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Statistical analysis of glaciers in Himachal Pradesh, north-west Himalaya, India

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A statistical analysis of Himachal glaciers has been carried out. The maximum concentration of glaciers is in the elevation range 4500–5500 m. More glaciers are of transverse simple type than longitudinal type.

THE Himalaya, on the southern slopes of the Tibetan plateau, is one of the most important glacier systems

on the earth. The main snow-gathering ground is in the higher Greater Himalayan ranges, whose relationship with climate changes on various time scales indicates topographic and climatic conditions favourable for the formation of the glaciers. The present work is in continuation of our glacier inventory¹.

The study area is situated in the western part of the Himalaya, extending about 315 km between UP Himalaya in the east and the Kashmir Himalaya in the west (Figure 1). It encompasses mountain area of about 48,034 km² out of the total land area of 55,673 km² of the Himachal Himalaya. It is estimated that 9.4% (approximate 10%) is glaciated area of 4516.22 km² out of the total mountainous area of 48,034 km². Every 1 km² of the land area is glaciated to the extent of 0.09 km². Six hundred one glaciers have been identified in six drainage basins², Chandra–Bhaga (200), Beas–Parbati (80), Ravi (54), Malung (40), Spiti (159) and Satluj (68). Statistical analysis of glaciers in these drainage basins has been carried out on the basis of earlier works^{2–8}.

Glaciers are unevenly distributed between the Great Himalayan, Pir-Panjol and Dhauladhar ranges, controlled by the topographic variation and the amount of precipitation in the region. The altitude increases from NW to SE, where maximum precipitation occurs. So, the Satluj basin, which receives more precipitation and is at higher elevation, remains covered with snow for longer duration than the other basins. In this study the identification of glaciers is from LANDSAT imagery. Data for the glaciers are summarized in Tables 1 and 2.

In Chandra–Bhaga, Spiti and Satluj basins the highest frequency of glaciers is in the length range 2–4 km, while in Beas–Parbati, Ravi and Malung basins the highest frequency is around 2 km (Figure 2a). It is also observed that 35% of the glaciers fall in the range 2–4 km in length, 55% are around 5 km, and the remaining 10% are 10 km or more in length. Bara-Shigri is the longest glacier (29 km) of the Himachal Himalaya.

The area covered by individual glaciers was calculated by digital planimeter. Figure 2b shows that majority of the glacial cover area of Himachal extends over 2 to 6 km², but some glaciers are more than 10 km² in area. An examination of Table 1 shows that the Chandra–Bhaga, Malung and Spiti basins are relatively balanced in basin area and glaciated area, while the Beas, Ravi and Satluj are less glaciated compared to the basin area. The glaciers in NW Himachal Pradesh are bigger than those in the SE region.

Broadly the glaciers have been classified into two main types (i) Longitudinal and (ii) Transverse, on the basis of their flow direction³. These are further subdivided into simple and compound types. Simple glaciers have a single accumulation zone while compound glaciers have two or more accumulation zones in a single basin.

RESEARCH COMMUNICATIONS

About 69.5% of the Himachal glaciers are of transverse simple (TS) and compound (TC) types and 30% are of longitudinal simple (LS) and compound (LC) types. The largest class of glaciers is the transverse simple (TS) type (Figure 3) while longitudinal glaciers are fewer, and occupy wider valleys and are larger in size. The distribution of transverse and longitudinal glaciers in different basins is, respectively:

Chandra-Bhaga, 67 and 33%;
 Beas-Parbati, 74 and 26%;
 Ravi, 58 and 42%;
 Spiti, 65 and 35%, and
 Satluj, 75 and 25%.

Glaciers in Malung basin are of only transverse type.
 It is well known that the orientation (flow direction)

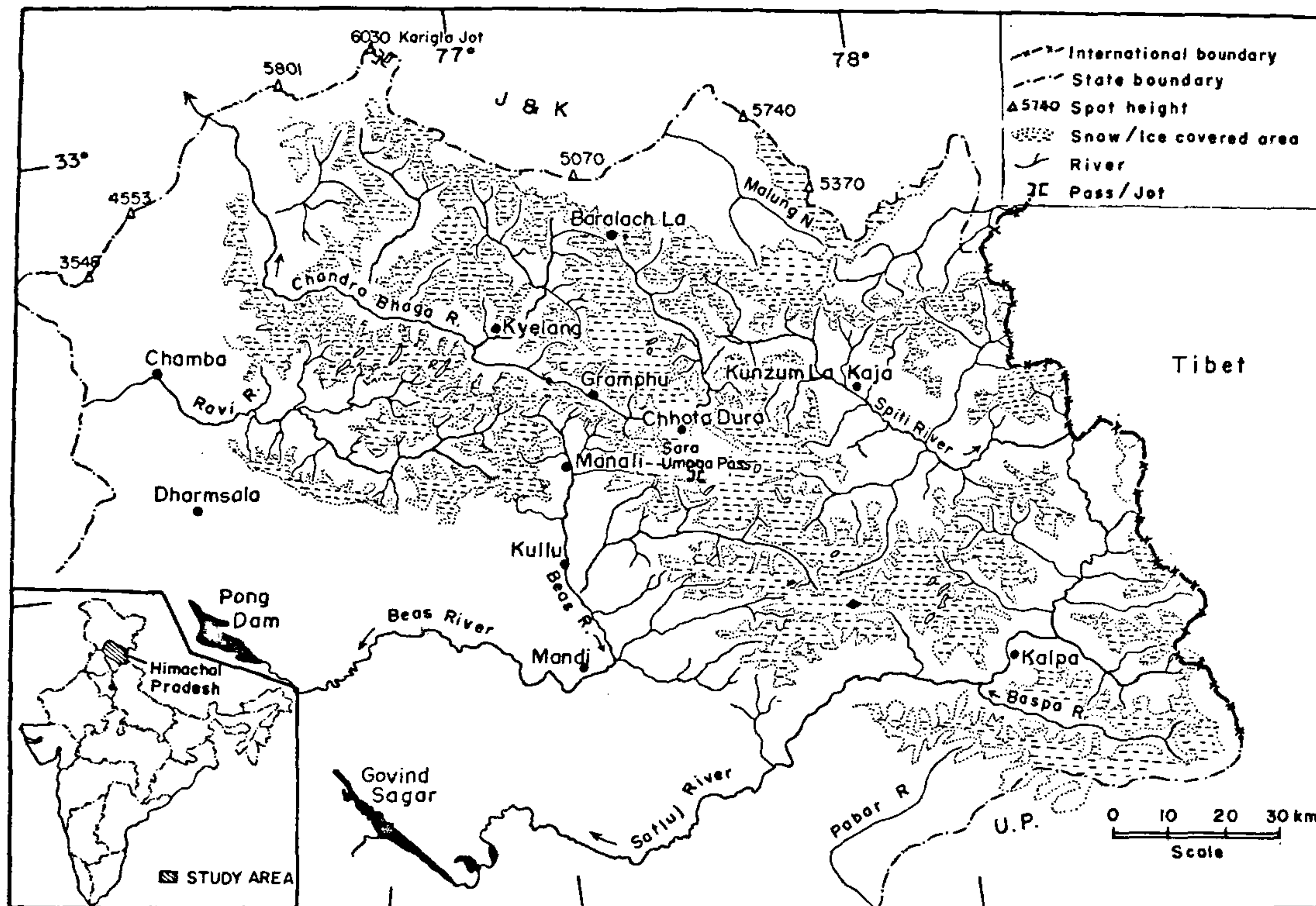


Figure 1. Permanent snow cover and glaciers regime map of study area (H.P.) (Based on Satellite Data, Oct.-Nov. 1988).

Table I. Number of glaciers identified in different basins

Basin	Basin area (km ²)	Glaciated area (km ²)	No. of glaciers	Average size (km ²)	Ratio between basin and glaciated areas
Chandra-Bhaga	7510	1778.98	200	8.89	4.22 : 1
Beas-Parbati	14,070	729.59	80	8.03	19.28 : 1
Ravi	5154	340.97	54	6.03	15.10 : 1
Malung	1570	231.86	40	5.78	6.77 : 1
Spiti	5440	1151.12	159	7.23	4.30 : 1
Satluj	14,290	283.70	68	4.17	50.00 : 1
Total	48,034	4516.22	601		

Table 2. Summarized statistics for the glaciers in six basins

Parameters	Chandra-Bhaga	Beas-Parbati	Ravi	Mulang	Spiti	Satluj
Total basin area (km ²)	7510	14,070	5154	1570	5440	4290
Glacierized area (km ²)	1778.98	729.59	340.97	231.86	1151.12	283.70
Glacierized area % of basin area	23.60	5.19	6.62	14.77	21.16	1.99
No. of glaciers	200	80	54	40	159	68
Length						
a) > 5 km	40	16	07	07	15	03
b) < 5 km	160	64	47	33	144	65
Types						
Longitudinal	66	21	23	—	56	17
Transverse	134	59	31	40	103	51
Largest glacier						
Length (km)	29	17.50	9.00	5.5	10.00	6.50
Area (km ²)	157	82.00	18.75	13.8	26.63	15.54
Elevation						
Maximum (m)	6200	5500	5400	6000	6000	6000
Minimum (m)	4000	4000	4000	5000	5000	5000

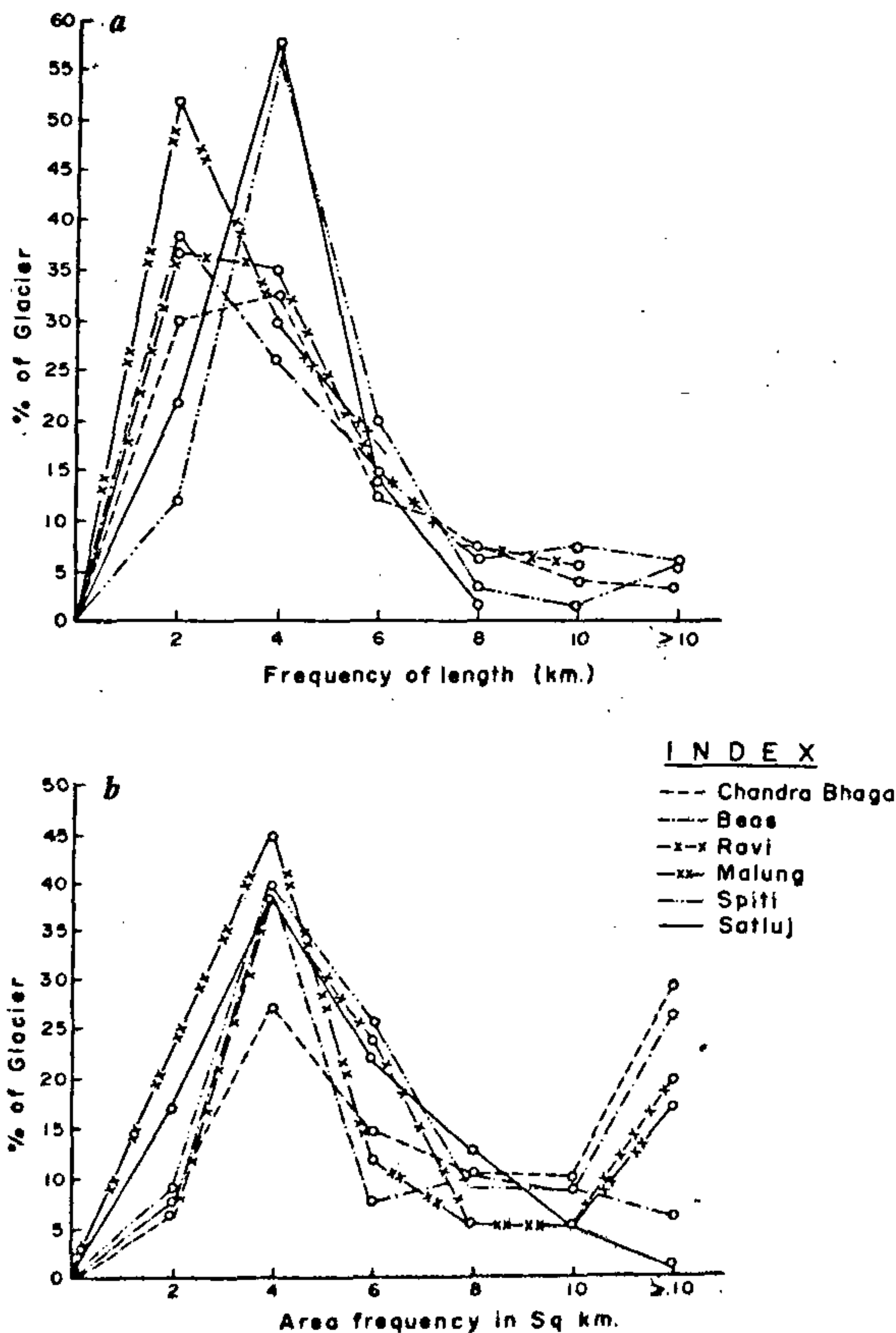


Figure 2. Frequency diagram of (a) length vs glacier % and (b) area vs glacier %.

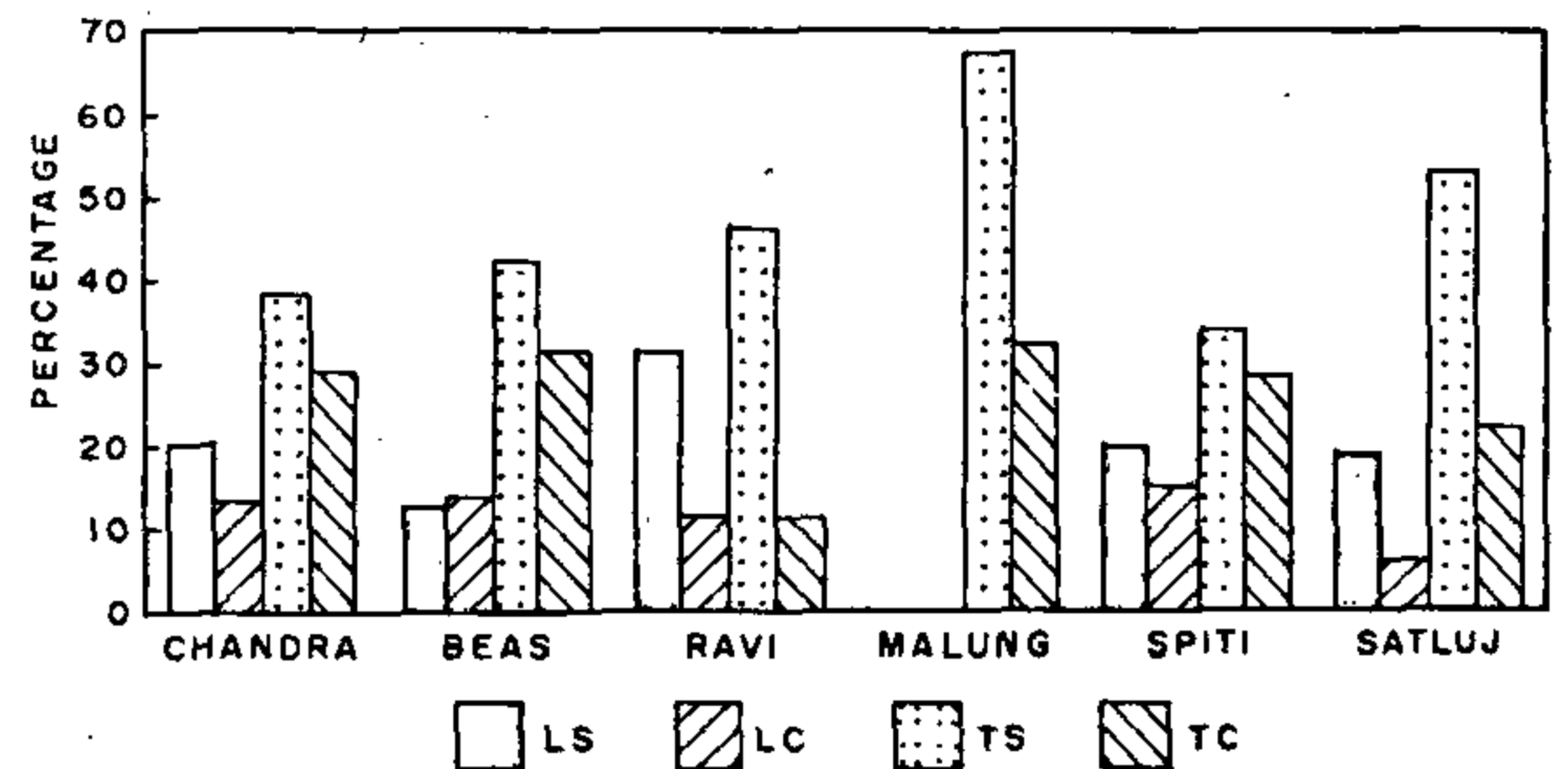


Figure 3. Distribution of glacier types in different basins.

of the glacier is controlled by topographical slope of the region. Most of the Himalayan glaciers are oriented N-S whereas valleys are mostly E-W or parallel to the orographic trend of the Himalaya. In Himachal Pradesh the orientations of identified glaciers have been determined and rose diagrams prepared on the proportion of glacier catchment in sixteen compass sectors (Figure 4). Glaciers in Chandra-Bhaga, Spiti, Malung and Satluj are mostly northward oriented (> 50%), while the majority of glaciers in Beas-Parbati and Ravi basins are southward. It is also observed that glaciers with northward orientation are longer and cover larger area, for example Bara Shigri (29 km covering 157 km²), Mujrilangang (13.75 km covering 30.7 km²) and Chhota Shigri (9 km, covering 8.75 km²); southward glaciers are smaller in length, cover less area and are steeper.

The maximum concentration of the glaciers is between 4500 m and 5000 m altitude, while a few of them extend down to 3800 m. The lower limit (snout position) of

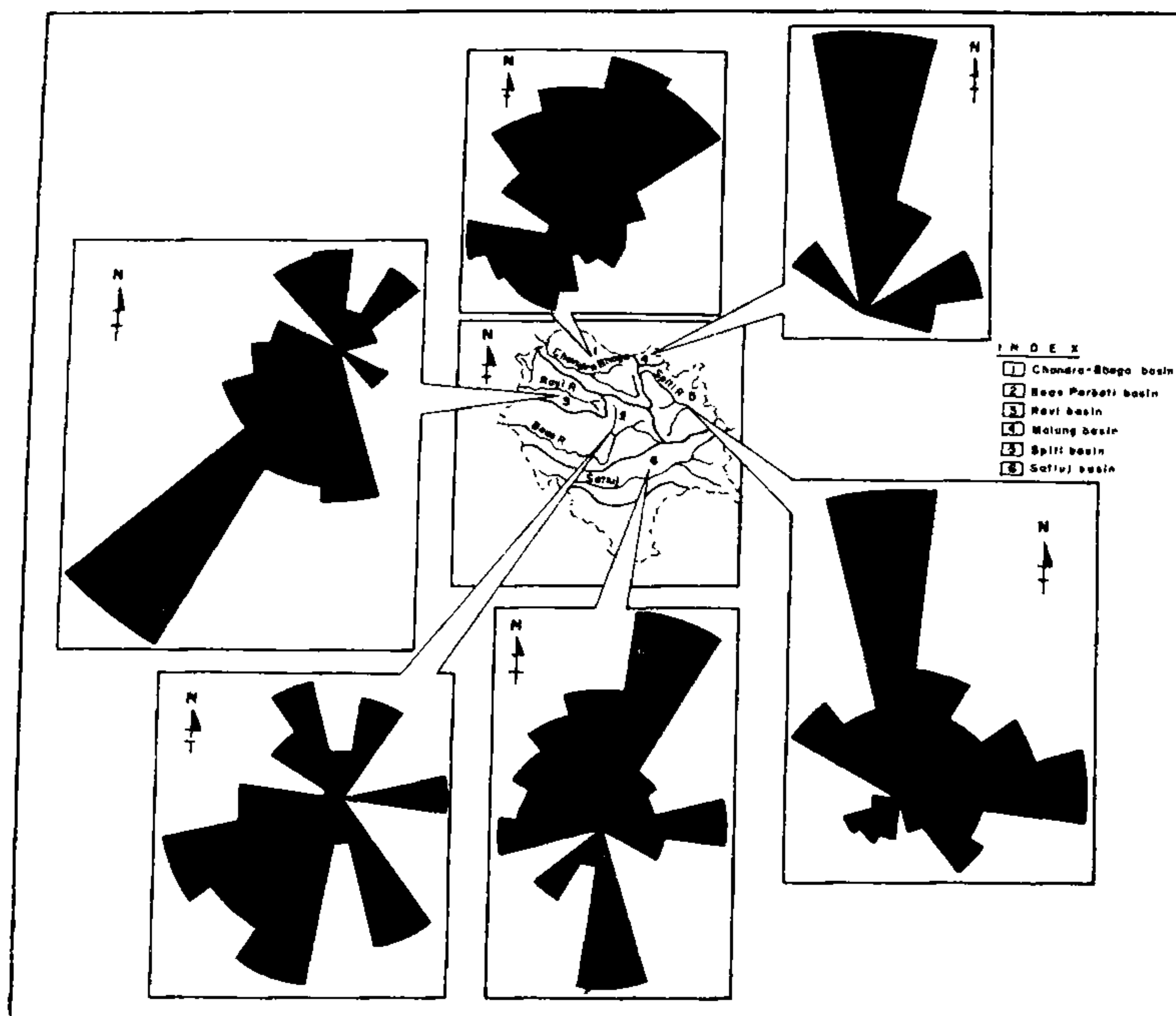


Figure 4. Glacier orientation in different basins of Himachal Pradesh.

the glacier fluctuates between 4000 and 5000 m in different basins. The orientation of the glaciers depends on the topographic conditions and the orographic control of the mountain. Thus orientation is spread over in all directions, with main concentration northward (58%) and southward (32%).

The slope/gradient of the glaciers varies between 3 and 33 degrees, but sometimes sudden increase in slope gives the evidence of surging or ice cliff on the glacier body. Where the slope is more the snow does not stand longer. Such glaciers can be considered as hanging glaciers and become vulnerable to avalanches and other glacier hazards.

Glacier development in a terrain is dependent on the topographic and climatic conditions of the region. Study of glacier development is useful for understanding present and past climatic and environmental changes. Statistical comparison of higher latitude glaciers with lower latitude glaciers (Himalayan type) can give an idea and correlation of control of precipitation and palaeoenvironment.

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