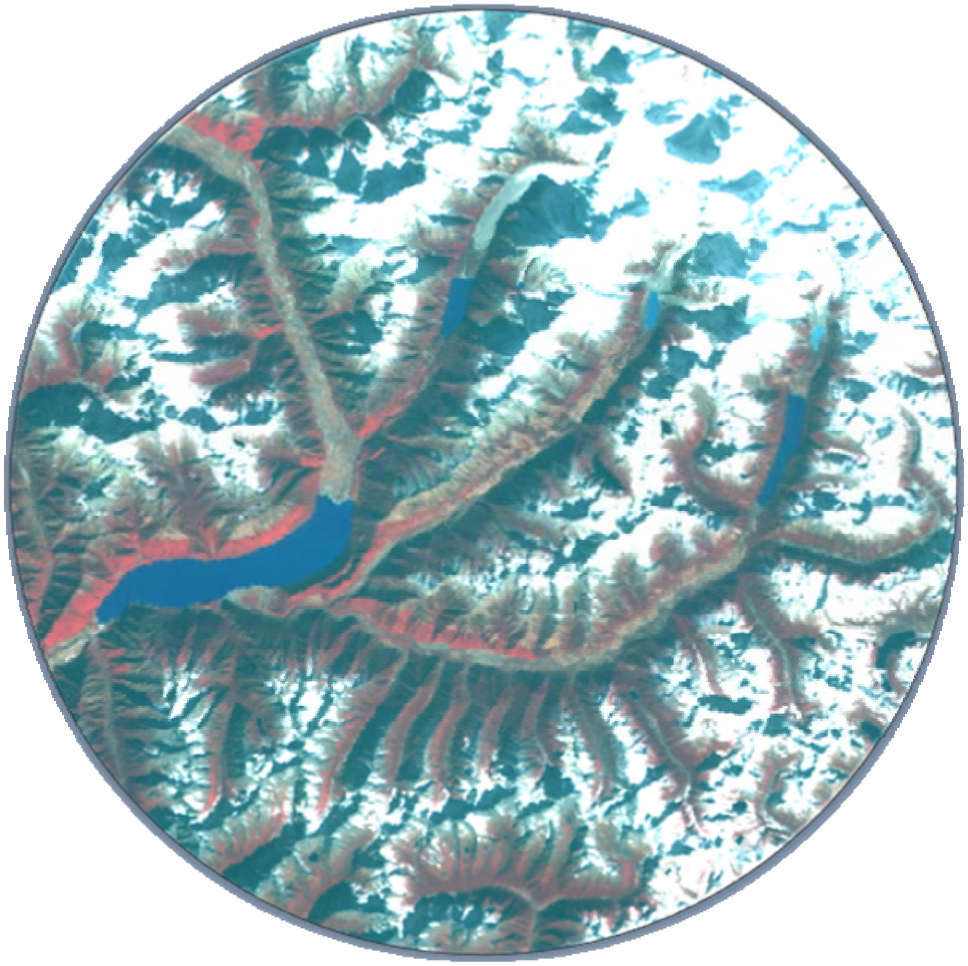
Inventory and Monitoring of Glacial Lakes/Water Bodies in the Himalayan Region of Indian River Basins

Technical Document



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<tr><td>Abstract
(with Keywords)</td><td colspan="4">Glacial lakes are common in the high elevation of glacierised basin. They are formed when glacial ice or moraines impound water. These lakes normally drain their water through seepage in front of the retreating glacier. Flash floods caused by the outburst of glacial lakes, called as Glacial Lake Outburst Flood (GLOF), are well known in Himalayan terrain, where such lakes are formed due to landslides. On the behest of Climate Change and IAD Directorate, Central Water Commission (CWC), satellite remote sensing based mapping, inventory and monitoring of the glacial lakes and water bodies, covering Indian river basins of Himalayan region, was taken up.

The inventory of glacial lakes/water bodies was initially done for the year 2009 using IRS Satellite data. Subsequently, monitoring of these glacial lakes/water bodies in the months from June to October were also completed for three subsequent years (2011, 2012 & 2013).

This document presents the details of the project on inventory and monitoring of glacial lakes and water bodies in the Himalayan region of Indian river basins using satellite remote sensing technique.</td></tr>
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1. Introduction

Glacial lakes are common in the high elevation of glacierised basin. They are formed when glacial ice or moraines impound water. There are varieties of such lakes, ranging from melt water ponds on the surface of glacier to large lakes in side valleys dammed by a glacier in the main valley. These lakes normally drain their water through seepage in front of the retreating glacier. The moraine creates topographic depression in which the melt water is generally accumulated leading to formation of glacial lake. When this lake is watertight, melt waters will accumulate in the basin until seepage or overflow limits the lake level. Such moraine-dammed lakes appear to be the most common type of glacial lakes. The impoundment of the lake may be unstable, leading to sudden release of large quantities of stored water. Failure of these ice or moraine dams as very destructive events has been documented throughout the world. Flash floods caused by the outburst of glacial lakes, called as Glacial Lake Outburst Flood (GLOF), are well known in Himalaya where such lakes had been formed by landslides. The unabated shrinkage of Himalayan glaciers has resulted in the formation of more moraine-dammed lakes. Bursting of such lakes leads to flash floods and these floods redistribute sediments and modify the landscape.

Planning & Development Directorate of Central Water Commission (CWC) desired to use satellite remote sensing techniques to map, inventory and monitor the glacial lakes & water bodies in Himalayan region of Indian river basins. In this connection, CWC approached National Remote Sensing Centre (NRSC) to carry out the study using the latest satellite remote sensing data. Accordingly, NRSC carried out this study for inventory and monitoring of glacial lakes/water bodies in the Himalayan region of Indian River basins using satellite remote sensing technique.

2. Remote Sensing Technology

Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. Satellite remote sensing technology contributed significantly to the acquisition of Earth’s resources and thus helping for better management of these resources. Satellite remote sensing plays a complementary role to other means of spatial data acquisition i.e., through conventional procedures. Satellite remote sensing offers several unique advantages quick data collection, reliability, more accurate, repetitive collection, geometric integrity and digital storage, which makes it an ideal tool for mapping, inventorying and monitoring the natural resources.

Glaciers and glacial lakes are generally located in remote areas, where access is through tough and difficult terrain. The inventory of glacial lakes using conventional methods requires extensive time and resources together with undergoing hardship in the field. Creating inventories and monitoring of the glacial lakes can be done quickly and correctly using satellite images and aerial photographs. Use of these images and photographs for the evaluation of physical conditions of the area provides greater accuracy. The multi-stage approach using remotely sensed data and field investigation increases the ability and accuracy of the work. Visual and digital image analysis techniques integrated with

techniques of geographic information systems (GIS) are very useful for the study of glacier, glacial lakes.

3. Study area

The present study is carried out for the area covering Himalayas under the major river basins of Indus, Ganga and Brahmaputra. The study area extends across different countries namely India, Nepal, Bhutan and China. The index map showing study area is given in Figure 1.

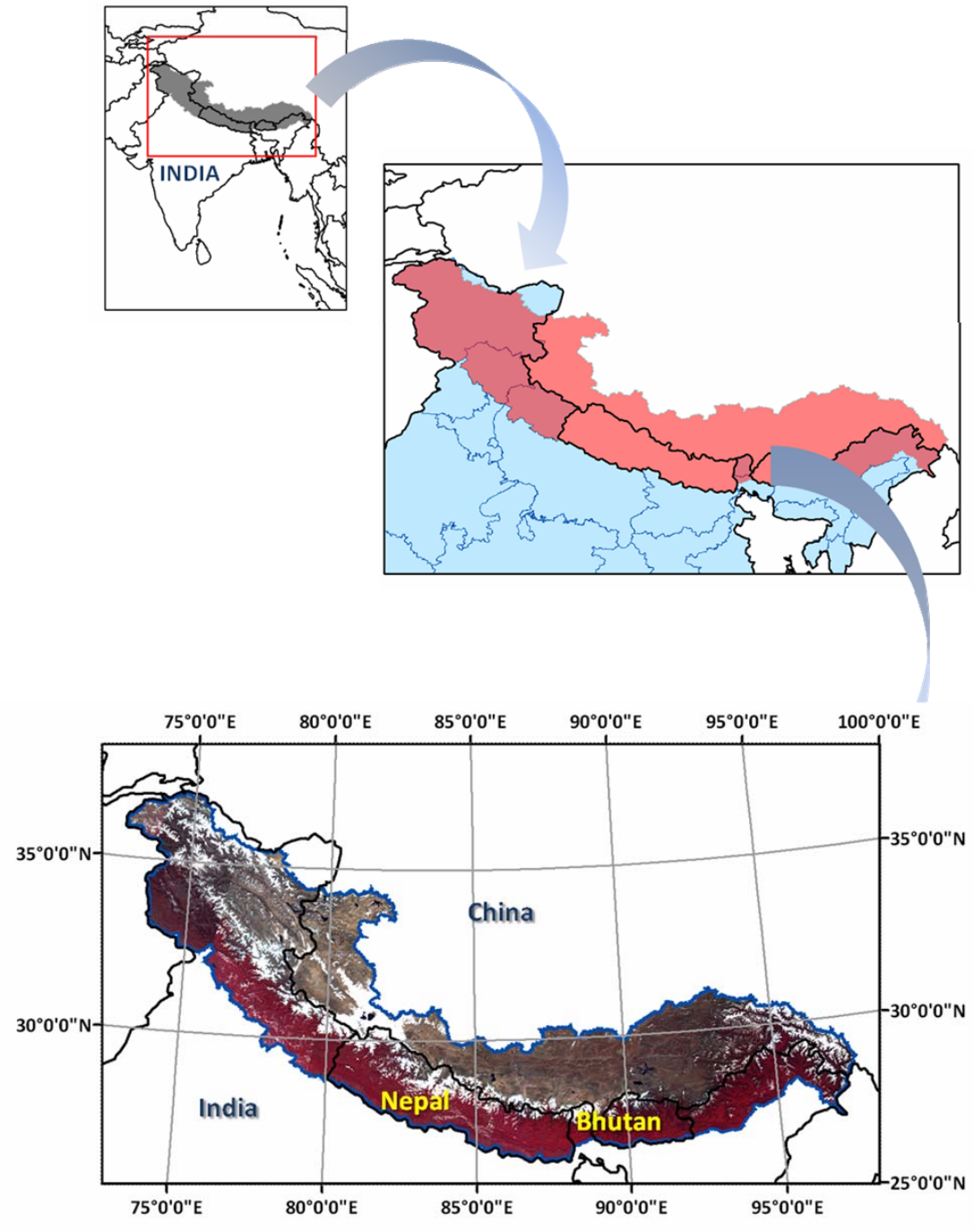

Figure 1 Index map of study area

4. Methodology

For glacial lake identification from satellite images, it is preferable to have images with least snow cover and cloud free. Generally the least snow cover occurs in the period between May and September in the Himalayas. But during this season, monsoon clouds will block the views. If snow precipitation is late in the year, winter images are also suitable except for the problem of long relief shadows in the high mountain regions. In the present study, the satellite data from AWiFS was browsed for cloud cover during the period of May-Nov, 2009.

The inventory of glacial lakes and water bodies in the Himalayan region using satellite images involves the following steps.

- Basin boundary delineation
- Ortho-rectification of satellite data
- Identification & digitization of glacial lakes & water bodies
- Organisation of digital database

The flow chart depicting the methodology is shown in figure 2.

In this study, orthorectification of AWiFS data was carried out using Projective Transform model available in ERDAS Imagine software. The Projective Transform models are simulation models purely solved by the Ground Control Points (GCPs). The orthorectified Landsat ETM images were used as reference image for collections of GCPs and the elevation values for GCPs were collected from SRTM DEM.

The glacial lakes & water bodies were delineated based on the visual interpretation of satellite images of Resourcesat AWiFS sensor. Identification of features was done through panchromatic mode and/or different colour combinations of the multi-spectral bands namely green, red, near infrared and shortwave infrared. To identify the glacial lakes & water bodies, different image enhancement techniques are used to improve the visual interpretation. This method is complimented with the knowledge and experience of the Himalayan terrain conditions for inventorying glacial lakes and water bodies. With different spectral band combinations in false colour composite (FCC) and in individual spectral bands, glacial lakes and water bodies can be identified. Figure 3 and Figure 4 shows how typical water bodies and glacial lakes respectively are seen in satellite image. The water spread area of the lakes in images ranges in appearance from light blue to blue to black. The frozen lakes appear white in colour. They are generally associated with glaciers in the case of high lying areas, or rivers in the case of low lying areas.

The boundary of glacial lakes and water bodies are digitized using on-screen digitisation techniques as polygon feature. The polygons are geoprocessed and the water spread area of glacial lakes/water bodies were computed digitally. The lakes are identified and digitized as on the date of satellite data. There is a possibility that some lakes that are frozen or overlaid

with snow might have been omitted in this inventory. However, during monitoring phase of this study, the inventory was updated. Even though it was planned to map only the glacial lakes & water bodies that are larger than 50 ha in area, in this inventory, glacial lakes and water bodies having area more than 10 ha were also digitised.

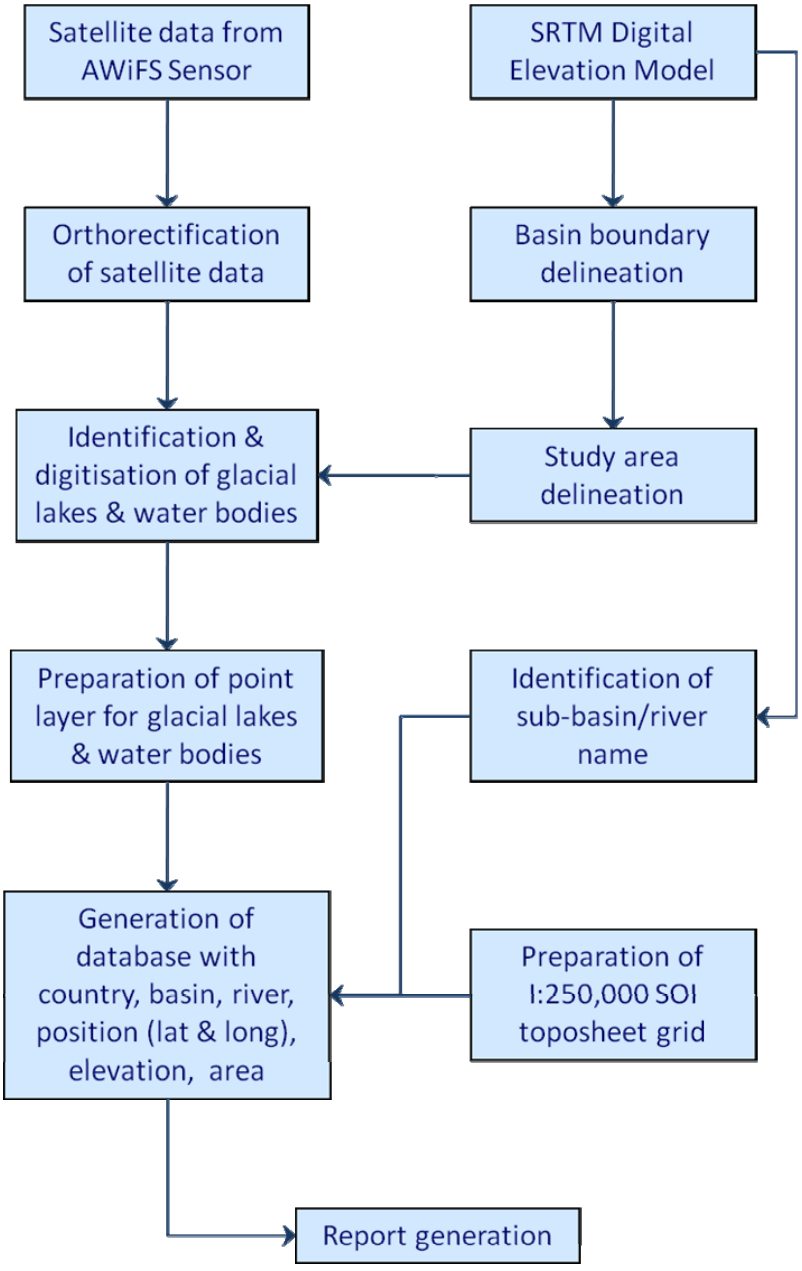

Figure 2 Flow chart showing methodology

SWIR NIR Red

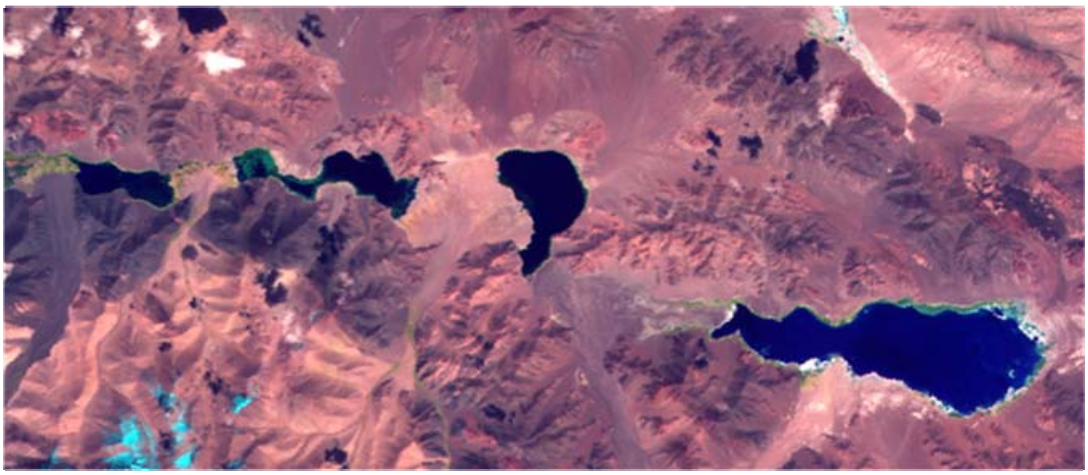

Figure 3 Water bodies as seen in satellite image

SWIR NIR Red

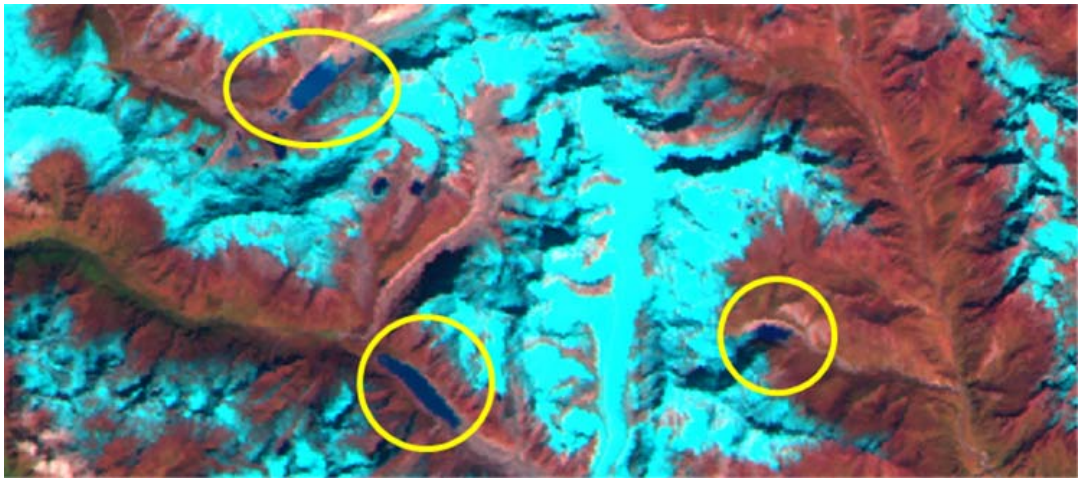

Figure 4 Glacial lakes as seen in satellite image

5. Potential Use of Glacial Lakes/Water Bodies Inventory

The shrinkage of glaciers results in the formation of moraine-dammed lakes. Bursting of such lakes leads to flash floods called Glacial Lake Outburst Flood (GLOF), which are well known phenomenon in Himalayas. In order to mitigate GLOF, risk assessment and prioritisation of potential GLOF lakes is important. The shape and size of the glacial lakes is one of the important parameter among many criteria for risk assessment. In addition to this, the rate of change in size of the glacial lakes/water bodies also an important criteria. The inventory and monitoring database will be useful in GLOF risk assessment. This will be useful for studying the impact of climate change on glacial lakes/water bodies in Himalayas.

6. Limitations

Since AWiFS data of 56 m resolution was used in mapping the glacial lakes/water bodies, this database should be used at scales smaller than 1:250,000.

7. Disclaimer

- The accuracy of identification of glacial lakes/water bodies are subject to availability of cloud/snow free satellite data.
- Data cannot be used for any legal purpose.
- Maps should not be used for commercial purpose.
- User shall exercise reasonable skill, care and diligence while using the information and will keep indemnified NRSC/ISRO in respect of any loss, damage or claim howsoever arising out of use of this information.
- User of this data/information will consult NRSC to commercially exploit / use the intellectual property generated in the projects.

8. Project Team

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10. Citation

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11. References

NRSC, June 2011. *Final Report of "Inventory and Monitoring of Glacial Lakes / Water Bodies in the Himalayan Region of Indian River Basins"*, Technical Report Published by National Remote Sensing Centre, Hyderabad.

NRSC, April 2012. *Report on "Monitoring of Glacial Lakes/Water Bodies in the Himalayan Region of Indian River Basins during 2011"*, Technical Report Published by National Remote Sensing Centre, Hyderabad.

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