Semi-Automated Cartographic Techniques to Analyse the Geomorphometric Parameters in High Altitude Glacierised Terrain using SRTM DEM Data

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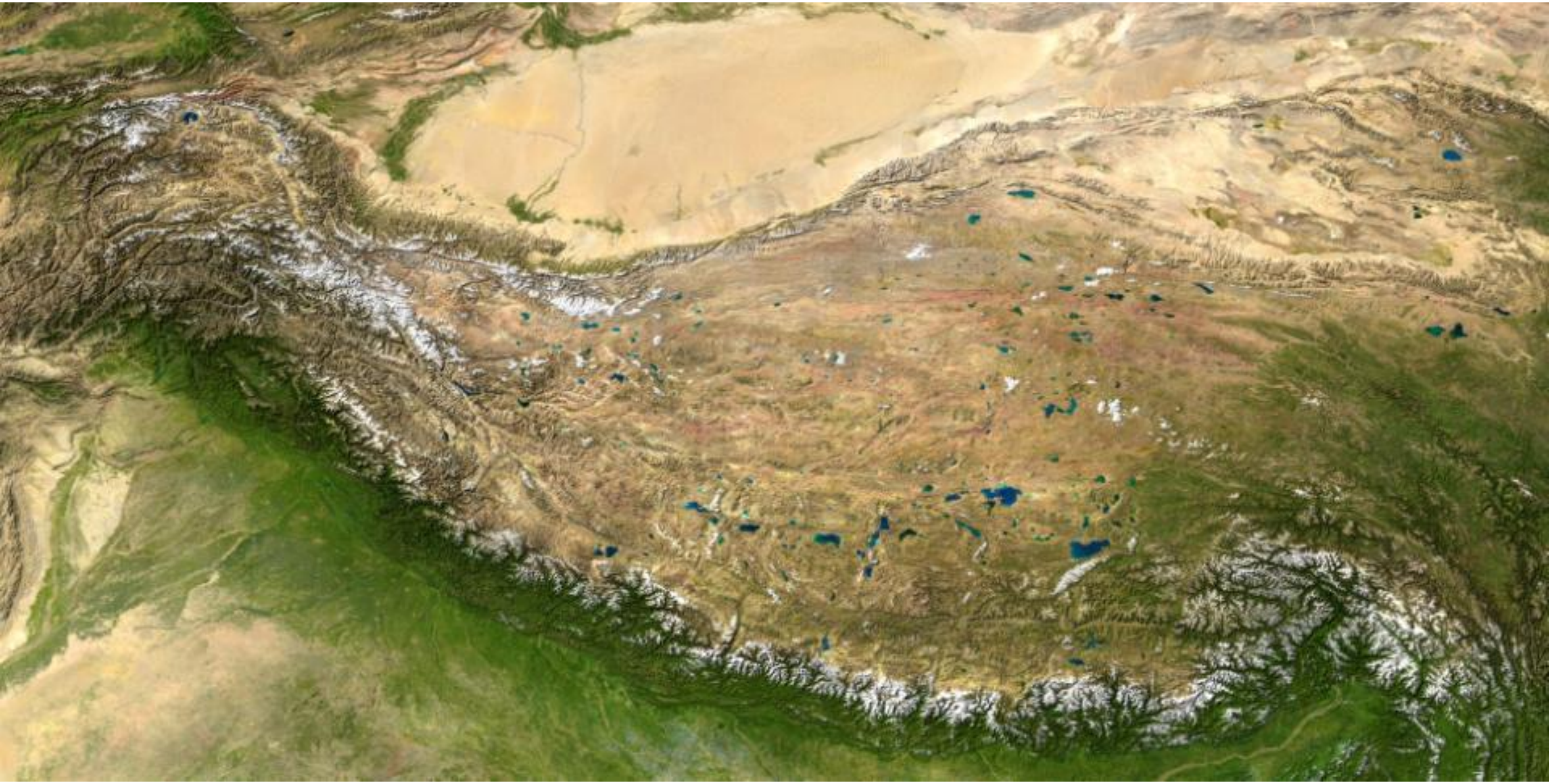
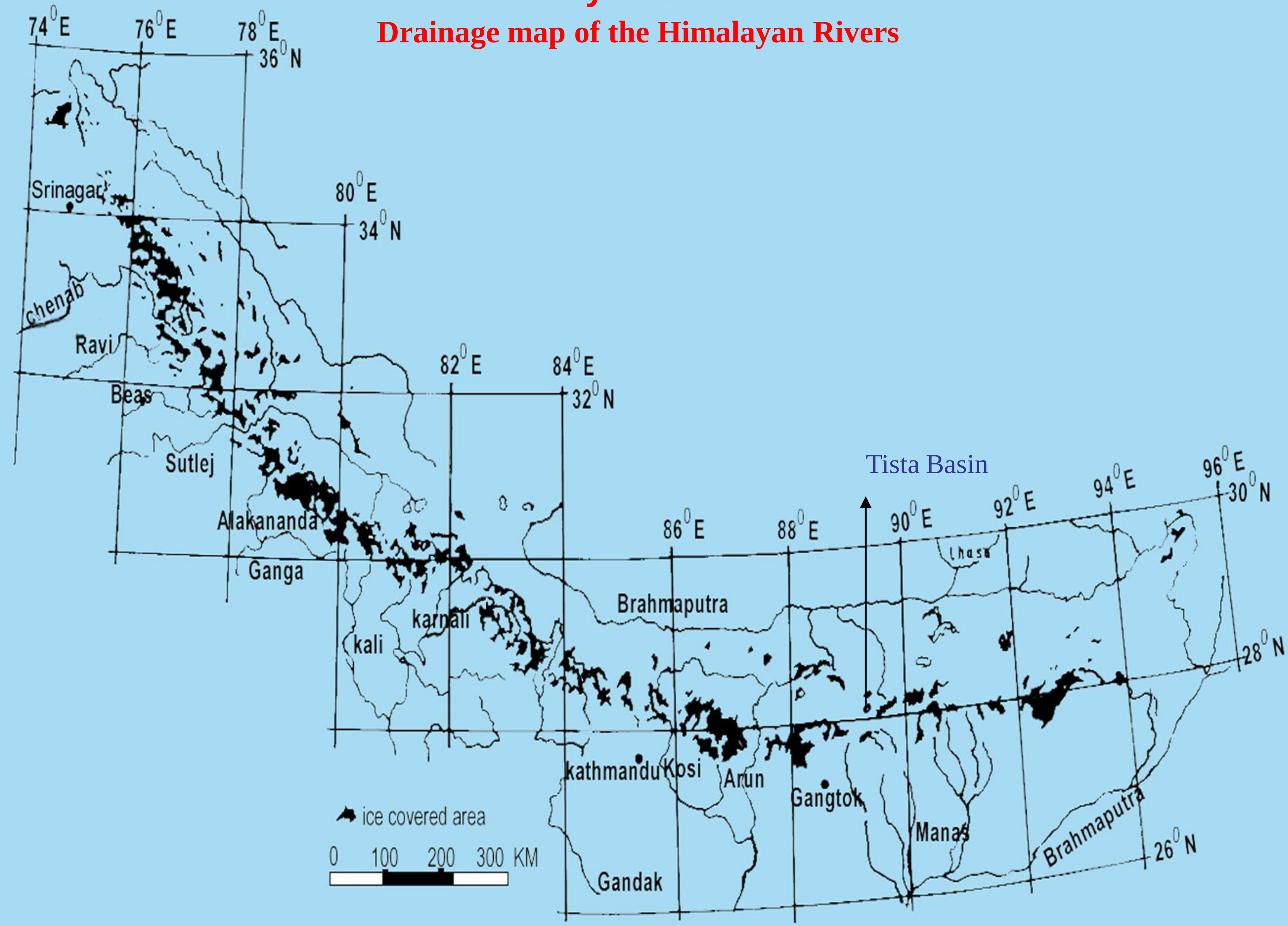
Third Pole



Himalayan Glaciers

Drainage map of the Himalayan Rivers

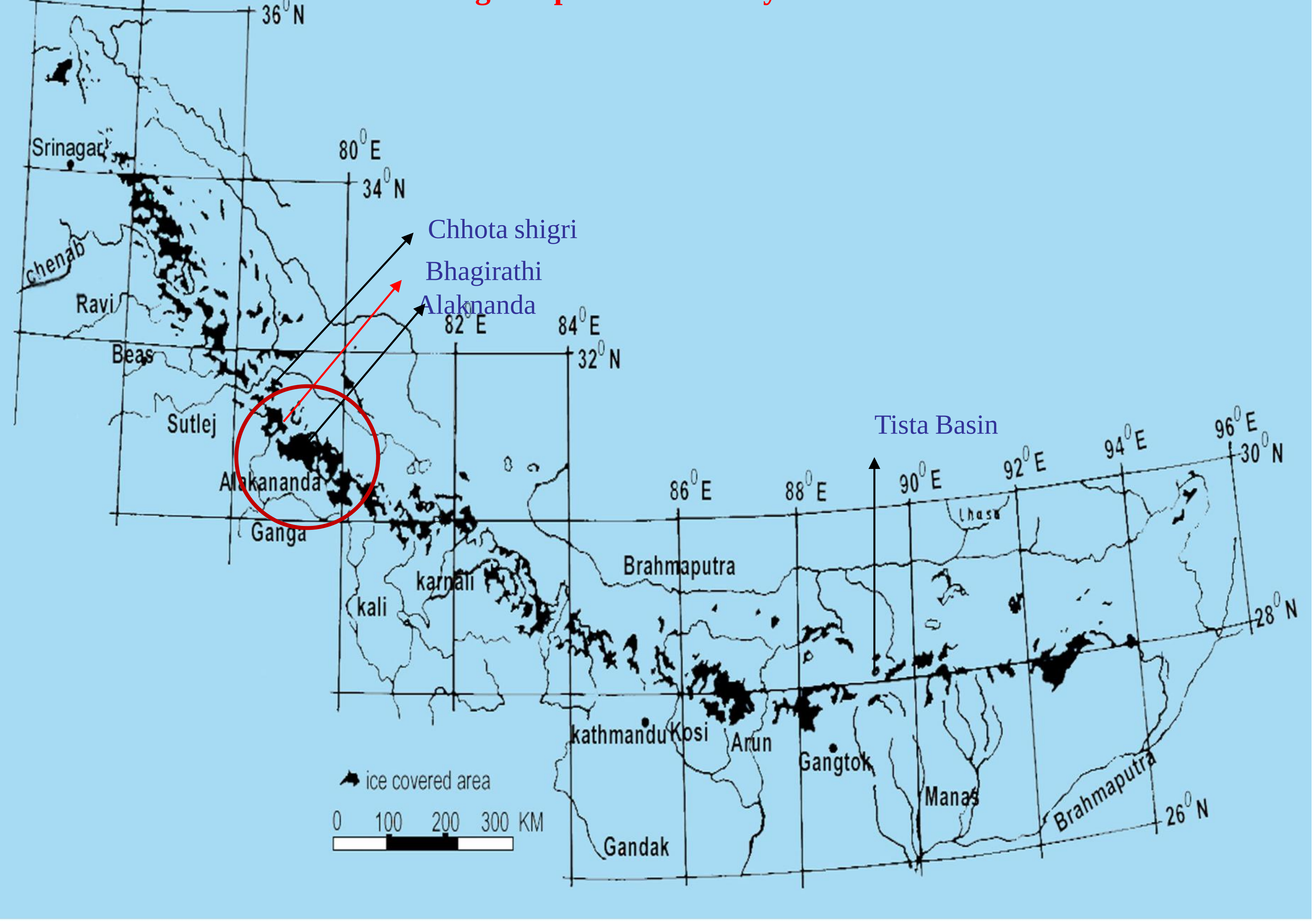


Principal Glacier Fed River System of Himalayas

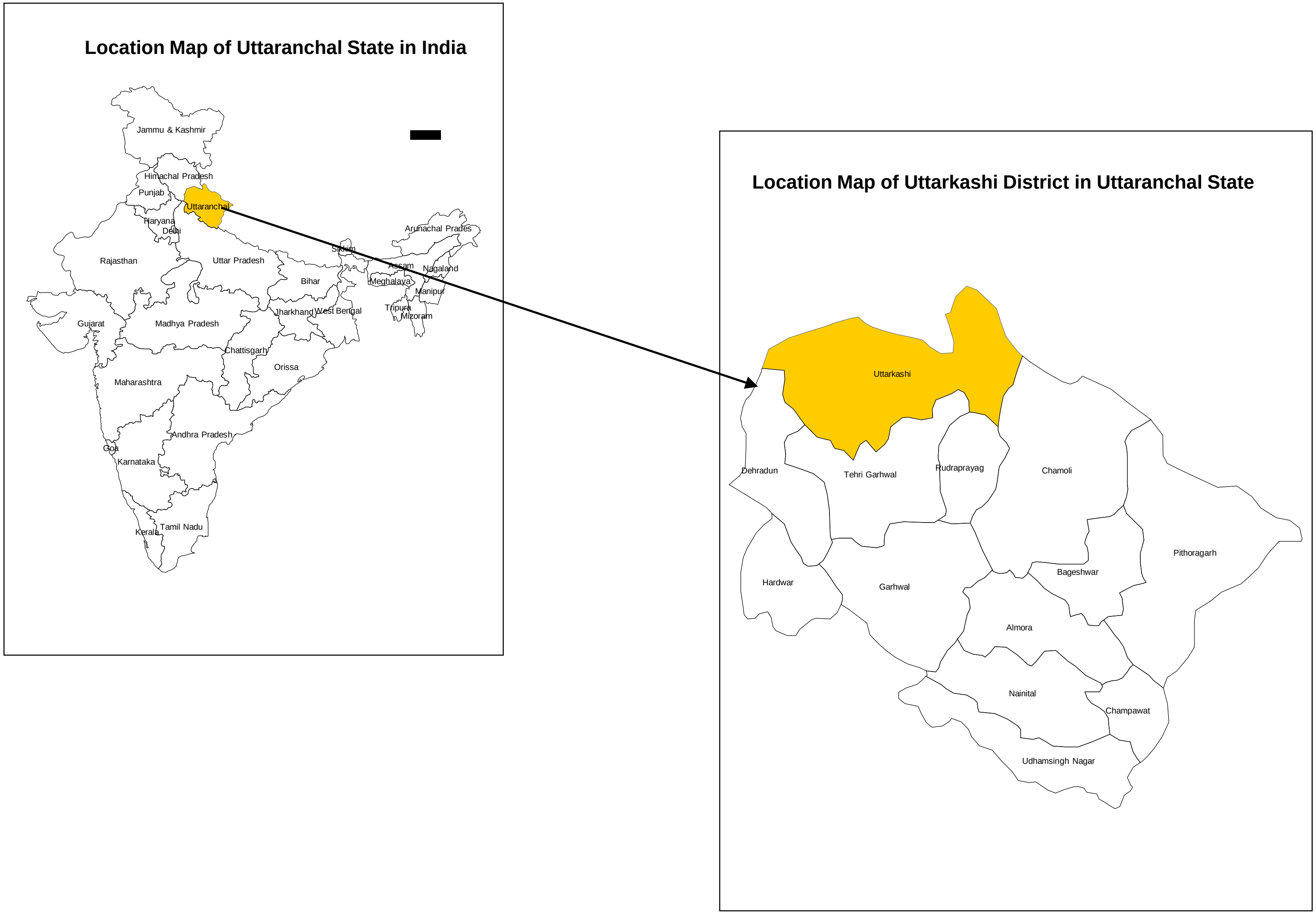
Major river system	Name of river/ tributary	Catchment area (sq. km) covered by		Percentage Glaciation
		Mountains	Glaciers	
Indus		268,482	8,790	3.3
		33,670	170	5.0
		27,195	2,944	10.0
		8,029	206	2.5
		47,915	1,295	2.7
		14,504	638	4.4
Ganga	Yamuna	11,655	125	1.1
		23,051	2,312	10.0
	Ramganga	6,734	3	0.04
	Kali	16,317	997	6.01
	Karnali	53,354	1,543	2.9
	Gandak	37,814	1,845	4.9
Brahmaputra	Kosi	61,901	1,318	2.1
	Tista	12,432	495	4.0
	Raidak	26,418	195	0.7
	Manas	31,080	528	1.7
	Subansiri	18,130	725	4.0
		256,928	1,080	0.4
	Dibang	12,950	90	0.7
	Lohit	20,720	425	2.01
Gross		**10,01,294**	**25,724**	**2.6**

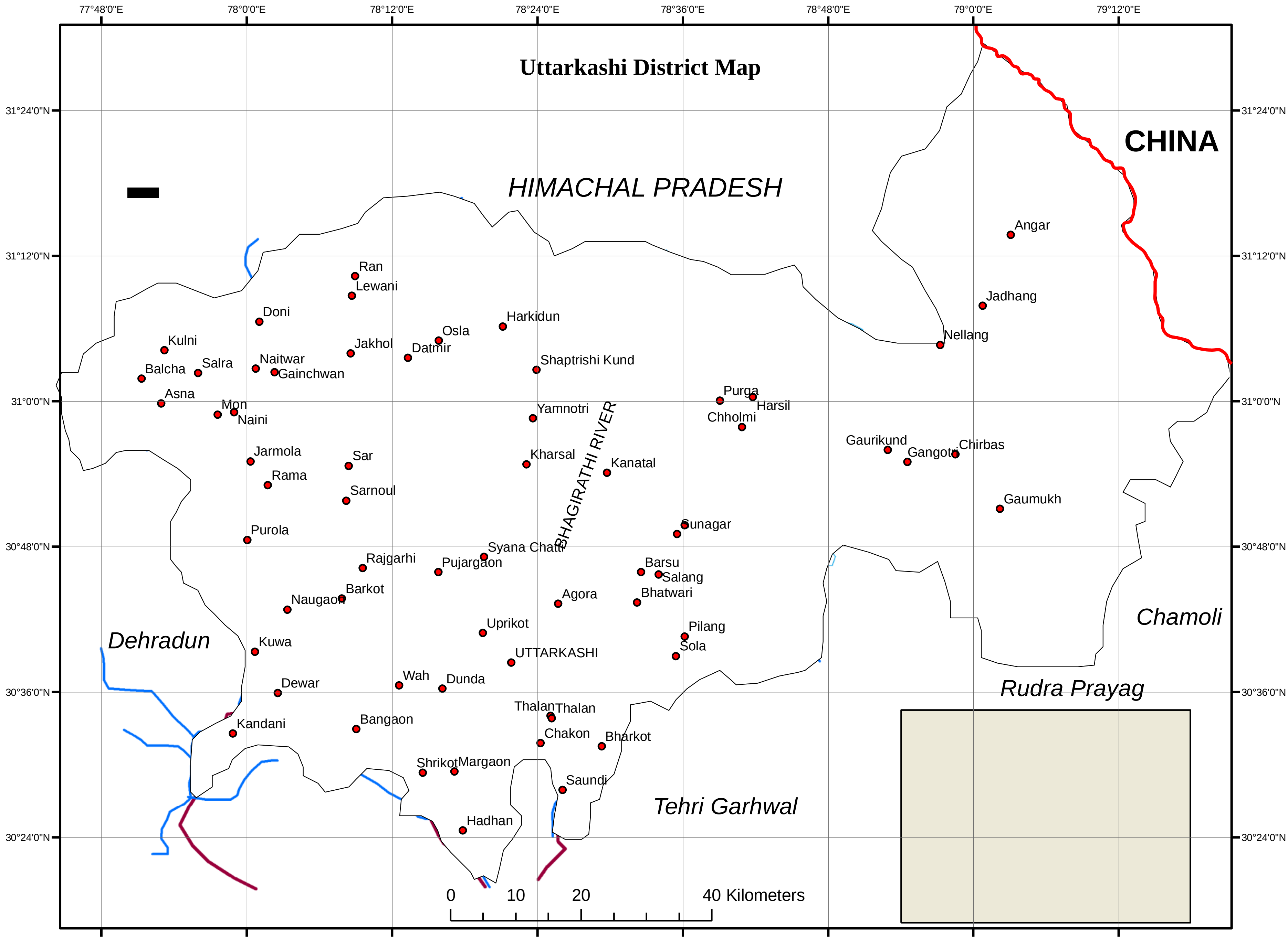
Himalayan Glaciers

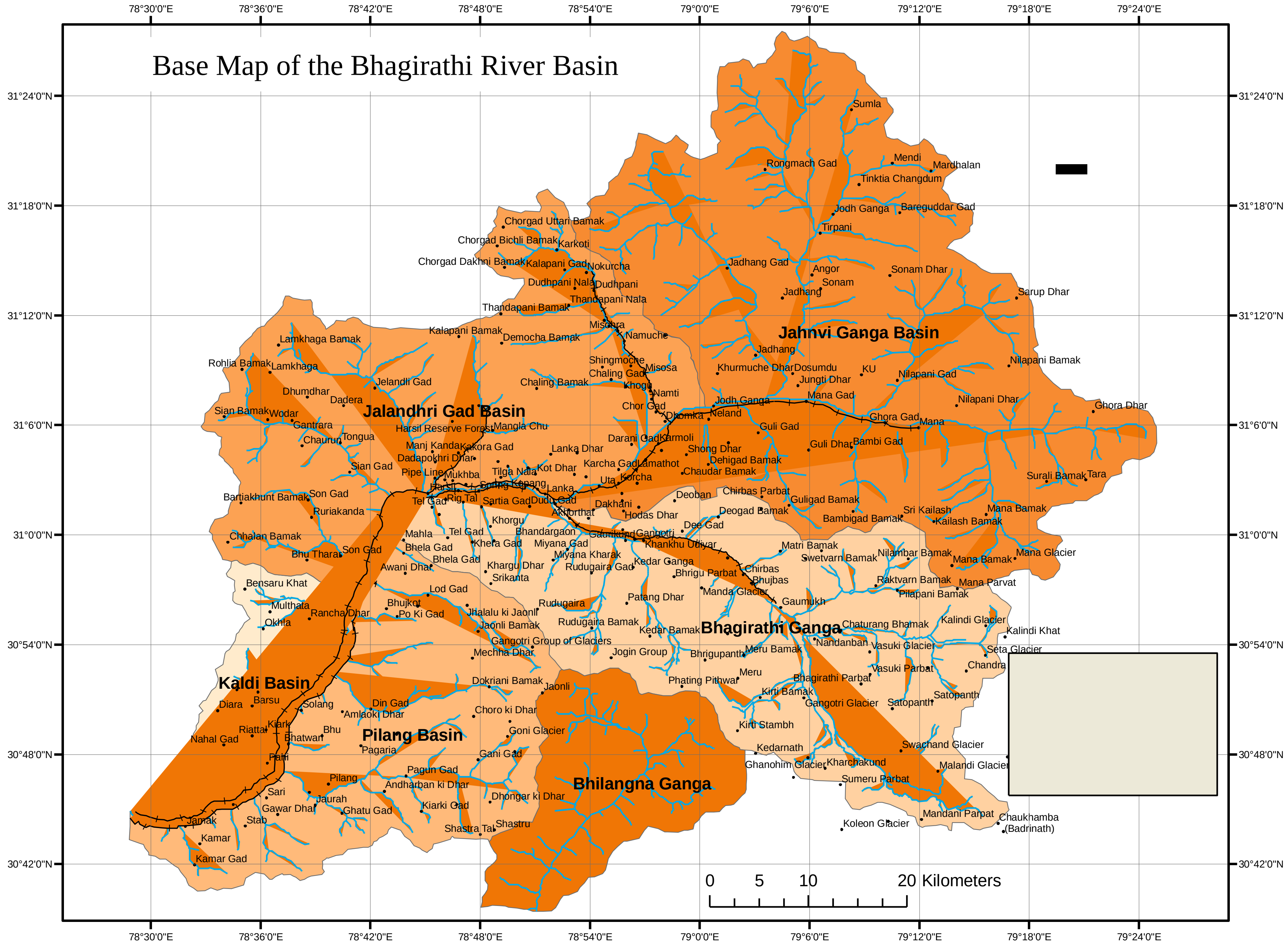
Drainage map of the Himalayan Rivers



Location Map of Uttarkashi District in Uttaranchal State




Uttarkashi District Map
77°48'0"E
78°0'0"E
78°12'0"E
78°24'0"E
78°36'0"E
78°48'0"E
79°0'0"E
79°12'0"E
31°24'0"N
31°12'0"N
31°0'0"N
30°48'0"N
30°36'0"N
30°24'0"N
CHINA
HIMACHAL PRADESH
Angar
Ran
Lewani
Jadhang
Doni
Harkidun
Osla
Nellang
Kulni
Jakhol
Datmir
Naitwar
Salra
Shaptrishi Kund
Balcha
Gainchwan
Asna
Purga
Harsil
Mon
Naini
Yamnotri
Chholmi
BHAGIRATHI RIVER
Gaurikund
Chirbas
Gangotri
Jarmola
Sar
Kharsal
Kanatal
Rama
Sarnoul
Gaumukh
Sunagar
Purola
Syana Chatti
Rajgarhi
Pujargaon
Barsu
Salang
Barkot
Naugaon
Agora
Bhatwari
Chamoli
Uprikot
Pilang
Dehradun
Kuwa
Sola
UTTARKASHI
Wah
Dunda
Dewar
Rudra Prayag
Thalan
Thalan
Kandani
Bangaon
Chakon
Bharkot
Shrikot
Margaon
Saundi
Tehri Garhwal
Hadhan
0
10
20
40 Kilometers


Base Map of the Bhagirathi River Basin
78°30'0"E
78°36'0"E
78°42'0"E
78°48'0"E
78°54'0"E
79°0'0"E
79°6'0"E
79°12'0"E
79°18'0"E
79°24'0"E
31°24'0"N
31°18'0"N
31°12'0"N
31°6'0"N
31°0'0"N
30°54'0"N
30°48'0"N
30°42'0"N
Jahnvi Ganga Basin
Jalandhri Gad Basin
Bhagirathi Ganga
Kaldi Basin
Pilang Basin
Bhilangna Ganga
Sumla
Rongmach Gad
Mendi
Mardhalan
Tinktia Changdum
Jodh Ganga
Bareguddar Gad
Tirpani
Chorgad Uttari Bamak
Chorgad Bichli Bamak
Karkoti
Chorgad Dakhni Bamak
Kalapani Gad
Nokurcha
Jadhang Gad
Angor
Sonam Dhar
Sonam
Jadhang
Sarup Dhar
Dudhpani Nala
Dudhpani
Thandapani Nala
Thandapani Bamak
Mischra
Namuche
Kalapani Bamak
Democha Bamak
Lamkhaga Bamak
Rohlia Bamak
Lamkhaga
Shingmoche
Misosa
Chaling Gad
Khurmuche Dhar
Dosumdu
KU
Nilapani Bamak
Jungti Dhar
Nilapani Gad
Jelandli Gad
Chaling Bamak
Khogu
Namti
Mana Gad
Dhumdhar
Dadera
Jodh Ganga
Nilapani Dhar
Ghora Dhar
Sian Bamak
Wodar
Chor Gad
Neland
Dhomka
Ghora Gad
Mana
Gantrara
Harsil Reserve Forest
Mangla Chu
Guli Gad
Chaurun
Tongua
Darani Gad
Karmoli
Guli Dhar
Bambi Gad
Manj Kanda
Kakora Gad
Lanka Dhar
Shong Dhar
Dadapokhri Dhar
Dehigad Bamak
Sian Gad
Karcha Gad
Lamathot
Pipe Line
Tilga Nala
Kot Dhar
Chaudar Bamak
Surali Bamak
Tara
Mukhba
Uta
Korcha
Harsil
Sprint
Kopang
Lanka
Chirbas Parbat
Son Gad
Deoban
Bartiakhunt Bamak
Guligad Bamak
Tel Gad
Rig Tal
Sartia Gad
Dudu Gad
Dakhani
Ruriakanda
Deogad Bamak
Sri Kailash
Mana Bamak
Akhorthat
Hodas Dhar
Bambigad Bamak
Kailash Bamak
Khorgu
Dee Gad
Mahla
Tel Gad
Bhandargaon
Chhalan Bamak
Gaurikund
Gangotri
Bhela Gad
Khera Gad
Miyana Gad
Khanku Udiyar
Matri Bamak
Son Gad
Bhu Tharas
Miyana Kharak
Swetvarn Bhamak
Nilambar Bamak
Mana Glacier
Bhela Gad
Kedar Ganga
Mana Bamak
Awani Dhar
Khargu Dhar
Rudugaira Gad
Chirbas
Bhrigu Parbat
Srikanta
Bhujbas
Raktvarn Bamak
Mana Parvat
Bensaru Khat
Lod Gad
Manda Glacier
Pilapani Bamak
Patang Dhar
Multhata
Bhujkot
Rudugaira
Gaumukh
Rancha Dhar
Po Ki Gad
Jhalalu ki Jaonli
Kalindi Glacier
Okhla
Jaonli Bamak
Rudugaira Bamak
Kedar Bamak
Chaturang Bhamak
Kalindi Khat
Gangotri Group of Glaciers
Nandanban
Vasuki Glacier
Mechha Dhar
Jogin Group
Bhrigupanth
Meru Bamak
Seta Glacier
Chandra
Vasuki Parbat
Meru
Dokriani Bamak
Phating Pithwar
Bhagirathi Parbat
Jaonli
Kirti Bamak
Satopanth
Barsu
Diara
Solang
Din Gad
Gangotri Glacier
Satopanth
Amlaoki Dhar
Choro ki Dhar
Kirti Stambh
Kiark
Riatta
Bhu
Goni Glacier
Bhatwari
Nahal Gad
Pagaria
Kedarnath
Swachand Glacier
Palhi
Gani Gad
Pagun Gad
Ghanohim Glacier
Kharchakund
Malandi Glacier
Pilang
Andharban ki Dhar
Sari
Sumeru Parbat
Jaurah
Dhongar ki Dhar
Gawar Dhar
Kiarki Gad
Ghatu Gad
Jamak
Stab
Shastra Tal
Shastru
Mandani Parpat
Chaukhamba (Badrinath)
Koleon Glacier
Kamar
Kamar Gad
0
5
10
20 Kilometers

Chaukhamba peak

Shivling Peak

Different Group of Peaks

Gaumukh, Snout of the Bhagirathi River

Flow of Bhagirathi River

Debris / Ice Cover in the Gangotri Glacier

Snout positions of the Gangotri Glacier since 1817 to 1971

Retreat of the Gangotri Glacier by Earth Observatory, NASA, 2004

Physiographic Impacts on the Hydro-Geomorphology

- Measurement and calculation of surface modifying natural factors and their impact zonation considering coverage area. Tectonic forces originating deep below the surface of earth are capable of changing surface configuration, increase or reduce the rate of surface intensity.

- Understanding the role of surface agents which tends to modify the face of earth surface. These agents and their activities are distributed in various intensities, forms and continuously modify the Earth’s surface.

- Therefore, it becomes imperative to discuss the distribution of these processes and their forming agents. In the present theme, the surface processes are analysed through the morphometric analysis techniques.

- Morphomteric analysis are applied in character as well as integrated in the approach. It provides a clear picture of the physiography of a region.

- For any demarcation based on divide a region into certain homogenous regions, such analysis becomes an essential ingredient. Morphomteric analysis are applied in character as well as integrated in approach. It provides a clear picture of the physiography of a region.

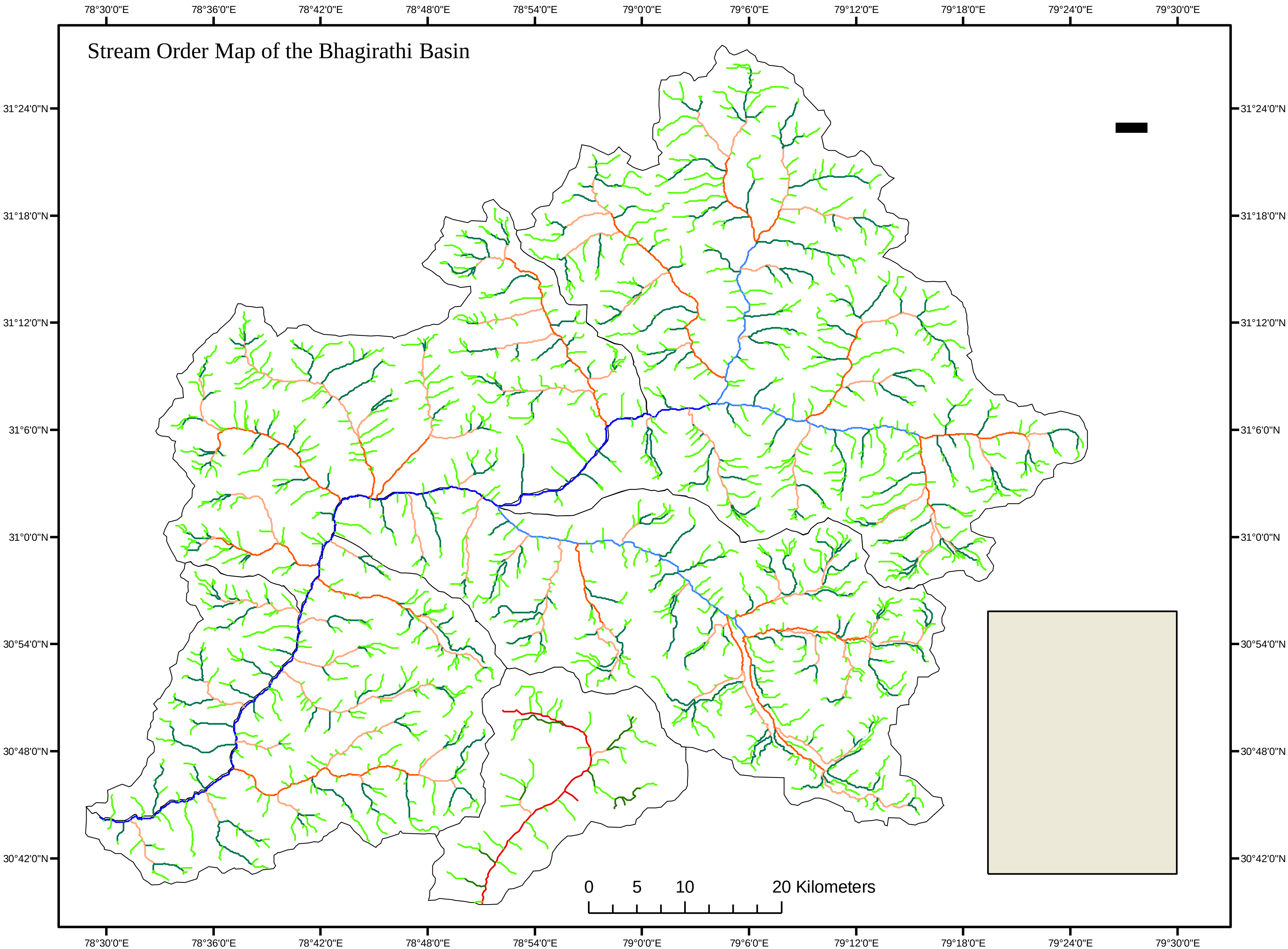
GEOMORPHOLOGICAL ANALYSIS

- The basin morphometry constitutes three types of properties such as areal, linear and relief. For the purpose of this study, areal properties such as stream frequency, drainage texture, drainage density and relief properties such as average relief, relative relief, dissection index and ruggedness index have been analysed.

- A quantitative approach is adopted here for showing the morphometric characteristics and spatial variations in the region. The database for this purpose is generated with the help of sources such as satellite imagery, SRTM data and toposheet.

- For morphometric analysis, contour intervals at 30 meters has been used. Contours are generated at 30 meter intervals and verified and modified with SOI toposheets.

- The study area is divided into 6,392 square grids of 1km x 1km and detailed statistics calculated for each grid is done.



Stream Order Map of the Bhagirathi Basin
78°30'0"E
78°36'0"E
78°42'0"E
78°48'0"E
78°54'0"E
79°0'0"E
79°6'0"E
79°12'0"E
79°18'0"E
79°24'0"E
79°30'0"E
31°24'0"N
31°18'0"N
31°12'0"N
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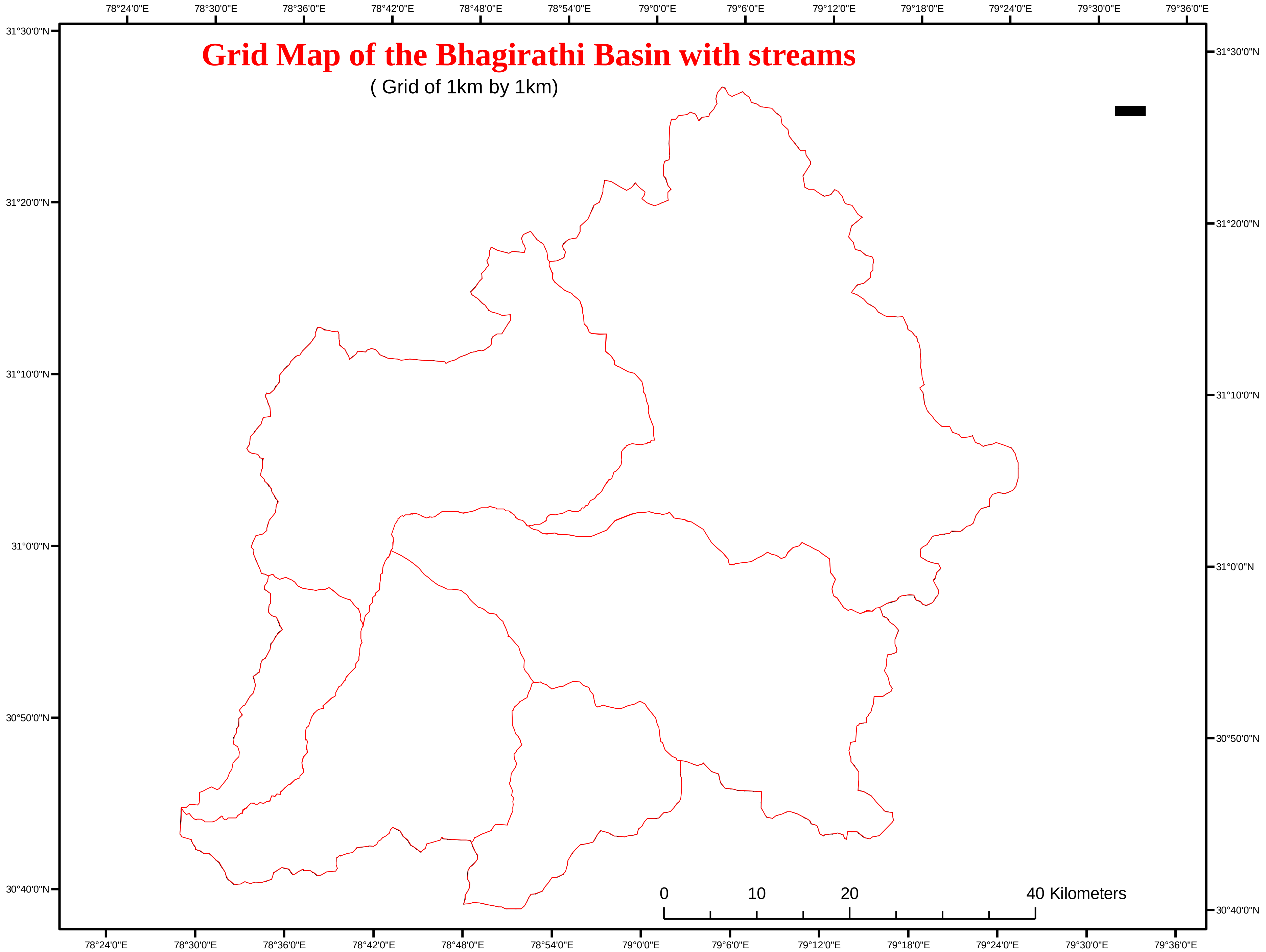
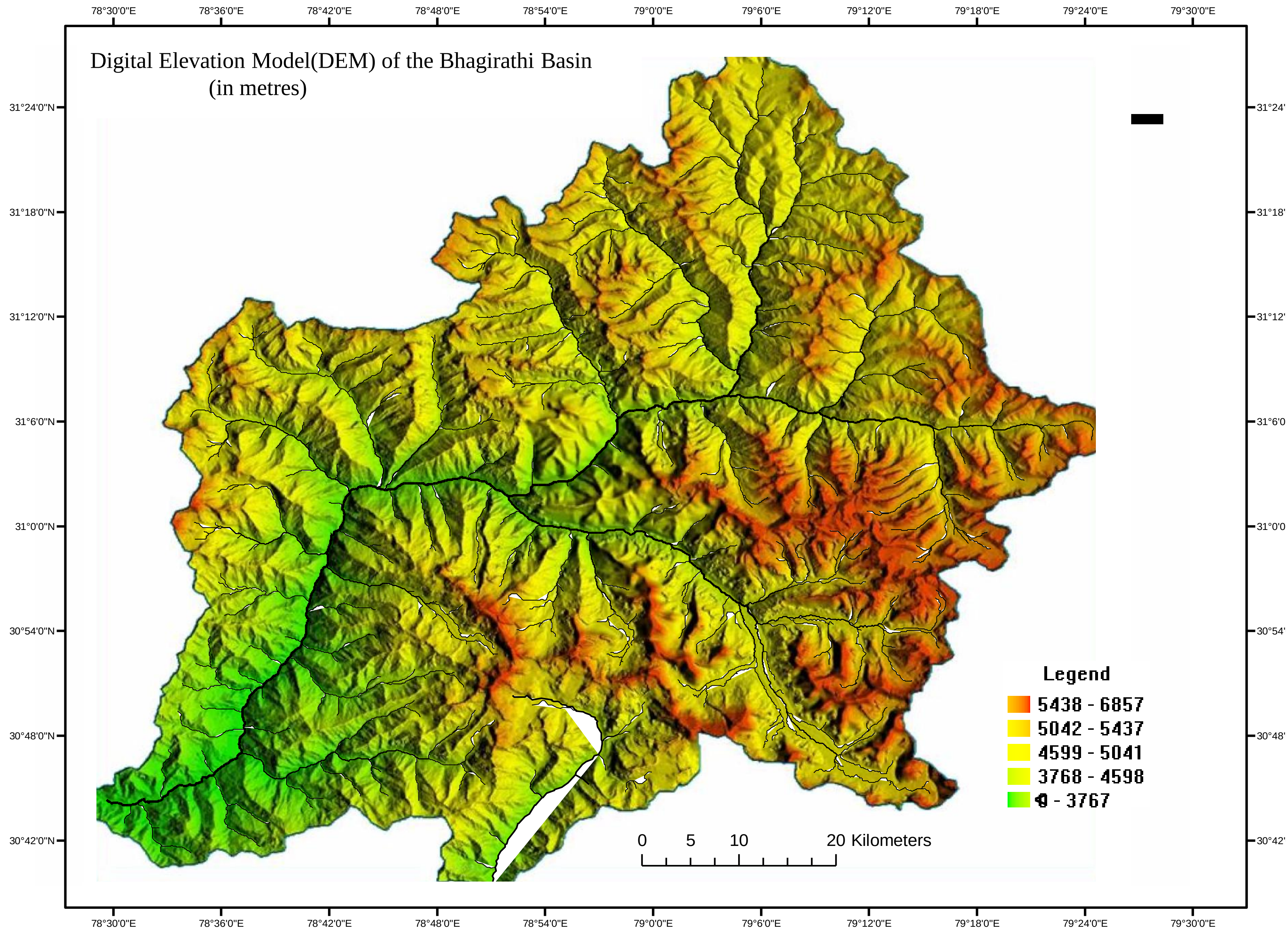
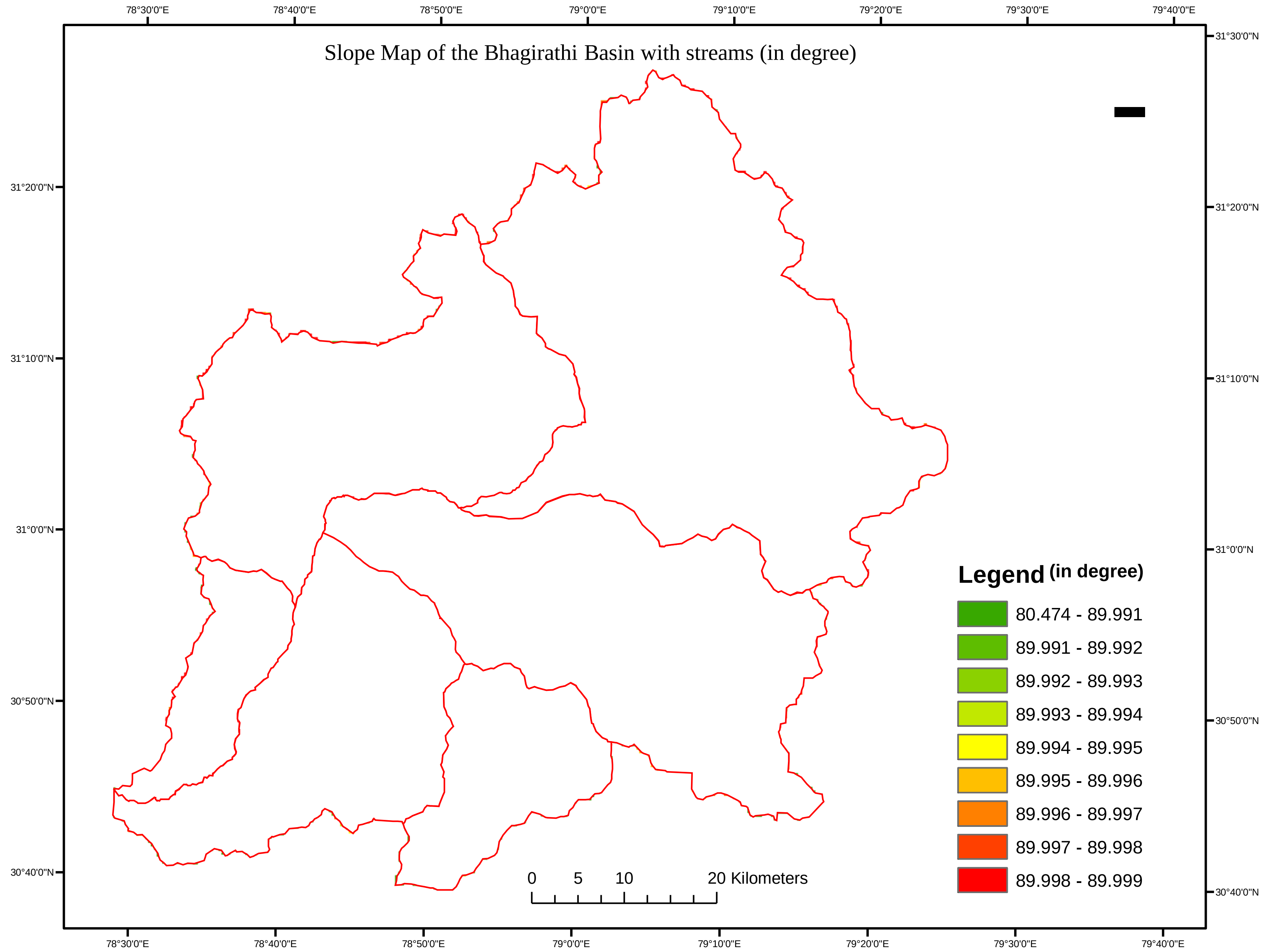
31°0'0"N
30°54'0"N
30°48'0"N
30°42'0"N
0 5 10 20 Kilometers



Grid Map of the Bhagirathi Basin with streams
(Grid of 1km by 1km)
78°24'0"E
78°30'0"E
78°36'0"E
78°42'0"E
78°48'0"E
78°54'0"E
79°0'0"E
79°6'0"E
79°12'0"E
79°18'0"E
79°24'0"E
79°30'0"E
79°36'0"E
31°30'0"N
31°20'0"N
31°10'0"N
31°0'0"N
30°50'0"N
30°40'0"N
0
10
20
40 Kilometers

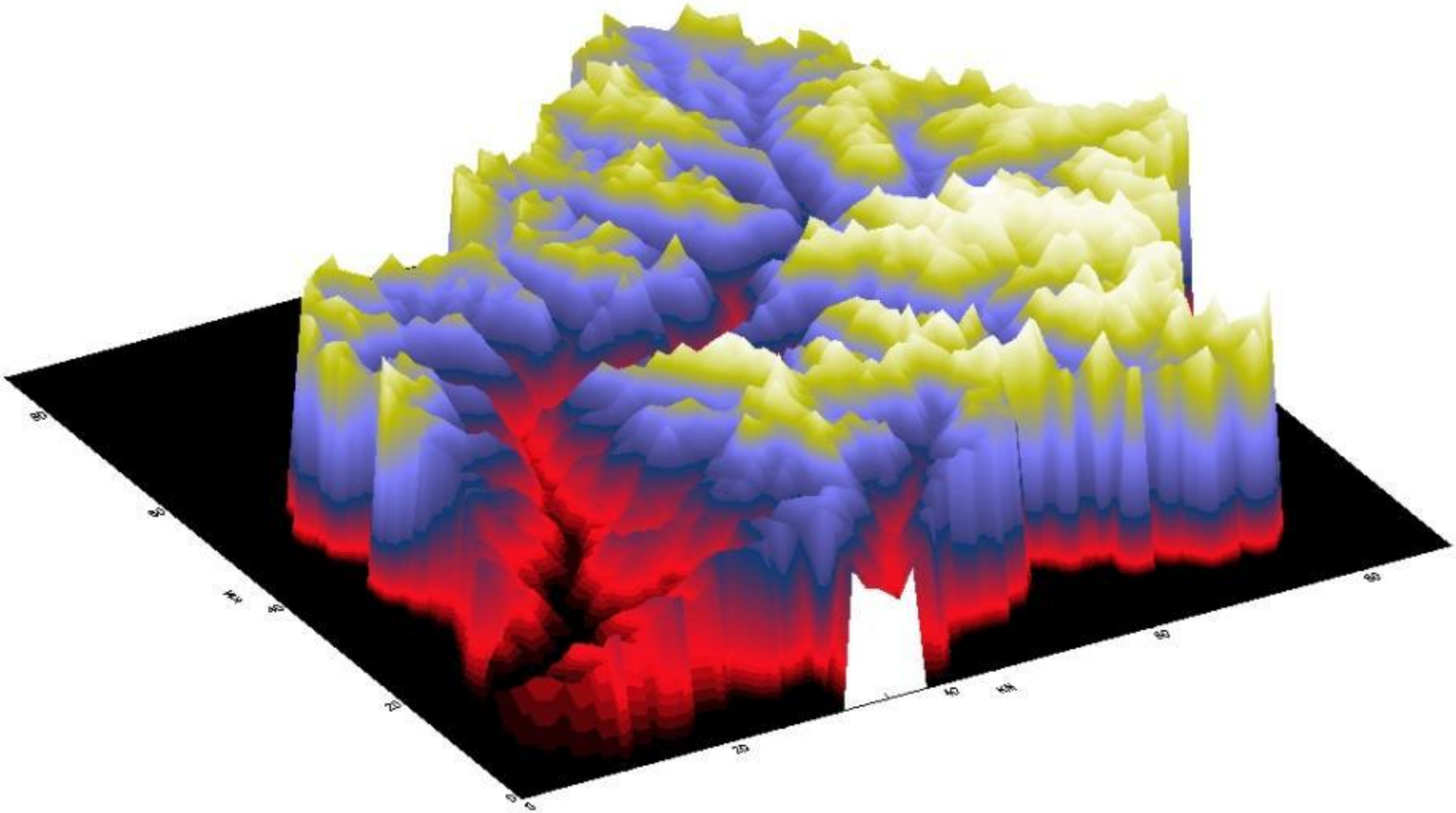


Digital Elevation Model(DEM) of the Bhagirathi Basin
(in metres)
78°30'0"E
78°36'0"E
78°42'0"E
78°48'0"E
78°54'0"E
79°0'0"E
79°6'0"E
79°12'0"E
79°18'0"E
79°24'0"E
79°30'0"E
31°24'0"N
31°18'0"N
31°12'0"N
31°6'0"N
31°0'0"N
30°54'0"N
30°48'0"N
30°42'0"N
Legend
5438 - 6857
5042 - 5437
4599 - 5041
3768 - 4598
0 - 3767
0 5 10 20 Kilometers



Slope Map of the Bhagirathi Basin with streams (in degree)
78°30'0"E
78°40'0"E
78°50'0"E
79°0'0"E
79°10'0"E
79°20'0"E
79°30'0"E
79°40'0"E
31°30'0"N
31°20'0"N
31°10'0"N
31°0'0"N
30°50'0"N
30°40'0"N
Legend (in degree)
80.474 - 89.991
89.991 - 89.992
89.992 - 89.993
89.993 - 89.994
89.994 - 89.995
89.995 - 89.996
89.996 - 89.997
89.997 - 89.998
89.998 - 89.999
0 5 10 20 Kilometers

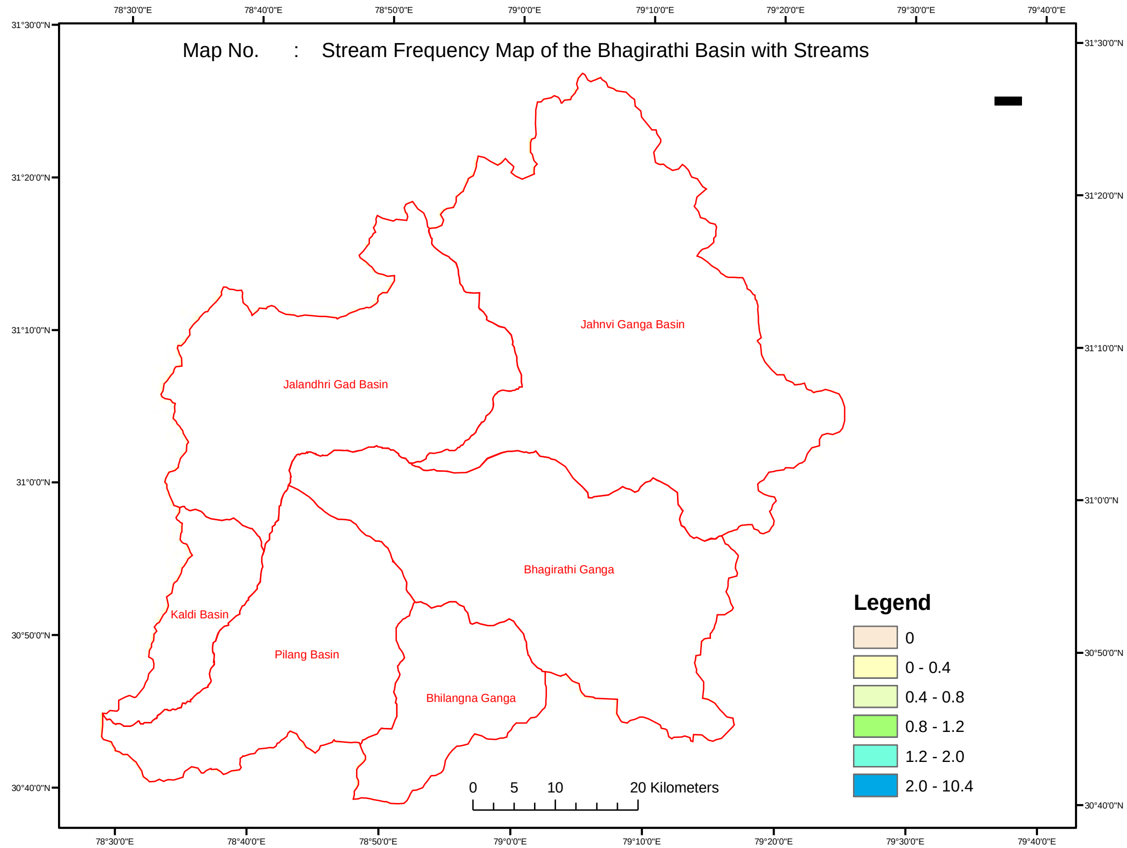
Surface Plot of the Bhagirathi Basin



Stream Frequency (Number of Streams/Sq.km.)

Stream frequency (S.F.) = ∑ N / A

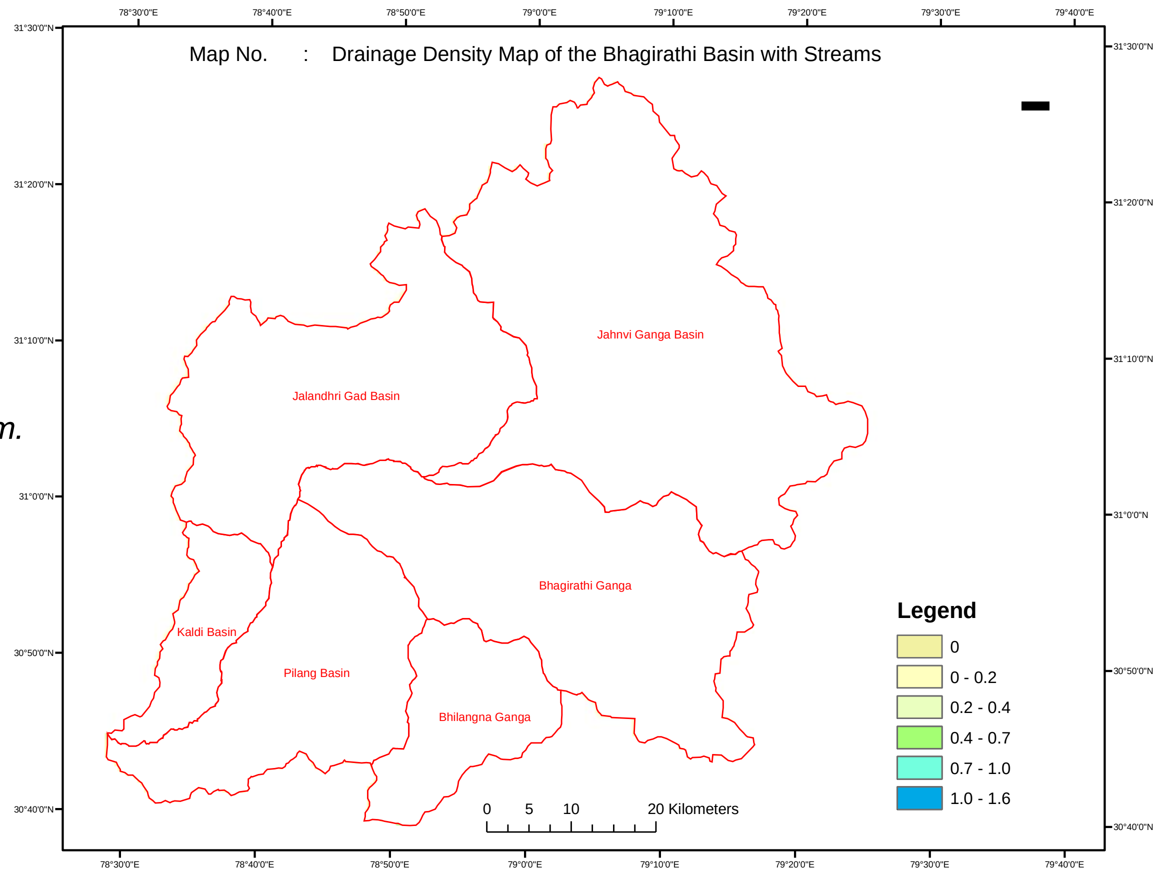
Where ∑ N total number of stream segments



High to very high stream frequency is found in the Bhagirathi and Jahnvi sub-basins. Moderate frequency found in other basins equally. The reason may be due to the numerous seasonal streams coming out of these basins.

S.No.	Classes	Frequency classes	% of Area Covered
1	Very high	2.01-5.83	3.26
2	High	1.21-2.0	11.51
3	Moderate	0.81-1.2	19.40
4	Low	0.41-0.8	19.43
5	Very low	0.01-0.4	46.40

Drainage Density (Length of Streams/Sq.km.)



Drainage density (DD) = ∑ L /A

Where ∑L is total length of stream segments, in km. and A is the unit area in sq. km.

Shows equal drainage density for all most all the basins. Jahnvi and Bhagirathi sub-basins are dominating, may be due to large area of coverage and more number of glaciers available.

S.No.	Classes	Frequency classes	% of Area Covered
1	Very high	1.0-1.6	1.44
2	High	0.7-1.0	9.01
3	Moderate	0.4-0.7	21.42
4	Low	0.2-0.4	18.93
5	Very low	0.01-0.2	49.19

Drainage Texture (No. of Streams/km)

$$Dt = AS = \frac{1}{(t+p)/2}$$

Where, Dt = Drainage Texture,
AS = Average spacing between two streams

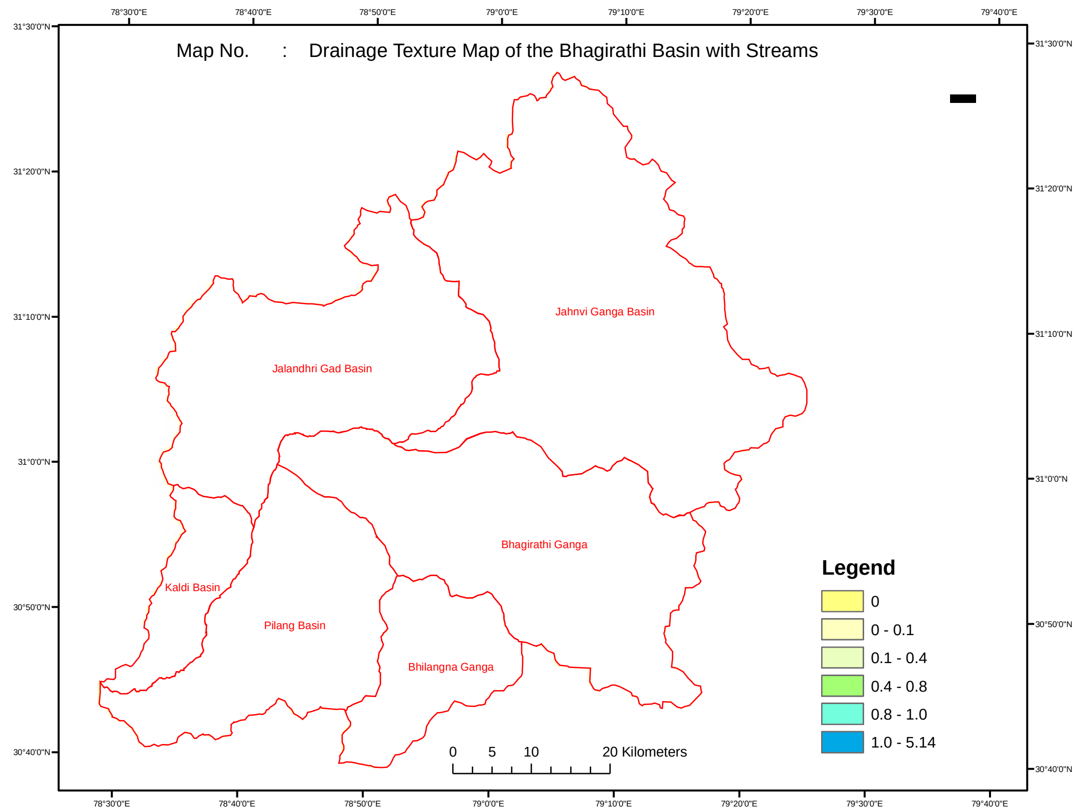
$$t = \frac{(t_1+t_2)/2}{\sqrt{2}}$$

t_1, t_2 = Number of intersections between the stream Network and grid square diagonal And,

$$p = \frac{p_1+p_2+p_3+p_4}{4}$$

p_1 to p_2 = Number of intersections between the stream Network and grid square edges.

High to very high drainage texture is found along Bhagirathi sub-basin due to dip-controlled slope. Maximum area is covered by moderate to very low drainage texture.

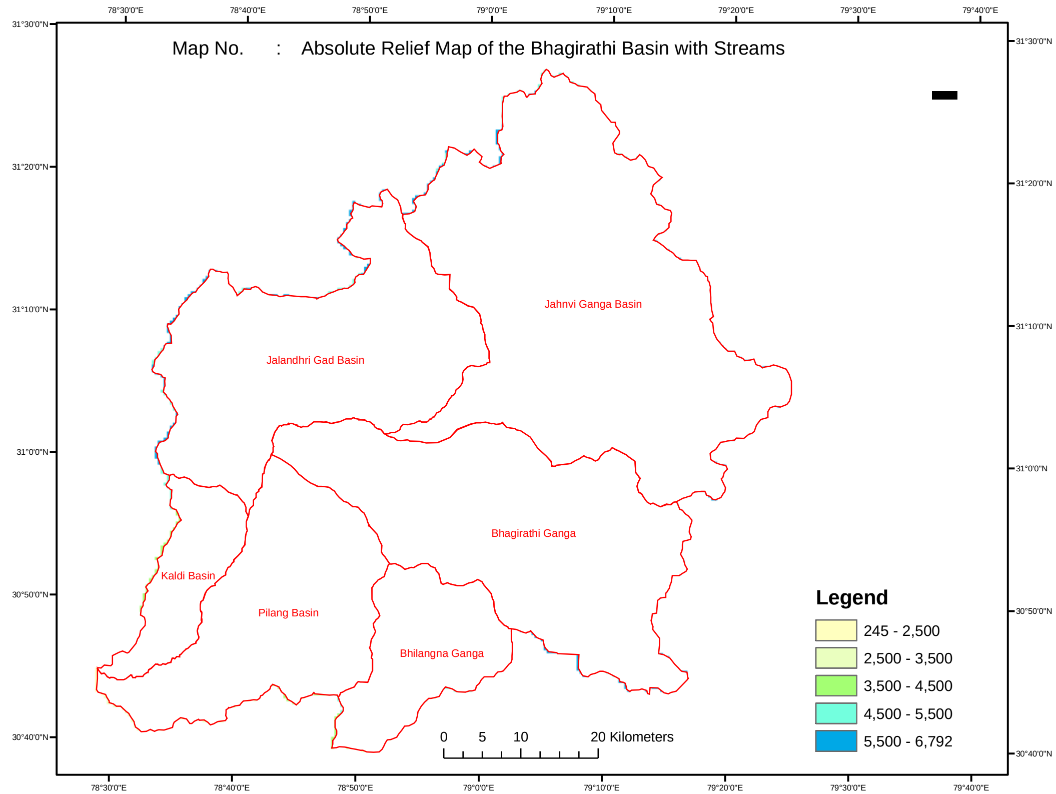


S.No.	Classes	Frequency classes	% of Area Covered
1	Very high	1.0-5.14	9.93
2	High	0.8-1.0	7.19
3	Moderate	0.4-0.8	22.51
4	Low	0.1-0.4	30.33
5	Very low	0.01-0.1	30.04

Absolute Relief in Metres

Absolute relief gives the elevation of any area above the sea level in exact figure.

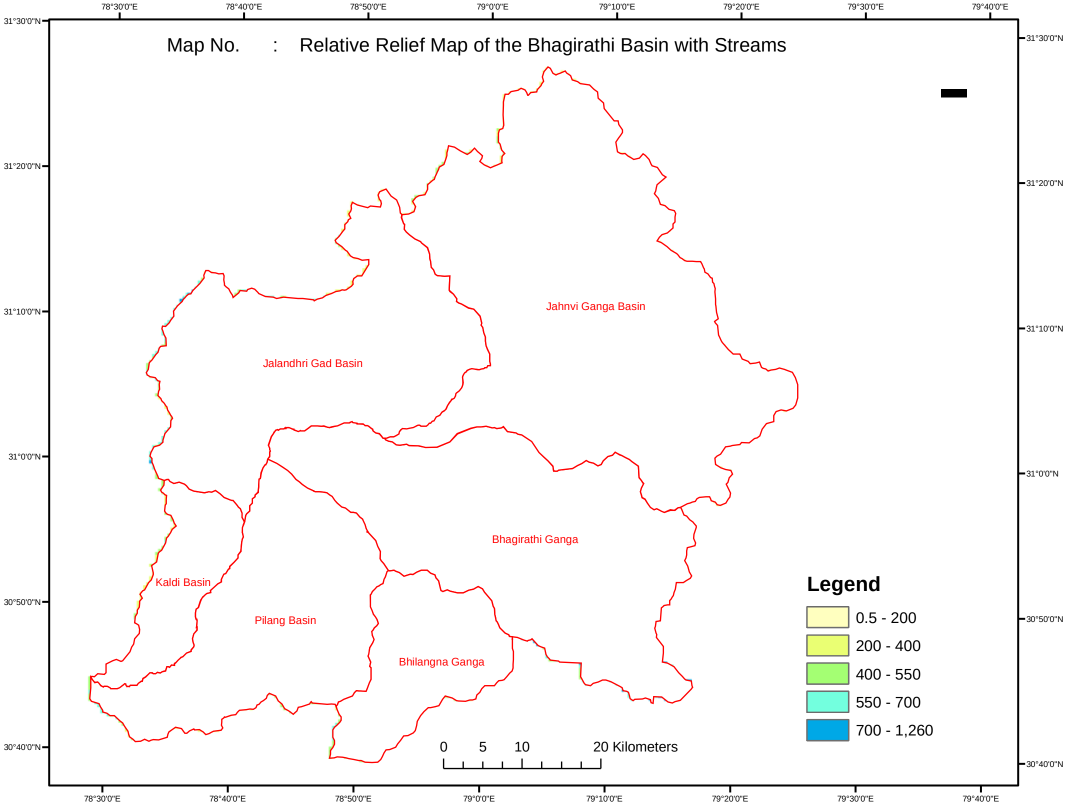
Absolute relief high in all glacierised area of the basin. The upper part is made up of high level fan deposits and the central part acts as a water divide. The whole region is equally well distributed among the five classes. Among them maximum area is occupied by the very high frequency class that is between 5500 to 6792 meters.



S.No.	Classes	Frequency classes	% of Area Covered
1	Very high	5500-6792	35.25
2	High	4500-5500	31.29
3	Moderate	3500-4500	13.99
4	Low	2500-3500	16.85
5	Very low	< 2500	2.62

Relative Relief (in Meters)

Relative Relief (RR) =
highest contour value - lowest contour value

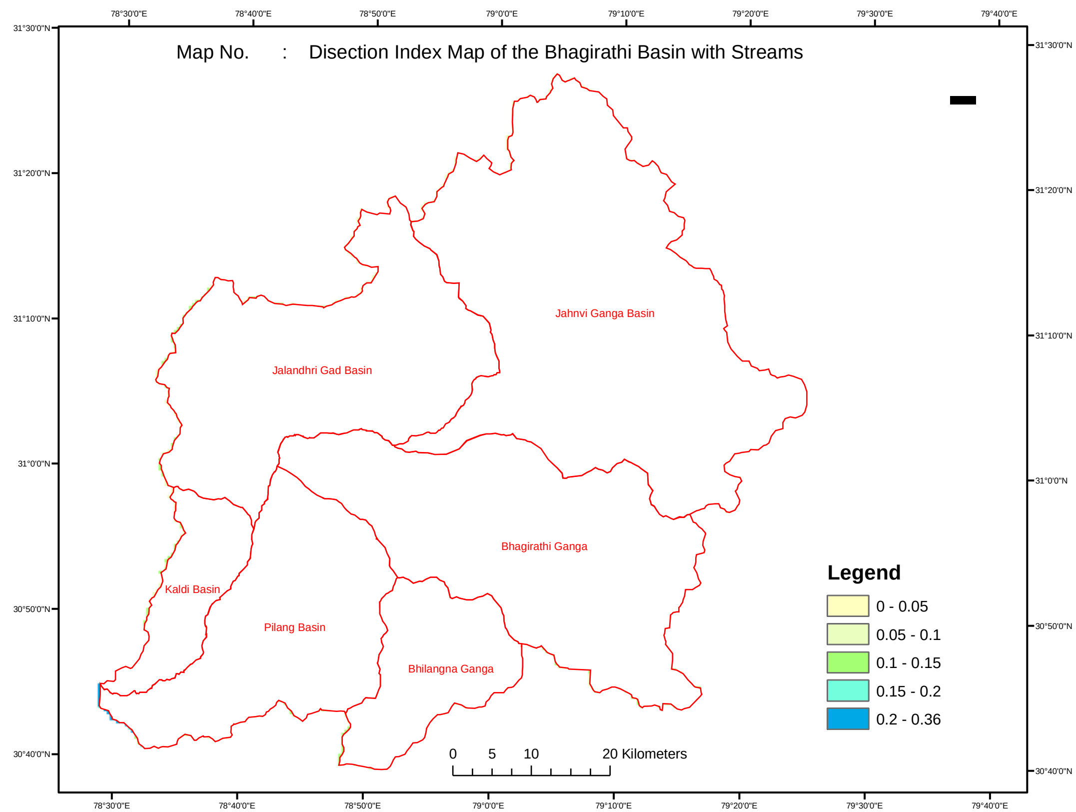


High relative relief in Jalandhri Basin and small patch of Jahnvi Basin. The moderate frequency classes have maximum occurrence. The zero relative relief does not found any where in the region. The values and the figure clearly indicate that it is more or less flat valley.

S.No.	Classes	Frequency classes	% of Area Covered
1	Very high	700-1260	11.33
2	High	550-700	26.47
3	Moderate	400-550	32.88
4	Low	200-400	27.22
5	Very low	0.5-200	2.10

Dissection Index

Dissection index (DI) = Relative relief (RR)/ Absolute relief (AR).

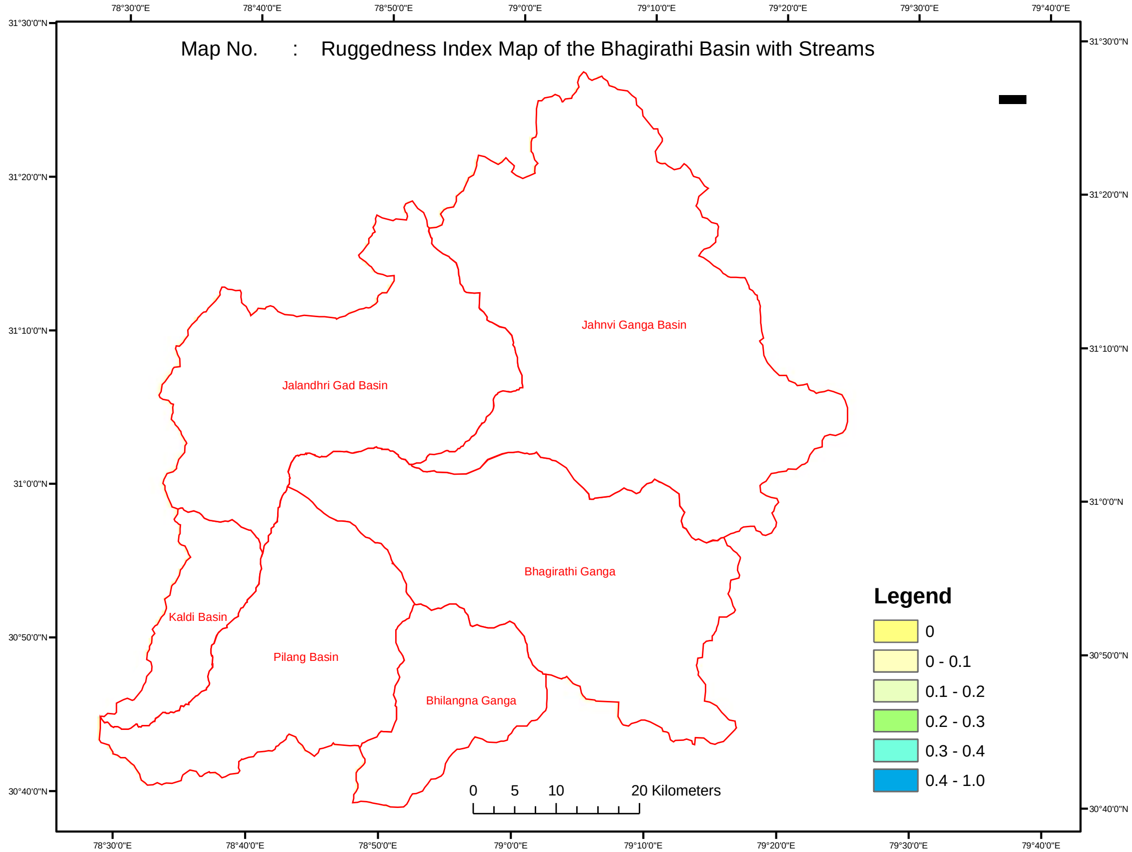


Moderate to low frequency class of dissection index occurs in major part of the basin. High and very high frequency class of dissection index is shown less part of the basin in the south-western part. The reason behind it is that it is having low relative relief.

S.No.	Classes	Frequency classes	% of Area Covered
1	Very high	0.20-0.36	17.06
2	High	0.15-0.20	21.22
3	Moderate	0.10-0.15	32.74
4	Low	0.05-0.10	24.10
5	Very low	0.01-0.05	4.88

Ruggedness Index

*Ruggedness index (RI) = relative relief (RR) * drainage density / 1000(constant)*



Moderate to very high frequency classes of ruggedness index generally at the region where it is having high relative relief and dissection index, but the moderate value of frequency classes also occur towards valley area and also towards in some patches in the north and eastern part which shows that it is also dependent on drainage density.

But, as the value of relative relief are very high compared to the value of drainage density that is why the figure of ruggedness index is more alike to the figure relative relief etc.

It clearly shows that high values of dissection index are found in Jahnvi and Jalandhri Basins. Very low value frequency classes of dissection index is found in almost whole valley.

S.No.	Classes	Frequency classes	% of Area Covered
1	Very high	0.40-1.00	55.45
2	High	0.30-0.40	20.45
3	Moderate	0.20-0.30	13.08
4	Low	0.10-0.20	6.64
5	Very low	0.01-0.10	4.38

Map No. 2.3: Bhagirathi Sub-Basins with River Network and Glacier Locations

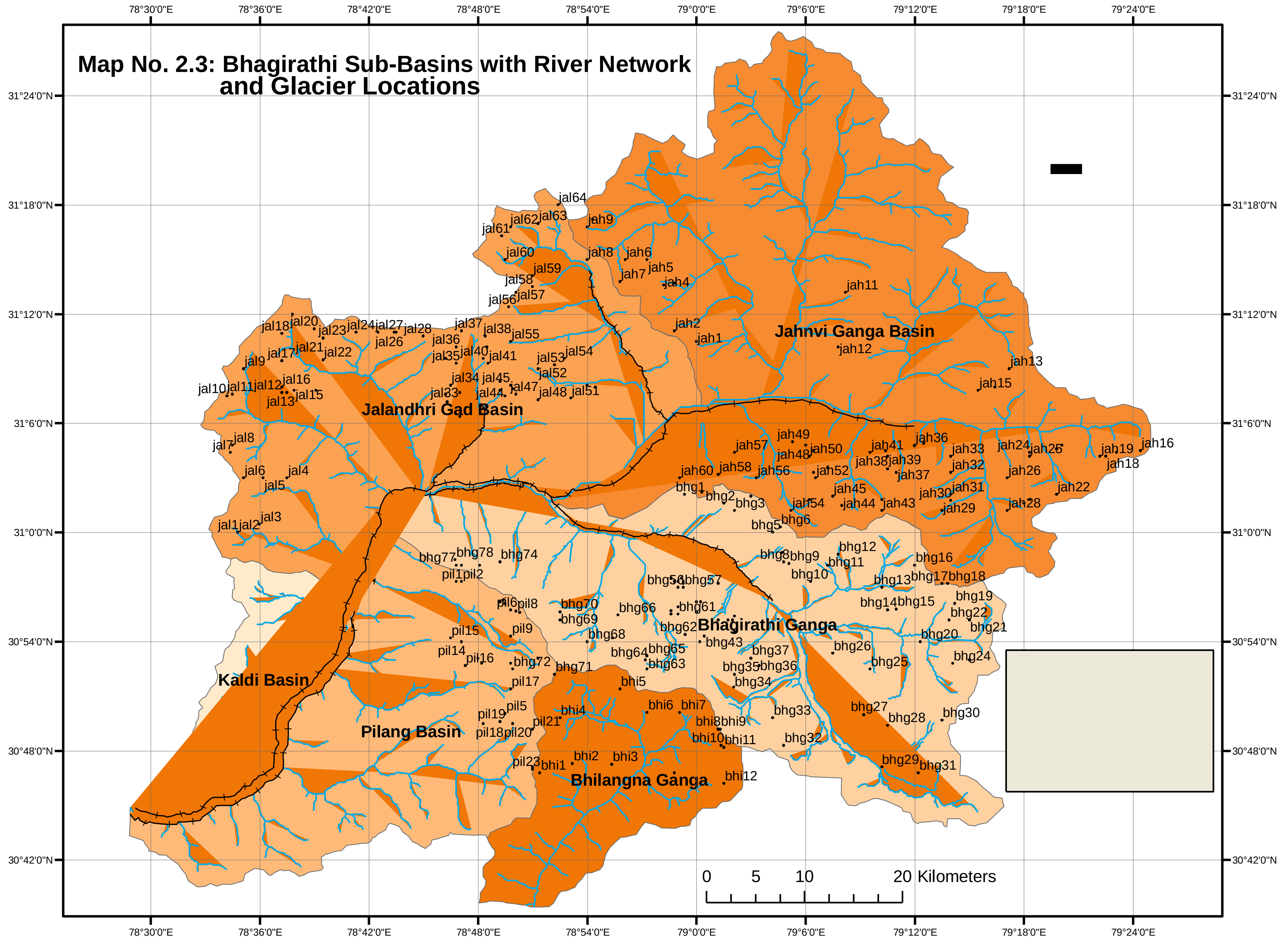
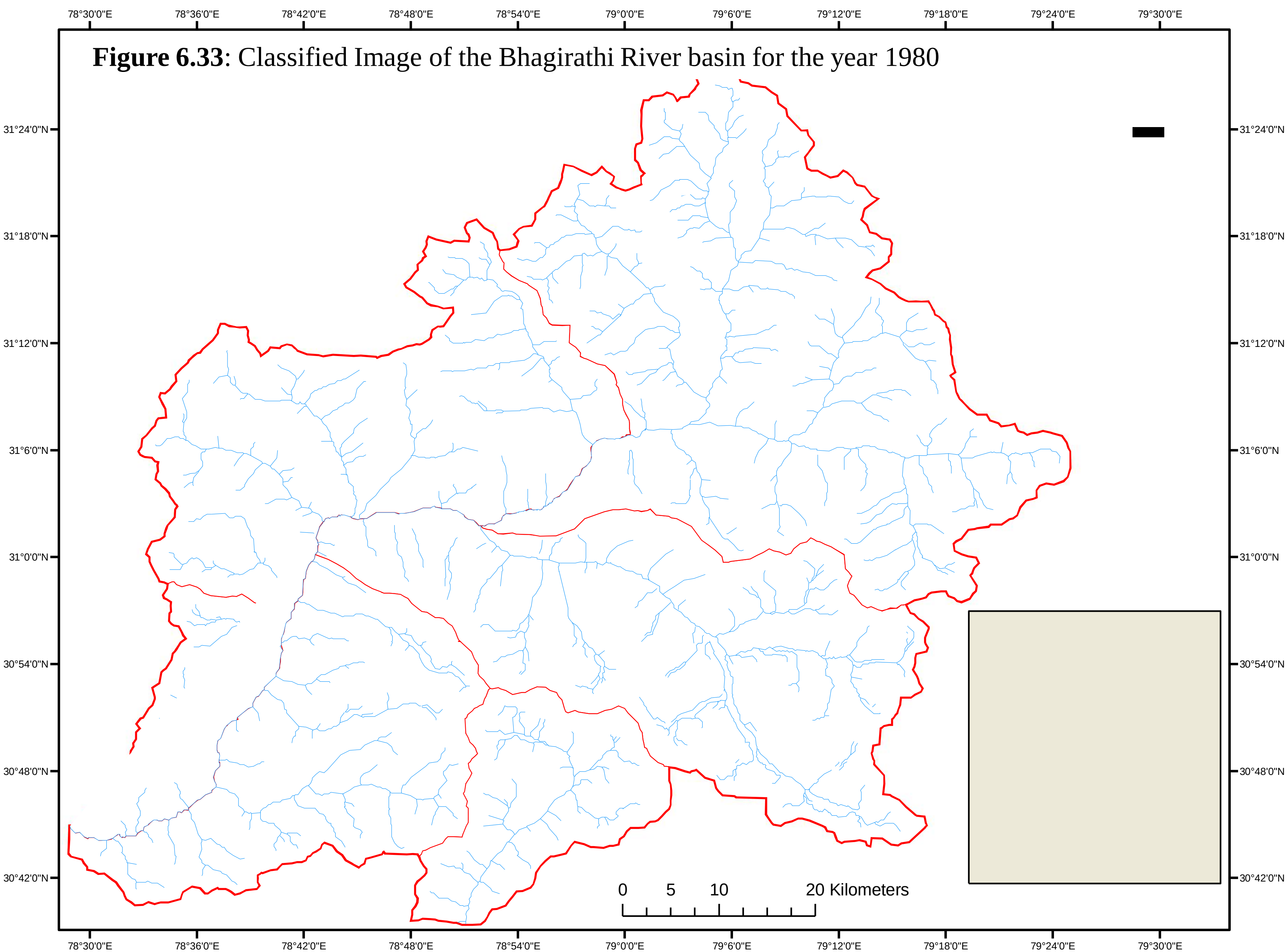
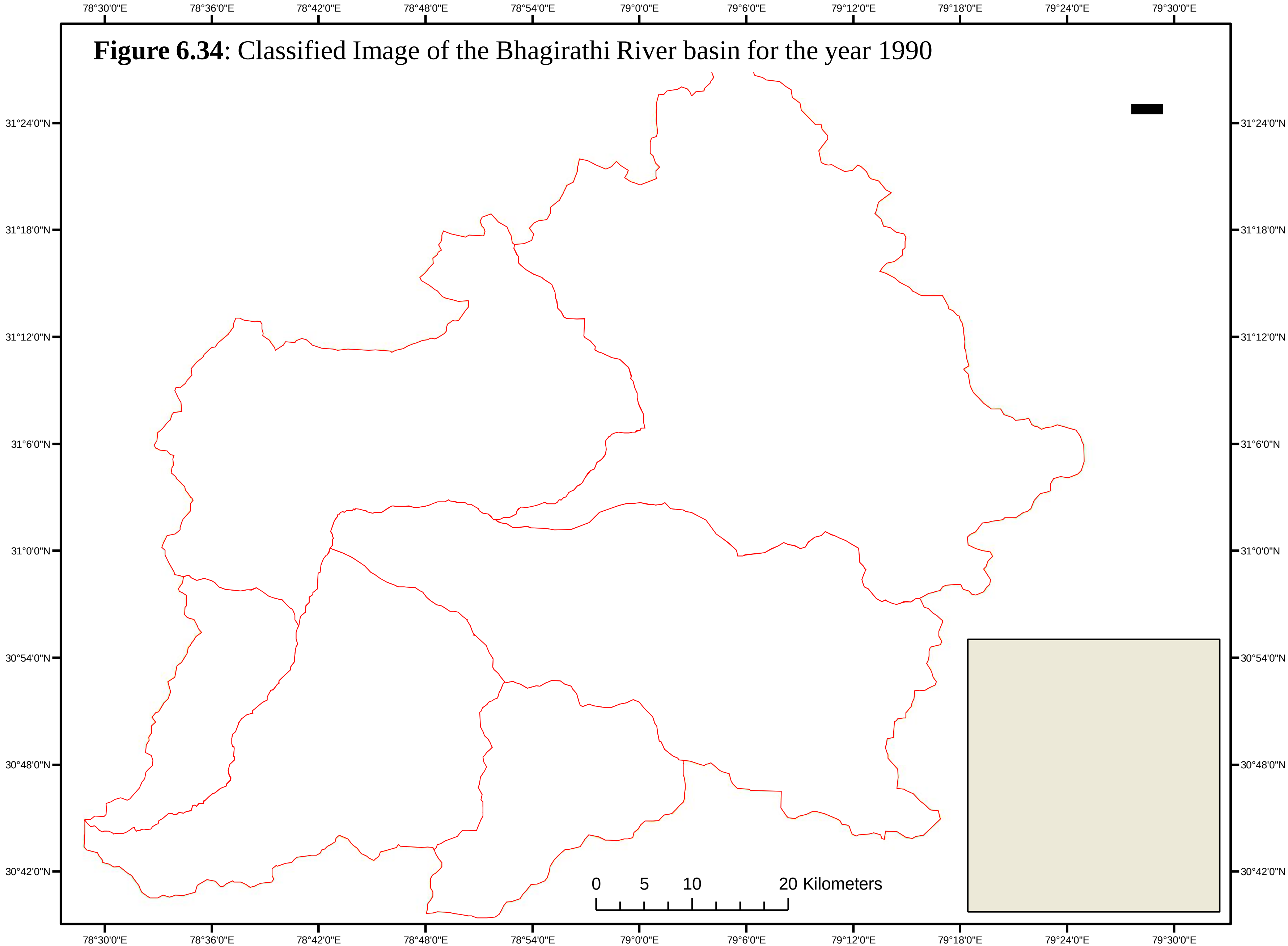


Figure 6.33: Classified Image of the Bhagirathi River basin for the year 1980



Source: MSS Imagery of December 1980

Figure 6.34: Classified Image of the Bhagirathi River basin for the year 1990



Source: TM Imagery of October 1990

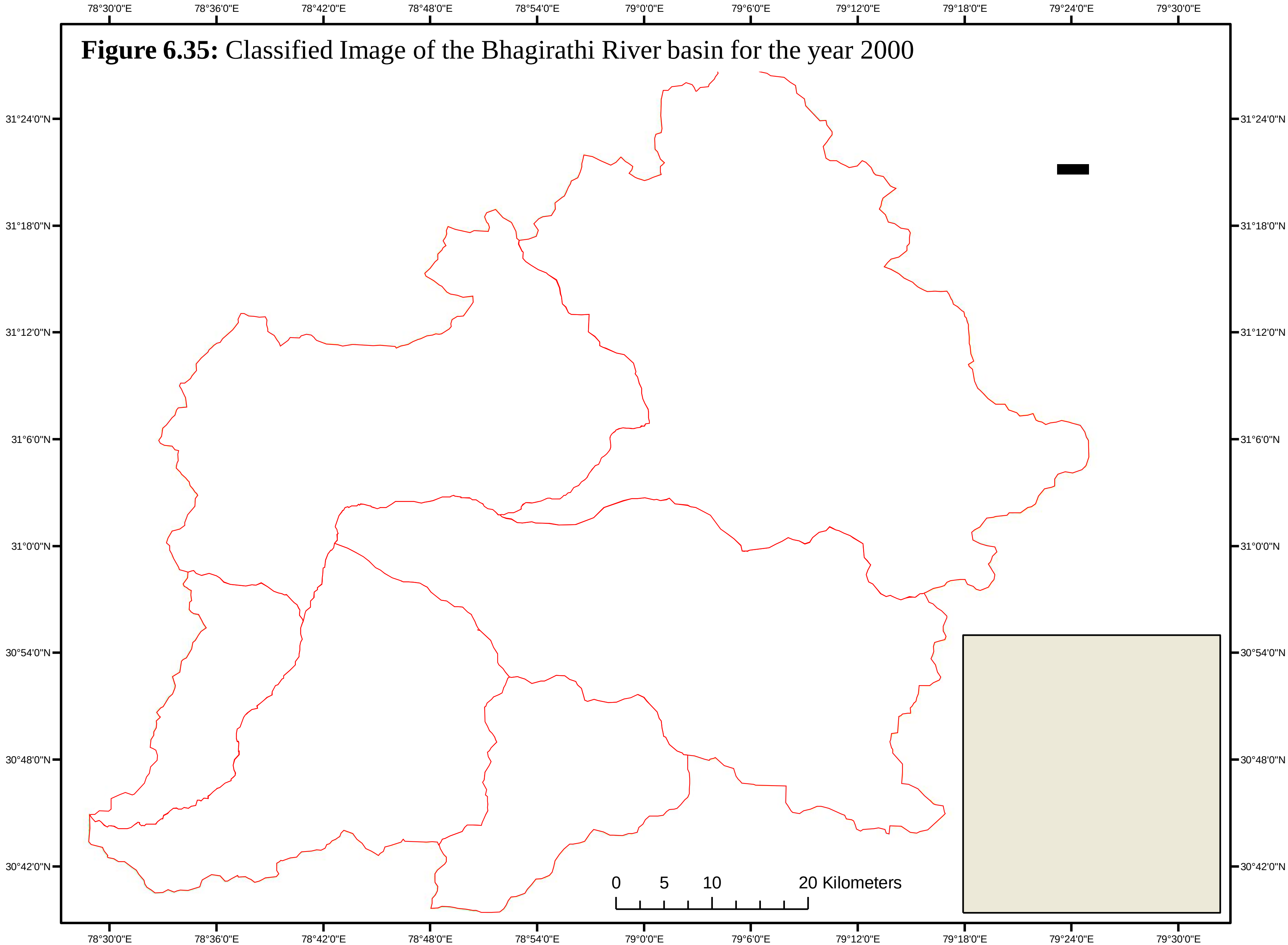
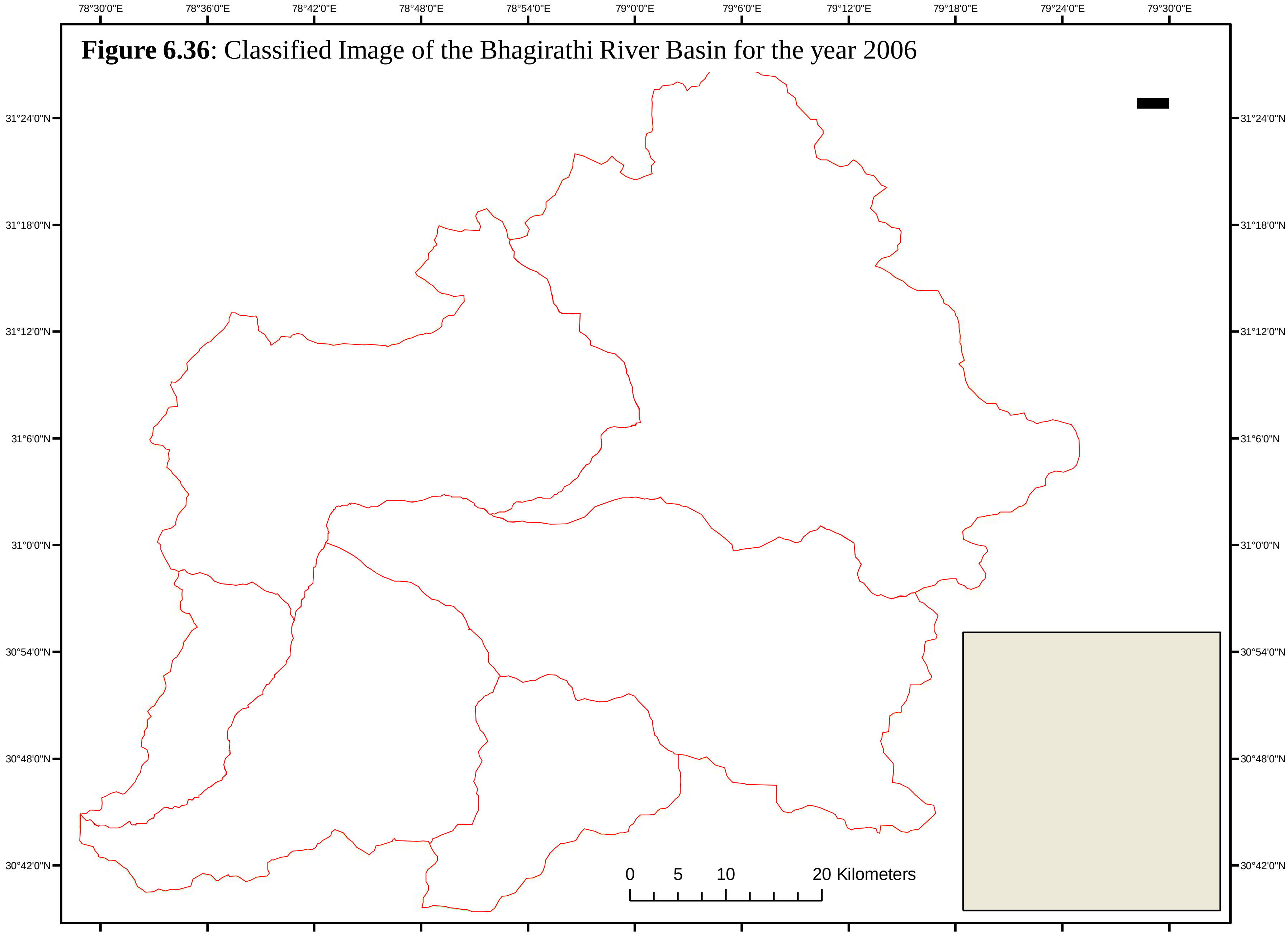


Figure 6.35: Classified Image of the Bhagirathi River basin for the year 2000

Source: ETM+ Imagery of October 2000

Figure 6.36: Classified Image of the Bhagirathi River Basin for the year 2006



Source: IRSP6-LISS-III of October 2006

Hypsometric Analysis

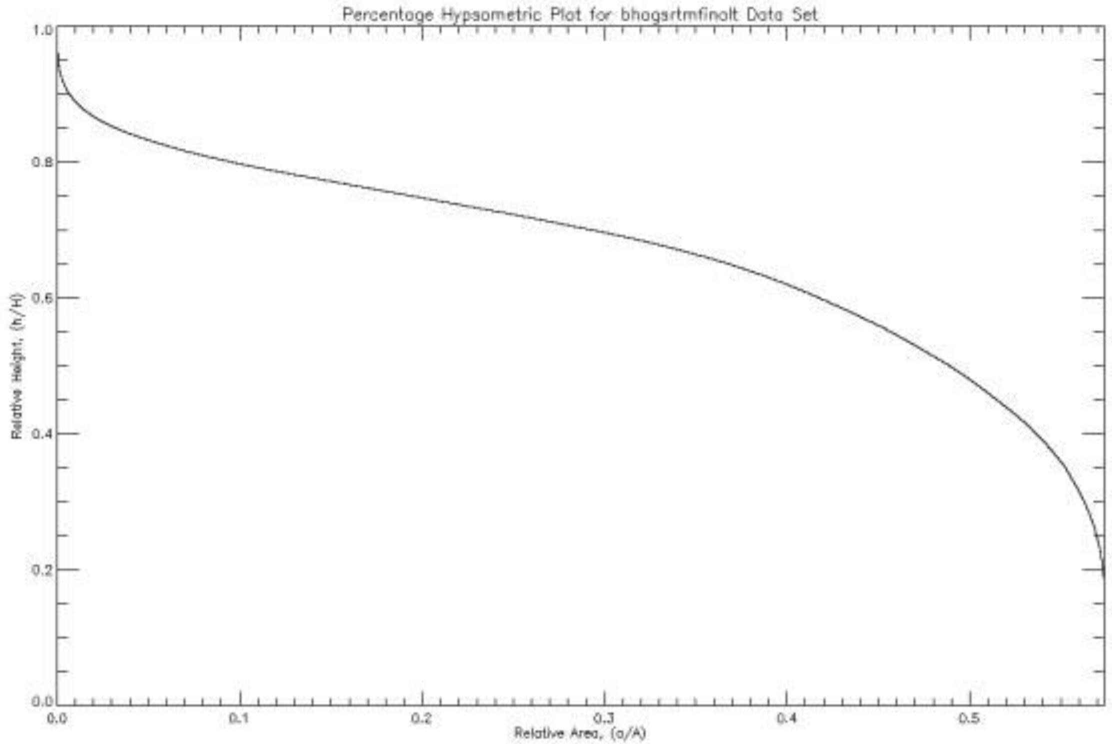
➢ Hypsometric analysis (or area-altitude analysis) is the study of the distribution of horizontal cross-sectional area of a landmass with respect to elevation (Strahler, 1952).

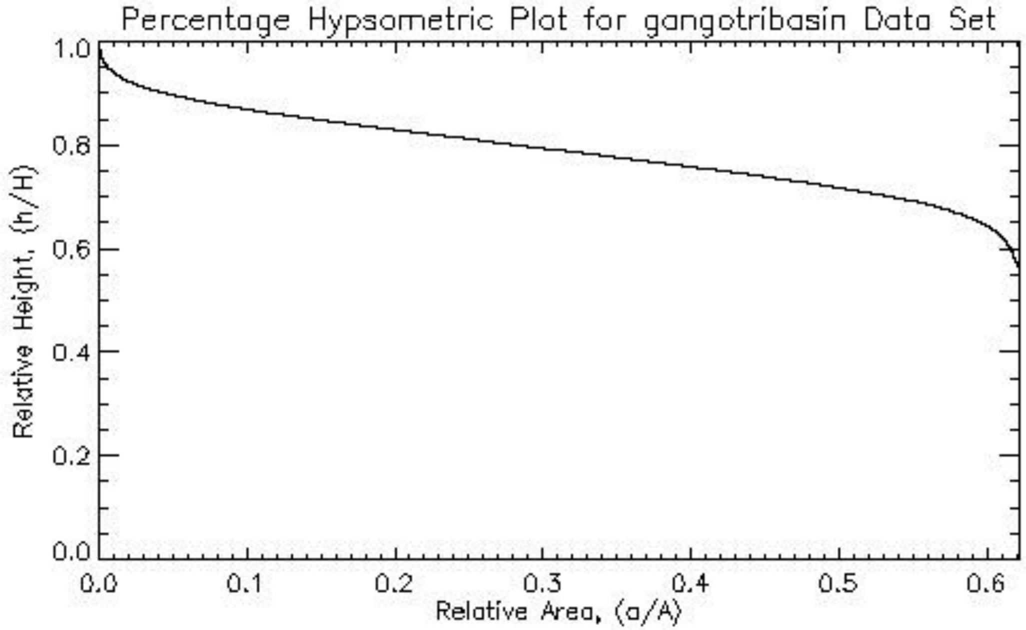
➢ Classically, hypsometric analysis has been used to differentiate between erosional landforms at different stages during their evolution

➢ Hypsometric curves and integrals can be interpreted in terms of degree of basin dissection and relative landform age: Convex-up curves with high integrals are typical for youth, undissected (disequilibrium stage) landscapes; smooth, s-shaped curves crossing the center of the diagram characterize mature (equilibrium stage) landscapes, and concave-up with low integrals typify old and deeply dissected landscapes.

➢Hypsometric data were derived for the entire basin from the 50m DEM data. The percentage hypsometric method used here relates the area enclosed between a given contour and the basal plane of the analyzed area to the height of that contour above the basal plane.

Percentage Hypsometric Curve of the entire Bhagirathi River Basin





Percentage Hypsometric Curve of the Gangotri Basin

Conclusion

- The resulting hypsometric curve permits comparison of areas of different sizes and elevations. It expresses the manner in which the volume above the basal plane is distributed from base to top. Hypsometric curves always originate in the lower left-hand corner and reach the upper right-hand corner. It may, however, take any one of a variety of paths between these points, depending upon the distribution of the landmass from base to top.

- As these two results one is for Bhagirathi River Basin and another is for Gangotri Basin are clearly shows that Hypsometric curve starts from top in the shape of the concave and in the middle in changes and it become convex shape and ends.

- This kind of shape is clearly shows that the basin is very dynamic and disequilibrium stage in nature.

- It shows that the basin is vulnerable to the land slide, land erosion or any other natural phenomena.

Thanks and Questions