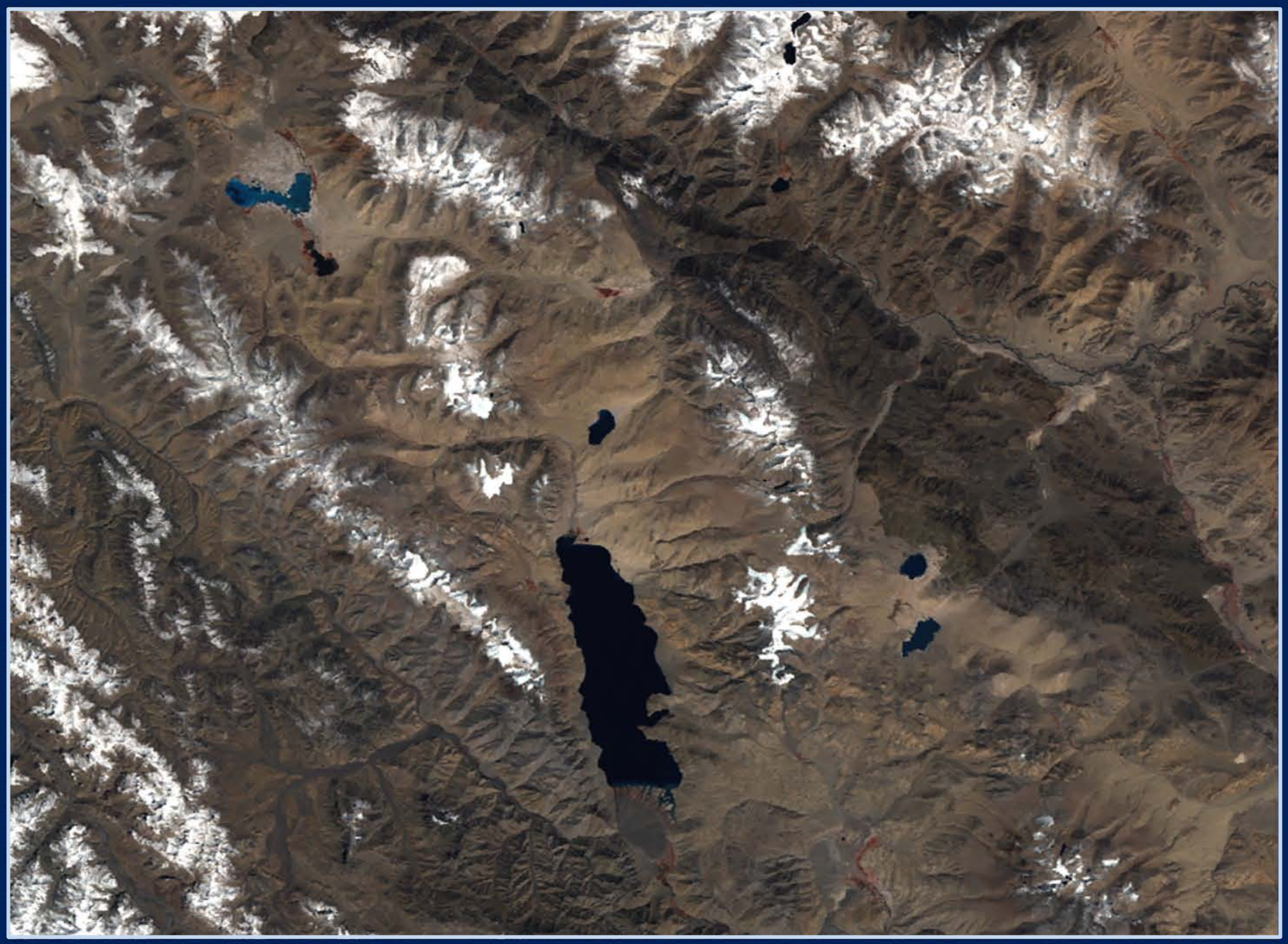
सत्यमेव जयते

NATIONAL WETLAND ATLAS:

HIGH ALTITUDE LAKES OF INDIA

SPONSORED BY MINISTRY OF ENVIRONMENT AND FORESTS
GOVERNMENT OF INDIA



इसरो isro

SPACE APPLICATIONS CENTRE, ISRO
GOVT. OF INDIA

NATIONAL WETLAND ATLAS :

HIGH ALTITUDE LAKES OF INDIA

Sponsored by Ministry of Environment and Forests, Government of India

Space Applications Centre, ISRO, Government of India,

Ahmedabad – 380 015

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MESSAGE

I am delighted to introduce the Atlas on High Altitude Lakes, the latest in series published under the Ministry of Environment and Forests sponsored “National Wetland Inventory and Assessment” project prepared by the Space Applications Centre, ISRO, Ahmedabad. This exercise has been undertaken under National Natural Resources Management System (NNRMS) Standing Committee on Bio-resources and Environment (SC-B) of the Ministry of Environment and Forests.

I have been told that this atlas contains maps and statistics on the High Altitude Lakes (HALs) found exclusively in the Himalayan region at an altitude above 3000 m above mean sea level. These are very special wetlands and play significant role in the hydrological cycle and water resources of Indian subcontinent, and harbors unique biodiversity. However, very little scientific information is available for the most of the Himalayan High Altitude Lakes due to the remoteness, harsh climatic condition and inaccessibility of the terrain of the region.

Aware of their importance, India has already declared two such lakes as Ramsar sites, one Tso Morriri in Jammu & Kashmir and another the Chandertal in Himachal Pradesh. Efforts towards bringing more such lakes under notified/protected/Ramsar site are being initiated. An accurate and updated data base is the first and foremost requirement for such planning. I am sure this atlas fulfils this requirement.

I have also been told that this atlas has been prepared using the 2006-8 remote sensing images from the Indian Remote Sensing Satellite RESOURCESAT (IRS P6) including pre and post monsoon to achieve high accuracy of identification of lakes. The lakes are mapped at 1:50,000 scale for the entire Himalayan states, where as 1:25,000 scale mapping has been done for the state of Sikkim and the digital elevation data has been used to generate the elevation information and give the distribution pattern of lakes in relation to elevation.

I hope that this atlas provides details of size and altitude wise distribution of High Altitude Lakes at district and state level. This is the first such atlas of the High Altitude Lakes of the Himalayas. My congratulation to the scientists of Space Applications Centre, ISRO, Ahmedabad and Dr. G. V. Subrahamanyam, Advisor, Ministry of Environment and Forests and his team who worked for successful accomplishment of this project.

I am sure that this informative atlas will be of immense use to scientists, planners and other stakeholders.

Jayanthi Natarajan

(Jayanthi Natarajan)

XI Conference of Parties
CONVENTION ON BIOLOGICAL DIVERSITY
HYDERABAD INDIA 2012

तिष्यरक्षित चटर्जी
Dr. Tishya Chatterjee

सत्यमेव जयते

सचिव
भारत सरकार
पर्यावरण एवं वन मंत्रालय
Secretary
Government of India
Ministry of Environment and Forests

MESSAGE

The ‘High Altitude Lakes- HAL’ found at an altitude above 3000 m, above mean sea level (amsl), mainly in the Himalayan region, is one of the important natural wetlands of India. Many of the lakes in the Himalayan region are cross boarded ones, many sharing their catchments between two or more countries. However, very little scientific information is available about most of these lakes due to the harsh climatic set up and terrain condition. Satellite remote sensing technique is the most viable technique to gather information pertaining to such areas. Towards this, the Ministry of Environment & Forests sponsored a project “ National Wetland Inventory & Assessment- NWIA” with the objectives of mapping all the wetlands in the country at 1:50, 000 scale using satellite remote sensing data and creating the digital data base using Geographic Information System. Space Applications Centre, Ahmedabad - a premier Institute of Indian Space Research Organization implemented this project. Pre and post monsoon image data from the Indian Remote Sensing Satellite –Resourcesat-1 satellite was used to map the wetlands of India. The results of this study showed that India has 15.26 M ha area under wetlands, which is 4.63 per cent of the geographic area. The wetland atlases published for each state and UT is now available in MoEF site for public use. High Altitude Wetland (HAW) is one of the 19 classes of wetlands mapped for the first time.

The present atlas is a part of the output of NWIA project, specifically addressing the High Altitude Lakes. Digital Elevation Model (DEM) has been used to analyse the distribution of the lakes as per elevation gradient. The results are organized as per size of lakes and their altitudinal distribution. The two season image data has reflected the freezing and melting behavior and the vegetation status of lake and adjoining area. The data are organized at map sheet level (Survey of India), district and state level. Feature codification scheme has been used to give unique identity to each lake. This is the first such report of High Altitude Lakes of Himalaya.

I congratulate the Scientists at the Space Applications Centre, ISRO, Ahmedabad and Dr. G. V. Subrahmanayam, Advisor and his team in MoEF for successfully carrying out this project and in creating the spatial database of High Altitude Lakes and compiling the results in the form of Atlas. I sincerely hope that this will be of useful source of information to researchers, planners and other stakeholders.

(T. CHATTERJEE)

जहाँ है हरियाली।
वहाँ है खुशहाली।।

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FOREWORD

The Earth Observation Programme in India is focused towards the national natural resources management and planning requirement. India today has a number of state of art remote sensing satellites in orbit to meet the mapping and monitoring requirements of natural resources at various scales. Under National Resource Census programme, Indian Space Research Organisation is generating a number of thematic database at regular interval. Wetland is one of the important resources and of great socio-economic value and role in hydrology. The first mapping of wetlands of India had been carried out by Space Applications Centre (SAC) at 250, 000 scale using Indian Remote Sensing data from IRS LISS II of 1992-93. Realising the requirement of upgrading the wetland maps at 1:50, 000 scale, SAC took up the task under the "National Wetland Inventory & Assessment-NWIA" project sponsored by Ministry of Environment and Forests. The wetland atlases of all the states and Union territories have been prepared at 1:50, 000 scale using RESOURCESAT (IRS P6) LISS III data of 2006-8. The atlases have been released for public use since June 2011.

This atlas is part of the NWIA results addressing one of the most important wetland class - High Altitude Lakes (HALs). These are found exclusively in the Himalayan region at an altitude above 3000 m. These are very special wetlands with unique biodiversity due to the extreme climatic regime. They play significant role in the hydrological cycle and water resources of Indian subcontinent and of great socio-economic importance to the local community. Till date there has been no inventory of HALs. This Atlas contains maps and statistics of HALs in India. The mapping has been done at 1:50, 000 scale for all the Himalayan states, while 1:25,000 scale mapping has been done additionally for the state of Sikkim. The Digital Elevation Model data has been used to generate the elevation information and identify the lakes harboured above 3000 m. The atlas also contains information on size wise and altitude wise distribution of HALs. The district and state level maps are shown in the Atlas, while the original database also contains topographic map sheet level information.

I congratulate the scientific team for taking this initiative to bring out this exclusive atlas on High Altitude Lakes. I am sure that this informative atlas will be of immense value to researchers, planners as well as general public.

(A S Kiran Kumar)

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Wetlands are defined as 'lands transitional between terrestrial and aquatic eco-systems where the water table is usually at or near the surface or the land is covered by shallow water. Conservation of wetlands has gained momentum in recent years due to their significant role in hydrological processes. India with its large geographic spread, diverse climate and terrain, harbors a diverse types of wetlands. Inventory of wetlands at 50,000 scale has been considered as the minimum requirement, as numerous small size wetlands abound in India which have significant value to local environment. To fulfill this objective, the project "National Wetland Inventory & Assessment- NWIA" has been taken up by Space Applications Centre, ISRO, Ahmedabad. We acknowledge the financial grant from Ministry of Environment & Forestry (MoEF), Govt. of India for execution of this project. The project has been successfully completed and results have been brought out as Atlases for each state and Union Territory of India. We are grateful to H'ble Minister Shri Jairam Ramesh for gracing the function to release the publications for public use on June 2011. We are thankful to MoEF for facilitating public access to all the atlases and information brought out of this project through the website.

High Altitude Wetland is one of the 19 classes of wetlands of India that have been mapped under NWIA project. These are mainly lakes occurring above 3000 m elevation range and mainly found in the Himalayan states. Realizing the need by planners, researchers, special effort has been made to bring out this special atlas on High Altitude Lakes.

We are grateful to Shri Kiran Kumar, Director, Space Applications Centre, for his encouragement to bring out this exclusive atlas. Earnest thanks are due to Dr. Jai Singh Parihar, Dy. Director, Space Applications Centre, who inspired us to carry out further churning of data and his guidance all along.

We are thankful to our collaborating partner institutes for implementation of the NWIA project in the respective Himalayan states. viz: Kashmir University, Srinagar, J&K, Remote Sensing Cell, Shimla, Himachal Pradesh, Uttarakhand Space Applications Centre, Dehradun, Uttarakhand and State Council of Science & Technology for Sikkim, Gangtok, Sikkim. The hard work put up by the team members associated in each state for implementation of the project is very praise worthy.

We acknowledge the positive role played by 16th SC-B (Standing Committee on Bio-resources and Environment) of NNRMS (National Natural Resources Management System) meeting in formulating this project. We are extremely thankful to the members of the "Steering Committee" of the project, under the chairmanship of Dr E J James, Director – Water Institute, Karunya University, for their periodical review, critical comments and appreciation of the efforts by the project team. We are thankful to SC-B under the chairmanship of Secretary, MoEF, for periodic review of the progress of the project and guidance towards timely completion of the work.

We are grateful to Dr G V Subramanyam, Adviser, MoEF, for his very active and positive role implementation of the NWIA project and bringing out this exclusive atlas. We are thankful Dr Harendra Kharkwal, Deputy Director, MoEF for his constant support in budget, project review and other management activities.

We acknowledge the efforts put by Mrs Yatisha P Vaishnav, Geology Department, M G Science Institute, Ahmedabad in finalization of map outputs for this atlas.

We are thankful to Dr Manab Chakraborty, Group Director, ATDG, SAC for his critical comments and providing some of the Figures concerning DEM used in this atlas. We are thankful to the members of "Technical Review Committee" of SAC for critical comments and suggestion to finalise this atlas.

(Sushma Panigrahy)

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1.0 BACKGROUND

The ‘high altitude wetlands-HAW’ is a generic term to describe “**areas of swamp, marsh, meadow, fen, peat-land or water bodies located at an altitude higher than 3000 m, above mean sea level (amsl), whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or saline**”. They are extreme ecosystems, characterised by adverse climate and presence of a seasonal or diurnal permafrost layer. The high altitude wetlands are fed by snow-melt, precipitation and springs, unlike lower altitudes lakes which receive water from local rains, through streams and runoff. Among the globally distributed areas of HAWs, the Himalaya and the Tibetan plateau is the largest and it harbours numerous lakes of different geological origin in myriad of shapes and sizes (Fig.1).

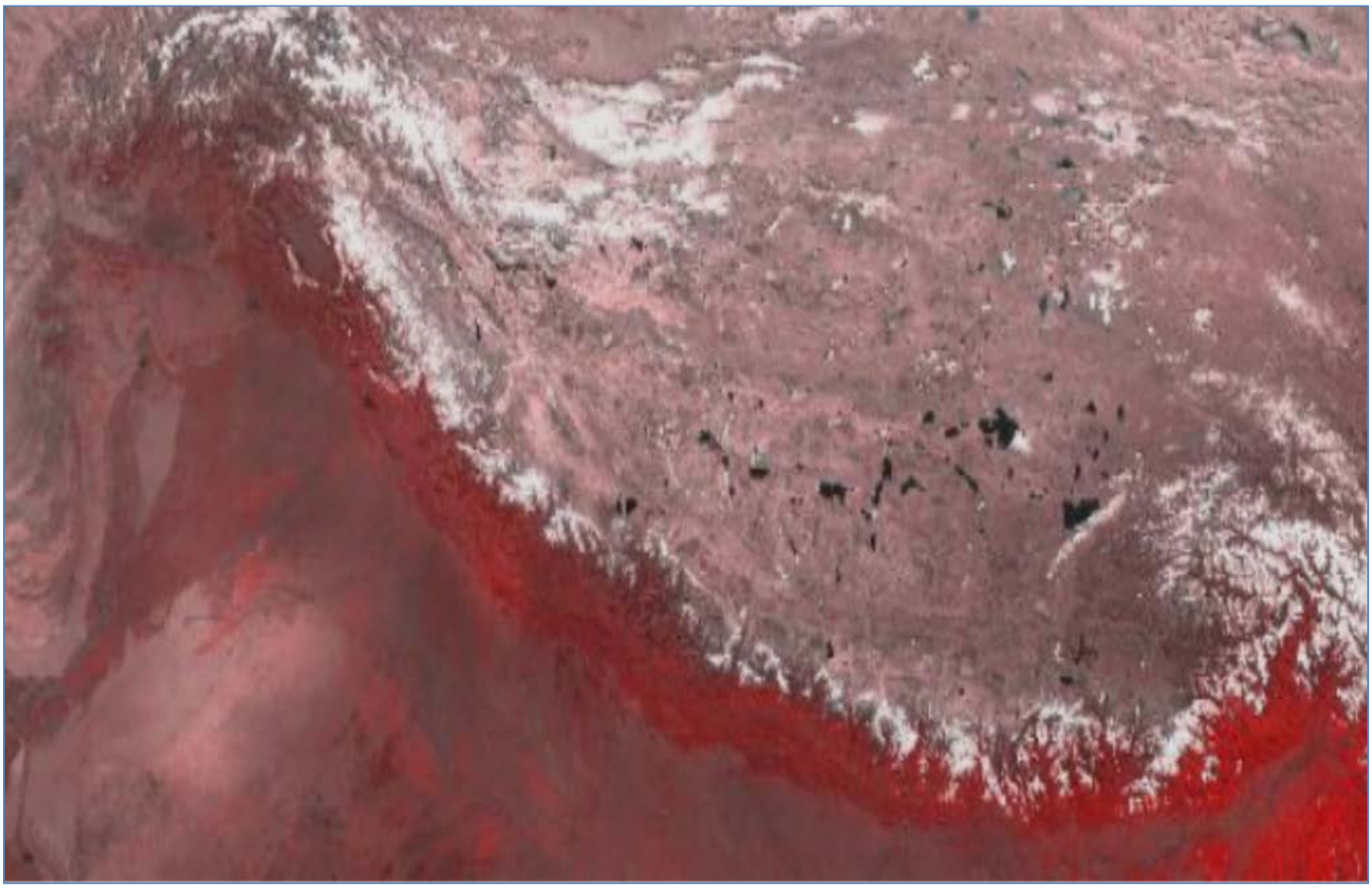


Fig.-1. The Himalayan-Tibetan plateau- the largest among the regions harbouring high altitude lakes in the world as seen in INSAT image.

One of the well known and highly revered high altitude lake of this region is Mansorovar, a large fresh water lake (Fig.2). Set amidst Mount Kailash and Mount Gurla Mandhata at the height of 4590 m amsl in the Tibetan Plateau, the lake has a circumference of about 88 km, spread over 320 km^2 and approximately 90 m deep. From the vicinity of this lake originate four of the great rivers of the Indian subcontinent. It is connected to another large lake- Rakshastal by a natural channel. The Himalayan high altitude lakes are characterised by freezing and melting cycle and have vertical mixing of water column. The water is relatively poor in nutrient and salinity is wide spread. The clear water allows deep penetration of electromagnetic radiation. The lakes are in general oligotrophic, biodiversity is low, but support unique and endemic species. The catchment of the lakes is generally above 4000m and devoid

of woody vegetation. The lake water is brackish or fresh, with or without inflow and out flow. The outflow of many lakes turns into streams and give rise to mighty rivers. Many large lakes of Lesser Himalaya are fault basin lakes, formed due to tectonic activity resulting in blocking of the streams/rivers during Holocene period. The main source of water is through precipitation and underground springs. Such lakes are found in Kumaun, Himachal Pradesh and Jammu region of India. The lakes show varying chemistry in terms of solutes, bio-geochemistry and mineralogy vis-à-vis eco-hydrology, primarily due to high altitude variation governing the climate, lithology, tectonics and intensity of erosion/ weathering at source.

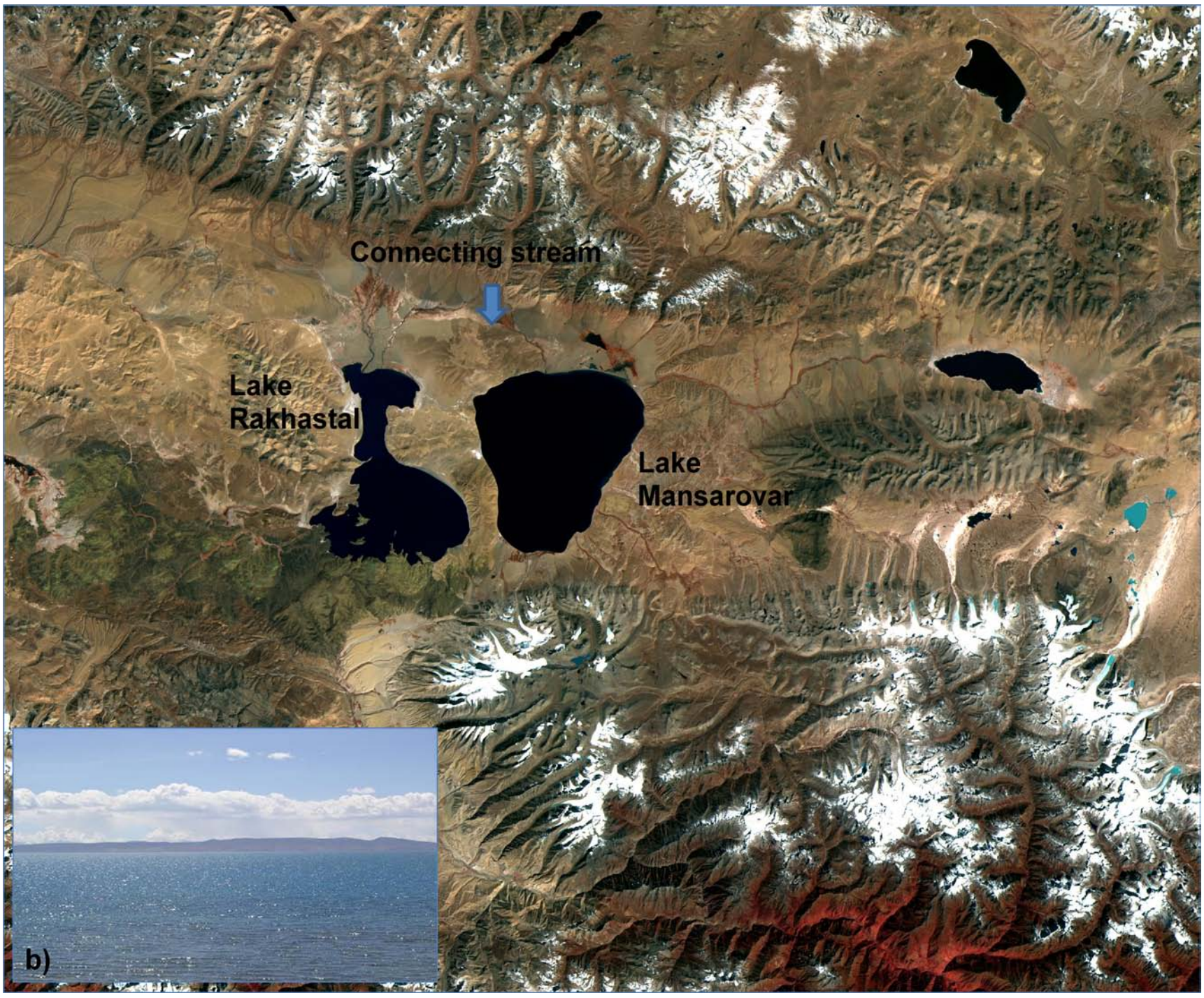
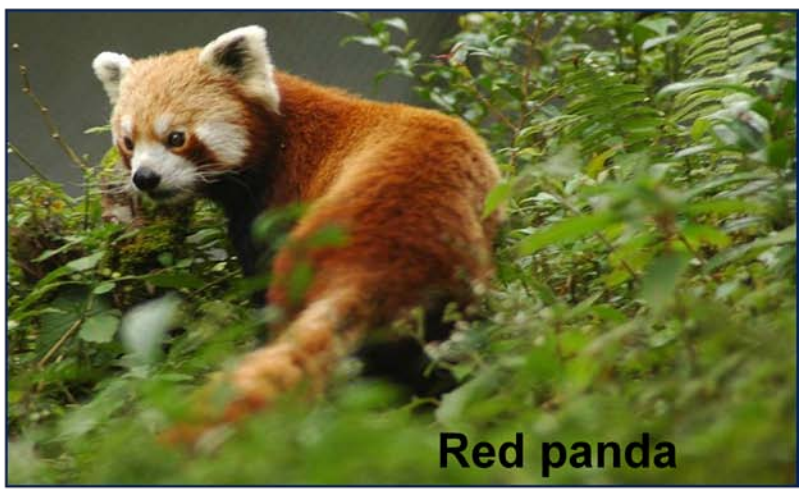


Fig.-2. Manasarovar- a well known high altitude lake in Himalayas and its surrounding as seen in IRS AWiFS image (summer season) ; (inset) photograph of the large lake with deep blue water.

High altitude wetlands play key role in the hydrology and ecology of rivers by acting as reservoirs or aquifers for storing water in wet seasons and releasing during the drier periods. All the major rivers in Southeast Asia namely the Ganges, Indus, Brahmaputra, Irrawaddy, Salween, Mekong, Amu Darya, Hilmand, Yangtze, and Yellow River originate in high altitude wetlands in the Himalayas and the Tibetan Plateau. Apart from their hydrological significance, HAWs play crucial role in hosting biodiversity, wildlife habitat, and socioeconomic aspects.



The high altitude lakes in Ladakh are the only breeding grounds for migratory bird species like the Black-necked Crane and Bar-headed Goose in India.

The lake catchment is habitat of many endemic fauna like Red Panda, wild Yak, wild ass or Kiang, Snow Leopard, Tibetan Gazzle, Tibetan Antelope, Musk Deer etc.

Rare and endemic flora of medicinal use abound the lake catchments.

The lakes play very important role in the socio-economy of local community regardless of whether they are settled or nomadic. Pasture lands near the wetlands are used for grazing livestock. In Ladakh about 90 percent of the economy of local nomadic communities, near the lakes, depends on their livestock like sheep, horses, yak which graze on wetland pastures.

Many of these lakes have religious significance to the communities. The marshy catchment area is also used for cultivation.

The unique climatic setup of the HAWs makes it sensitive to climate change. The high altitude wetlands are characterized by extreme cold, dry and alpine climate conditions, particularly due to low air temperature and higher ultraviolet radiation. The area has simple vegetation cover in terms of composition, predominantly grassland and shrubs, most of which are endemic to the region. The region experiences strong solar radiation and extreme temperature variation both diurnally and seasonally. Unlike other wetlands, these undergo a seasonal freezing and melting cycle that influence the bio-geo-cycle and ecology of the lakes. The freezing period generally extends from September to April. The region is influenced by East and Southwest Asian monsoon during summer and Westerly monsoon during winter. The mean annual precipitation ranges from 300 to 600 mm with more than 80 per cent of all annual precipitation occurring during the growing (warm) season. Global initiatives to understand the impact of global warming on the HAWs is accelerating. Initial studies indicate trend in glacier retreat and formation/expansion of glacial lakes. A baseline study conducted between 1999 and 2003 reported about 15,000 glaciers and 9,000 glacial lakes in Bhutan, Nepal, Pakistan, and selected basins of China and India (Mool et al. 2005). Some HAWs have the potential to cause catastrophic damage to people and the landscapes they live in by glacial lake outburst floods (GLOFs). Impact of climate change on the quality of water and biological productivity has also been predicted (Chatterjee A, et al 2010, WWF 2006). National and international collaborative efforts are now focused to gather more information to understand the ecology of HAWs and preserve the pristine environment of the HAWs. India has identified two HAWs as Ramsar sites (http://ramsar.org/key_guide_list2006). Efforts are being made to bring more HAWs under protection.

1.1 National Wetland Inventory and Assessment (NWIA)

Decisions concerning the conservation, management, and wise-use of wetlands including HAWs require accurate and updated inventory (Finlayson 1996). Over the past few decades, satellite remote sensing data has been widely used to map the natural resources of the earth, including wetlands. The technological advancement achieved in satellite remote sensing in terms of spatial, temporal, spectral resolution as well as development of analysis tools and techniques, has enhanced the scope of generating timely and accurate inventory of natural resources at range of scales. Wetlands, particularly the water bodies exhibit unique signature in the remote sensing data both from optical and microwave sensors. The usefulness of mapping wetlands using different types of remote sensing data is reviewed in detail by (Stacy L Ozesmi, Marvin E Bauer, 2002). Mapping of wetlands using multispectral optical remote sensing data, with high accuracy is now well established and used world over. With the launch of a series of Indian Remote Sensing Satellites, the nation has access to indigenous satellite remote sensing data of various spatial resolutions catering to wide range of scales of mapping.

Pre-requisite to any mapping/inventory is a proper classification system. The Ramsar definition has gained worldwide recognition and acceptance; and has been adopted as the basis for national wetland inventory. (Ramsar, Iran, 1971).

Ramsar definition of wetland " areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres." Article 2.1 of the Ramsar Convention also mention that areas defined as wetlands 'may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands'.

Based on the above frame work, national/regional wetland inventory are designed to support multi-scale, hierarchical classification system using earth observation technology. The national wetland inventory of India has been designed based on this guideline. India harbours diverse types of wetlands, both natural and manmade. The first wetland inventory of India was carried out using satellite remote sensing data of 1992-93 at 1:250,000 scale (Garg et al., 1998). However, no mapping of HAWs was done at a larger scale. An updated inventory of the wetlands of the nation using satellite remote sensing data at 1:50,000 scale was taken up by Space Applications Centre under the project "National Wetland Inventory and Assessment (NWIA)' sponsored by Ministry of Environment & Forests, Govt. of India. A classification system based on IUCN/RAMSAR definition and amenable to remotely sensed data was designed and used to categorise the wetlands into 19 types under a hierarchical system (Anon, 2011, Panigrahy et al., 2012). This classification system includes inland and coastal wetlands at level-I followed by level-II comprising natural and man-made wetlands, which were further categorised to account for 19 types of wetlands at level-III. The results have been published as state and national level atlases and available at the MoEF website (www.moef.nic.in). Total area under wetland of the country estimated by mapping at 1:50,000 scale was 15.26 M ha, which is around 4.63 per cent of the geographical area of India.

High Altitude Wetland is one of the 19 wetland classes mapped under the NWIA project for the first time in the country. These wetlands are found in the states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh (Anon, 2009, 2010a, b, c, 2011a, b). The High Altitude Wetland class includes rivers and marshes besides the lakes. The high altitude rivers are in general of low width due to steep gradient, show seasonal change in state of water, devoid of bank vegetation, particularly woody ones (Fig.-3). Due to the small width, these are mostly mapped as line features at 1:50,000 scale. Marshes abound the catchments of large lakes. Chushul Marsh (also known as Shushul or Chishul), in Jammu and Kashmir is one such example (Fig.-4). Chushul, lies on the eastern border of Leh and is about 4,150 m above sea level, in a narrow sandy valley flanked by mountains that rise to over 6000 m. A complex of shallow ponds, marshes and wet meadows are created by springs and streams flowing down into the valley from the Ladakh Range to the southwest. Some streams terminate on the sandy plains in stagnant pools which become saline as they get evaporated. It is a preferred habitat of the wild ass known as Kiangs.

This atlas focuses on the High Altitude Lakes (HAL) and is the first such atlas of High Altitude Lakes of Indian Himalayas.

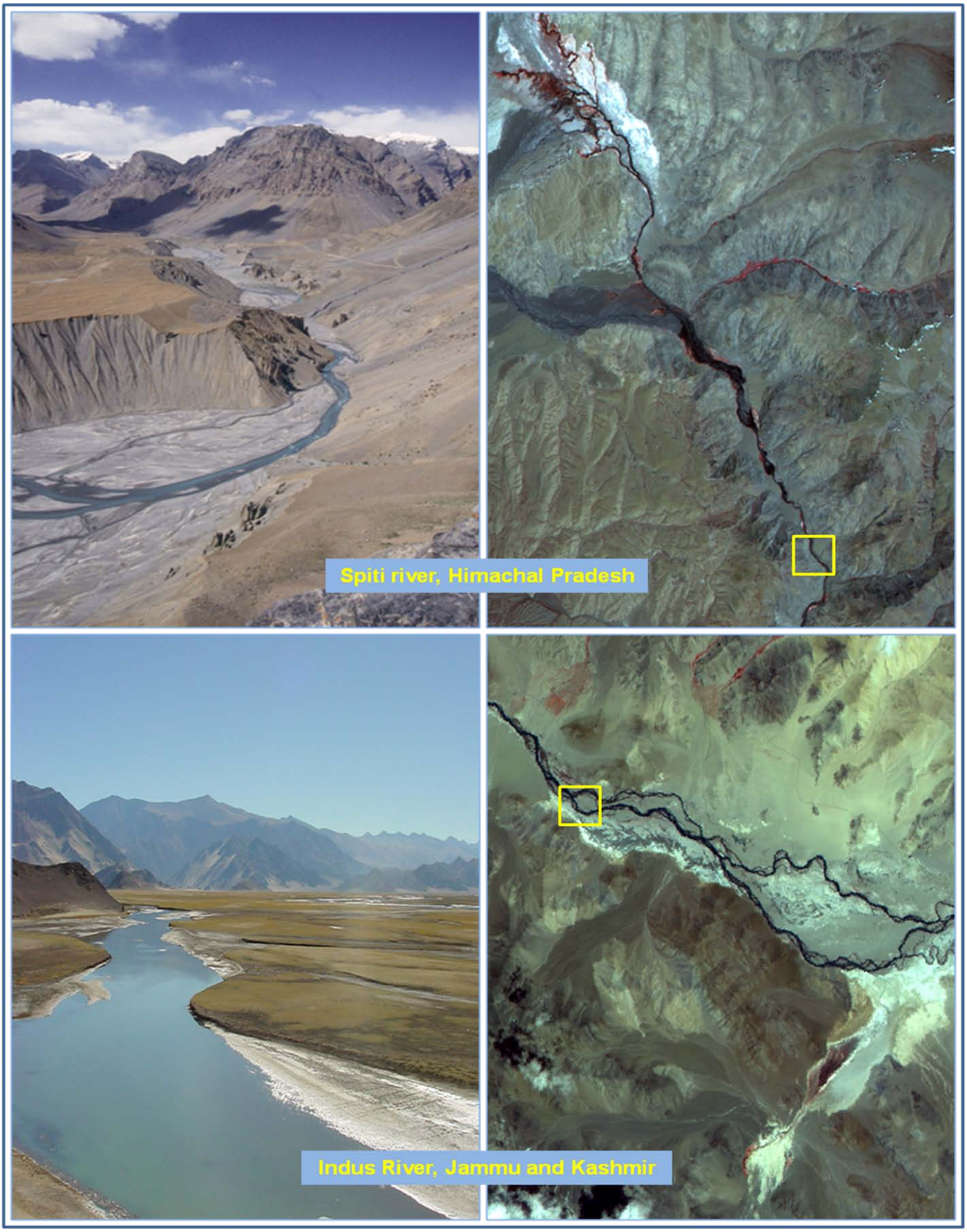


Fig.-3 Photographs showing the typical landscape of High Altitude Rivers (narrow width, high gradient and the banks devoid of woody vegetation) and as seen in IRS LISS III FCC

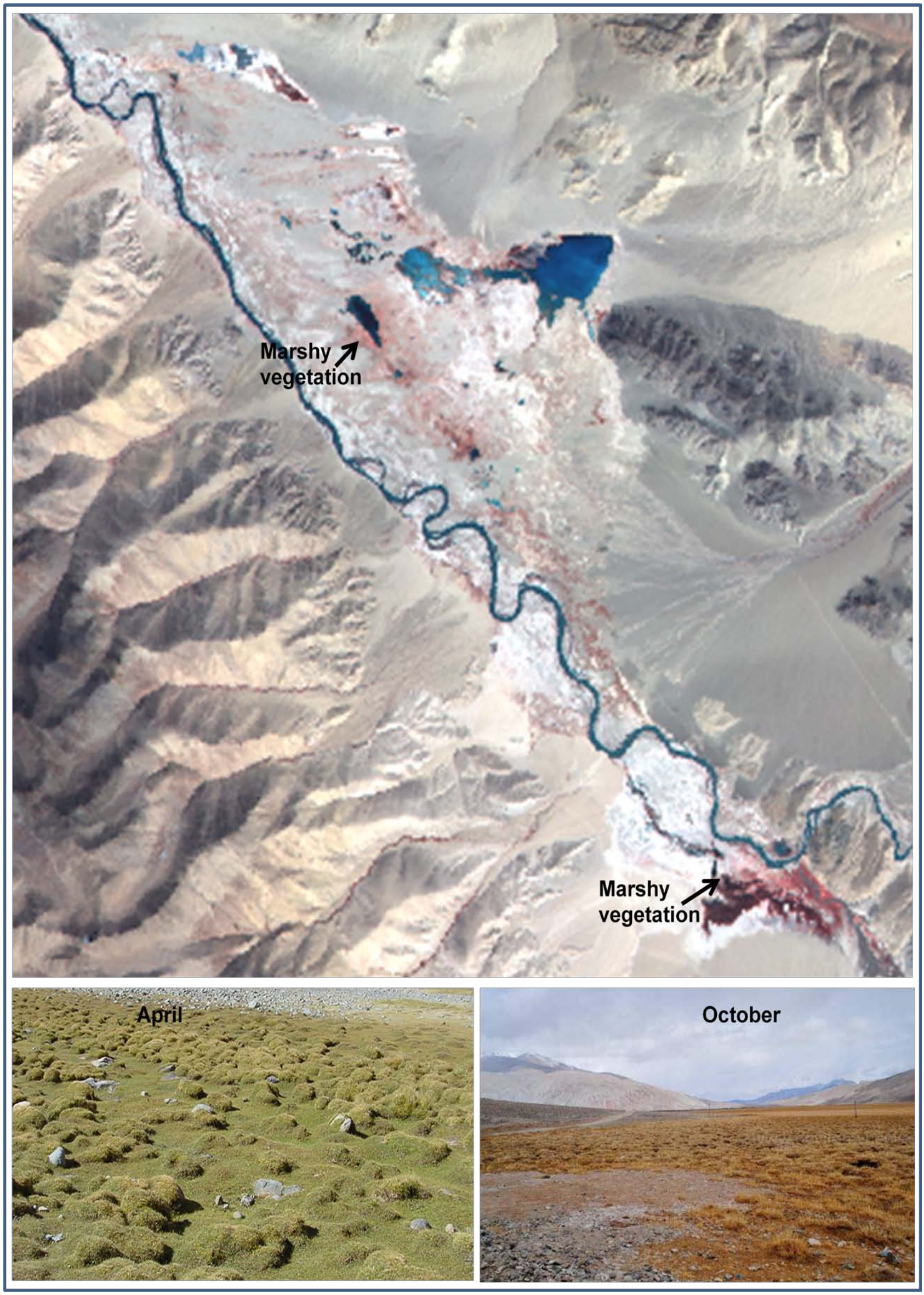


Fig.-4 Chushul marshes in Jammu and Kashmir, as seen in IRS LISS III FCC (October) and photograph of the marshy vegetation in October and April.

2.0 STUDY AREA AND DATA USED

Himalayan mountain system is home of the world's highest peaks having 14 of them with elevation over 8,000 metres. The main Himalayan range runs west to east, from the Indus river valley to the Brahmaputra river valley, forming a 2,400 km long arc, which varies in width from 400 km in the western Kashmir-Xinjiang region to 150 km in the eastern Tibet-Arunachal Pradesh region. The Himalayas cover an area of approximately 600,000 sq. km in south Asia (Fig.5).The range consists of three coextensive sub-ranges with the northernmost, and highest, known as the Great or Inner Himalaya. Longitudinally, Himalayan Range is also divided into five tectonic zones (Gansser, 1964), known as :Gangetic Plain, Sub-Himalayan Zone, Lesser Himalayan Zone, Higher Himalayan Zone, and Tibetan-Tethys Himalayan Zone, These east-west extending zones run almost parallel to each other (Fig.-6). They have different lithology, structure, and geological history. The higher regions of the Himalayas are snowbound throughout the year acting as the source for several large perennial rivers. The snow line varies from 4,500 to 6,000 meters.

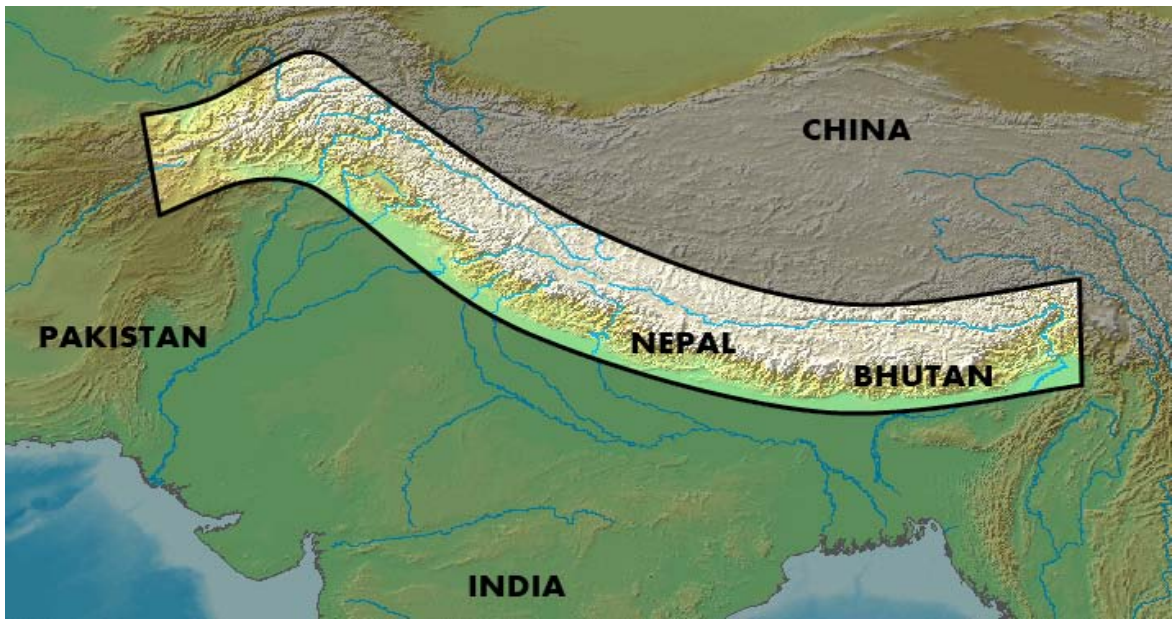


Fig.-5 Geographical setting of the Himalayas across Asian countries

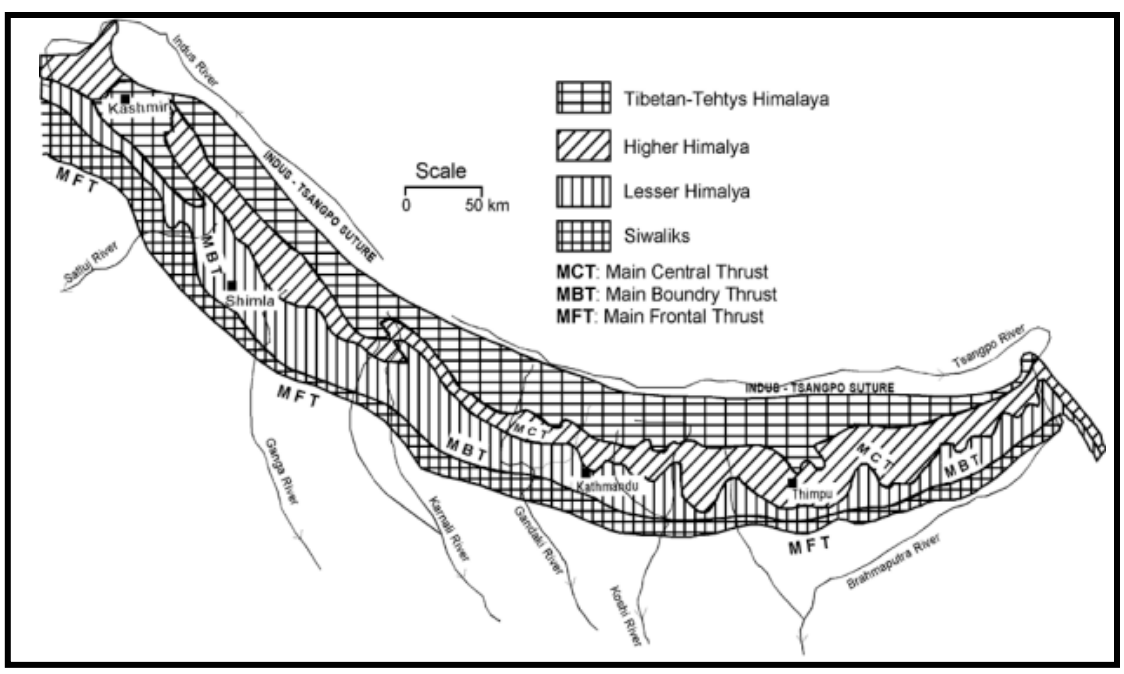


Fig.- 6 Longitudinal Subdivisions of the Himalayas

The Study area addressed in this atlas covers the Indian Himalayan region spread across five states: Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. The area lies between 27^{o} 00' to 37^{o} 9' N latitude and 72^{o} 20' to 97^{o} 20 E longitude with a geographic area of 419995

sq. km. (Table-1) The area is covered in 797 Survey of India (SOI) topographical maps (15’ x 15’ graticule) at 1:50,000 scale (Fig.-7)

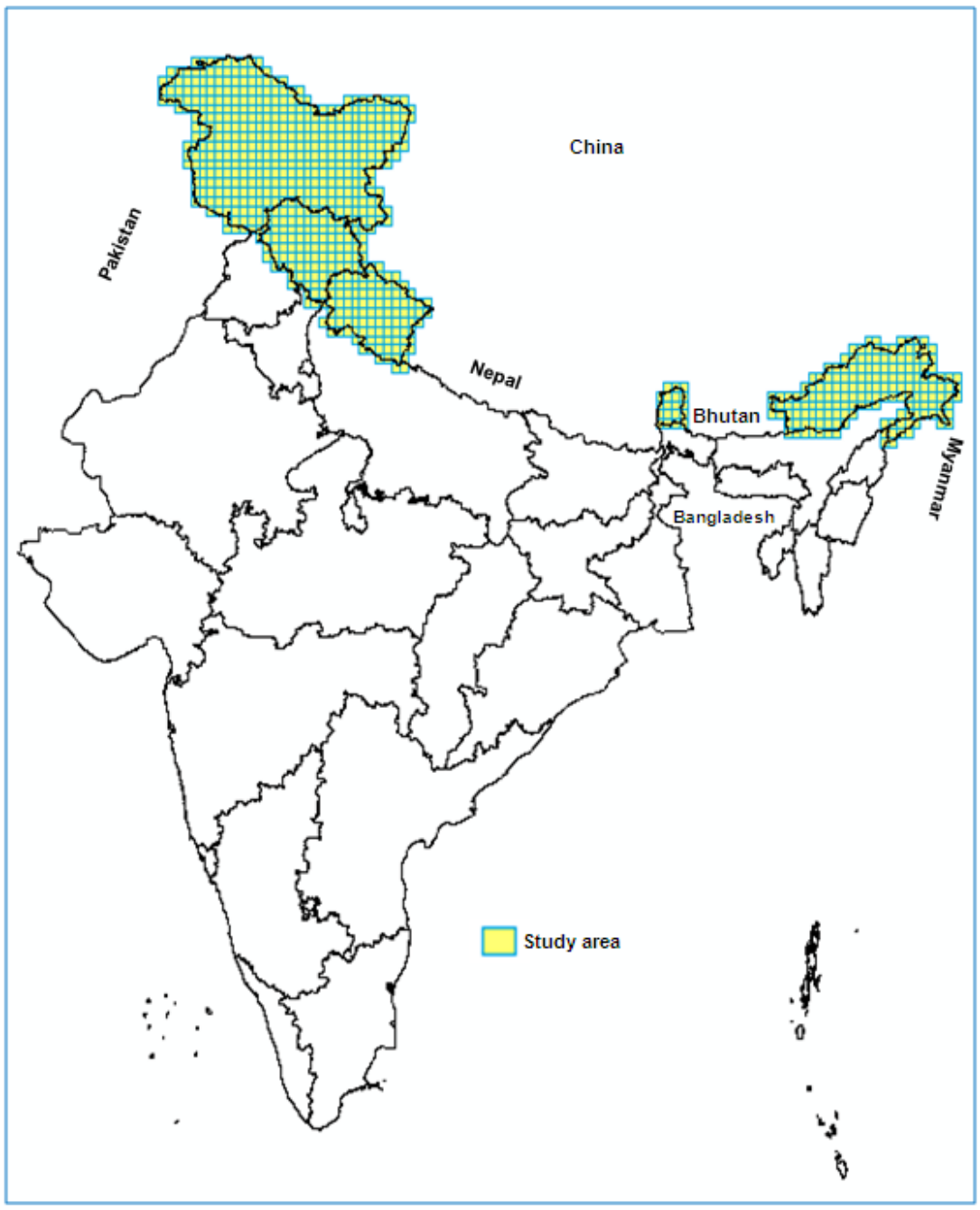


Fig.-7. Study area: Himalayan states of India

Indian Remote Sensing Satellite (IRS) P6-LISS III and LISS IV data were used for mapping (Fig.-8). LISS III providing data in four spectral bands viz: Green, Red, Near Infra Red (NIR) and Short Wave Infra Red (SWIR) with 23.5 m spatial resolution was used for 1:50,000 scale mapping. IRS LISS IV multispectral data having 5.8 m spatial resolution was used additionally for mapping some of the important HAWs and that of Sikkim state. The study area is covered by 58 LISS-III scenes. Two date geocoded, orthorectified data representing the pre monsoon (April-May) and post monsoon (October-November) periods of 2006-8 were used to map the seasonal dynamics of the wetlands (Fig.-9).

The Digital Elevation Model (DEM) derived from Shuttle Radar Topography Mission (SRTM) data was used to generate elevation contours and classify the lakes as per altitude range. SRTM data is available on 3 arc-second grid which roughly translates to a 90-meter horizontal spatial resolution. Its absolute horizontal and vertical accuracies are given as equal to 20 meters (circular error at 90% confidence) and 16 meters (linear error at 90% confidence) respectively.

Ancillary data like settlements, administrative boundaries and spatial frame work parameters (1:50,000 scale Survey of India topographic map frames) were taken from NRDB database. Elevation values were derived from satellite based DEM and given in meter.

Table-1: Details of study area

Sr. No.	State	No. of Districts	Geographical Area (Sq. Km)	Coverage by IRS LISS-III scenes	No. of SOI topographic maps on 1:50,000 scale
1	Jammu and Kashmir	20	222236	28	420
2	Himachal Pradesh	12	55673	11	116
3	Uttarakhand	13	53566	9	106
4	Sikkim	4	7096	2	9
5	Arunachal Pradesh	13	81424	14	172
	Total	**62**	**419995**	**58**	**797**

3.0 METHODOLOGY

High Altitude Lakes give unique signature on the satellite images, mainly due to the contrasting signature of associated land cover classes viz. rocks, scree, snow etc. Most of the lakes have very clear water, thus appeared dark in satellite image due to very low reflectance. Data acquired during the period when the lake water is in liquid state facilitated easy delineation of the lake boundary. Two season satellite data captured the freezing and melting scenario of lakes and enhanced identification accuracy (Fig 9). To increase the classification accuracy, various indices were generated from the spectral bands as given below:

i) Normalised Difference Water Index (NDWI) = (Green-NIR) / (Green + NIR)

ii) Normalised Difference Vegetation Index (NDVI) = (NIR - Red) / (NIR + Red)

iii) Normalised Difference Pond Index (NDPI) = (MIR – Green / MIR + Green)

Suitable combinations of indices were used to enhance the wetland boundary, open water and discrimination of snow from cloud.

The Spatial Framework and database design are based on standards as suggested in National Natural Resources management System (NNRMS) guidelines (Anon. 2005). The classified images were integrated from SOI map sheet level to district, state and national level using the recommended map projection in WGS84 datum. Geographical Information System was used to create the digital database. Each wetland has been given a unique 16 digit code beside other attributes keeping in view the nation-wide administrative as well as natural hierarchy. Wetland layers comprising Wetland extent, Open-water extent and Aquatic vegetation extent have been generated for each wetland. Small wetlands which are identifiable, but smaller than the minimum mapping unit were marked as points features (Fig.-10). Ancillary layers like major road network, settlements and surface drainage were mapped.

Elevation contours generated from the SRTM data were used to delineate the wetlands above 3000 m and designated as HAWs. Further analysis has been done to categorise the HAWs as per altitude. Statistics of lakes viz. total number, size- wise category, altitude- wise distribution pattern, area, perimeter etc were generated from the database. A typical map output at SOI topographic map level showing the high altitude lakes and other wetland classes is shown in Map.1.

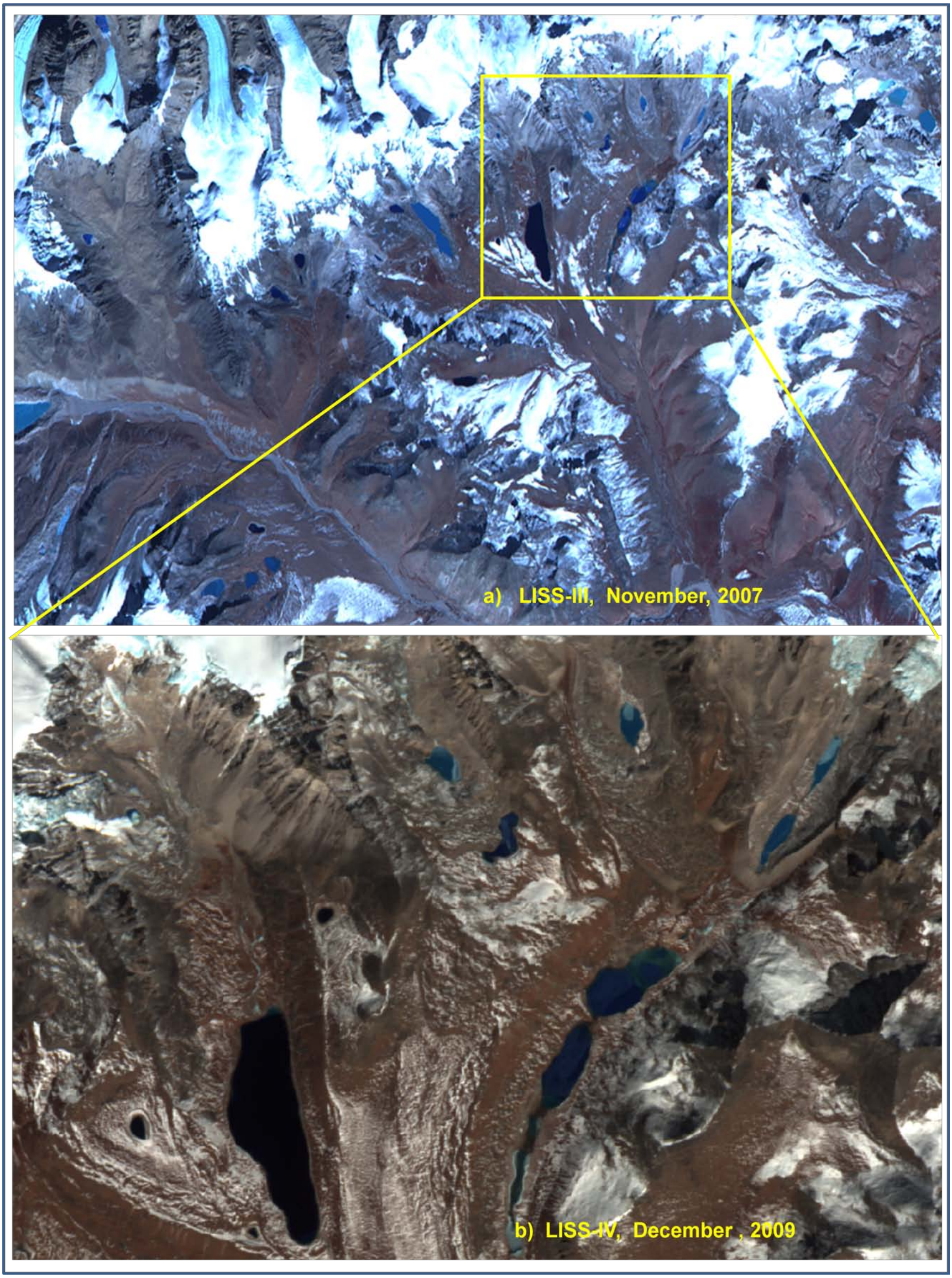


Fig.-8: Data Used: LISS III (a) and LISS IV (b) – three band False Color Composite, part of north Sikkim

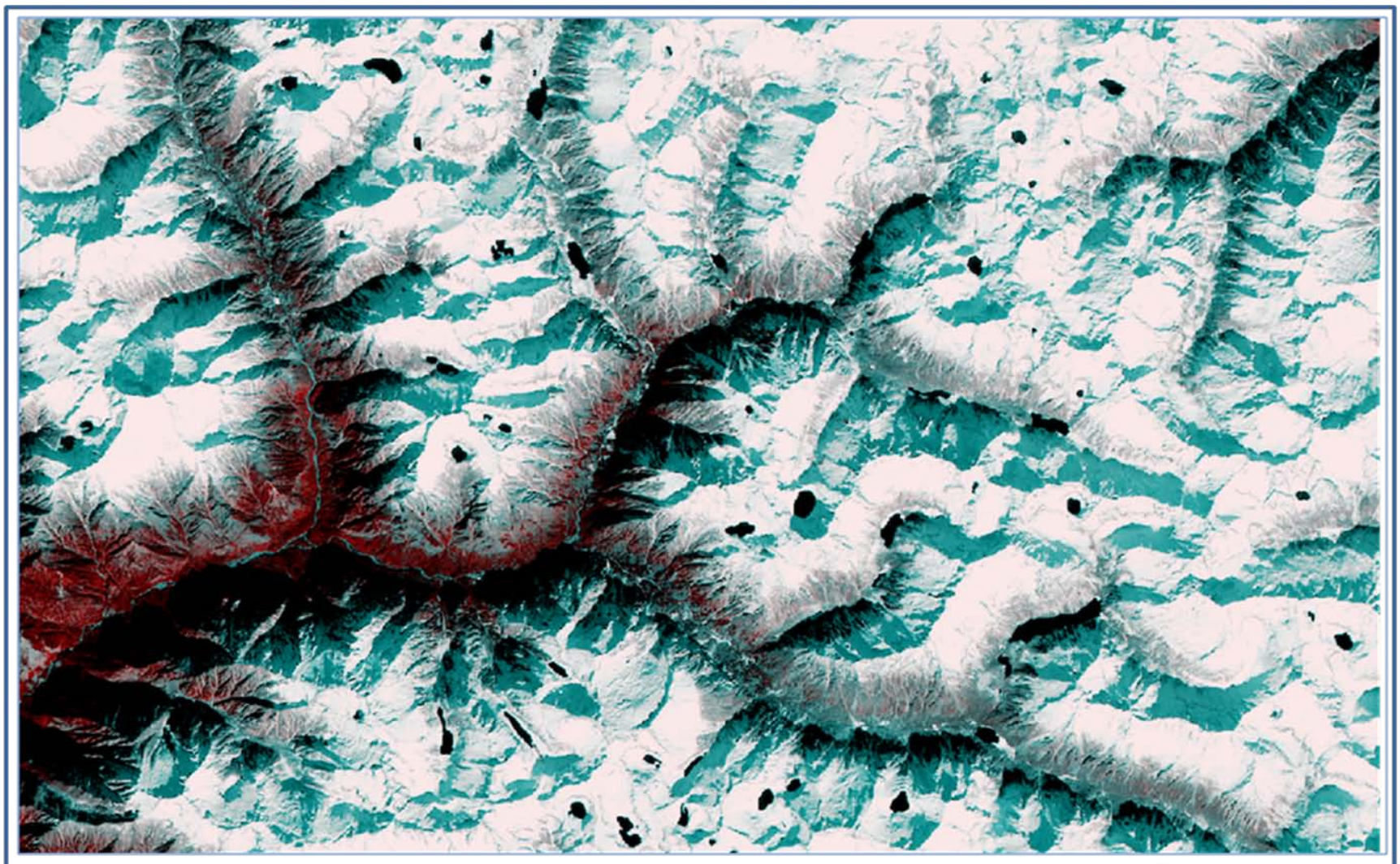


Fig.-9. Data Used: Two season LISS III (False Color Composite – Part of Dibang Valley, Arunachal Pradesh) showing the change in the water state of the lakes

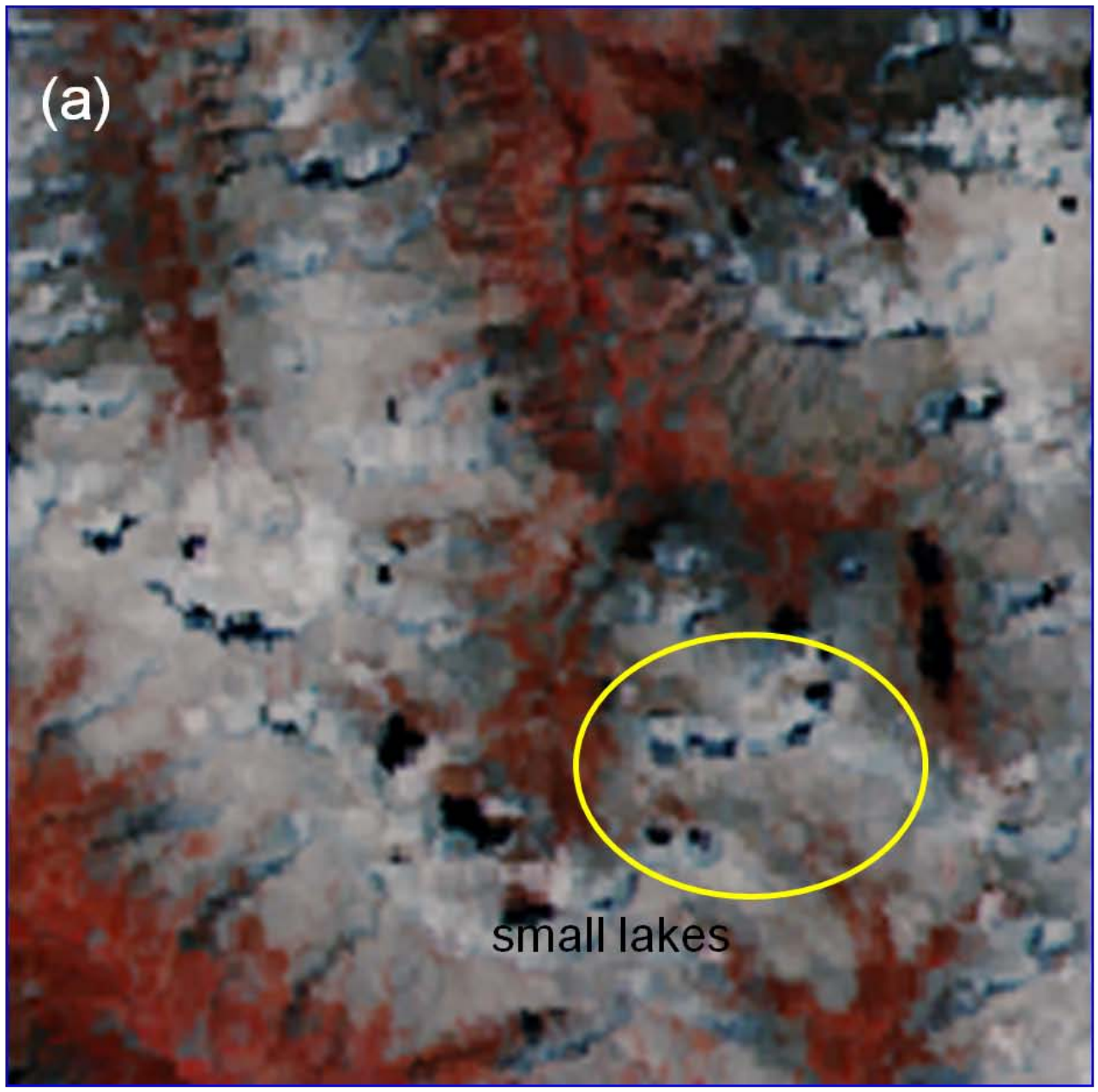
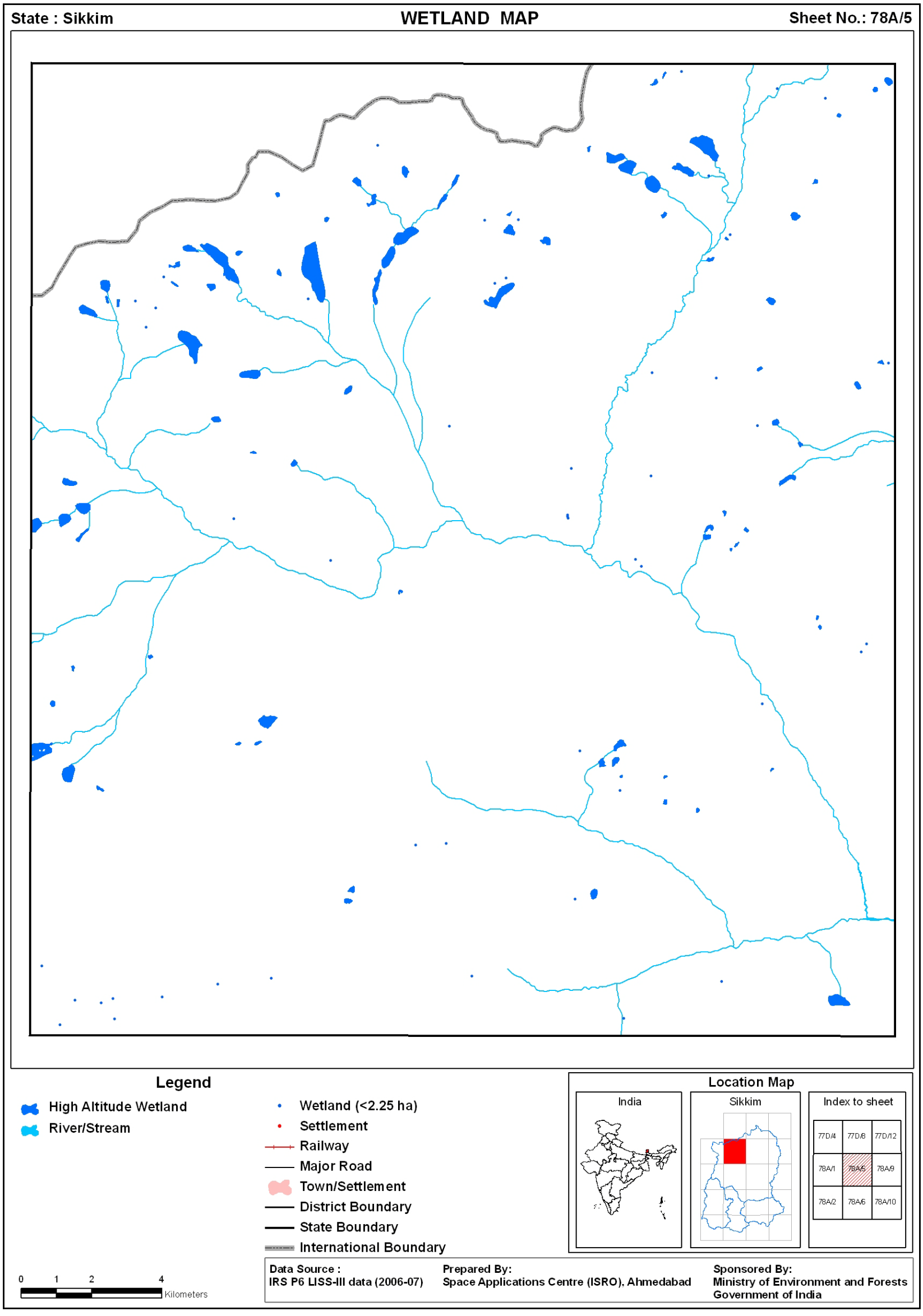


Fig.-10: Very small lakes mapped as point feature (a) at 1:50,000 scale (LISS III FCC, part of J&K), (b) at 1:25,000 scale (LISS IV FCC, part of Sikkim)



Map.-1: A typical high altitude wetland map at SOI Topographical sheet level (1:50,000 scale)

4.0 RESULTS AND DISCUSSION

Elevation analysis of the Himalayan region spread from Jammu and Kashmir in the west to Arunachal Pradesh in the east showed that around 56.4 per cent area of the region is above the altitude of 3000 m (Fig.11). This elevation range is observed in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh.

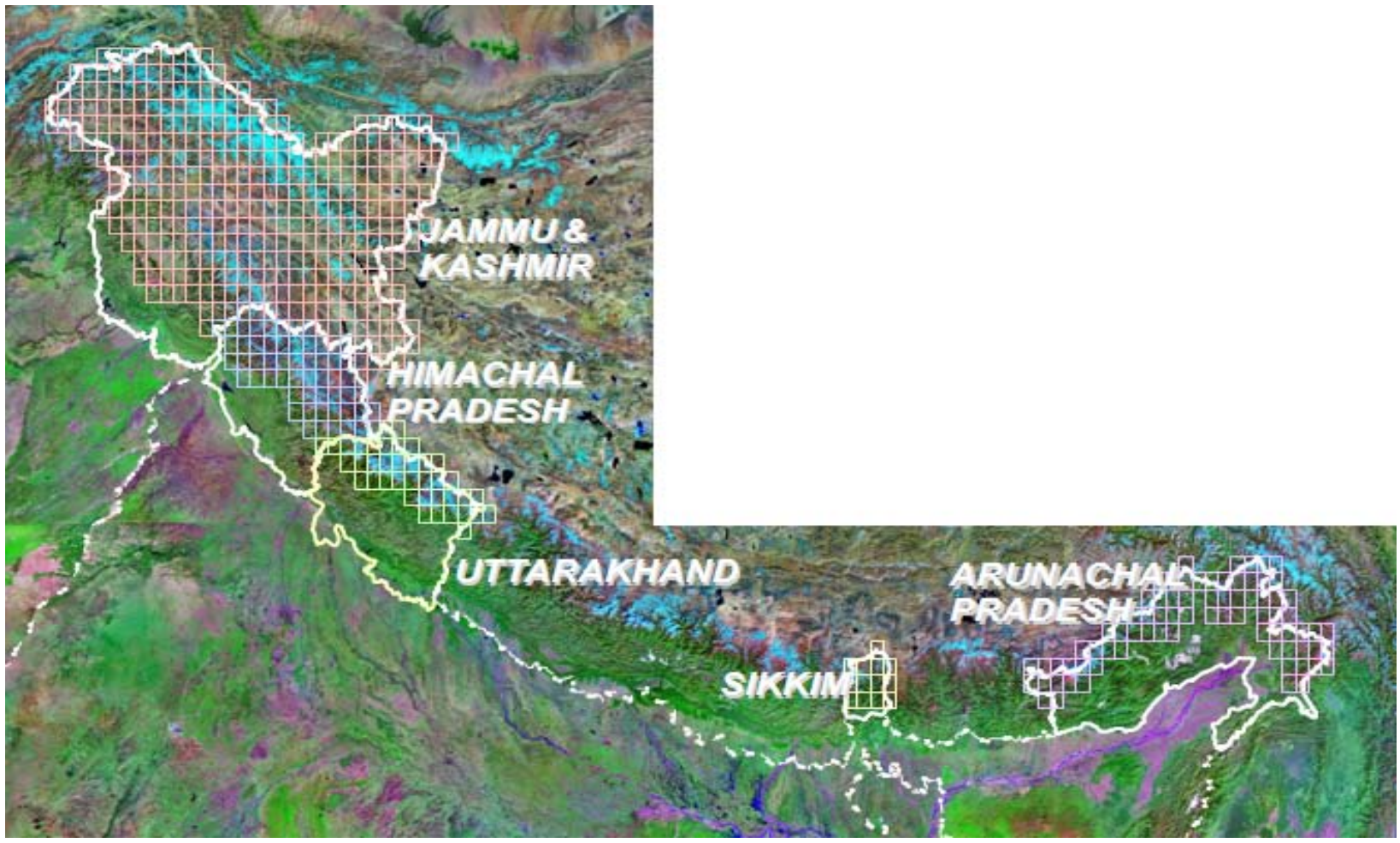


Fig.-11: Index map showing the regions above 3000 m in the Indian Himalayan states

4.1 National Statistics

4.1.1 Size wise distribution

A total 4699 lakes have been mapped at 1: 50,000 scale. This included 1966 lakes mapped as point features. The smallest size lakes of a size <2.25 ha are highest in number, followed by small size lakes of 2-10 ha area (Table-2). Large to very large lakes having more than 100 ha area are very few (43), but their share to total area under lakes area is the highest. Only 12 lakes having >500 ha, categorised as very large have been observed, the largest being 29345 ha (Table-3).

Table-2: Size-wise distribution of high altitude lakes in India

Sr. No.	Class	Range	No. of lakes	Area (ha)
1	Very Large	> 500 ha	12	95499
2	Large	100 - 500 ha	31	4993
3	Medium	25 - 100 ha	177	7366
4	Small	10 - 25 ha	498	7679
5	Very Small	2.25 - 10 ha	1985	8592
6	< 2.25 ha	< 2.25 ha	1996	1996*
Total			**4699**	**126125**

* Note: The number of small lakes (< 2.25 ha) are 1996 occupying 1996 ha area assuming that each is of one ha.

Table-3: Details of high altitude lakes in Indian Himalaya having >100 ha area

Sr. No.	Wetland code**	Location (Central Longitude, Latitude)	Area (ha)	Perimeter (Km)	Altitude (m)	Name of the Lake	State
1	0107005211090002	78° 41' 1" E, 33° 43' 47" N	29345	247.9	4238	Pangong Tso	Jammu and Kashmir
2	0107005213160001	79° 52' 8' E, 35° 12' 22" N	22104	69.98	4849		Jammu and Kashmir
3	0107005212050001	78° 19' 1" E, 32° 53' 44" N	14530	108.75	4522	Tso Morari	Jammu and Kashmir
4	0107005214100002	79° 41' 27" E, 34° 40' 43" N	7026	48.81	5192		Jammu and Kashmir
5	0107005211030002	78° 00' 42" E, 33° 18' 48" N	6179	50.51	4541	Tso Kar	Jammu and Kashmir
6	0107006101040002	80° 8' 53" E, 35° 3' 34" N	5556	43.04	4868		Jammu and Kashmir
7	0107005214050004	79° 21' 9" E, 34° 53' 17" N	3592	37.27	5207		Jammu and Kashmir
8	0107005211140002	78° 52' 26" E, 33° 31' 51" N	3473	40.67	4292		Jammu and Kashmir
9	0107005209150005	78° 55' 49" E, 35° 27' 45" N	1939	69.85	4832		Jammu and Kashmir
10	0107005212090002	78° 36' 5" E, 32° 55' 19" N	666	14.98	4983		Jammu and Kashmir
11	0107006102010001	80° 3' 10" E, 34° 49' 52" N	654	12.21	5055		Jammu and Kashmir
12	0107005211080002	78° 18' 8" E, 33° 6' 18" N	526	9.95	4673		Jammu and Kashmir
13	0107005215040021	79° 10' 8" E, 33° 4' 17" N	441	20.77	4152	Chushul Marshes1	Jammu and Kashmir
14	0107005212090001	78° 35' 44" E, 32° 58' 54" N	346	7.55	4989		Jammu and Kashmir
15	0117004208090001	73° 42' 7" E, 36° 52' 48" N	269	7.43	4290		Jammu and Kashmir
16	0107005213030001	79° 7' 13" E, 35° 22' 52" N	239	7.14	4957		Jammu and Kashmir
17	0107005209070001	78° 16' 56" E, 35° 24' 40" N	222	7.31	5157		Jammu and Kashmir
18	0107005211110001	78° 36' 42" E, 33° 27' 54" N	197	7.88	4912		Jammu and Kashmir
19	0107005213120001	79° 44' 19" E, 35° 12' 2" N	191	15.99	4844		Jammu and Kashmir
20	0107005211070005	78° 28' 37" E, 33° 18' 53" N	181	6.67	4678		Jammu and Kashmir
21	0107005211070003	78° 29' 9" E, 33° 25' 40" N	179	6.26	5282		Jammu and Kashmir
22	1101007801130001	88° 48' 50" E, 27° 59' 33" N	172	8.65	5303	Khangchung chho	Sikkim
23	0103004310150019	74° 55' 22" E, 34° 25' 59" N	167	6.37	3566	Gangbal Lake	Jammu and Kashmir
24	0107005211070002	78° 29' 47" E, 33° 27' 24" N	150	7.29	5310		Jammu and Kashmir
25	0107005215040004	79° 6' 5" E, 33° 6' 40" N	147	6.96	4150	Chushul Marshes2	Jammu and Kashmir
26	0107005214010002	79° 0' 40" E, 35° 51' 4" N	143	6.44	5271		Jammu and Kashmir
27	1210009103030008	96° 7' 45" E, 29° 18' 48" N	143	7	4276		Arunachal Pradesh
28	0107005209120001	78° 31' 17" E, 35° 1' 45" N	139	8.1	5344		Jammu and Kashmir
29	0117004313120001	75° 37' 53" E, 35° 13' 59" N	131	5.22	2638		Jammu and Kashmir
30	0117004314010001	75° 14' 9" E, 34° 59' 29" N	131	4.31	4139		Jammu and Kashmir
31	1101007704120006	88° 42' 36" E, 28° 1' 4" N	118	5.34	5148	Gurudogmar Lake	Sikkim
32	1101007704120009	88° 42' 44" E, 28° 0' 25" N	115	4.56	5238		Sikkim
33	0106004311140002	74° 46' 5" E, 33° 30' 42" N	110	6.87	3489		Jammu and Kashmir
34	1210009104090011	96° 31' 54" E, 28° 46' 32" N	110	7.01	3511		Arunachal Pradesh
35	1210009103040001	96° 11' 13' 'E, 29° 13' 45" N	109	4.5	3569		Arunachal Pradesh
36	0117004208100001	73° 38' 48" E, 36° 38' 37" N	106	5.22	3831		Jammu and Kashmir
37	0107005210080005	78° 26' 12" E, 34° 10' 22" N	106	4.56	5394		Jammu and Kashmir
38	1101007704160001	88° 45' 22" E, 28° 0' 41" N	106	5.89	5014	Chholhamu Lake	Sikkim
39	0117004204120002	72° 32' 16" E, 36° 4' 44" N	104	4.24	3685		Jammu and Kashmir
40	0107005213100002	79° 30' 40" E, 35° 37' 16" N	103	4.72	4882		Jammu and Kashmir
41	0107005209030003	78° 12' 59" E, 35° 23' 28" N	103	3.92	5141		Jammu and Kashmir
42	0117004301090001	72° 35' 37" E, 35° 56' 40" N	102	5.33	3764		Jammu and Kashmir
43	1101007704120010	88° 41' 48" E, 28° 0' 28" N	101	6.02	5211		Sikkim

***Wetland code: Unique identification number of 16 digit using*
State code(2)+District code(2)+Taluka code(2)+SOI toposheet code(6)+Wetland number(4)

Cluster of large lakes of > 500 ha are observed in the western Himalaya in the Ladakh region (Fig.-12). Cluster of large lakes of >100 ha area are found in Eastern Himalaya near Khangchengyao Range, next to Tibetan Plateau (Fig.-13). Density of small lakes of 2-10 ha is observed in the eastern most part of Himalaya in the state of Arunachal Pradesh (Fig.-14).

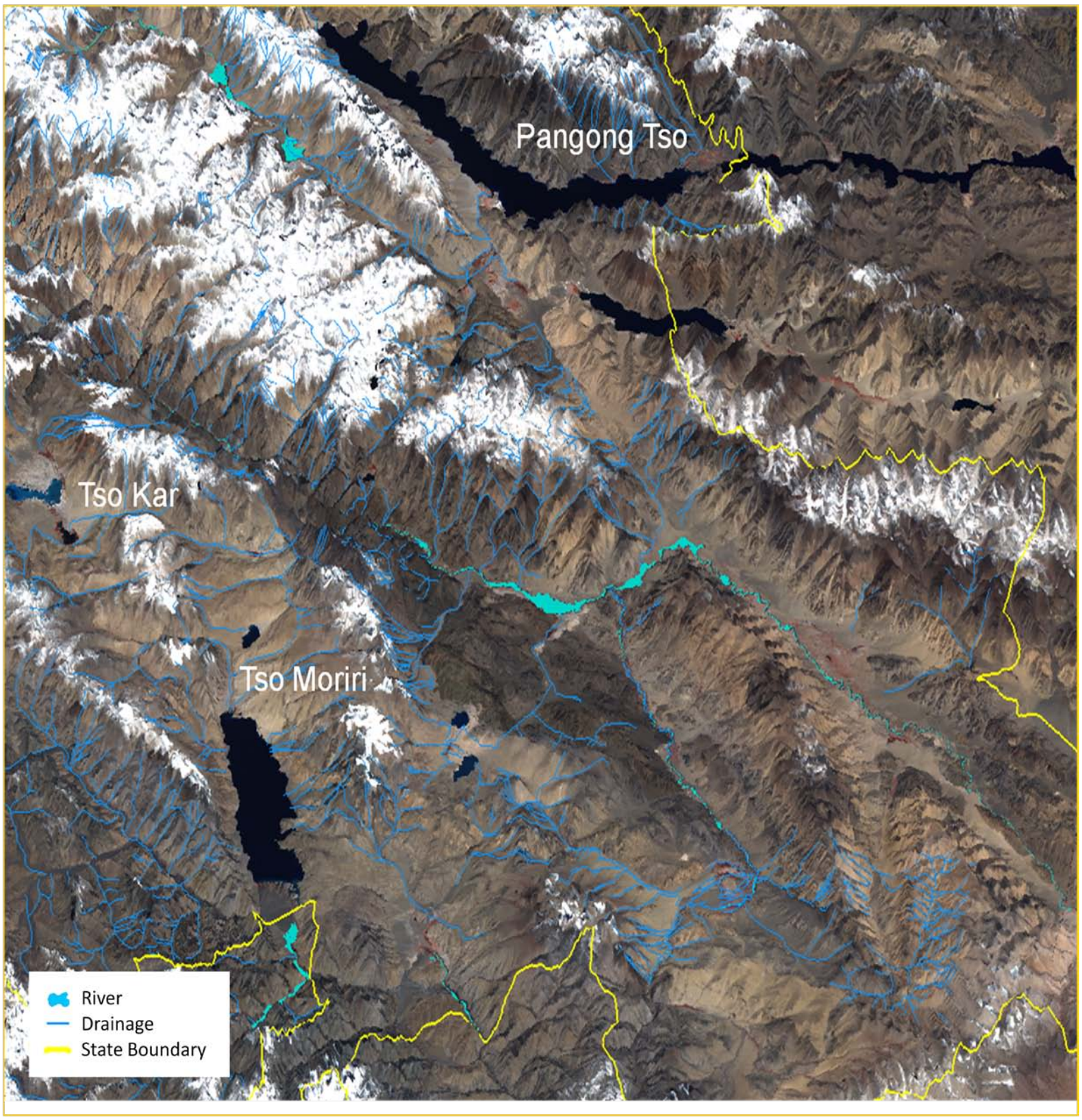


Fig.-12: Cluster of Very large high altitude lakes in Western Himalaya – Jammu and Kashmir

4.1.2 Altitude wise distribution

Altitude-wise distribution shows that maximum numbers of lakes are located in the elevation range of 4000-5000 m. There are 2666 lakes (56.2% of total number) mapped in this elevation range with a total area of 100824 ha (79.9% area). Very large lakes are also observed in this elevation range. Total of 734 lakes are identified in the very high altitude range of >5000 m elevation (Table-4). Details of high altitude lakes having altitude >5000 m and area of > 25 ha in Indian Himalaya are listed in Table-5.

Table-4: Altitude-wise distribution of high altitude lakes in Indian Himalaya

Sr. No.	Category	Altitude range (m)	No. of lakes	Area (ha)
1.	High Altitude	3000-4000	1299	8348
2.	Higher Altitude	4000-5000	2666	100824
3.	Very high Altitude	>5000	734	16953
Total			**4699**	**126125**

The distribution pattern of lakes in the Indian Himalayan region is shown in Map 2a and 2b.

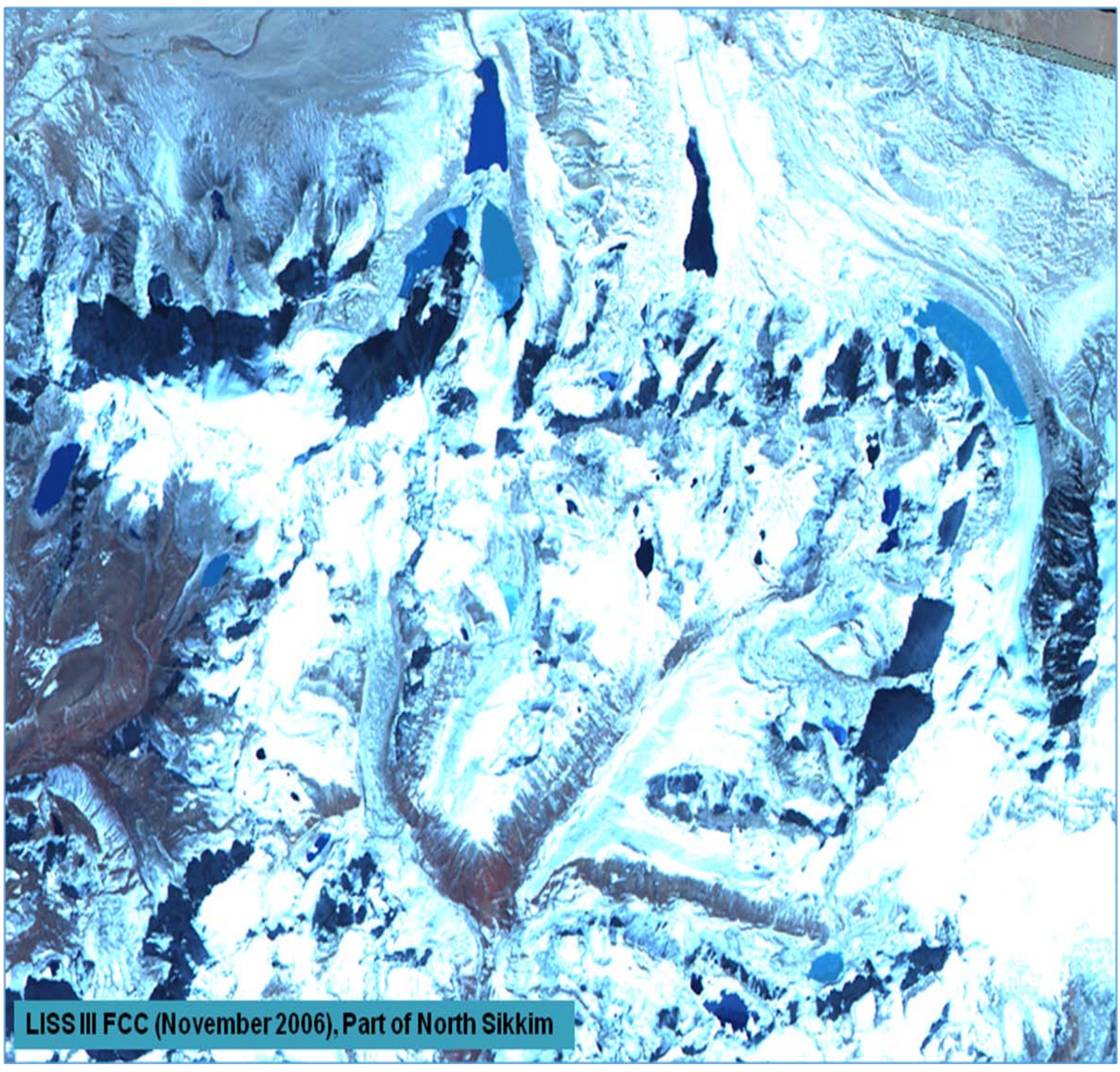


Fig.-13: Cluster of large high altitude lakes in Eastern Himalaya- North Sikkim

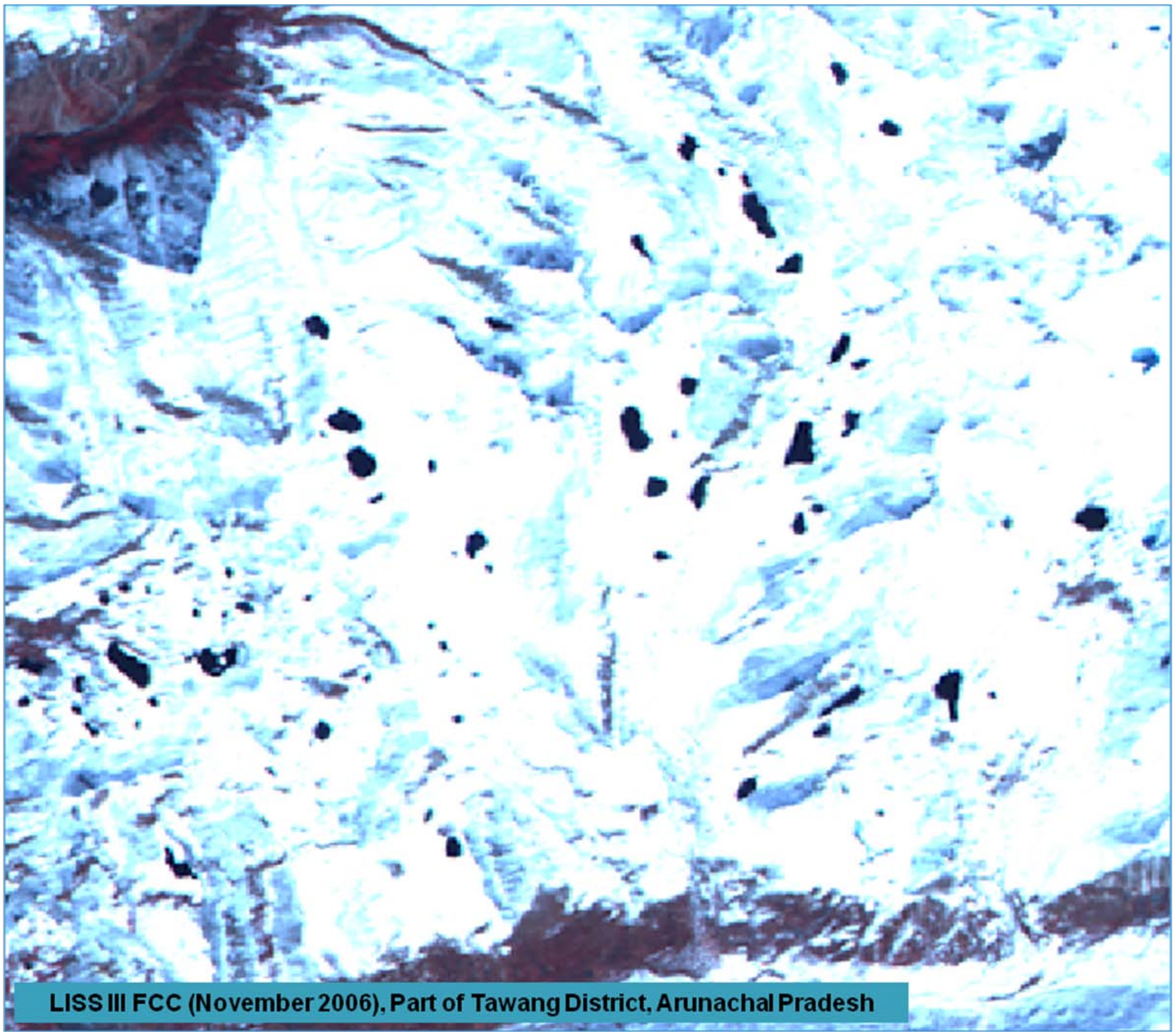


Fig.-14: Cluster of small high altitude lakes in Eastern Himalaya - Arunachal Pradesh

All the large lakes of >500 ha are found in the Leh region of Western Himalaya. It harbours the largest lake Pangong Tso, a cross boarder lake. Tso Moriri, another large lake that has been declared as Ramsar site as well as Tso Kar , a well known salt water lake also located in this region.

Table-5: High altitude lakes (>25 ha) in Indian Himalaya located at >5000 m altitude

Sr. No.	Wetland code	Location (Central Longitude, Latitude)	Altitude (m)	Area (ha)	Perimeter (Km)	Name of the Lake	State
1	0107005211080013	78° 28' 5" E, 33° 3' 19" N	5749	37	3.87		Jammu and Kashmir
2	0107005211030001	78° 13' 39" E, 33° 17' 4" N	5654	34	3.31		Jammu and Kashmir
3	1101007801010016	88° 13' 48" E, 27° 49' 40" N	5614	25	2.52		Sikkim
4	0107005210120003	78° 33' 6" E, 34° 9' 3" N	5564	65	5.31		Jammu and Kashmir
5	1101007801050005	88° 24' 15" E, 27° 58' 42" N	5564	33	2.62		Sikkim
6	0107006101030001	80° 5' 47" E, 35° 28' 14" N	5543	33	2.24		Jammu and Kashmir
7	0107005213100003	79° 31' 19" E, 35° 42' 19" N	5444	49	2.7		Jammu and Kashmir
8	1101007801010004	89° 9' 31" E, 27° 55' 10" N	5442	60	3.51	Lhonark Chho	Sikkim
9	0107005210080009	78° 26' 6" E, 34° 9' 49" N	5436	43	3.85		Jammu and Kashmir
10	0107005210120002	78° 30' 23" E, 34° 11' 12" N	5430	48	2.72		Jammu and Kashmir
11	1101007801050040	88° 17' 43" E, 27° 55' 42" N	5428	29	2.51		Sikkim
12	1101007704120014	88° 38' 18" E, 28° 0' 9" N	5426	27	2.34		Sikkim
13	0107005214140005	79° 47' 13" E, 34° 30' 50" N	5414	34	3.85		Jammu and Kashmir
14	0107005214020004	79° 9' 23" E, 34° 41' 35" N	5409	33	2.46		Jammu and Kashmir
15	0107005209110001	78° 31' 24" E, 35° 24' 2" N	5407	25	2.04		Jammu and Kashmir
16	0107005210080005	78° 26' 12" E, 34° 10' 22" N	5394	106	4.56		Jammu and Kashmir
17	0107005210080002	78° 25' 29" E, 34° 13' 59" N	5351	69	4.13		Jammu and Kashmir
18	0107005210080004	78° 23' 58" E, 34° 11' 31" N	5350	33	2.44		Jammu and Kashmir
19	0107005209120001	78° 31' 17" E, 35° 1' 45" N	5344	139	8.1		Jammu and Kashmir
20	0107005209110004	78° 34' 49" E, 35° 24' 49" N	5314	28	2.27		Jammu and Kashmir
21	0107005209030005	78° 10' 54" E, 35° 29' 5" N	5312	29	2.19		Jammu and Kashmir
22	0107005211070002	78° 29' 47" E, 33° 27' 24" N	5310	150	7.29		Jammu and Kashmir
23	1101007801130001	88° 48' 50" E, 27° 59' 33" N	5303	172	8.65	Khangchung chho	Sikkim
24	0107005209070006	78° 23' 24' E, 35° 24' 42" N	5302	26	2.28		Jammu and Kashmir
25	0107005210030001	78° 8' 5" E, 34° 27' 25" N	5297	97	4.88		Jammu and Kashmir
26	0107005211070003	78° 29' 9" E, 33° 25' 40" N	5282	179	6.26		Jammu and Kashmir
27	0107005214010001	79° 12' 36" E, 34° 57' 24" N	5275	36	2.9		Jammu and Kashmir
28	0107005214010002	79° 0' 40" E, 35° 51' 4" N	5271	143	6.44		Jammu and Kashmir
29	0107005214140002	79° 46' 30" E, 34° 38' 2" N	5251	94	4.26		Jammu and Kashmir
30	1101007801050006	88° 24' 54" E, 27° 58' 31" N	5247	29	2.41		Sikkim
31	1101007704120009	88° 42' 44" E, 28° 0' 25" N	5238	115	4.56		Sikkim
32	0107005214060001	79° 18' 21" E, 34° 43' 23" N	5238	28	2.26		Jammu and Kashmir
33	1101007801130012	88° 45' 38" E, 27° 53' 42" N	5236	41	3.46		Sikkim
34	0107005214100003	79° 41' 51" E, 34° 37' 11" N	5213	26	2.21		Jammu and Kashmir
35	1101007704120010	88° 41' 48" E, 28° 0' 28" N	5211	101	6.02		Sikkim
36	0107005214050004	79° 21' 9" E, 34° 53' 17" N	5207	3592	37.27		Jammu and Kashmir
37	1101007801010006	88° 11' 52" E, 27° 54' 47" N	5197	84	4.19	South Lonark Chho	Sikkim
38	0107005214100002	79° 41' 27" E, 34° 40' 43" N	5192	7026	48.81		Jammu and Kashmir
39	1101007801050004	88° 26' 42" E, 27° 58' 42" N	5168	30	2.21		Sikkim
40	1101007801090003	88° 32' 48" E, 27° 59' 36" N	5164	57	4.09		Sikkim
41	0115005209070001	78° 16' 56" E, 35° 24' 40" N	5157	222	7.31		Jammu and Kashmir
42	1101007704120006	88° 42' 36" E, 28° 1' 4" N	5148	118	5.34	Gurudogmar Lake	Sikkim
43	0107005213040003	79° 11' 13" E, 35° 6' 38" N	5146	92	4.59		Jammu and Kashmir
44	0107005209030003	78° 12' 59" E, 35° 23' 28" N	5141	103	3.92		Jammu and Kashmir
45	1101007801130011	88° 46' 54" E, 27° 54' 3" N	5113	29	2.12		Sikkim
46	1101007704120008	88° 33' 36" E, 28° 0' 33" N	5070	29	2.56		Sikkim
47	0107006102010001	80° 3' 10" E, 34° 49' 52" N	5055	654	12.21		Jammu and Kashmir
48	1101007801050022	88° 18' 15" E, 27° 56' 59" N	5050	40	3.39		Sikkim
49	1101007801050023	88° 19' 48" E, 27° 56' 49" N	5030	60	3.89	Khora Chhobuk	Sikkim
50	1101007704080002	88° 29' 35" E, 28° 0' 23" N	5023	47	3.17		Sikkim
51	1101007704160001	88° 45' 22" E, 28° 0' 41" N	5014	106	5.89	Chholhamu Lake	Sikkim
52	1101007704120011	88° 34' 12" E, 28° 0' 30" N	5007	33	2.61		Sikkim
53	0107005207130001	77° 58' 45" E, 33° 59' 56" N	5003	42	3.11		Jammu and Kashmir

***Wetland code: Unique identification number of 16 digit using*
State code(2)+District code(2)+Taluka code(2)+SOI toposheet code(6)+Wetland number(4)

The Largest Lake

The largest lake in the Himalaya is **Pangong Tso**. It is a long narrow lake spread over the Indian and Chinese territory in the upper drainage basin of the Indus river, at the east end of the Karakoram Range. The lake is actually a chain of four interconnected water bodies formed by natural damming of the valley. Five rivers, fed by perennial springs and snow-melt, flow into the Indian portion of the lake; the outlet at the west end flows northwest into the Shyok river, a tributary of the Indus. Brackish to saline marshes and alpine meadows in the catchment of lake have been observed and detected in satellite image. The characteristics derived are:

Code : 0107005211090002
Location : Between 33^0 40' N to 34^0 00' N latitudes and 78^0 24' E to 79^0 01' E longitudes
Average altitude : 4238 m
Total lake area : 29345 ha (in India)
Length : 28.6 km
Perimeter : 247.9 km

The perspective view of the lake is shown in Fig.-15. The lake shows characteristic freezing and melting cycle (Fig.-16). The surrounding hillsides support low, thorn scrub and perennial herbs. This lake is declared as the High Altitude Cold Desert National Park. A great diversity of ichthyological fauna is recorded from this lake. It also is an ideal breeding and nesting place of migratory birds. The region around the lake supports a number of species of wildlife including the Kiang and the Marmot (Fig.-16).

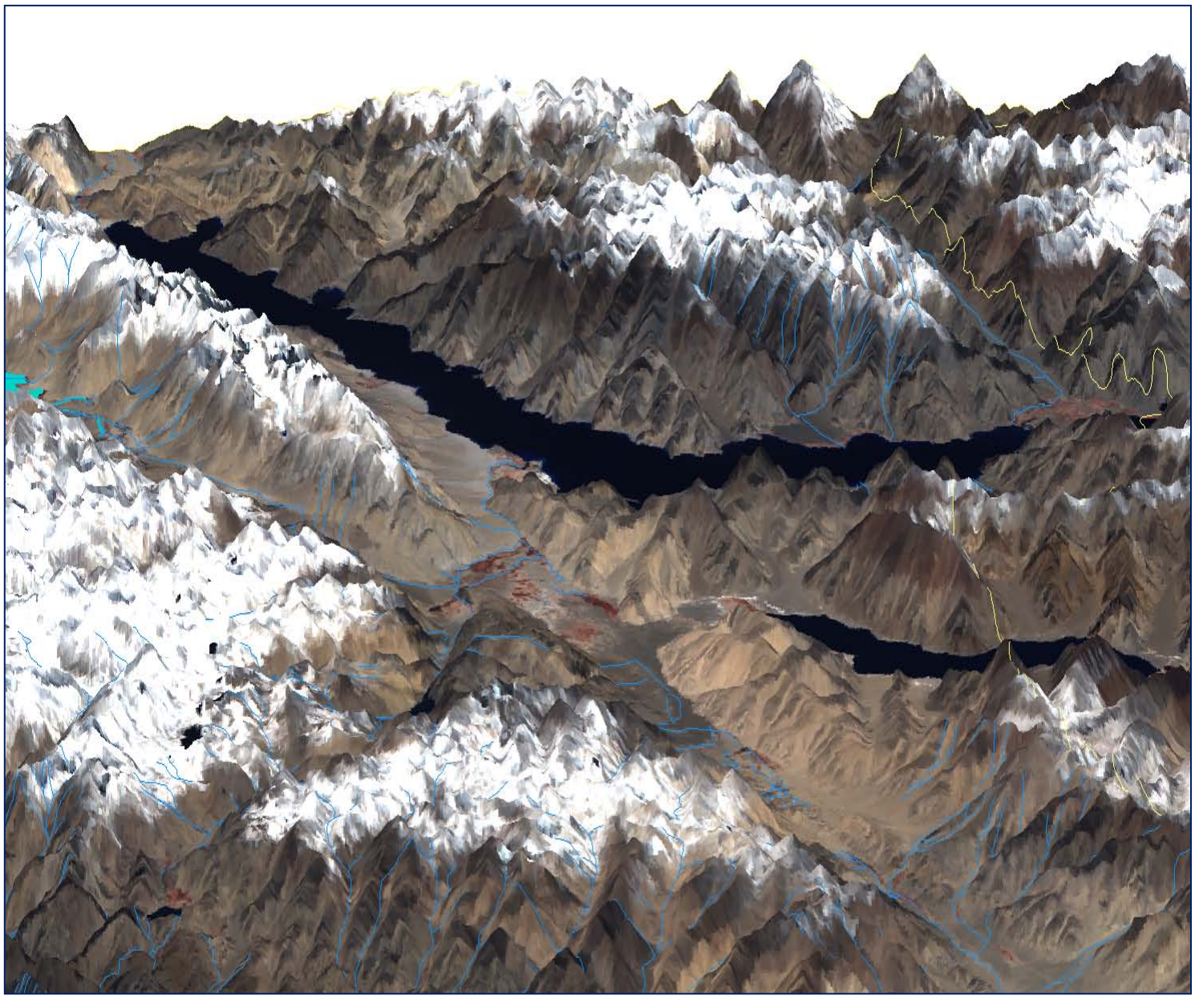


Fig.-15: Perspective view of Pangong Tso as seen in LISS III FCC draped in DEM

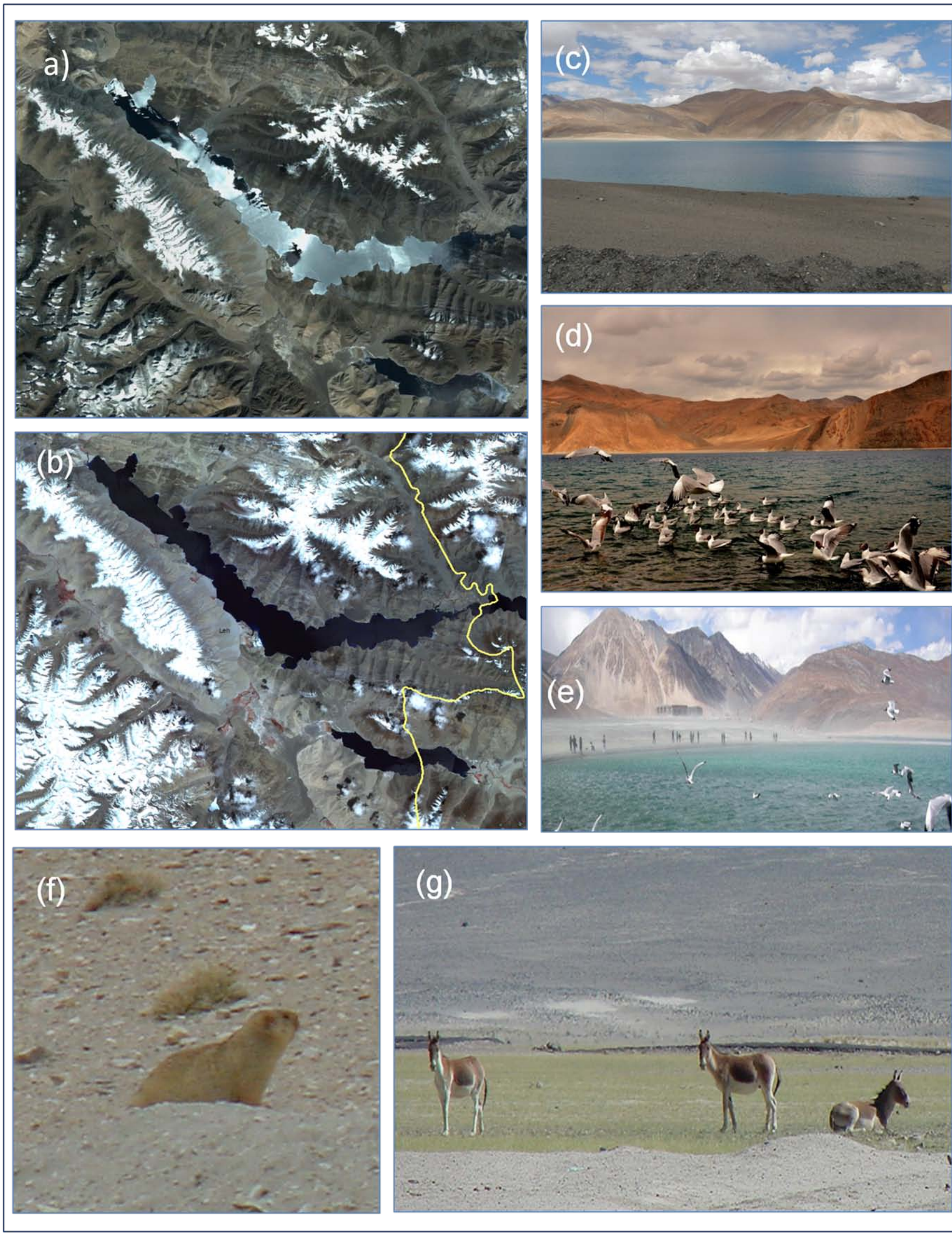


Fig.-16. Satellite image showing the winter (a) and summer (b) status of Pangong Tso (c) photographs of the lake during summer, faunal diversity. (d-e) migratory birds, (f) marmots and (g) kiangs.

Highest lakes

Altitudinal distribution shows that lakes are detected up to 6000m altitude. However most of these are very small and mapped as point feature. Among the sizable lakes with at least 25 ha area, the highest one is observed in western Himalaya in Jammu & Kashmir (Fig.-17), as given below:

Code : 0107005211080013
Location : 33^{o} 3' 19'' N latitude and 78^{o} 28' 5'' E longitude
Altitude : 5749 m
Area : 37 ha
Perimeter : 3.87 km
Length : 1.4 km

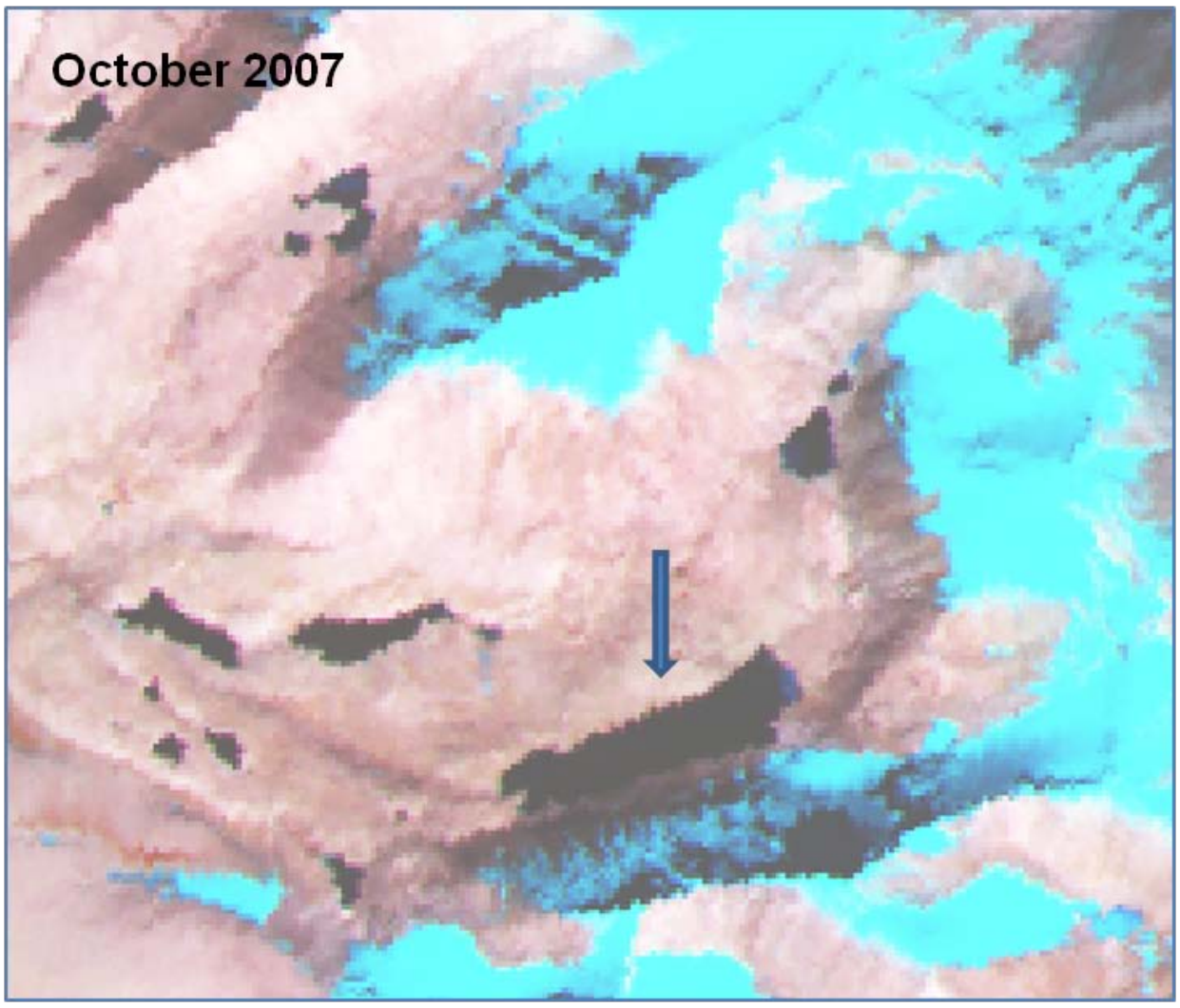


Fig.-17: The highest high altitude lake (>25 ha) in Indian Himalayas (at 5749 m in Jammu and Kashmir)

Among the large lakes of >100 ha, the highest location is also observed in Ladakh region of Western Himalaya, as below:

Code : 0107005214100002
Location : 34^{o} 40' 43'' N latitude and 79^{o} 41' 27'' E longitude
Altitude : 5192 m
Area : 7026 ha.
Perimeter : 48.8 km

The lake is oblong in shape (Fig.-18).

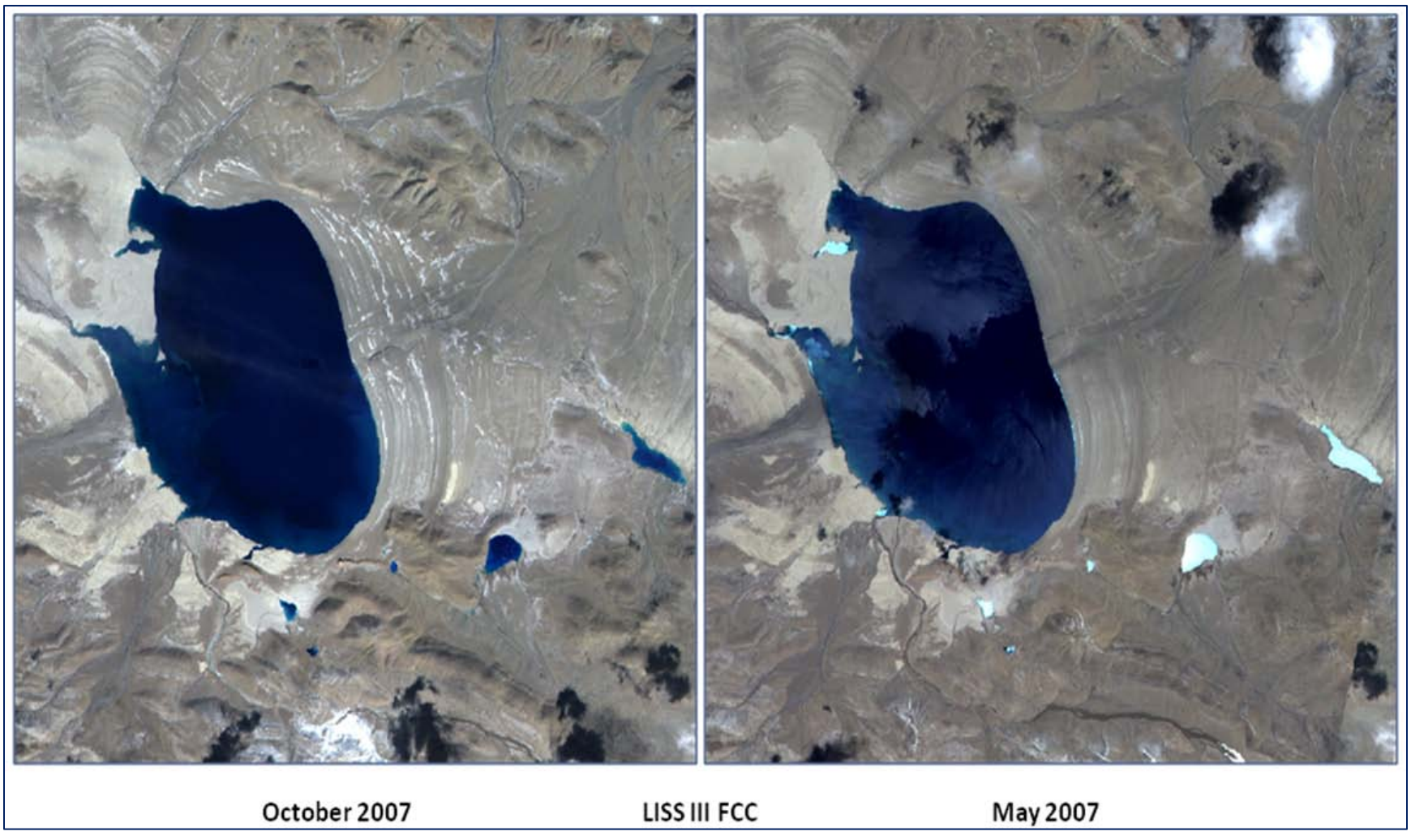


Fig.-18: LISS III FCC showing the status of the largest high altitude lake above 5000 m (located in J&K, with 7026 ha at 5192 m). The smaller lakes nearby are fully frozen.

In general, the lakes above 5000 m are concentrated in the Western Himalaya, in the Changtham region.

Highest lakes in Eastern Himalaya

In eastern Himalaya, lakes above 5000 m are observed in the state of Sikkim. A cluster of large lakes are nestled at the altitude of >5000 m in the north-eastern side of the Kanchanjangha range (Khangchengyao), next to the Tibetan plateau (Fig.-13). One of the lakes in this cluster is Cholamu (Tso Lahmu), the source of river Teesta or Tista. It is a small lake formed by the melting of the Tista Khaytse glacier. The reported depth of the lake is around 5.5 m. The first survey of this lake has been done by the British explorer Joseph Dalton Hooker, during 1847. His findings with the view of the lake as observed from the Donkiana pass was published in 1849 (www.wikipedia.org**).** The lake as observed then and now from the summit of the pass is shown in Fig.-19. This lake is known as the highest large lake in Himalaya with reported height of 5330 m amsl. The findings of this study are given below:

Code : 1101007704160001
Location : 28^{o} 0' 41" N latitude and 88^{o} 45' 22" E longitude
Altitude : 5014 m
Area : 106 ha
Perimeter : 5.89 km

From the northern side of the lake originates a small stream which is downstream known as river Teesta. The lake catchment is of cold desert type with no vegetation. The lake remains frozen for considerable time of the year, even up to April (Fig.-20).

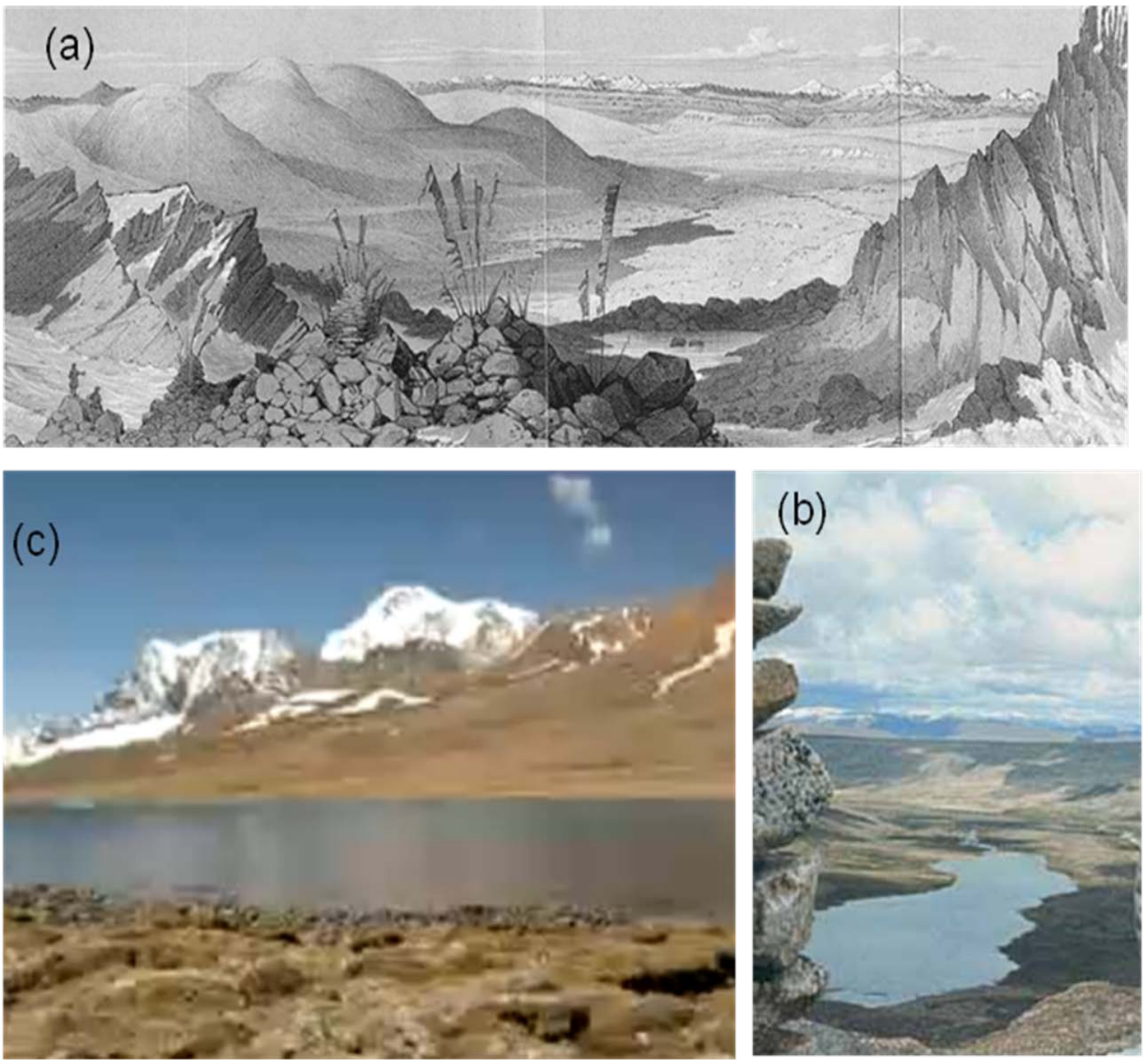


Fig.-19 Cholamu lake as seen from Donkiala pass (a) sketch by Hooker, 1849, (b) a recent photograph; (c) phtograph of the lake in summer

The altitudinal variation of the region nestling Cholamu and other important lakes like Gurudongmar in the state of Sikkim derived using DEM is shown in Fig.-21.

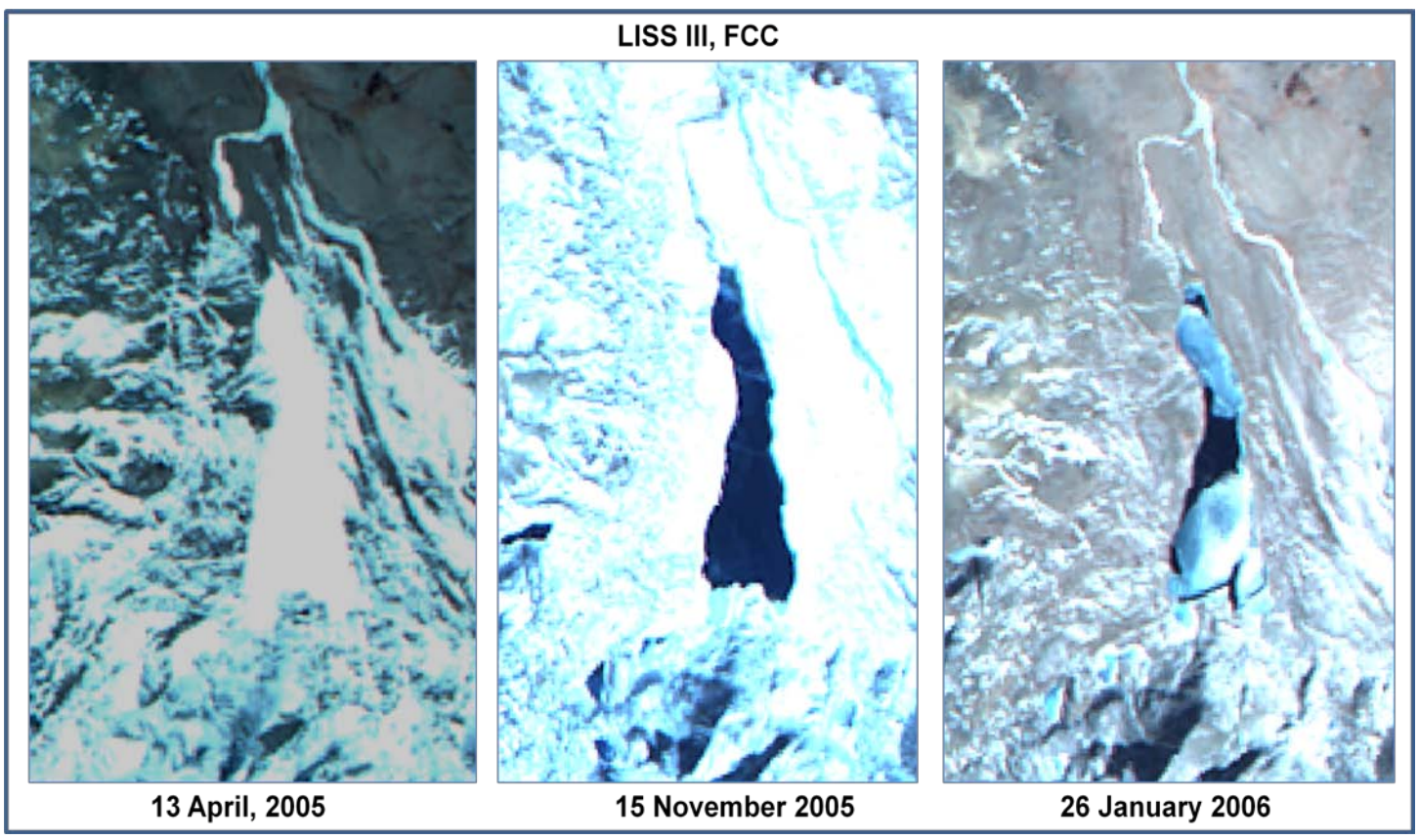


Fig.-20: Seasonal variation of Cholamu Lake (Tso Lhamu) as observed in LISS III FCC

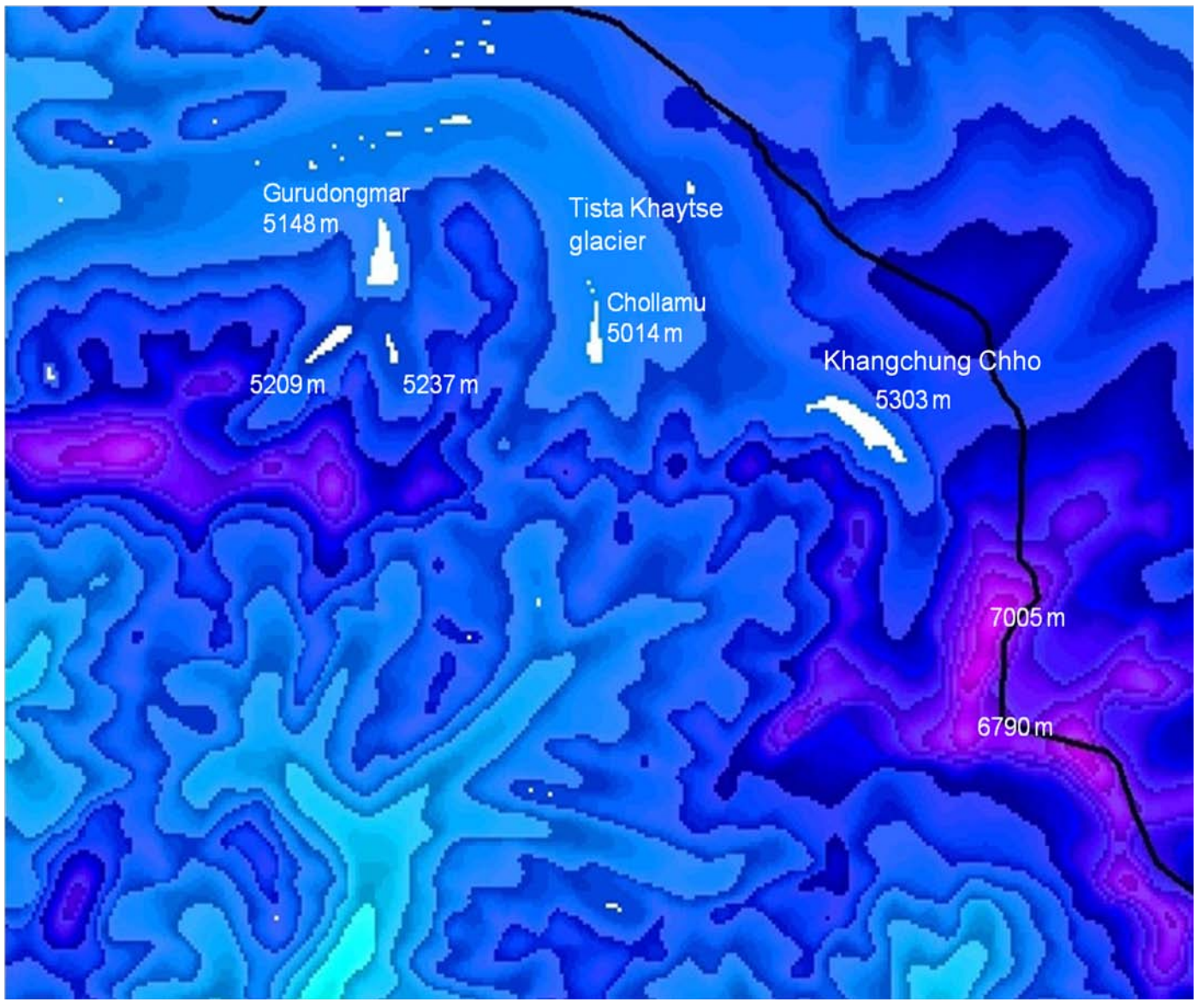


Fig.-21 Elevation setting of Cholamu and other lakes in the north of Khangchengyao Range in eastern Himalayan state of Sikkim

A large lake (Khangchung chho) on the eastern side of Cholamu lake is located at 5303 m and it is the highest among the lakes observed in this region (Fig.-22). The findings of this study are given below:

Code : 1101007801130046
Location : 27^{o} 59' 32'' N latitude and 88^{o} 48' 52'' E longitude
Altitude : 5303 m
Area : 172 ha
Perimeter : 8.65 km

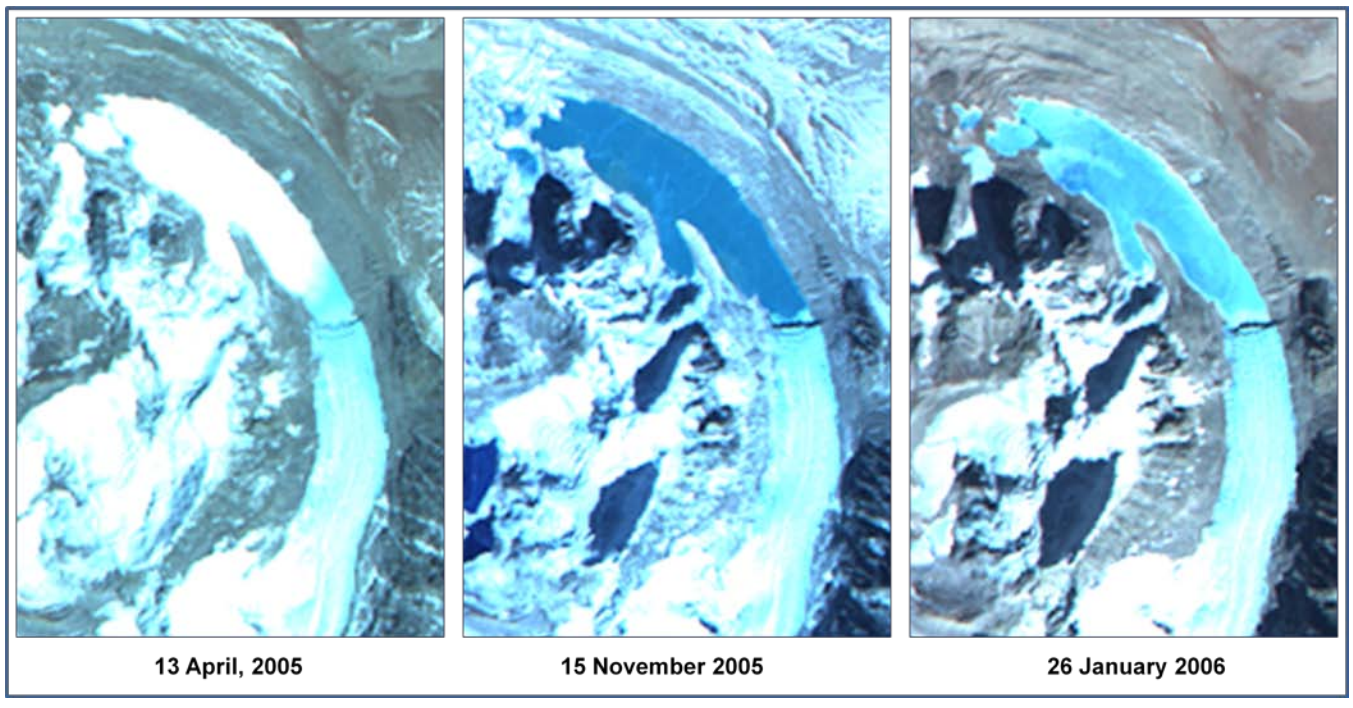


Fig.-22: IRS LISS III FCC showing the seasonal variation of the Khangchung chho

The distribution pattern of the high altitude lakes in the Indian Himalayan region with respect to altitude range and size is shown in Maps. 2a and 2b.

4.2 State level Statistics

Among the Himalayan states, Jammu & Kashmir is the leading state with 2104 high altitude lakes, occupying around 110131 ha area. Arunachal Pradesh ranked second with 1672 high altitude lakes occupying 11864 ha (Table-6). However, HALs are of special significance in case to Sikkim as HALs occupy around 44.5 per cent of total wetland area of the state. Sikkim is ranked first in terms of number of lakes per 100 km^2 followed by Arunachal Pradesh (Table-7).

Table-6: State-wise distribution of high altitude lakes in India

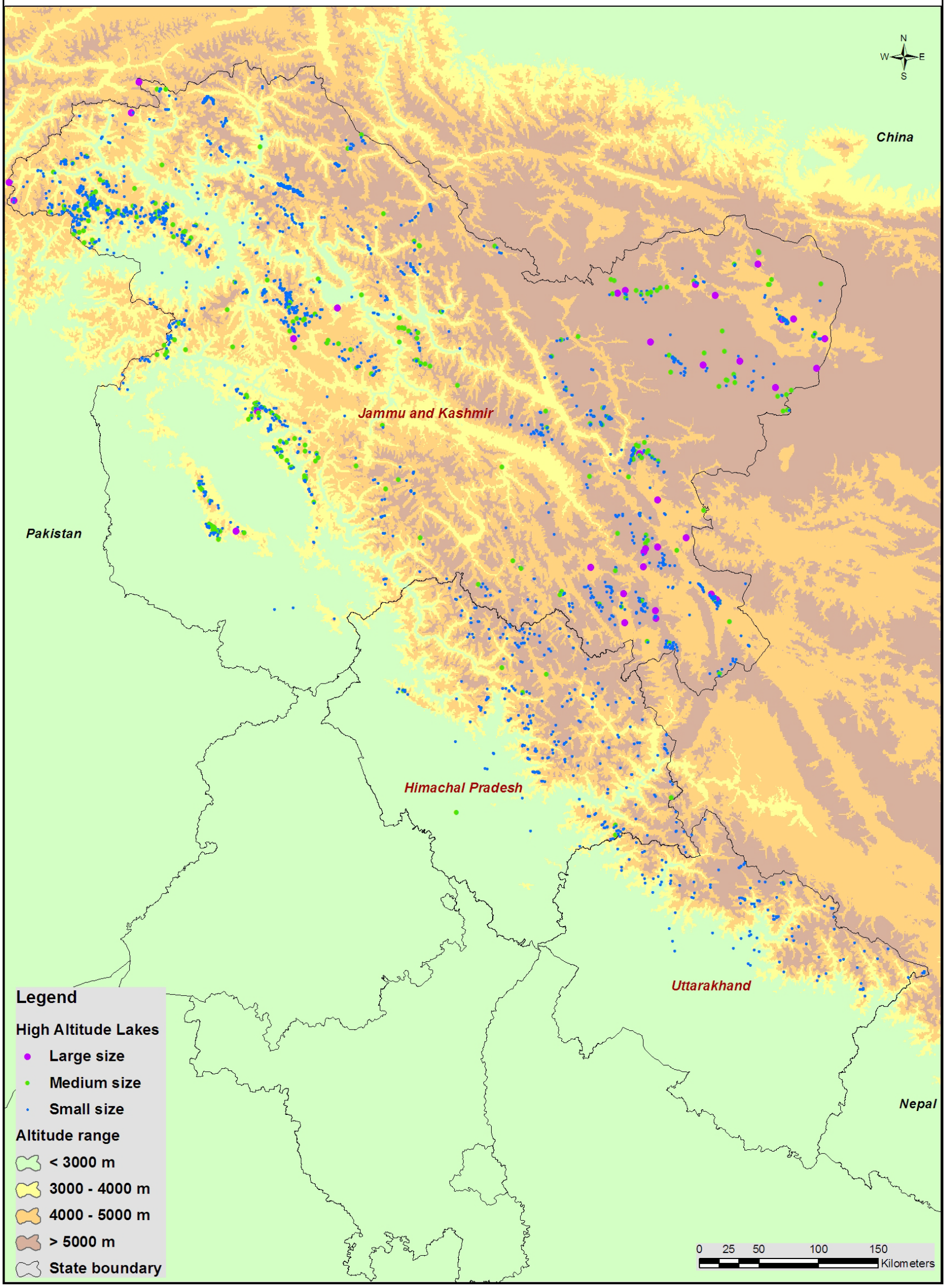
Sr. No.	State	Total	
		No. of lakes	Area (ha)
1	Jammu and Kashmir	2104	110131
2	Himachal Pradesh	271	575
3	Uttarakhand	118	231
4	Sikkim	534	3324
5	Arunachal Pradesh	1672	11864
	Total	**4699**	**126125**

Table-7: State-wise density of high altitude lakes (no of lakes / 100 km^2)

Sr. No.	State	Total Geographical area (km^2)	Geographical area (above 3000 m amsl) (km^2)	Per cent area above 3000 m amsl	No. of lakes	HAL density (No. of lakes/100 km^2)
1	Jammu and Kashmir	222236	174146	78.4	2104	1
2	Himachal Pradesh	55673	27531	49.4	271	1
3	Uttarakhand	53566	14965	27.9	118	1
4	Sikkim	7096	2783	39.2	534	19
5	Arunachal Pradesh	81424	17630	21.6	1672	9
	Total	419995	237055	56.4	4699	2

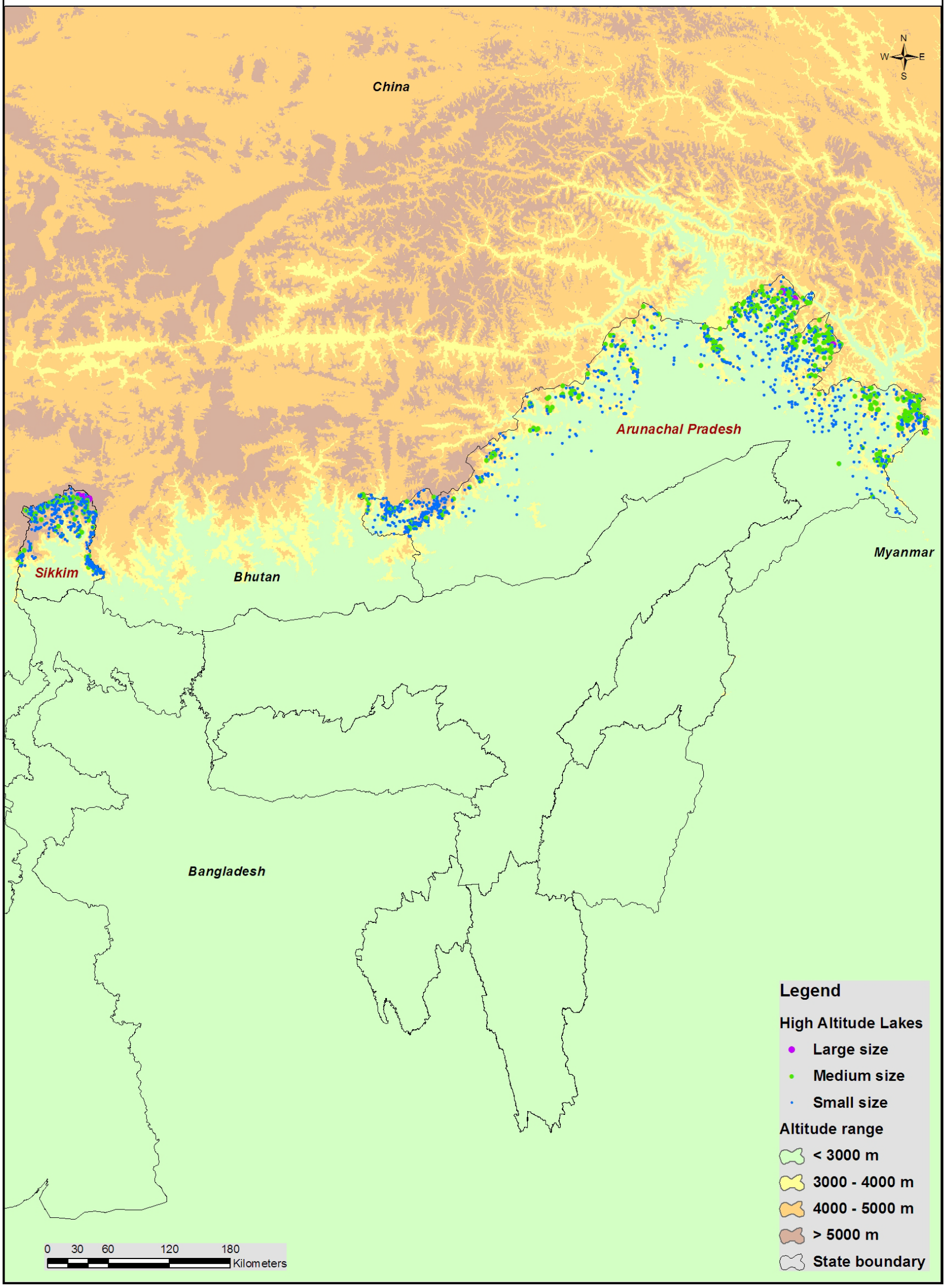
Highest number of lakes in the altitudinal range of >5000 m are also observed in case of Jammu and Kashmir, followed by Sikkim. Summary of altitude-range wise distribution of high altitude lakes is given in Table-8 and distribution pattern in term of no. of lakes and area are shown in Fig.-23a and 23b, respectively. Summary of size-wise distribution of high altitude lakes is given in Table-9 and distribution pattern in term of no. of lakes and area are shown in Fig.-24a and 24b, respectively.

Distribution pattern of high altitude lakes in Western Indian Himalayan region with respect to altitude range and size



Map-2a: Distribution pattern of the high altitude lakes in the Western Indian Himalayan region with respect to altitude and size

Distribution pattern of high altitude lakes in Eastern Indian Himalayan region with respect to altitude range and size



Map-2b: Distribution pattern of the high altitude lakes in the Eastern Indian Himalayan region with respect to altitude and size

Table-8: Altitude range-wise distribution of high altitude lakes in India

Sr. No.	State	Altitudinal range (amsl)						Total	
		(3000-4000m)		(4000-5000m)		(>5000m)			
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)
1	Jammu and Kashmir	443	3078	1245	92389	416	14664	2104	110131
2	Himachal Pradesh	20	20	168	424	83	131	271	575
3	Uttarakhand	40	43	68	159	10	29	118	231
4	Sikkim	6	18	323	1231	205	2075	534	3324
5	Arunachal Pradesh	790	5189	862	6621	20	54	1672	11864
	Total	**1299**	**8348**	**2666**	**100824**	**734**	**16953**	**4699**	**126125**

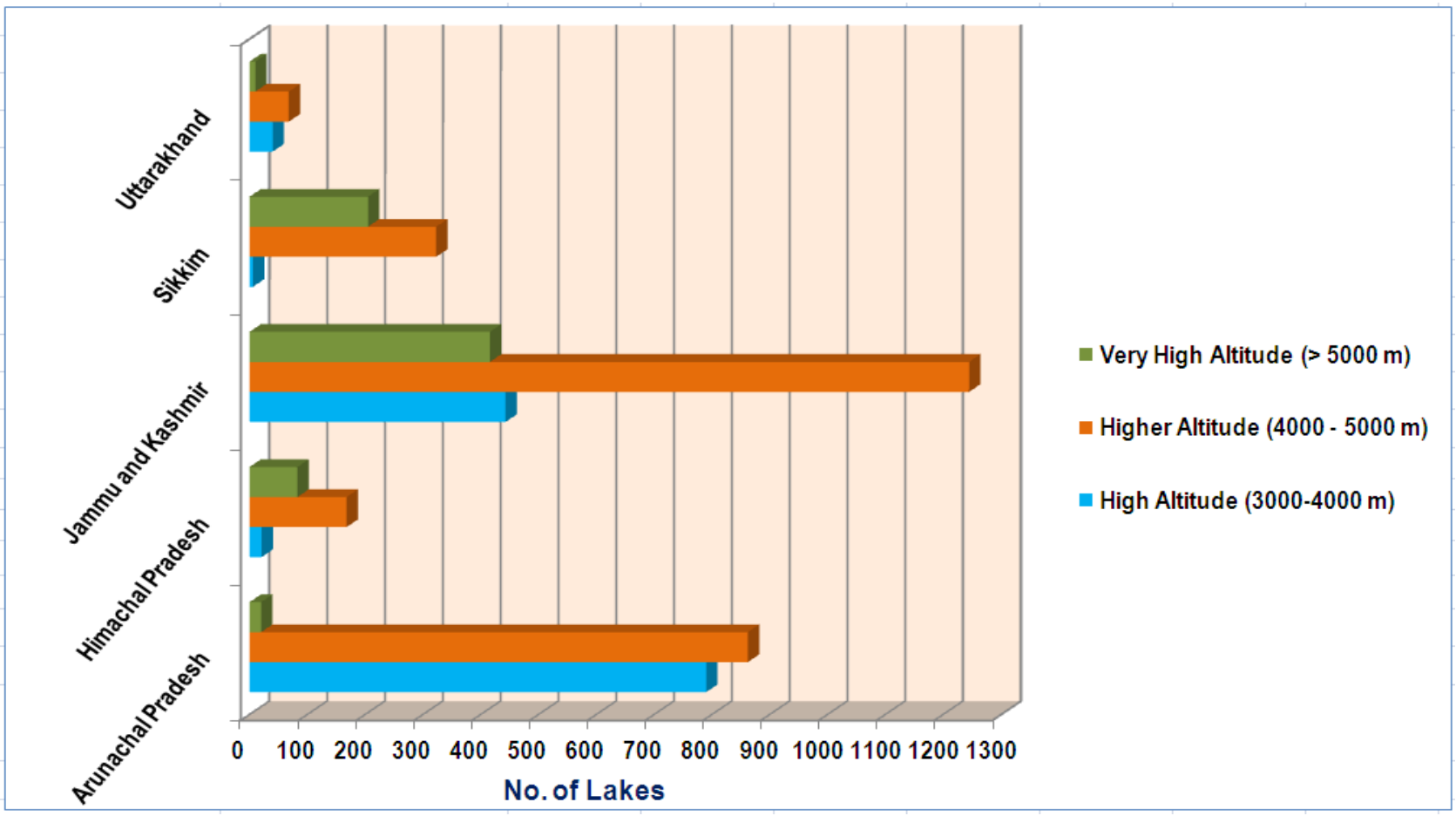


Fig.-23a: Altitude range-wise distribution of high altitude lakes in India (number)

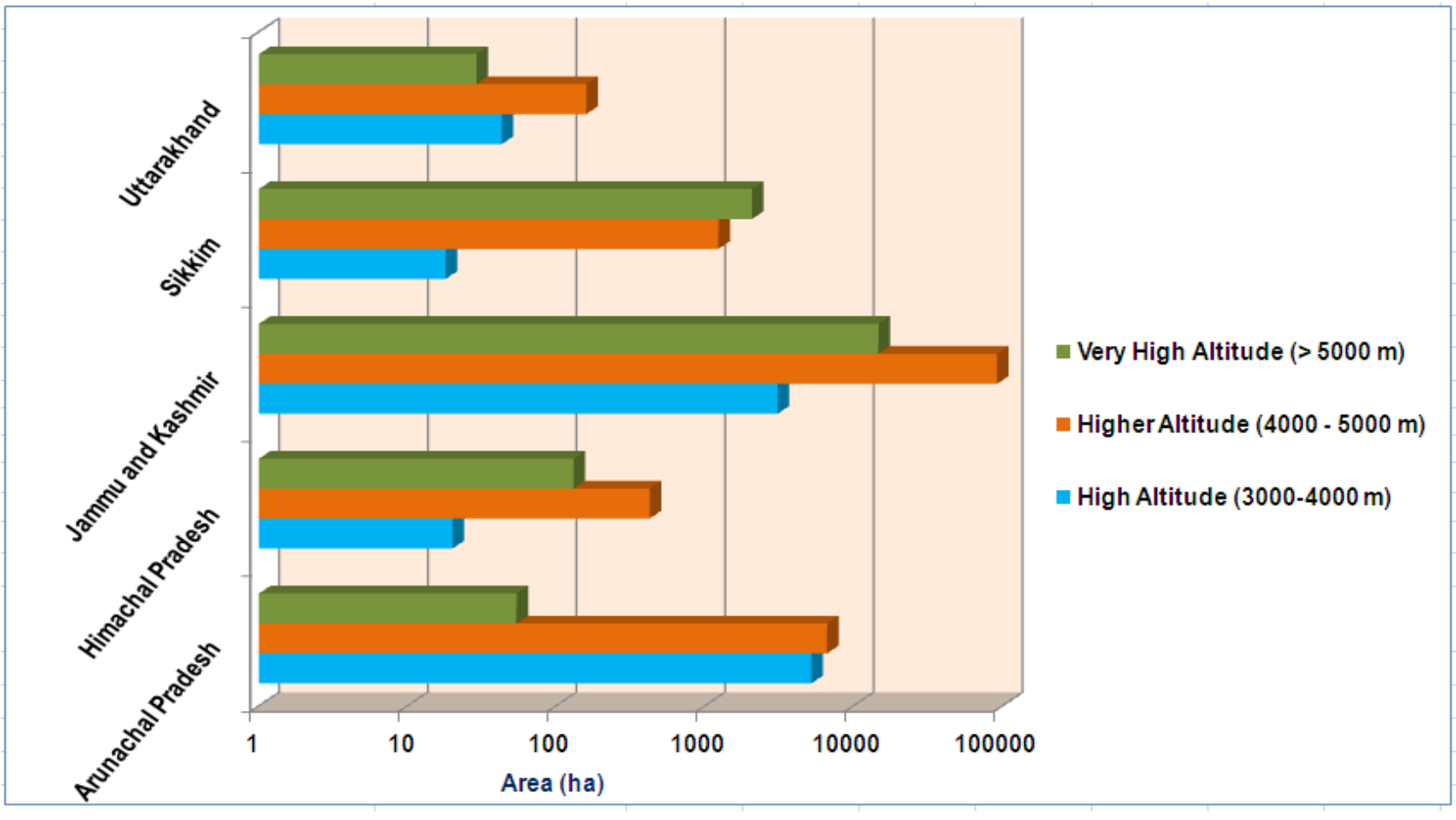


Fig.-23b: Altitude range-wise distribution of high altitude lakes in India (area)

Table-9: Size-wise distribution of high altitude lakes in India

Sr. No.	State	Very Large (> 500 ha)		Large (100-500 ha)		Medium (25-100 ha)		Small (10-25 ha)		Very Small (<10 ha)		<2.25 ha		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area* (ha)	No. of lakes	Area (ha)
1	Jammu and Kashmir	12	95499	24	4124	78	3272	185	2821	844	3454	961	961	2104	110131
2	Himachal Pradesh	0	0	0	0	2	103	5	78	34	164	230	230	271	575
3	Uttarakhand	0	0	0	0	0	0	1	17	28	125	89	89	118	231
4	Sikkim	0	0	4	497	20	874	55	826	180	852	275	275	534	3324
5	Arunachal Pradesh	0	0	3	372	77	3117	252	3937	899	3997	441	441	1672	11864
	Total	12	95499	31	4993	177	7366	498	7679	1985	8592	1996	1996	4699	126125

** Nominal assignment*

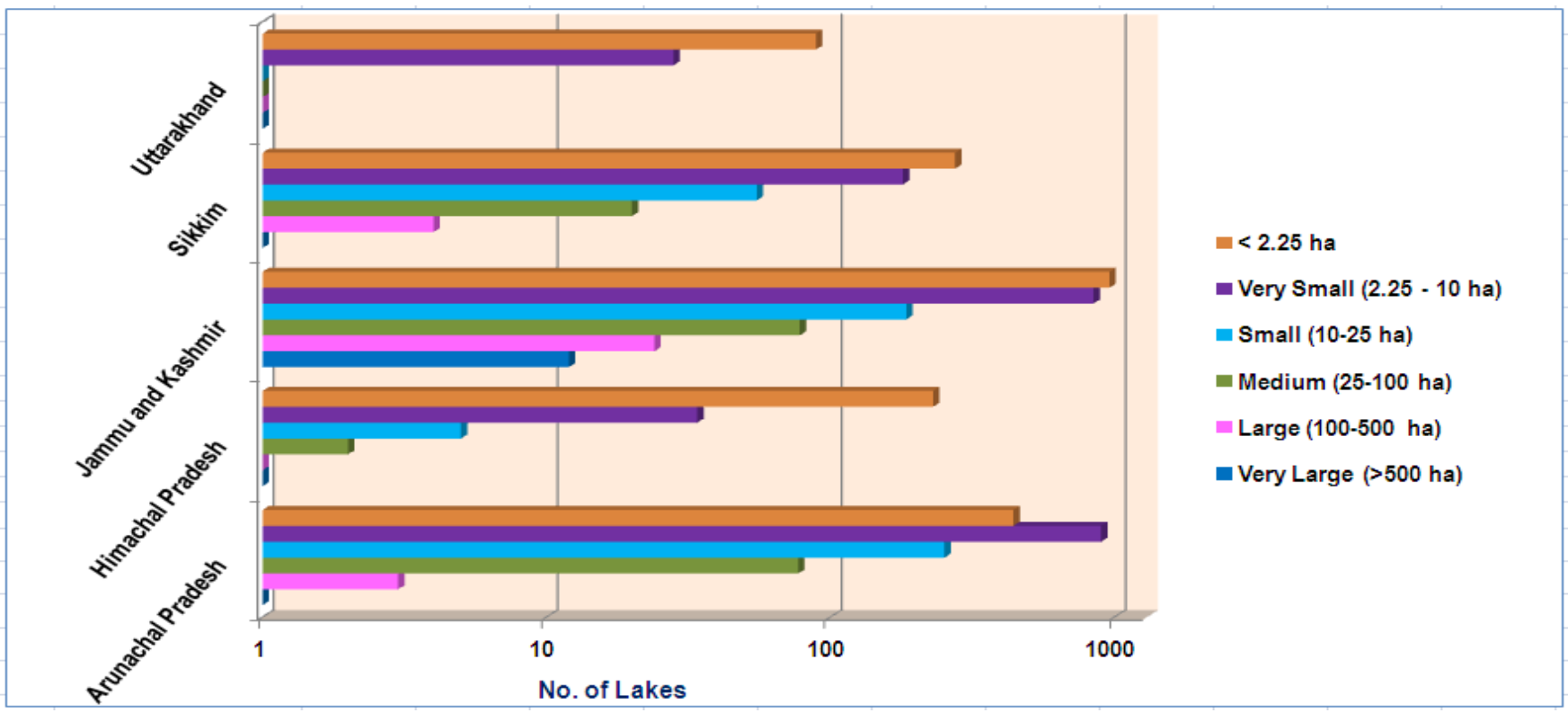


Fig.-24a: Size-wise distribution of high altitude lakes in India (number)

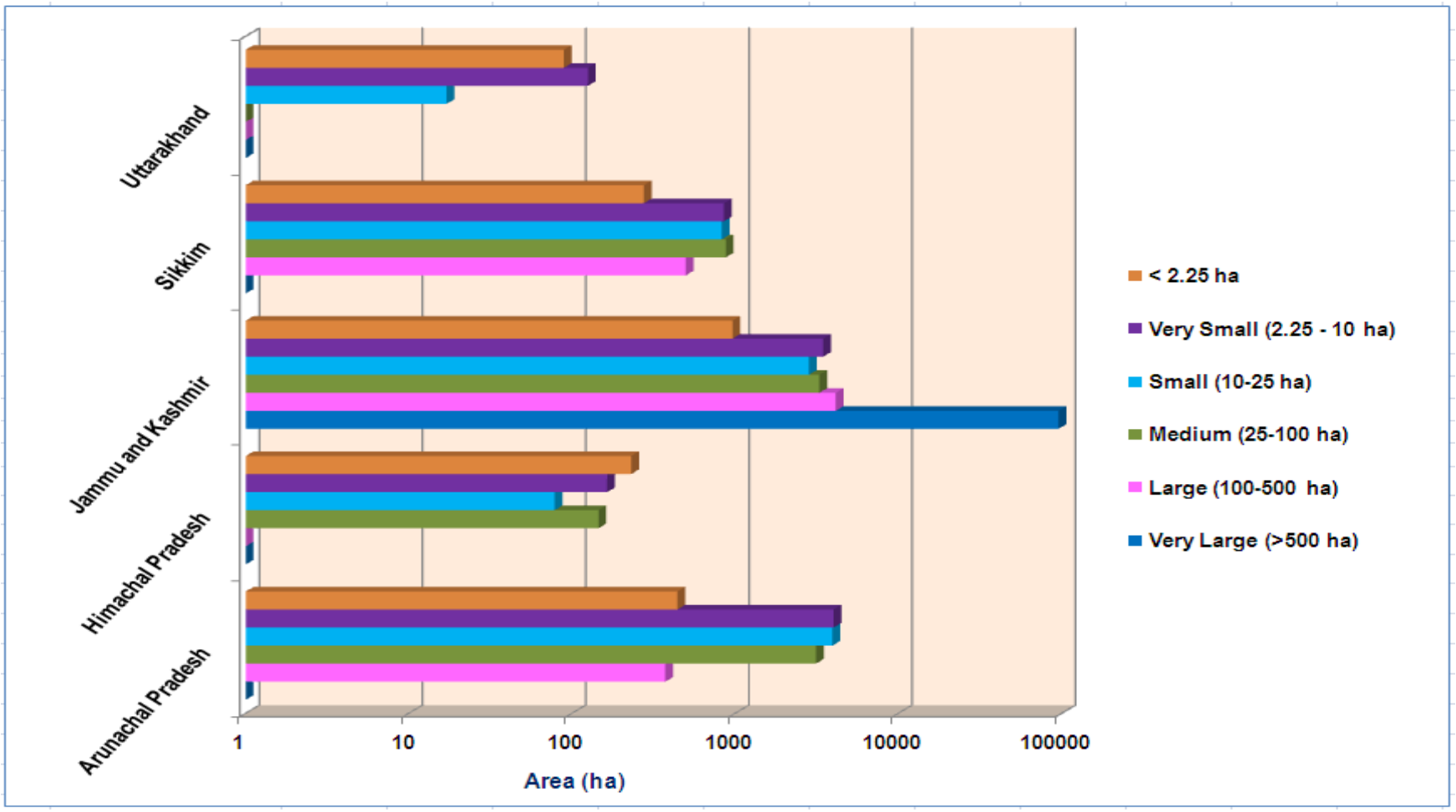


Fig.-24b: Size-wise distribution of high altitude lakes in India (area)

4.2.1 Jammu and Kashmir :

Jammu and Kashmir is the western most state of the Himalayan region in India. The total area of the state is about 2,22,236 sq. km. The state comprises three natural divisions, namely, Jammu, Kashmir and Ladakh (Fig.-25). The Himalayas divide the Kashmir valley from Ladakh while the Pir_Panjal range, which encloses the valley from the west and the south, separates it from the Great Plains of northern India. The average elevation of Ladakh region is >3000m, thus most of the high altitude lakes are nestled in this region. The climate of Ladakh is extremely dry and cold with annual precipitation of around 100 mm. All the rivers and lakes freeze during winter. The total numbers of districts in the state are twenty, with Leh having largest geographic area and Budgam, the smallest.

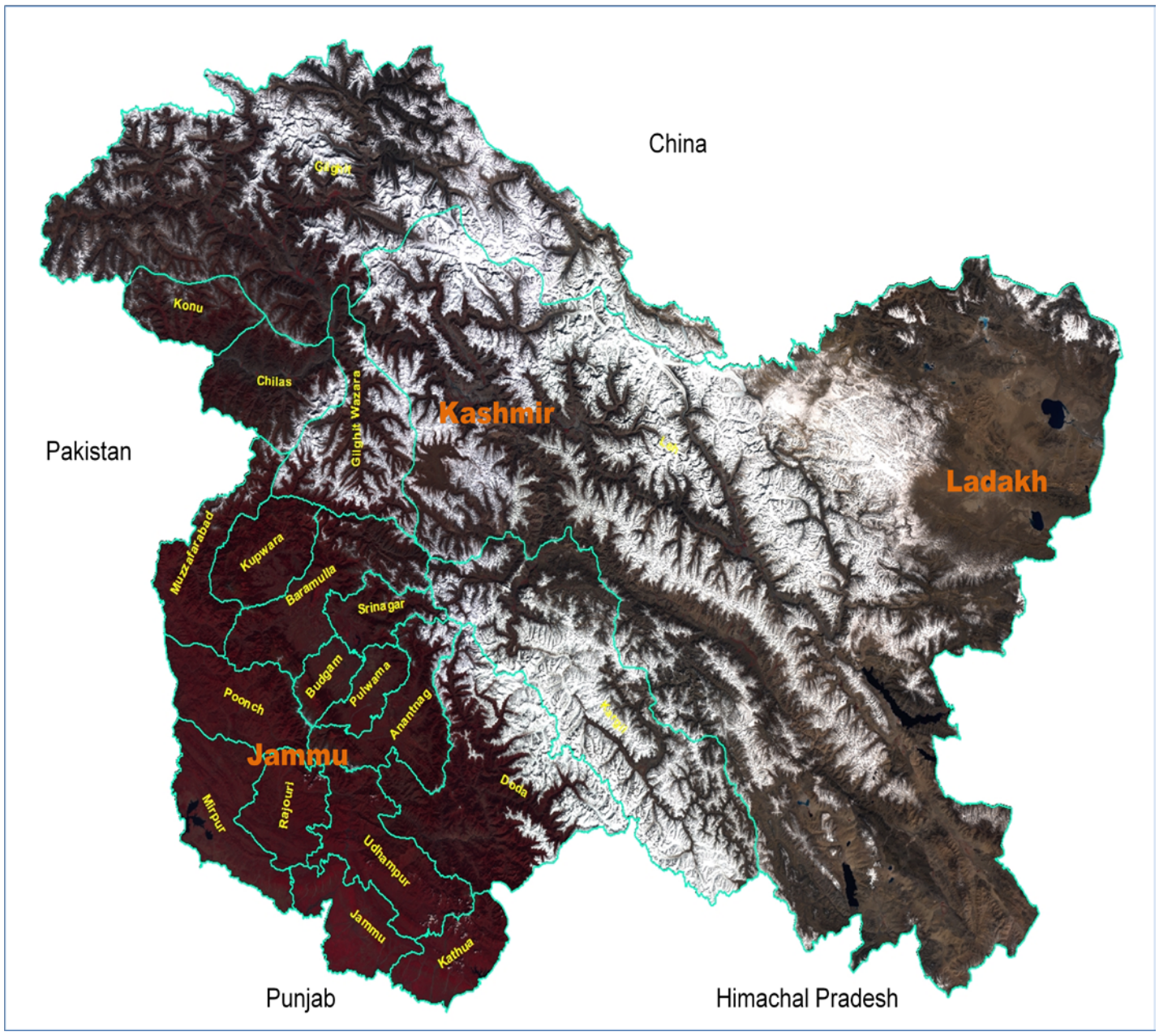


Fig.-25: The geographical setting of Jammu, Kashmir and Ladakh regions in the state of Jammu and Kashmir as seen in IRS AWiFS FCC (district boundaries shown in cyan line)

Total 1143 high altitude lakes are mapped at 1:50,000 scale and 961 small ones marked as point features, taking the total number to 2104 in the state. Size wise distribution showed that, maximum number of lakes have < 10 ha area, followed by 185 lakes of the size of 10-25 ha (Table-10). However, this state harbours all the 12 large lakes (area > 500 ha) mapped in the entire Indian Himalayas (Table-3) Altitude wise distribution of lakes showed that maximum number of lakes (1245) are in the elevation range of 4000-5000 m (Table-11). This state also has 416 lakes situated in altitude range of >5000 m (Fig.-26). The distribution pattern of high altitude lakes in the state with respect to altitude range is shown in Map-3.

Table-10: Size-wise distribution of high altitude lakes in Jammu & Kashmir

Sr. No.	Class	Range	No. of lakes	Area (ha)
1	Very Large	> 500 ha	12	95499
2	Large	100-500 ha	24	4124
3	Medium	25-100 ha	78	3272
4	Small	10-25 ha	185	2821
5	Very Small	2.25-10 ha	844	3454
6	< 2.25 ha	< 2.25 ha	961	961*
Total			**2104**	**110131**

* *Nominal assignment*

Table-11: Altitude-wise distribution of lakes in Jammu & Kashmir

Sr. No.	Category	Altitude Range (m)	No. of lakes	Area (ha)
1.	High Altitude	3000-4000	443	3078
2.	Higher Altitude	4000-5000	1245	92389
3.	Very high Altitude	>5000	416	14664
Total			**2104**	**110131**

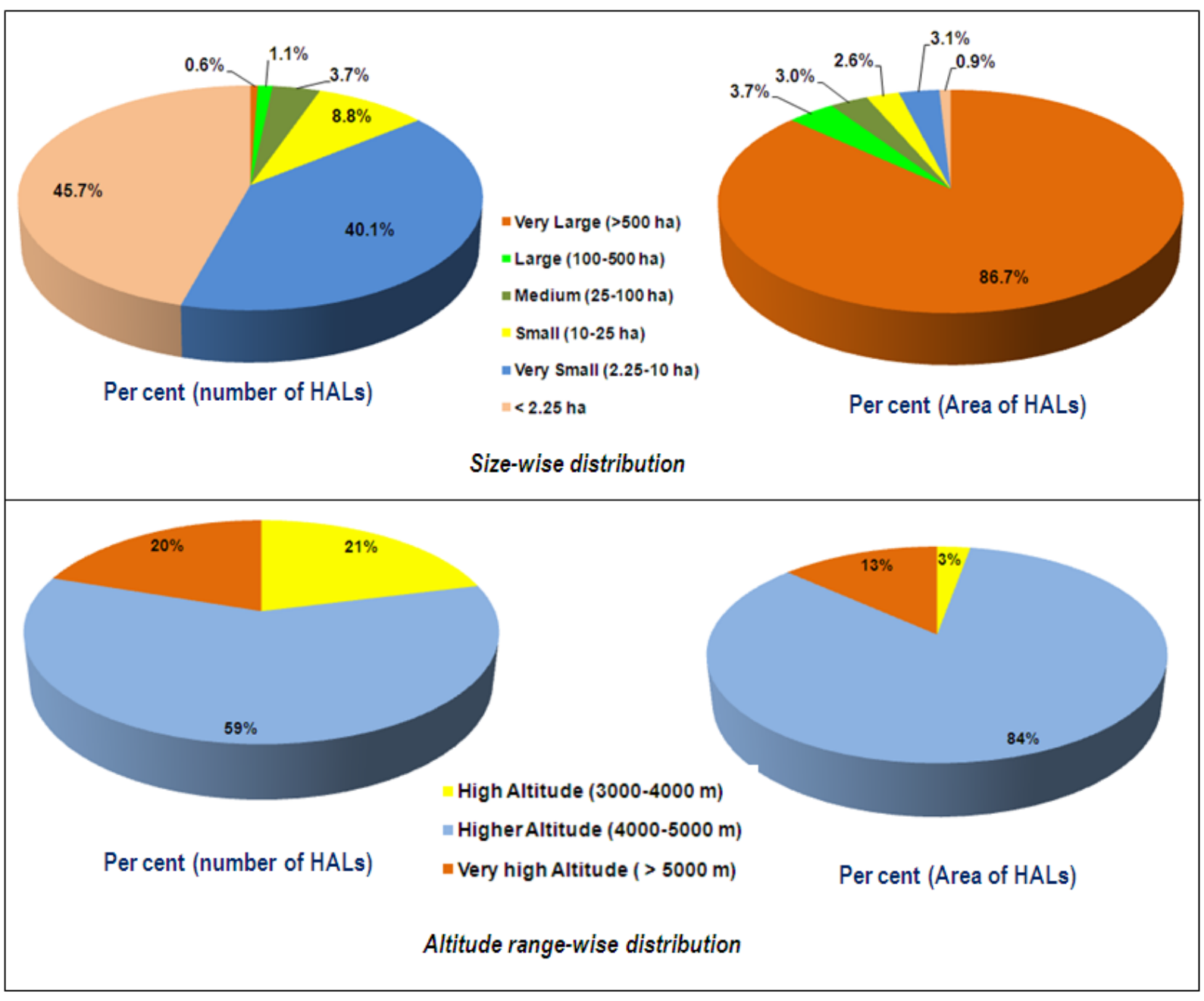


Fig.-26: Size-wise and Altitude range-wise distribution of high latitude lakes in Jammu and Kashmir

Most of the lakes in this state fall under the remnant category and are saline or brackish in nature. The Ladakh region harbours a large number of HALs and some of the large lakes like Pangong Tso, Tso Moriri and Tso Kar. The geographical setting of this area as derived from DEM is shown in Fig.27.

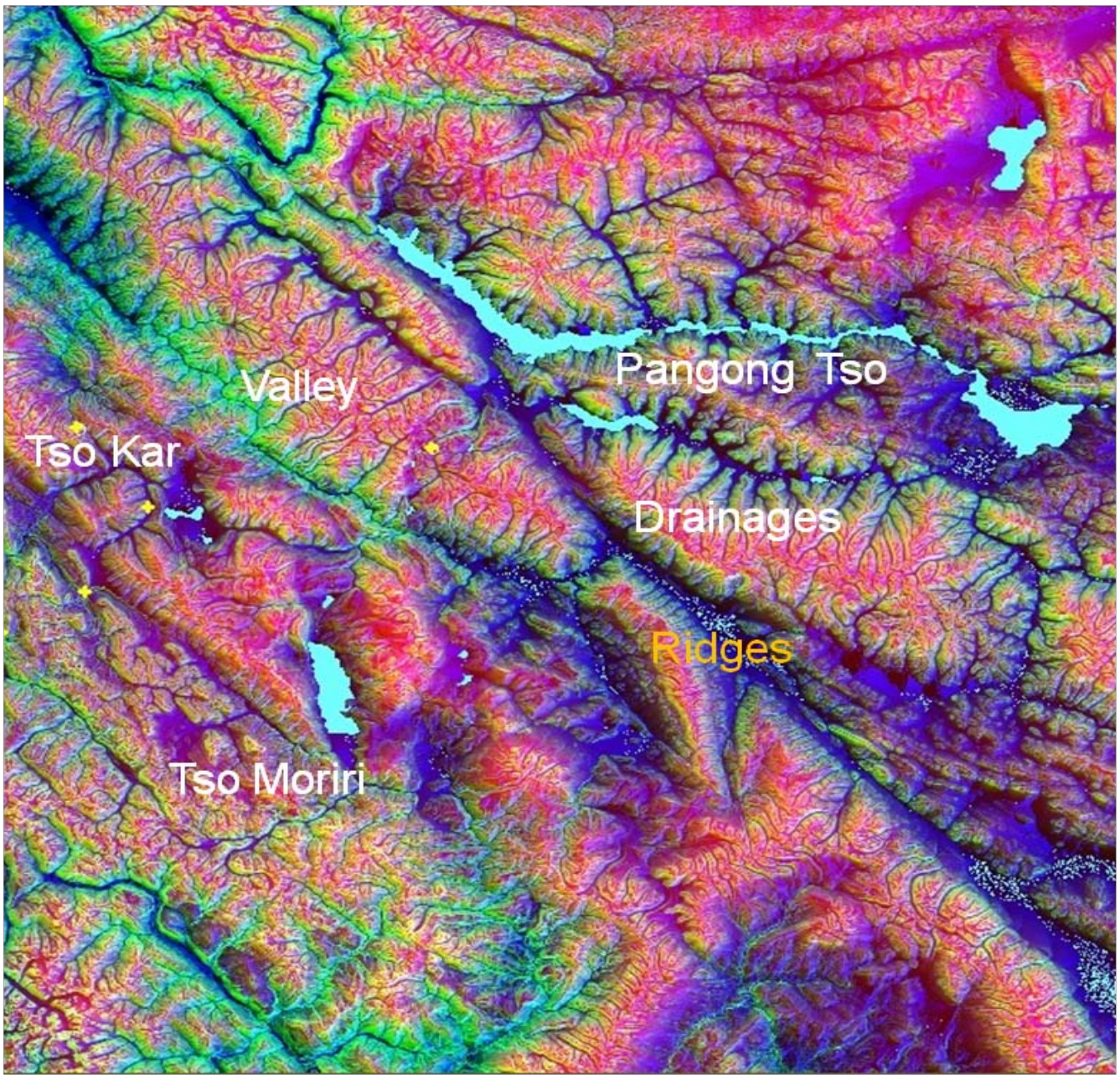


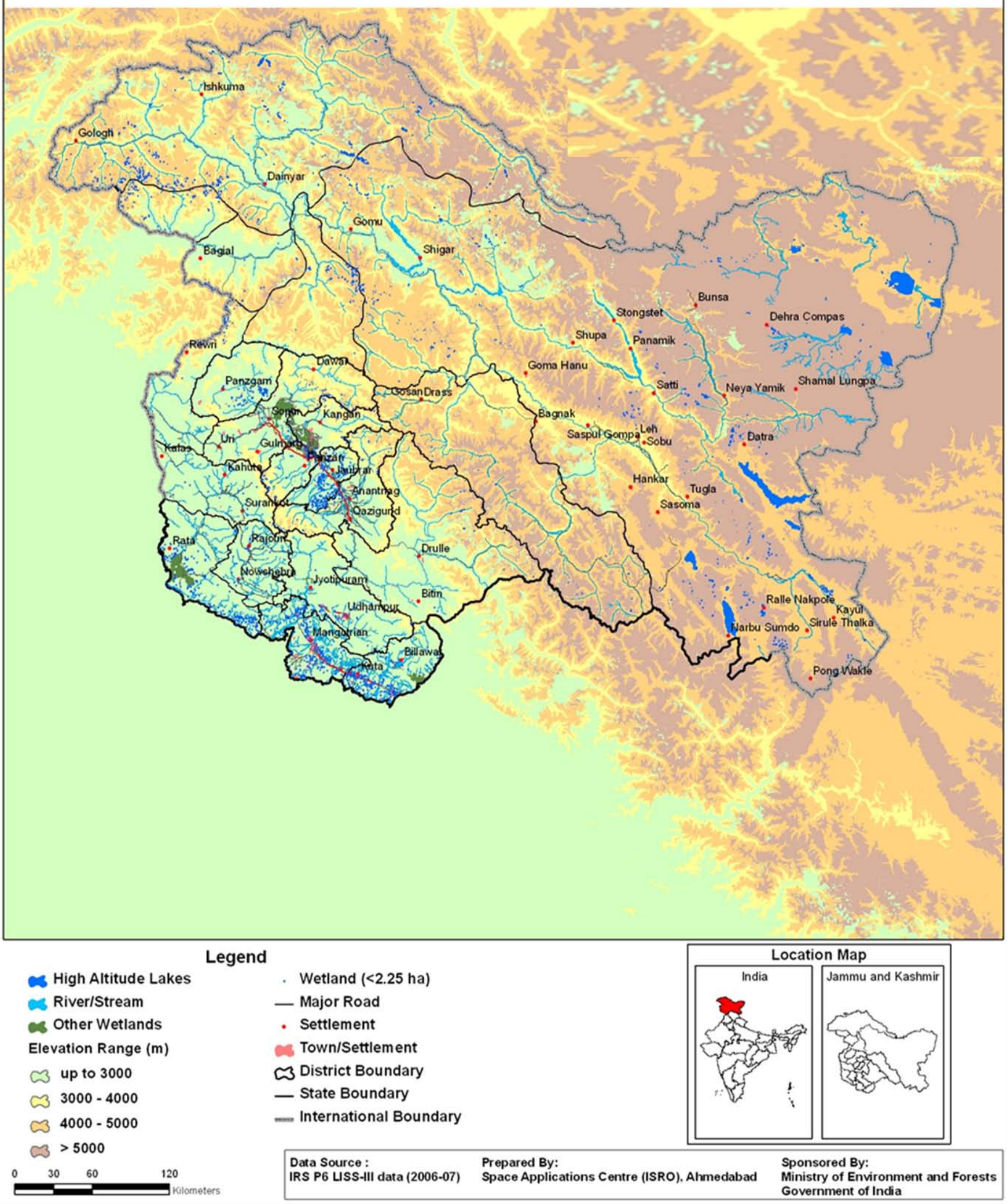
Fig.-27: The geographical setting of the Ladakh region with large number of lakes nestled above 4000 m elevation derived using DEM

The lakes in this region are found at an average altitude of 4400 m amsl. The region is devoid of any vegetation except the grasslands found in low depressions/marshy areas. The area is characterised by arctic wind-swept cold desert and barren hills. Borax deposit in the dried marshy areas and around the lake is very common (Fig.28). The lakes remain frozen for 3-4 months (December-March). When the lakes start melting during March, these are visited by migratory birds. Tso Kar and Tso Moriri are two well known lakes of the state. A small lake the Nuro Sumdo (with a catchment area of 20 km^2), lies around 30 km south of Tso Moriri in the catchment of Pare Chu river.

Fig.-28 The cold desert landscape of Changthang, sheltering important remnant lakes like Tso Moriri, Tso Kar, Nuro Sumdo (a) windswept barren hills, (b) borax laden soil with sparse vegetation

State : Jammu and Kashmir

High Altitude Lakes



Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands
- Elevation Range (m)
  - up to 3000
  - 3000 - 4000
  - 4000 - 5000
  - > 5000
- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 30 60 120 Kilometers

Location Map

India | Jammu and Kashmir

Data Source :	Prepared By:	Sponsored By:
IRS P6 LISS-III data (2006-07)	Space Applications Centre (ISRO), Ahmedabad	Ministry of Environment and Forests Government of India

Map-3: Distribution pattern of high altitude lakes in Jammu and Kashmir with respect to elevation range

Tso Moriri

Tso Moriri (official name: Tsomoriri Wetland Conservation Reserve) is one of the two recognised high altitude lake Ramsar sites in India and only one in J&K. The lake is in the Changthang region with catchment area of around 120 sq.km. It is surrounded by the elevated valley with hills rising to 6000 m. It is an elongated lake, with around 40 m of maximum depth (Fig.-29). The information derived about this lake are:

Code : 0107005212050001
Location : 32^0 45' N to 33^0 00' N latitudes and 78^0 15' E to 78^0 22' E longitudes
Altitude : 4,522 m.
Length : 30 km length
Width : average 9 km.
Area : 14,530 ha
Perimeter : 108.7 km

It is a fresh to brackish water lake (< 5.86 g/l NaCl during summer). The lakes have no aquatic vegetation, only the shallow water fringing the lake harbour *Potamogeton* sp. 3D perspective view of Tsomoriri is shown in Fig.-30. The, the deep, clear, oligotrophic nature of the lake is manifested by its very dark signature in the satellite image. The lake is an important breeding ground for the barheaded goose and water fowls.

The lake formerly had an outlet to the Sutlej river, but it has contracted considerably and become land locked; as a result; the water is now brackish to saline. The snow peaks of the Changthang plateau are the source of water for the Lake. Several small mountain streams, notably two major ones feed the Lake, one entering the lake from the north, the other from the south-west. Both stream systems create extensive marshes while entering the lake. Marshes support several species of sedges and reeds, particularly *Carex, Caragana and Astragalus sps*,. These are of high value to the Changpas - the nomadic pastoral communities as grazing ground of yak, sheep, goat, and horses. The alluvial plain formed by the third stream that enters the lake from west near the village Korzan is cultivated.

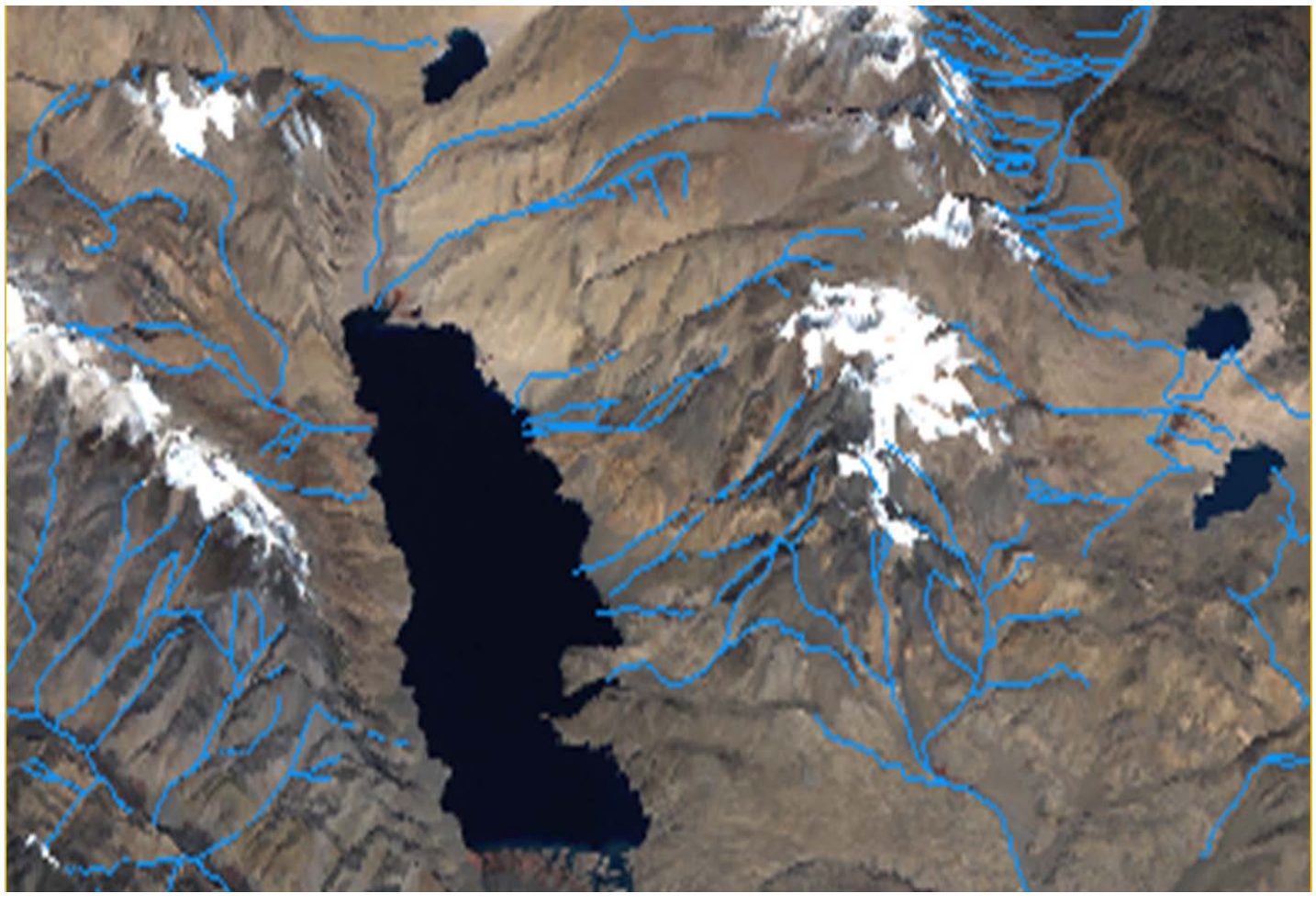
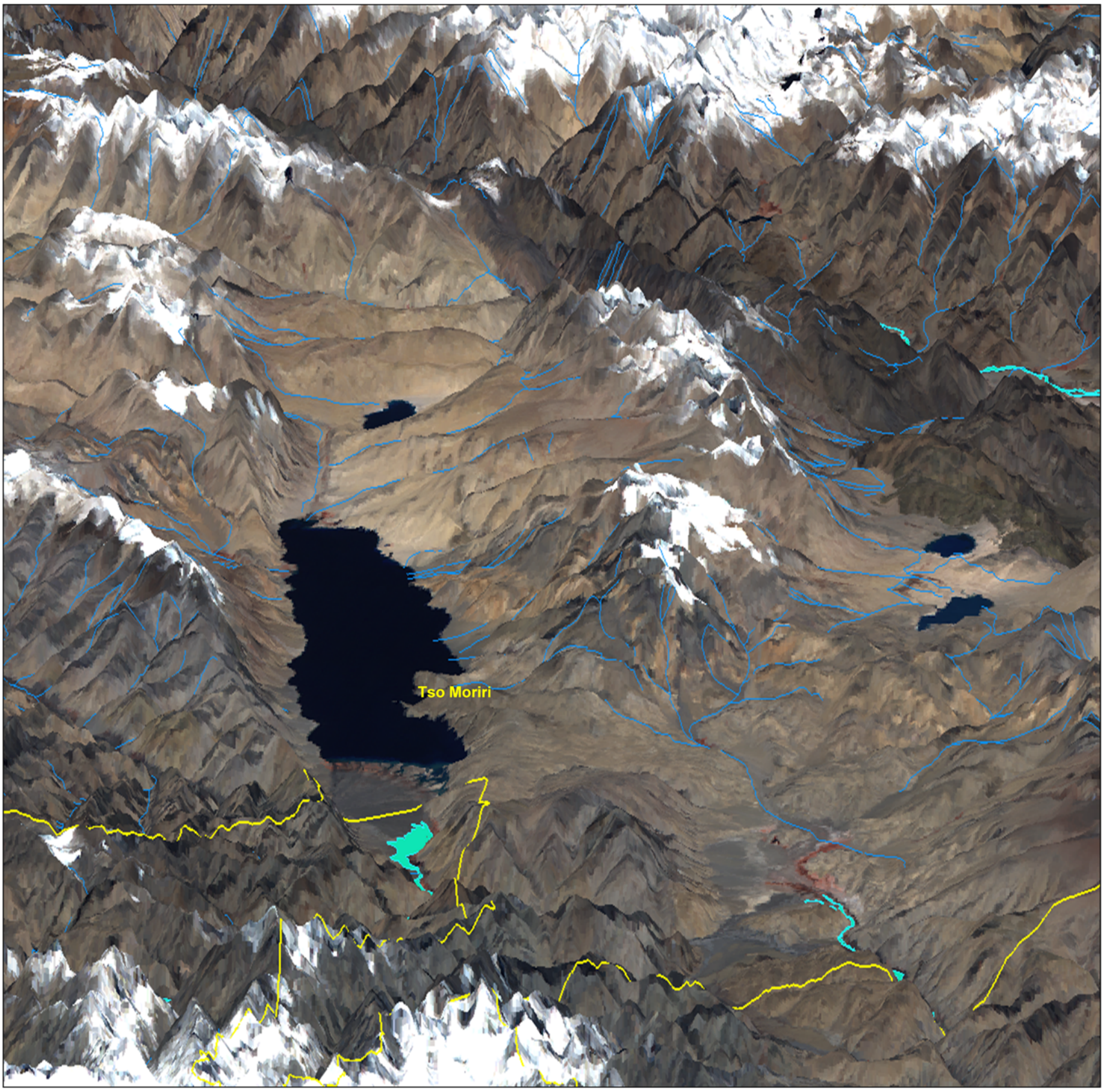


Fig.29: LISS III FCC of October showing the Tso Moriri and its surrounding (blue lines are the drainage channels)

State : Jammu and Kashmir

3D perspective view

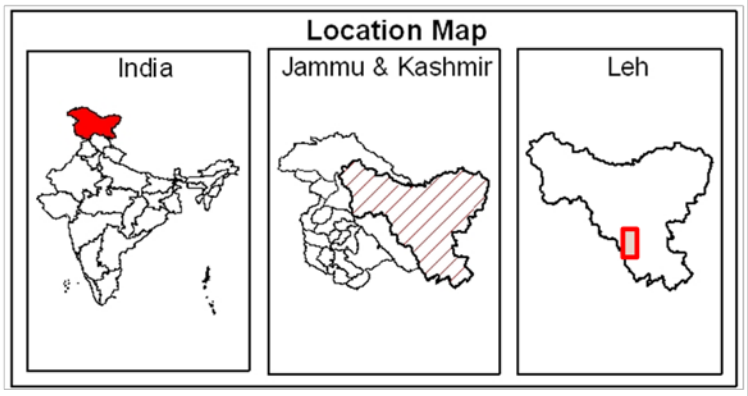
Tso Moriri, Leh District



IRS P6 LISS-III image draped on DEM

River
Drainage
State Boundary

Location Map



Data Source :
- IRS P6 LISS-III data (2007)
- SRTM DEM
- NWIA Geodatabase

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests, Government of India

Fig.-30: 3D perspective view of Tso Moriri (LISS III image draped on DEM)

Tso Kar

Tso Kar lake is located in the north-western side of Tso Moriri. It is supposed to be evolved from a former large freshwater lake. Currently it is split into two having an irregular L shape. The lake basin is now land locked. It is a salt water lake with large area of the catchment showing salt deposit and sand corrals (calcium bi carbonate). The lake is connected from its south side by a narrow channel to a fresh water lake Startsapuk Tso (Fig.-31). Facts derived in this study are:

Code : 0107005211030002
Location : 33^0 14' N to 33^0 22' N latitudes and 77^0 57' E to 78^0 03' E longitudes
Altitude : 4541 m.
Area : 6,179 ha.
Perimeter : 50.5 km

The small part of the lake has aquatic and marshy vegetation in the periphery, composed of *Potamogeton sp.* and *Hydrilla sp.* These plants dry up in winter to form floating mats of weed. The adjacent freshwater marshes and damp meadows support a mixture of *Carex sp*. and *Ranunculus sp*. The arid steppe vegetation of surrounding areas is dominated by species of *Astragalus and Caragana*. This is a favourite grazing ground for the Wild ass and Tibetan gazelles. The basin is a major breeding area for Barheaded goose, Brahminy duck, brown-headed gull, and common tern. Marmots (*Marmota bobak*) are commonly found around the lakes creating small mounds while digging burrows. 3D perspective view of Tso Kar is shown in Fig.-32.

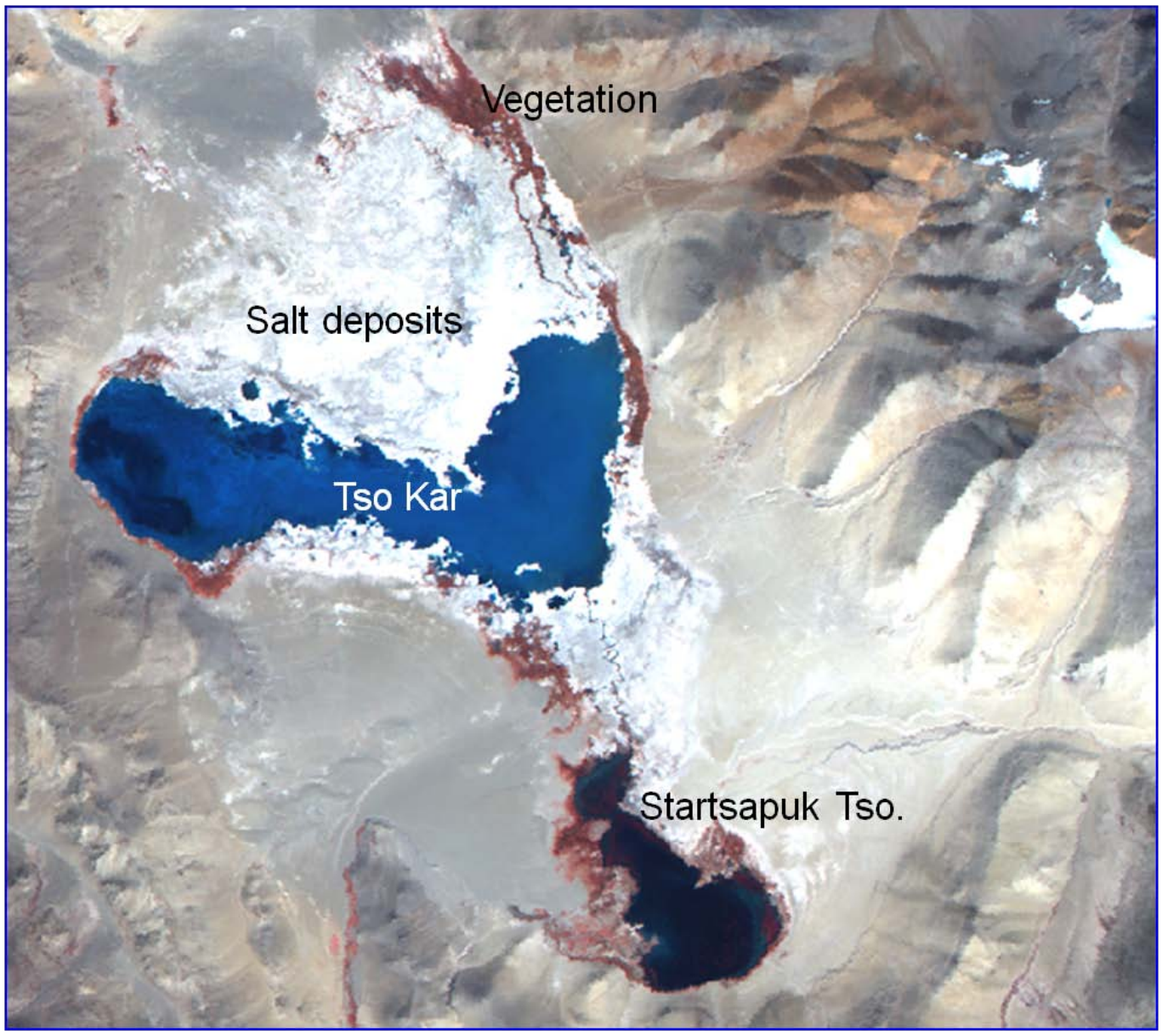


Fig.-31 LISS III FCC of October showing Tso Kar and its environment

State : Jammu and Kashmir

3D perspective view

Tso Kar, Leh District

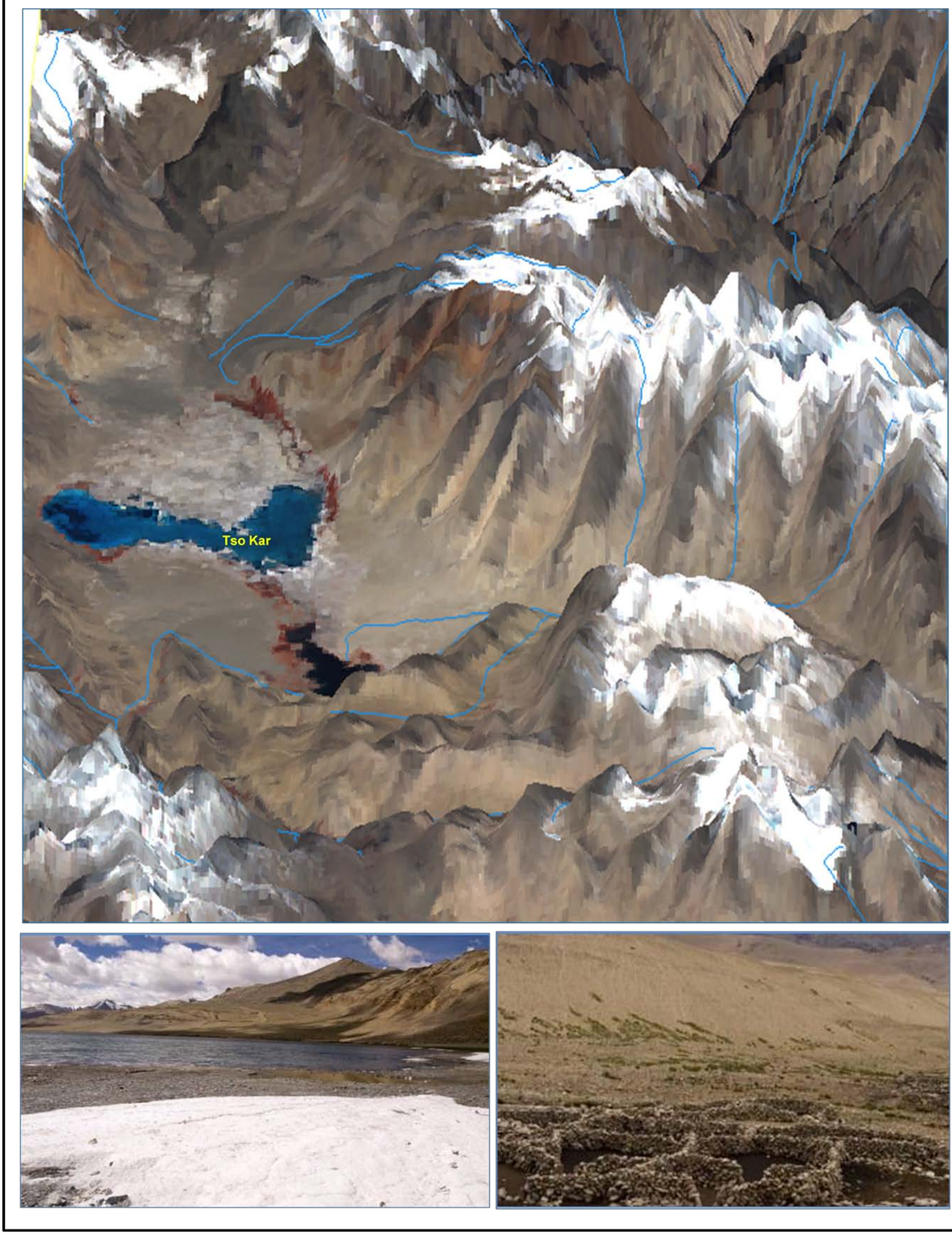


Fig.-32: 3D perspective view of Tso Kar (LISS III image draped on DEM) and photograph showing salt deposit and sand corrals in dried-up lake area.

District-wise analysis

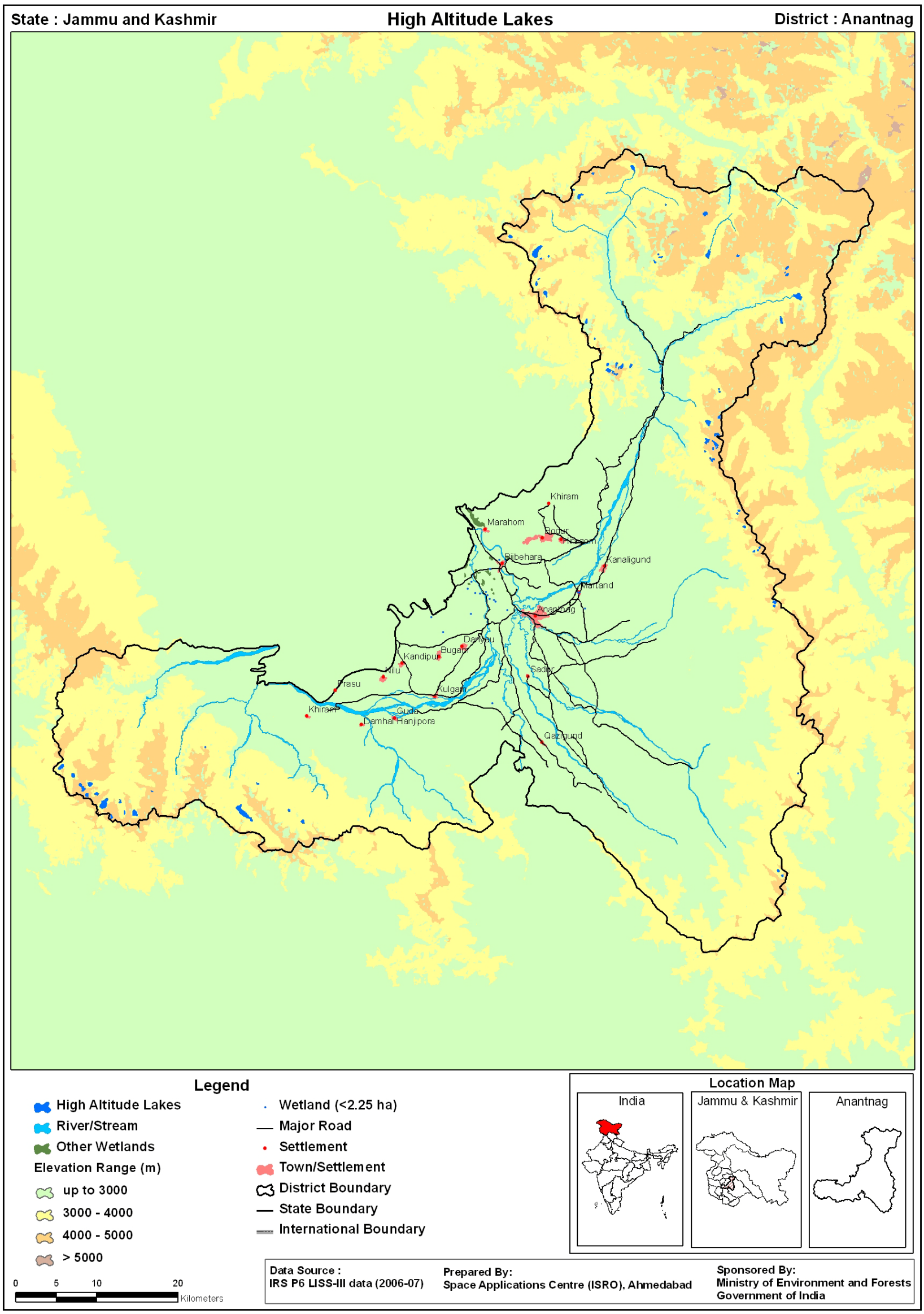
HALs are observed to be present in 16 districts out of 20 districts. Leh and Gilgit are the two districts with large number of HALs i.e. 925 and 601 respectively. Leh district also has the distinction of having maximum number of lakes in the altitudinal range of >5000 m. The other two districts which have lakes in this altitudinal range are Gilgit and Kargil. Leh also harbours all the 12 large lakes (>500 ha area) found in the Indian Himalayas, including the largest lake Pangong Tso. The altitudinal range-wise and size-wise distribution of high altitude lakes in each district of the state is shown in Table-12 and 13 respectively. District-wise maps are shown from Map-4 to 19.

Table-12: Altitudinal range-wise distribution of high altitude lakes in each district of Jammu and Kashmir

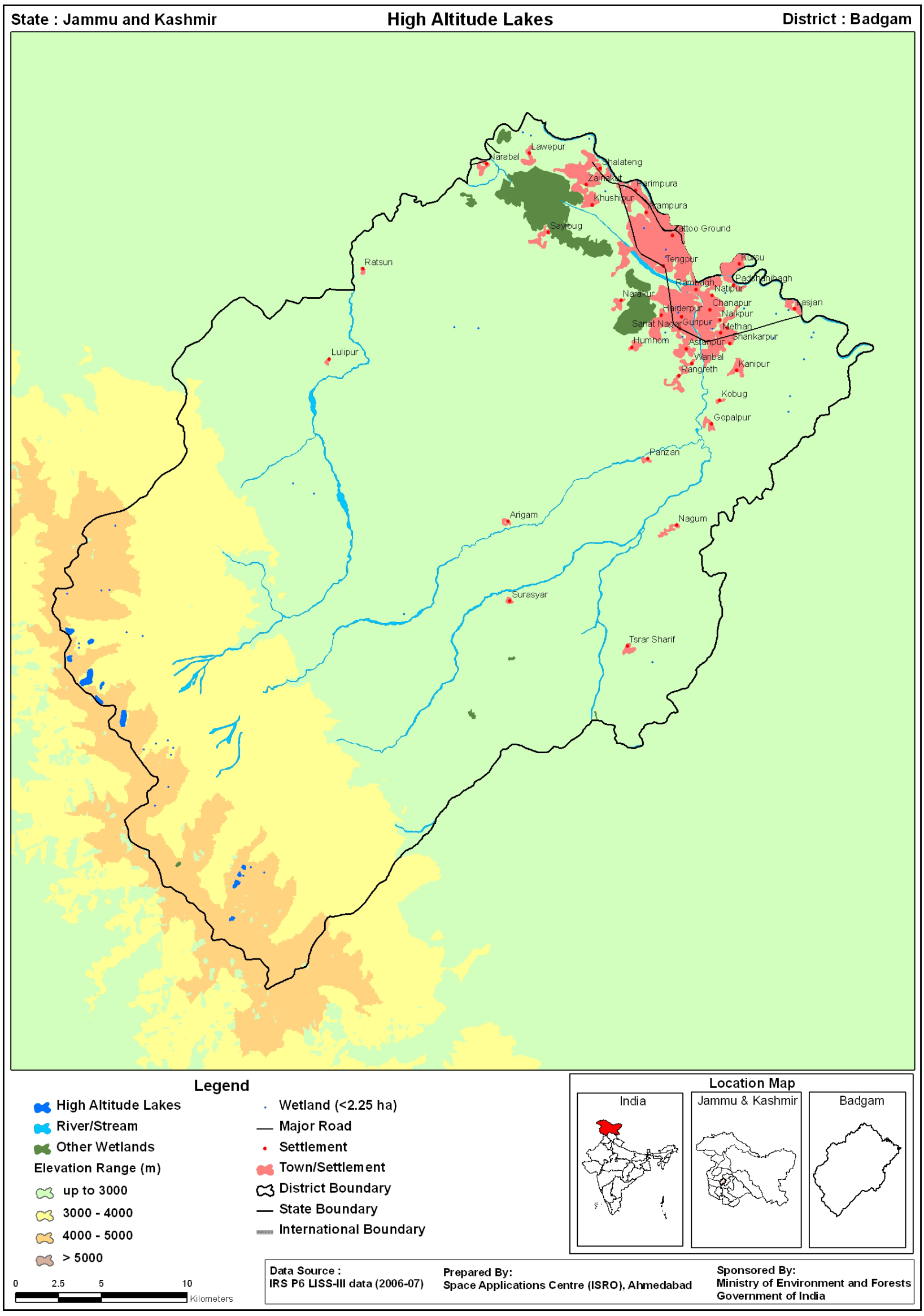
Sr. No.	District	High Altitude (3000-4000m)		Higher Altitude (4000-5000m)		Very High Altitude (>5000m)		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)
1	Anantnag	49	780	24	250	-	-	73	1030
2	Badgam	8	20	21	148	-	-	29	168
3	Baramula	31	411	15	45	-	-	46	456
4	Chilas	9	31	17	30	-	-	26	61
5	Doda	10	16	14	76	-	-	24	92
6	Gilghit	167	690	426	2040	8	22	601	2752
7	Gilghit Wazara	19	99	90	397	-	-	109	496
8	Kargil	2	11	34	198	7	20	43	229
9	Konu	19	162	93	462	-	-	112	624
10	Leh (Ladakh)	75	250	449	88502	401	14622	925	103374
11	Muzzafarabad	21	219	29	109	-	-	50	328
12	Poonch	10	33	3	29	-	-	13	62
13	Pulwama	1	2	1	2	-	-	2	4
14	Rajauri	6	37	-	-	-	-	6	37
15	Srinagar	15	313	27	92	-	-	42	405
16	Udhampur	1	4	2	9	-	-	3	13
	Total	**443**	**3078**	**1245**	**92389**	**416**	**14664**	**2104**	**110131**

Table-13: Size-wise distribution of high altitude lakes in each district of Jammu and Kashmir

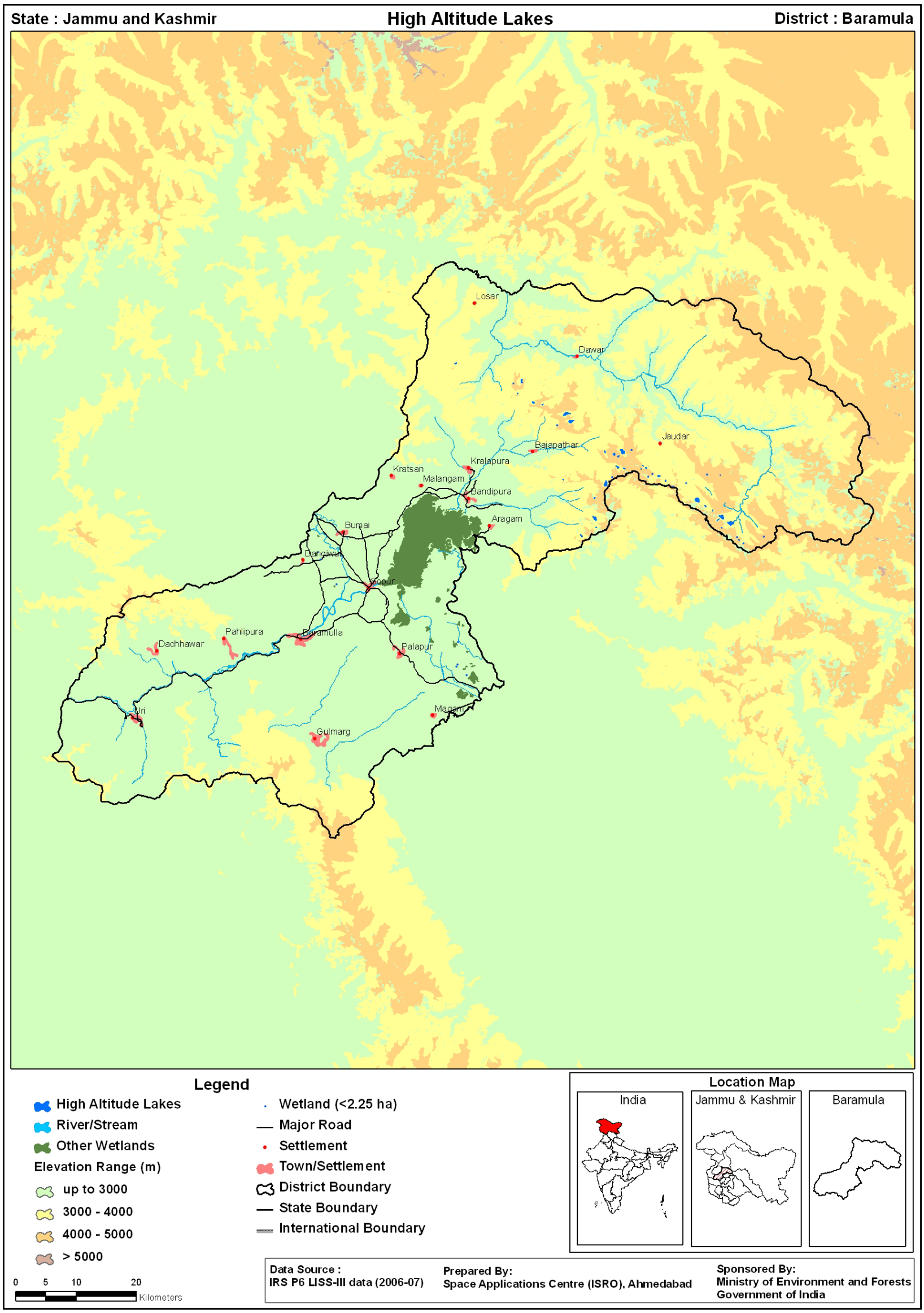
Sr. No	District	Very Large (> 500 ha)		Large (100-500 ha)		Medium (25-100 ha)		Small (10-25 ha)		Very Small (<10 ha)		<2.25 ha		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)
1	Anantnag	-	-	1	110	8	362	20	340	40	214	4	4	73	1030
2	Badgam	-	-	-	-	2	70	3	40	6	40	18	18	29	168
3	Baramula	-	-	-	-	7	268	5	68	26	112	8	8	46	456
4	Chilas	-	-	-	-	-	-	1	10	11	37	14	14	26	61
5	Doda	-	-	-	-	1	27	1	12	9	40	13	13	24	92
6	Gilghit	-	-	4	583	11	422	38	521	222	900	326	326	601	2752
7	Gilghit Wazara	-	-	1	121	-	-	11	157	51	172	46	46	109	496
8	Kargil	-	-	-	-	3	111	3	35	27	73	10	10	43	229
9	Konu	-	-	-	-	3	146	13	207	57	232	39	39	112	624
10	Leh (Ladakh)	12	95499	17	3143	39	1656	77	1227	340	1409	440	440	925	103374
11	Muzzafarabad	-	-	-	-	2	125	5	102	16	74	27	27	50	328
12	Poonch	-	-	-	-	-	-	2	24	8	35	3	3	13	62
13	Pulwama	-	-	-	-	-	-	-	-	2	4	-	-	2	4
14	Rajauri	-	-	-	-	-	-	1	15	5	22	-	-	6	37
15	Srinagar	-	-	1	167	2	85	5	63	21	77	13	13	42	405
16	Udhampur	-	-	-	-	-	-	-	-	3	13	-	-	3	13
	Total	**12**	**95499**	**24**	**4124**	**78**	**3272**	**185**	**2821**	**844**	**3454**	**961**	**961**	**2104**	**110131**



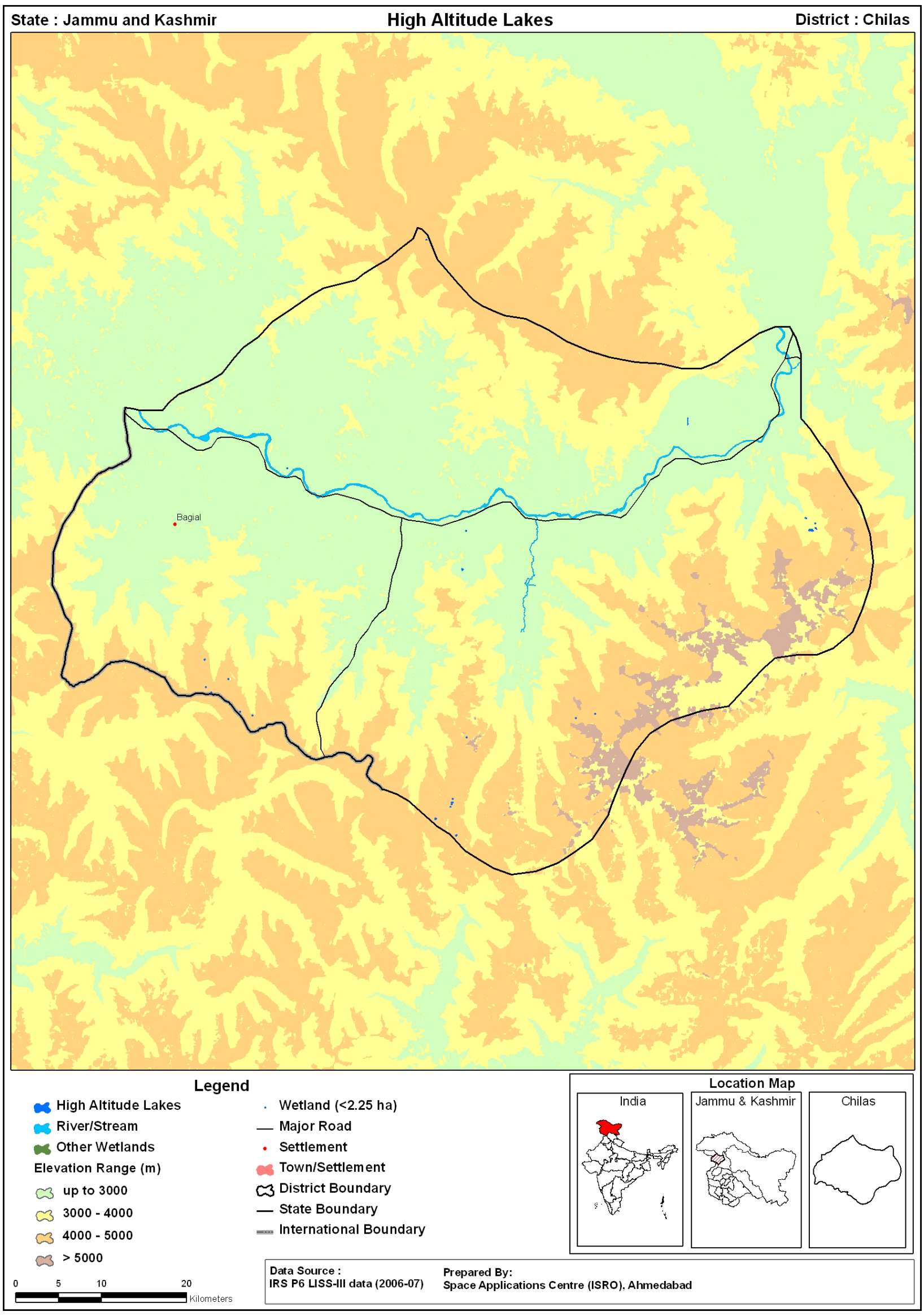
Map-4: High altitude lakes of Anantnag district



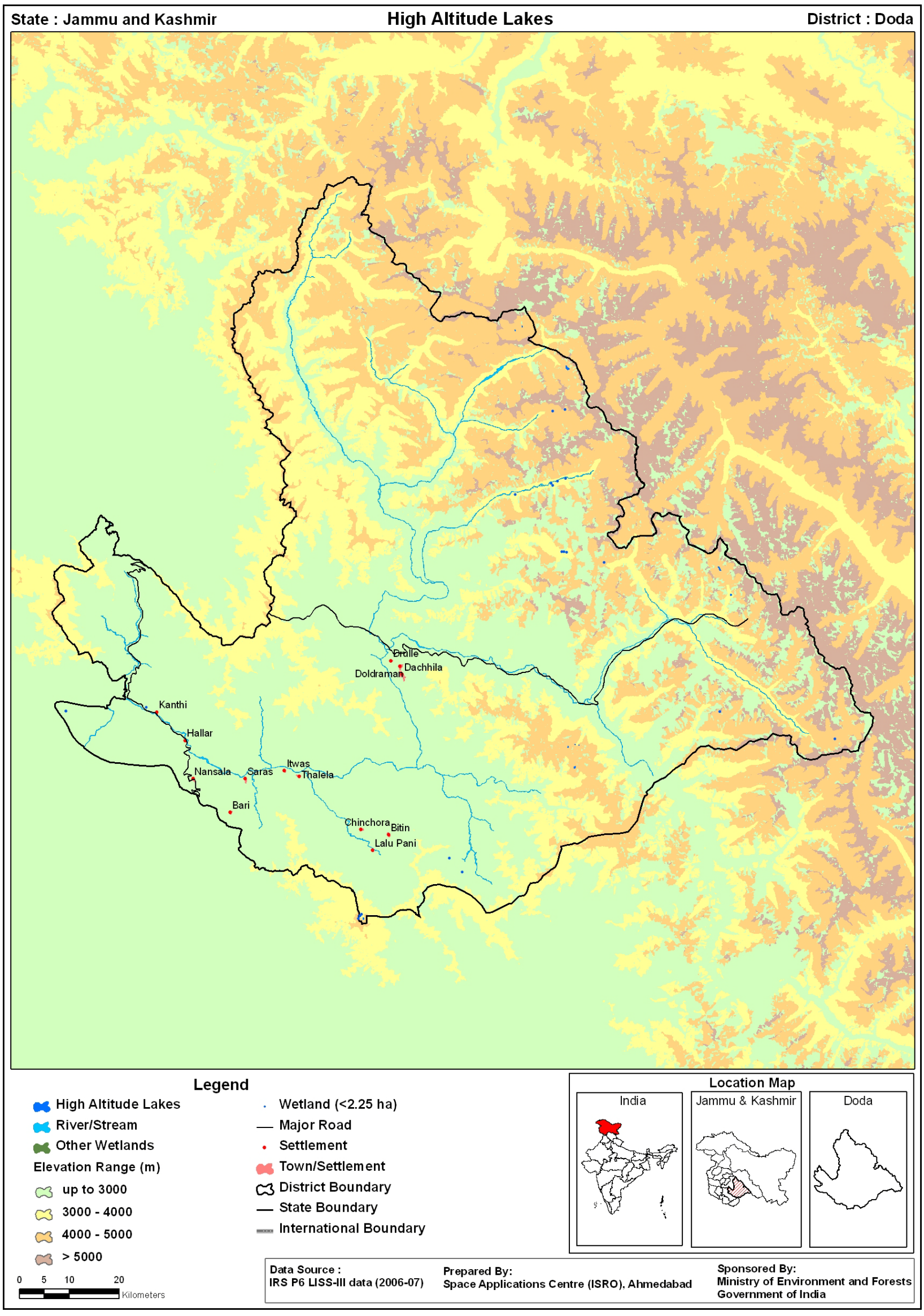
Map-5: High altitude lakes of Badgam district



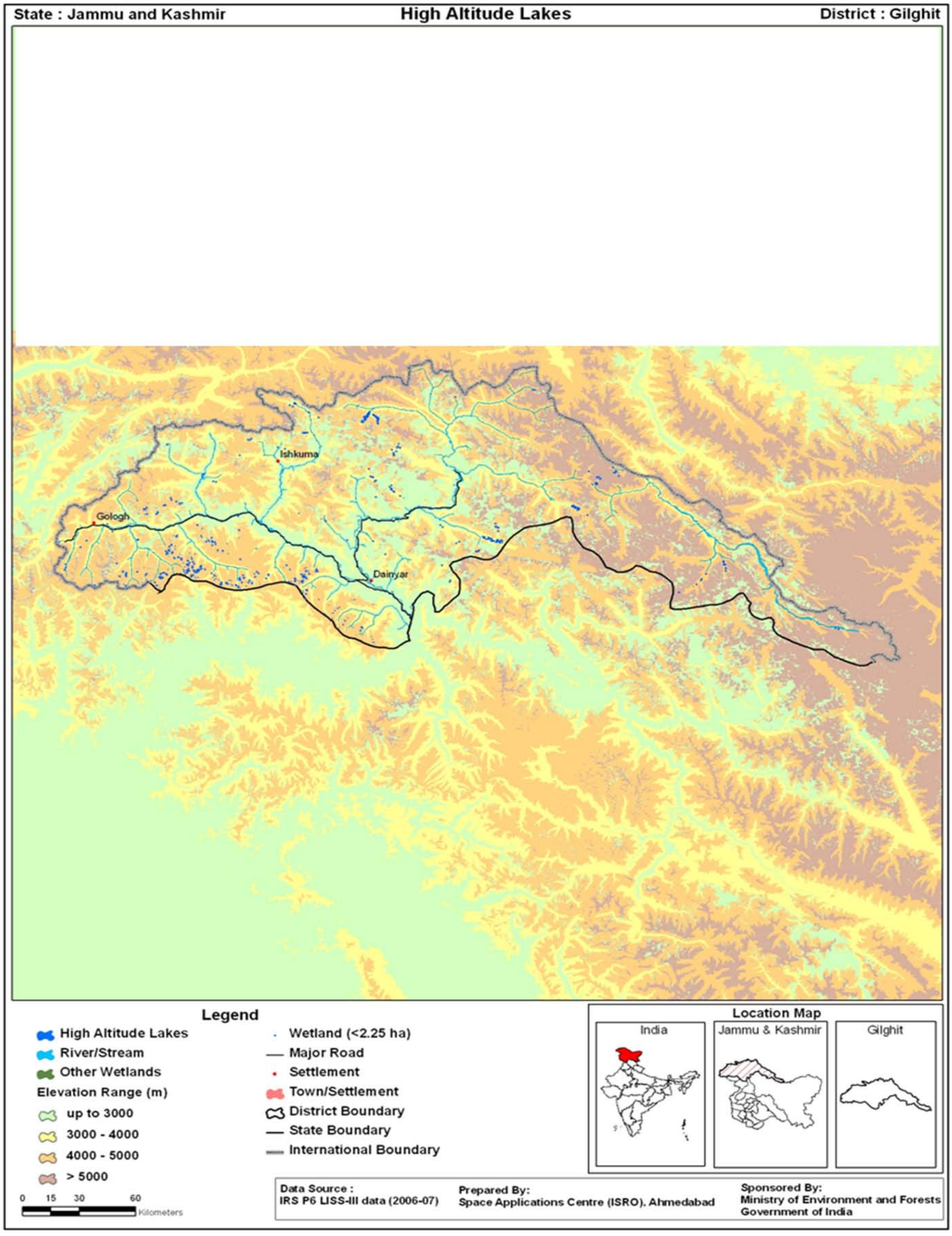
Map-6: High altitude lakes of Baramula district



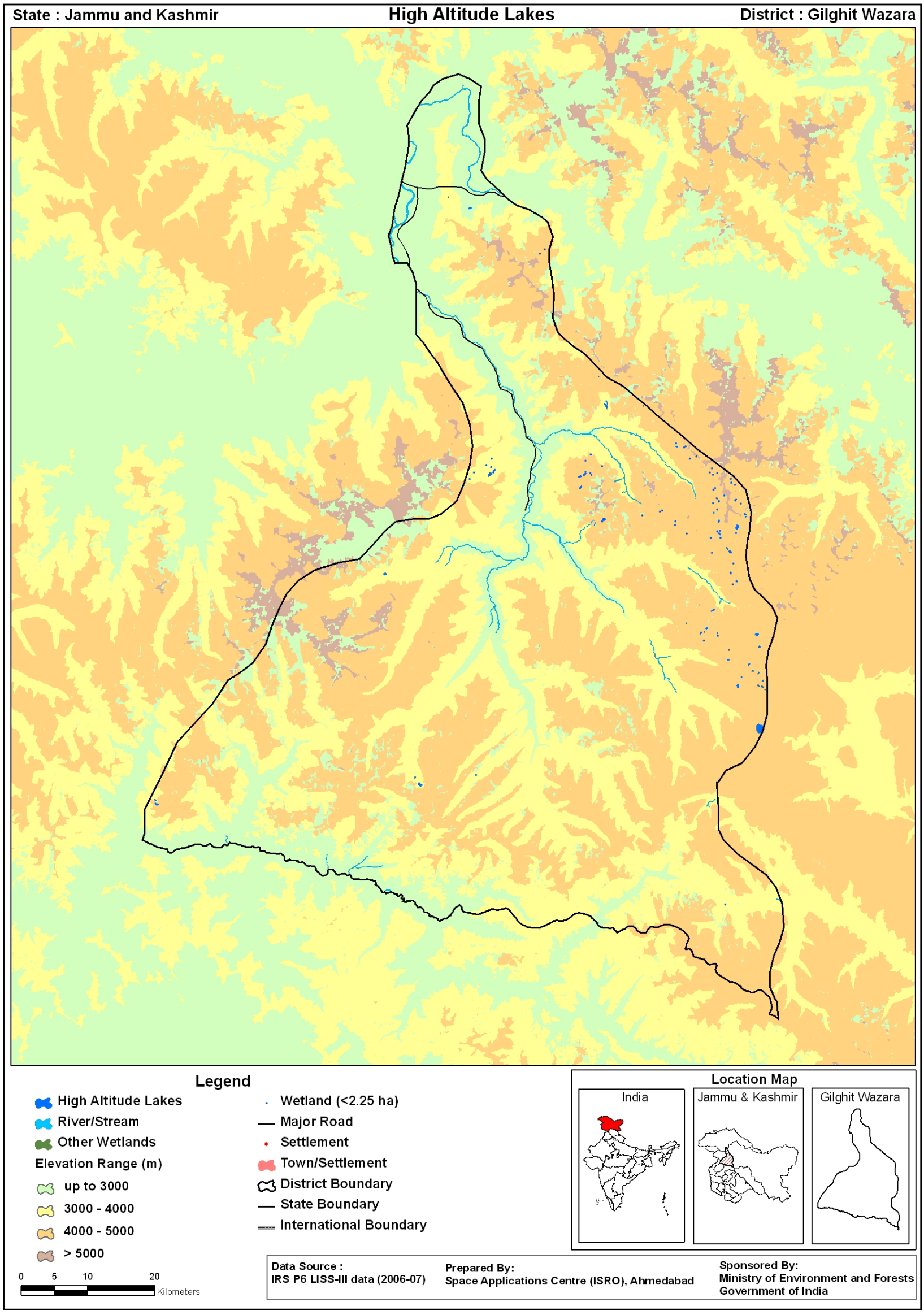
Map-7: High altitude lakes of Chilas district



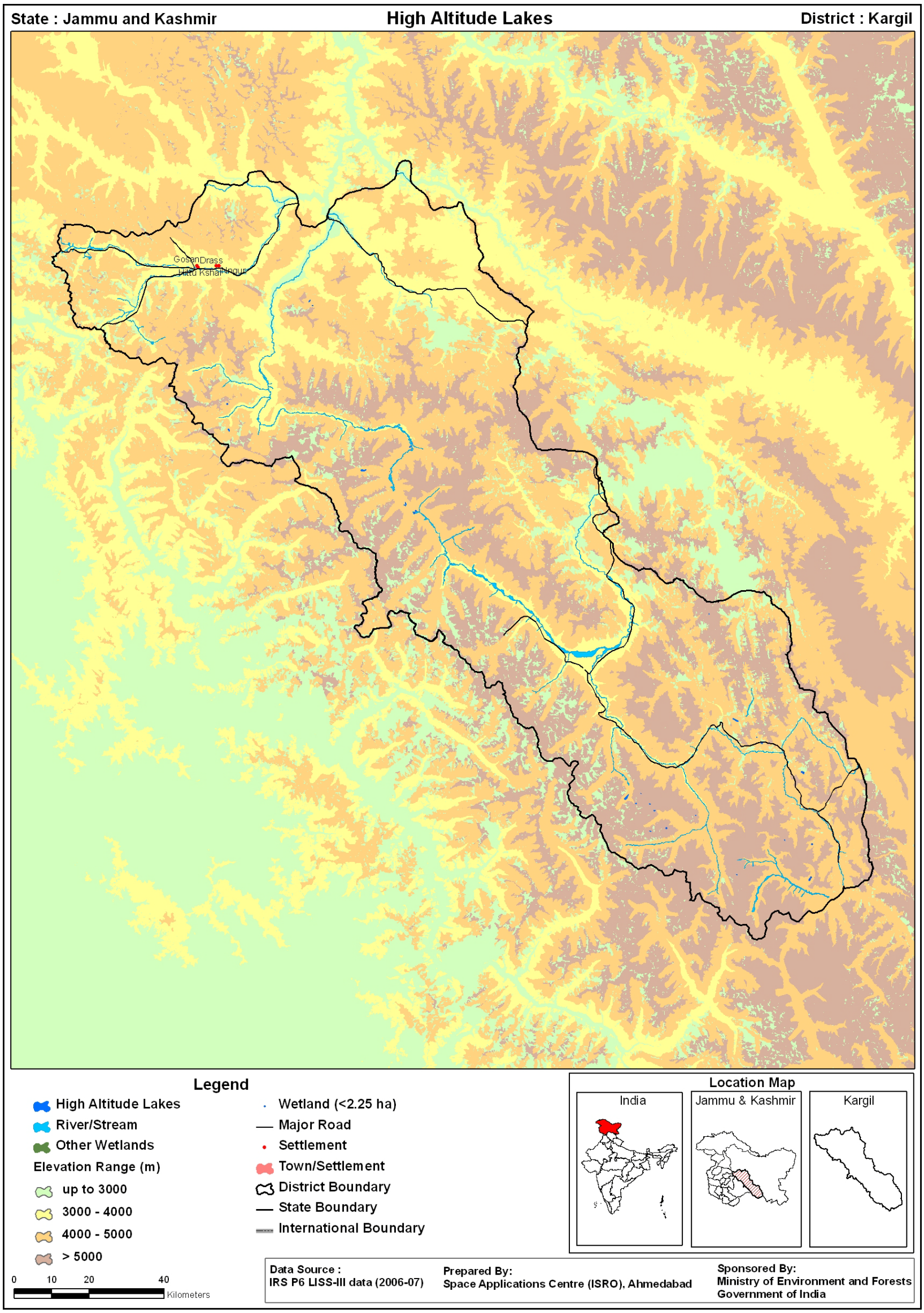
Map-8: High altitude lakes of Doda district



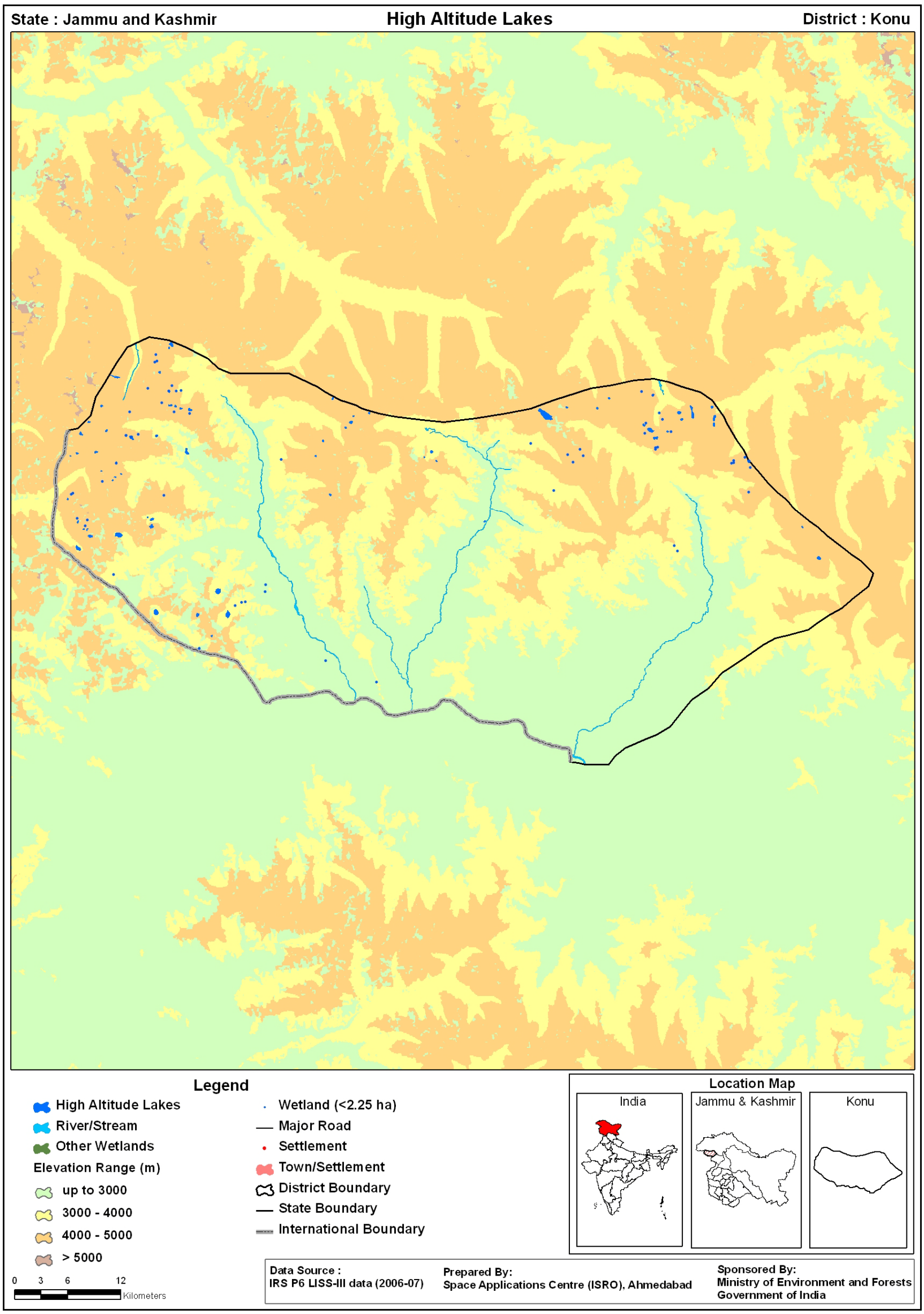
Map-9: High altitude lakes of Gilghit district



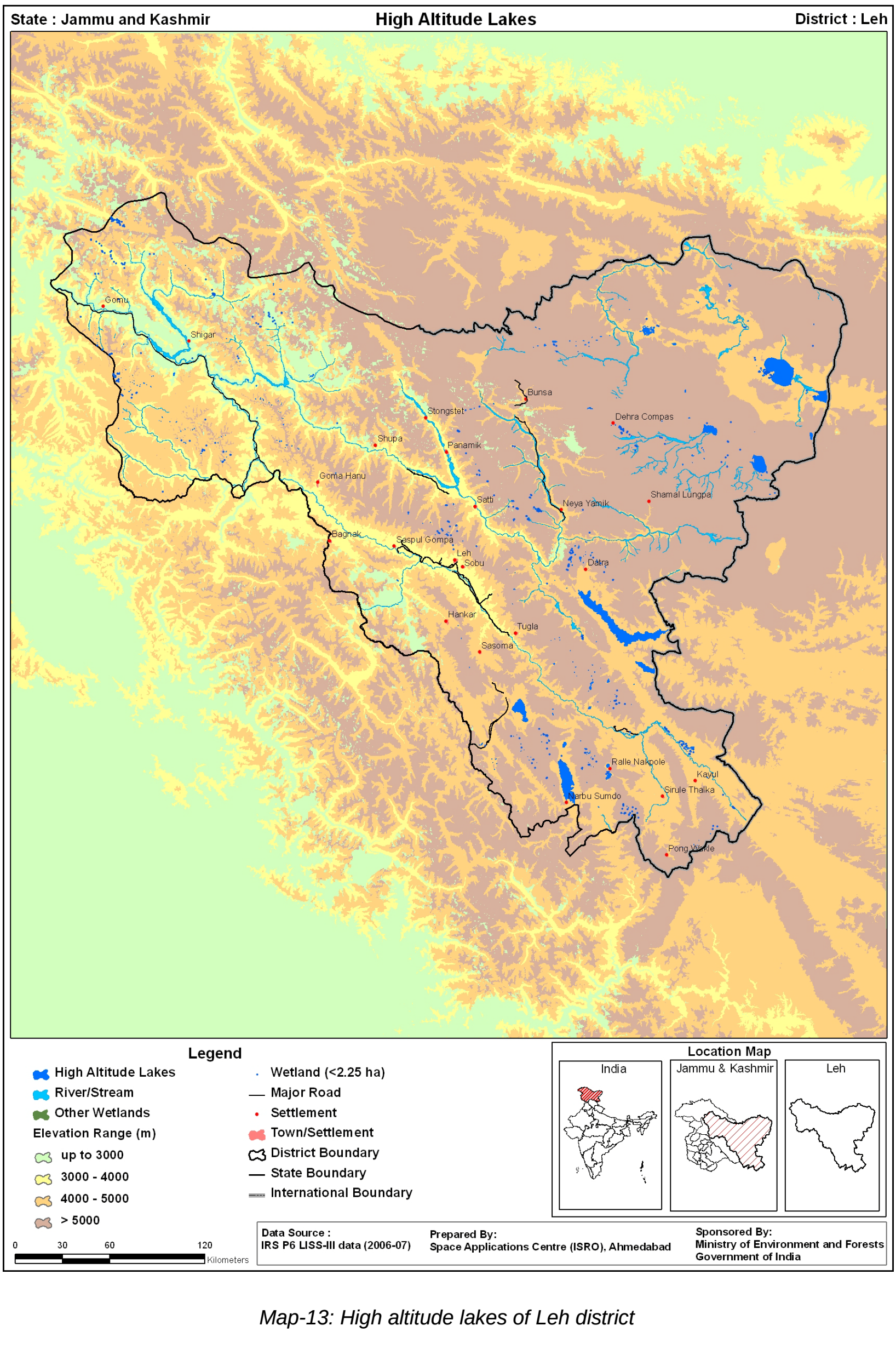
Map-10: High altitude lakes of Gilghit Wazara district



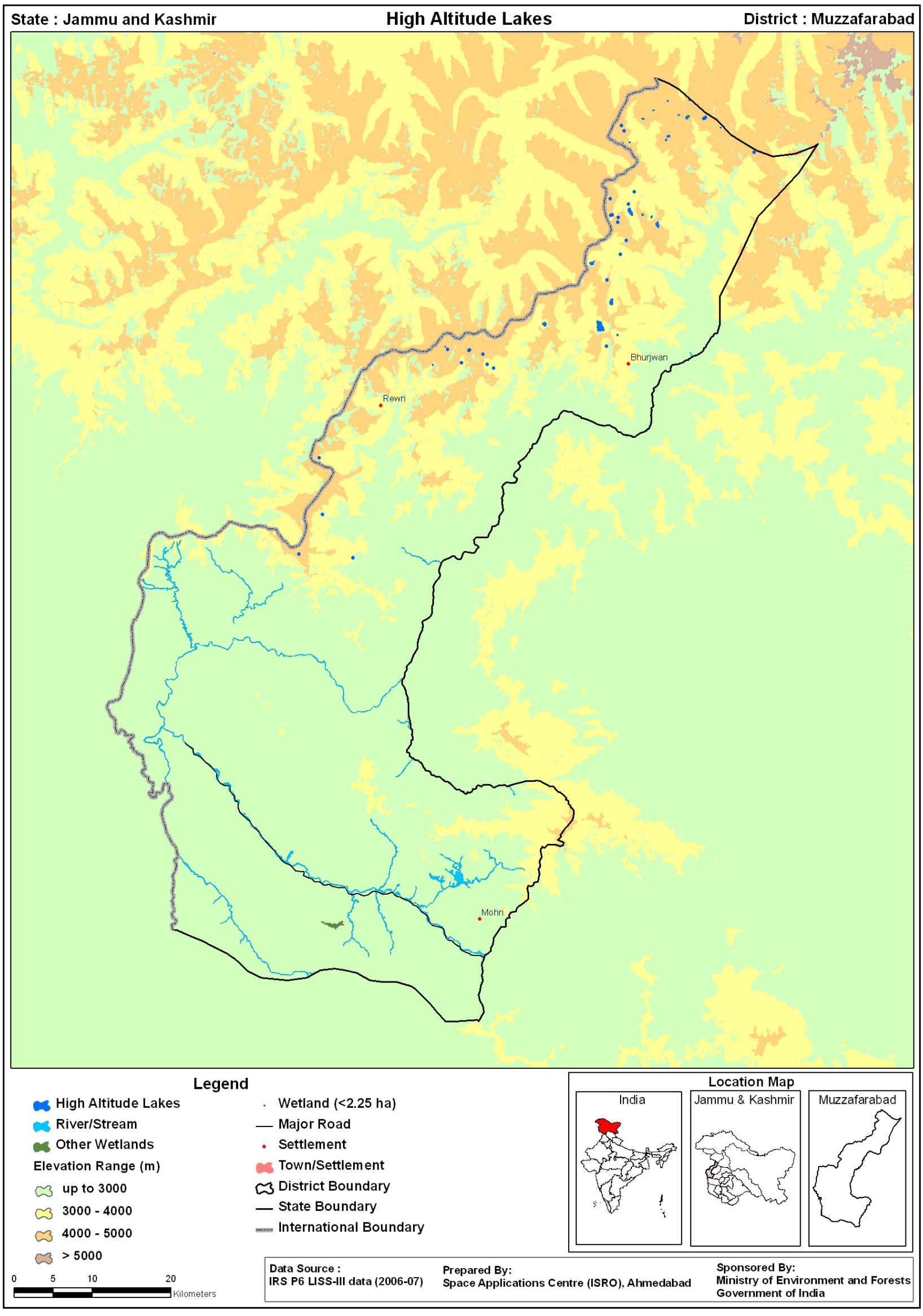
Map-11: High altitude lakes of Kargil district



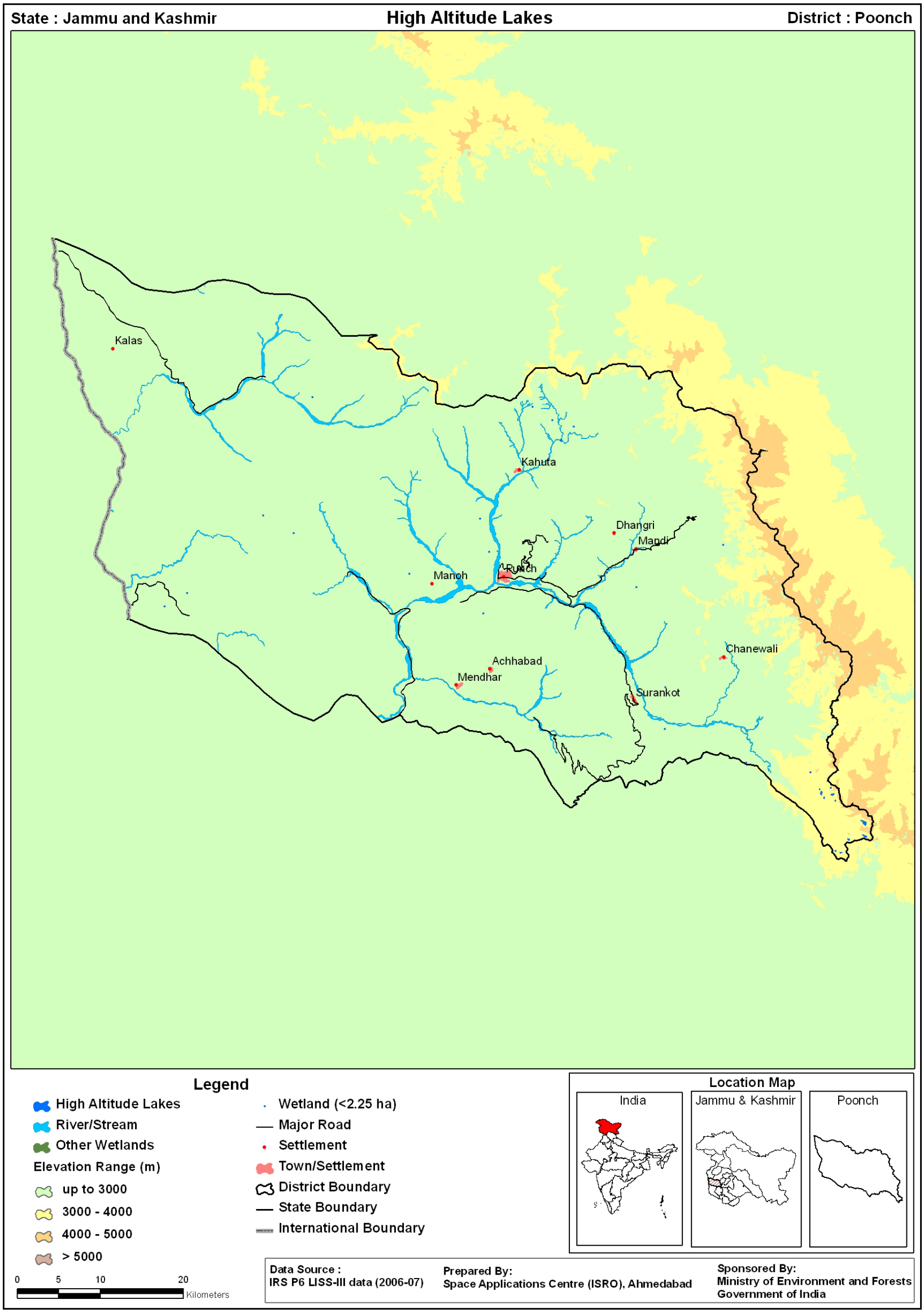
Map-12: High altitude lakes of Konu district



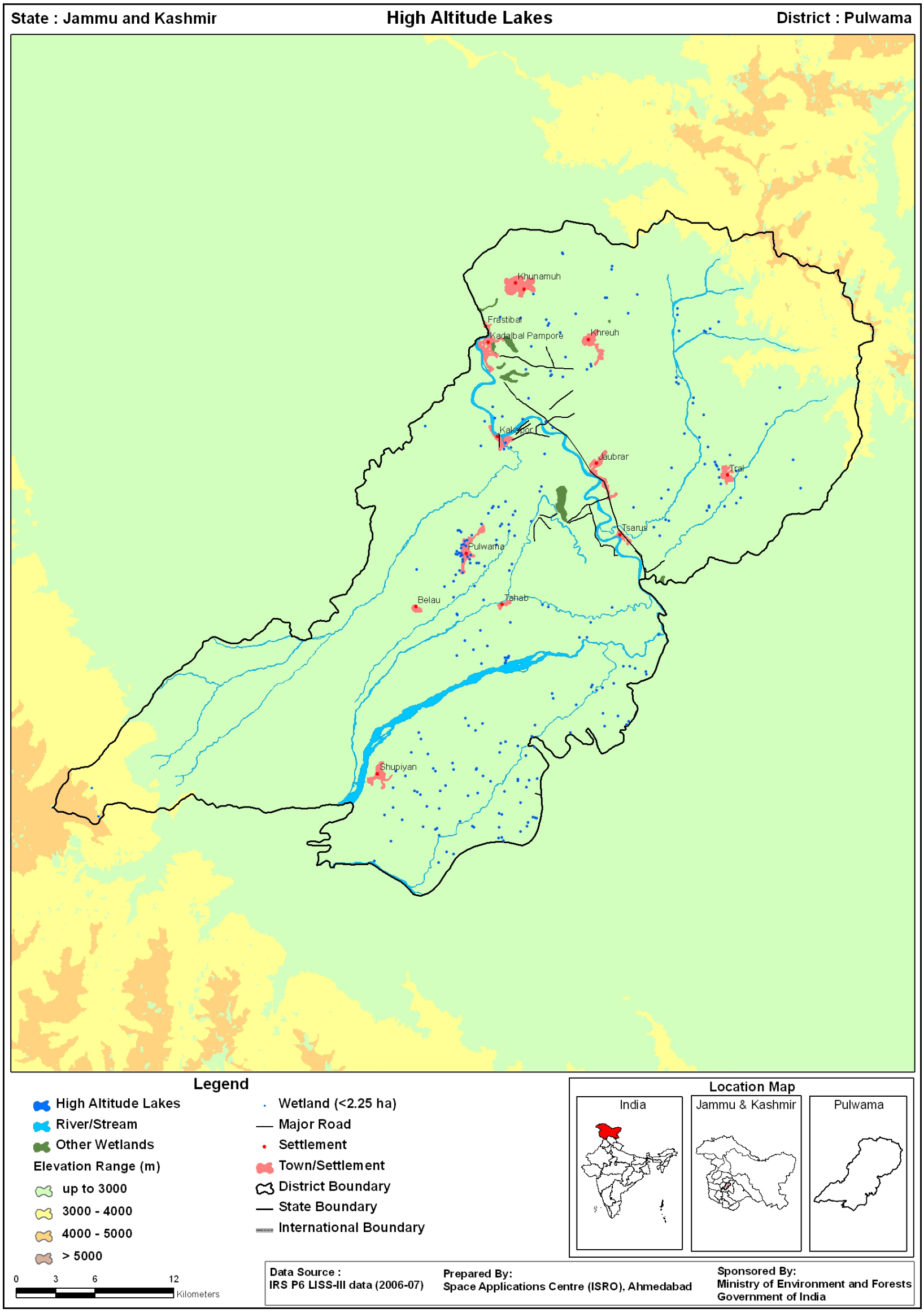
Map-13: High altitude lakes of Leh district



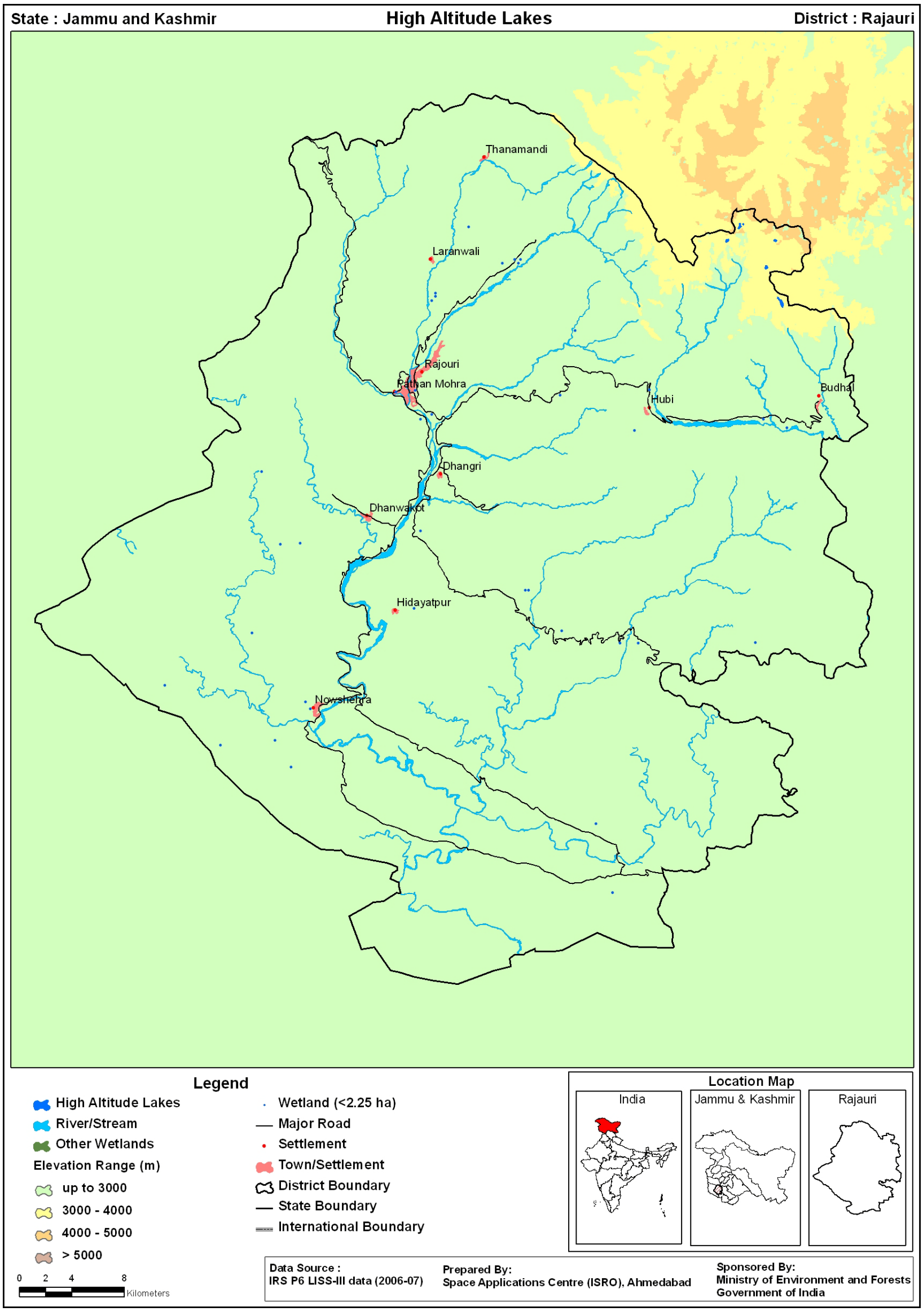
Map-14: High altitude lakes of Muzzafarabad district



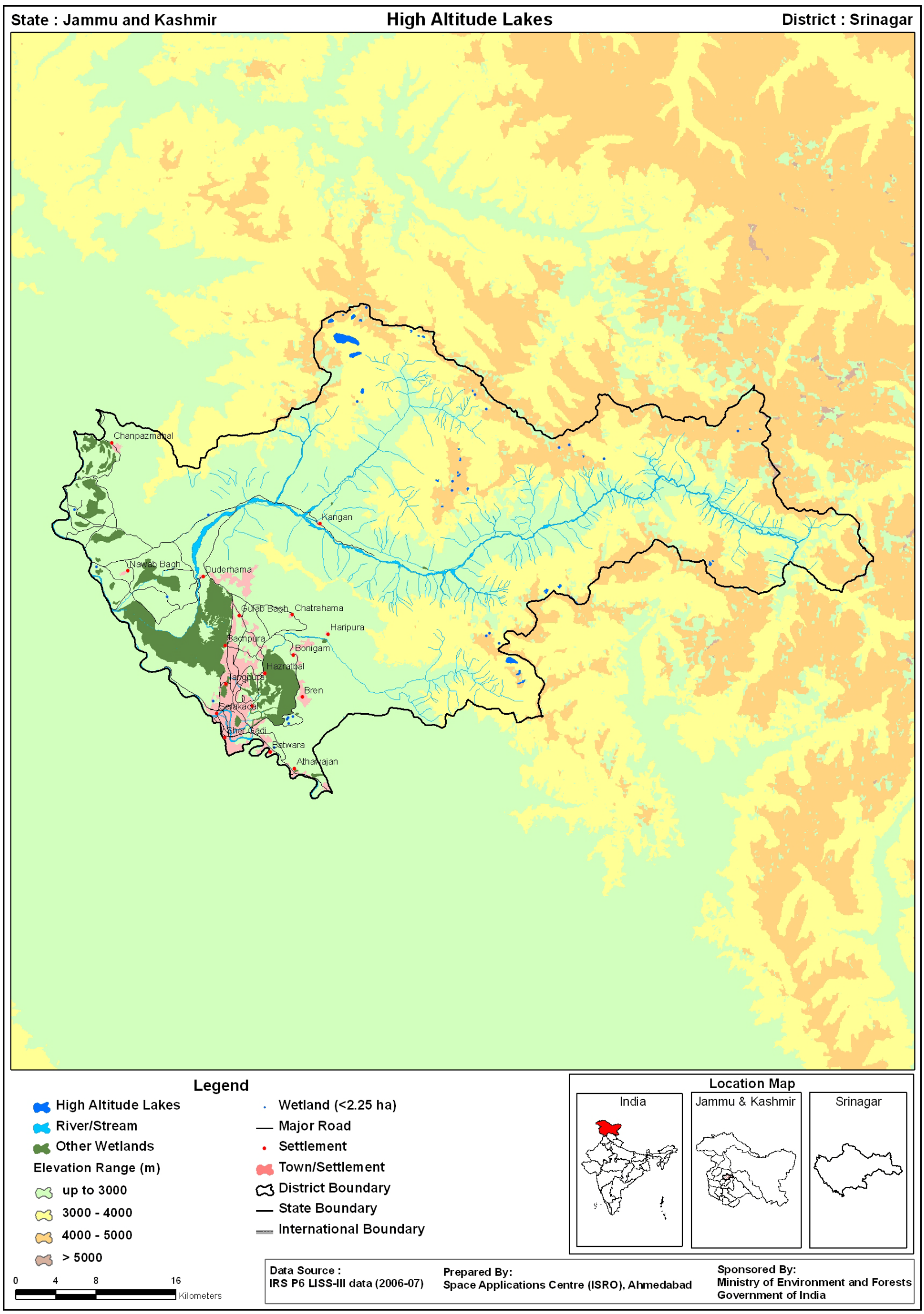
Map-15: High altitude lakes of Poonch district



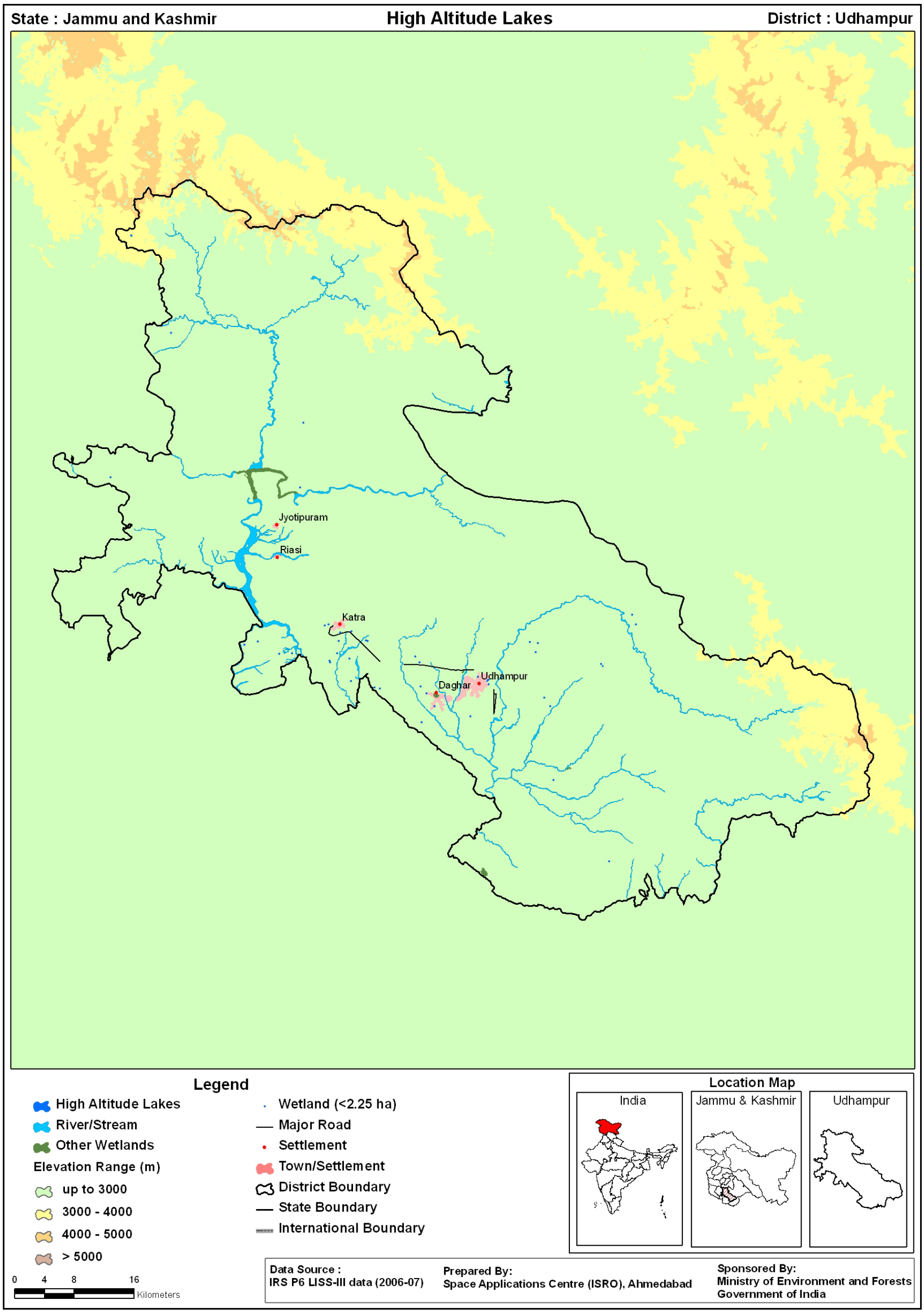
Map-16: High altitude lakes of Pulwama district



Map-17: High altitude lakes of Rajauri district



Map-18: High altitude lakes of Srinagar district



Map-19: High altitude lakes of Udhampur district

4.2.2 Himachal Pradesh

Himachal Pradesh is situated in the western Himalayas, covering an area of 55,673 kilometres. The boarders touch Uttarakhand, Punjab, Haryana, Jammu & Kashmir, and Tibet. There are 12 districts in the state (Fig.-33). The state is a mountainous one with elevation going up to 6600 meters above sea level. There is general increase in elevation from west to east and from south to north. The state is drained by numerous rivers like the Chandra, the Bhaga or the Chenab, the Ravi, the Beas, the Sutlej and the Yamuna and have numerous glaciers. The northern and eastern part of the state with alpine and glacial climate harbours a number of high altitude lakes.

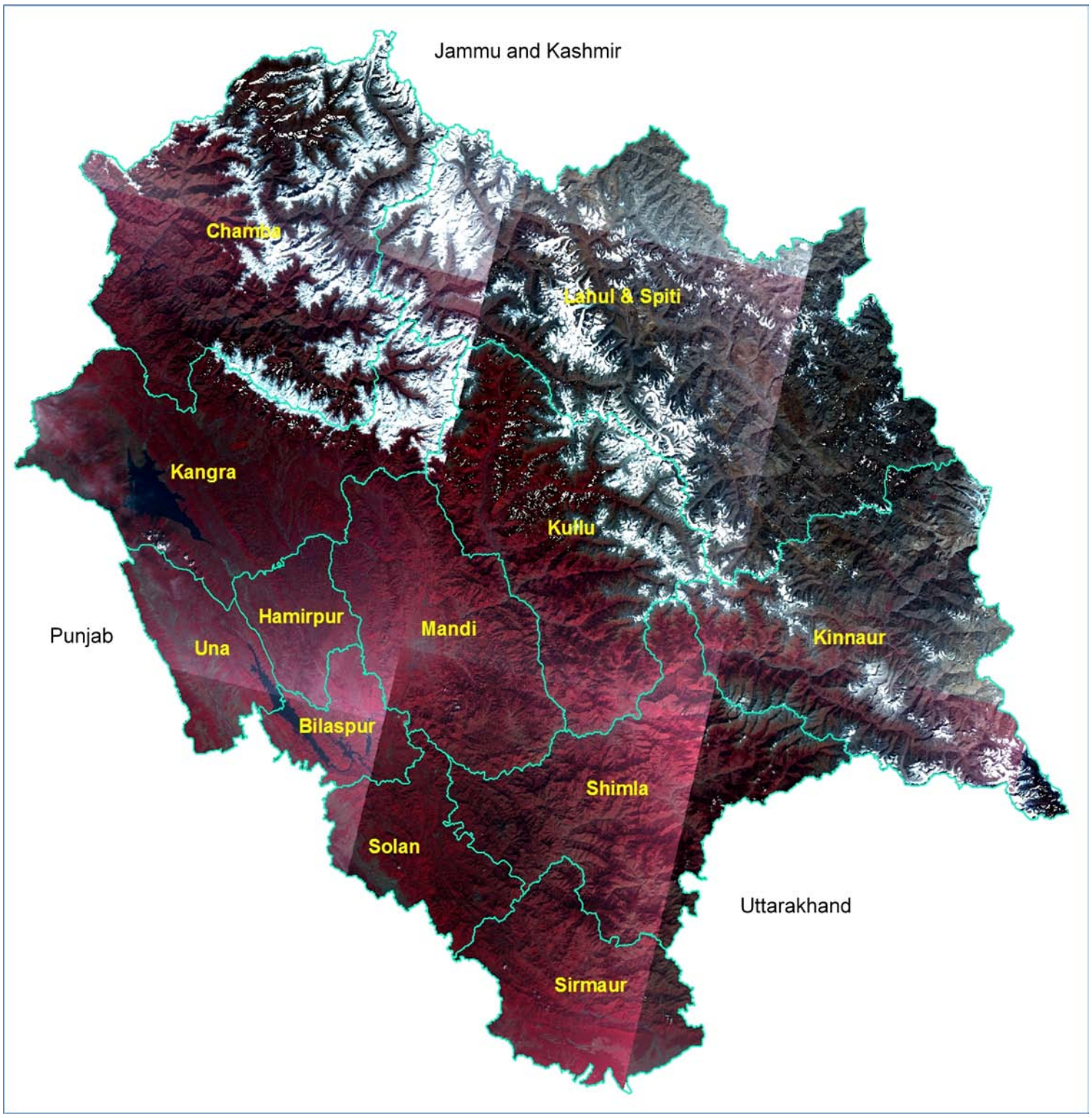


Fig.-33: Himachal Pradesh as seen in IRS LISS III FCC (district boundaries shown in cyan line)

Total of 271 HALs were delineated constituting 575 ha area that accounts for less than one per cent of total wetland area of the state. Maximum number of lakes (230) are of very small size (<2.25 ha area). There are no lakes of size >100 ha. Only two lakes of above 25 ha are mapped (Table-14). Altitudinal distribution of these wetlands showed that highest concentration is in the range of 4000 to 5000 m. (Table-15). The distribution pattern of high altitude lakes in the state with respect to altitude and size is shown in Fig.-34 and Map-20.

Table-14: Size-wise statistics of high altitude lakes in Himachal Pradesh

Sr. No.	Class	Range	No. of lakes	Area (ha)
1	Very Large	> 500 ha	-	-
2	Large	100-500 ha	-	-
3	Medium	25-100 ha	2	103
4	Small	10-25 ha	5	78
5	Very Small	2.25-10 ha	34	164
6	< 2.25 ha	< 2.25 ha	230	230*
Total			**271**	**575**

* *Nominal assignment*

Table-15: Altitude-wise statistics of the high altitude lakes in Himachal Pradesh

Sr. No.	Category	Altitude range(m)	No. of lakes	Area (ha)
1.	High Altitude	3000-4000	20	20
2.	Higher Altitude	4000-5000	168	424
3.	Very High Altitude	>5000	83	131
Total			**271**	**575**

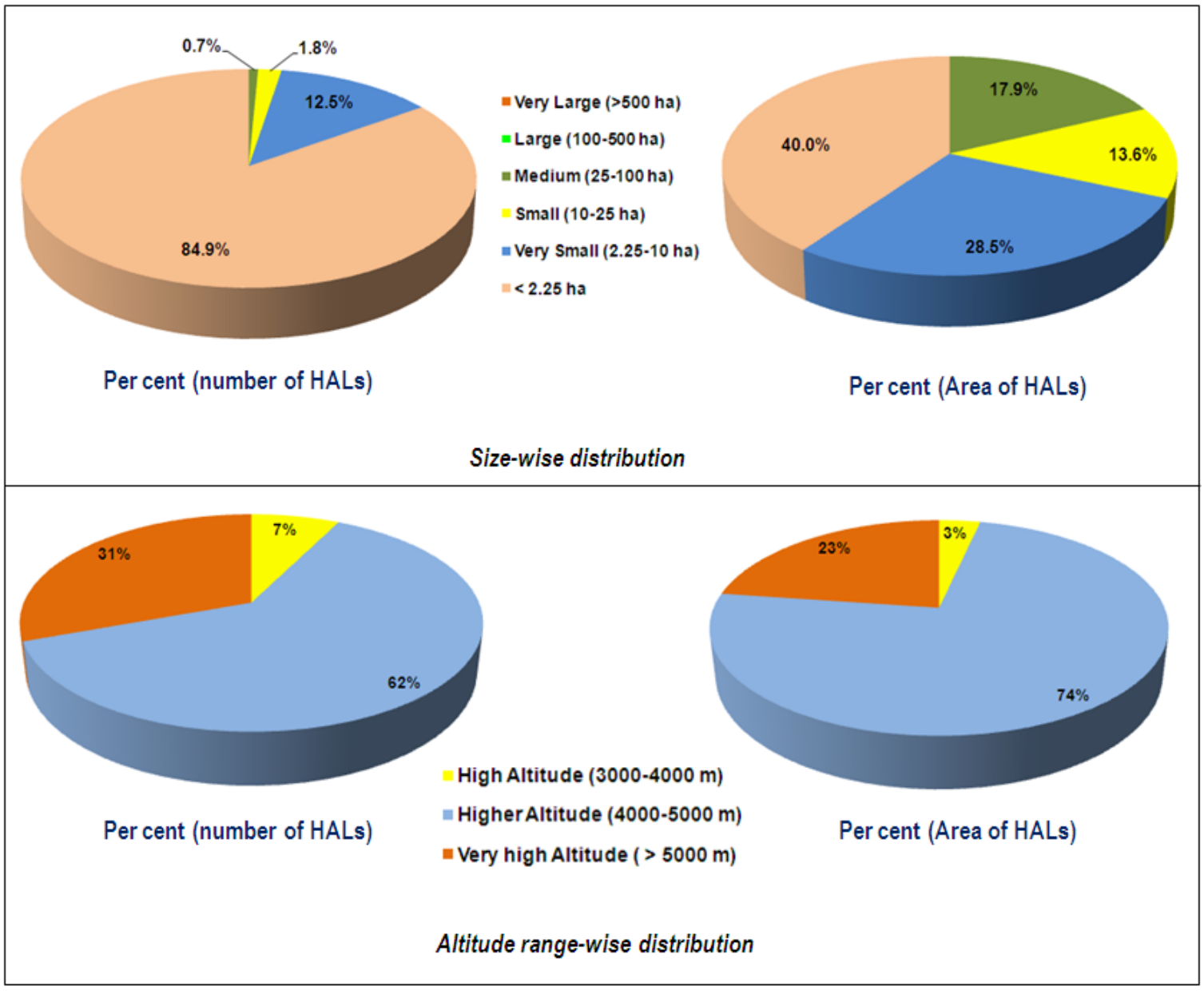


Fig.-34: Size-wise and Altitude range-wise distribution of high latitude lakes in Himachal Pradesh

There are many high altitude lakes lying above 3000 m elevation range, mainly in Northern districts of the state. Chandertal lake is probably the best and most visited high altitude lake of the state. Some of the other famous lakes are:, Suraj Tal, Brigu Lake, Nako Lake, Dhankar Lake, Dashair, Seruvalsar, Manimahesh, Ghadhasaru, Mahakali and Lama Dal.

State : Himachal Pradesh

High Altitude Lakes

Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands

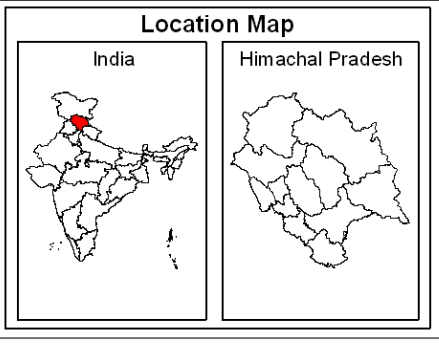
Elevation Range (m)

- up to 3000
- 3000 - 4000
- 4000 - 5000
- > 5000

- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 10 20 40 Kilometers

Location Map



Data Source :
IRS P6 LISS-III data (2006-07)

Prepared By:
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

Map-20: Distribution pattern of high altitude lakes in Himachal Pradesh with respect to elevation range

The Chandertal

Also known as Chandratal Wetland (*As per Ramsar site declaration on November 08, 2005*). This is a high altitude lake on the upper Chandra valley flowing to the Chandra river of the Western Himalayas, in Lahul and Spiti district and lies at 32^{O} 29' N and 77^{O} 36 ' E at an altitude of 4270 m. The lake can be approached from 'Batal' which is 120 Km from Manali on Manali – Kaza State Highway. Alternatively, one can reach Chandertal via 'Kunjam La' that connects Spiti and Lahul. This natural lake is about one km in length, half km in breadth at its widest part and has a circumference of 2.5 km. The total area of the wetland is about 49 ha. The lake owes its name either to the fact that it is the source of the river Chandra, or by virtue of its crescent moon like shape. It is surrounded by the mountain ranges of Moulkila and Chandrabhaga.

The lake lies in a broad grassy plain, which in ancient times was a glacier. The lake has been formed due to blockage of rock basin by scree and para glacial deposits and the glaciers are the main source of inflow. There is also a regular outflow of water that varies with the season. The Lake and its catchment area fall in the Alpine zone that is characterized by the absence of trees. About 65 per cent of the catchment area has degraded forest due to glacial action. Herbs and grasses cover rest of 35 per cent of the area. Shepherds from Kangra, Mandi and Kulu graze their herds of sheep at these pastures from June to September. Facts derived in this study are:

Code : 0203005208110002
Location : 32^{0} 29' N latitude and 77^{0} 36' E longitude
Altitude : 4270 m
Area : 49 ha
Perimeter : 3.9 km

The clean water of the lake with small marshy patches around attracts many migratory birds. Important species noted are: Snow cock, Chukar, Black winged stilt, Brahmni duck, Golden eagle and Chugh, Hoopoe, Yellow Headed Wagtail, Jungle crow, Blue rock pigeon, Common rose finch, Black Redstart, Short toed Eagle, Common Sandpiper, Teal, Magpie Robin etc. The important wild life species found in the region are Marmota Bobak, Snow leopard, Red fox, Snow wolf, Capra ibex, Blue sheep and Lynx etc. Fig.-35 shows field photographs and satellite images of the lake. 3D perspective view of Chandertal is shown in Fig.-36.

Photographs of the Chandertal lake during summer

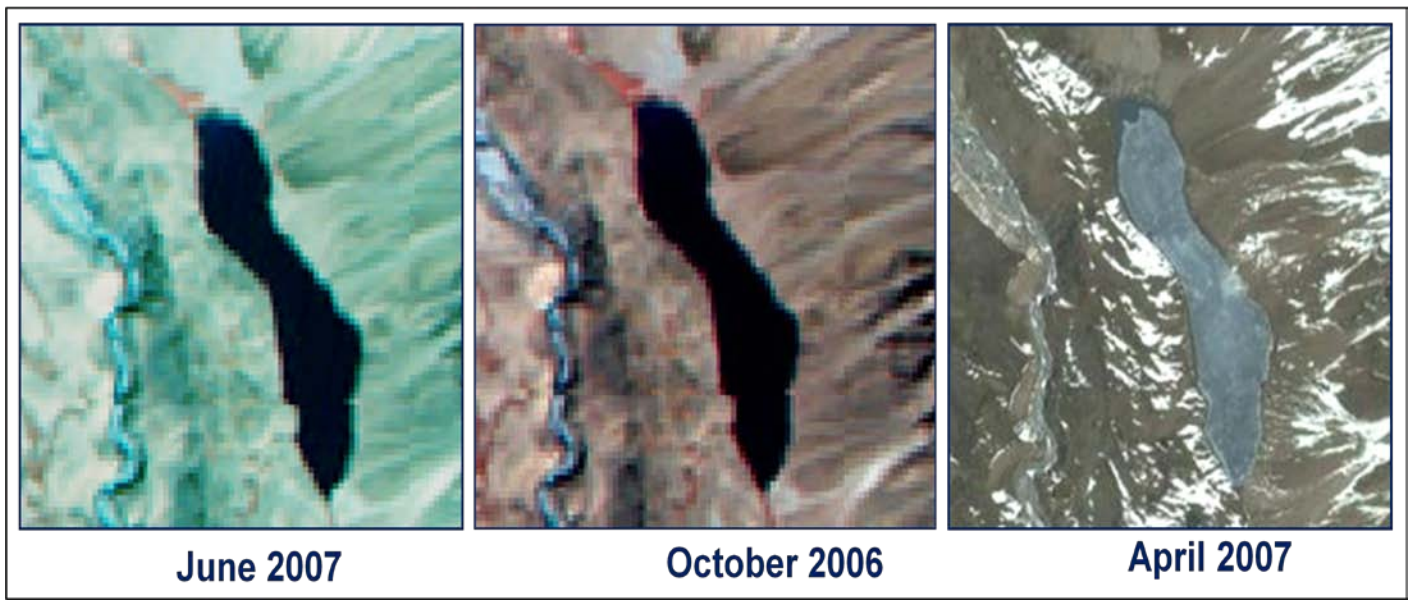


Fig.-35: LISS III FCC showing the seasonal variation of Chandertal

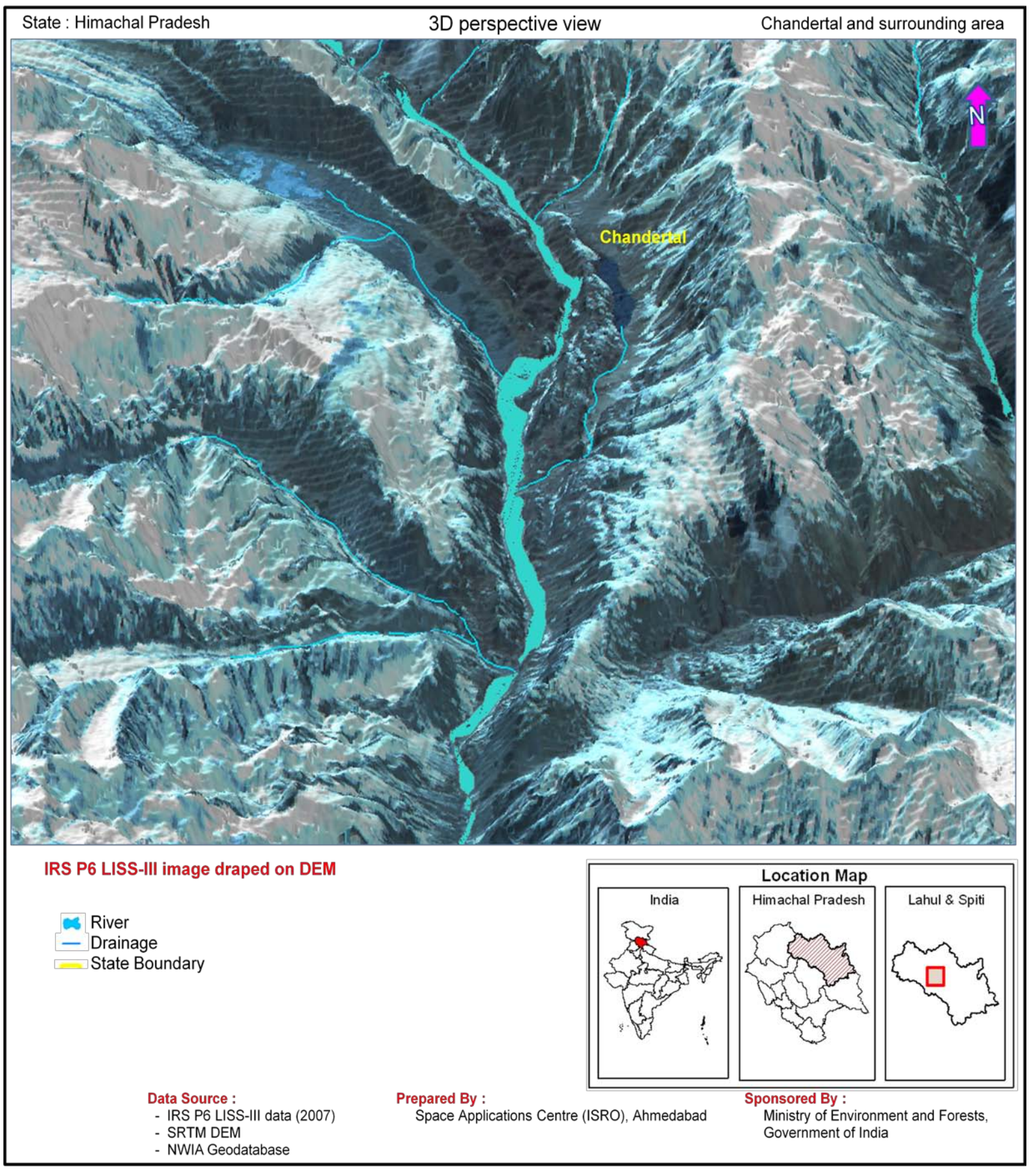


Fig.-36: 3D perspective view of Chandertal and surrounding area

Suraj Tal is a well known high altitude lake of this state. It lies just below the Bara-lacha-la pass (4,890m) in the Lahaul and Spiti valley. It is the source of Bhaga River which joins the Chandra River downstream at Tandi to form the Chandrabhaga River. The lake is fed from the glaciers and torrential streams originating from the Bara-lacha-la pass. The pass is 8 km long and called the "Pass with crossroads on summit" since roads from Zanskar, Ladakh, Spiti and Lahaul meet at this pass. Snowfall in this zone, though scanty, is reported to be spread all round the year. Rainfall precipitation is rare in the region. Snow starts melting from May. Even in July one can observe snow on the slopes encircling the lake, though the lake is fully in liquid state (Fig.-37).

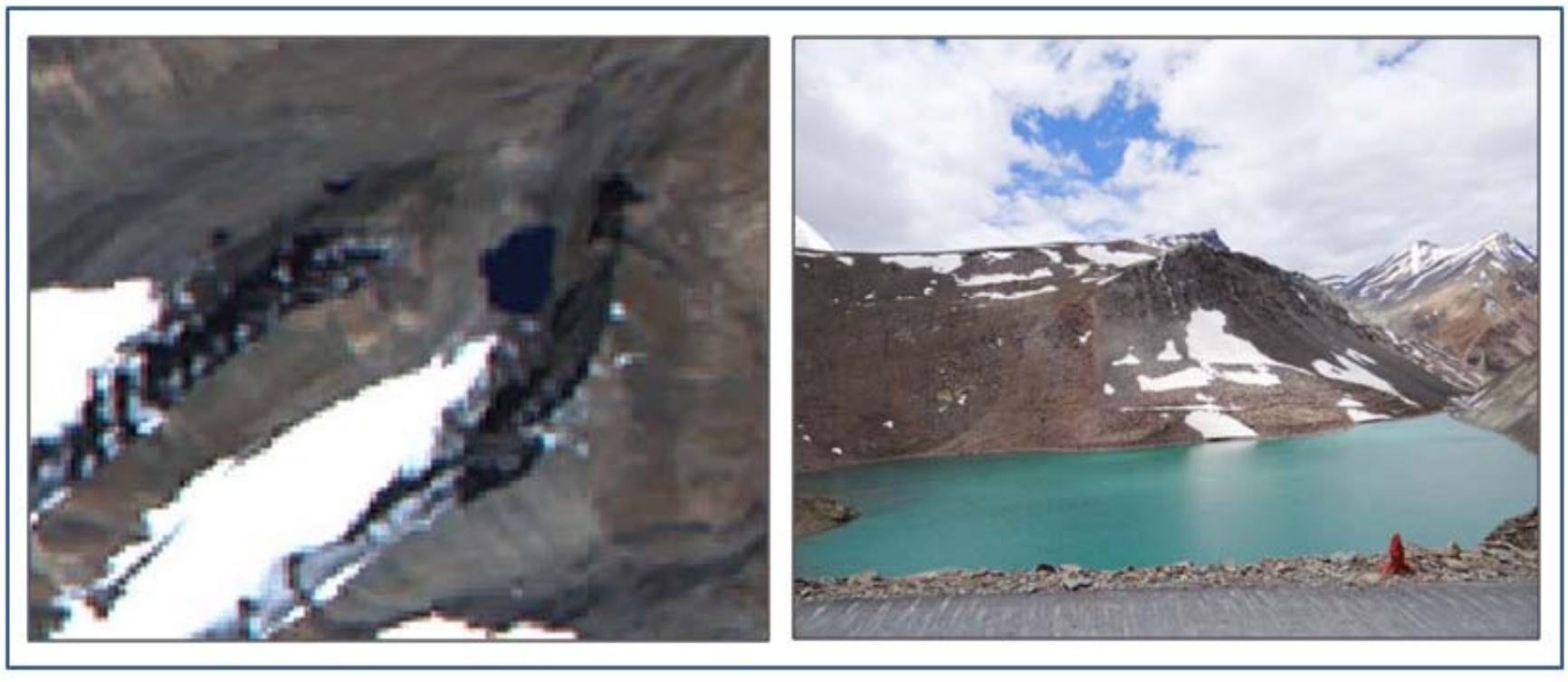


Figure 37: LISS III FCC showing the Suraj tal during post monsoon and photograph of the scenic view of the lake

Bhrigu lake (Fig.38) situated at a height of 4200 m near Manali with Vashist and Gulabo as approach points it draws its name from Bhrigu Peak.

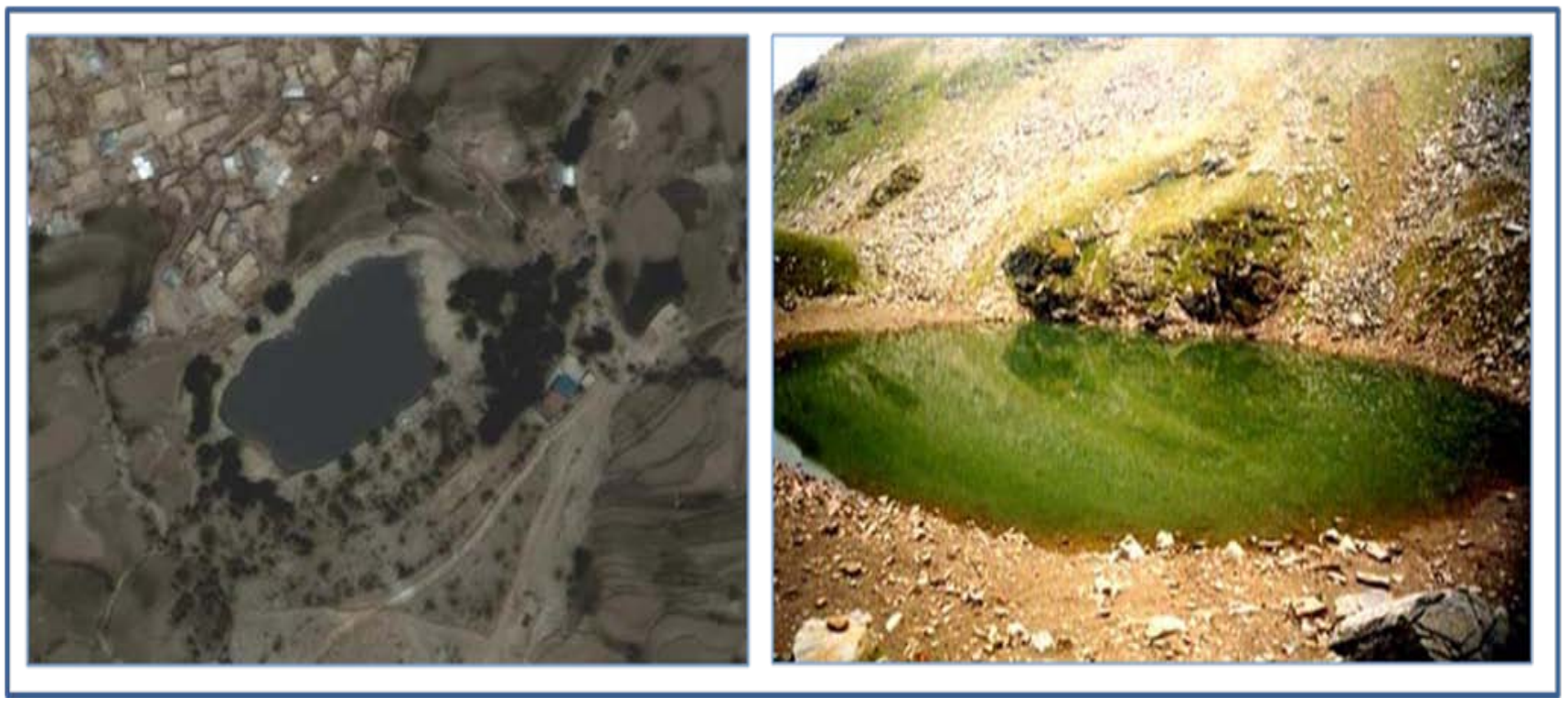


Fig.-38: Bhrigu lake as seen in satellite image and the field photograph

Nako Lake is situated at an altitude of 3635 m amsl, surrounded by hills in village Nako, 3-4km from Recong-Peo, the head-quater of district Kinnaur. The lake is surrounded by willow and poplar trees. It is famous for its wonderful climatic conditions. The water for Nako lake comes from its bottom core.

District-wise Analysis

There are 12 districts in the state. The geographic area of the districts varies from 1118 sq.km (Hamirpur) to 13835 sq.km (Lahul and Spiti). Only 5 districts harboured the high altitude lakes. Maximum number of lakes are in Lahul and Spiti district, followed by Kullu district. Least number of lakes (17) are observed in Shimla district. Lahul & Spiti district also has maximum number of lakes above >5000 m elevation, followed by Kinnaur district. Lahul &Spiti, Kullu and Kinnaur have large number of lakes mapped as point features, indicating requirement of larger scale mapping to capture the details about these lakes.

The altitudinal range-wise and size-wise distribution of high altitude lakes in each district of the state are shown in Table-16 and 17 respectively. District-wise high altitude lake maps are shown from Map-21 to 25.

Table-16: Altitudinal range-wise distribution of high altitude lakes in each district of Himachal Pradesh

Sr. No.	District	High Altitude (3000-4000m)		Higher Altitude (4000-5000m)		Very High Altitude (>5000m)		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)
1	Chamba	1	1	11	35	4	6	16	42
2	Kinnaur	4	4	25	45	21	41	50	90
3	Kullu	6	6	71	91	1	1	78	98
4	Lahul & Spiti	7	7	46	188	57	83	110	278
5	Shimla	2	2	15	65	-	-	17	67
	Total	**20**	**20**	**168**	**424**	**83**	**131**	**271**	**575**

Table-17: Size-wise distribution of high altitude lakes in each district of Himachal Pradesh

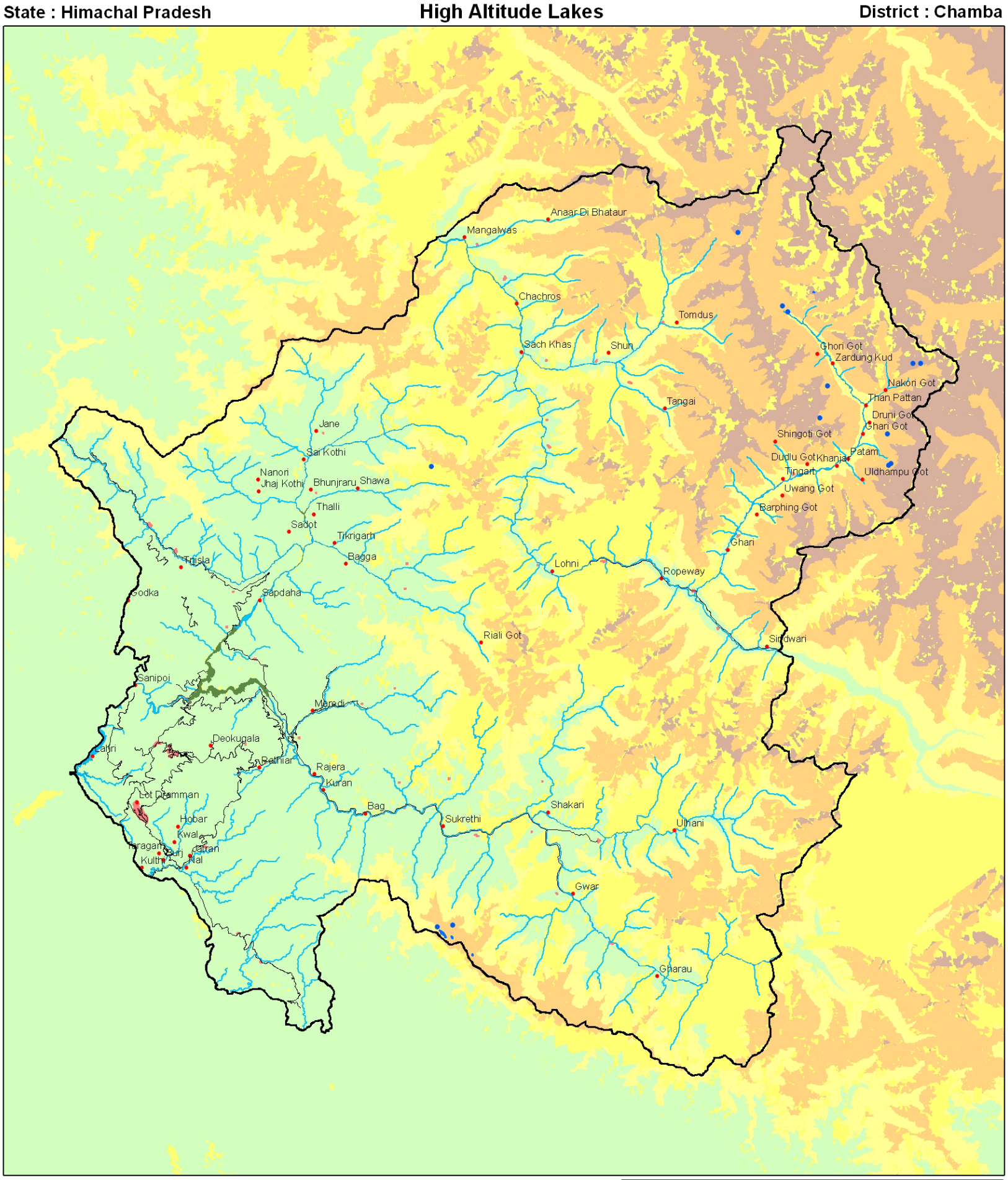
Sr. No.	District	Very Large (> 500 ha)		Large (100-500 ha)		Medium (25-100 ha)		Small (10-25 ha)		Very Small (<10 ha)		<2.25 ha		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area* (ha)	No. of lakes	Area (ha)
1	Chamba	-	-	-	-	-	-	1	21	3	9	12	12	16	42
2	Kinnaur	-	-	-	-	-	-	2	21	5	26	43	43	50	90
3	Kullu	-	-	-	-	-	-	-	-	7	27	71	71	78	98
4	Lahul & Spiti	-	-	-	-	2	103	1	16	13	65	94	94	110	278
5	Shimla	-	-	-	-	-	-	1	20	6	37	10	10	17	67
	Total	**-**	**-**	**-**	**-**	**2**	**103**	**5**	**78**	**34**	**164**	**230**	**230**	**271**	**575**

* *Nominal assignment*

State : Himachal Pradesh

High Altitude Lakes

District : Chamba



Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands

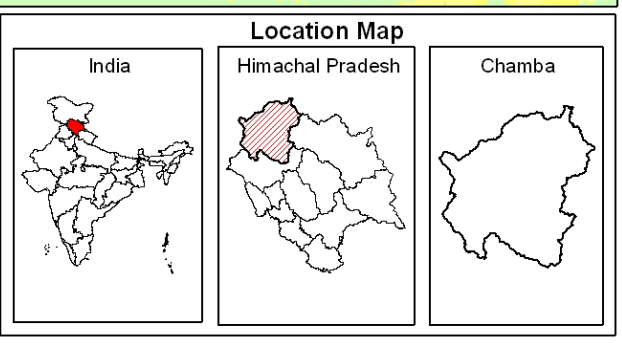
Elevation Range (m)

- up to 3000
- 3000 - 4000
- 4000 - 5000
- > 5000

- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 5 10 20 Kilometers

Location Map

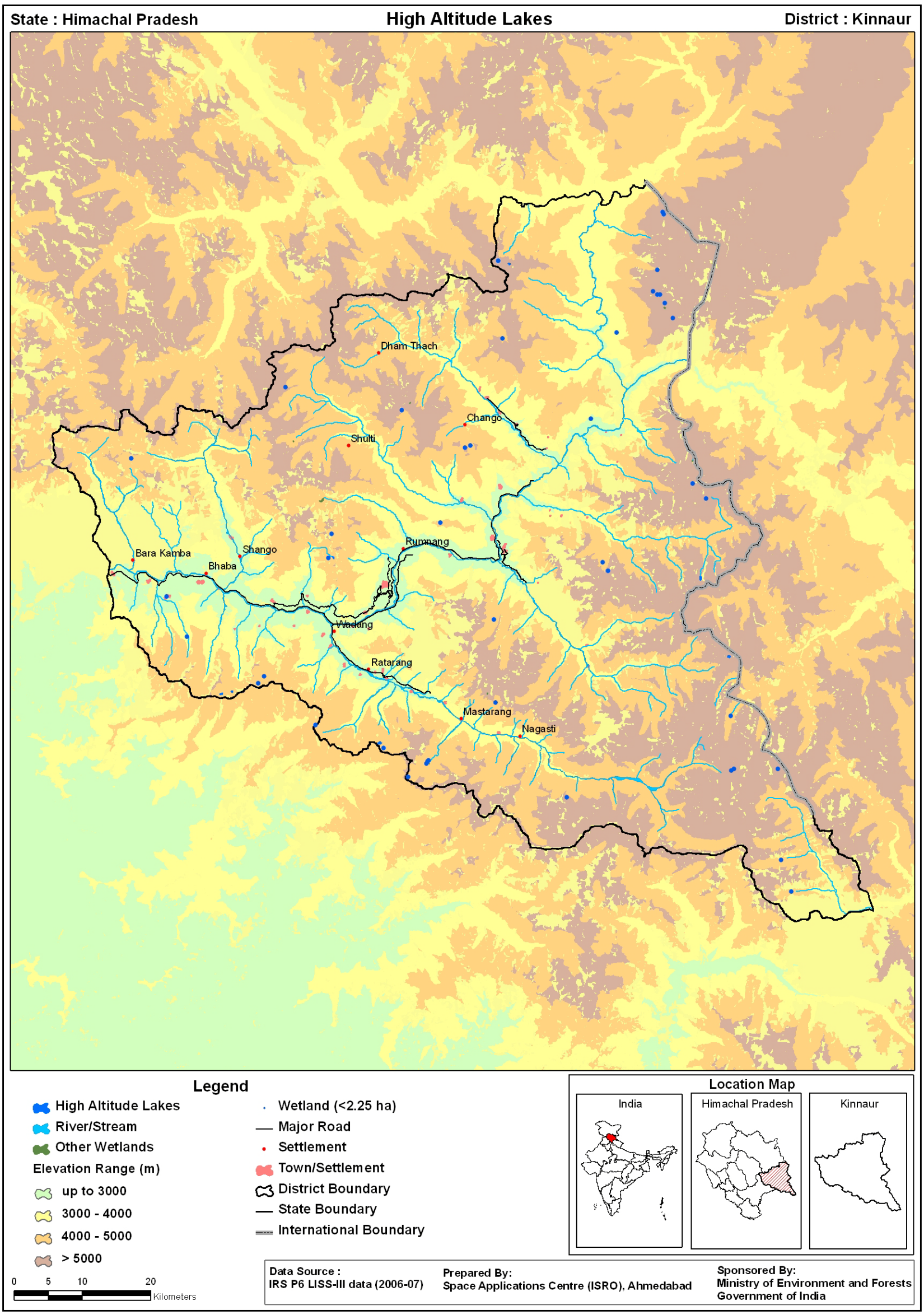


Data Source :
IRS P6 LISS-III data (2006-07)

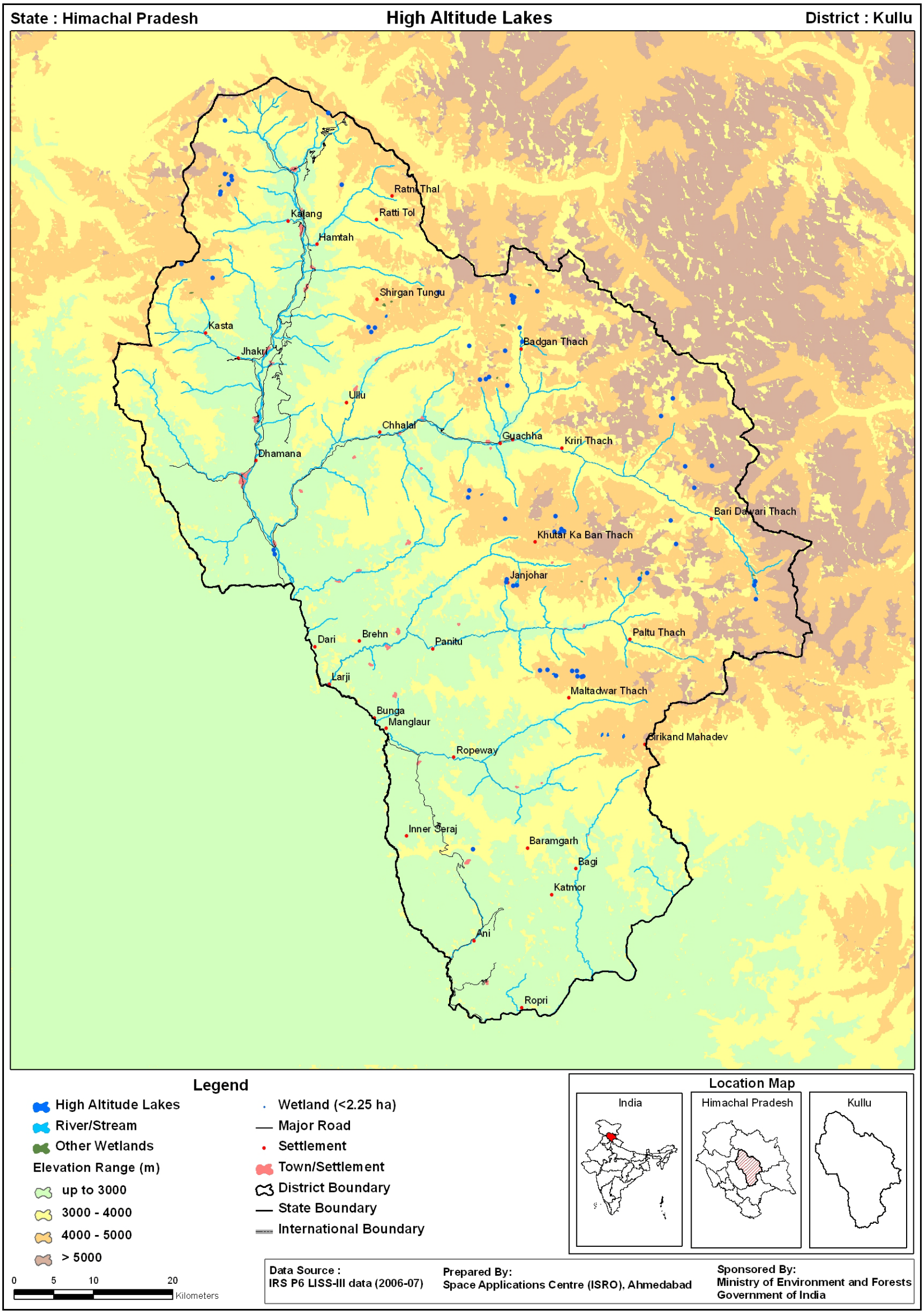
Prepared By:
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

Map-21 High altitude lakes of Chamba district



Map-22: High altitude lakes of Kinnaur district

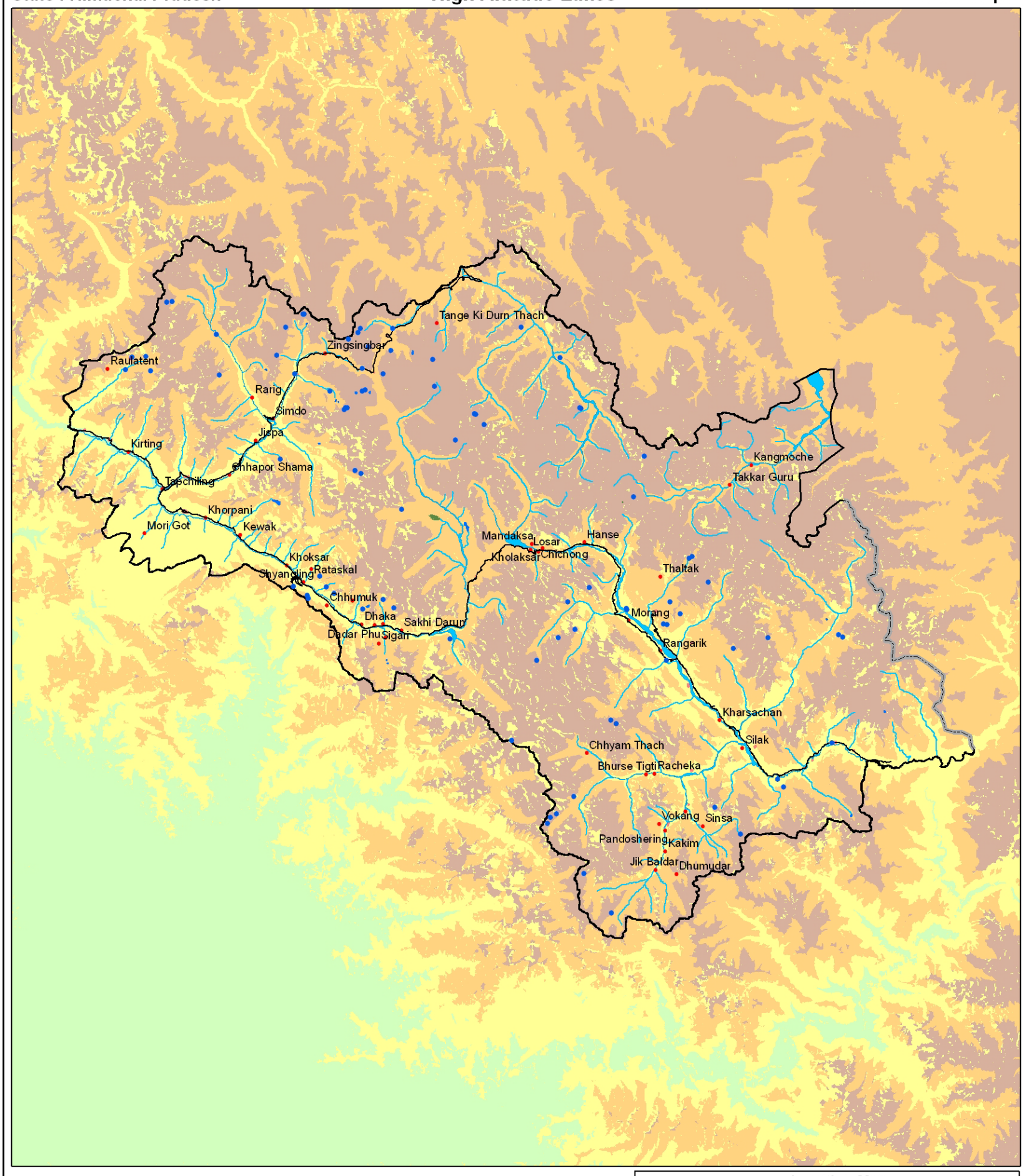


Map-23: High altitude lakes of Kullu district

State : Himachal Pradesh

High Altitude Lakes

District : Lahul & Spiti



Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands

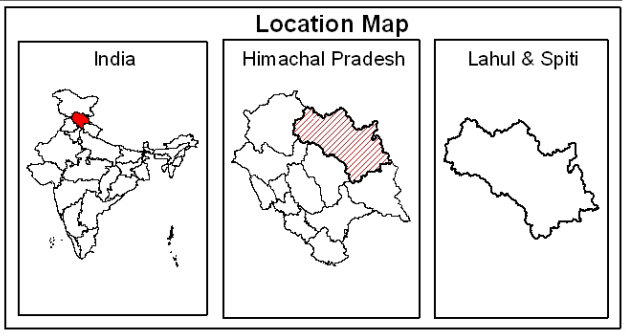
Elevation Range (m)

- up to 3000
- 3000 - 4000
- 4000 - 5000
- > 5000

- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 10 20 40 Kilometers

Location Map



Data Source :
IRS P6 LISS-III data (2006-07)

Prepared By:
Space Applications Centre (ISRO), Ahmedabad

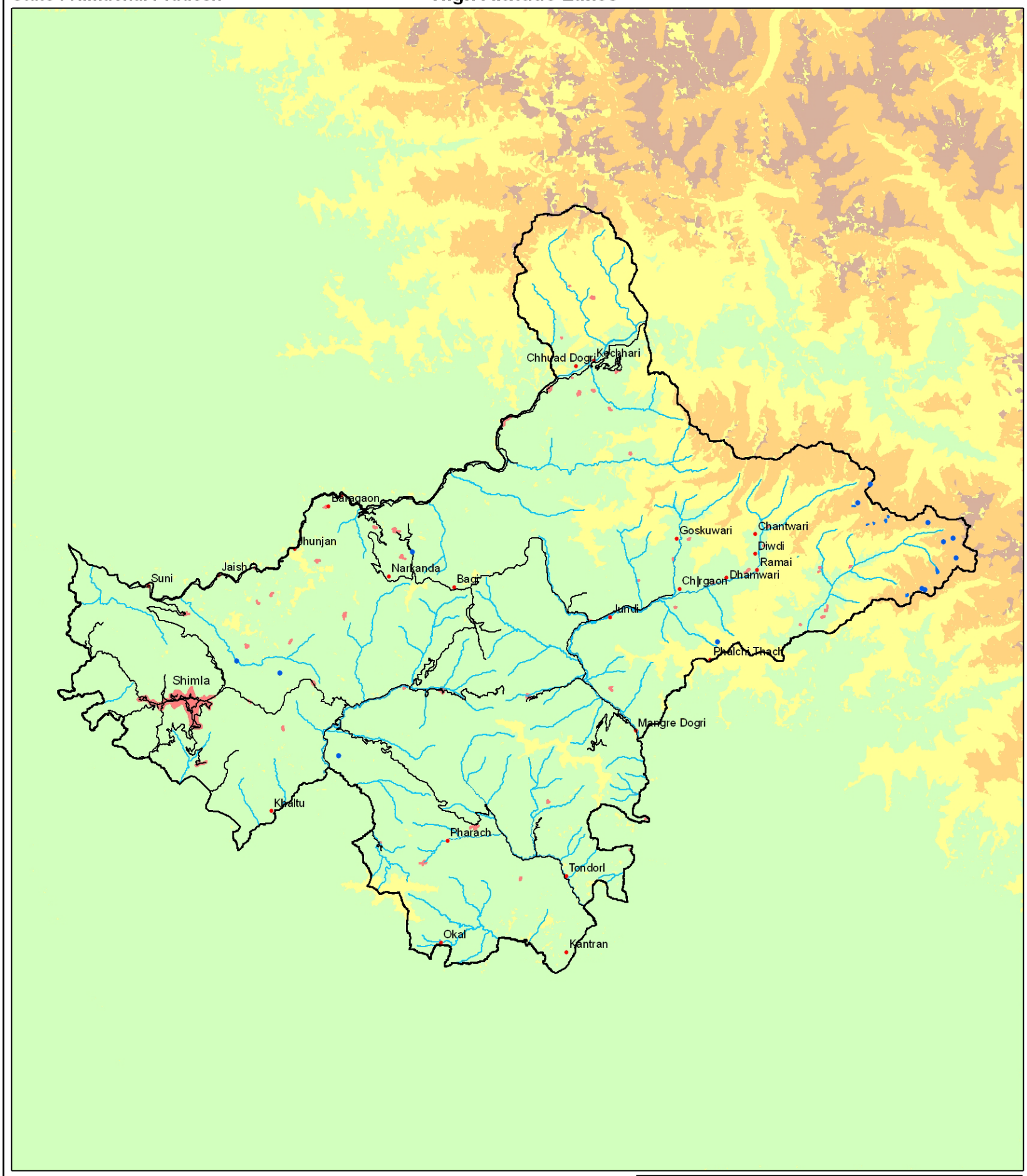
Sponsored By:
Ministry of Environment and Forests
Government of India

Map-24: High altitude lakes of Lahul & Spiti district

State : Himachal Pradesh

High Altitude Lakes

District : Shimla



Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands

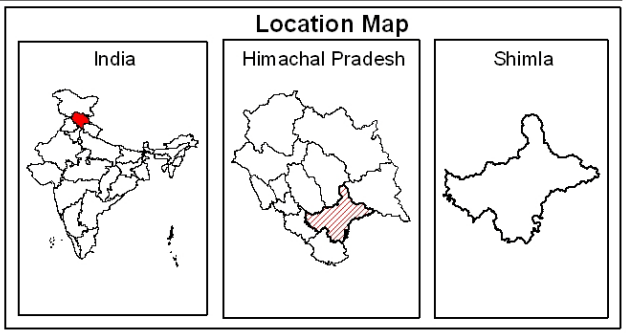
Elevation Range (m)

- up to 3000
- 3000 - 4000
- 4000 - 5000
- > 5000

- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 5 10 20 Kilometers

Location Map



Data Source :
IRS P6 LISS-III data (2006-07)

Prepared By:
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

Map-25: High altitude lakes of Shimla district

4.2.3 Uttarakhand

Uttarakhand situated between 28^0 41` to $31^0$ 27` N latitude and 77^0 34` to $81^0$ 2` E longitude, borders Tibet in the north, Nepal in the east, and the states of Himachal Pradesh and Uttar Pradesh in the west and south respectively(Fig.-39). There are 13 districts in the state. The geographical area of the state is 53,566 km^2 of which 93 per cent is mountainous and 64 per cent is covered with forest. The main rivers of Uttarakhand are Alaknanda, Dhualiganga, Yamuna and Ganges. Two of India's mightiest perennial rivers, the Ganga and the Yamuna originate in the glaciers of Uttarakhand, and fed by myriad lakes, glacial melts and streams in the region.

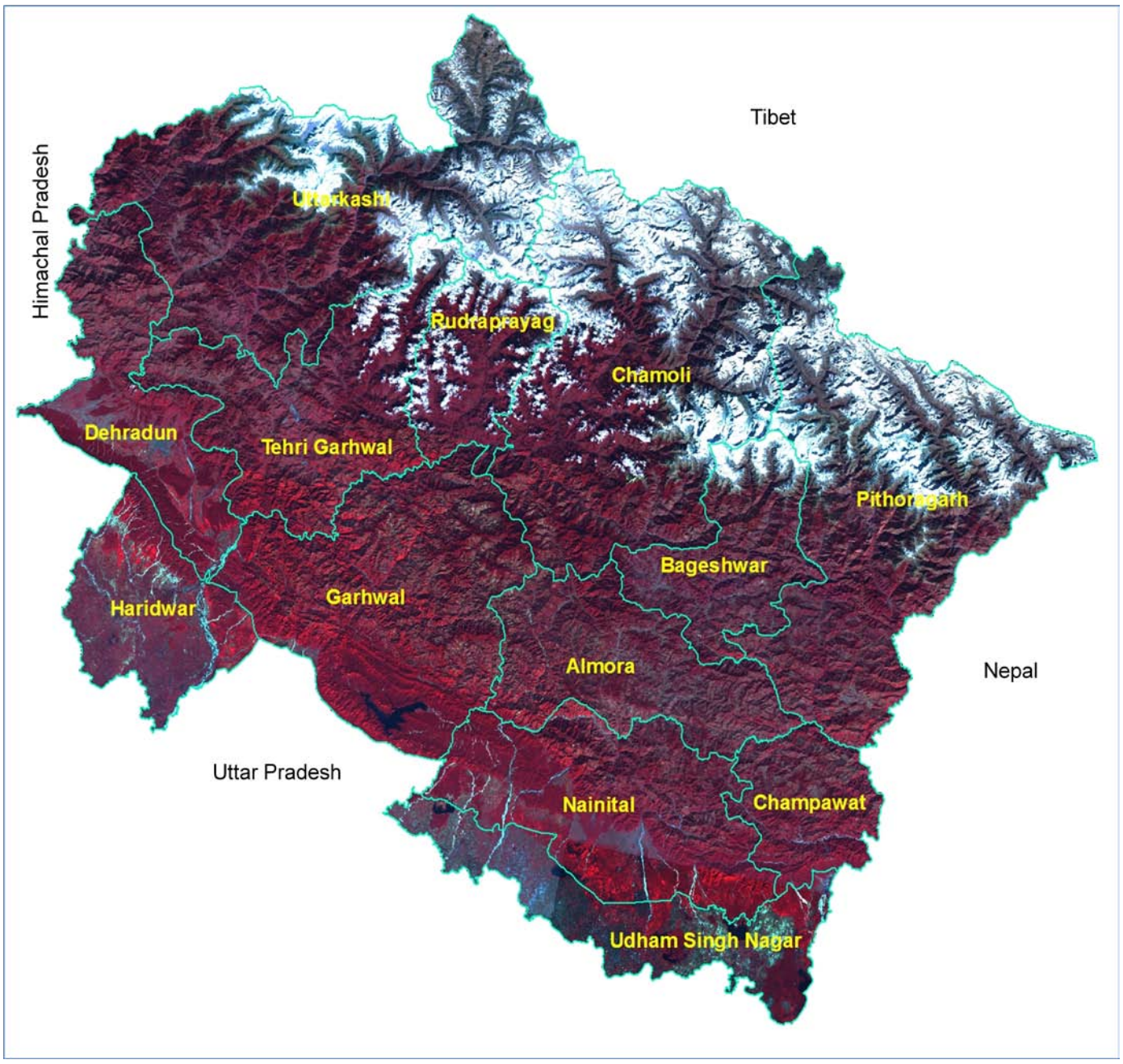


Fig.-39: Uttarakhand as seen in IRS LISS III FCC (district boundaries shown in cyan line)

In all 118 high altitude lakes were delineated constituting 231 ha area that accounts for less than one per cent of total wetland area of the state. Among the districts, Chamoli has the maximum number of 60 HALs with an area of 112 ha. Pithoragarh has 25 HALs occupying 76 ha. Majority of the lakes are of very small size (<2.25 ha) and mapped as point features, indicating requirement of larger scale mapping to capture the details about these lakes (Table-18). There are 28 lakes in range of 2.25-10 ha and one lake in 10-25 ha category.

Table-18: Size-wise distribution of high altitude lakes in Uttarakhand state

Sr. No.	Class	Range	No. of lakes	Area (ha)
1	Very Large	> 500 ha	-	-
2	Large	100-500 ha	-	-
3	Medium	25-100 ha	-	-
4	Small	10-25 ha	1	17
5	Very Small	2.25-10 ha	28	125
6	< 2.25 ha	< 2.25 ha	89	89*
Total			**118**	**231**

* *Nominal assignment*

Altitudinal distribution pattern of these wetlands shows that about 68 wetlands exist in the elevation range of 4000 to 5000 m and 10 wetlands exist in the very high altitude of >5000 m, as shown in Table-19. The distribution pattern of high altitude lakes in the state with respect to altitude range is shown in Fig.-40 and Map-26.

Table-19: Altitude-wise statistics of high altitude lakes in Uttarakhand state

Sr. No.	Category	Altitude range (m)	No. of lakes	Area (ha)
1.	High Altitude	3000-4000	40	43
2.	Steep Altitude	4000-5000	68	159
3.	Very Steep Altitude	>5000	10	64
Total			**118**	**231**

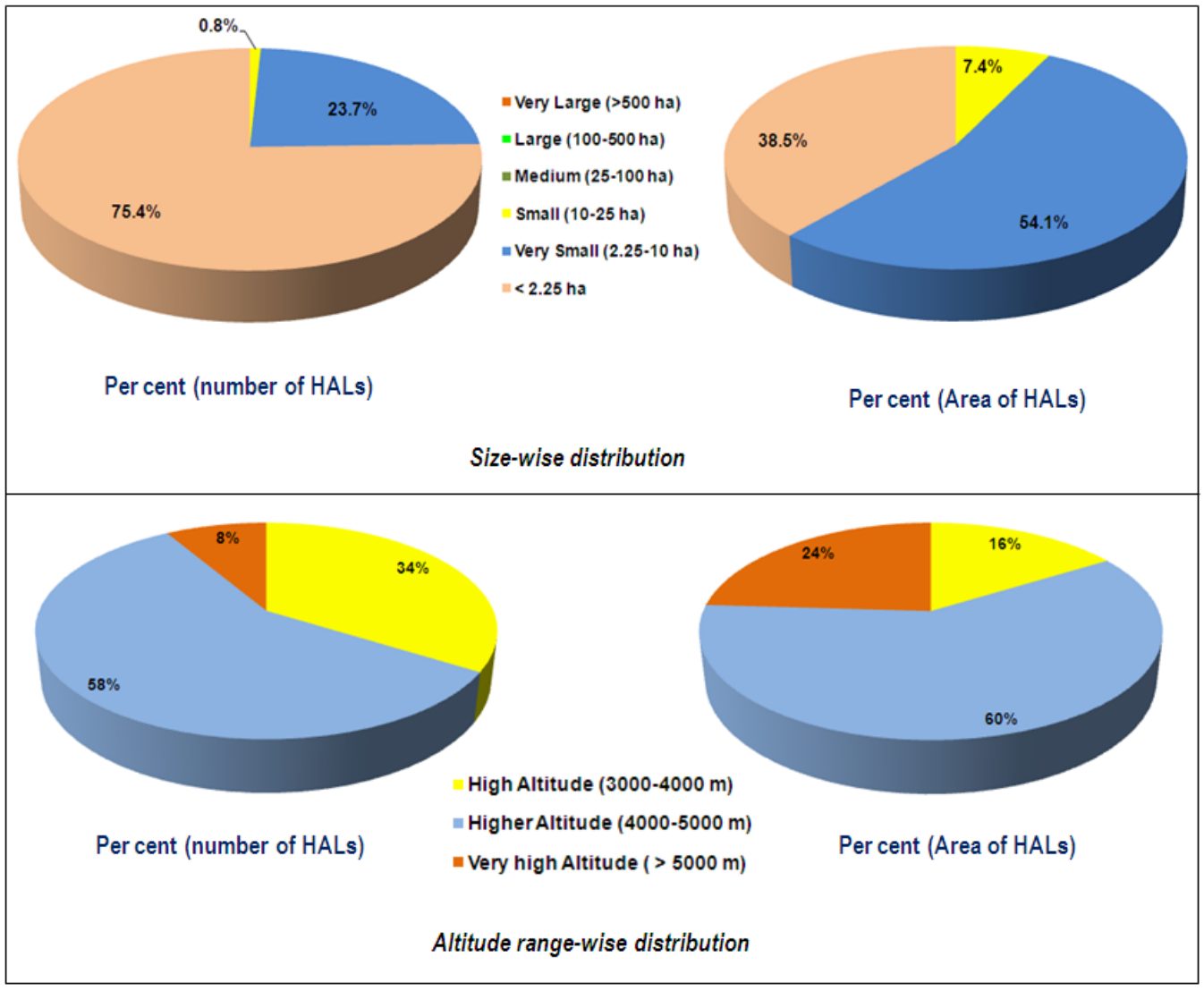
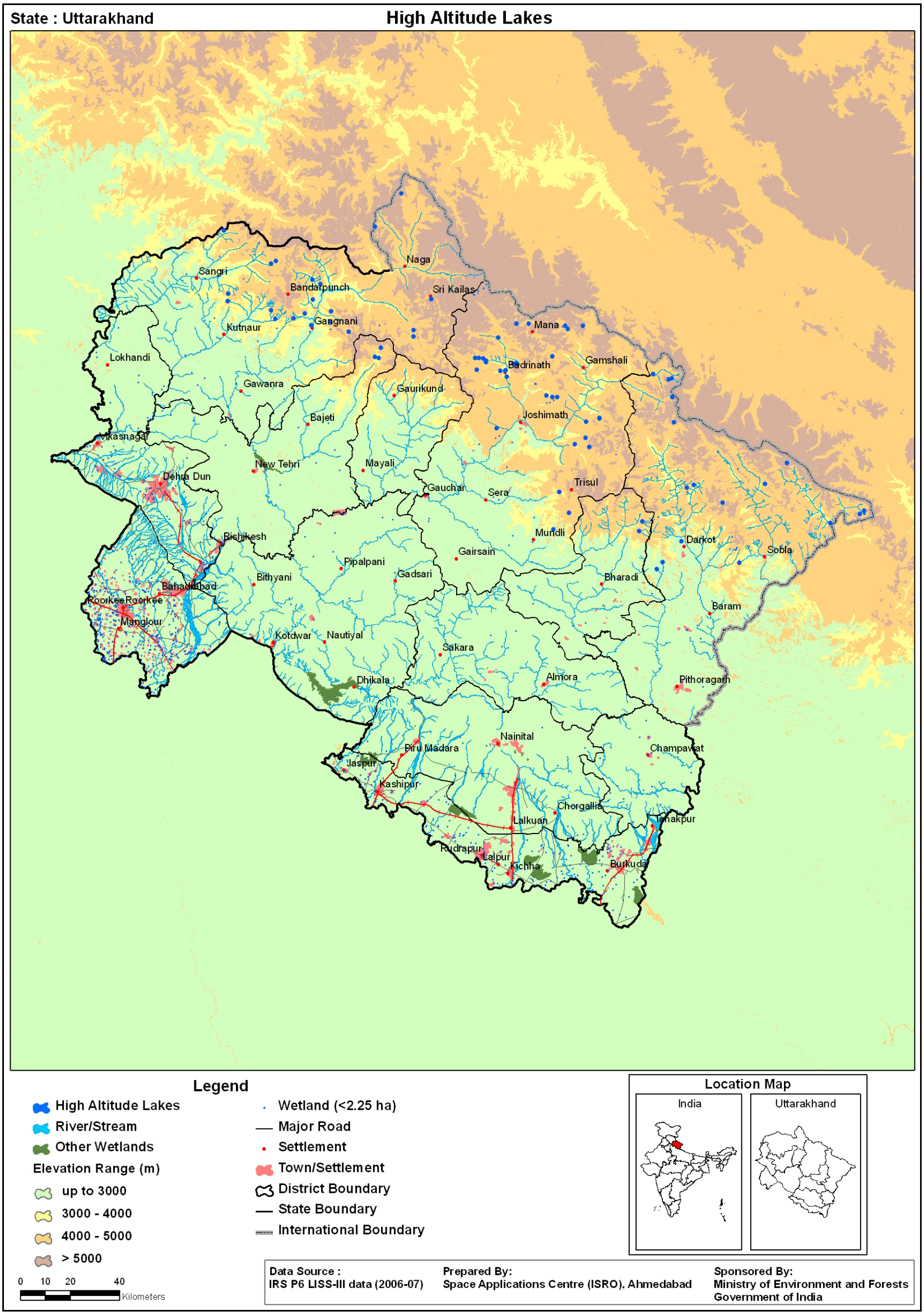


Fig.-40: Size-wise and altitude range-wise distribution of high altitude lakes in Uttarakhand



Map-26: The distribution pattern of high altitude lakes in the Uttarakhand state with respect to elevation range

Kedar Tal in Uttarkashi district at 4425 m elevation is a famous high altitude lake of the sate (Fig.-41). It is near Gangotri along Kedar Ganga, a tributary of Bhagirathi River. Shasra Lake is a popular destination for tourists, situated at 4572m. This splendid lake is in Uttarkashi district, beyond the Kyarki Khar pass. Vasuki Tal/Lake in Chamoli district lies at 4135m, near famous Hindu shrine of Kedarnath. Other well known lakes in Chamoli district are Roopkund and Hemkund. These are very small lakes and mapped as point feature. Roopkund lake is situated in the interior of the Chamoli district. This is a shallow lake of about 2 m depth, with the edges covered with snow almost throughout the year. After the snow melts, skeletal remains which are believed to be 500-600 year old get exposed. The lake is nestled amidst panoramic mountain scenery

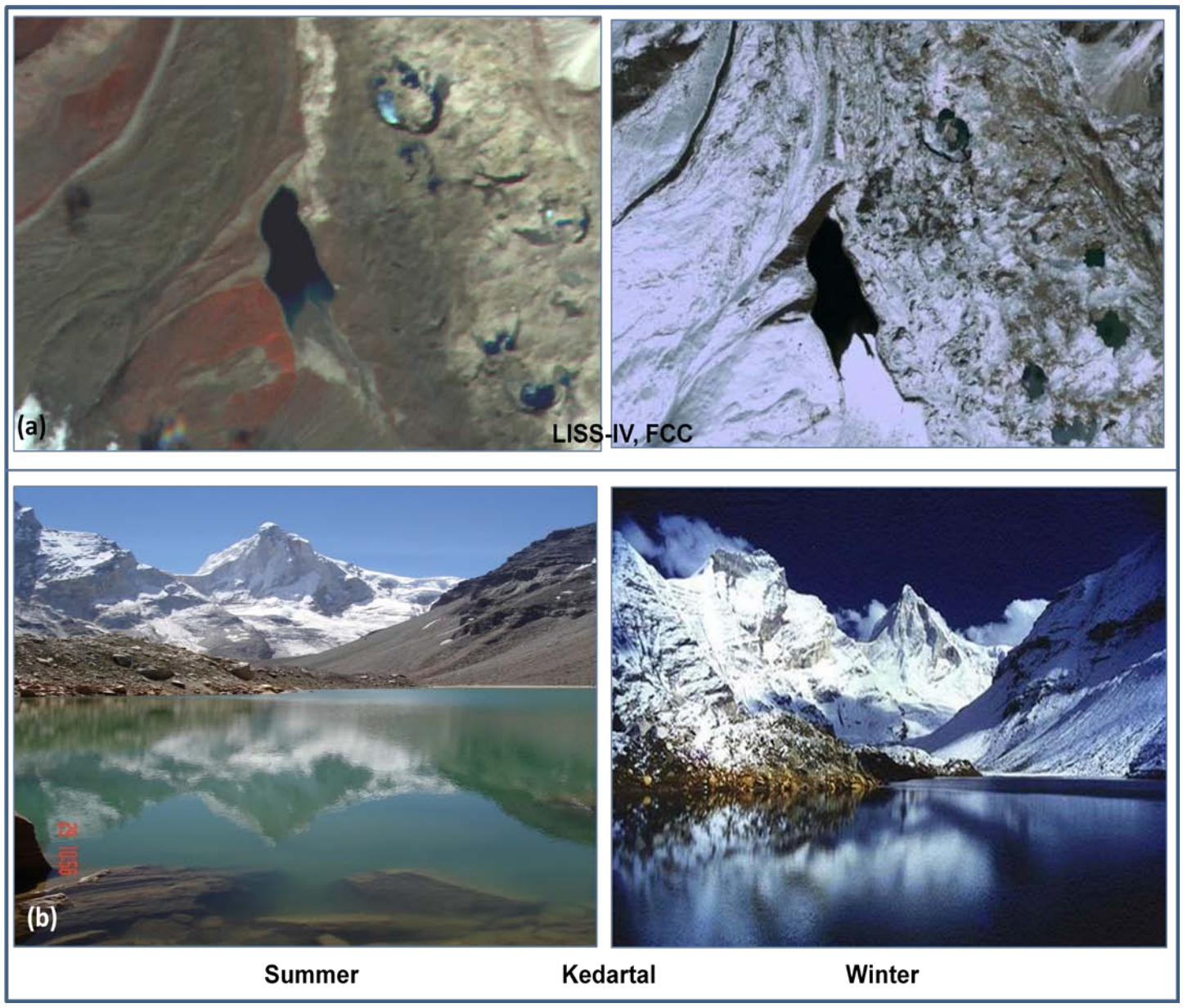


Fig.-41: Kedar Tal- a revered high altitude lake of Uttarakhand as seen in (a) LISS IV FCC of and (b) photographs of the serene lake in summer and winter

District level statistics

The state has 13 districts, Uttarkashi being the largest district of the state having 7951 sq km geographic area.. Only 4 districts viz. Chamoli, Pithoragarh, Rudraprayag and Uttarkashi harboured the high altitude lakes. Maximum number of 60 HALs are in Chamoli district, followed by Uttarkashi having 32. Only one lake is mapped in Rudraprayag district. Most of the high altitude lakes are very small in size (<2.25 ha), thus, mapped as point feature. The only large high altitude lake of the state of 17 ha area is observed in Chamoli district at 30^{o} 54' 4" N Latitude and 79^{o} 45' 18" E Longitude (Fig.-42). Lakes above 5000 m are observed in Chamoli and Pithoragarh districts. The altitudinal

range and size-wise distribution of high altitude lakes in each district of the state is shown in Table-20 and 21 respectively. District-wise maps are shown from Map-27 to 30.

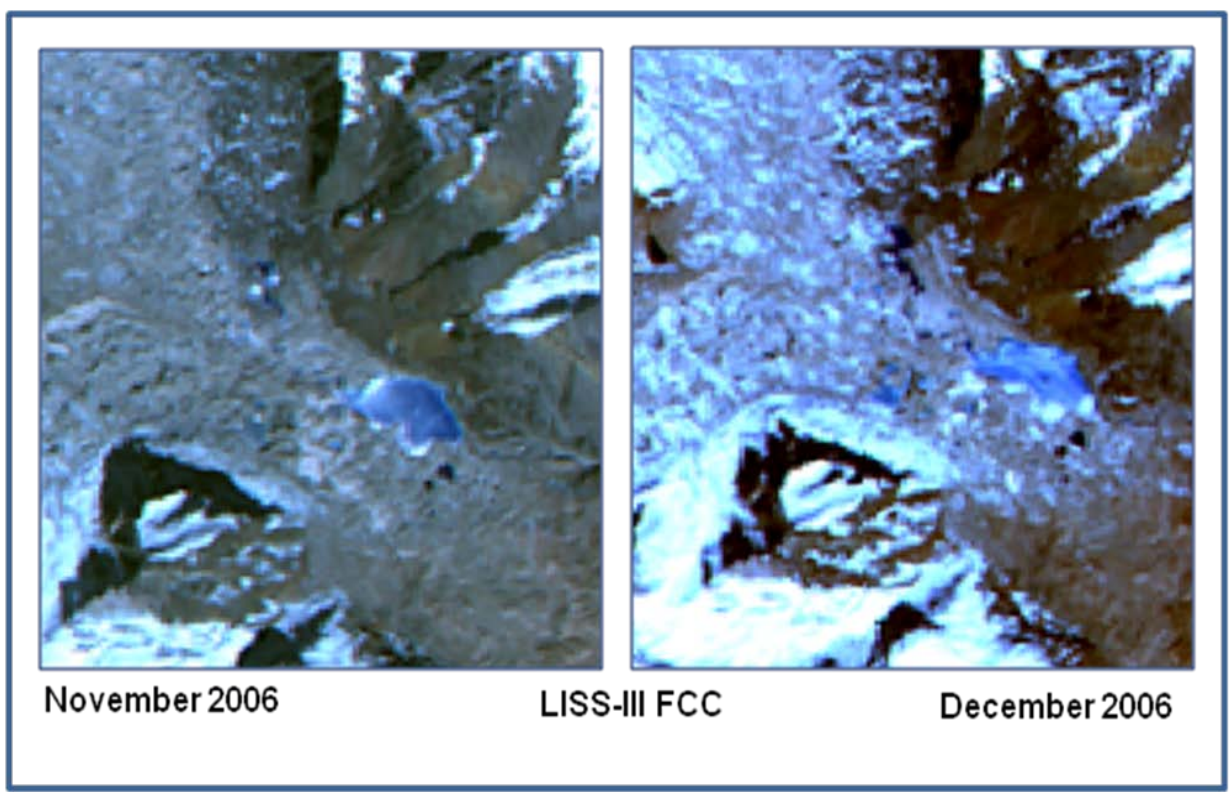


Fig.-42: LISS III FCC of November and December showing the status of the largest high altitude lake in Uttarakhand state located in Chamoli district

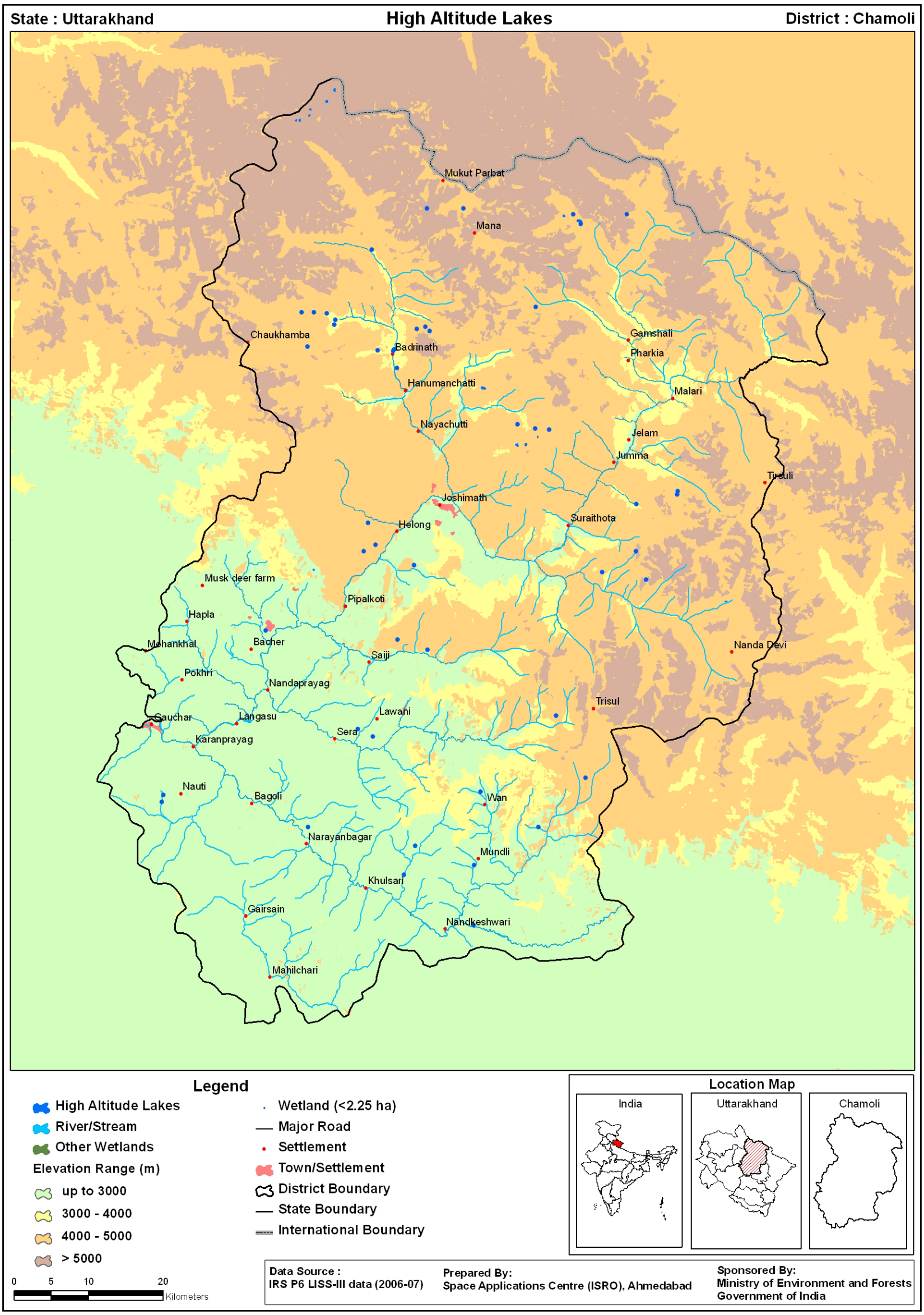
Table-20: Altitudinal range-wise distribution of high altitude lakes in each district of Uttarakhand

Sr. No.	District	High Altitude (3000-4000m)		Higher Altitude (4000-5000m)		Very High Altitude (>5000m)		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)
1	Chamoli	26	28	26	63	8	21	60	112
2	Pithoragarh	3	3	20	65	2	8	25	76
3	Rudraprayag	1	2	-	-	-	-	1	2
4	Uttarkashi	10	10	22	31	-	-	32	41
	Total	**40**	**43**	**68**	**159**	**10**	**29**	**118**	**231**

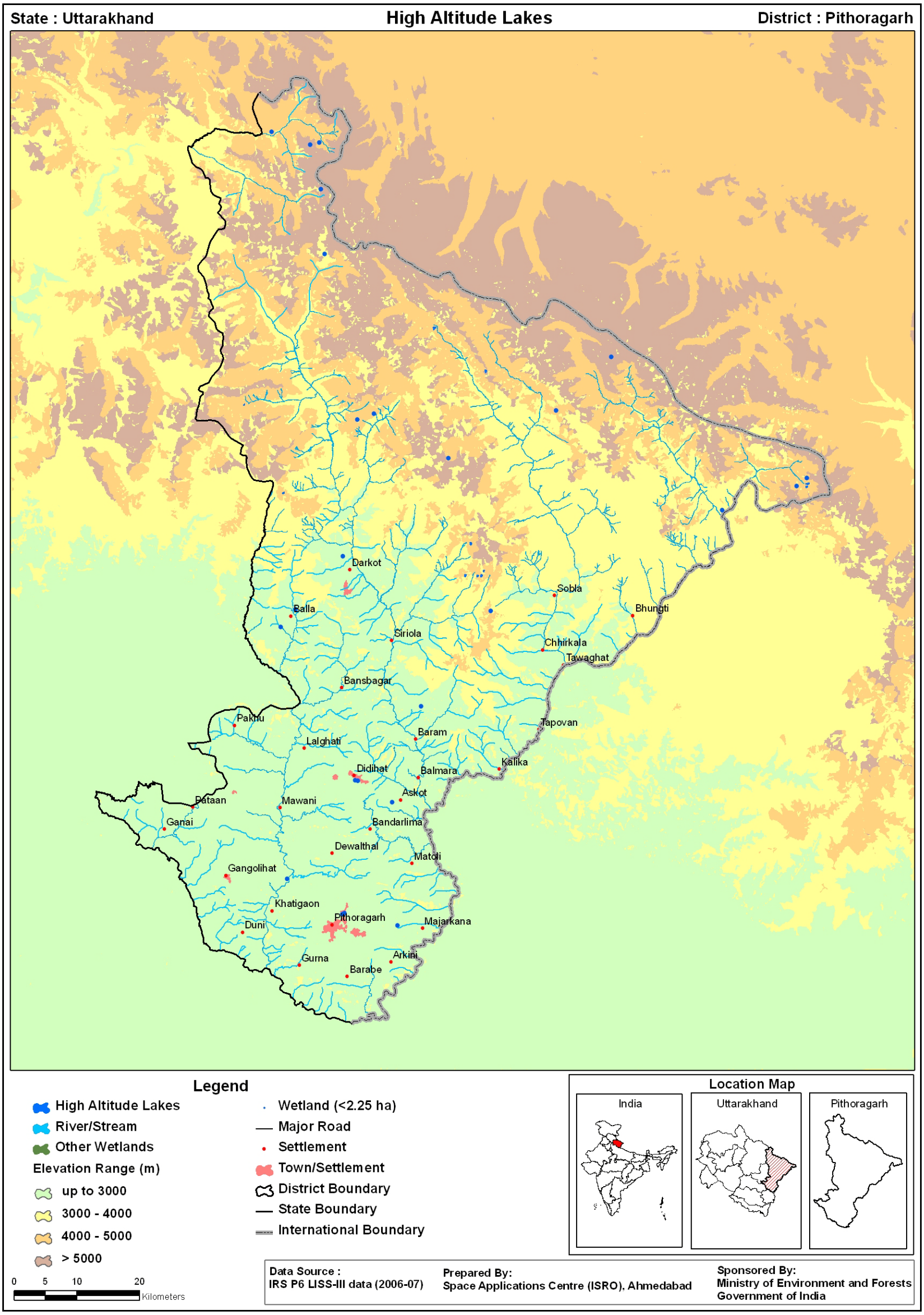
Table-21: Size-wise distribution of high altitude lakes in each district of Uttarakhand

Sr. No.	District	Very Large (> 500 ha)		Large (100-500 ha)		Medium (25-100 ha)		Small (10-25 ha)		Very Small (<10 ha)		<2.25 ha		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area* (ha)	No. of lakes	Area (ha)
1	Chamoli	-	-	-	-	-	-	1	17	13	49	46	46	60	112
2	Pithoragarh	-	-	-	-	-	-	-	-	11	62	14	14	25	76
3	Rudraprayag	-	-	-	-	-	-	-	-	1	2	-	-	1	2
4	Uttarkashi	-	-	-	-	-	-	-	-	3	12	29	29	32	41
	Total	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**17**	**28**	**125**	**89**	**89**	**118**	**231**

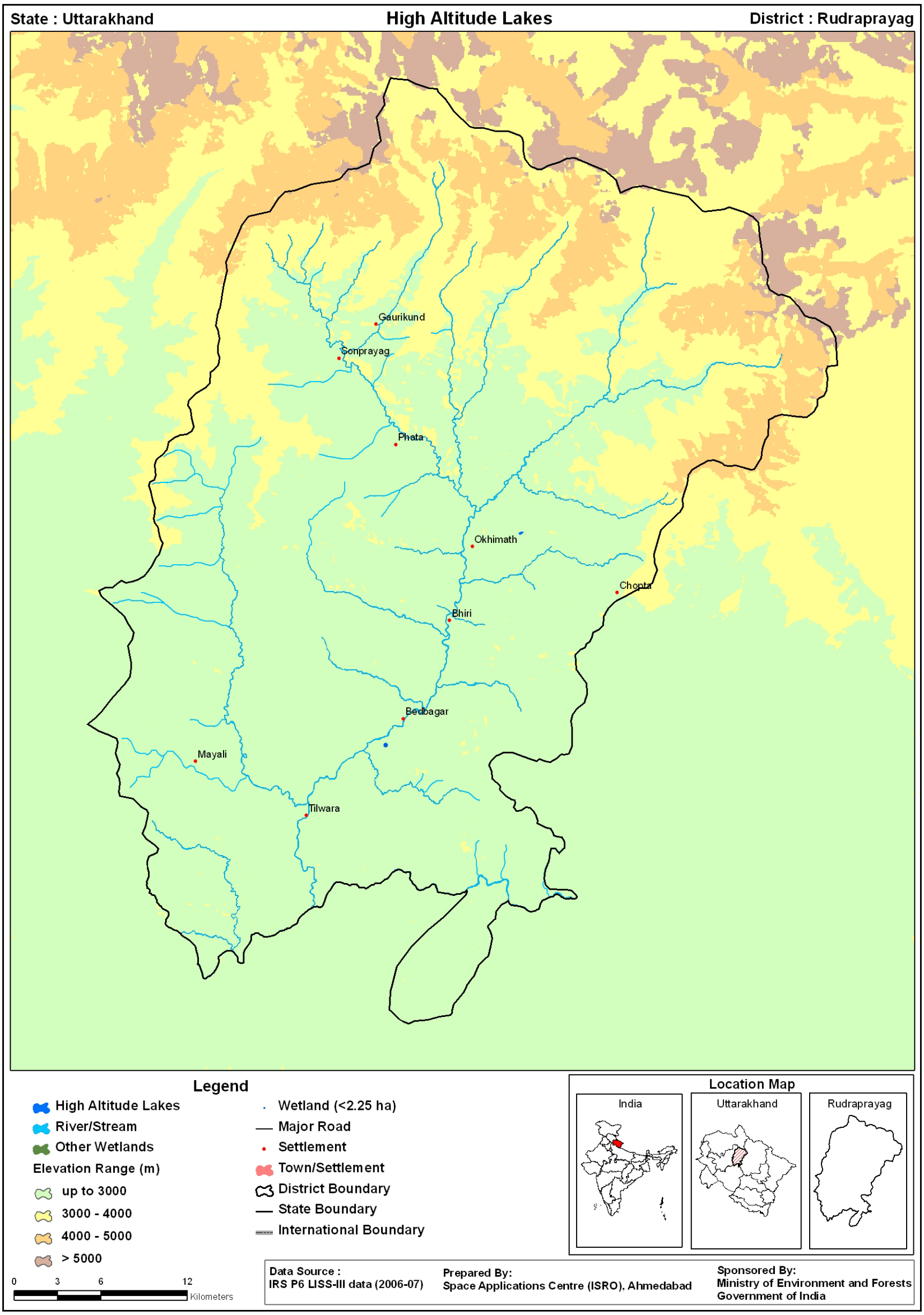
* *Nominal assignment*



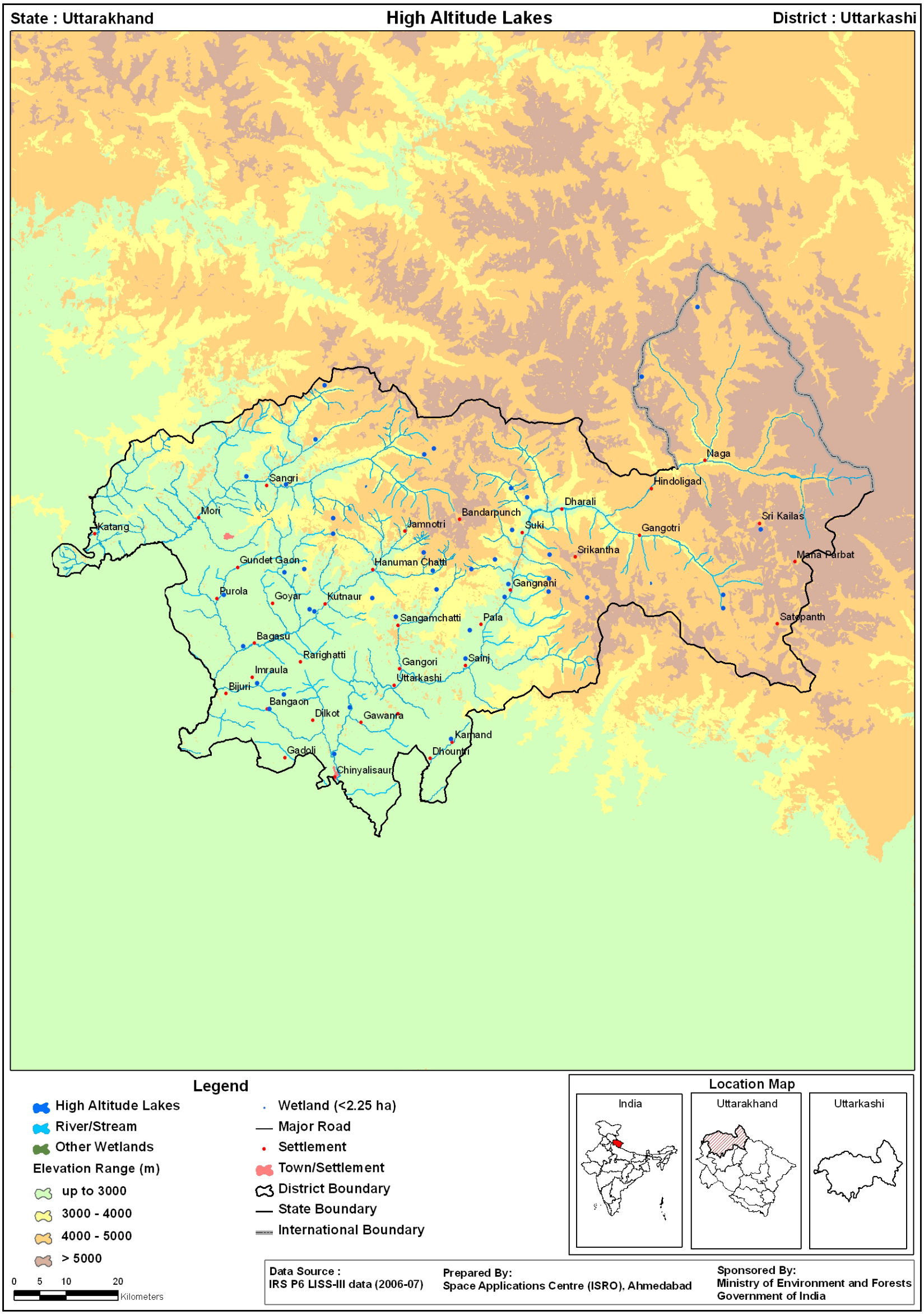
Map-27: High altitude lakes of Chamoli district



Map-28: High altitude lakes of Pithoragarh district



Map-29: High altitude lakes of Rudraprayag district



Map-30: High altitude lakes of Uttarkashi district

4.2.4 Sikkim

Sikkim is situated in the North Eastern region of India. The state borders Nepal in the west, China in the north and east and Bhutan in the south-east. The Indian state of West Bengal borders Sikkim to its south. It lies between 27° 05' 46'' N to 28° 07' 48''N latitude and 88° 00' 58'' to 88° 55' 25''E longitude. The geographical area of the state is 7,096 km^2. The state has four districts (Fig.-43). The Himalayan mountains surround the northern, eastern and western borders of Sikkim. Almost the entire state is hilly, with elevation reaching up to 8,585 metres. The state has 28 mountain peaks, more than 80 glaciers, and numerous high-altitude lakes. Kanchenjunga - the third-highest peak of the world - is the highest point in the state, situated on the border between Sikkim and Nepal. Sikkim is one of the few states in India to receive regular snowfall. The snow line ranges from 6096 m in the north of the state to 4877 m in the south. Teesta River and its tributary, the Rangeet, which flow through the state from north to south are the major rivers. The catchment of many of the high altitude lakes, abound with Rhododendron (the state flower), few species like *Rhododendron nivale* growing even on rocky situation gregariously at 5,000 m.

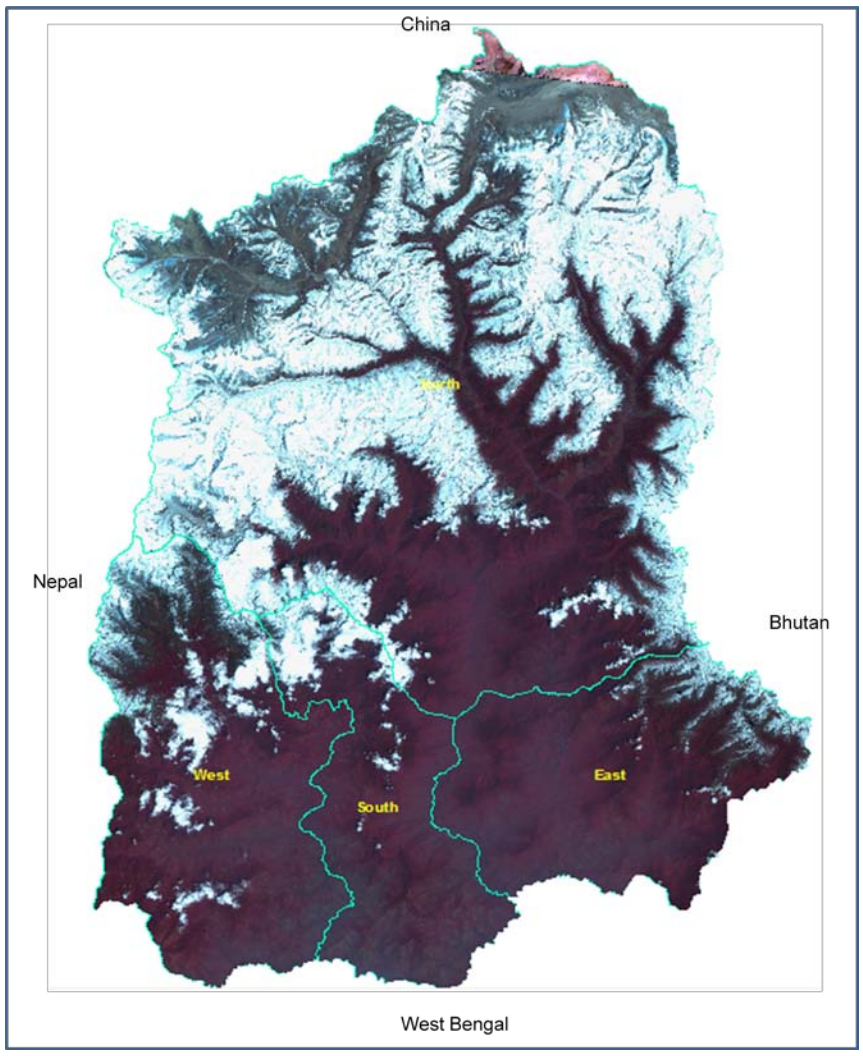


Fig.-43: Sikkim as seen in IRS LISS III FCC (district boundaries shown in cyan line)

Results of 1:25,000 scale (using LISS IV) data is reported here. Thus, lakes <0.5 ha area are mapped as point features.

Total of 677 HALs have been mapped including 231 lakes identified as point features, with an area of 3326 ha. Highest number of lakes is in the size category of 0.5-10 ha. Only five lakes of >100 ha are observed (Table-22). Distribution pattern in relation to altitude showed that maximum number of lakes are in the range of 4000-5000 m, followed by >5000 m . Only 27 lakes are in the lower elevation of 3000-4000 m (Table-23). The distribution pattern of high altitude lakes in the state with respect to altitude range is shown in Fig.-44 and Map-31.

Table- 22: Size-wise distribution of high altitude lakes of Sikkim

Sr. No.	Class	Range	No. of Wetlands	Area(ha)
1	Very large	> 500 ha	-	-
2	Large	100-500 ha	5	618
3	Medium	25-100 ha	21	836
4	Small	10-25 ha	45	651
5	Very Small	0.5-10 ha	375	1004
6	< 0.5 ha	< 0.5 ha	231	117*
	Total		677	3226

* *Note: The number of small lakes (< 0.5 ha) are 231 occupying 117 ha area assuming that each is of 0.25 ha.*

Table-23: Altitude-wise statistics of high altitude lakes in Sikkim

Sr. No.	Elevation Range	Altitude range (m)	No. of Lakes	Area (ha)
1	High Altitude	3000-4000	27	127
2	Higher Altitude	4000-5000	384	1069
3	Very High Altitude	>5000	266	2030
	Total		677	3226

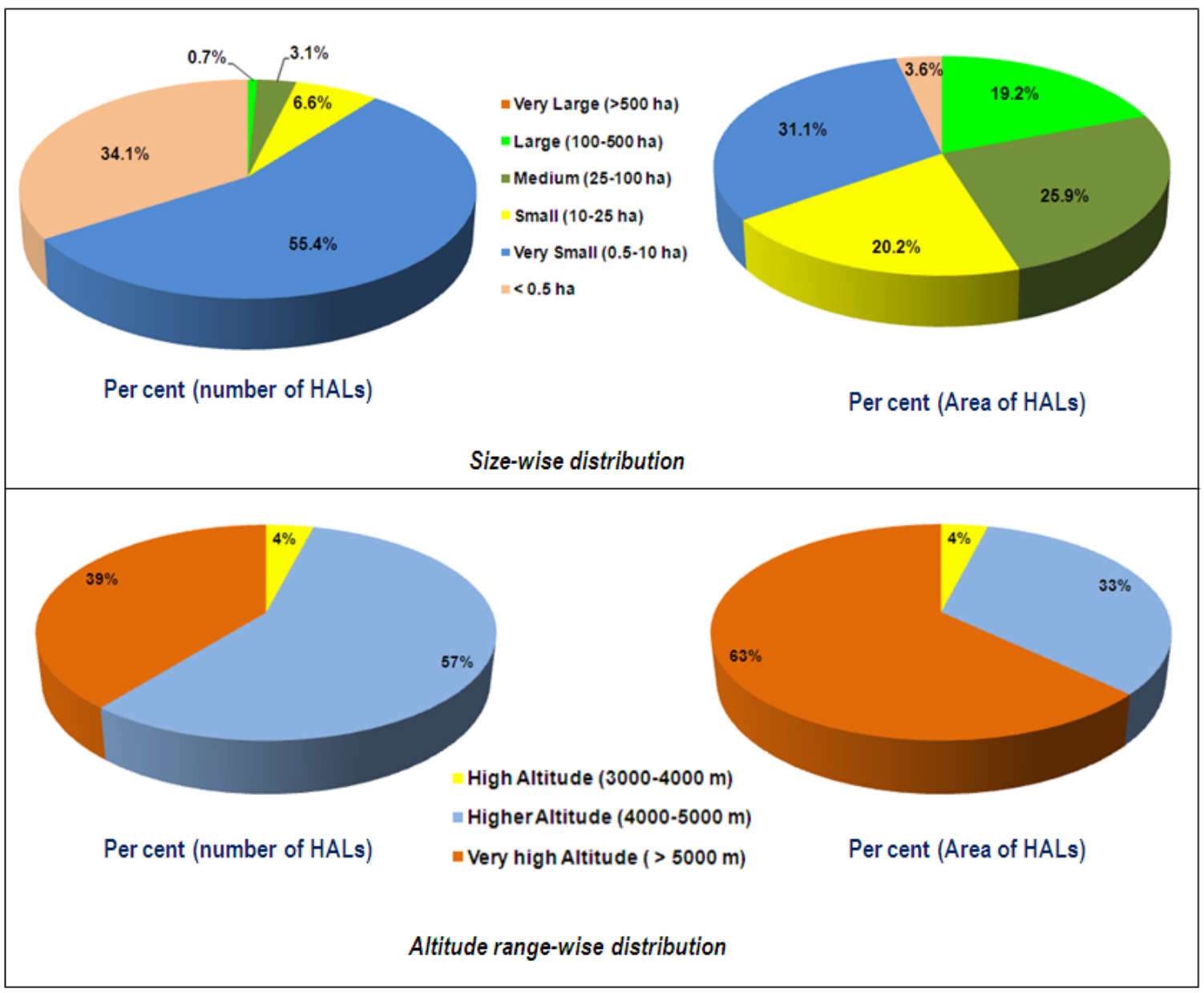
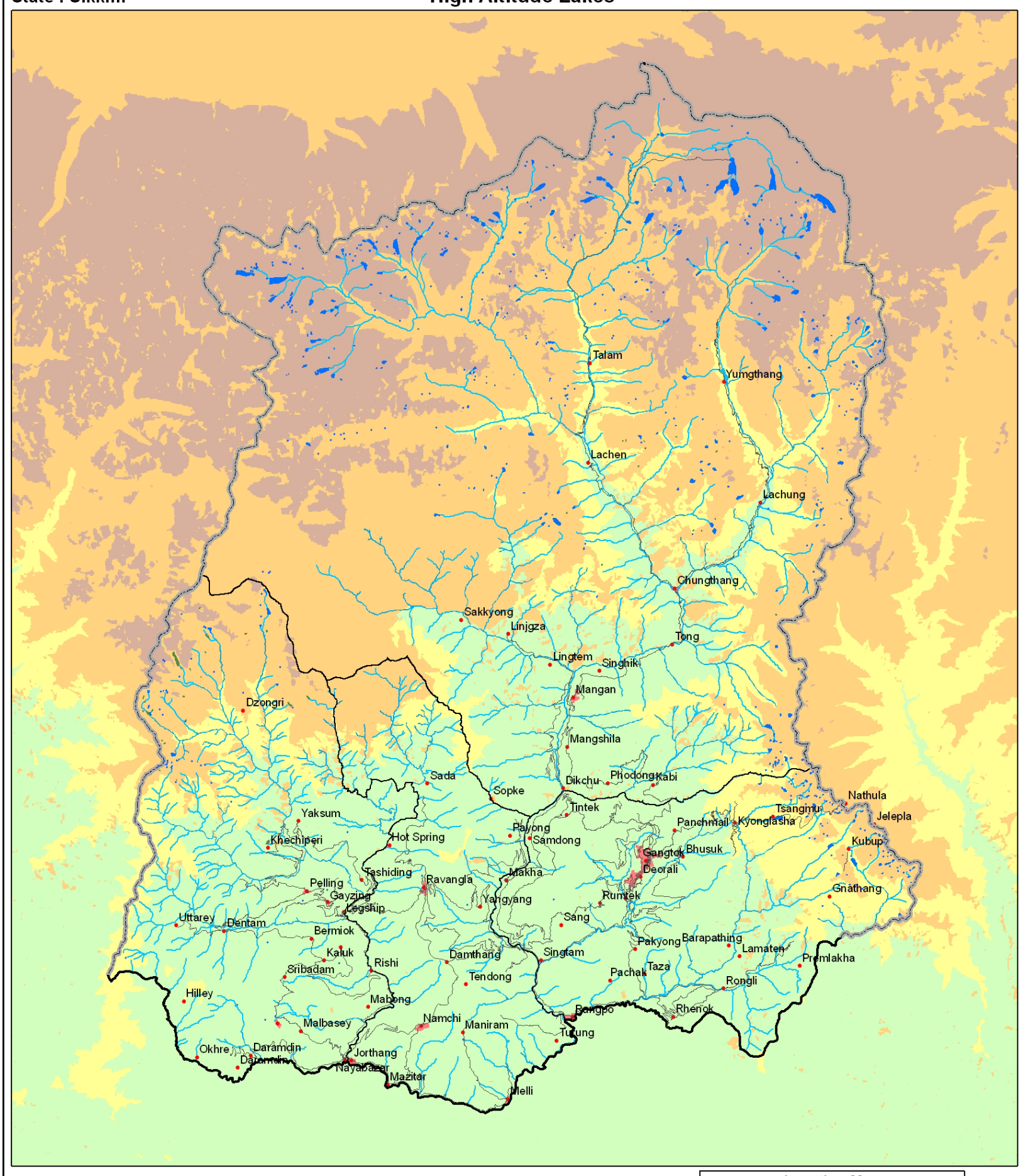


Fig.-44: *Size-wise and altitude range-wise distribution of high altitude lakes in Sikkim*

The lakes in the state are of glacial type. A large number of lakes are at very high elevation of >5000 m. Some of the well known lakes are Cholamu, Gurudongmar, Tsomgo, Khangchung chho, Lhonark chho, Khora chhobuk etc. 3D perspective view of part of North district with large cluster of high altitude lakes with LISS IV image draped on DEM, are shown in Fig.-45 and 46.

State : Sikkim

High Altitude Lakes



Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands

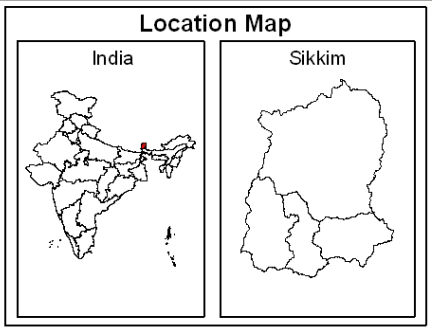
Elevation Range (m)

- up to 3000
- 3000 - 4000
- 4000 - 5000
- > 5000

- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 3 6 12 Kilometers

Location Map



Data Source :	Prepared By:	Sponsored By:
IRS P6 LISS-III/IV data (2006-07)	Space Applications Centre (ISRO), Ahmedabad	Ministry of Environment and Forests Government of India

Map-31: Distribution pattern of high altitude lakes in Sikkim with respect to elevation range

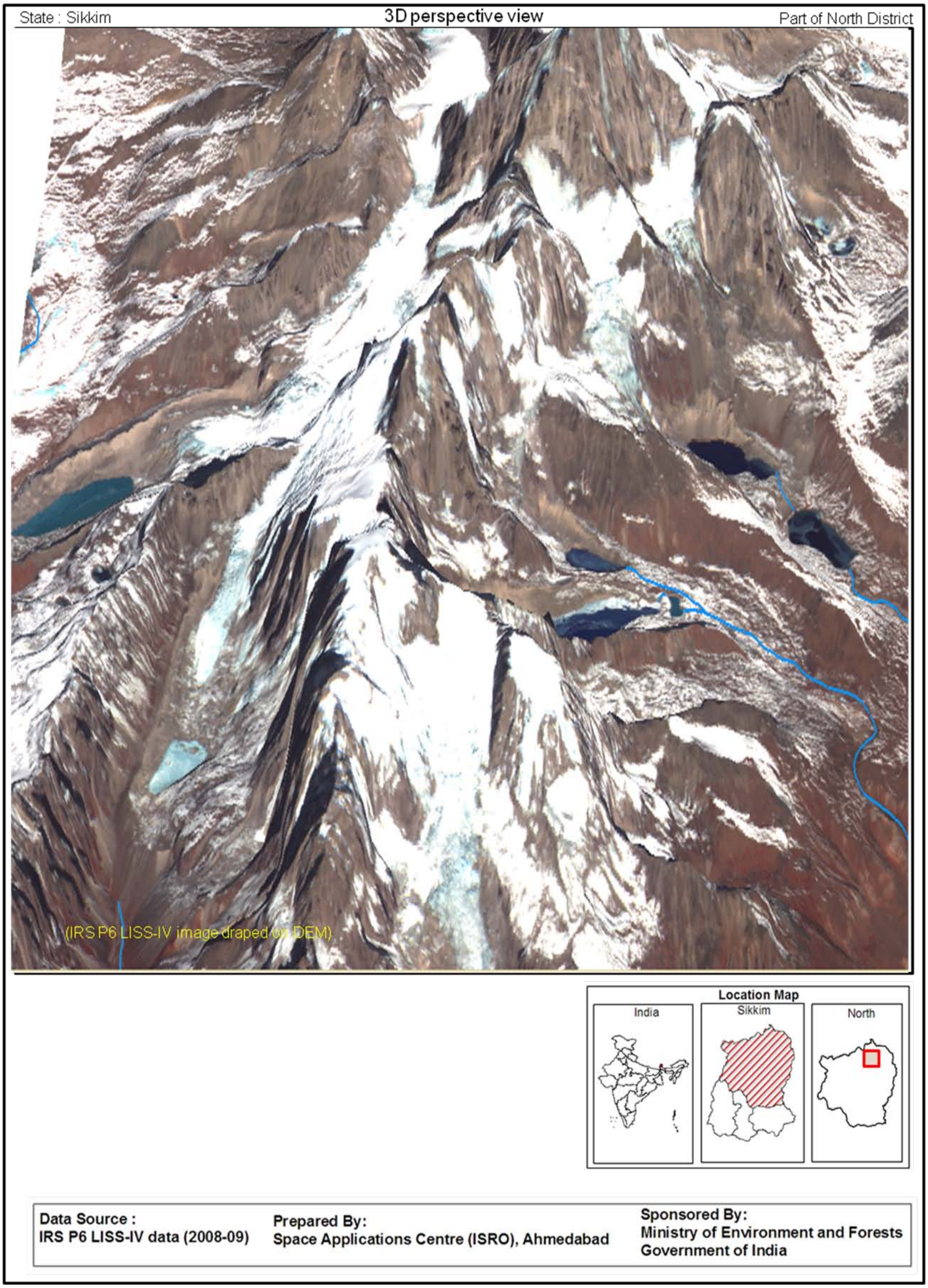


Fig.-45: 3D perspective view of Part of North district (LISS IV image draped on DEM) showing cluster of medium size lakes

Fig.-46: 3D perspective view of Part of North district (LISS IV image draped on DEM) showing cluster of small lakes.

Gurudongmar Lake

Gurudongmar Lake (also known as Gurudogmar Lake) the largest and one of the highest lake in Sikkim, rests on the northern side of the Khangchengyao Range, close to the Indo-China Border in the province of North Sikkim in a high plateau area next to the Tibetan Plateau. Gurudongmar Lake is of high reverence for the Sikkimese and Buddhists. The stream emerging northern side of lake joins the stream originating from the near by lake Tso Lahmu, which later becomes River Teesta. The lake is flanked by two large lakes at its southern part.

Code : 1101007704120006

Location : 28^0 02' 07.88" N latitude and 88^0 42' 44.36" E longitude

Altitude : 5,148 m

Area : 118 ha

Perimeter : 5.34 km

The lake freezes completely during winter (Fig.-47). The 3D perspective view of the lake is shown in Fig.-48.

Gurudongmar is the land of Yaks, blue ships and other high altitude animals. The road to Gurudongmar from Thangu passes through the high alpine pastures carpeted with thick rhododendron bushes. The terrain leading to Gurudongmar is very hostile and yet very beautiful. The land resembles Tibetan plateau, vegetation is very limited and the road is through stony moraine like unpaved path. The lake shows the typical freezing cycle of very high altitude lakes.

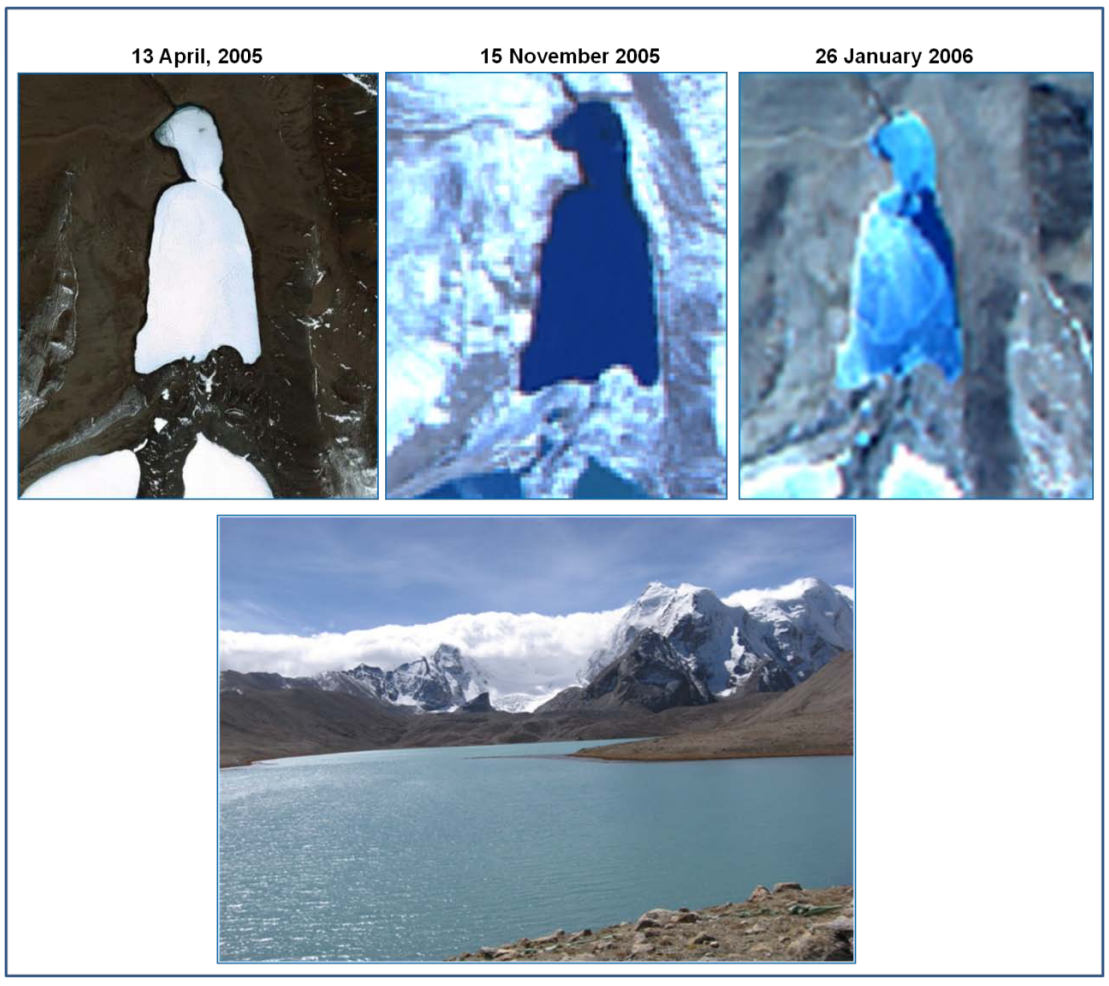
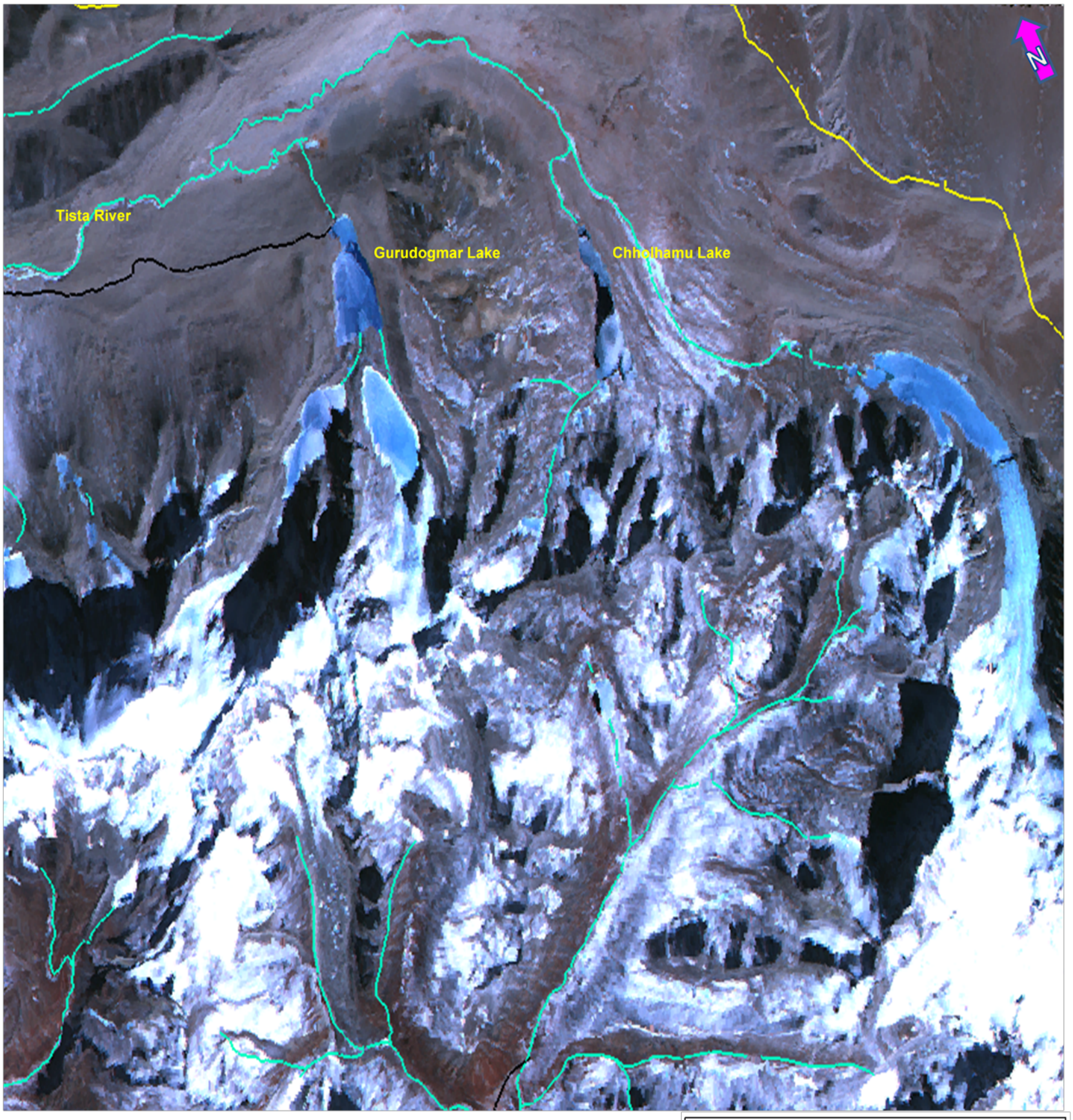


Fig.-47 LISS III FCC showing the seasonal variation of the Gurudongmar lake

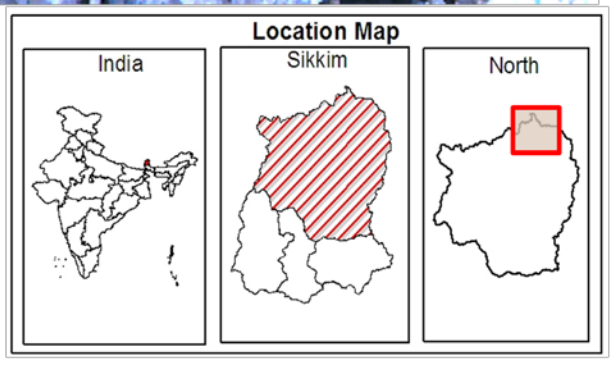
State : Sikkim

3D perspective view

Part of North District



(IRS P6 LISS-III image draped on DEM)



Data Source :
- IRS P6 LISS-III data (2007)
- SRTM DEM
- NWIA Geodatabase

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests, Government of India

Fig.-48: 3D perspective LISS III FCC of Chollahmu and Gurudongmar lakes and surrounding area

Tsomgo Lake

Tsomgo Lake (also called Changu Lake or Tsongmo Lake) is located between 27^0 21’ 28.36” N and 88^0 46’ 00.40” E at an altitude of 3780 m in the north eastern part of Sikkim. It is oval-shaped, with a length of nearly a kilometer and has an average depth of fifteen meters. This lake has been worshipped as a holy lake by Sikkimese. The lake is also an important tourist destination. It is home of Brahminy ducks. The surrounding is also an ideal habitat for the Red Panda and various species of birds. Many tributary glaciers in the side valleys feed the lake. These glaciers open into the main Zemu Valley from different directions.

Code : 1104007801110020

Location : 27^0 21’ 28.36” N latitude and 88^0 46’ 00.40” E longitude

Altitude : 3780 m

Area : 23.6 ha

Perimeter : 2 km

Field photographs and satellite images of the lake are shown in Fig.-49. Between May and August the lake catchment becomes green and colorful with a variety of flowers, including the Rhododendrons, Primulas, Poppies, and Irises etc. 3D perspective view of Tsomgo lake and surrounding area is shown in Fig.-50.

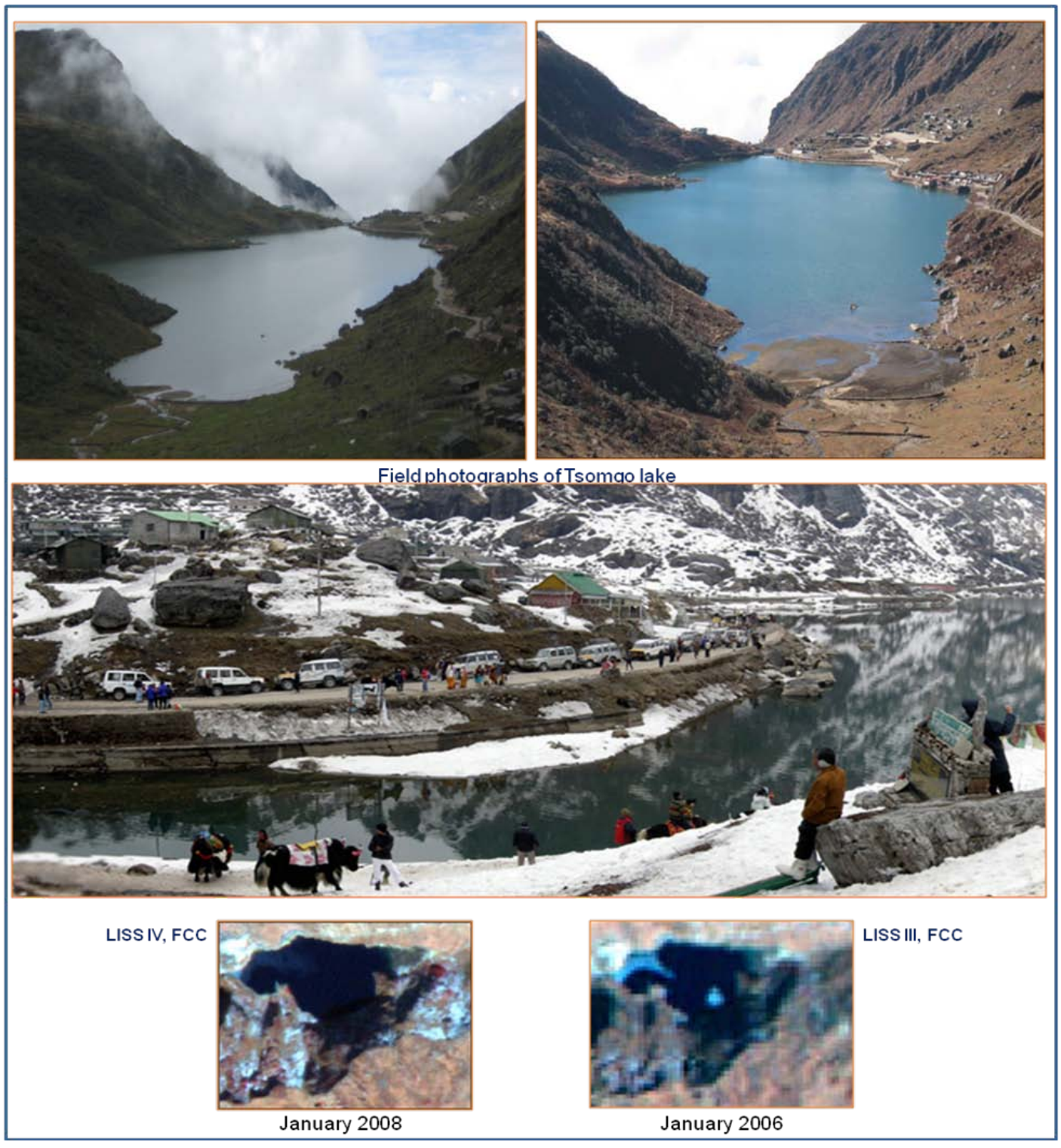


Fig.-49: Field photographs and satellite images of Tsomgo lake

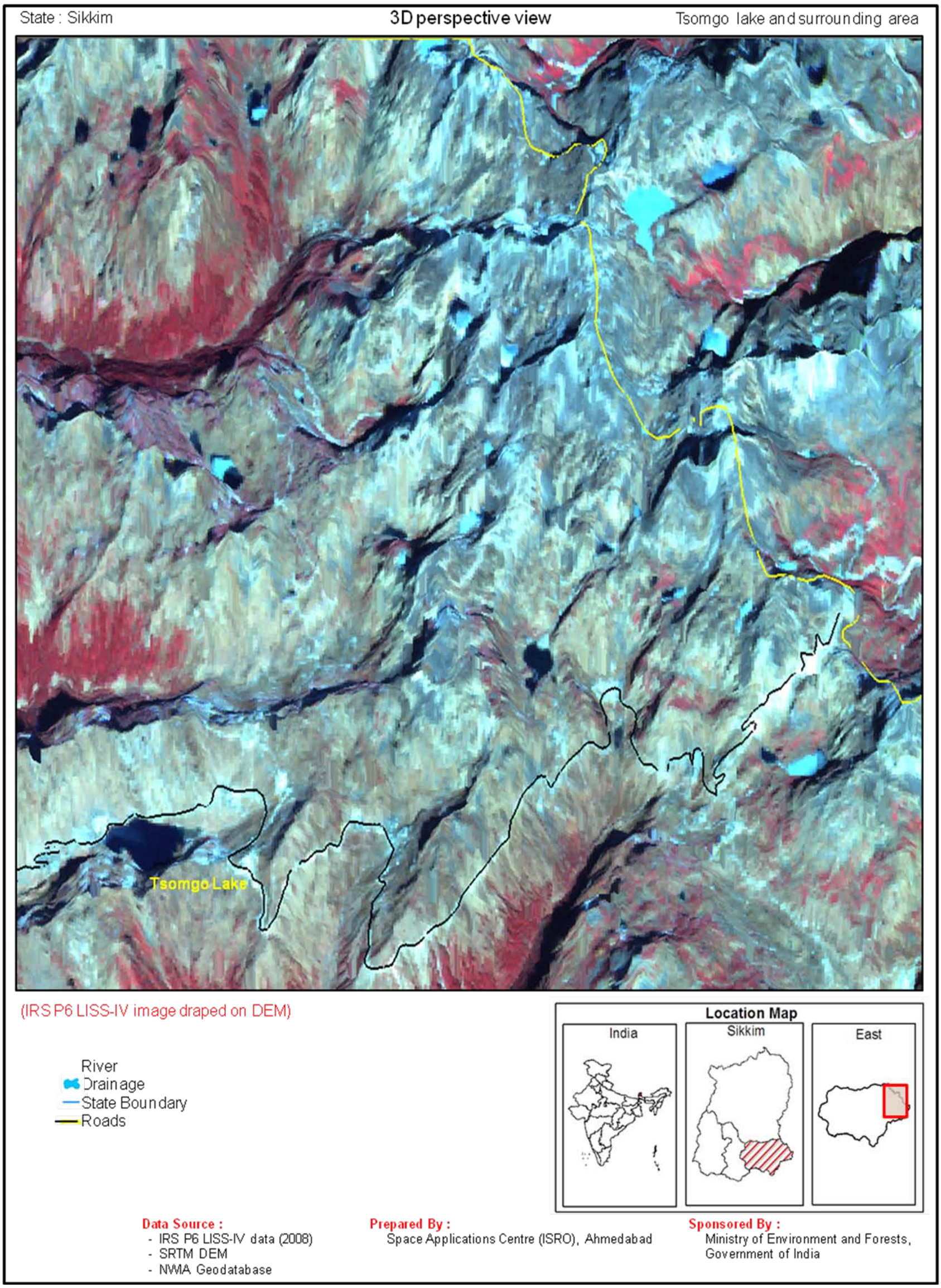


Fig.-50: 3D perspective view of Tsomgo lake and surrounding area

District-wise analysis

The state has four districts. District wise analysis shows that except for the South district, high altitude lakes are found in other three districts. North district has the maximum number of 506 followed by East district with 97 HALs. North district also harbours all the 5 large lakes of >100 ha in the state. The altitudinal range-wise and size-wise distribution of high altitude lakes in each district of the state is shown in Table-24 and 25 respectively.

District level maps are shown from Map-32 to 34.

Table-24: Altitudinal range-wise distribution of high altitude lakes in each district of Sikkim

Sr. No.	District	High Altitude (3000-4000m)		Higher Altitude (4000-5000m)		Very High Altitude (>5000m)		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)
1	East	17	104	80	140	-	-	97	244
2	North	8	22	235	749	263	2027	506	2798
3	West	2	1	69	180	3	3	74	184
	Total	**27**	**127**	**384**	**1069**	**266**	**2030**	**677**	**3226**

Table-25: Size-wise distribution of high altitude lakes in each district of Sikkim

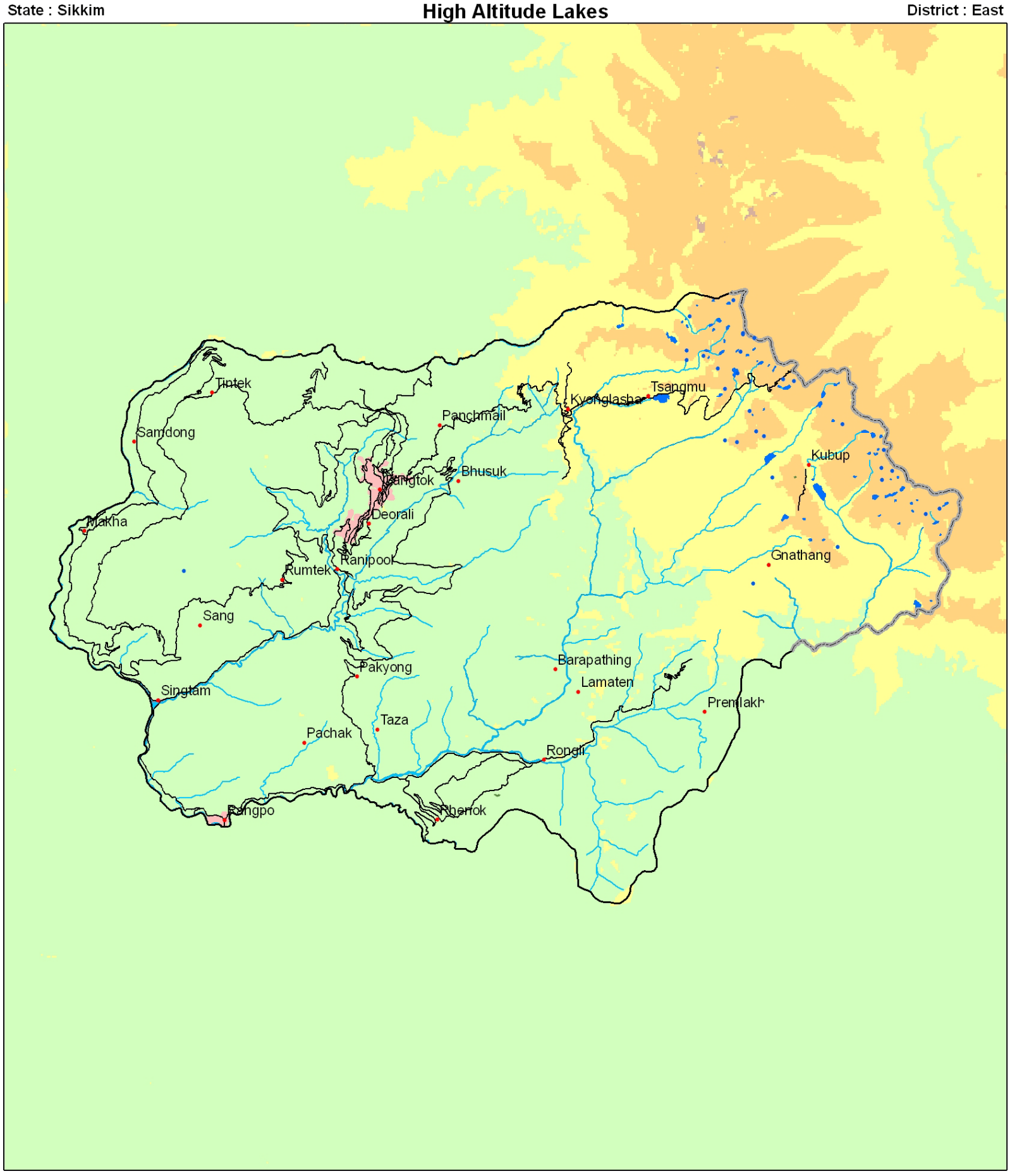
Sr. No.	District	Very Large (> 500 ha)		Large (100-500 ha)		Medium (25-100 ha)		Small (10-25 ha)		Very Small (<0.5 -10 ha)		<0.5 ha		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area* (ha)	No. of lakes	Area (ha)
1	East	-	-	-	-	2	54	2	29	64	146	29	15	97	244
2	North	-	-	5	618	18	745	40	579	273	770	170	86	506	2798
3	West	-	-	-	-	1	37	3	43	38	88	32	16	74	184
	Total	-	-	5	618	21	836	45	651	375	1004	231	117	677	3226

* *Nominal assignment*

State : Sikkim

High Altitude Lakes

District : East

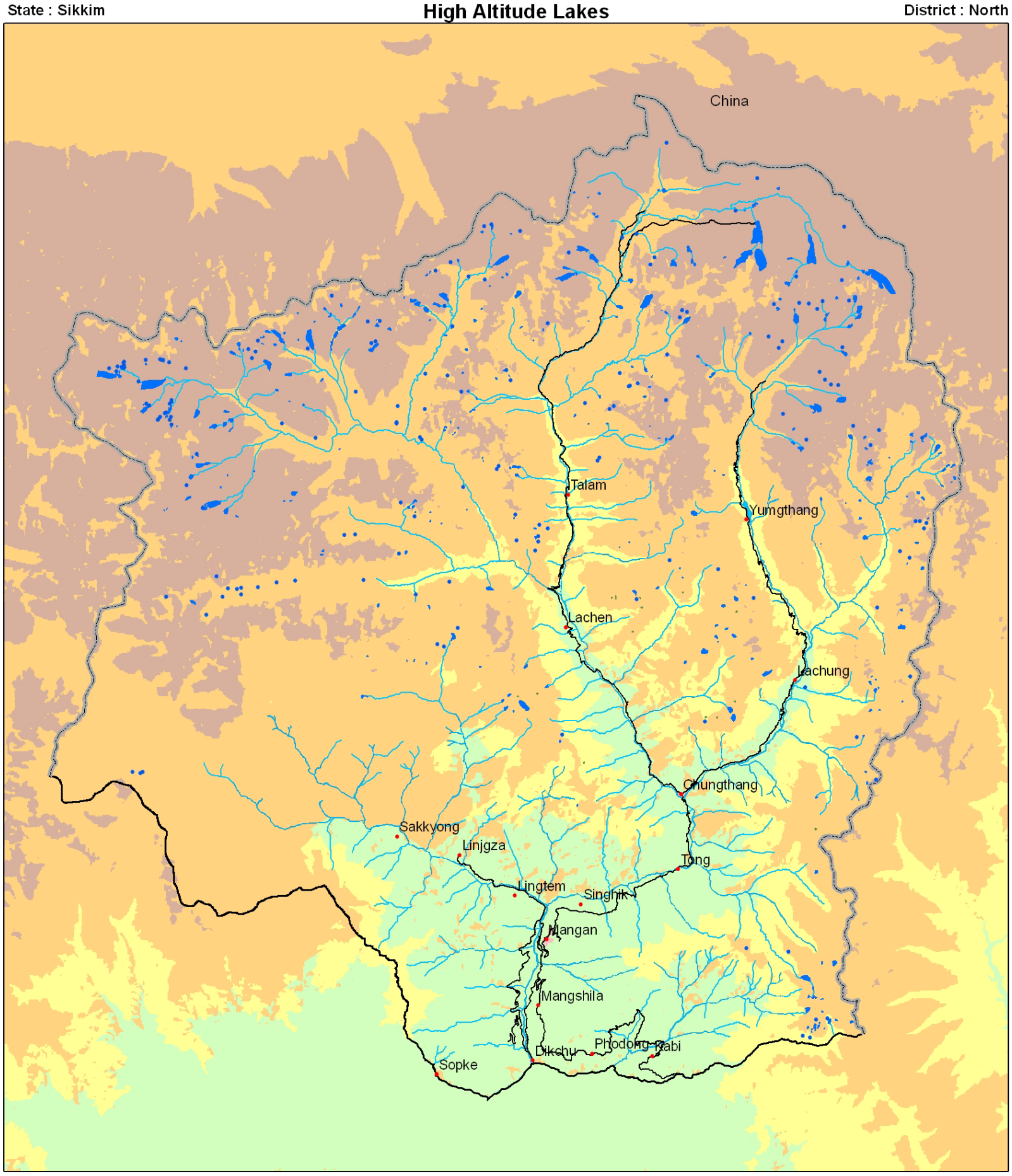


Map-32: High altitude lakes of East district

State : Sikkim

High Altitude Lakes

District : North



Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands

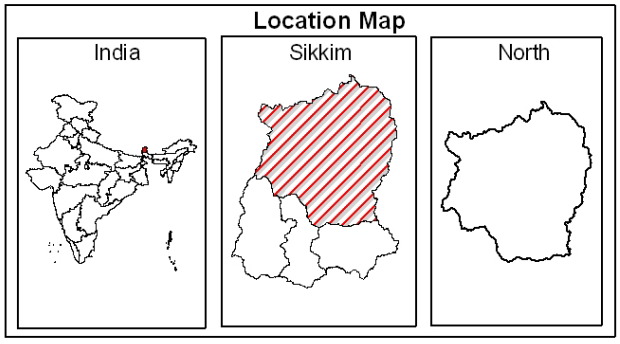
Elevation Range (m)

- up to 3000
- 3000 - 4000
- 4000 - 5000
- > 5000

- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 3 6 12 Kilometers

Location Map

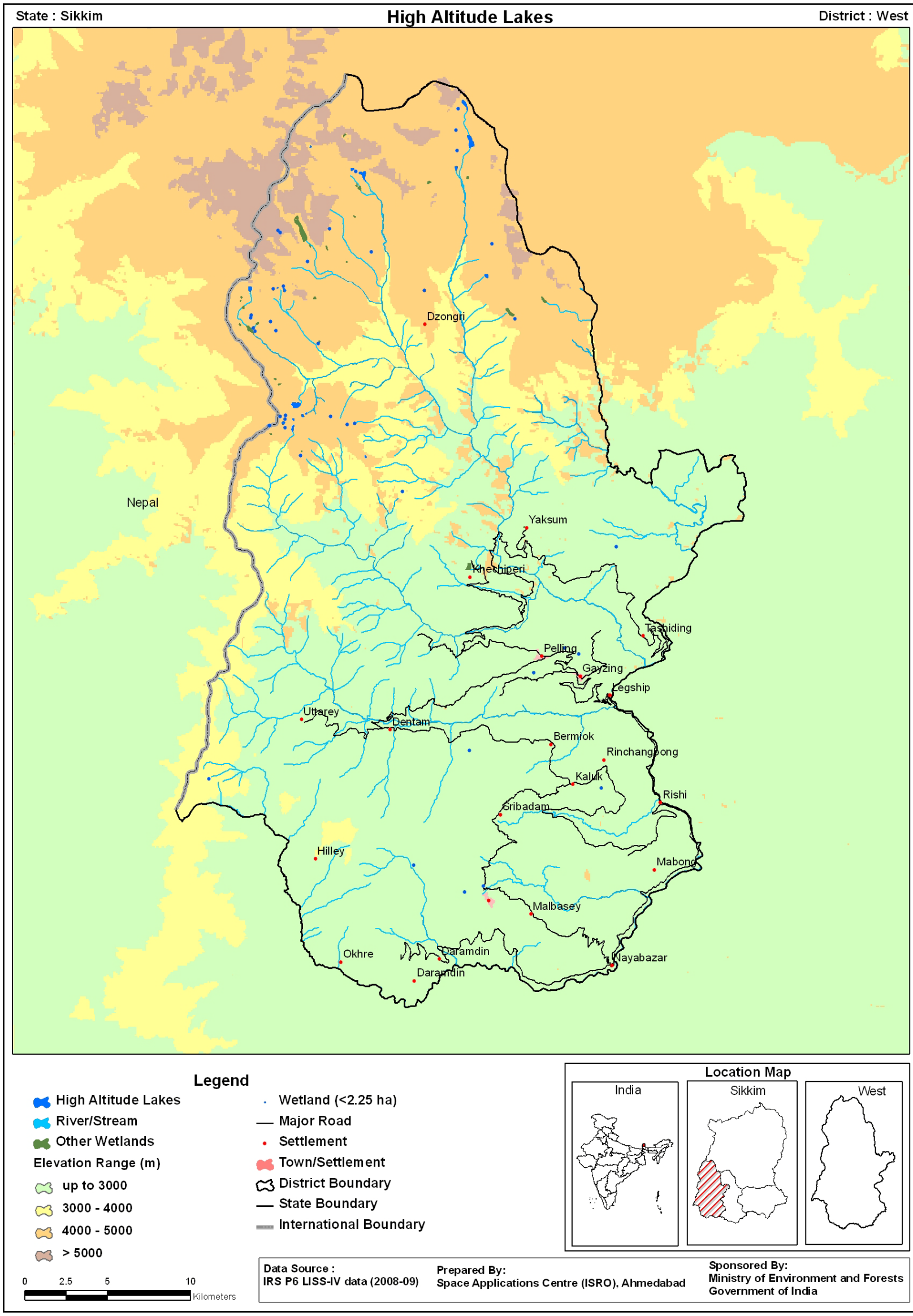


Data Source :
IRS P6 LISS-IV data (2008-09)

Prepared By:
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

Map-33: High altitude lakes of North district



Map-34: High altitude lakes of West district

4.2.5 Arunachal Pradesh

Arunachal Pradesh is the easternmost state of Indian Himalaya. It lies between 26^0 37' to 29^0 28' N latitude and 91^0 32' E to 97^0 26' E longitude and with geographical area of 81,424 sq km. Much of the state fall in the Himalaya. However, parts of Lohit, Changlang and Tirap are covered by the Patkai hills. The state has 13 districts (Fig.-51). Areas of very high elevation prevailing in the Upper Himalayas close to the Tibetan border has alpine or tundra climate, which harbours numerous high altitude lakes. Most of the high altitude lakes in this state are of very small size. The lakes and its catchment harbour a rich biodiversity. However, very little information is known as most of them are unexplored due to the tough terrain.

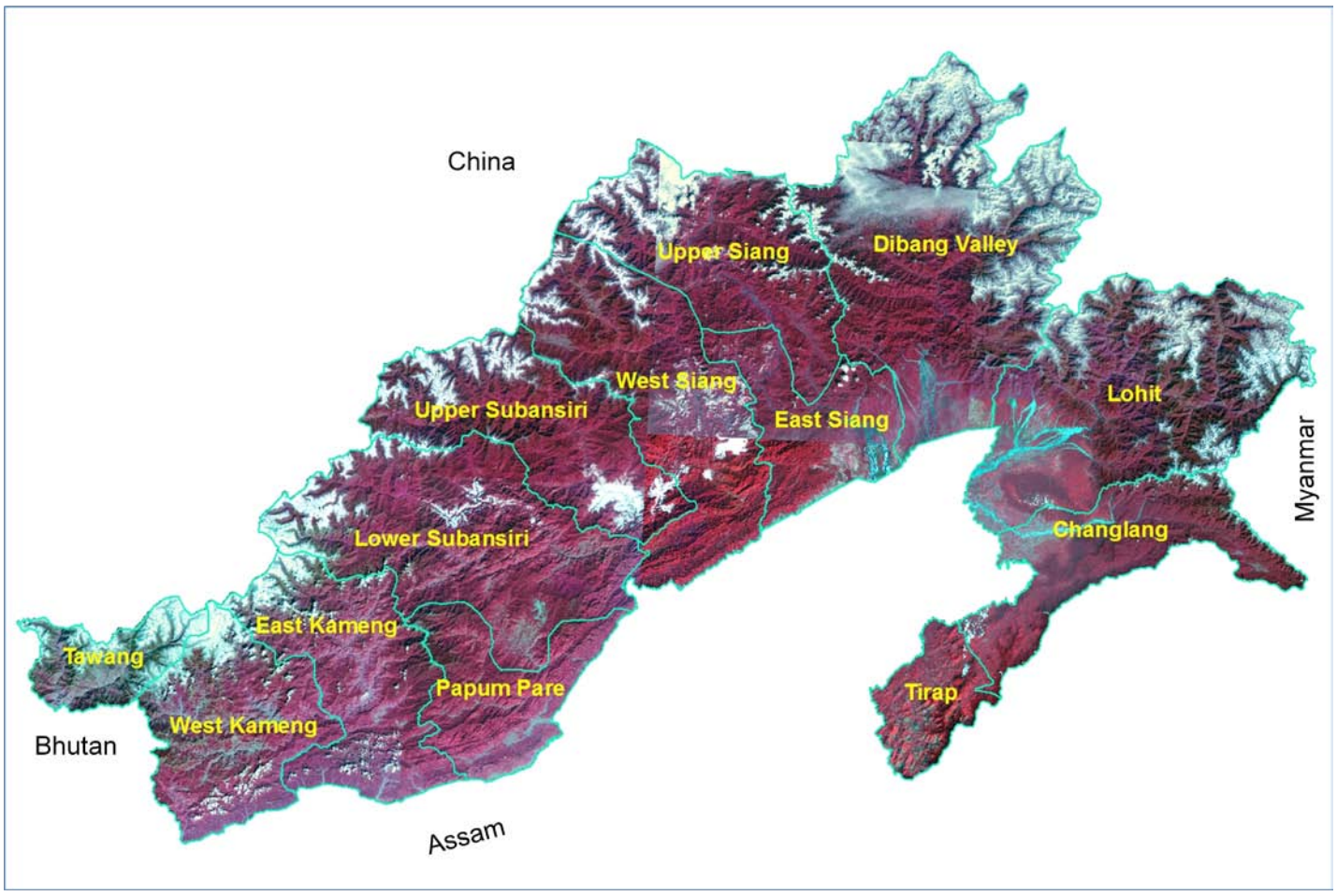


Fig.-51: Arunachal Pradesh as seen in IRS LISS III FCC (district boundaries shown in cyan line)

Total 1672 HALs have been delineated. The total area under these lakes is 11864 ha. Maximum number of lakes are of small size (<10 ha). Only 3 lakes having an area of 100-500 ha (Table-26). Altitudinal distribution pattern shows concentration of lakes in 4000-5000 m elevation range. (Table-27). Only 20 lakes are observed in the altitudinal range of >5000 m. The distribution pattern of high altitude lakes in the state with respect to altitude range is shown in Fig.-52 and Map-35.

Table-26: Size-wise distribution of high altitude lakes in Arunachal Pradesh

Sr. No.	Class	Range	No. of lakes	Area (ha)
1	Very Large	> 500 ha	-	-
2	Large	100-500 ha	3	372
3	Medium	25-100 ha	77	3117
4	Small	10-25 ha	252	3937
5	Very Small	2.25-10 ha	899	3997
6	< 2.25 ha	< 2.25 ha	441	441*
Total			**1672**	**11864**

* *Nominal assignment*

Table-27: Altitude-wise distribution of high altitude lakes in Arunachal Pradesh

Sr. No.	Category	Altitude range (m)	No. of lakes	Area (ha)
1.	High Altitude	3000-4000	790	5189
2.	Higher Altitude	4000-5000	862	6621
3.	Very high Altitude	>5000	20	54
Total			**1672**	**11864**

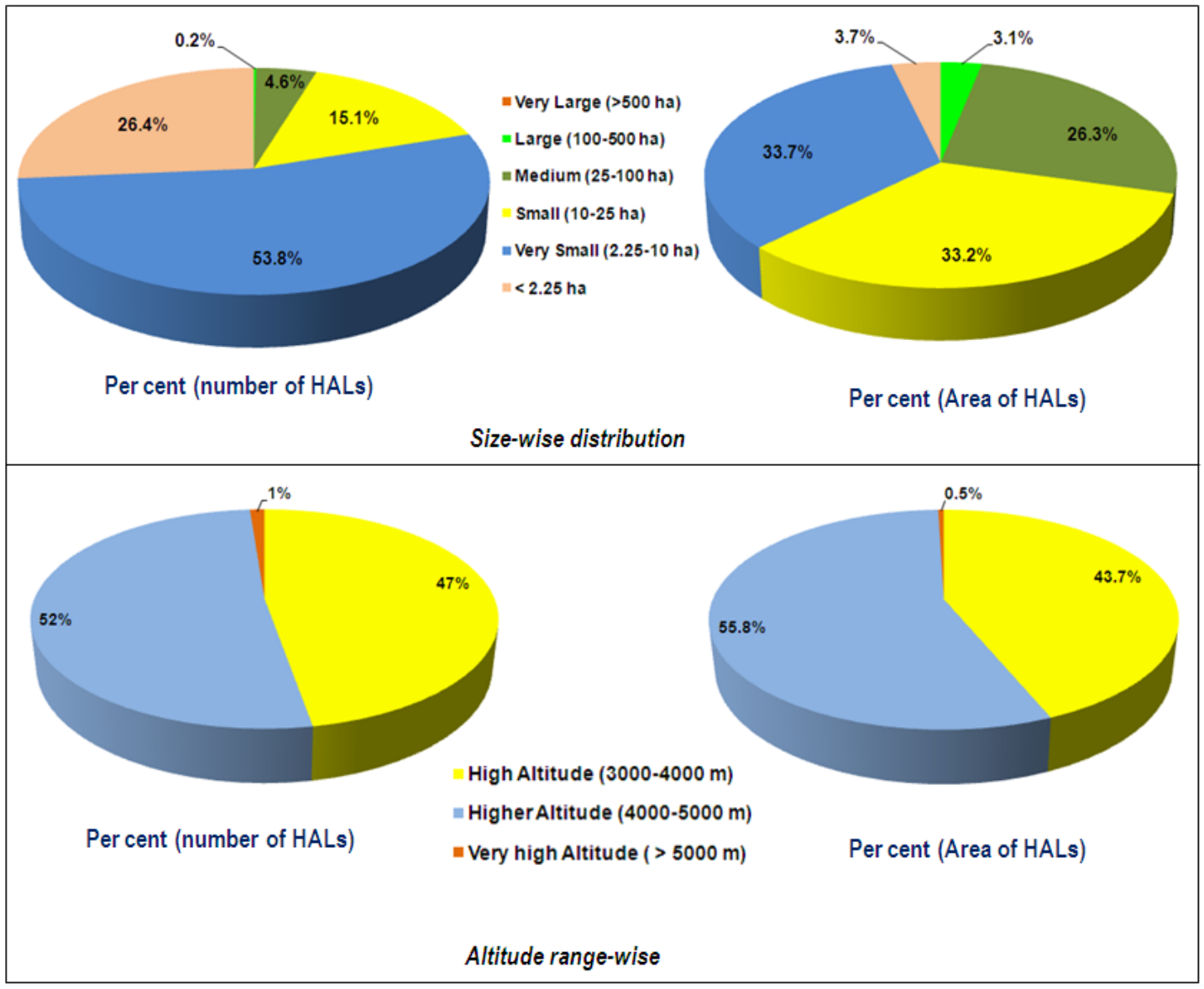


Fig.-52: *Size-wise and altitude range-wise distribution of high altitude lakes in Arunachal Pradesh*

The high altitude lakes in this state occur as a cluster known as Wetland complexes. Bhagajang Nagula, Thembang Bapu CCA and Pangchen Lumpo are important wetland complexes located above 3000m altitude. As per the survey carried out by WWF, India, these complexes harbour number of high altitude lake and act as reservoir for the three major rivers – Tawangchu, Nyamjangchu and Kameng River, which are important tributaries of Brahmaputra. The complexes support rich diversity of Rhododendrons and rare medicinal and habitat for rare and threatened high altitude fauna like red panda (*Ailurus fulgens*), takin (*Budorcas taxicolor*), Chinese goral (*Nemorhaedus griseus*), red goral (*Naemorhedus baileyi*), wild dog (*Cuon alpinus*), snow leopard (*Panthera uncia*), musk deer (*Moschus chrysogaster*) etc.

The Sela pass area is the region is dotted with hundreds of HALs. The Sela Pass is a high-altitude mountain pass located in Tawang district at an elevation of 4170 m. It connects Tawang town to Guwahati. A little beyond the pass are two glacial lakes. The pass and one of the lake is named after the local damsel who helped an Indian soldier in keeping the Chinese at bay for days (Fig.-53)

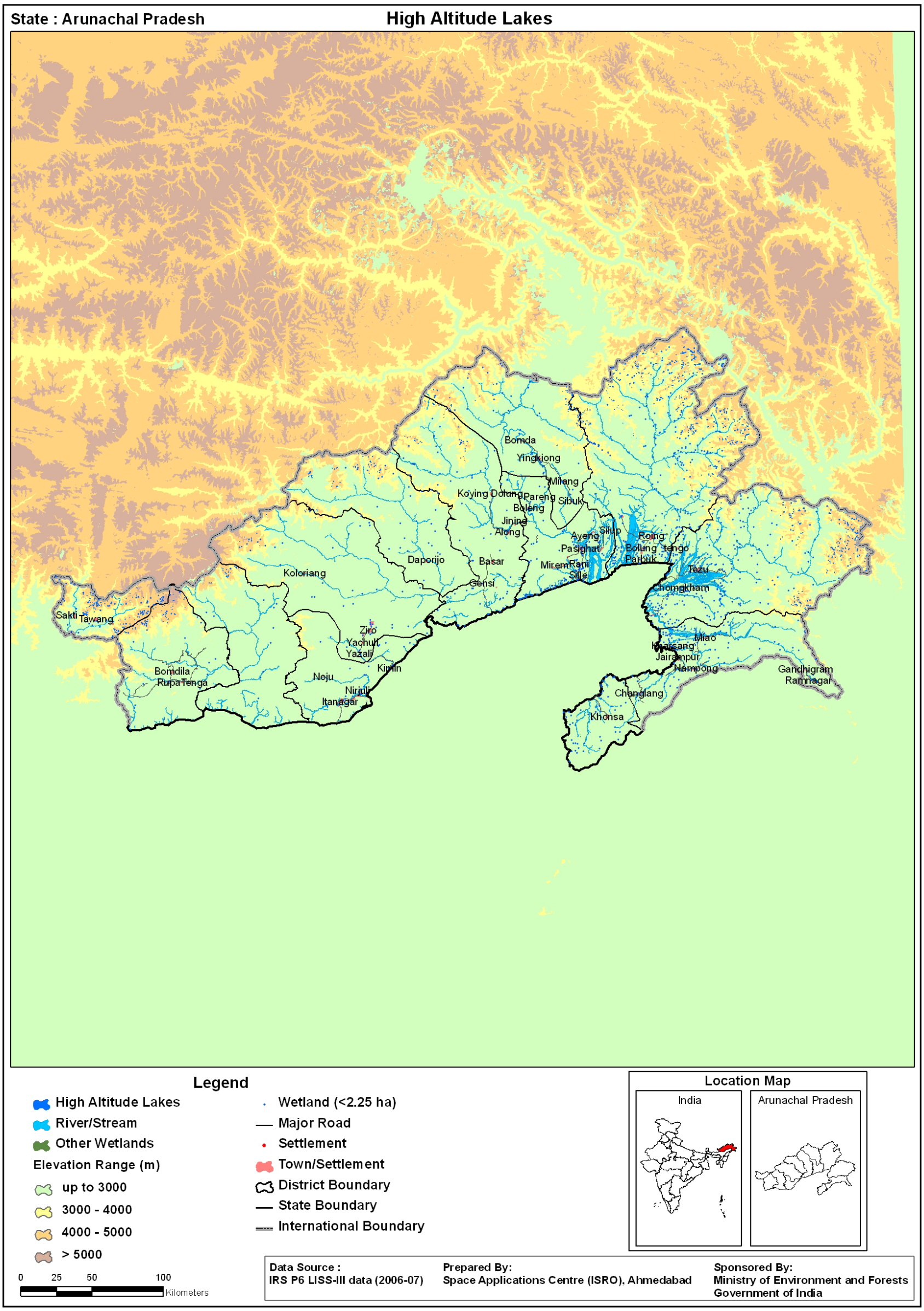
Fig.-53: Sela Lake and its surrounding as seen in satellite image

Nagula wetland complex is situated to the north of the Tawang Township, bordering Tibet. It contains about 100 permanent alpine freshwater lakes located between the altitudes of 3505 m to 4420 m. The lakes are fed by snow melt water. This wetland complex acts as a reservoir for the Nyamjangchu river, an important tributary of the river Manas that drains through Bhutan and Assam. The catchment area is rich in rare medicinal plant species.

The Bhagajang Wetland Complex is located in the southwest part of the Tawang district of Arunachal Pradesh, within the altitudinal range of 4000 - 4400 m amsl. Comprising nearly 20 lakes, this complex supports faunal species listed in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

Some of the other well known small lakes in Western Arunachal are: Sangeeta Lake, at 3658 m altitude is about 30 kilometres North East of Tawang. One can observe dead pine trunks jutting out of the lake. Apparently, the lake has shifted from its original location to pine forested area due to technntonic activity. Tsomgo Ama is located at an altitude of 4535 m, West Kameng district. Penga Teng Tso or PT Tso as it is locally known, at around 3658 m feet situated around 23 km from city of Tawang , Tsokio Tso and Gombulake are some of well known small high altitude lakes of the state (Fig.-54).

Fig.-54: Some of the well known high altitude lakes of very small size in Arunachal Pradesh mapped as point features



Map-35: Distribution of high altitude lakes in Arunachal Pradesh with respect to elevation range

District-wise analysis

The state has thirteen districts. District-wise analysis shows that high altitude lakes are located in 10 districts. Dibang, Lohit and Tawang are the major high altitude lake districts. Tawang and West Kamang are the only two districts having HALs in the altitudinal range of >5000 m. Dibang has highest number of lakes in the altitudinal range of 3000-4000 and 4000-5000 m. Dibang also harbors all the 3 large lakes of 100-500 ha size.

The altitudinal range-wise and size-wise distribution of high altitude lakes in each district of the state is shown in Table-28 and 29 respectively. District level maps are shown from Map- 36 to 47.

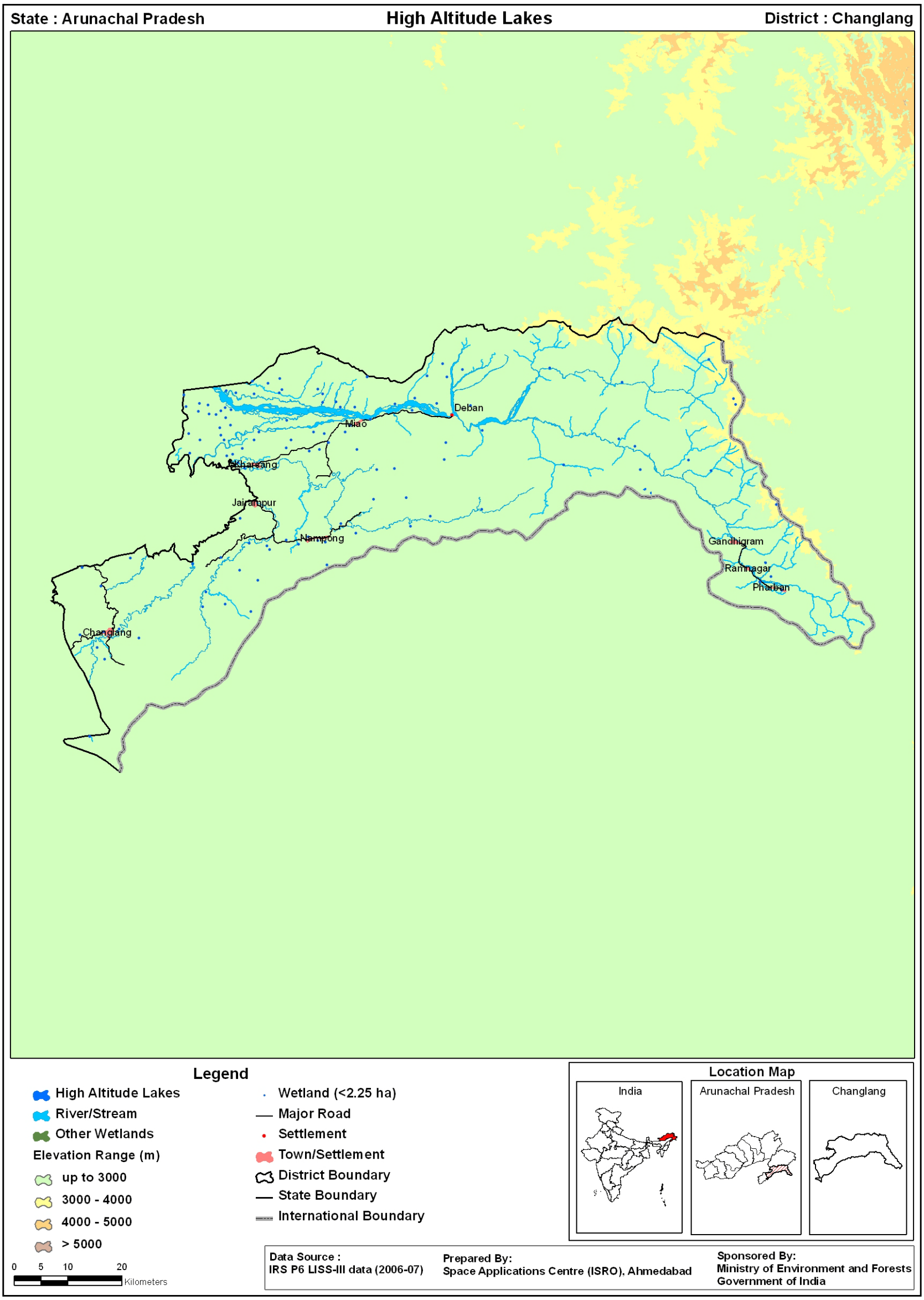
Table-28: Altitudinal range-wise distribution of high altitude lakes in each district of Arunachal Pradesh

Sr. No.	District	High Altitude (3000-4000m)		Higher Altitude (4000-5000m)		Very High Altitude (>5000m)		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)
1	Changlang	19	34	-	-	-	-	19	34
2	Dibang Valley	388	2855	231	2612	-	-	619	5467
3	East Kameng	10	78	24	144	-	-	34	222
4	Lohit	171	1166	175	1564	-	-	346	2730
5	Lower Subansiri	19	47	29	211	-	-	48	258
6	Tawang	18	36	223	1076	12	27	253	1139
7	Upper Siang	79	482	22	119	-	-	101	601
8	Upper Subansiri	39	290	28	301	-	-	67	591
9	West Kameng	6	15	92	389	8	27	106	431
10	West Siang	41	186	38	205	-	-	79	391
	Total	**790**	**5189**	**862**	**6621**	**20**	**54**	**1672**	**11864**

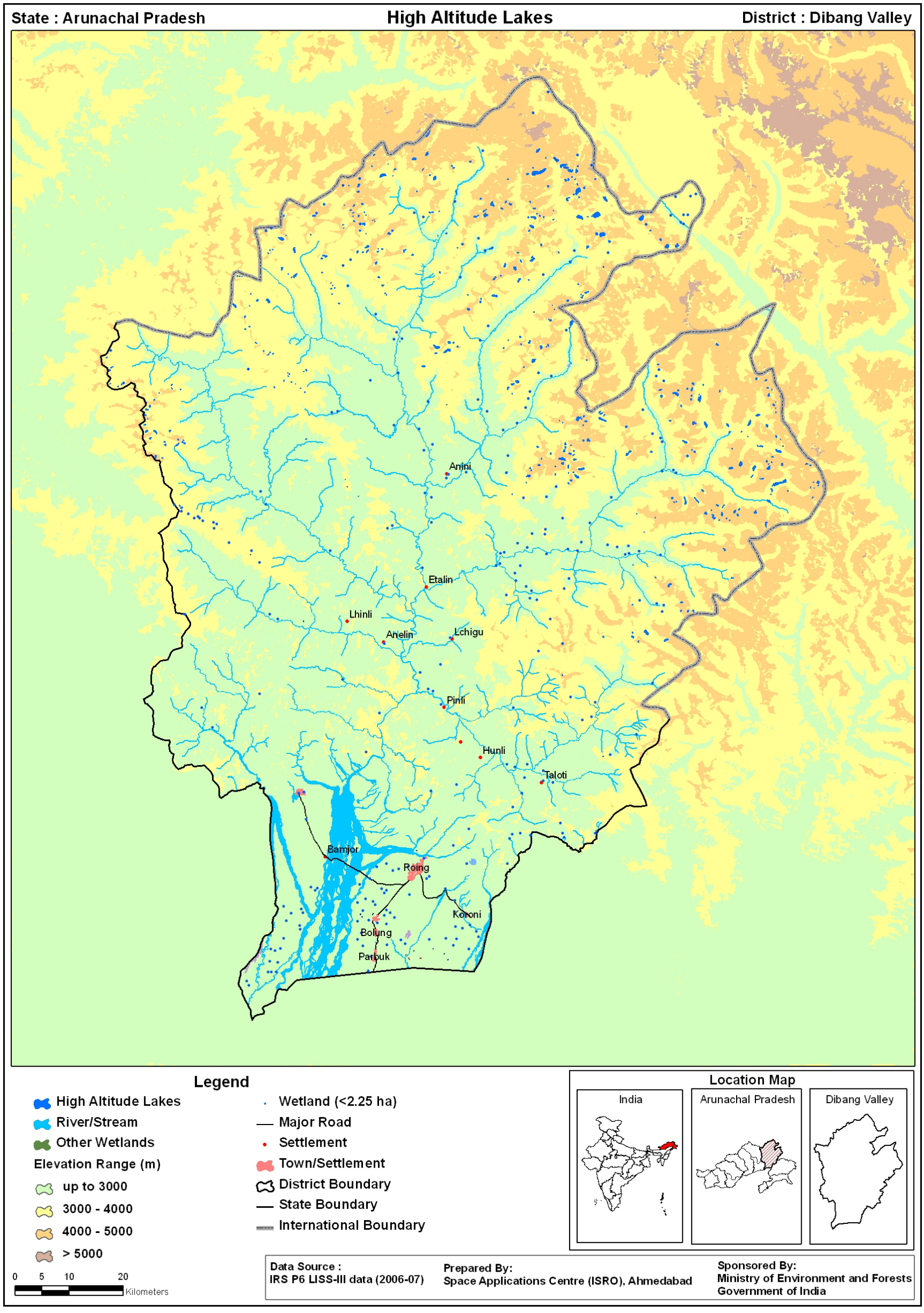
Table-29: Size-wise distribution of high altitude lakes in each district of Arunachal Pradesh

Sr. No.	District	Very Large (> 500 ha)		Large (100-500 ha)		Medium (25-100 ha)		Small (10-25 ha)		Very Small (<10 ha)		<2.25 ha		Total	
		No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area (ha)	No. of lakes	Area* (ha)	No. of lakes	Area (ha)
1	Changlang	-	-	-	-	-	-	1	11	2	7	16	16	19	34
2	Dibang Valley	-	-	3	372	47	1872	103	1660	290	1387	176	176	619	5467
3	East Kameng	-	-	-	-	1	37	4	55	22	123	7	7	34	222
4	Lohit	-	-	-	-	18	716	74	1130	164	794	90	90	346	2730
5	Lower Subansiri	-	-	-	-	1	54	5	89	25	98	17	17	48	258
6	Tawang	-	-	-	-	5	233	13	189	180	662	55	55	253	1139
7	Upper Siang	-	-	-	-	-	-	21	341	46	226	34	34	101	601
8	Upper Subansiri	-	-	-	-	4	154	16	238	33	185	14	14	67	591
9	West Kameng	-	-	-	-	-	-	8	123	88	298	10	10	106	431
10	West Siang	-	-	-	-	1	51	7	101	49	217	22	22	79	391
	Total	**-**	**-**	**3**	**372**	**77**	**3117**	**252**	**3937**	**899**	**3997**	**441**	**441**	**1672**	**11864**

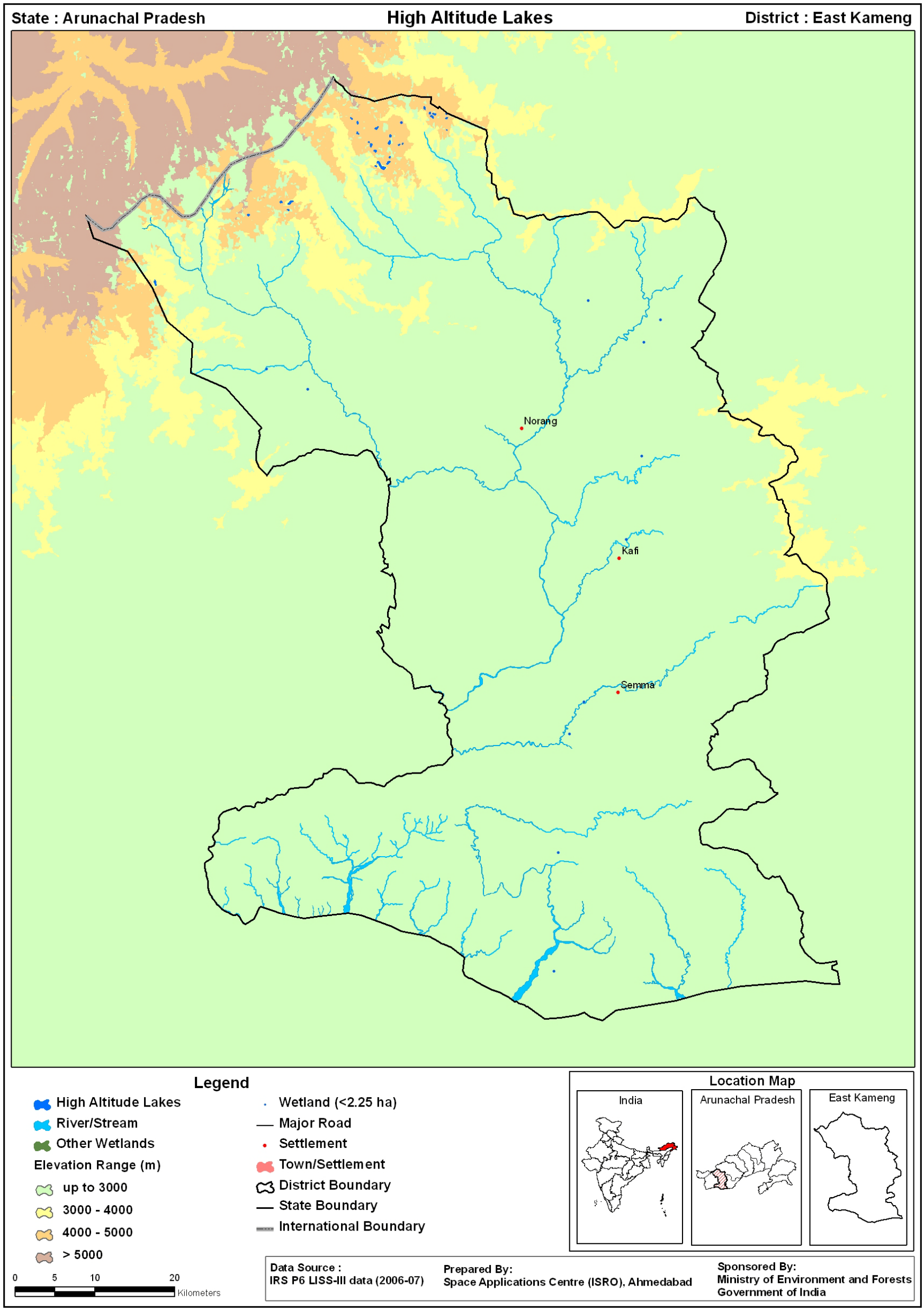
* *Nominal assignment*



Map-36: High altitude lakes of Changlang district



Map-37: High altitude lakes of Dibang Valley district

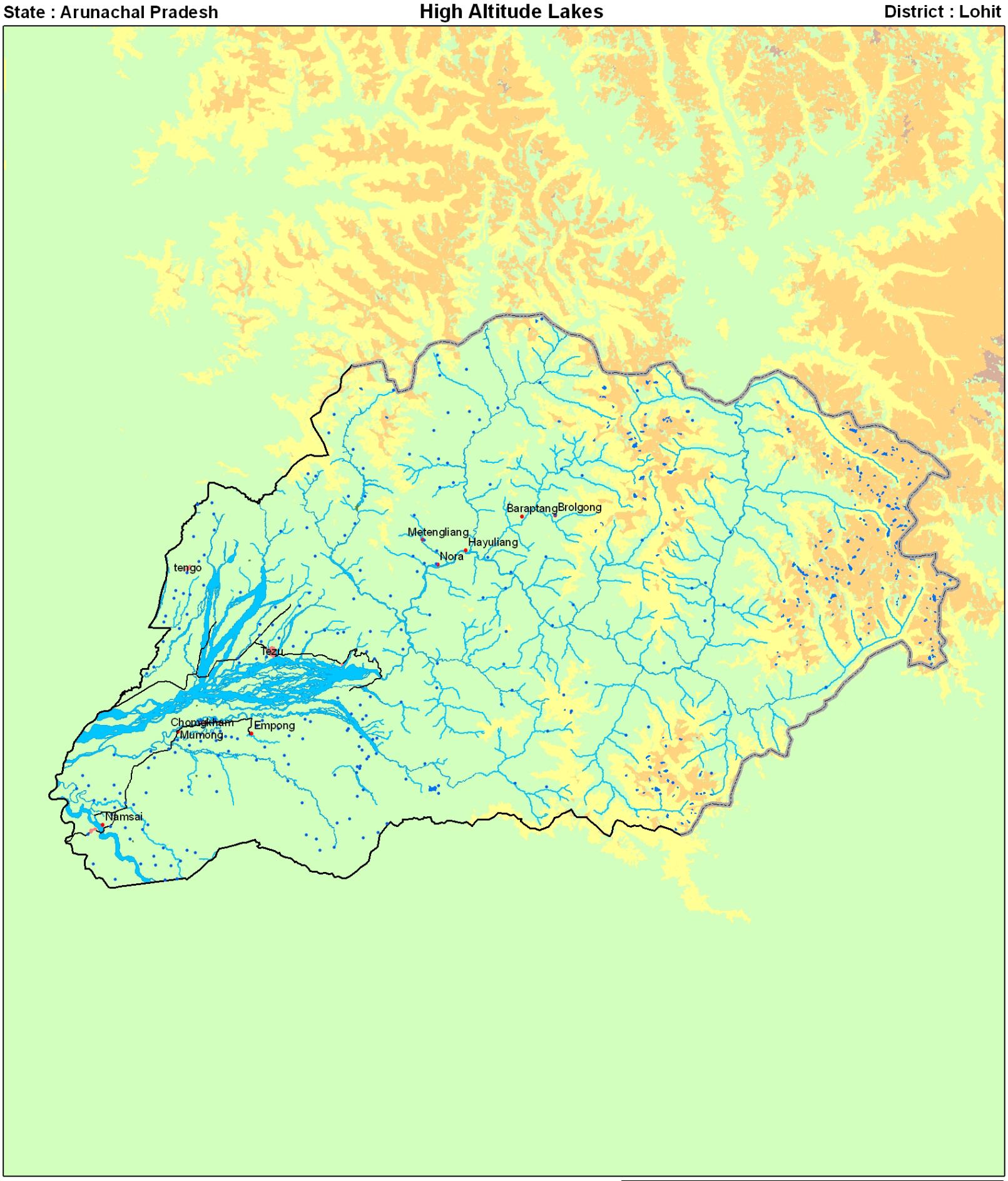


Map-38: High altitude lakes of East Kameng district

State : Arunachal Pradesh

High Altitude Lakes

District : Lohit



Legend

- High Altitude Lakes
- River/Stream
- Other Wetlands

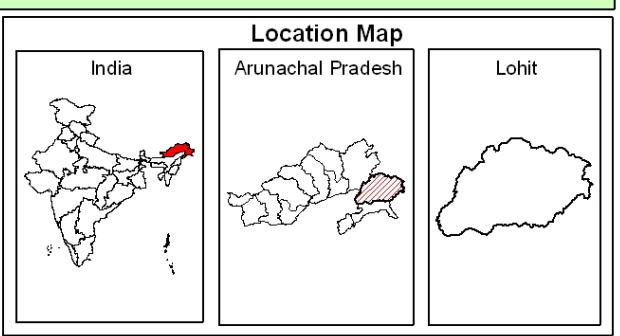
Elevation Range (m)

- up to 3000
- 3000 - 4000
- 4000 - 5000
- > 5000

- Wetland (<2.25 ha)
- Major Road
- Settlement
- Town/Settlement
- District Boundary
- State Boundary
- International Boundary

0 5 10 20 Kilometers

Location Map

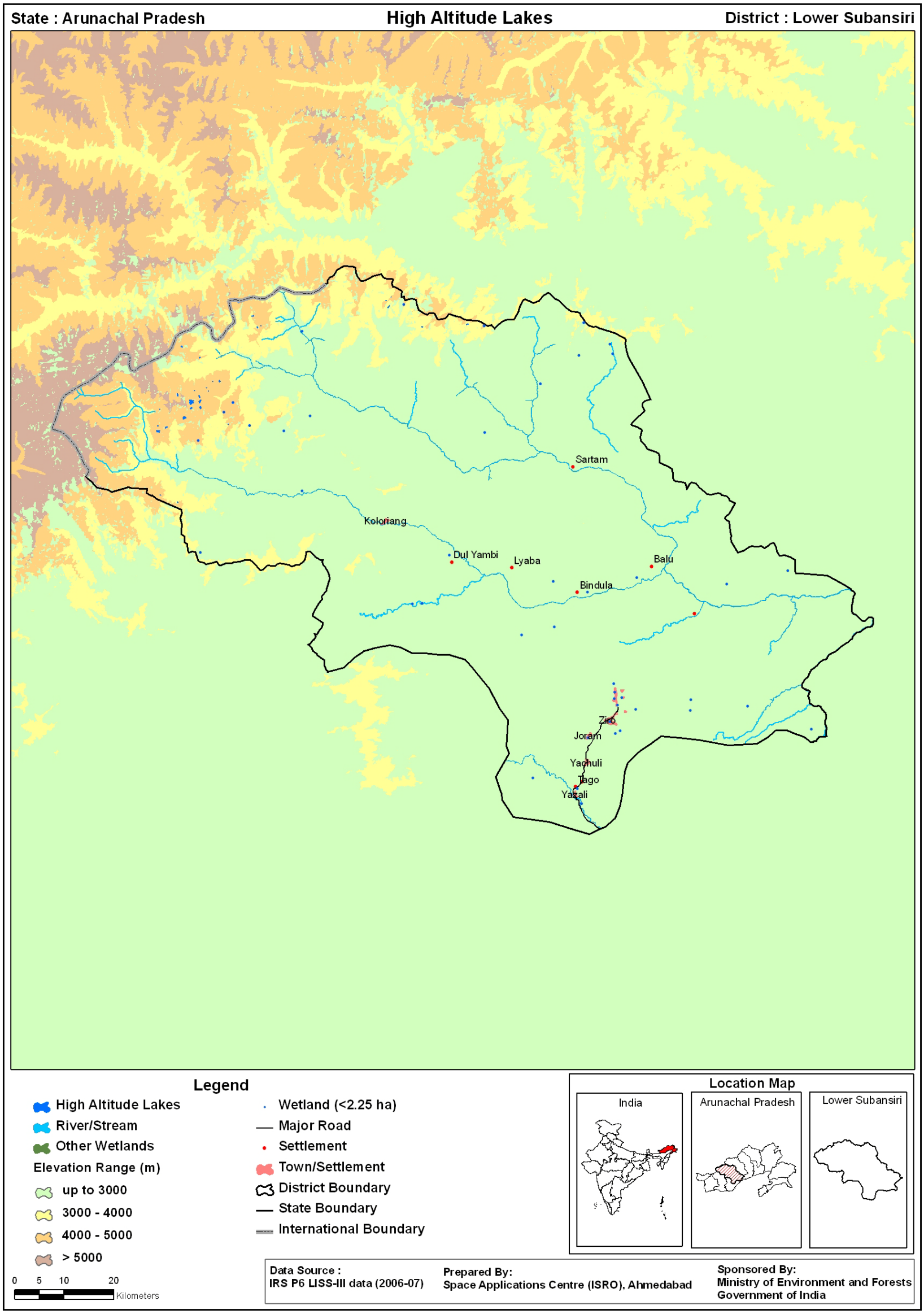


Data Source :
IRS P6 LISS-III data (2006-07)

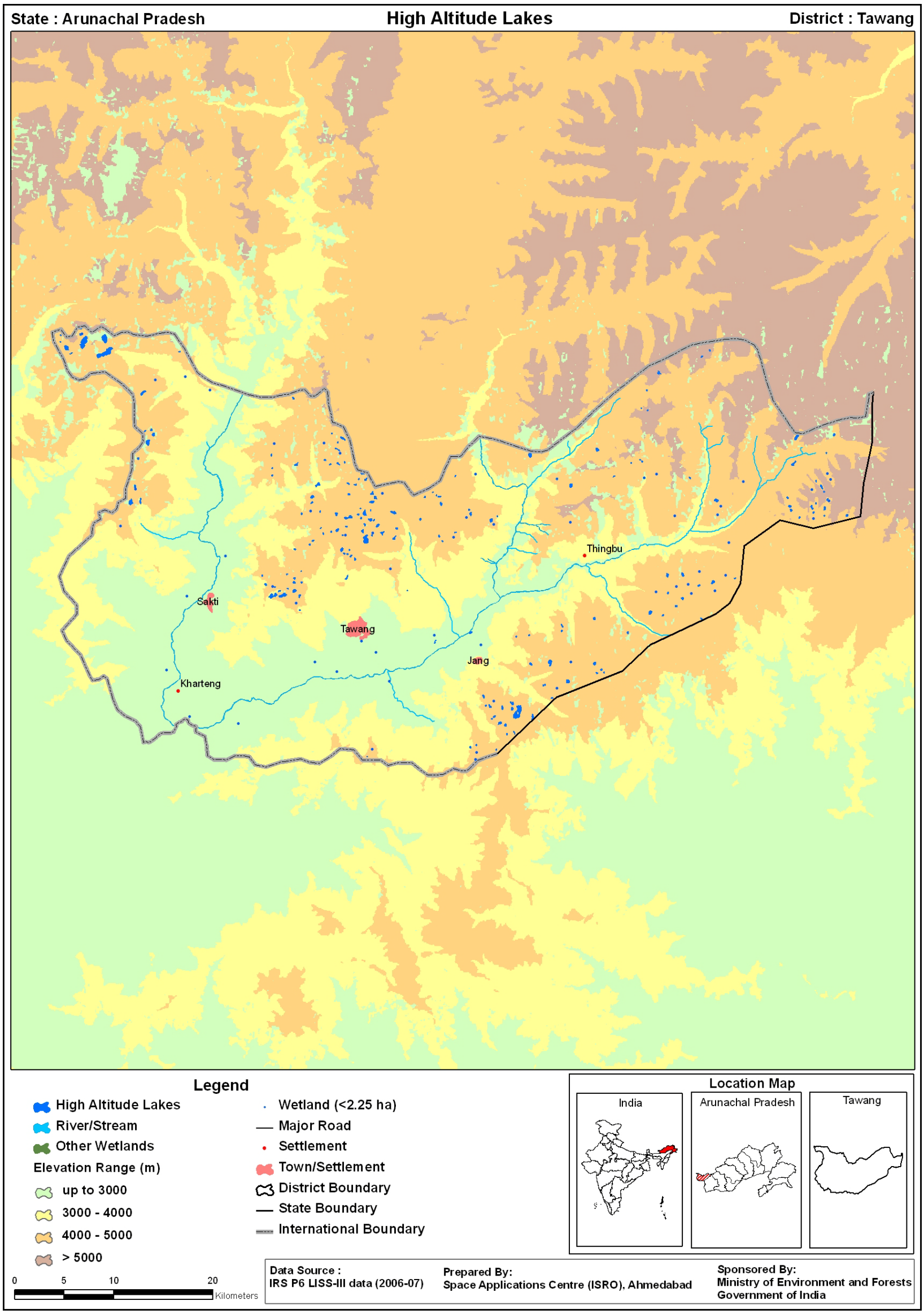
Prepared By:
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

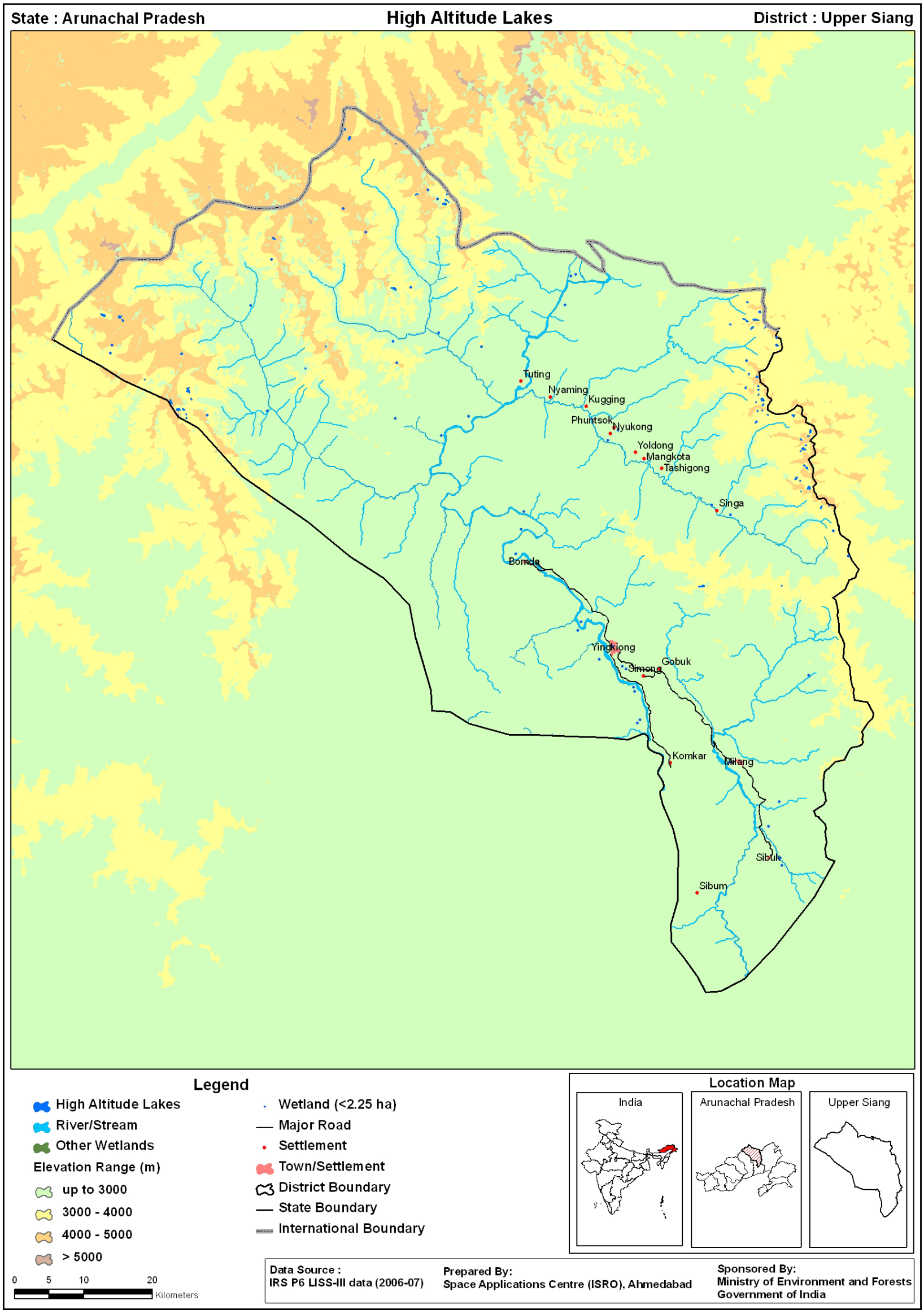
Map-39: High altitude lakes of Lohit district



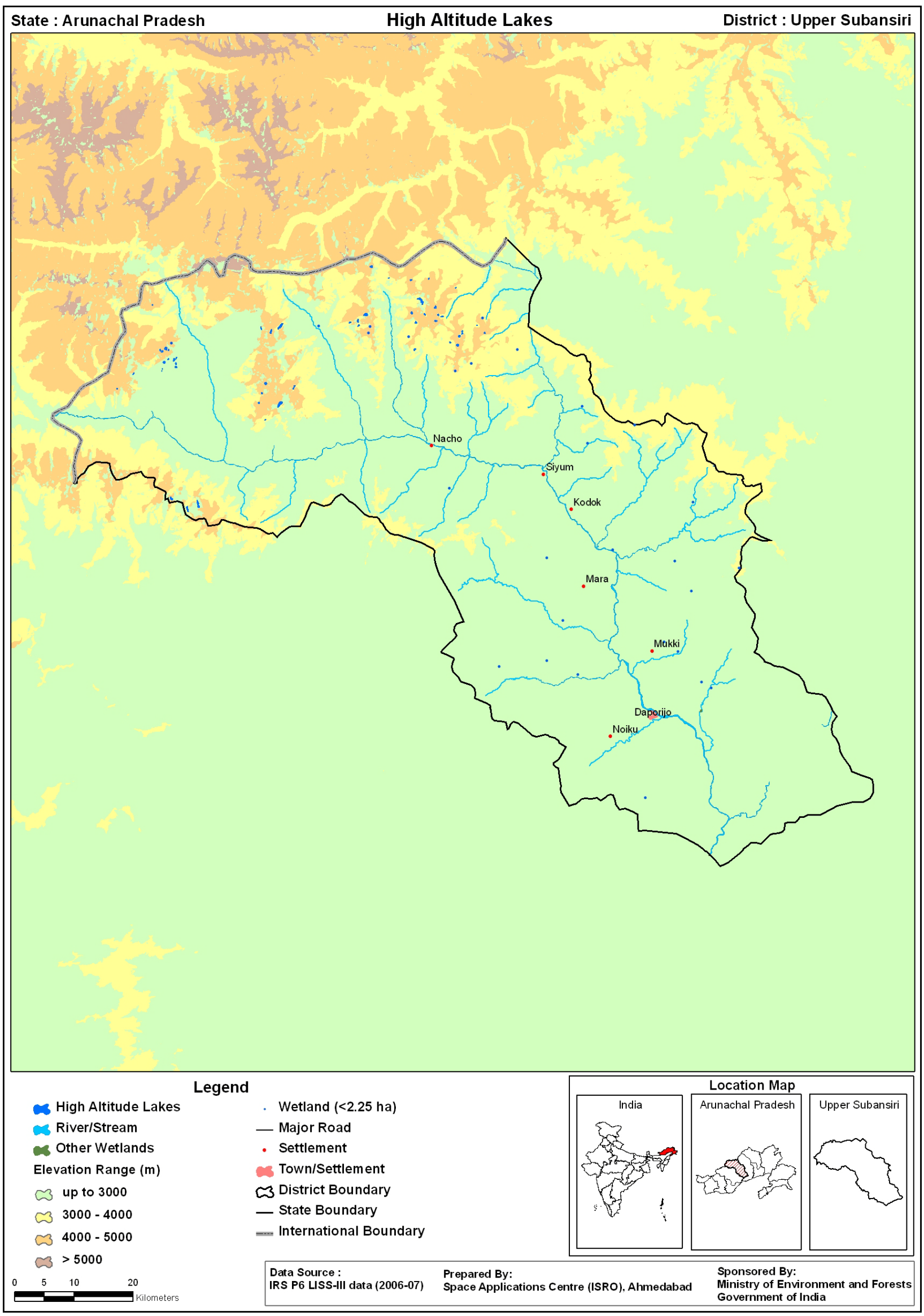
Map-40: High altitude lakes of Lower Subansiri district



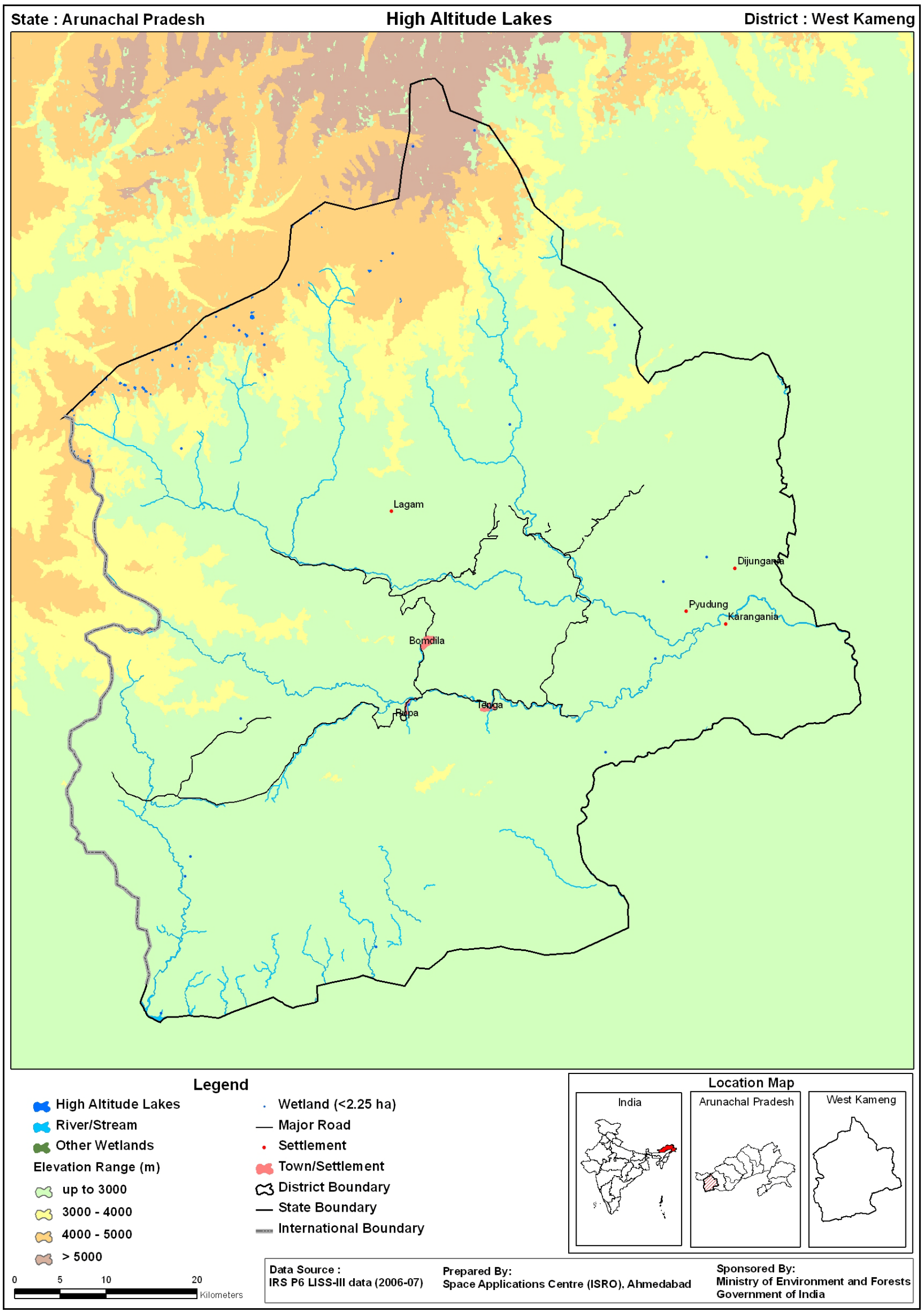
Map-41: High altitude lakes of Tawang district



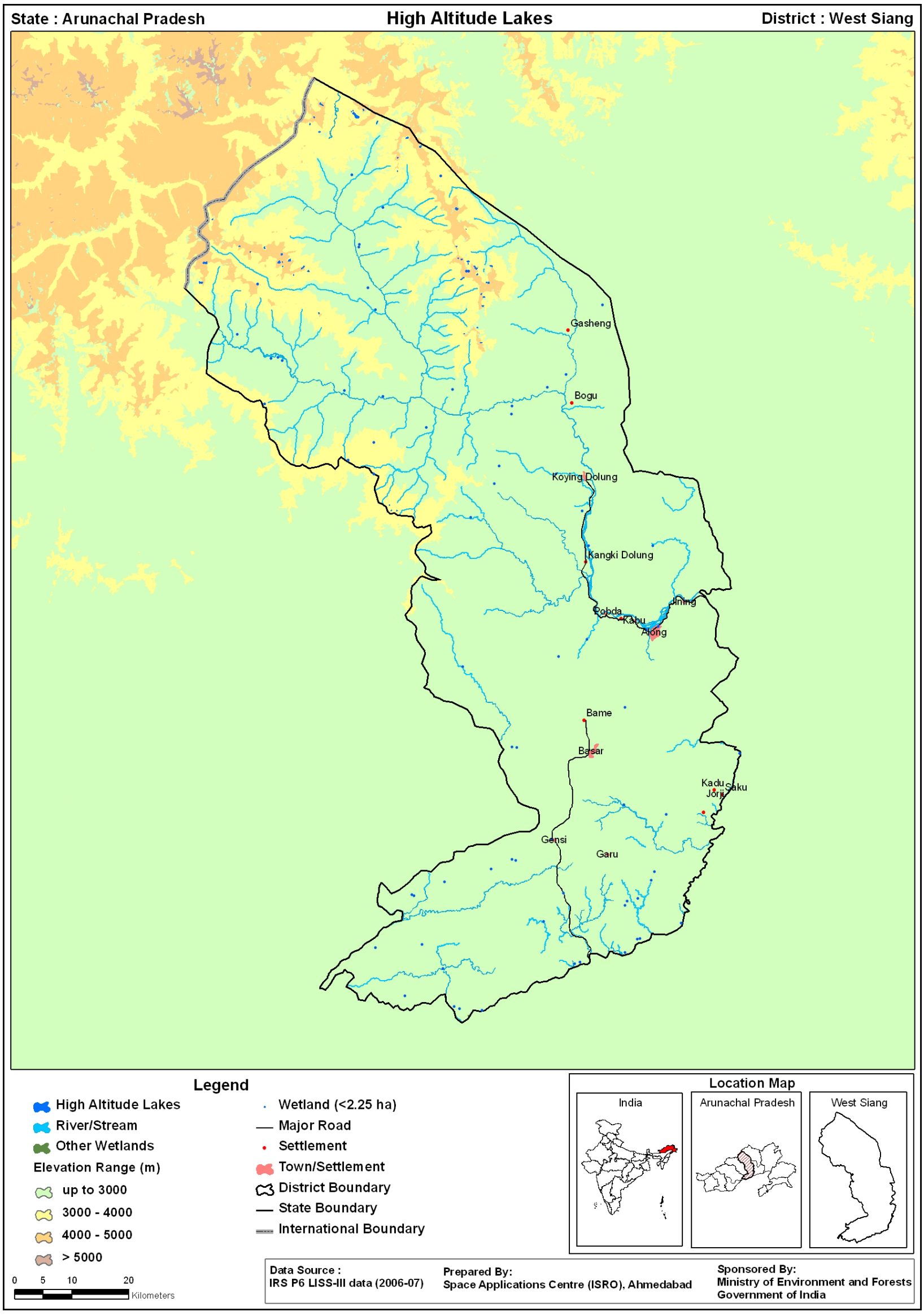
Map-42: High altitude lakes of Upper Siang district



Map-43: High altitude lakes of Upper Subansiri district



Map-44: High altitude lakes of West Kameng district



Map-45: High altitude lakes of West Siang district

Conclusion

The present atlas fills the information void of high altitude lakes in India. The data base is created at topographic map sheet to district, state level and stored in Geographic Information System. Each lake has been given unique identity code along with its geographic coordinates. Thus, the data base will facilitate both updating higher scale as well as monitoring changes in time scale.

One of the finding of this study is the high concentration of small lakes. Mapping at 1:50,000 scale has revealed that around 84 per cent of lakes are of small size of <10 ha area. Around 42 per cent are of lakes are of < 2 ha area , which are mapped as point features, but further details of lake parameters could not be done. Altitudinal analysis of distribution pattern of lakes has shown that most of the small lakes are in the higher altitudinal range above 5000 m. Small lakes prevail in the central and eastern Himalaya. These lakes are mostly glacial lakes (Fig.-55), and of great interest in the context of climate change study**.** Mapping of the small lakes using very high spatial resolution satellite data and modeling through Digital Elevation Model (DEM) need to be taken up. Along with inventory, the present study has acquired some information on lake vegetation, qualitative turbidity of water. Further strengthening of this information needs to be taken up.

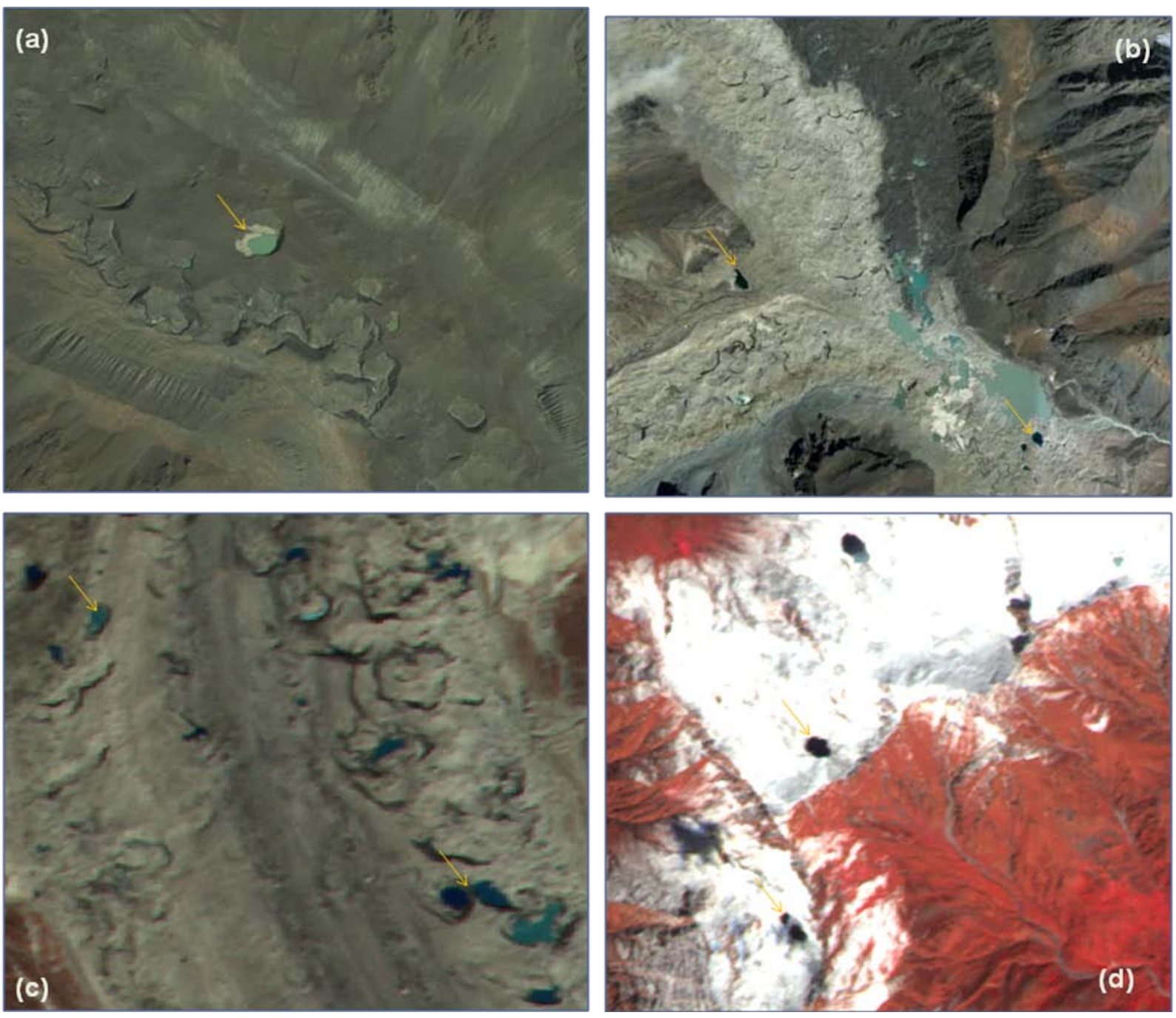


Fig.-55: High resolution satellite images in central Himalayas over part of Uttarakhand: Small lakes of glacial origin (a), small lakes in uttarkashi district (b), cluster of small lakes in northern part of Uttarkashi district and small lakes in part of Chamoli district

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Front cover page : IRS AWiFS image of Tso Moriri lake and surrounding area, Jammu and Kashmir
Back cover page : Photograph of Samiti Lake, Sikkim

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Ahmedabad – 380015
Email: director@sac.isro.gov.in