake ID	GL283554E33627N
Lake Type	SGL
Area (m2)	1500
Perimeter (m)	161
Elevation(m asl)	4274
Slope (deg.)	6.86°
Aspect	North-East
Lat/Long	33.6268°/76.4459°

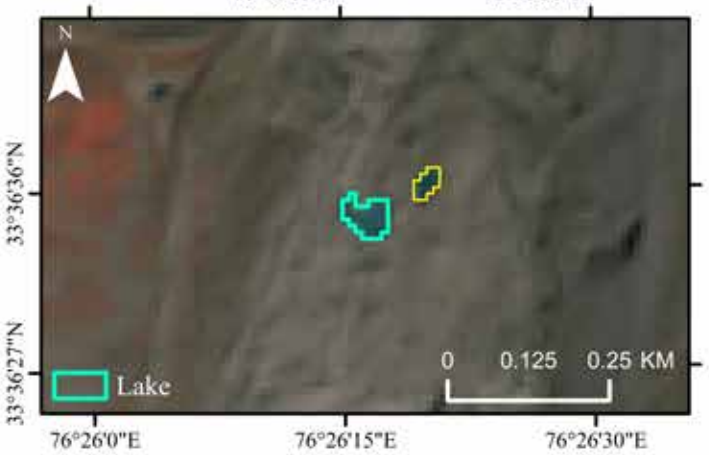


Lake ID	GL283553E33623N
Lake Type	SGL
Area (m²)	11504
Perimeter (m)	580
Elevation(m asl)	4297
Slope (deg.)	8.49°
Aspect	West
Lat/Long	33.6231°/76.4466°

Lake ID	GL283554E33620N
Lake Type	SGL
Area (m2)	2497
Perimeter (m)	222
Elevation(m asl)	4320
Slope (deg.)	8.03°
Aspect	West
Lat/Long	33.6196°/76.4464°



Lake ID	GL283561E33610N
Lake Type	SGL
Area (m2)	1405
Perimeter (m)	181
Elevation(m asl)	4379
Slope (deg.)	4.4°
Aspect	East
Lat/Long	33.6101°/76.4389°

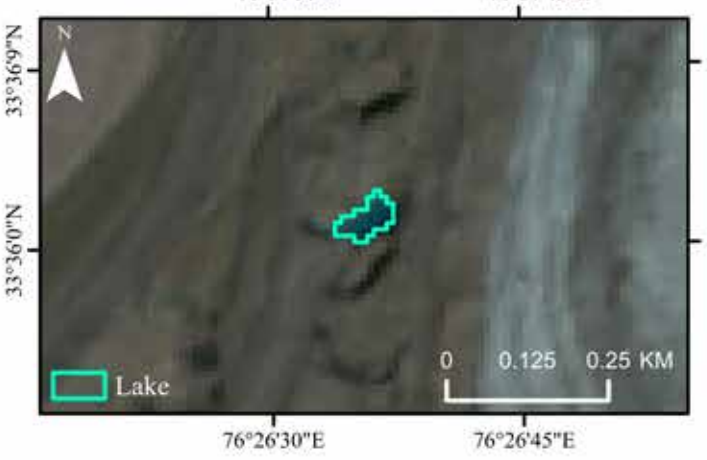


Lake ID	GL283562E33610N
Lake Type	SGL
Area (m2)	3398
Perimeter (m)	301
Elevation(m asl)	4381
Slope (deg.)	2.99°
Aspect	South
Lat/Long	33.6096°/76.4379°

Lake ID	GL283717E33609N
Lake Type	SGL
Area (m²)	3214
Perimeter (m)	381
Elevation(m asl)	4559
Slope (deg.)	16.33°
Aspect	South-East
Lat/Long	33.6094°/76.2827°

Lake ID	GL283415E33604N
Lake Type	SGL
Area (m2)	1207
Perimeter (m)	180
Elevation(m asl)	4756
Slope (deg.)	4.07°
Aspect	East
Lat/Long	33.6038°/76.5854°

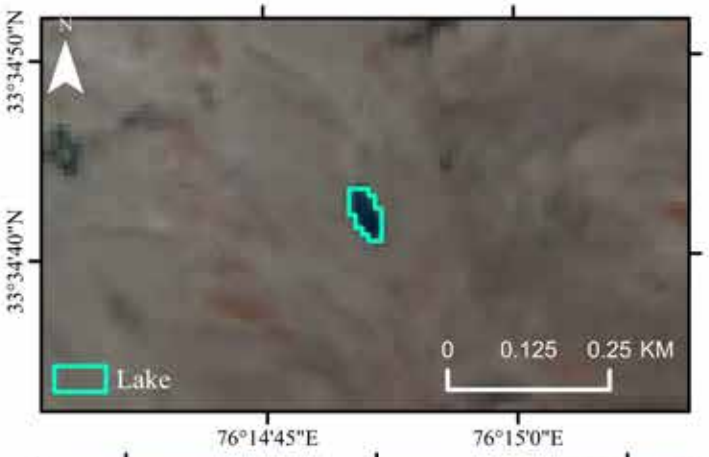
Lake ID	GL283374E33600N
Lake Type	SGL
Area (m2)	2417
Perimeter (m)	239
Elevation(m asl)	5006
Slope (deg.)	9.08°
Aspect	South-West
Lat/Long	33.5999°/76.6263°



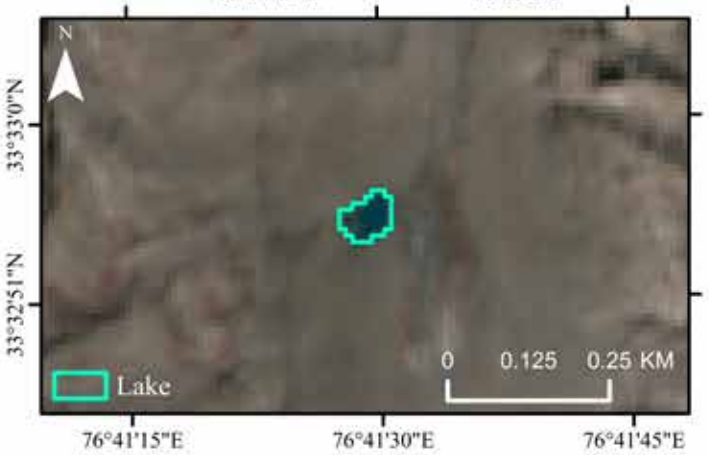
Lake ID	GL283557E33600N
Lake Type	SGL
Area (m2)	3819
Perimeter (m)	341
Elevation(m asl)	4419
Slope (deg.)	7.58°
Aspect	West
Lat/Long	33.6004°/76.4432°

Lake ID	GL283572E33599N
Lake Type	SGL
Area (m²)	3633
Perimeter (m)	326
Elevation(m asl)	4472
Slope (deg.)	2.22°
Aspect	North
Lat/Long	33.5993°/76.428°

Lake ID	GL283577E33585N
Lake Type	PGLC
Area (m2)	3631
Perimeter (m)	281
Elevation(m asl)	4516
Slope (deg.)	2.27°
Aspect	East
Lat/Long	33.5848°/76.423°

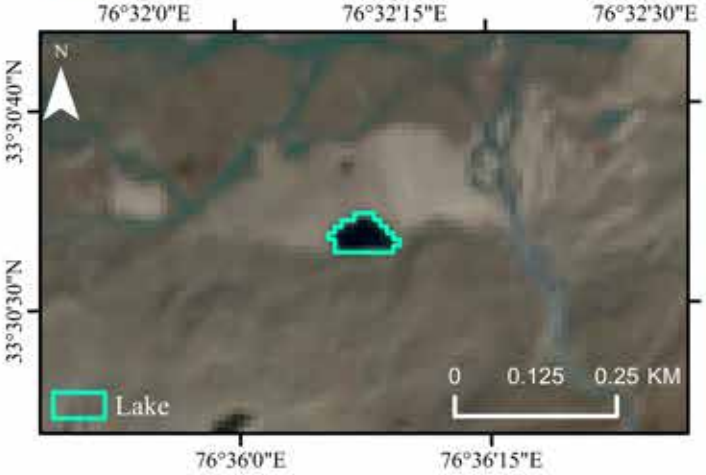


Lake ID	GL283752E33578N
Lake Type	PGLA
Area (m2)	2911
Perimeter (m)	261
Elevation(m asl)	4547
Slope (deg.)	9.01°
Aspect	South
Lat/Long	33.5784°/76.2475°

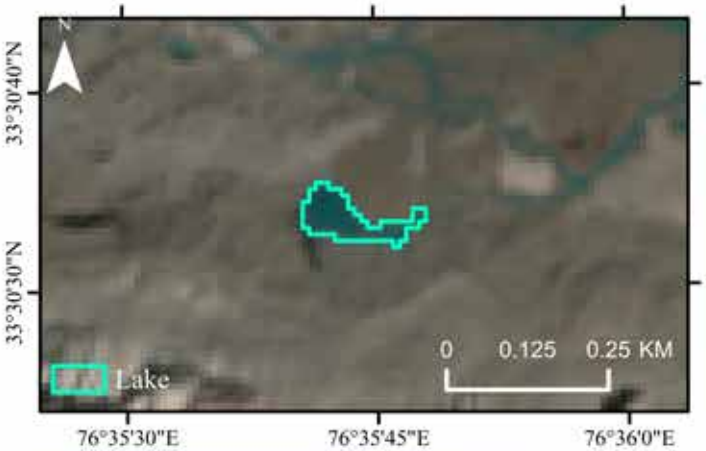


Lake ID	GL283309E33549N
Lake Type	PGLA
Area (m2)	4504
Perimeter (m)	320
Elevation(m asl)	4779
Slope (deg.)	6.95°
Aspect	South-West
Lat/Long	33.5486°/76.6914°

Lake ID	GL283463E33523N
Lake Type	SGL
Area (m²)	1606
Perimeter (m)	200
Elevation(m asl)	5037
Slope (deg.)	8.01°
Aspect	South-West
Lat/Long	33.5226°/76.537°

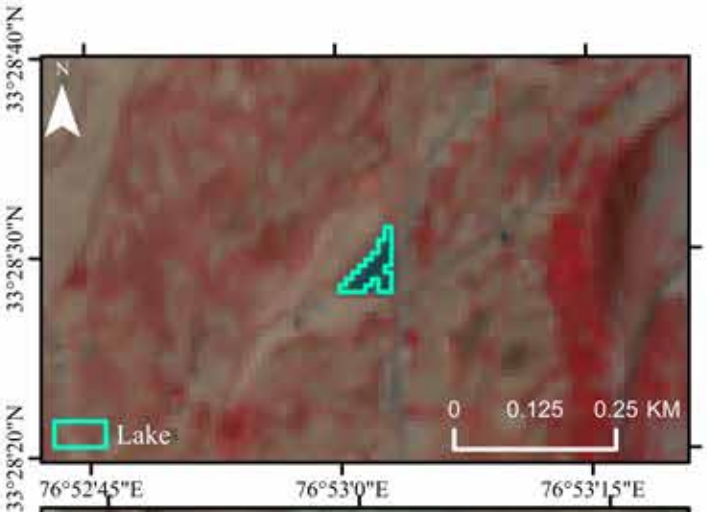


Lake ID	GL283398E33509N
Lake Type	PGLA
Area (m2)	4602
Perimeter (m)	341
Elevation(m asl)	4148
Slope (deg.)	6.7°
Aspect	South-West
Lat/Long	33.5093°/76.6021°

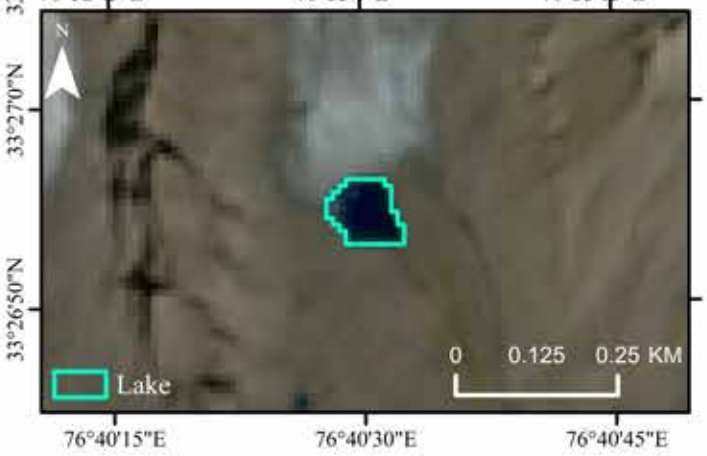


Lake ID	GL283405E33509N
Lake Type	PGLC
Area (m2)	8408
Perimeter (m)	639
Elevation(m asl)	4165
Slope (deg.)	17.99°
Aspect	North-East
Lat/Long	33.5093°/76.5954°

Lake ID	GL283355E33504N
Lake Type	PGLA
Area (m2)	1812
Perimeter (m)	239
Elevation(m asl)	4832
Slope (deg.)	12.6°
Aspect	North-East
Lat/Long	33.5044°/76.6448°

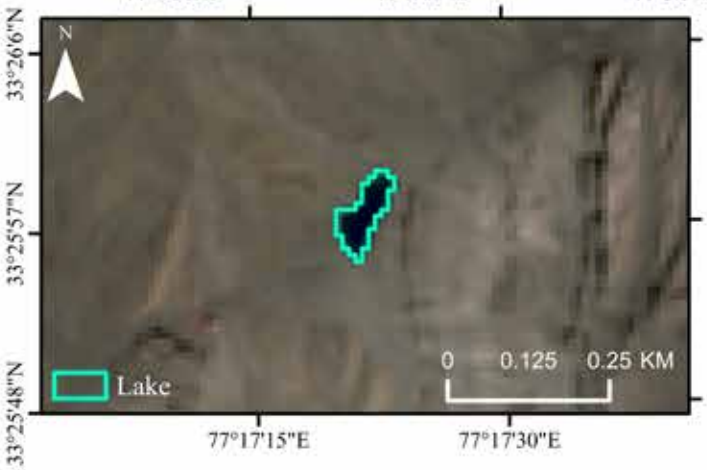


Lake ID	GL283116E33475N
Lake Type	OL
Area (m^2)	3513
Perimeter (m)	421
Elevation(m asl)	3531
Slope (deg.)	1.66°
Aspect	North-East
Lat/Long	33.4748°/76.8839°



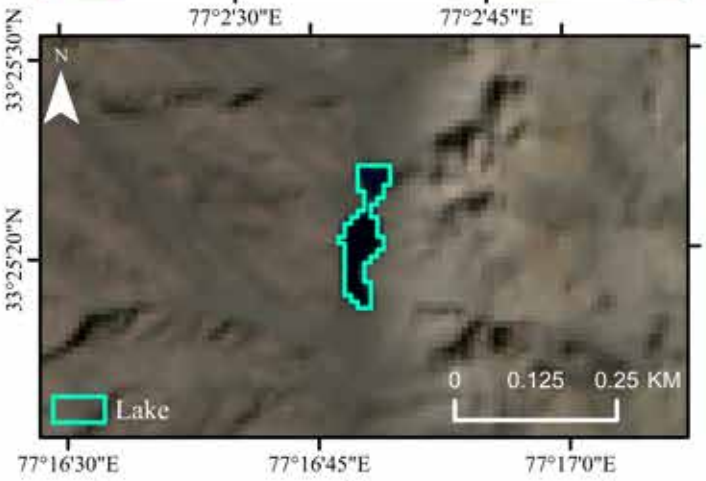
Lake ID	GL283325E33448N
Lake Type	PGLC
Area (m2)	9200
Perimeter (m)	440
Elevation(m asl)	5278
Slope (deg.)	22.37°
Aspect	South-East
Lat/Long	33.4485°/76.675°

Lake ID	GL282955E33438N
Lake Type	PGLA
Area (m2)	2501
Perimeter (m)	241
Elevation(m asl)	5220
Slope (deg.)	6.76°
Aspect	East
Lat/Long	33.4379°/77.0449°

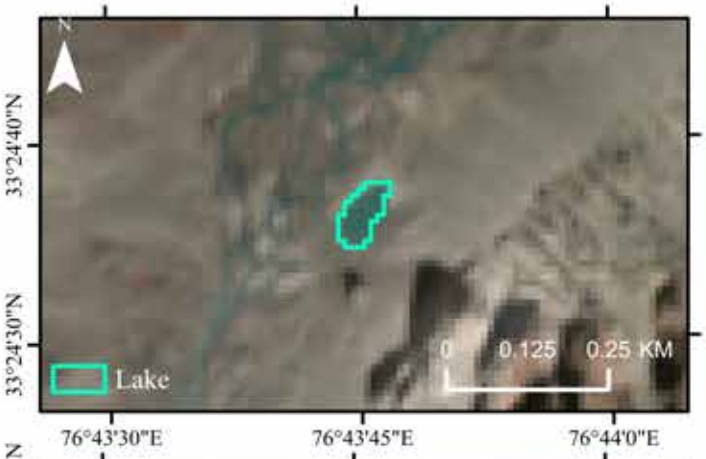


Lake ID	GL282711E33433N
Lake Type	PGLA
Area (m2)	5900
Perimeter (m)	460
Elevation(m asl)	4770
Slope (deg.)	14.76°
Aspect	South-West
Lat/Long	33.4327°/77.2893°

Lake ID	GL282956E33435N
Lake Type	PGLA
Area (m²)	801
Perimeter (m)	121
Elevation(m asl)	5250
Slope (deg.)	5.46°
Aspect	North-East
Lat/Long	33.4353°/77.0438°

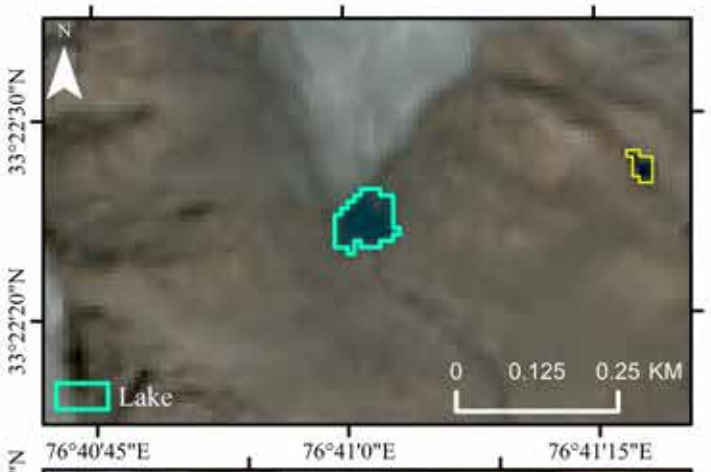


Lake ID	GL282720E33422N
Lake Type	PGLA
Area (m2)	8558
Perimeter (m)	680
Elevation(m asl)	4690
Slope (deg.)	16.58°
Aspect	South
Lat/Long	33.4225°/77.2799°



Lake ID	GL283271E33410N
Lake Type	PGLC
Area (m2)	5008
Perimeter (m)	360
Elevation(m asl)	4099
Slope (deg.)	11.45°
Aspect	North-West
Lat/Long	33.4101°/76.7292°

Lake ID	GL283237E33378N
Lake Type	PGLC
Area (m2)	1389
Perimeter (m)	181
Elevation(m asl)	4603
Slope (deg.)	16.6°
Aspect	East
Lat/Long	33.3776°/76.7626°

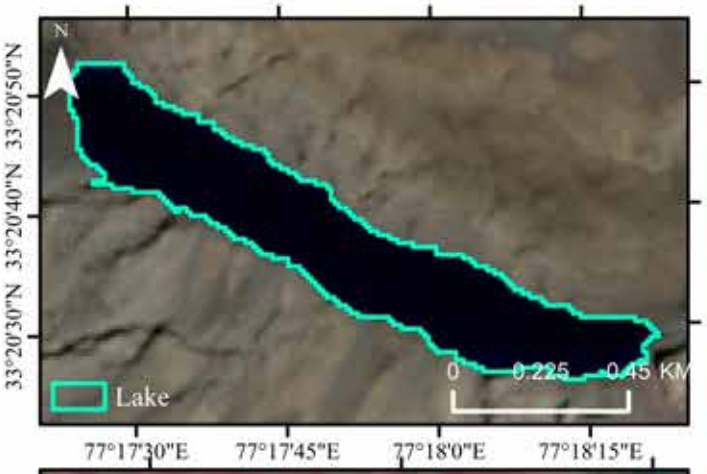


Lake ID	GL283316E33374N
Lake Type	PGLC
Area (m²)	6815
Perimeter (m)	420
Elevation(m asl)	5061
Slope (deg.)	20.8°
Aspect	South-East
Lat/Long	33.3735°/76.6837°

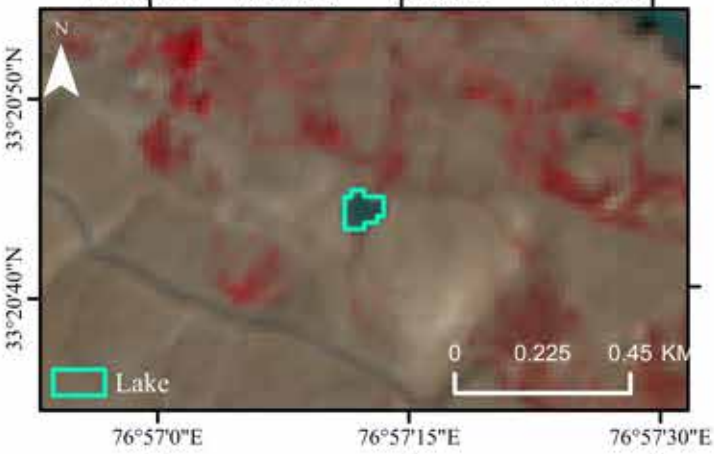
Lake ID	GL283261E33370N
Lake Type	SGL
Area (m2)	1200
Perimeter (m)	160
Elevation(m asl)	5458
Slope (deg.)	19.57°
Aspect	South-West
Lat/Long	33.3698°/76.7394°

Lake ID	GL283168E33366N
Lake Type	PGLA
Area (m2)	2614
Perimeter (m)	242
Elevation(m asl)	5332
Slope (deg.)	9.19°
Aspect	East
Lat/Long	33.3657°/76.8323°

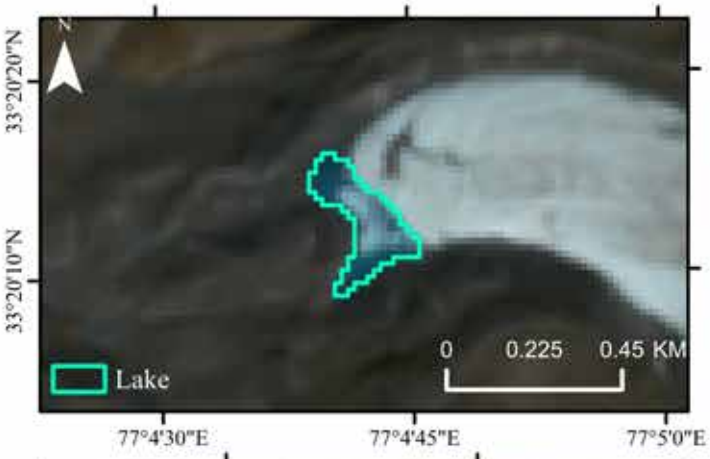
Lake ID	GL282914E33363N
Lake Type	PGLC
Area (m2)	11612
Perimeter (m)	880
Elevation(m asl)	5334
Slope (deg.)	20.79°
Aspect	West
Lat/Long	33.3629°/77.0861°



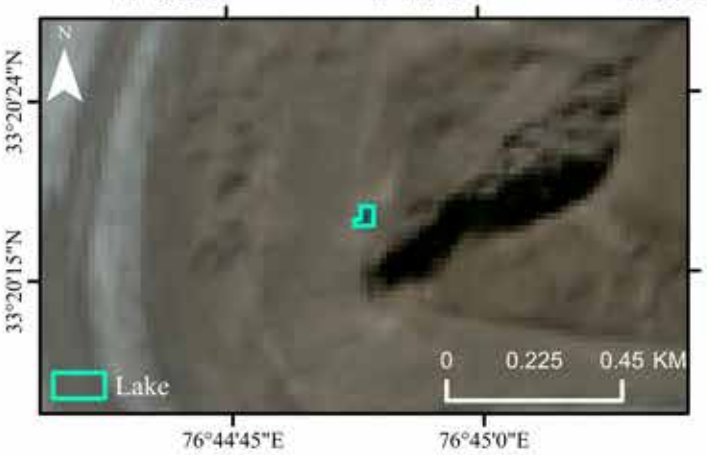
Lake ID	GL282703E33344N
Lake Type	OL
Area (m²)	337952
Perimeter (m)	4793
Elevation(m asl)	4078
Slope (deg.)	14.18°
Aspect	South
Lat/Long	33.3438°/77.2973°



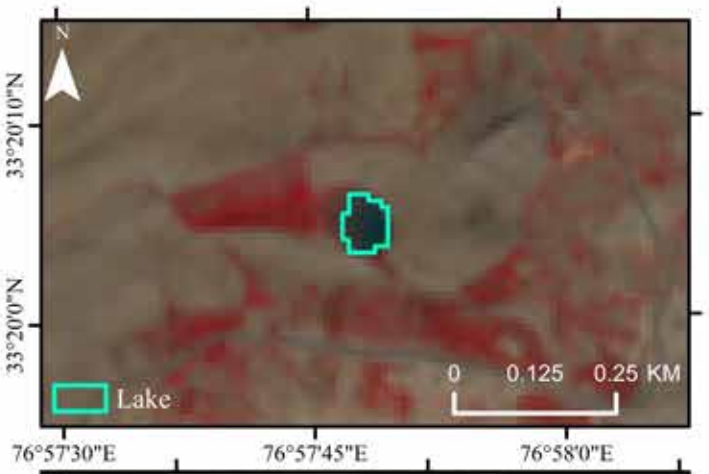
Lake ID	GL283047E33346N
Lake Type	OL
Area (m2)	2801
Perimeter (m)	240
Elevation(m asl)	3764
Slope (deg.)	5.74°
Aspect	North-East
Lat/Long	33.3456°/76.9534°



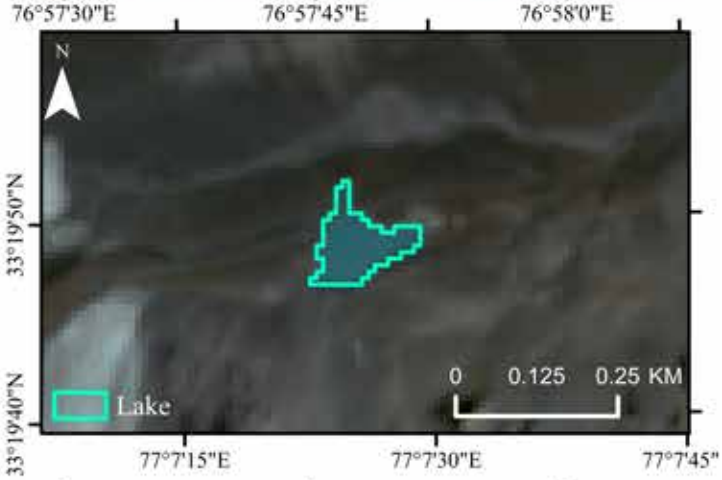
Lake ID	GL282922E33337N
Lake Type	PGLC
Area (m2)	15420
Perimeter (m)	893
Elevation(m asl)	5347
Slope (deg.)	14.77°
Aspect	South-West
Lat/Long	33.3369°/77.0784°



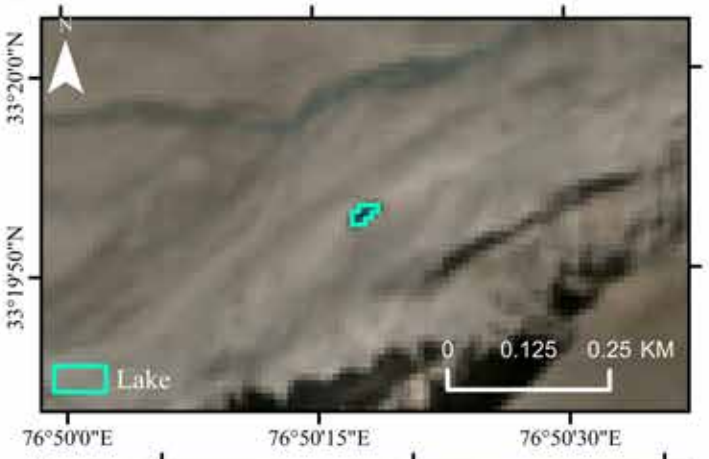
Lake ID	GL283252E33338N
Lake Type	PGLA
Area (m2)	696
Perimeter (m)	120
Elevation(m asl)	5068
Slope (deg.)	23.64°
Aspect	North-West
Lat/Long	33.3383°/76.7481°



Lake ID	GL283037E33335N
Lake Type	OL
Area (m^2)	5210
Perimeter (m)	319
Elevation(m asl)	3788
Slope (deg.)	6.85°
Aspect	South
Lat/Long	33.3347°/76.9634°

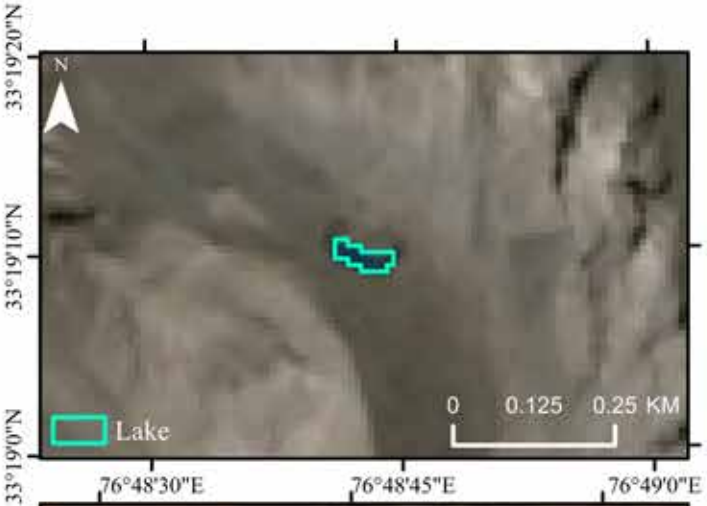


Lake ID	GL282876E33330N
Lake Type	PGLC
Area (m2)	12608
Perimeter (m)	700
Elevation(m asl)	5205
Slope (deg.)	5.09°
Aspect	East
Lat/Long	33.3302°/77.1238°

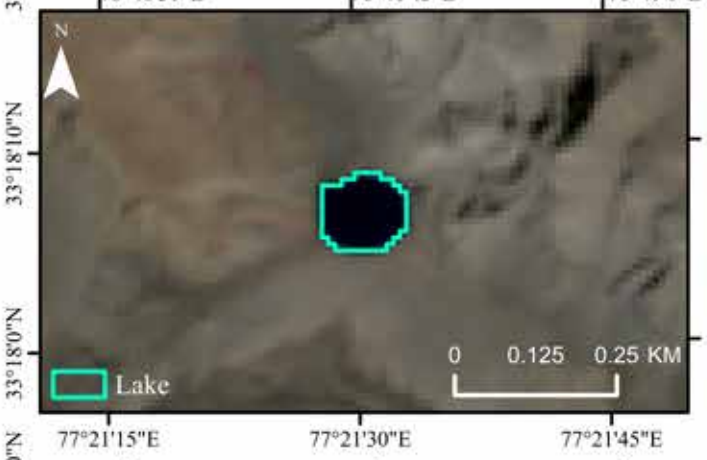


Lake ID	GL283162E33331N
Lake Type	PGLA
Area (m2)	800
Perimeter (m)	141
Elevation(m asl)	4940
Slope (deg.)	14.13°
Aspect	South
Lat/Long	33.3314°/76.8383°

Lake ID	GL283176E33331N
Lake Type	PGLC
Area (m2)	5310
Perimeter (m)	361
Elevation(m asl)	5106
Slope (deg.)	4.34°
Aspect	North-West
Lat/Long	33.3314°/76.8242°

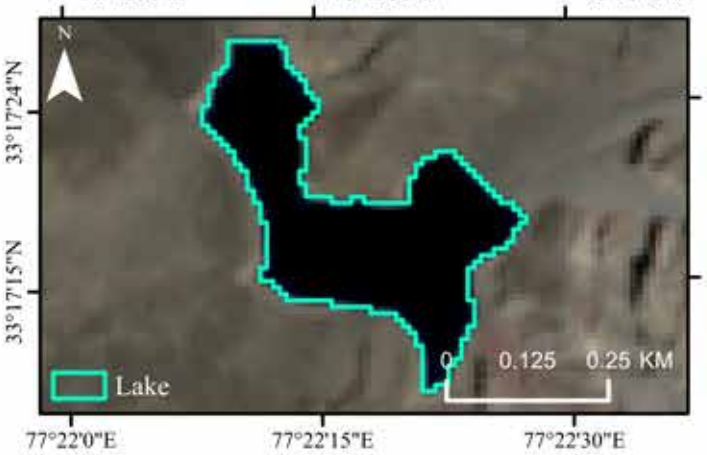


Lake ID	GL283188E33319N
Lake Type	PGLA
Area (m^2)	2595
Perimeter (m)	279
Elevation(m asl)	5282
Slope (deg.)	6.99°
Aspect	South-East
Lat/Long	33.3194°/76.8119°

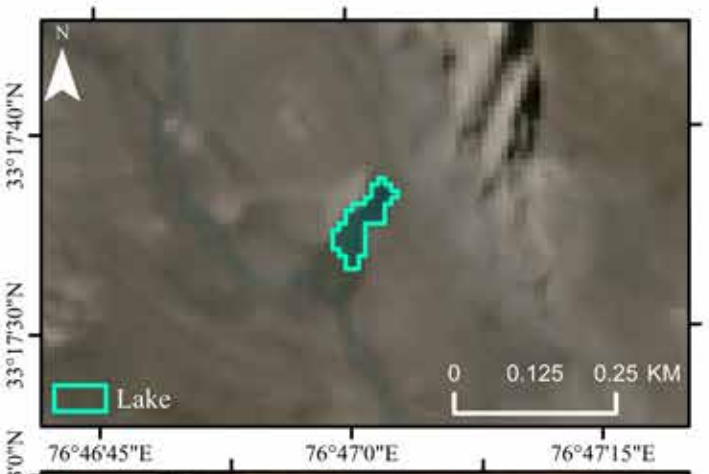


Lake ID	GL282642E33302N
Lake Type	OL
Area (m2)	13224
Perimeter (m)	502
Elevation(m asl)	4394
Slope (deg.)	10.83°
Aspect	South
Lat/Long	33.3018°/77.3585°

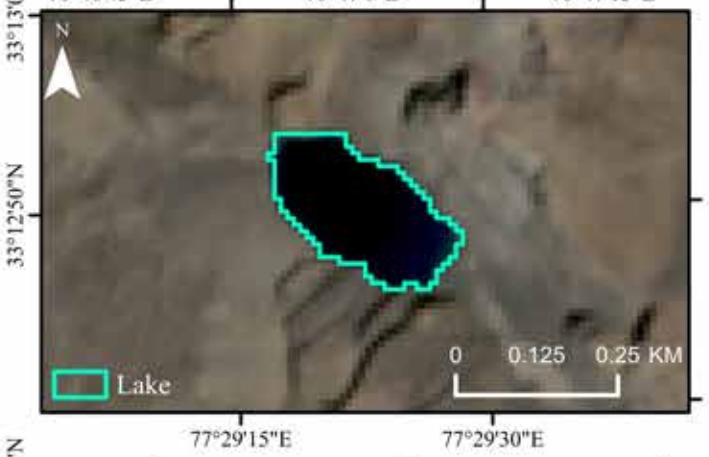
Lake ID	GL283225E33297N
Lake Type	PGLC
Area (m2)	3808
Perimeter (m)	322
Elevation(m asl)	5201
Slope (deg.)	25.32°
Aspect	East
Lat/Long	33.2972°/76.7747°



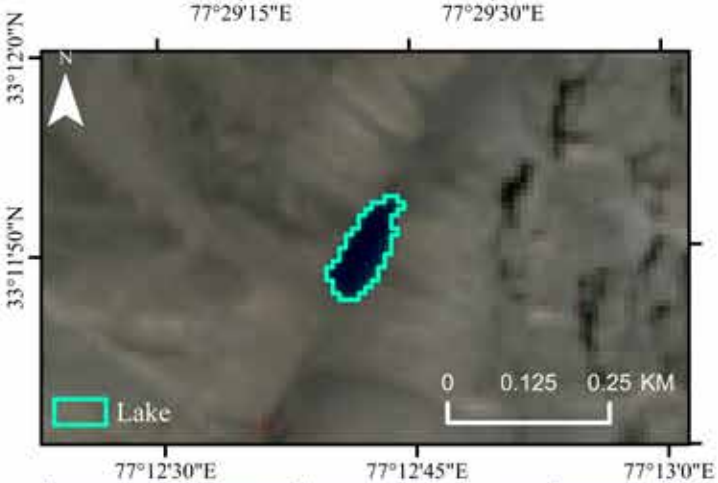
Lake ID	GL282628E33288N
Lake Type	OL
Area (m2)	101990
Perimeter (m)	2378
Elevation(m asl)	4241
Slope (deg.)	10.74°
Aspect	South
Lat/Long	33.2885°/77.3715°



Lake ID	GL283216E33293N
Lake Type	PGLA
Area (m²)	5640
Perimeter (m)	482
Elevation(m asl)	4990
Slope (deg.)	4.96°
Aspect	South-East
Lat/Long	33.2931°/76.7836°

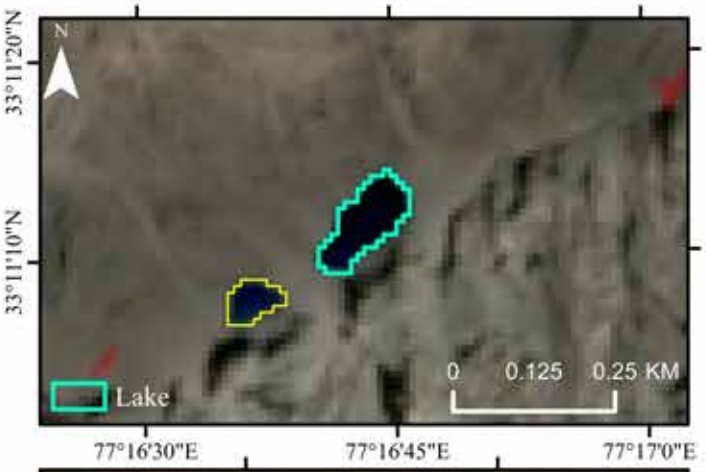


Lake ID	GL282510E33214N
Lake Type	OL
Area (m2)	43091
Perimeter (m)	1105
Elevation(m asl)	4419
Slope (deg.)	15.37°
Aspect	South
Lat/Long	33.2138°/77.4895°

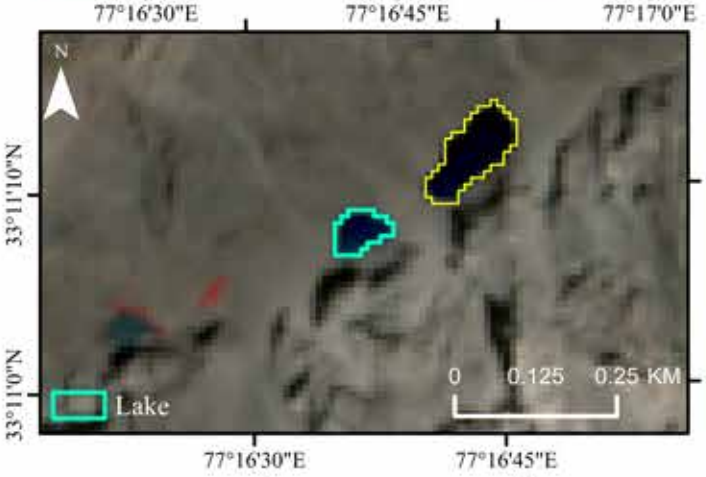


Lake ID	GL282788E33197N
Lake Type	PGLA
Area (m2)	9615
Perimeter (m)	580
Elevation(m asl)	4695
Slope (deg.)	10.35°
Aspect	West
Lat/Long	33.1972°/77.2117°

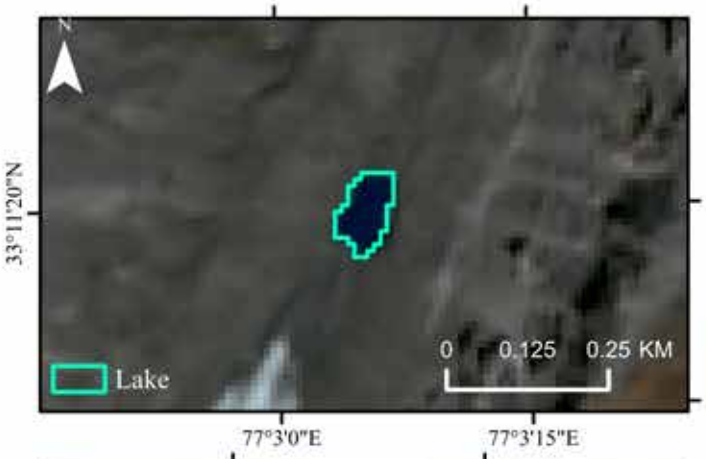
Lake ID	GL282982E33199N
Lake Type	PGLC
Area (m2)	3704
Perimeter (m)	281
Elevation(m asl)	5351
Slope (deg.)	24.82°
Aspect	North-East
Lat/Long	33.199°/77.0176°



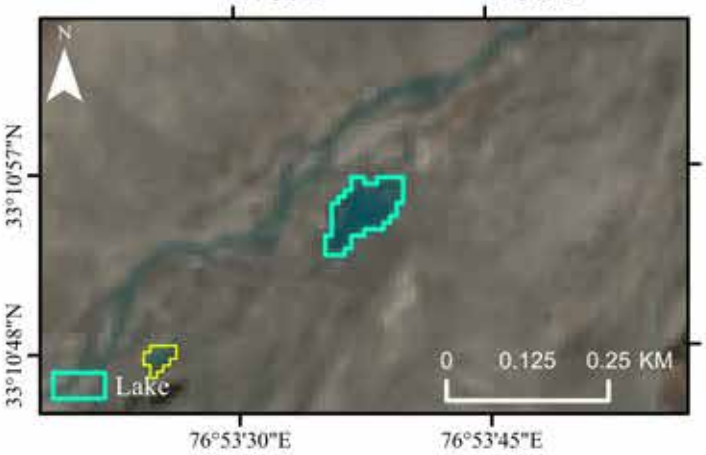
Lake ID	GL282721E33187N
Lake Type	PGLA
Area (m^2)	11457
Perimeter (m)	601
Elevation(m asl)	4313
Slope (deg.)	19.3°
Aspect	West
Lat/Long	33.1866°/77.2787°



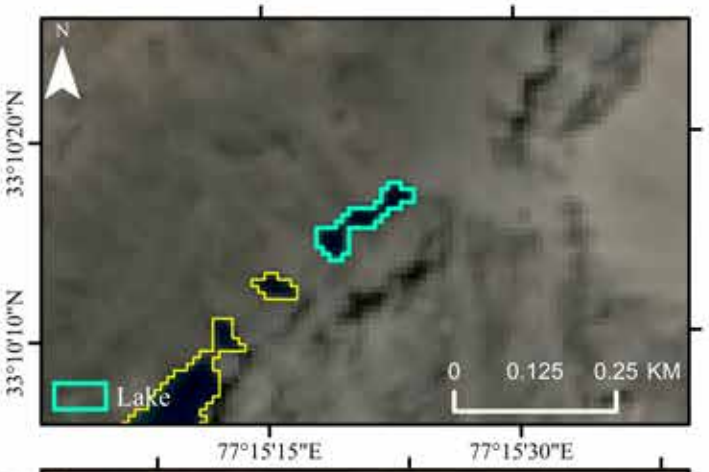
Lake ID	GL282723E33186N
Lake Type	PGLA
Area (m2)	4512
Perimeter (m)	320
Elevation(m asl)	4322
Slope (deg.)	16.46°
Aspect	South-West
Lat/Long	33.1855°/77.2768°



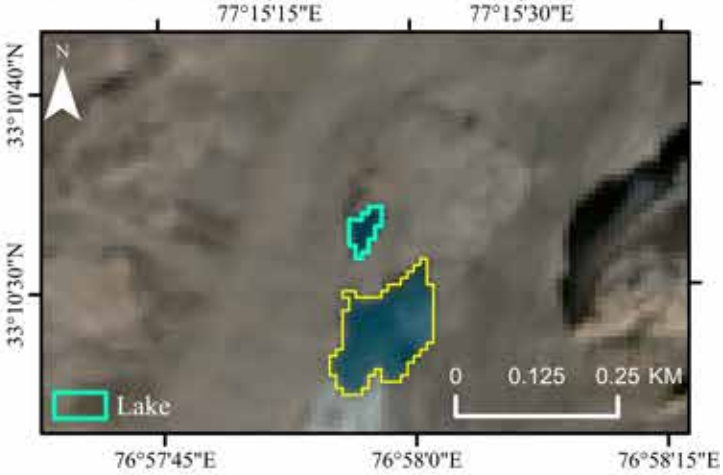
Lake ID	GL282949E33189N
Lake Type	PGLC
Area (m2)	8007
Perimeter (m)	441
Elevation(m asl)	5251
Slope (deg.)	12.54°
Aspect	South
Lat/Long	33.1888°/77.0514°



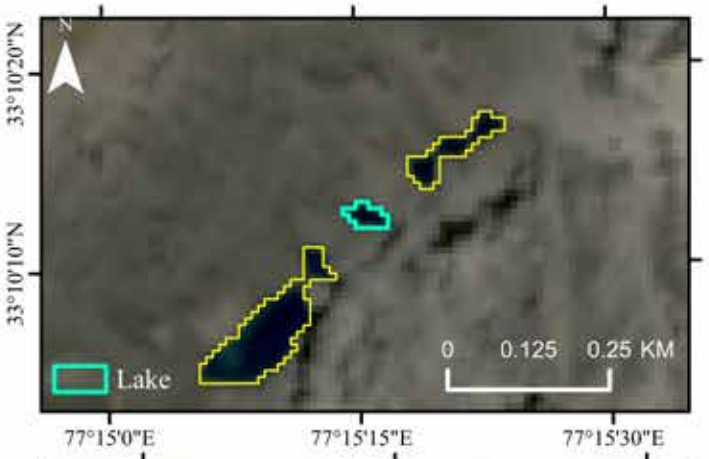
Lake ID	GL283106E33182N
Lake Type	PGLC
Area (m2)	8608
Perimeter (m)	501
Elevation(m asl)	4433
Slope (deg.)	14.41°
Aspect	South-West
Lat/Long	33.1819°/76.8937°



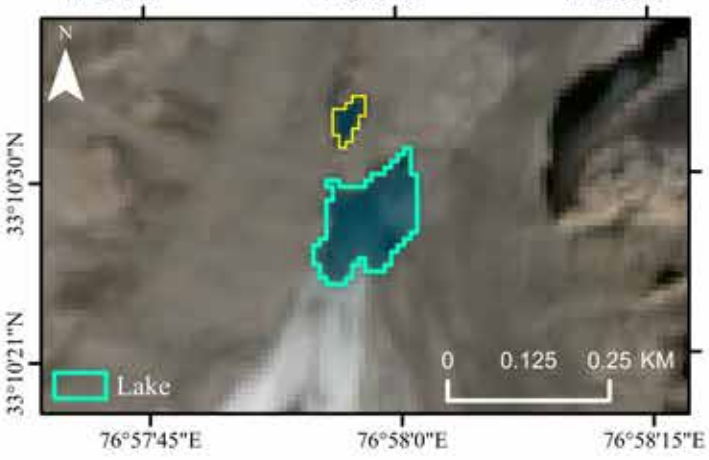
Lake ID	GL282744E33171N
Lake Type	PGLA
Area (m^2)	5533
Perimeter (m)	539
Elevation(m asl)	4648
Slope (deg.)	14.53°
Aspect	West
Lat/Long	33.171°/77.2557°



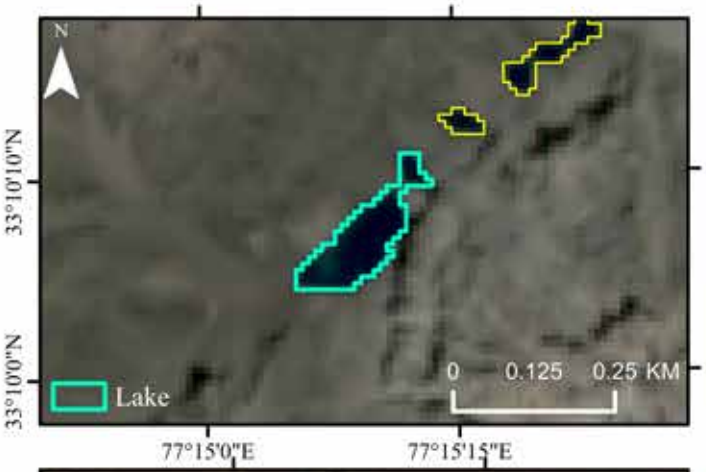
Lake ID	GL283034E33176N
Lake Type	PGLC
Area (m2)	2408
Perimeter (m)	261
Elevation(m asl)	5179
Slope (deg.)	6.36°
Aspect	East
Lat/Long	33.1758°/76.9658°



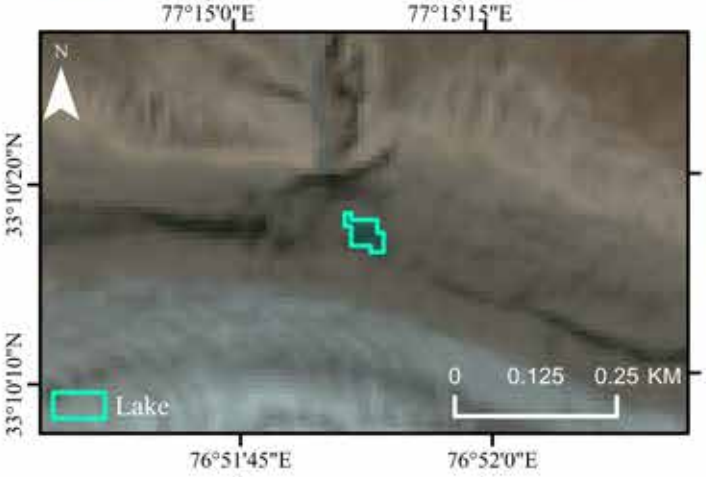
Lake ID	GL282746E33170N
Lake Type	PGLA
Area (m2)	1907
Perimeter (m)	220
Elevation(m asl)	4646
Slope (deg.)	13.92°
Aspect	South
Lat/Long	33.1701°/77.2543°



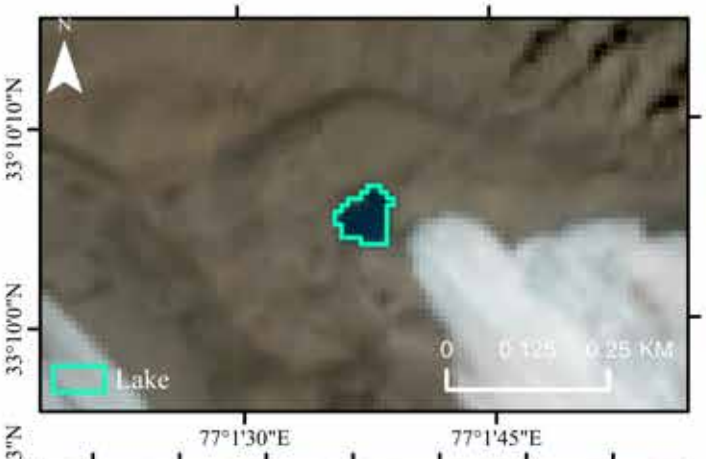
Lake ID	GL283034E33174N
Lake Type	PGLC
Area (m2)	20107
Perimeter (m)	820
Elevation(m asl)	5205
Slope (deg.)	10.41°
Aspect	South
Lat/Long	33.1744°/76.9661°



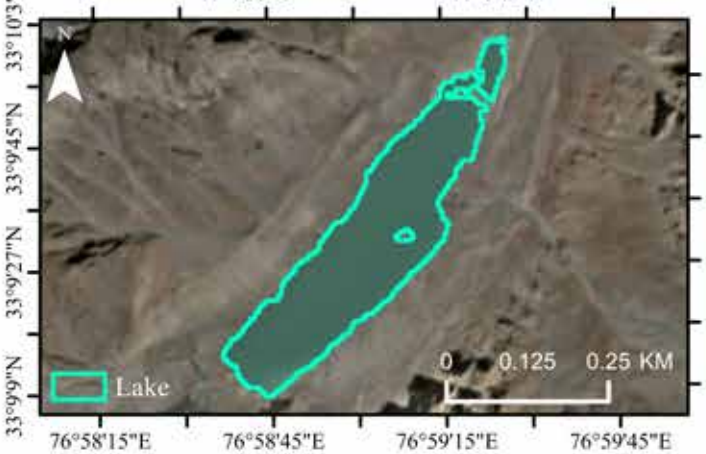
Lake ID	GL282747E33169N
Lake Type	PGLA
Area (m²)	15835
Perimeter (m)	882
Elevation(m asl)	4661
Slope (deg.)	11.07°
Aspect	South-West
Lat/Long	33.1686°/77.2526°



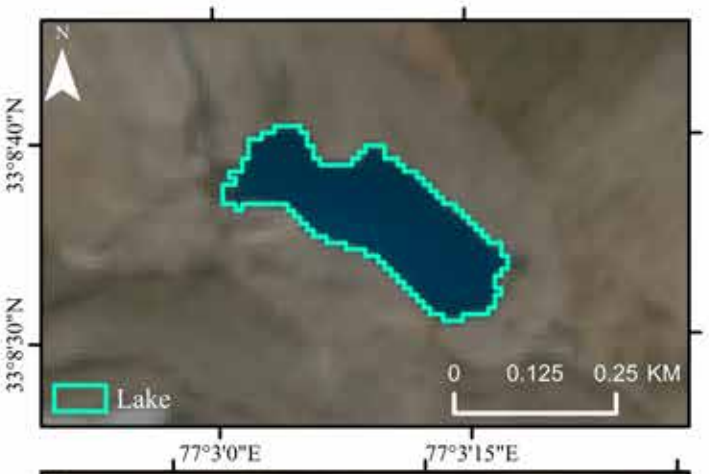
Lake ID	GL283135E33172N
Lake Type	SGL
Area (m2)	2208
Perimeter (m)	241
Elevation(m asl)	4761
Slope (deg.)	8.12°
Aspect	East
Lat/Long	33.1715°/76.8646°



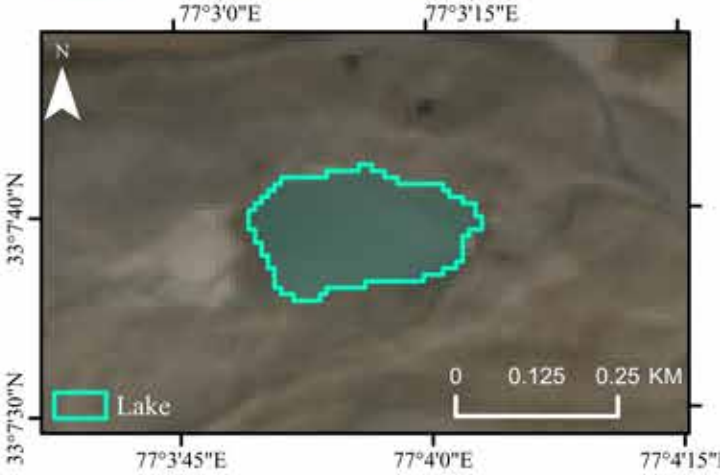
Lake ID	GL282973E33168N
Lake Type	PGLC
Area (m2)	5413
Perimeter (m)	361
Elevation(m asl)	5333
Slope (deg.)	7.69°
Aspect	South-West
Lat/Long	33.1681°/77.027°



Lake ID	GL283016E33159N
Lake Type	PGLC
Area (m2)	579237
Perimeter (m)	6833
Elevation(m asl)	4466
Slope (deg.)	4.6°
Aspect	East
Lat/Long	33.1586°/76.9839°

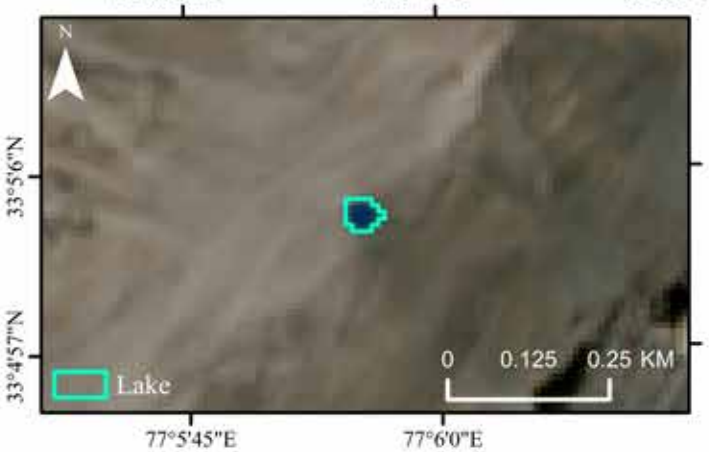


Lake ID	GL282947E33143N
Lake Type	PGLA
Area (m^2)	58313
Perimeter (m)	1602
Elevation(m asl)	5304
Slope (deg.)	9.71°
Aspect	South-East
Lat/Long	33.1433°/77.0526°



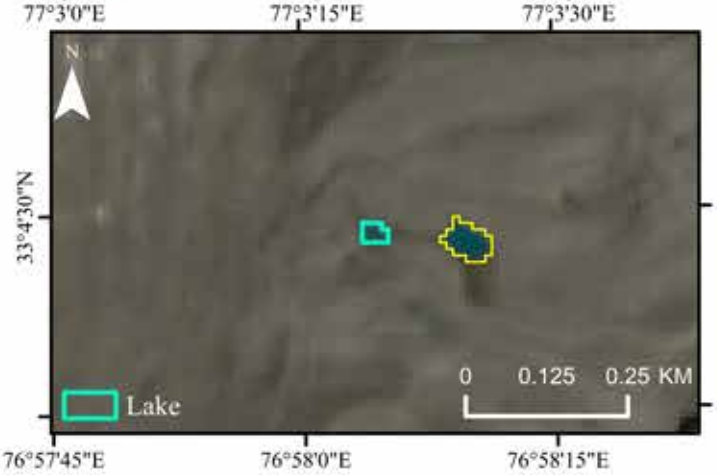
Lake ID	GL282935E33128N
Lake Type	PGLC
Area (m2)	51593
Perimeter (m)	1141
Elevation(m asl)	5019
Slope (deg.)	6.25°
Aspect	South-East
Lat/Long	33.1275°/77.0654°

Lake ID	GL283038E33117N
Lake Type	SGL
Area (m2)	3311
Perimeter (m)	420
Elevation(m asl)	5289
Slope (deg.)	5.81°
Aspect	South-East
Lat/Long	33.1174°/76.9617°

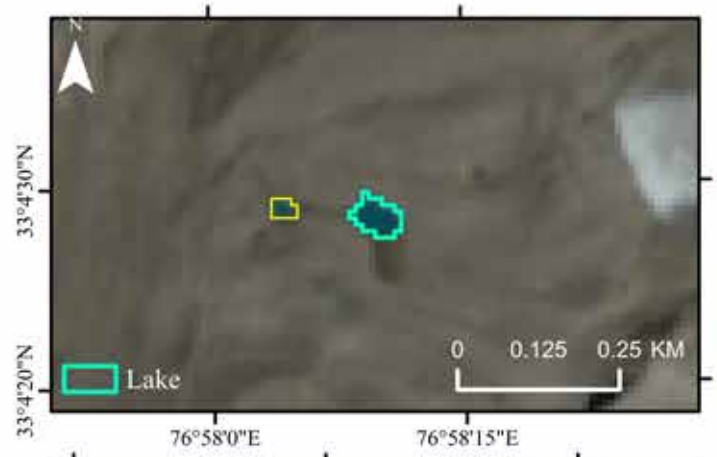


Lake ID	GL282901E33084N
Lake Type	PGLA
Area (m2)	2317
Perimeter (m)	221
Elevation(m asl)	5118
Slope (deg.)	6.65°
Aspect	East
Lat/Long	33.0844°/77.0987°

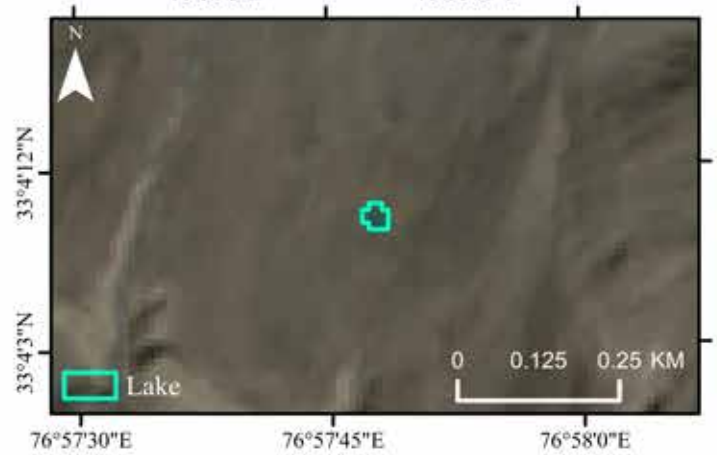
Lake ID	GL282945E33076N
Lake Type	SGL
Area (m²)	1705
Perimeter (m)	200
Elevation(m asl)	5231
Slope (deg.)	18.72°
Aspect	North-West
Lat/Long	33.0761°/77.0551°



Lake ID	GL283032E33075N
Lake Type	PGLA
Area (m2)	1101
Perimeter (m)	140
Elevation(m asl)	5147
Slope (deg.)	3.52°
Aspect	North-West
Lat/Long	33.0747°/76.9678°



Lake ID	GL283031E33075N
Lake Type	PGLA
Area (m2)	3409
Perimeter (m)	301
Elevation(m asl)	5151
Slope (deg.)	5.13°
Aspect	South-West
Lat/Long	33.0746°/76.9693°



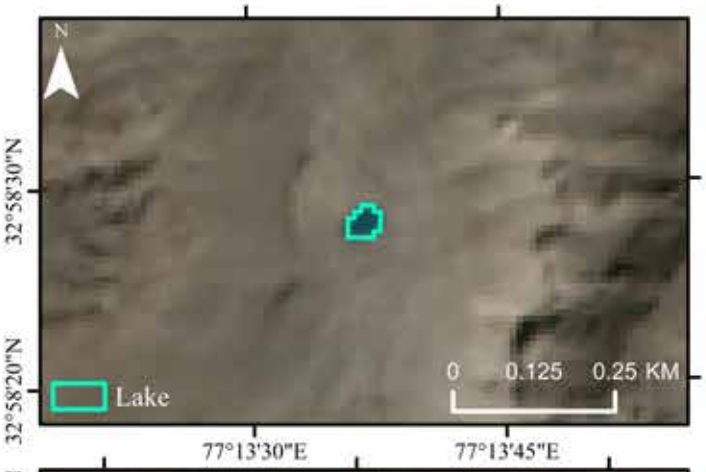
Lake ID	GL283037E33069N
Lake Type	PGLA
Area (m2)	1306
Perimeter (m)	160
Elevation(m asl)	5024
Slope (deg.)	6.95°
Aspect	South
Lat/Long	33.0693°/76.9632°

Lake ID	GL282675E33050N
Lake Type	PGLC
Area (m^2)	8612
Perimeter (m)	520
Elevation(m asl)	5305
Slope (deg.)	8.09°
Aspect	North-West
Lat/Long	33.0504°/77.3248°

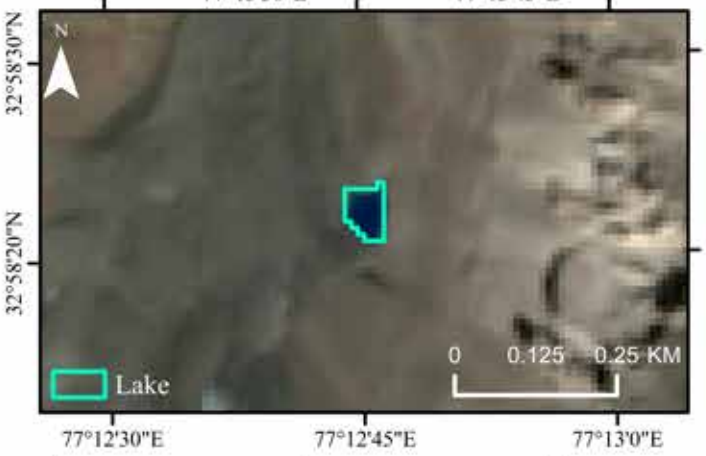
Lake ID	GL282724E33007N
Lake Type	PGLC
Area (m2)	8905
Perimeter (m)	461
Elevation(m asl)	5273
Slope (deg.)	16.58°
Aspect	North-West
Lat/Long	33.0074°/77.2755°

Lake ID	GL282972E33003N
Lake Type	PGLA
Area (m2)	1106
Perimeter (m)	161
Elevation(m asl)	4971
Slope (deg.)	18.24°
Aspect	South-East
Lat/Long	33.0027°/77.0284°

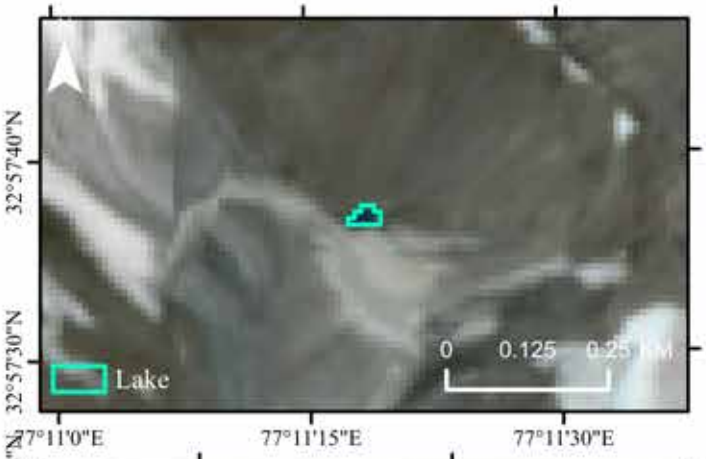
Lake ID	GL282838E32982N
Lake Type	PGLC
Area (m2)	3201
Perimeter (m)	260
Elevation(m asl)	5238
Slope (deg.)	17.09°
Aspect	East
Lat/Long	32.9816°/77.1622°



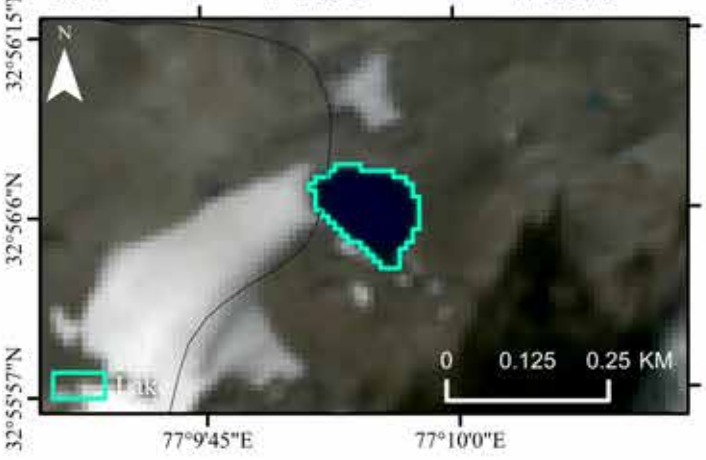
Lake ID	GL282773E32974N
Lake Type	PGLA
Area (m²)	2001
Perimeter (m)	200
Elevation(m asl)	5057
Slope (deg.)	10.14°
Aspect	North-West
Lat/Long	32.9745°/77.2268°



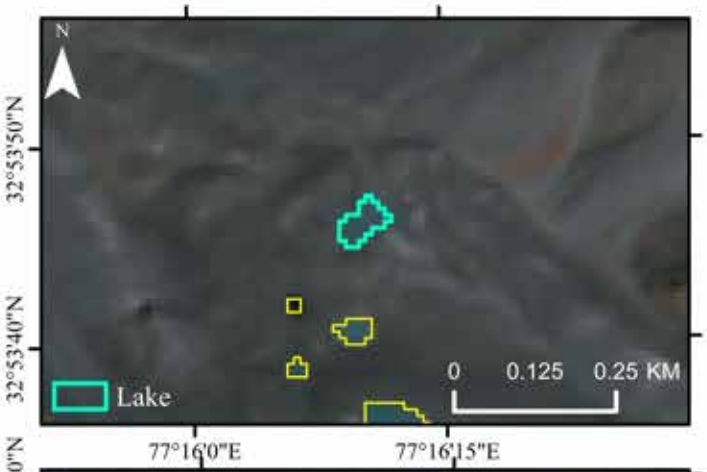
Lake ID	GL282788E32973N
Lake Type	PGLC
Area (m2)	4303
Perimeter (m)	301
Elevation(m asl)	5023
Slope (deg.)	11.81°
Aspect	West
Lat/Long	32.9728°/77.2125°



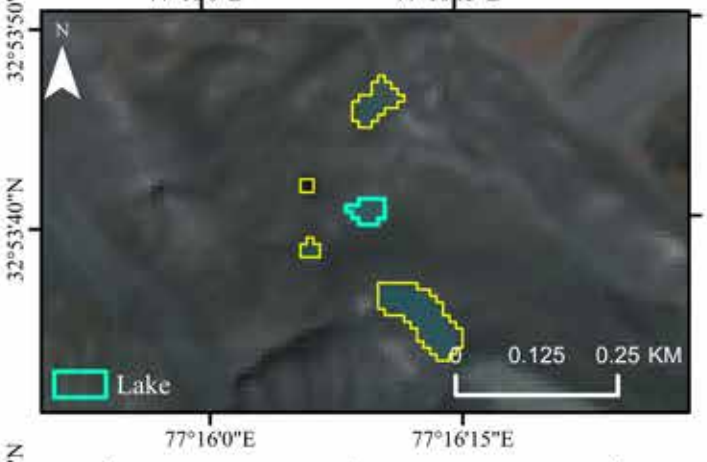
Lake ID	GL282812E32960N
Lake Type	PGLC
Area (m2)	1103
Perimeter (m)	161
Elevation(m asl)	5566
Slope (deg.)	5.14°
Aspect	West
Lat/Long	32.9603°/77.1884°



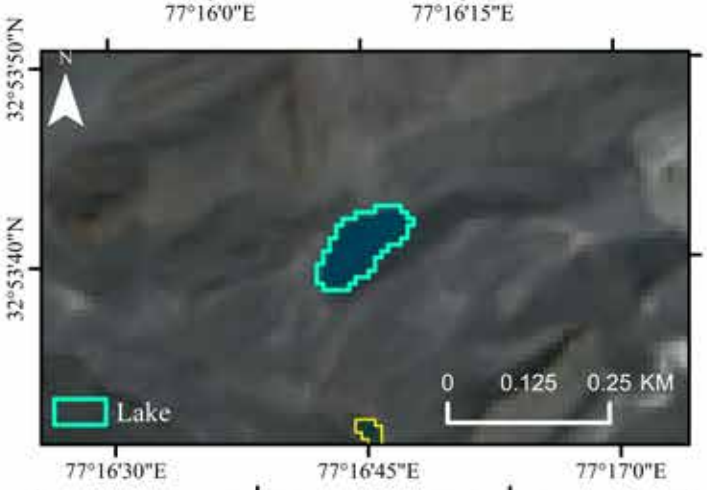
Lake ID	GL282835E32935N
Lake Type	PGLC
Area (m2)	17318
Perimeter (m)	662
Elevation(m asl)	5376
Slope (deg.)	7.34°
Aspect	East
Lat/Long	32.935°/77.1652°



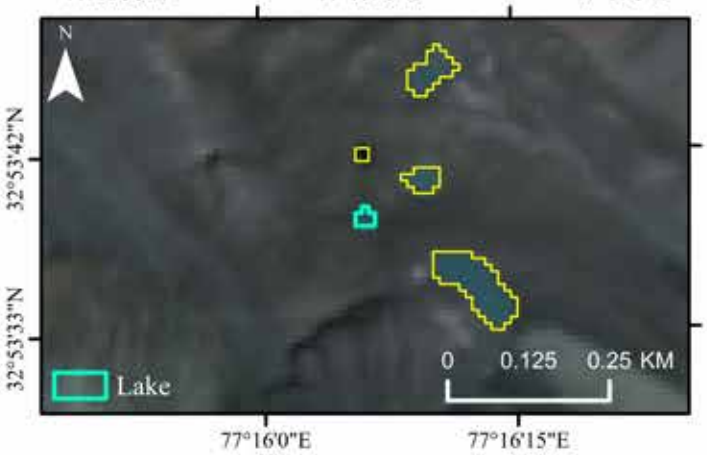
Lake ID	GL282731E32896N
Lake Type	PGLA
Area (m^2)	3310
Perimeter (m)	320
Elevation(m asl)	5028
Slope (deg.)	3.07°
Aspect	East
Lat/Long	32.8961°/77.2694°



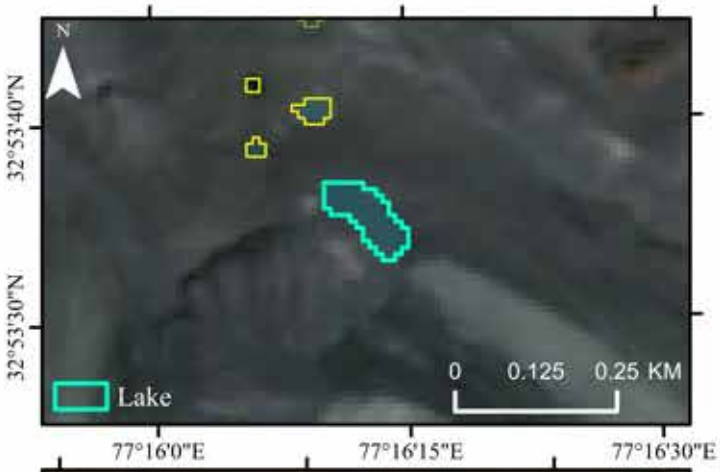
Lake ID	GL282731E32895N
Lake Type	PGLA
Area (m2)	1801
Perimeter (m)	200
Elevation(m asl)	5027
Slope (deg.)	4.41°
Aspect	West
Lat/Long	32.8946°/77.2693°



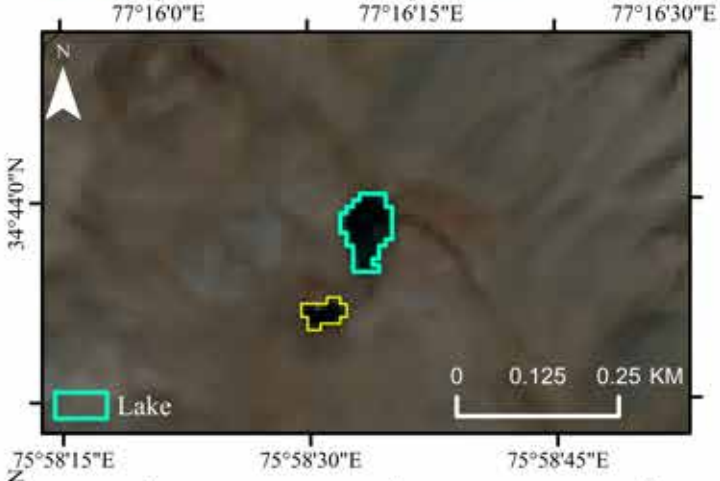
Lake ID	GL282721E32895N
Lake Type	PGLA
Area (m2)	10899
Perimeter (m)	559
Elevation(m asl)	5181
Slope (deg.)	10.99°
Aspect	South-West
Lat/Long	32.8947°/77.279°



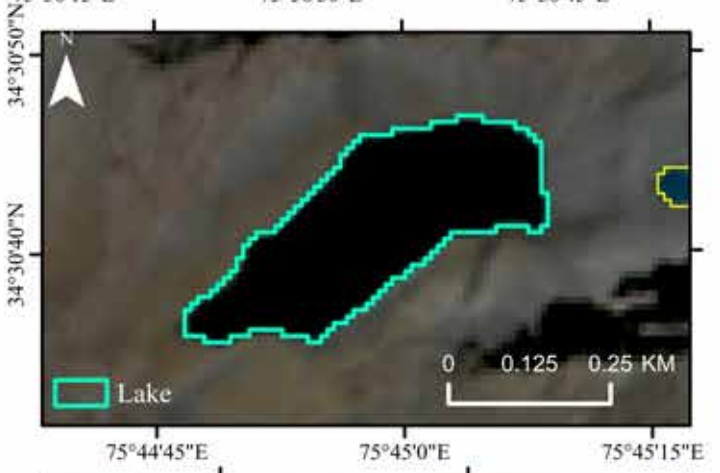
Lake ID	GL282732E32894N
Lake Type	PGLA
Area (m2)	701
Perimeter (m)	120
Elevation(m asl)	5020
Slope (deg.)	7.99°
Aspect	South-West
Lat/Long	32.8941°/77.2683°



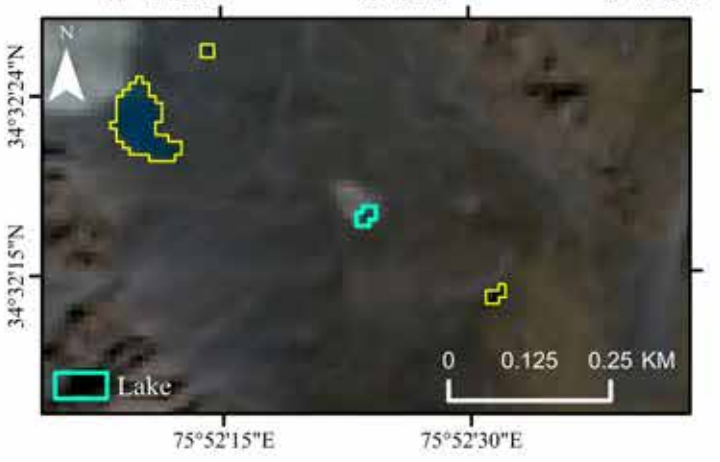
Lake ID	GL282730E32893N
Lake Type	PGLC
Area (m²)	8204
Perimeter (m)	501
Elevation(m asl)	5059
Slope (deg.)	9.04°
Aspect	West
Lat/Long	32.8931°/77.2701°



Lake ID	GL284024E34733N
Lake Type	PGLA
Area (m2)	6826
Perimeter (m)	420
Elevation(m asl)	4739
Slope (deg.)	5.91°
Aspect	East
Lat/Long	34.7329°/75.9759°



Lake ID	GL284250E34512N
Lake Type	PGLA
Area (m2)	98361
Perimeter (m)	1877
Elevation(m asl)	4664
Slope (deg.)	8.85°
Aspect	South
Lat/Long	34.5115°/75.7495°

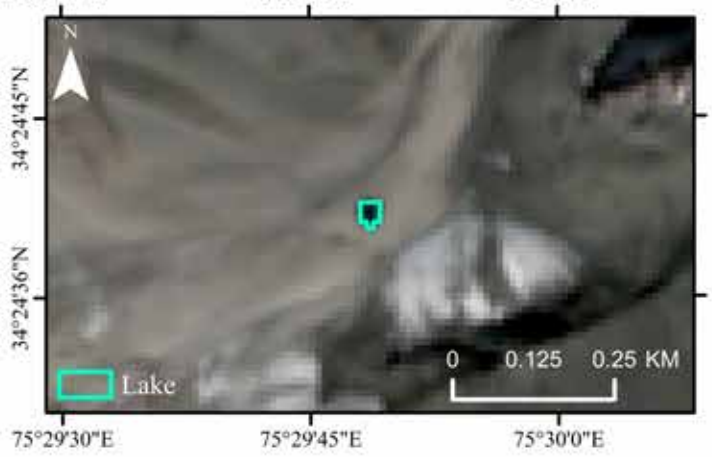


Lake ID	GL284127E34538N
Lake Type	PGLA
Area (m2)	708
Perimeter (m)	120
Elevation(m asl)	4801
Slope (deg.)	11.97°
Aspect	East
Lat/Long	34.5383°/75.8732°

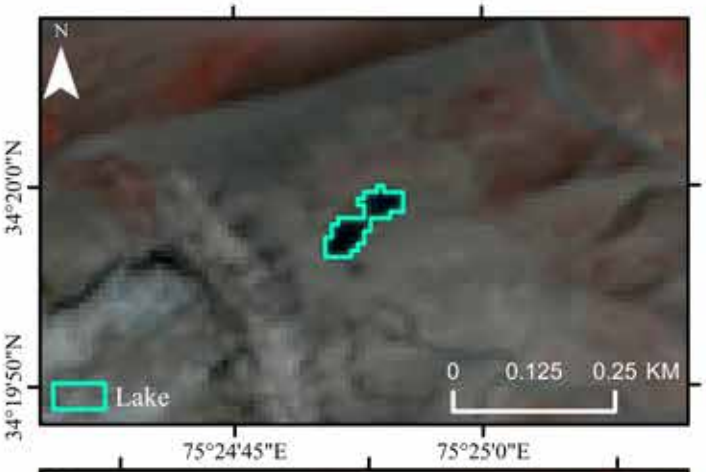
Lake ID	GL284129E34541N
Lake Type	PGLA
Area (m²)	409
Perimeter (m)	81
Elevation(m asl)	4839
Slope (deg.)	9.72°
Aspect	South
Lat/Long	34.5406°/75.8706°

Lake ID	GL284125E34537N
Lake Type	PGLA
Area (m2)	609
Perimeter (m)	121
Elevation(m asl)	4773
Slope (deg.)	5.64°
Aspect	South
Lat/Long	34.5372°/75.8754°

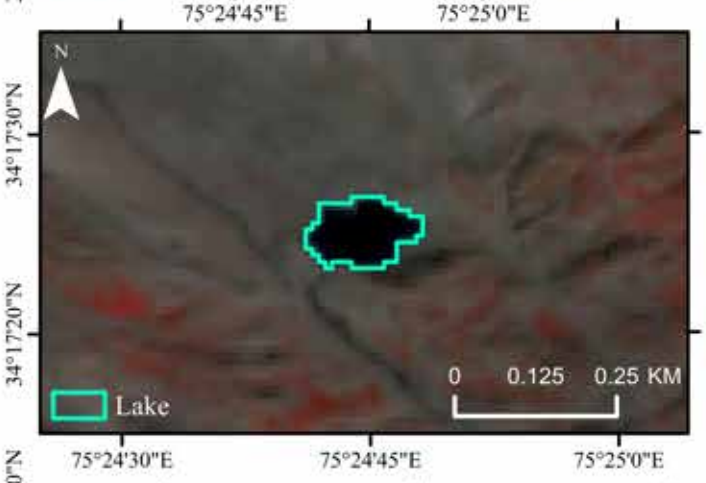
Lake ID	GL284120E34531N
Lake Type	PGLA
Area (m2)	611
Perimeter (m)	121
Elevation(m asl)	4729
Slope (deg.)	5.61°
Aspect	East
Lat/Long	34.5308°/75.8804°



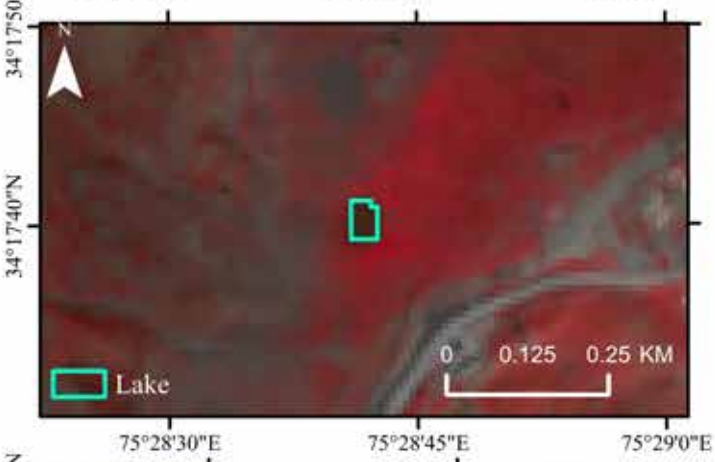
Lake ID	GL284503E34411N
Lake Type	PGLA
Area (m2)	1012
Perimeter (m)	141
Elevation(m asl)	4572
Slope (deg.)	4.7°
Aspect	East
Lat/Long	34.4112°/75.4968°



Lake ID	GL284585E34333N
Lake Type	PGLA
Area (m^2)	5531
Perimeter (m)	480
Elevation(m asl)	3761
Slope (deg.)	11.15°
Aspect	North-East
Lat/Long	34.3328°/75.4146°

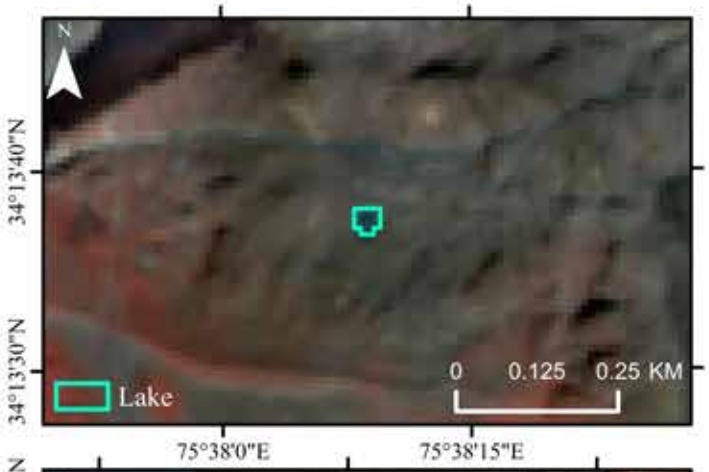


Lake ID	GL284588E34290N
Lake Type	PGLA
Area (m2)	14439
Perimeter (m)	600
Elevation(m asl)	4169
Slope (deg.)	7.13°
Aspect	West
Lat/Long	34.2903°/75.4124°



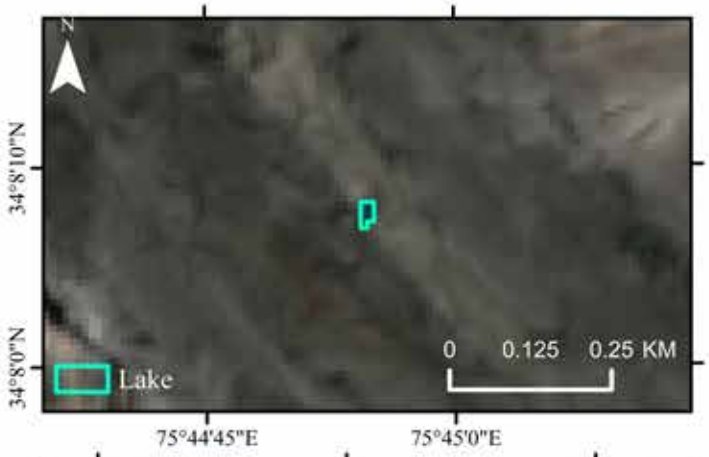
Lake ID	GL284522E34294N
Lake Type	OL
Area (m2)	2318
Perimeter (m)	201
Elevation(m asl)	3443
Slope (deg.)	14.31°
Aspect	South
Lat/Long	34.2945°/75.4783°

Lake ID	GL283864E34300N
Lake Type	PGLA
Area (m2)	1000
Perimeter (m)	140
Elevation(m asl)	4813
Slope (deg.)	17.09°
Aspect	North-East
Lat/Long	34.3001°/76.1359°



Lake ID	GL284364E34227N
Lake Type	PGLC
Area (m^2)	1410
Perimeter (m)	161
Elevation(m asl)	3996
Slope (deg.)	12.33°
Aspect	North-West
Lat/Long	34.2271°/75.6358°

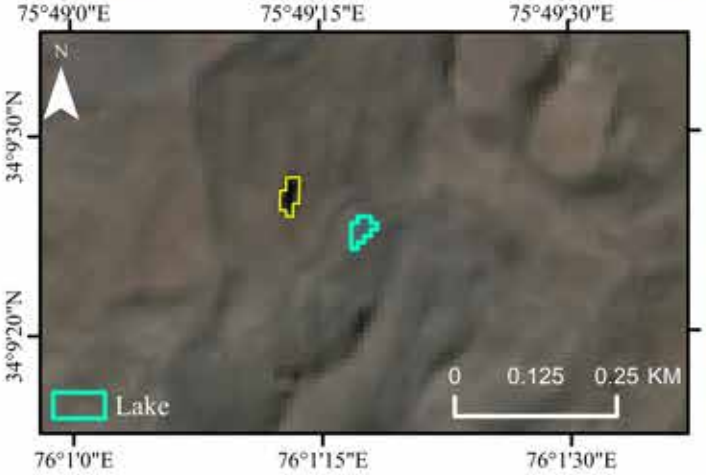
Lake ID	GL284266E34162N
Lake Type	SGL
Area (m2)	511
Perimeter (m)	121
Elevation(m asl)	4062
Slope (deg.)	5.68°
Aspect	South-East
Lat/Long	34.1615°/75.7336°



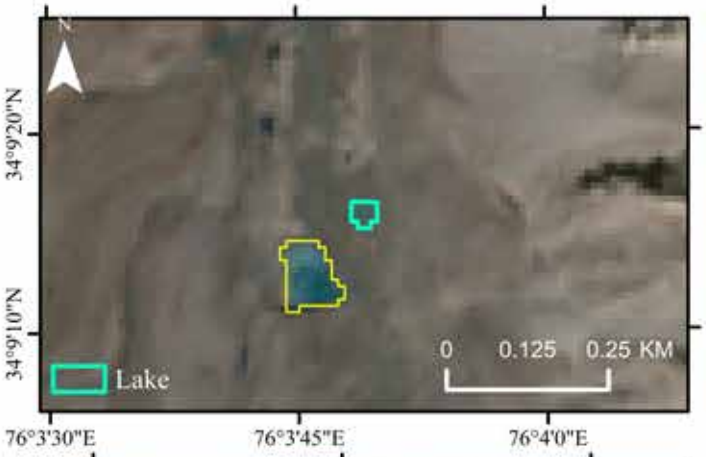
Lake ID	GL284252E34135N
Lake Type	SGL
Area (m2)	709
Perimeter (m)	120
Elevation(m asl)	4320
Slope (deg.)	6.59°
Aspect	North
Lat/Long	34.1354°/75.7485°

Lake ID	GL284237E34144N
Lake Type	PGLC
Area (m2)	1417
Perimeter (m)	201
Elevation(m asl)	4660
Slope (deg.)	23.28°
Aspect	North-West
Lat/Long	34.1439°/75.7628°

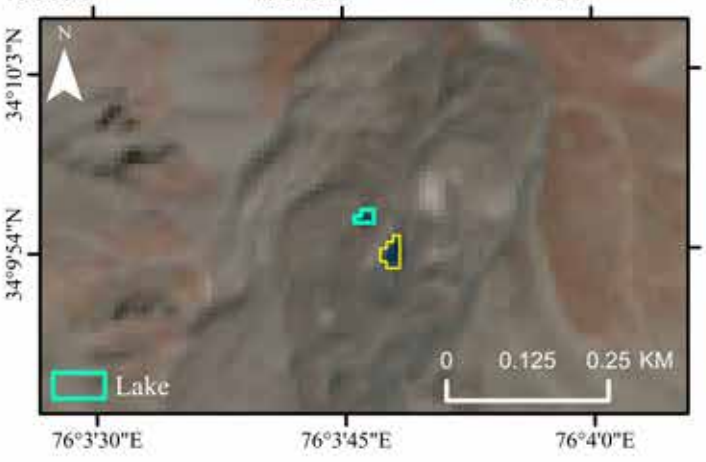
Lake ID	GL284178E34133N
Lake Type	PGLC
Area (m²)	599
Perimeter (m)	120
Elevation(m asl)	4385
Slope (deg.)	10.31°
Aspect	North-West
Lat/Long	34.1332°/75.8217°



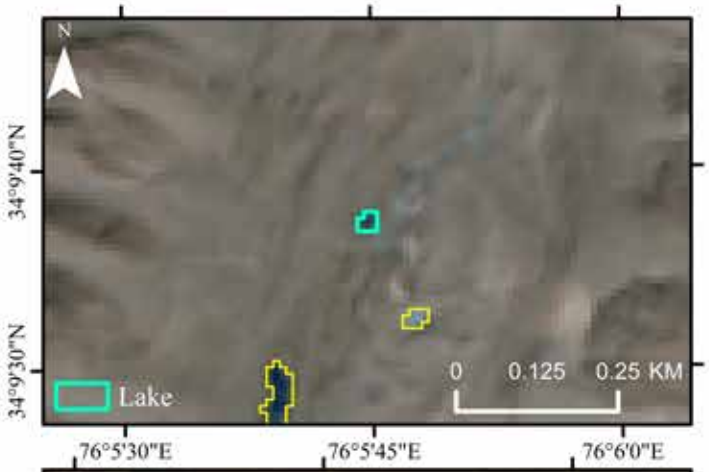
Lake ID	GL283978E34157N
Lake Type	PGLA
Area (m2)	1204
Perimeter (m)	180
Elevation(m asl)	4812
Slope (deg.)	15.54°
Aspect	North-West
Lat/Long	34.157°/76.0215°



Lake ID	GL283936E34154N
Lake Type	PGLA
Area (m2)	1409
Perimeter (m)	161
Elevation(m asl)	4627
Slope (deg.)	7.61°
Aspect	West
Lat/Long	34.1544°/76.0636°

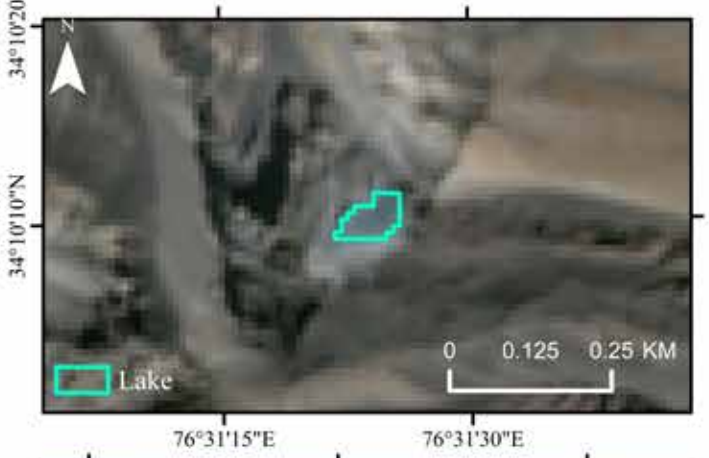


Lake ID	GL283937E34166N
Lake Type	PGLA
Area (m2)	502
Perimeter (m)	100
Elevation(m asl)	4509
Slope (deg.)	8.31°
Aspect	East
Lat/Long	34.1655°/76.0628°

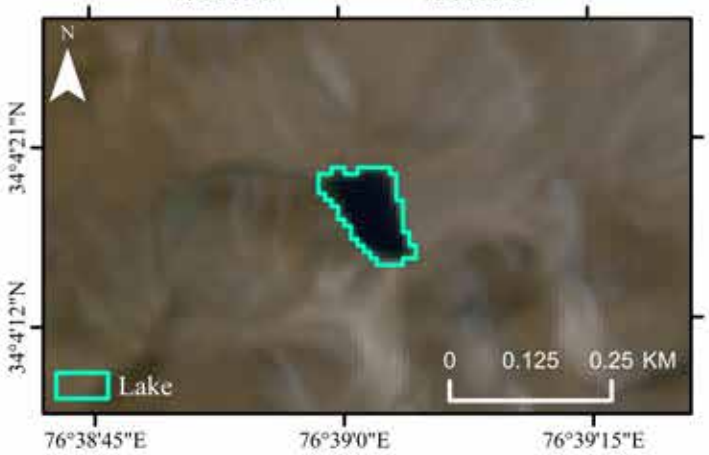


Lake ID	GL283904E34160N
Lake Type	PGLA
Area (m²)	807
Perimeter (m)	120
Elevation(m asl)	4757
Slope (deg.)	10.97°
Aspect	North
Lat/Long	34.1604°/76.0957°

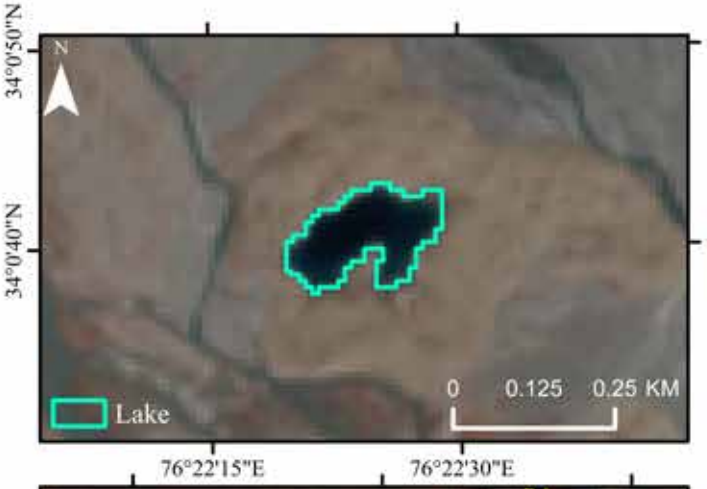
Lake ID	GL283995E34116N
Lake Type	OL
Area (m2)	708
Perimeter (m)	122
Elevation(m asl)	4886
Slope (deg.)	9.31°
Aspect	North-East
Lat/Long	34.1162°/76.0048°



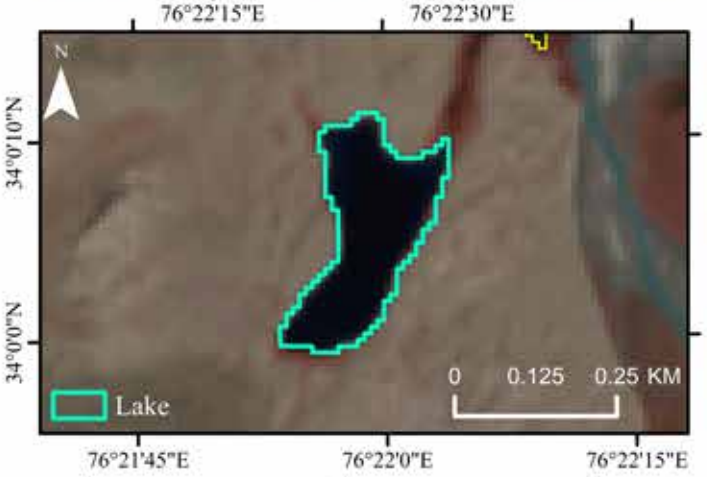
Lake ID	GL283477E34170N
Lake Type	OL
Area (m2)	4867
Perimeter (m)	342
Elevation(m asl)	5424
Slope (deg.)	40.04°
Aspect	South-East
Lat/Long	34.1695°/76.5233°



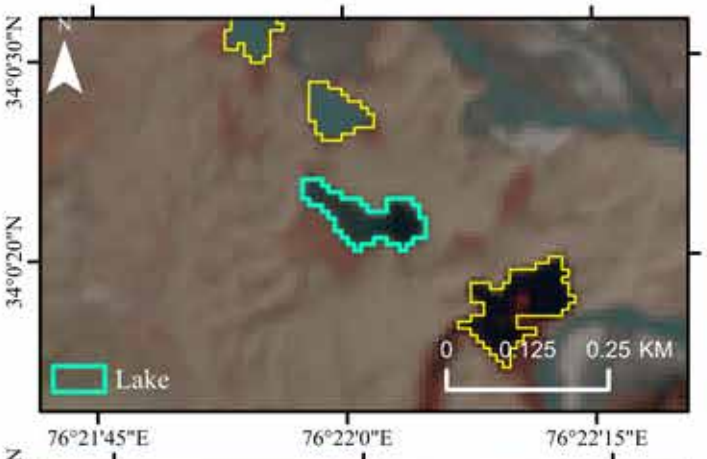
Lake ID	GL283350E34072N
Lake Type	PGLA
Area (m2)	13841
Perimeter (m)	621
Elevation(m asl)	5154
Slope (deg.)	13.63°
Aspect	South-East
Lat/Long	34.0715°/76.6504°



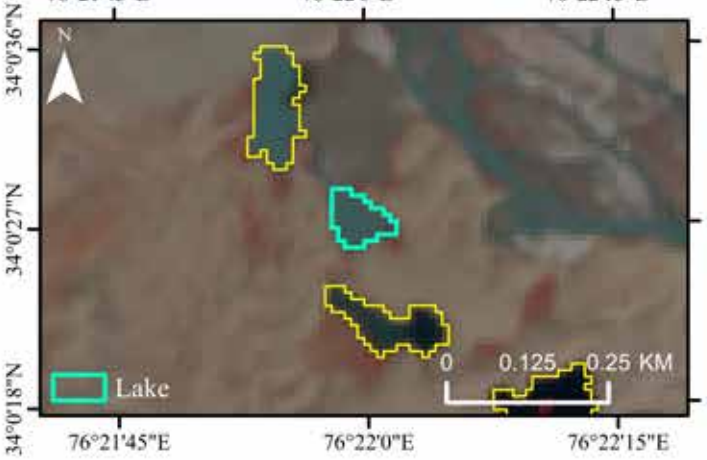
Lake ID	GL283627E34011N
Lake Type	PGLA
Area (m²)	25408
Perimeter (m)	979
Elevation(m asl)	3981
Slope (deg.)	4°
Aspect	South
Lat/Long	34.0112°/76.3734°



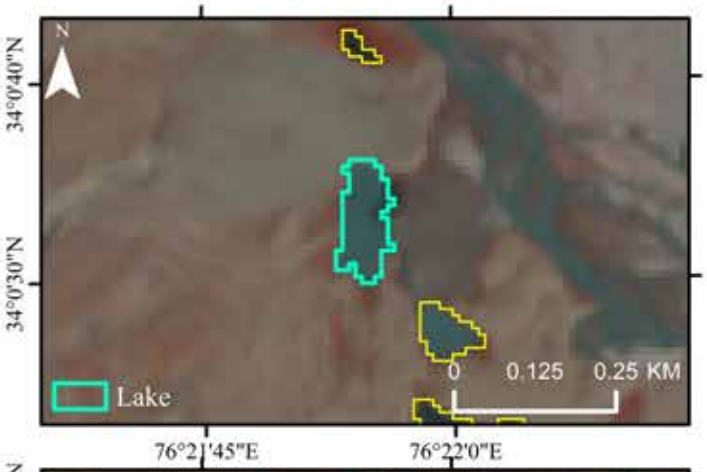
Lake ID	GL283634E34002N
Lake Type	PGLA
Area (m2)	48892
Perimeter (m)	1377
Elevation(m asl)	3990
Slope (deg.)	5.1°
Aspect	South
Lat/Long	34.0015°/76.3663°



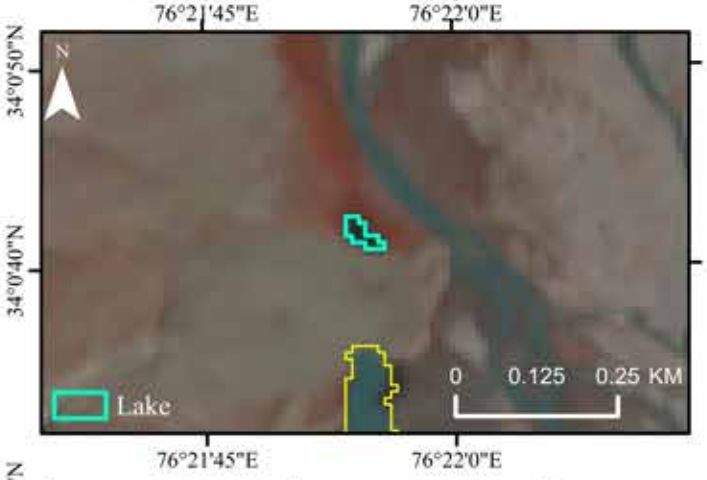
Lake ID	GL283633E34006N
Lake Type	PGLA
Area (m2)	10248
Perimeter (m)	680
Elevation(m asl)	3983
Slope (deg.)	5.69°
Aspect	South
Lat/Long	34.0061°/76.367°



Lake ID	GL283633E34008N
Lake Type	PGLA
Area (m2)	5923
Perimeter (m)	380
Elevation(m asl)	3986
Slope (deg.)	4.01°
Aspect	South-East
Lat/Long	34.0076°/76.3665°



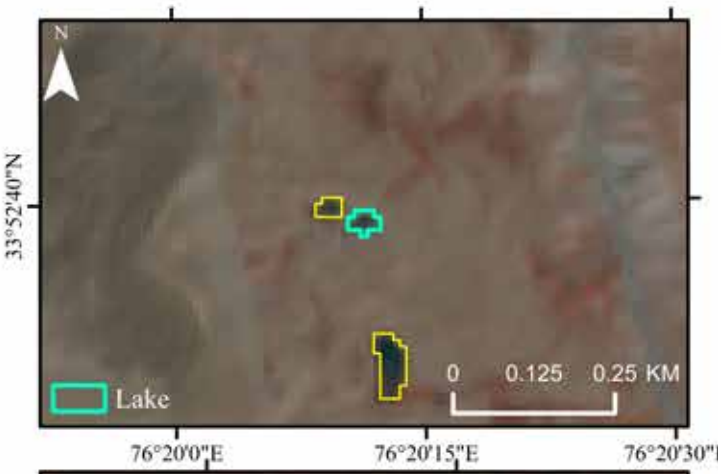
Lake ID	GL283635E34009N
Lake Type	PGLA
Area (m^2)	11747
Perimeter (m)	640
Elevation(m asl)	3982
Slope (deg.)	6.88°
Aspect	South-East
Lat/Long	34.0092°/76.3651°



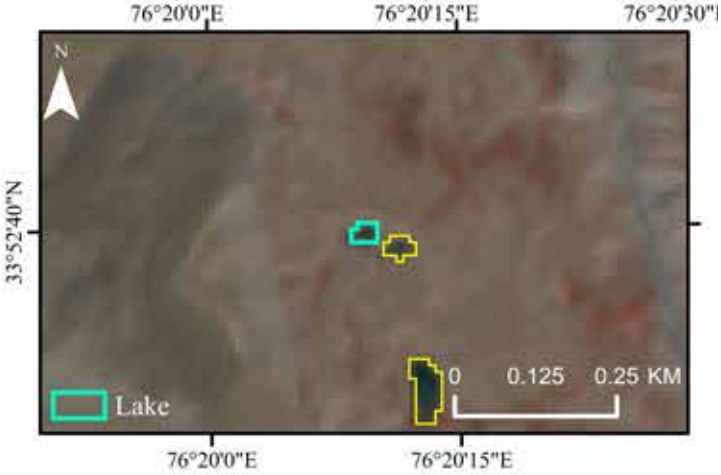
Lake ID	GL283635E34012N
Lake Type	PGLA
Area (m2)	1509
Perimeter (m)	220
Elevation(m asl)	3981
Slope (deg.)	5.77°
Aspect	South-West
Lat/Long	34.0116°/76.3651°

Lake ID	GL284003E34061N
Lake Type	SGL
Area (m2)	2915
Perimeter (m)	359
Elevation(m asl)	4257
Slope (deg.)	4.99°
Aspect	West
Lat/Long	34.0612°/75.9969°

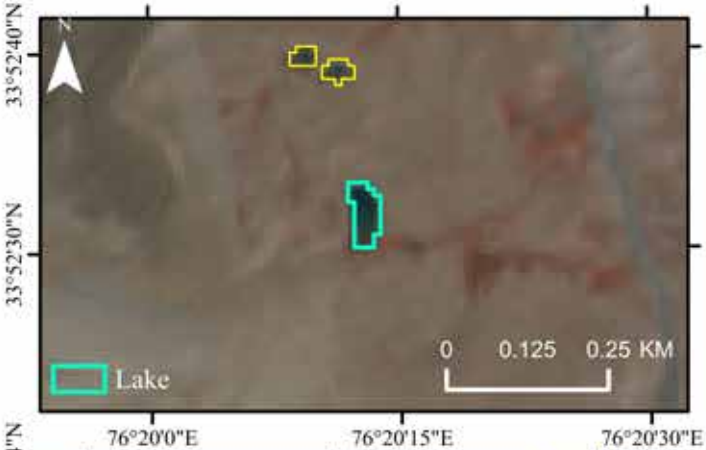
Lake ID	GL284109E34048N
Lake Type	SGL
Area (m2)	906
Perimeter (m)	160
Elevation(m asl)	4416
Slope (deg.)	7.84°
Aspect	South-East
Lat/Long	34.0481°/75.8909°



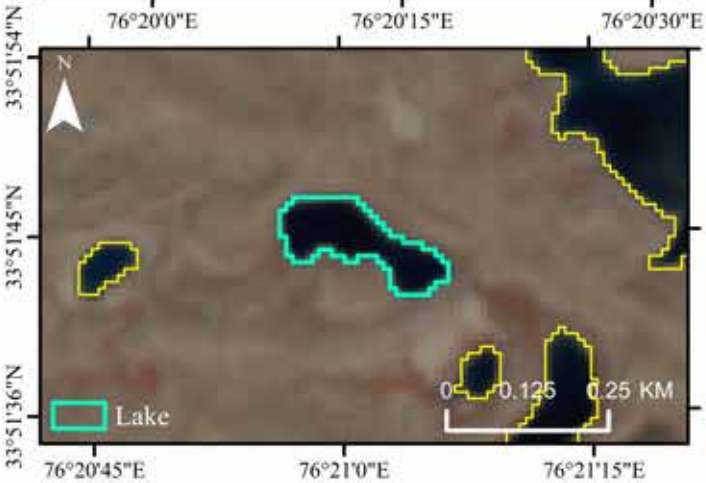
Lake ID	GL283664E33878N
Lake Type	PGLA
Area (m^2)	1414
Perimeter (m)	180
Elevation(m asl)	4450
Slope (deg.)	5.27°
Aspect	North-East
Lat/Long	33.8775°/76.3365°



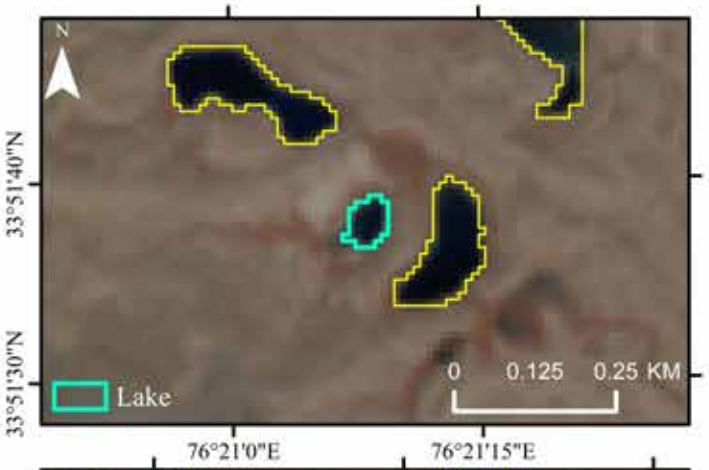
Lake ID	GL283664E33878N
Lake Type	PGLA
Area (m2)	1110
Perimeter (m)	141
Elevation(m asl)	4450
Slope (deg.)	3.31°
Aspect	West
Lat/Long	33.8777°/76.3359°



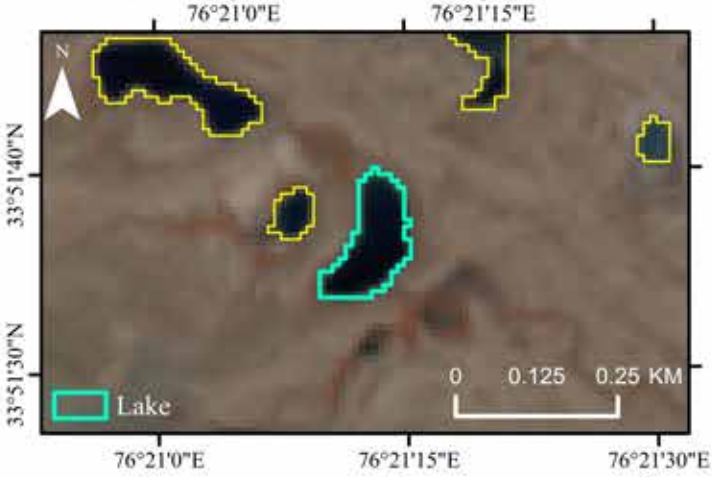
Lake ID	GL283663E33876N
Lake Type	PGLA
Area (m2)	3813
Perimeter (m)	300
Elevation(m asl)	4446
Slope (deg.)	4.48°
Aspect	South-East
Lat/Long	33.8755°/76.3369°



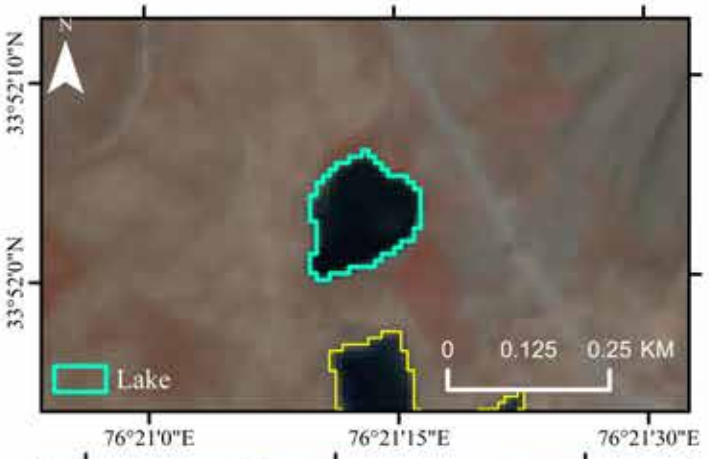
Lake ID	GL283650E33862N
Lake Type	PGLA
Area (m2)	19973
Perimeter (m)	882
Elevation(m asl)	4448
Slope (deg.)	3.75°
Aspect	South
Lat/Long	33.8624°/76.3502°



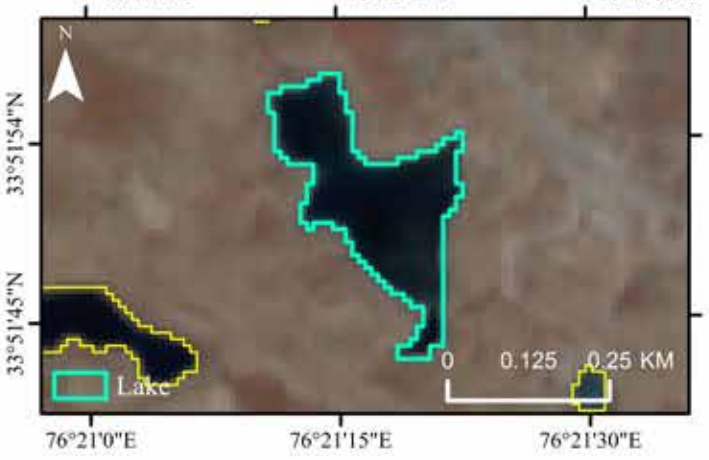
Lake ID	GL283648E33860N
Lake Type	PGLA
Area (m^2)	4010
Perimeter (m)	301
Elevation(m asl)	4447
Slope (deg.)	4.51°
Aspect	East
Lat/Long	33.8605°/76.3522°



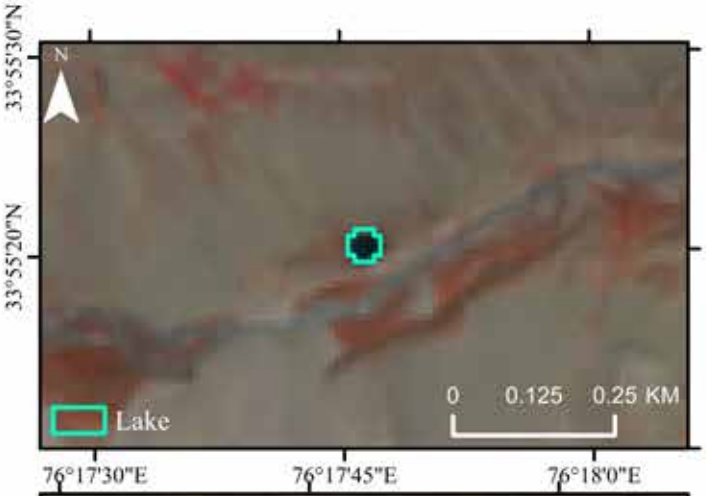
Lake ID	GL283646E33860N
Lake Type	PGLA
Area (m2)	15872
Perimeter (m)	702
Elevation(m asl)	4443
Slope (deg.)	4.52°
Aspect	South-West
Lat/Long	33.8601°/76.3535°



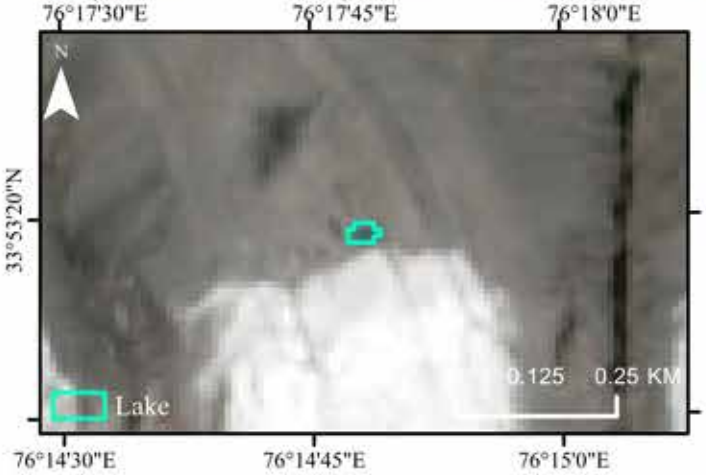
Lake ID	GL283646E33868N
Lake Type	PGLA
Area (m2)	23381
Perimeter (m)	761
Elevation(m asl)	4441
Slope (deg.)	3.4°
Aspect	South-East
Lat/Long	33.8675°/76.3535°



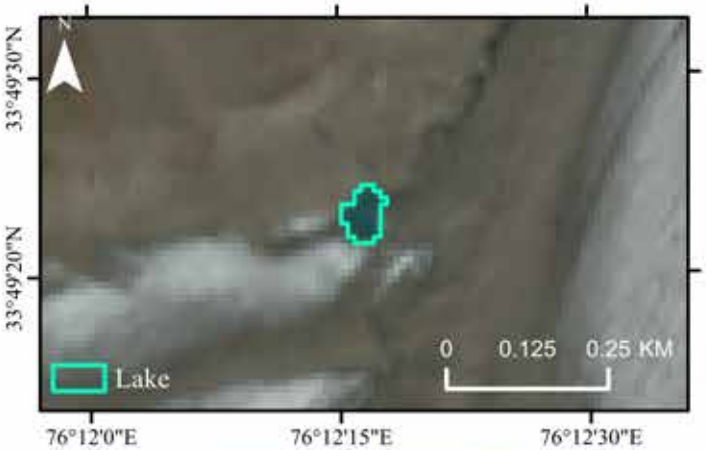
Lake ID	GL283645E33864N
Lake Type	PGLA
Area (m2)	56159
Perimeter (m)	1741
Elevation(m asl)	4438
Slope (deg.)	5.3°
Aspect	South-West
Lat/Long	33.8642°/76.3547°



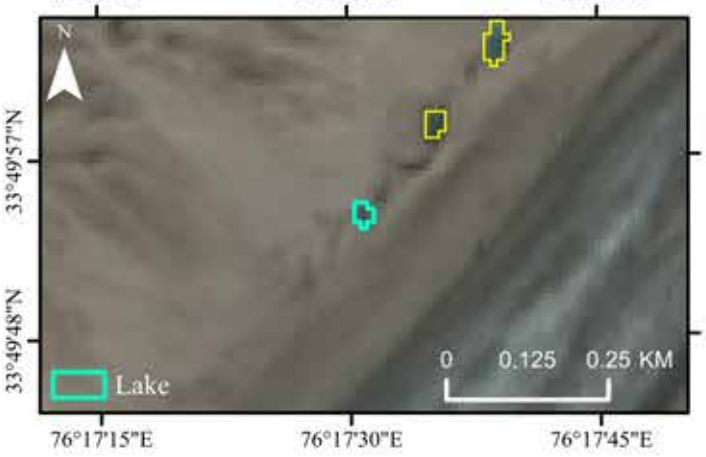
Lake ID	GL283704E33922N
Lake Type	PGLA
Area (m²)	2110
Perimeter (m)	200
Elevation(m asl)	4103
Slope (deg.)	17.56°
Aspect	South
Lat/Long	33.9223°/76.2962°



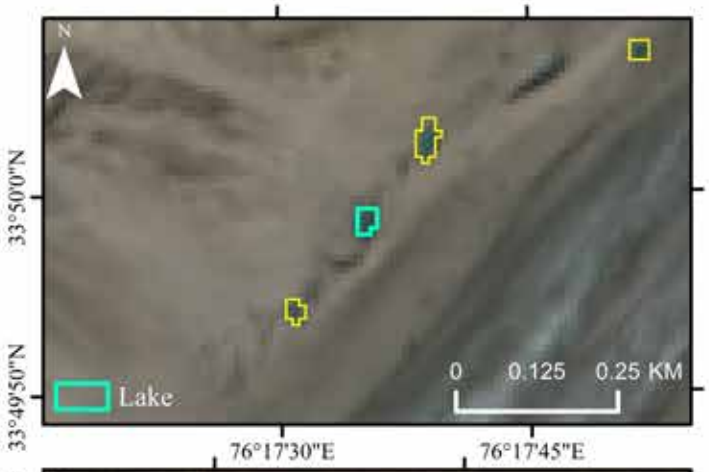
Lake ID	GL283753E33889N
Lake Type	PGLC
Area (m2)	1205
Perimeter (m)	160
Elevation(m asl)	4847
Slope (deg.)	11.17°
Aspect	North-West
Lat/Long	33.8886°/76.2466°



Lake ID	GL283796E33823N
Lake Type	SGL
Area (m2)	4240
Perimeter (m)	322
Elevation(m asl)	4609
Slope (deg.)	6.91°
Aspect	East
Lat/Long	33.823°/76.2045°



Lake ID	GL283708E33832N
Lake Type	PGLA
Area (m2)	905
Perimeter (m)	140
Elevation(m asl)	4934
Slope (deg.)	7.51°
Aspect	East
Lat/Long	33.8317°/76.2919°



Lake ID	GL283707E33833N
Lake Type	PGLA
Area (m^2)	1110
Perimeter (m)	140
Elevation(m asl)	4914
Slope (deg.)	10.07°
Aspect	East
Lat/Long	33.833°/76.2931°

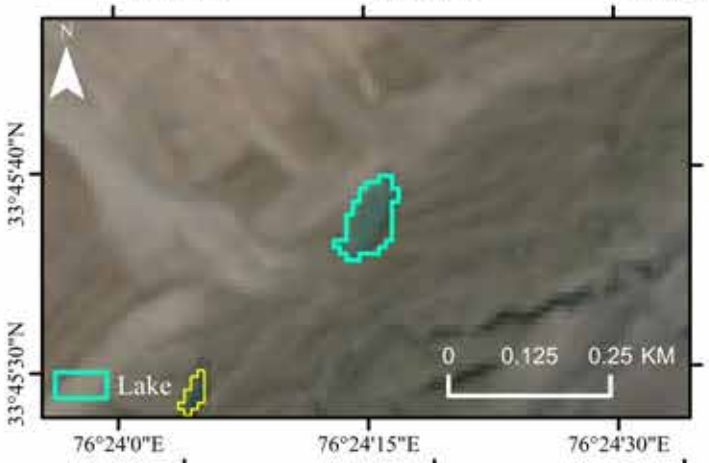
Lake ID	GL283706E33834N
Lake Type	PGLA
Area (m2)	1817
Perimeter (m)	220
Elevation(m asl)	4908
Slope (deg.)	7.58°
Aspect	North-East
Lat/Long	33.8341°/76.2941°

Lake ID	GL283702E33835N
Lake Type	SGL
Area (m2)	900
Perimeter (m)	120
Elevation(m asl)	4862
Slope (deg.)	4.16°
Aspect	North-East
Lat/Long	33.8353°/76.2977°

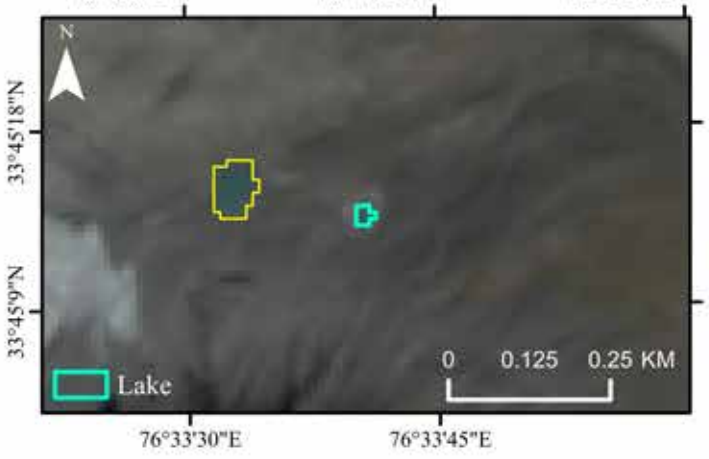
Lake ID	GL283679E33787N
Lake Type	SGL
Area (m2)	1309
Perimeter (m)	160
Elevation(m asl)	4619
Slope (deg.)	5.37°
Aspect	East
Lat/Long	33.7867°/76.3214°

Lake ID	GL283644E33824N
Lake Type	SGL
Area (m²)	5015
Perimeter (m)	361
Elevation(m asl)	4315
Slope (deg.)	5.36°
Aspect	East
Lat/Long	33.8239°/76.3559°

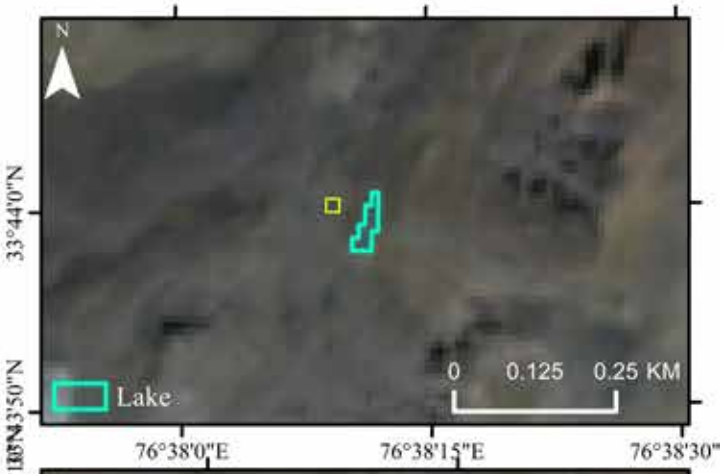
Lake ID	GL283601E33776N
Lake Type	PGLA
Area (m2)	1817
Perimeter (m)	221
Elevation(m asl)	5026
Slope (deg.)	8.09°
Aspect	East
Lat/Long	33.7763°/76.399°



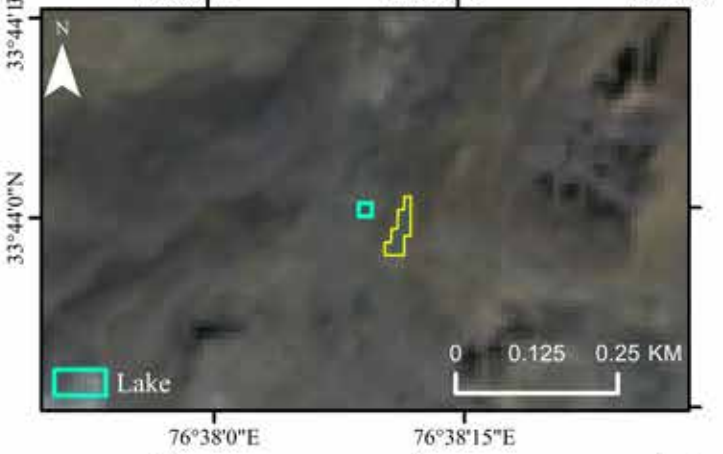
Lake ID	GL283596E33760N
Lake Type	SGL
Area (m2)	7464
Perimeter (m)	459
Elevation(m asl)	4360
Slope (deg.)	5.21°
Aspect	North-East
Lat/Long	33.7604°/76.4042°



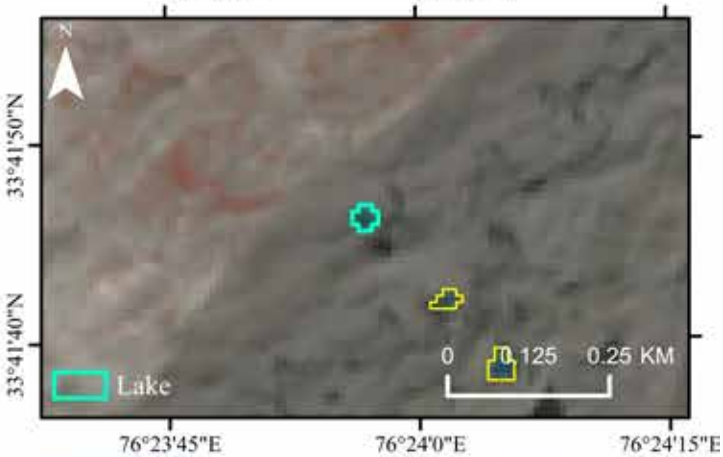
Lake ID	GL283439E33754N
Lake Type	PGLA
Area (m2)	706
Perimeter (m)	121
Elevation(m asl)	5020
Slope (deg.)	9.55°
Aspect	North-West
Lat/Long	33.7538°/76.5612°



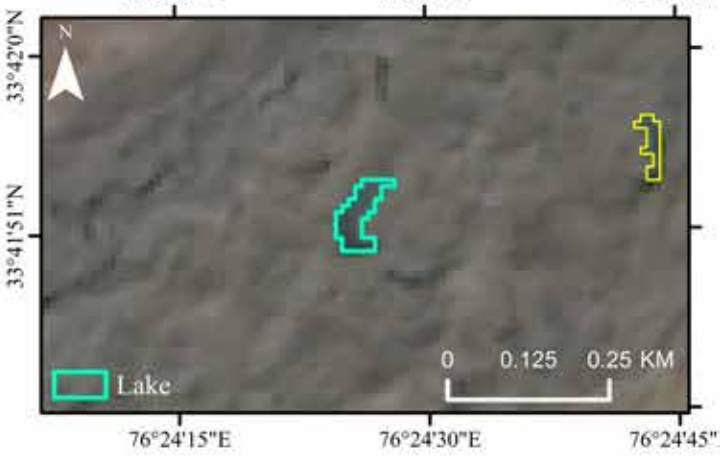
Lake ID	GL283364E33733N
Lake Type	PGLA
Area (m^2)	1908
Perimeter (m)	259
Elevation(m asl)	5022
Slope (deg.)	9.04°
Aspect	North-West
Lat/Long	33.7331°/76.6364°



Lake ID	GL283364E33733N
Lake Type	PGLA
Area (m2)	405
Perimeter (m)	81
Elevation(m asl)	5017
Slope (deg.)	1.81°
Aspect	South
Lat/Long	33.7334°/76.6358°

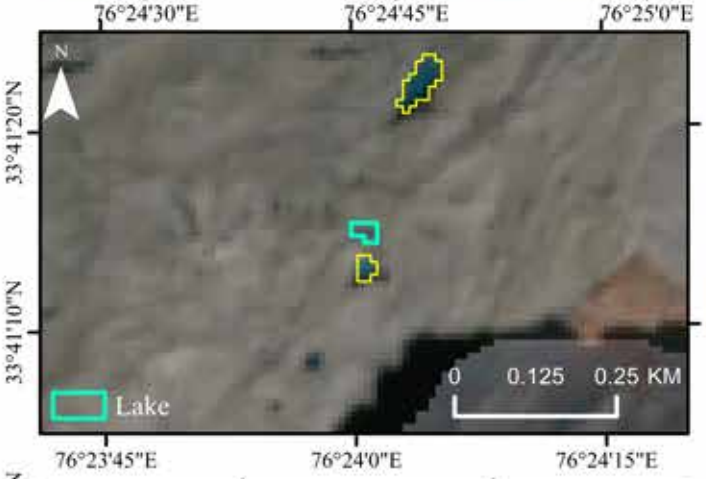


Lake ID	GL283601E33696N
Lake Type	SGL
Area (m2)	1212
Perimeter (m)	160
Elevation(m asl)	4168
Slope (deg.)	7.48°
Aspect	South
Lat/Long	33.6962°/76.3991°

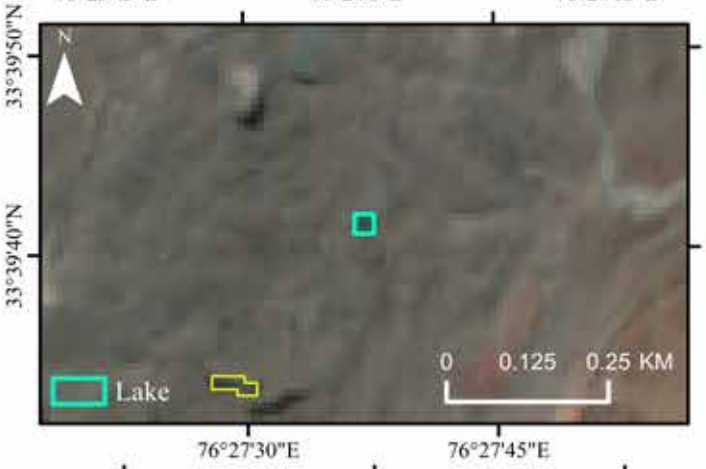


Lake ID	GL283593E33698N
Lake Type	SGL
Area (m2)	4953
Perimeter (m)	442
Elevation(m asl)	4139
Slope (deg.)	9.09°
Aspect	South-East
Lat/Long	33.6977°/76.4072°

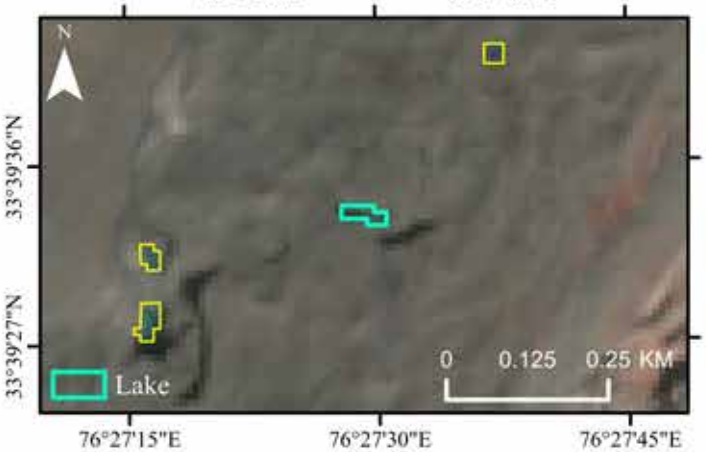
Lake ID	GL283588E33699N
Lake Type	SGL
Area (m²)	2107
Perimeter (m)	318
Elevation(m asl)	4101
Slope (deg.)	5.61°
Aspect	East
Lat/Long	33.6987°/76.412°



Lake ID	GL283600E33688N
Lake Type	SGL
Area (m2)	1016
Perimeter (m)	141
Elevation(m asl)	4213
Slope (deg.)	5.81°
Aspect	West
Lat/Long	33.6875°/76.4001°

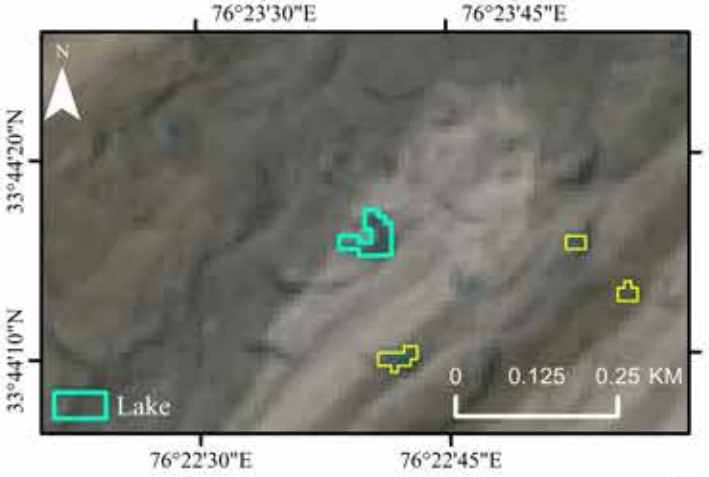


Lake ID	GL283540E33662N
Lake Type	SGL
Area (m2)	903
Perimeter (m)	120
Elevation(m asl)	3980
Slope (deg.)	5.16°
Aspect	North-West
Lat/Long	33.6615°/76.4603°



Lake ID	GL283542E33659N
Lake Type	SGL
Area (m2)	1498
Perimeter (m)	199
Elevation(m asl)	3994
Slope (deg.)	10.93°
Aspect	West
Lat/Long	33.6593°/76.4581°

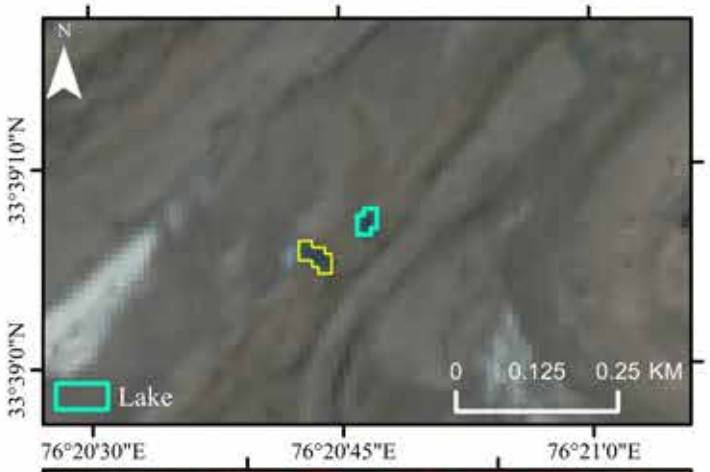
Lake ID	GL283607E33745N
Lake Type	SGL
Area (m²)	1308
Perimeter (m)	180
Elevation(m asl)	4524
Slope (deg.)	3.78°
Aspect	South
Lat/Long	33.7454°/76.3934°



Lake ID	GL283622E33738N
Lake Type	SGL
Area (m2)	3165
Perimeter (m)	343
Elevation(m asl)	4633
Slope (deg.)	4.75°
Aspect	South
Lat/Long	33.7378°/76.3778°

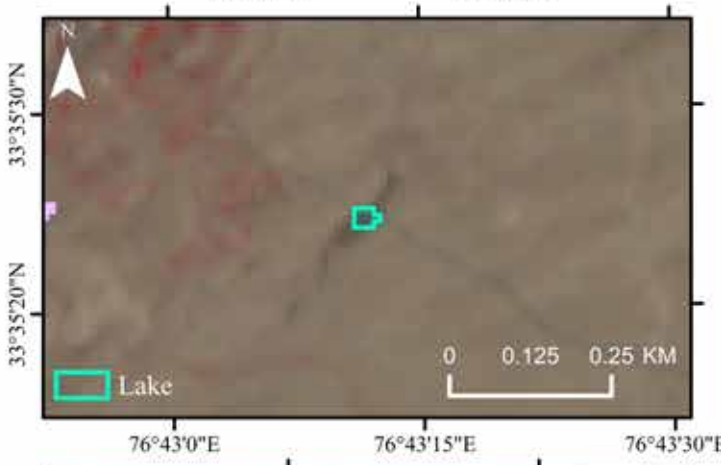
Lake ID	GL283618E33737N
Lake Type	SGL
Area (m2)	709
Perimeter (m)	120
Elevation(m asl)	4621
Slope (deg.)	3.84°
Aspect	South
Lat/Long	33.7369°/76.3821°

Lake ID	GL283606E33746N
Lake Type	SGL
Area (m2)	402
Perimeter (m)	80
Elevation(m asl)	4517
Slope (deg.)	3.43°
Aspect	South
Lat/Long	33.7463°/76.3942°

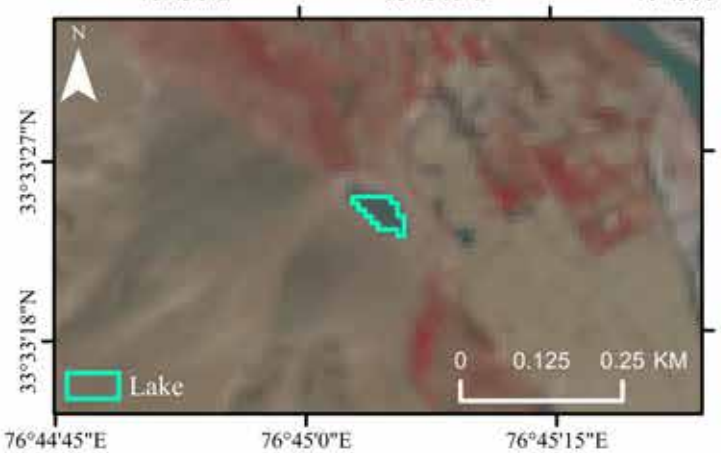


Lake ID	GL283654E33652N
Lake Type	SGL
Area (m²)	1018
Perimeter (m)	141
Elevation(m asl)	4537
Slope (deg.)	4.27°
Aspect	South
Lat/Long	33.652°/76.3462°

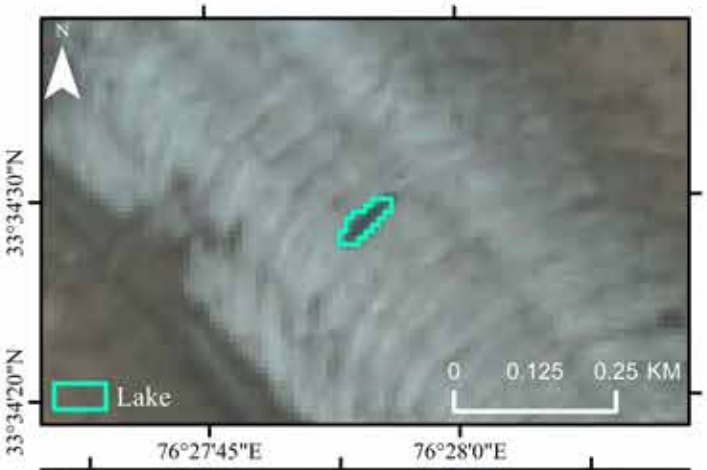
Lake ID	GL283286E33590N
Lake Type	PGLA
Area (m2)	2436
Perimeter (m)	240
Elevation(m asl)	3644
Slope (deg.)	4.07°
Aspect	North-East
Lat/Long	33.5902°/76.7144°



Lake ID	GL283280E33590N
Lake Type	PGLA
Area (m2)	1009
Perimeter (m)	141
Elevation(m asl)	3627
Slope (deg.)	1.36°
Aspect	East
Lat/Long	33.5902°/76.7198°



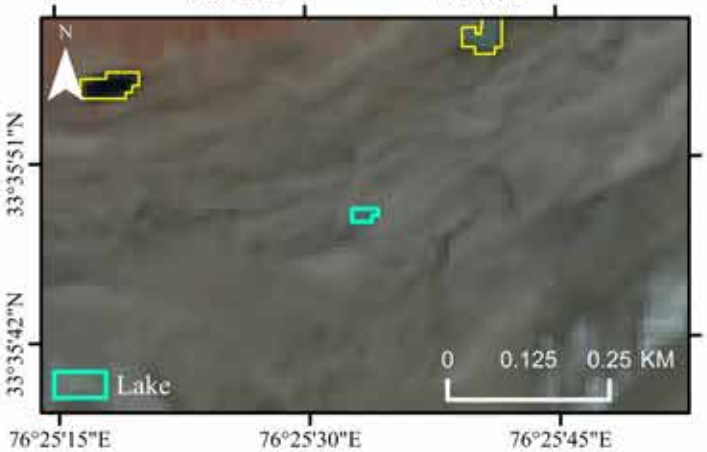
Lake ID	GL283249E33557N
Lake Type	PGLA
Area (m2)	2739
Perimeter (m)	281
Elevation(m asl)	3566
Slope (deg.)	2.9°
Aspect	South
Lat/Long	33.5567°/76.7513°



Lake ID	GL283535E33575N
Lake Type	SGL
Area (m^2)	2812
Perimeter (m)	300
Elevation(m asl)	4618
Slope (deg.)	8.46°
Aspect	South-East
Lat/Long	33.5747°/76.4651°

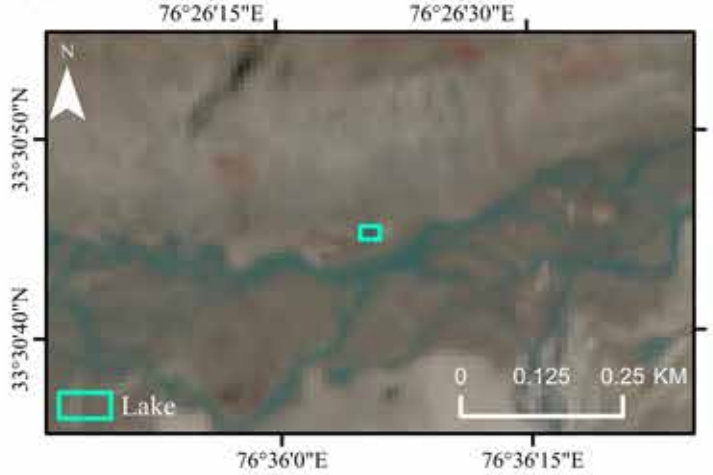
Lake ID	GL283570E33590N
Lake Type	SGL
Area (m2)	2009
Perimeter (m)	261
Elevation(m asl)	4501
Slope (deg.)	6.73°
Aspect	East
Lat/Long	33.5904°/76.4295°

Lake ID	GL283568E33593N
Lake Type	SGL
Area (m2)	1141
Perimeter (m)	142
Elevation(m asl)	4487
Slope (deg.)	11.4°
Aspect	South-East
Lat/Long	33.5928°/76.4315°



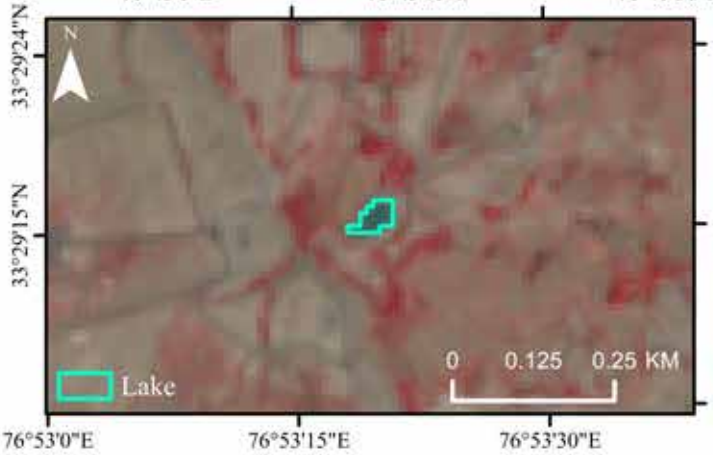
Lake ID	GL283574E33597N
Lake Type	SGL
Area (m2)	713
Perimeter (m)	121
Elevation(m asl)	4493
Slope (deg.)	9.18°
Aspect	North
Lat/Long	33.5967°/76.4259°

Lake ID	GL283560E33616N
Lake Type	SGL
Area (m^2)	796
Perimeter (m)	139
Elevation(m asl)	4354
Slope (deg.)	1.8°
Aspect	South-East
Lat/Long	33.6161°/76.4401°



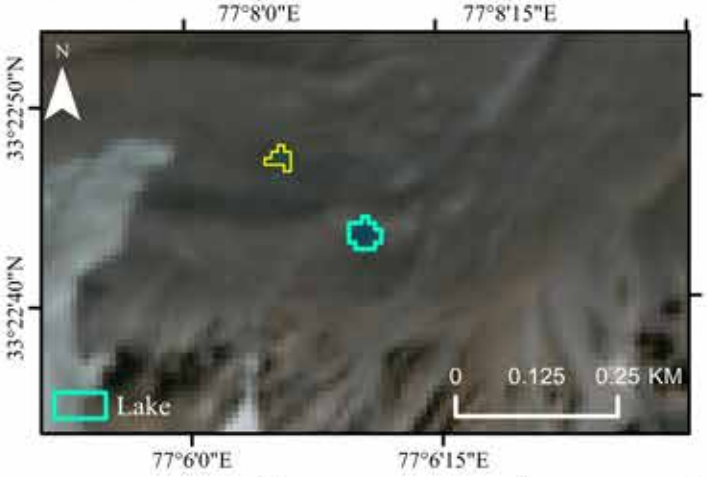
Lake ID	GL283398E33512N
Lake Type	PGLA
Area (m2)	618
Perimeter (m)	102
Elevation(m asl)	4150
Slope (deg.)	5.54°
Aspect	South
Lat/Long	33.5125°/76.6015°

Lake ID	GL283280E33445N
Lake Type	SGL
Area (m2)	816
Perimeter (m)	121
Elevation(m asl)	5060
Slope (deg.)	7.31°
Aspect	East
Lat/Long	33.4451°/76.7201°



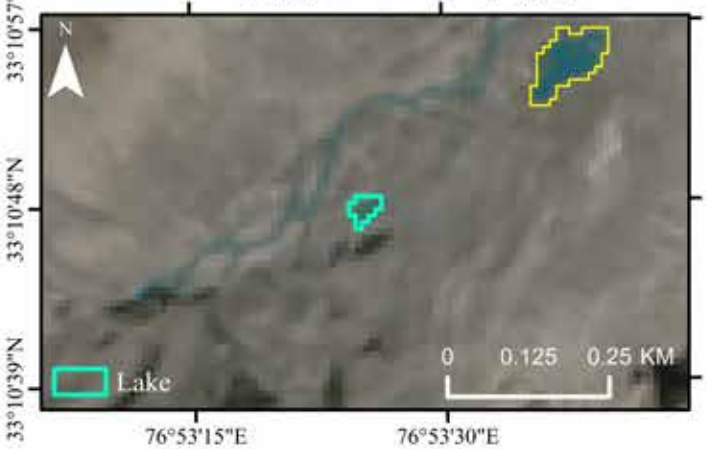
Lake ID	GL283111E33488N
Lake Type	OL
Area (m2)	2218
Perimeter (m)	241
Elevation(m asl)	3508
Slope (deg.)	2.56°
Aspect	South
Lat/Long	33.4877°/76.8888°

Lake ID	GL282865E33526N
Lake Type	PGLC
Area (m²)	711
Perimeter (m)	121
Elevation(m asl)	5562
Slope (deg.)	12.44°
Aspect	South-East
Lat/Long	33.5258°/77.1351°



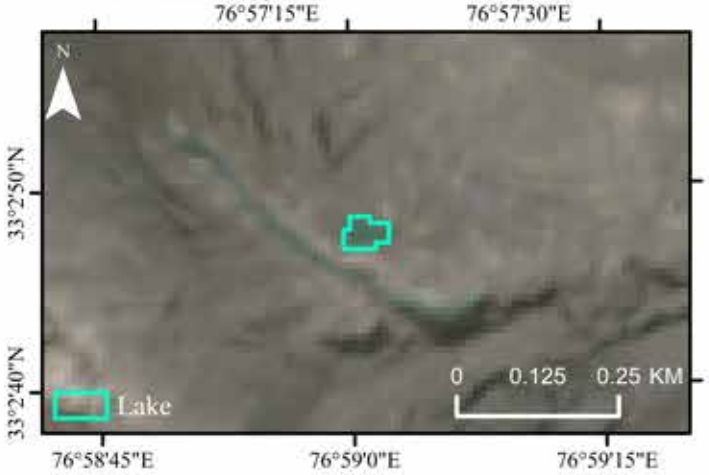
Lake ID	GL282897E33379N
Lake Type	PGLA
Area (m2)	1816
Perimeter (m)	200
Elevation(m asl)	5274
Slope (deg.)	6.79°
Aspect	North-East
Lat/Long	33.3787°/77.1029°

Lake ID	GL282898E33380N
Lake Type	PGLA
Area (m2)	906
Perimeter (m)	161
Elevation(m asl)	5290
Slope (deg.)	11.21°
Aspect	South-East
Lat/Long	33.3798°/77.1015°

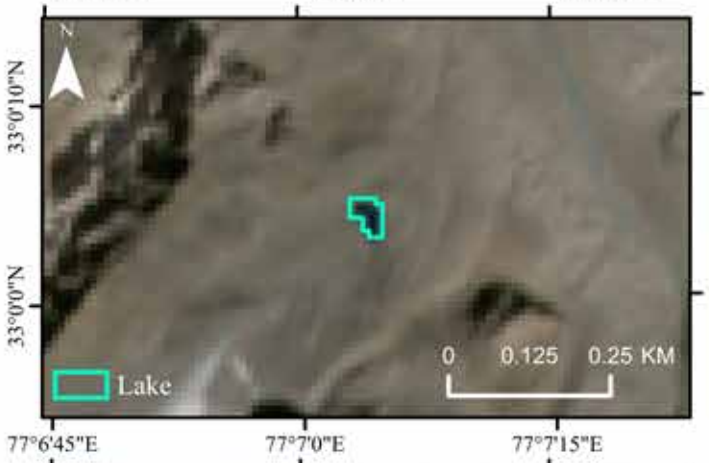


Lake ID	GL283110E33180N
Lake Type	SGL
Area (m2)	1612
Perimeter (m)	201
Elevation(m asl)	4472
Slope (deg.)	12.96°
Aspect	East
Lat/Long	33.1799°/76.8903°

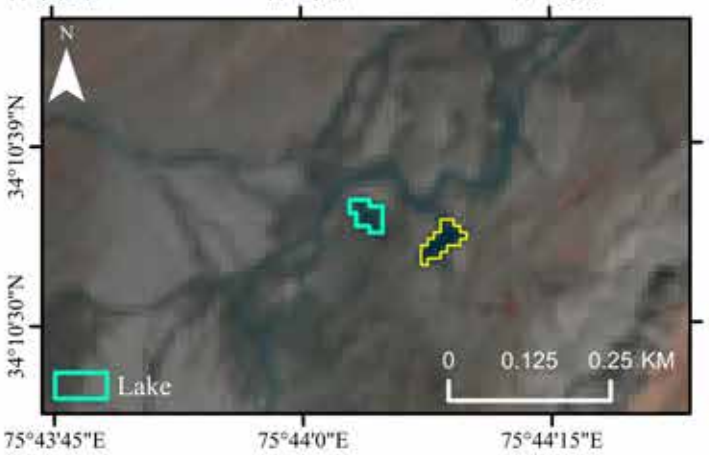
Lake ID	GL283044E33118N
Lake Type	SGL
Area (m^2)	1114
Perimeter (m)	141
Elevation(m asl)	5241
Slope (deg.)	6.56°
Aspect	West
Lat/Long	33.1185°/76.9558°



Lake ID	GL283016E33047N
Lake Type	PGLC
Area (m2)	2827
Perimeter (m)	240
Elevation(m asl)	4571
Slope (deg.)	9.5°
Aspect	South
Lat/Long	33.0466°/76.9835°

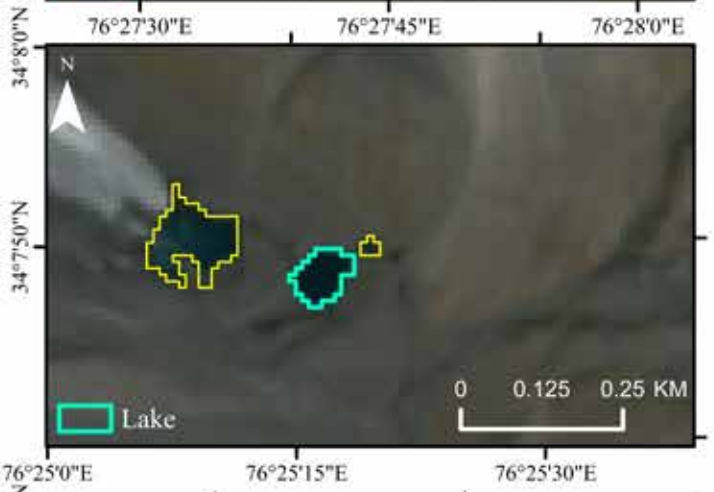


Lake ID	GL282882E33001N
Lake Type	PGLC
Area (m2)	2227
Perimeter (m)	221
Elevation(m asl)	4979
Slope (deg.)	5.96°
Aspect	South
Lat/Long	33.0012°/77.1177°

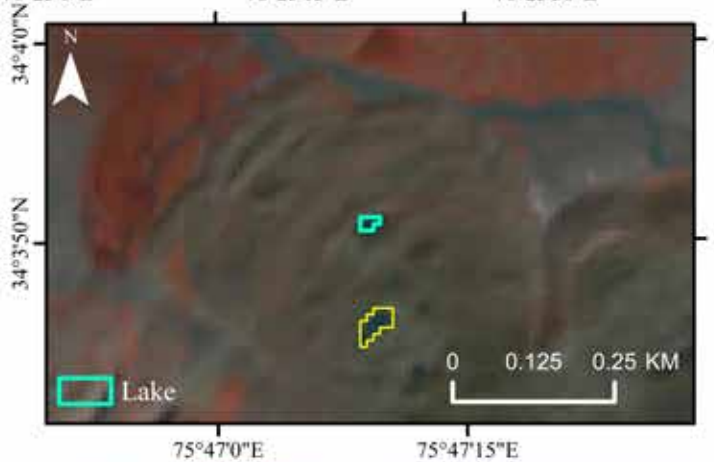


Lake ID	GL284266E34176N
Lake Type	PGLC
Area (m2)	1824
Perimeter (m)	201
Elevation(m asl)	3880
Slope (deg.)	9.7°
Aspect	South
Lat/Long	34.1765°/75.7344°

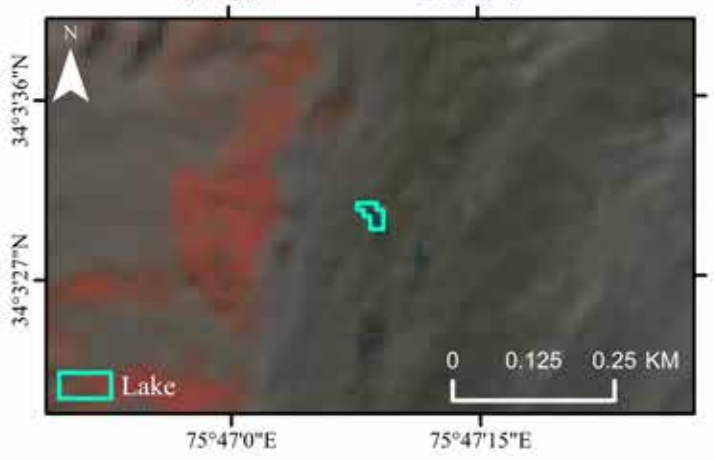
Lake ID	GL283538E34131N
Lake Type	PGLA
Area (m^2)	710
Perimeter (m)	121
Elevation(m asl)	4869
Slope (deg.)	14.02°
Aspect	North-East
Lat/Long	34.1306°/76.4622°



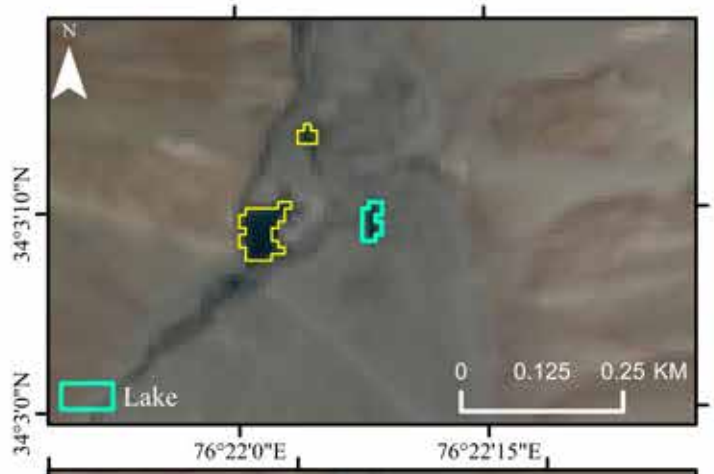
Lake ID	GL283578E34130N
Lake Type	PGLA
Area (m2)	710
Perimeter (m)	121
Elevation(m asl)	5144
Slope (deg.)	6.9°
Aspect	South-East
Lat/Long	34.1305°/76.4221°



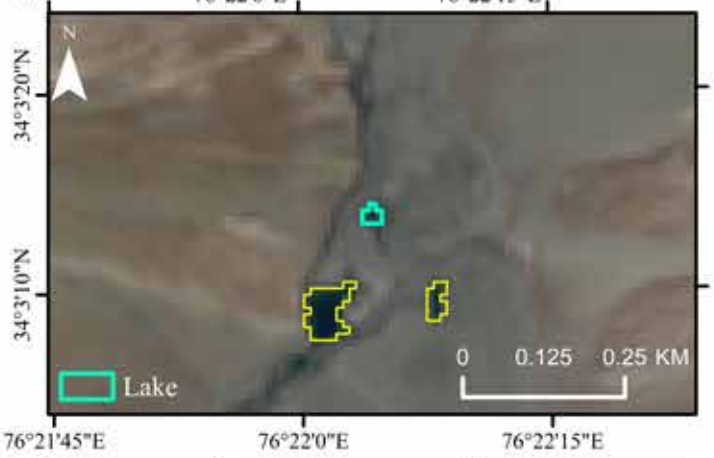
Lake ID	GL284214E34064N
Lake Type	PGLA
Area (m2)	522
Perimeter (m)	102
Elevation(m asl)	4128
Slope (deg.)	8.85°
Aspect	North-West
Lat/Long	34.0641°/75.7859°



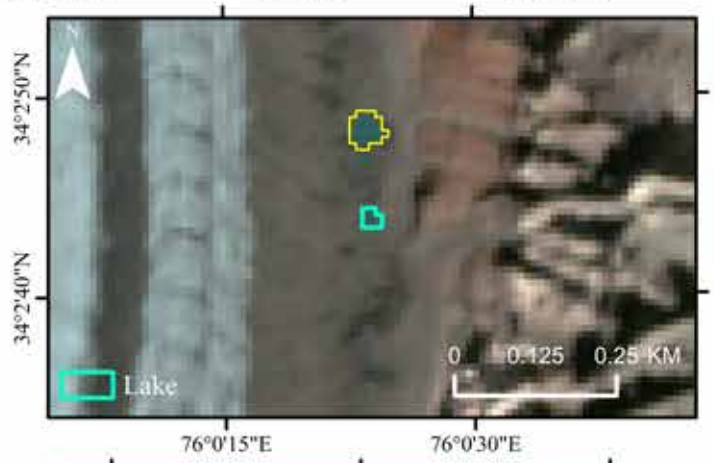
Lake ID	GL284214E34058N
Lake Type	SGL
Area (m2)	1011
Perimeter (m)	160
Elevation(m asl)	4193
Slope (deg.)	8.82°
Aspect	North
Lat/Long	34.0584°/75.7857°



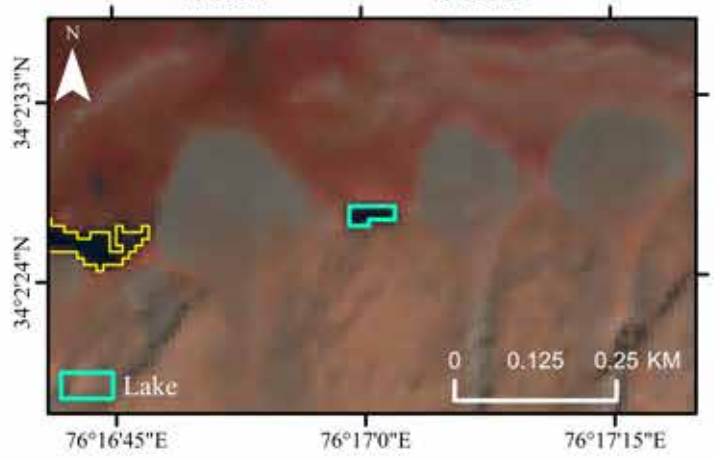
Lake ID	GL283631E34053N
Lake Type	OL
Area (m²)	1505
Perimeter (m)	200
Elevation(m asl)	3997
Slope (deg.)	3.34°
Aspect	South-East
Lat/Long	34.0526°/76.3689°



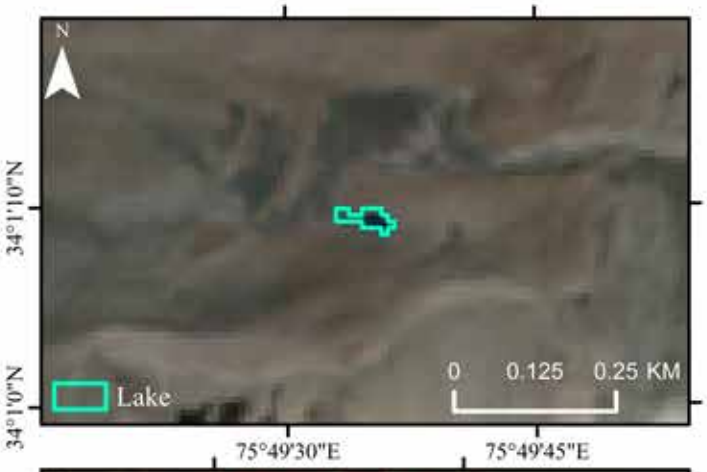
Lake ID	GL283632E34054N
Lake Type	OL
Area (m2)	709
Perimeter (m)	121
Elevation(m asl)	3994
Slope (deg.)	4.69°
Aspect	South
Lat/Long	34.0538°/76.3678°



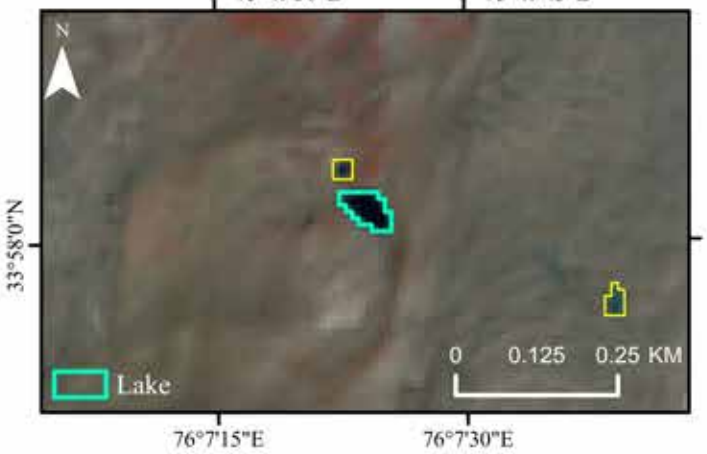
Lake ID	GL283993E34046N
Lake Type	SGL
Area (m2)	806
Perimeter (m)	120
Elevation(m asl)	4332
Slope (deg.)	8.59°
Aspect	North-West
Lat/Long	34.0455°/76.0066°



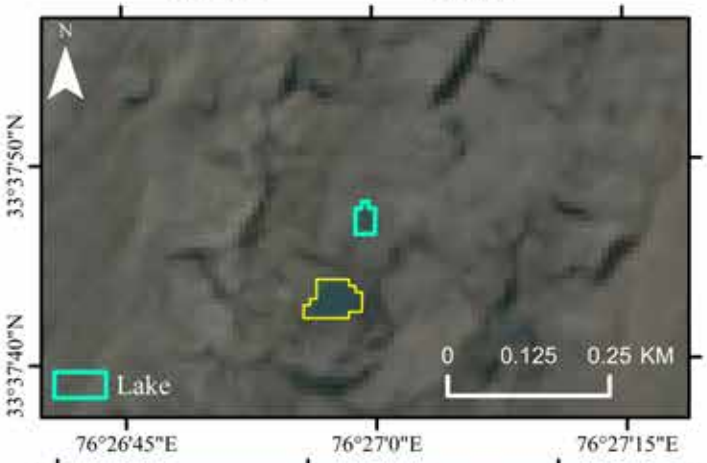
Lake ID	GL283717E34041N
Lake Type	OL
Area (m2)	1726
Perimeter (m)	201
Elevation(m asl)	3956
Slope (deg.)	18.96°
Aspect	South
Lat/Long	34.0409°/76.2834°



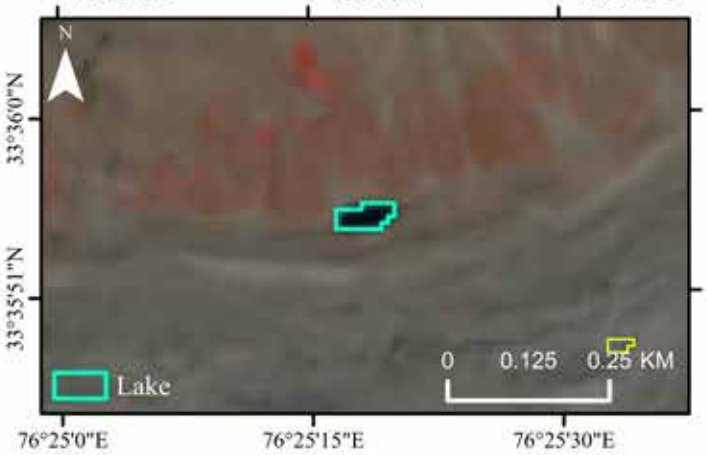
Lake ID	GL284174E34019N
Lake Type	PGLA
Area (m^2)	1904
Perimeter (m)	280
Elevation(m asl)	4280
Slope (deg.)	22.48°
Aspect	South
Lat/Long	34.0193°/75.8263°



Lake ID	GL283877E33967N
Lake Type	PGLA
Area (m2)	3310
Perimeter (m)	280
Elevation(m asl)	4450
Slope (deg.)	11.98°
Aspect	South
Lat/Long	33.9671°/76.1233°



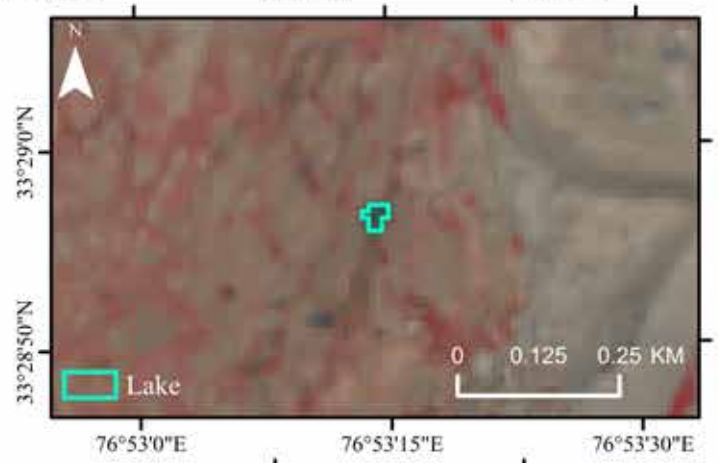
Lake ID	GL283550E33630N
Lake Type	SGL
Area (m2)	1304
Perimeter (m)	160
Elevation(m asl)	4266
Slope (deg.)	3.7°
Aspect	South
Lat/Long	33.6297°/76.4498°



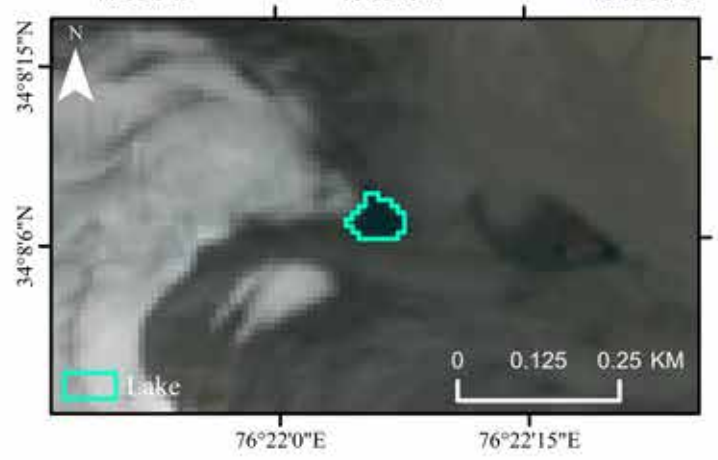
Lake ID	GL283578E33599N
Lake Type	PGLA
Area (m2)	2913
Perimeter (m)	260
Elevation(m asl)	4523
Slope (deg.)	8.96°
Aspect	South
Lat/Long	33.5986°/76.4217°

Lake ID	GL283312E33374N
Lake Type	PGLA
Area (m^2)	1315
Perimeter (m)	180
Elevation(m asl)	5050
Slope (deg.)	7.49°
Aspect	South
Lat/Long	33.3742°/76.6882°

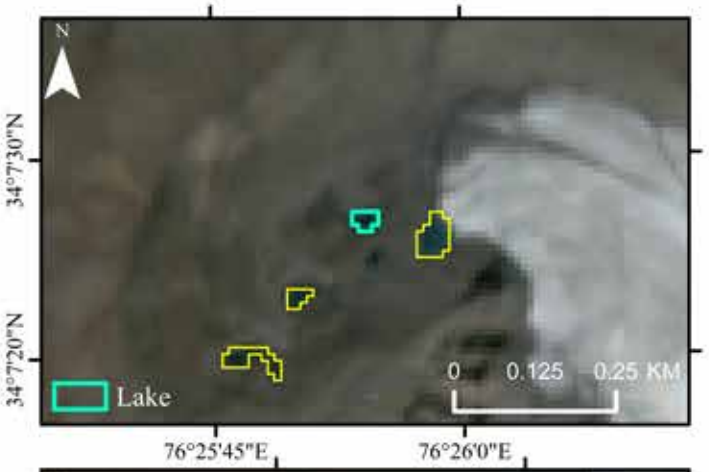
Lake ID	GL283599E33758N
Lake Type	SGL
Area (m2)	1524
Perimeter (m)	221
Elevation(m asl)	4397
Slope (deg.)	4.75°
Aspect	North-East
Lat/Long	33.758°/76.4012°



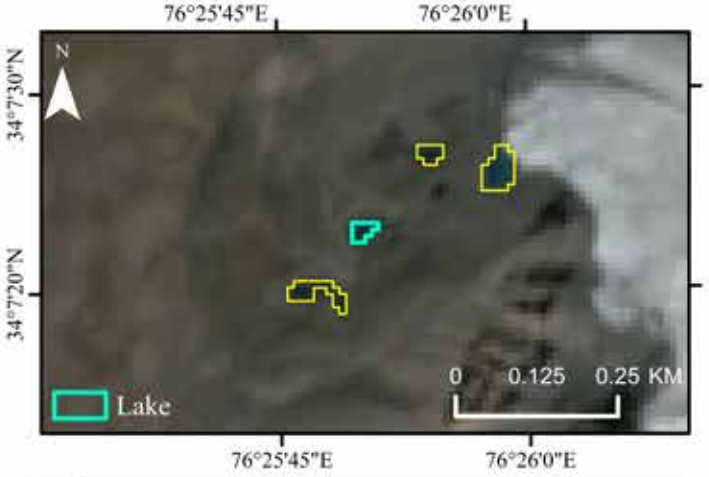
Lake ID	GL283113E33482N
Lake Type	OL
Area (m2)	1117
Perimeter (m)	161
Elevation(m asl)	3522
Slope (deg.)	3.04°
Aspect	West
Lat/Long	33.4824°/76.8873°



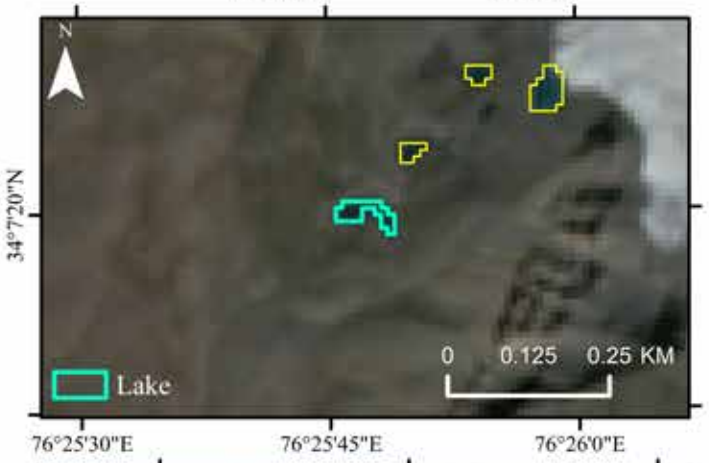
Lake ID	GL283632E34135N
Lake Type	PGLC
Area (m2)	4375
Perimeter (m)	323
Elevation(m asl)	5015
Slope (deg.)	15.88°
Aspect	East
Lat/Long	34.1353°/76.3683°



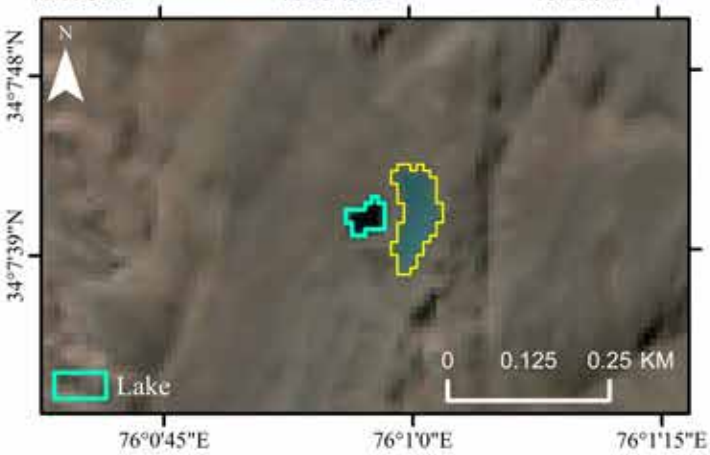
Lake ID	GL283568E34124N
Lake Type	PGLC
Area (m²)	1036
Perimeter (m)	142
Elevation(m asl)	5089
Slope (deg.)	6.54°
Aspect	South
Lat/Long	34.1241°/76.4317°



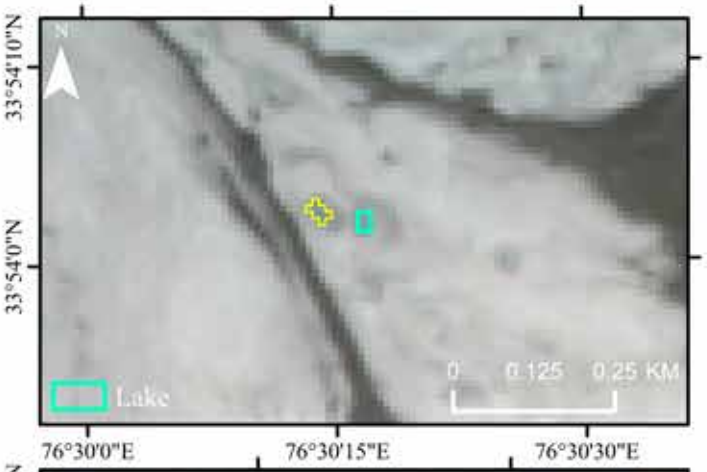
Lake ID	GL283570E34123N
Lake Type	PGLA
Area (m2)	924
Perimeter (m)	142
Elevation(m asl)	5088
Slope (deg.)	6.81°
Aspect	North-West
Lat/Long	34.123°/76.4305°



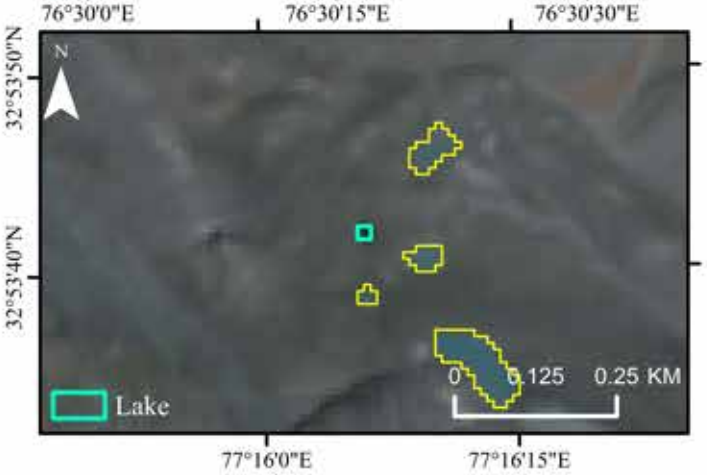
Lake ID	GL283570E34122N
Lake Type	PGLA
Area (m2)	2199
Perimeter (m)	323
Elevation(m asl)	5084
Slope (deg.)	6.88°
Aspect	South-West
Lat/Long	34.1222°/76.4298°



Lake ID	GL283984E34128N
Lake Type	PGLA
Area (m2)	2313
Perimeter (m)	240
Elevation(m asl)	4782
Slope (deg.)	8.38°
Aspect	North-East
Lat/Long	34.128°/76.0159°

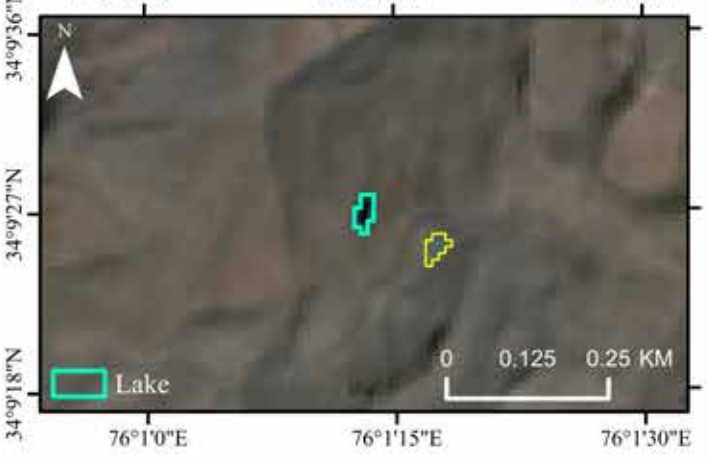


Lake ID	GL283495E33901N
Lake Type	SGL
Area (m^2)	583
Perimeter (m)	99
Elevation(m asl)	5182
Slope (deg.)	8.11°
Aspect	North-West
Lat/Long	33.9006°/76.5046°

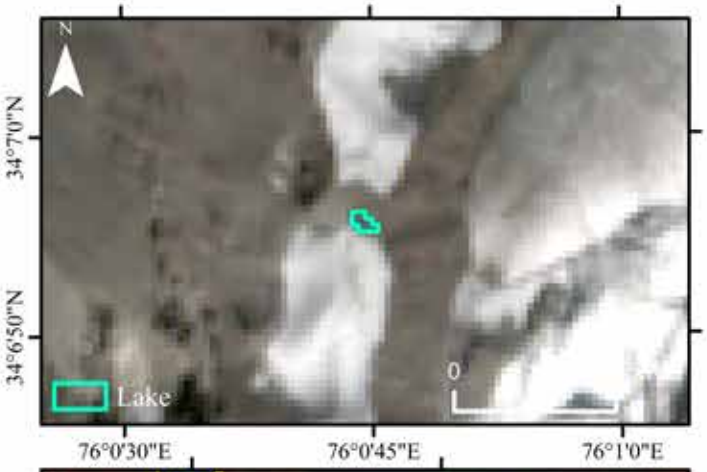


Lake ID	GL282732E32895N
Lake Type	PGLA
Area (m2)	405
Perimeter (m)	81
Elevation(m asl)	5030
Slope (deg.)	3.2°
Aspect	South-East
Lat/Long	32.895°/77.2683°

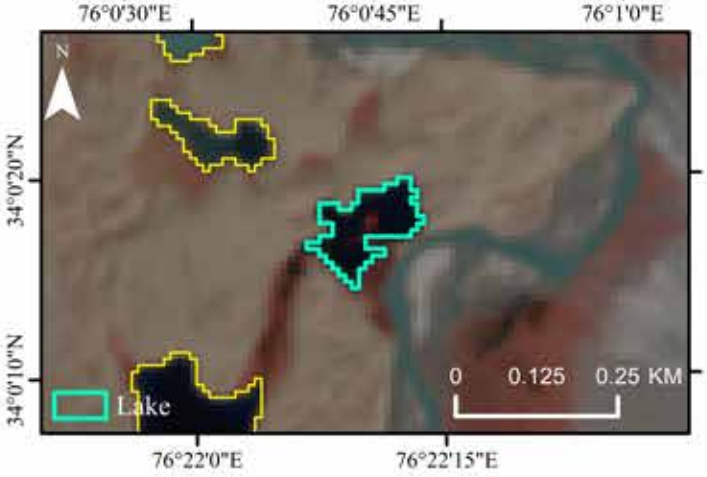
Lake ID	GL282721E32892N
Lake Type	PGLA
Area (m2)	1233
Perimeter (m)	162
Elevation(m asl)	5164
Slope (deg.)	11.76°
Aspect	West
Lat/Long	32.8921°/77.2791°



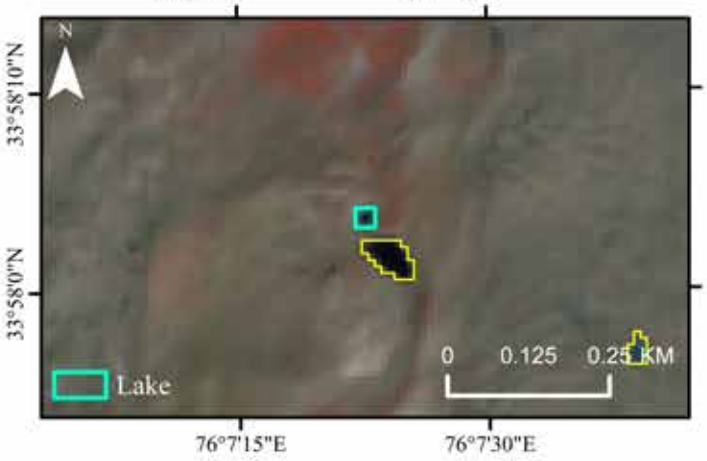
Lake ID	GL283980E34158N
Lake Type	PGLA
Area (m2)	1307
Perimeter (m)	180
Elevation(m asl)	4807
Slope (deg.)	6.28°
Aspect	East
Lat/Long	34.1575°/76.0203°



Lake ID	GL283988E34115N
Lake Type	PGLC
Area (m²)	822
Perimeter (m)	141
Elevation(m asl)	5155
Slope (deg.)	19.5°
Aspect	North-East
Lat/Long	34.1154°/76.0123°



Lake ID	GL283630E34005N
Lake Type	PGLA
Area (m2)	13952
Perimeter (m)	841
Elevation(m asl)	3986
Slope (deg.)	5.04°
Aspect	South-West
Lat/Long	34.0049°/76.3695°



Lake ID	GL283877E33968N
Lake Type	PGLA
Area (m2)	909
Perimeter (m)	121
Elevation(m asl)	4448
Slope (deg.)	10.12°
Aspect	South
Lat/Long	33.9677°/76.1229°

About the Institute:

G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora was established in 1988, during the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant, as an autonomous Institute of the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India. The institute has been identified as a focal agency to advance scientific knowledge, to evolve integrated management strategies, demonstrate their efficacy for conservation of natural resources, and to ensure environmentally sound development in the entire Indian Himalayan Region (IHR).

The Institute follows a multidisciplinary and holistic approach in all its Research and Development programmes with emphasis on interlinking natural and social sciences and particular attention is given to the conservation of fragile mountain ecosystems, indigenous knowledge systems and sustainable use of natural resources. Training, environmental education and awareness to different stakeholders are essential components of all the R&D programmes of the Institute.

G.B. Pant National Institute of Himalayan Environment (NIHE)

(An Autonomous Institute of Ministry of Environment, Forest and Climate Change, Government of India)

Kosi-Katarmal, Almora, Uttarakhand- 263643

(Code +91-5962) 241015 (Office), EPABX: (05962) 241041, 241154 Fax: (05962) 241014, 241150

Email: psdir@gbpihed.nic.in | Website: http://gbpihed.gov.in