

CHAPTER II

PHYSICAL SET UP OF NORTH SIKKIM

2.1 INTRODUCTION.

The State of Sikkim is bounded in the north by the vast stretches of the Tibetan Plateau (China) and to its west, lies the kingdom of Nepal. In the east, the State is bounded by Bhutan and the Chumbi vally of Tibet (China). The Darjeeling District of the State of West Bengal stretches along its southern boundaries. Geographically: Sikkim lies between $27^{\circ} 4'46''$ N to $28^{\circ} 7'48''$ North latitudes and between $88^{\circ} 55' 25''$ to $88^{\circ} 0'58''$ E longitudes extending approximately 114 km. from north to south and 64 km. from east to west. Since north Sikkim has been chosen as the area under the present study, it will be meaningful if the study area is defined in terms of its extension, delimitation and relative location .

North Sikkim as stated above is thus bounded by Nepal in the West, Tibet (China) in the north and east. In addition, the region has distinct mountain chains that separate itself from the neighbouring countries such as Nepal, Bhutan and Tibet (China) Singalila Chain of mountains in the west that commences from Kanchendzonga and stretches towards south, separates north Sikkim from Nepal. Similarly, central Himalayan chain that runs towards the north forms a natural boundary with Tibet (China) and in the process is broken up into many massive peaks such as Kanchendzonga, Kabru, Pyaramid, Tongsang, Lhonak peaks, Chomo Yommo, Kanchengyao and Pauhunri all lying in the east. The Dongkya or Chola chain runs from Pauhunri to the south and forms boundary between Tibet (Chain) and Bhutan. The elevation of the region varies between as low as 800 m. to as high as 8579 m. above sea level. Owing to this great altitudinal variations within a relatively small geographical space, climatic conditions to a varying degree from sub-tropical through alpine vegetations to perpetual snows generally prevail in the region.

The enclosed valleys are deeply cut by V shaped water courses (Plate 4) and their greatest effect is distinctly visible at Chungthang where two rivers namely Lachen and Lachung meet (Plate 5)



Plate 4. V shape Valley with meandering river Tholung (North Sikkim). The rivers are swift and not navigable.

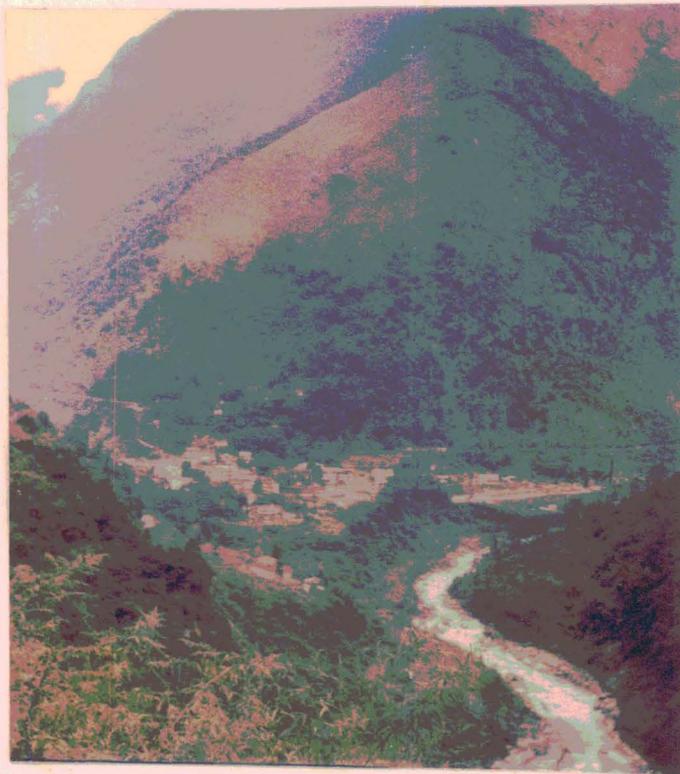


Plate 5. Chungthang town meeting place of Lachen and Lachung river.

2.2 AREA AND DELIMITATION.

North Sikkim consists of 4226 sq km. which accounts for about 60 percent of the total area of the state i.e. 7096 sq. km.. The break up of the area statistics of North Sikkim which is based on the survey conducted by the State Forest Department is given in Table 2.1.

Table 2.1
AREA STATISTICS FOR NORTH DISTRICT OF SIKKIM
(Area in sq. km.)

SL.No.	Class/Category	Area under Reserved Forests	Area falling under Revenue Block	Total Area	Percentage to Total geographical
1.	Crop Land	0.00	95.77	95.77	2.27
2.	Mixed Forest	476.70	177.93	654.63	15.49
3.	Conifer Forest	557.80	42.64	600.44	14.21
4.	Forest Blanks				
	Scrubs	103.21	0.00	103.21	2.44
5.	Alipine Scrub/ Pastures	890.00	18.53	908.61	21.50
6.	Alipine Barren	649.61	0.00	649.61	15.37
7.	Snow	1115.77	0.00	1115.77	26.40
8.	Lakes, Streams				
	Dry Rivers	80.93	10.86	91.79	2.17
9.	Township	0.00	0.17	0.17	0.01
10.	Major Land slides	1.61	0.00	1.61	0.14
11.	Misc.	4.39	0.00	4.39	0.10
	Total	3880.10	345.91	4226.01	100.00

Source: The Sikkim State Forest Department and RRSSC, Dept. of Space Govt of India (1988).

From the above table it can be seen that the total area available for cultivation in North Sikkim is as little as 95.77 sq. km. which accounts for about 2 percent of the total geographical area. However the area under the Forest is estimated to be 1255 sq.kms. that accounts as much as 30 percent of the total geographical area of the region. The area available for grazing is 908 sq.kms. i.e. 22 percent of the total area of North Sikkim. From this it could be inferred that North Sikkim has tremendous scope for livestock development in future.

2.3. GENERAL GEOLOGY

Transversely, from south north the Sikkim Himalaya can be divided into four tectonic belts namely (i) Foot hill belt (this belt falls in Darjeeling hills of west Bengal) (ii) Inner or lesser Himalayan belt (iii) Axial belt and (iv) Trans axial belt. Each tectonic belt is separated by Tectonic Thrust.

The stratigraphic units from north to south as worked out by different geologists are as follows :

Formation /group	Lithology
Gondwana	shale/sandstone with thin bands of coal. Pebble/boulder bed (Age - permo - carboniferous)
Uncoformity Buxas	Dolomites Limestone, Slate Calcareous & non-Calcareous & non-Calcareous purple phyllites. (Age-pre-Cambrian)
Thrust Dalings	Chloritic Phyllite, Sericitic Phyllitic, quartzitic phyllite, Phyllitic quartzite, Massive & thin bedded quartzites, Talc & Sulphide mineralisation (Age Pre-cambrian).

Thrust Gneiss	Biotite gneiss, high grade garnetiferous schist, Tourmaline bearing gneiss, Lingtse granitic gneiss. Calc gneiss, Marble, graphites etc. (Age Pre-cambrian)
Lachi Series/ Chho-Lhamo formation	Limestone, shales & quartzites (Age Jurassic)

The distribution of the above litho-units may be seen in Fig. 4 in the southern part of North Sikkim namely Dikchu, the rocks are classified under Darjeeling gneiss and are made of higher grade metamorphites. Similarly, at Mangan the rocks are of Chungthang gneiss which are again of higher grade metamorphites.

In the north of Kanchenzonga around Pauhunri, the important series include Chho Lhamo, Lechi, Mount Everest Limestone and Everest pelitic series etc.⁶

The photography of the Chho-Lhamo series of rocks are shown in plate 6. The plate shows extensive damage caused to the grazing ground by intensive weathering of Chho Lhamo series of rocks. This is a common feature at Lhonak, Muguthang and Chho-Lhamo grazing grounds where the debris along with screes are piled up. The situation is further aggravated by the presence of strong wind in the high altitude areas, leading to spreading up of small stones all over the grazing ground there by affecting the growth of the grasses adversely.

6. Rama, V.K. and Bhattacharya, M. Sedimentaries of North Sikkim. Records of the Geological Survey of India. Vol. 106(2) 1975. P 75-85.

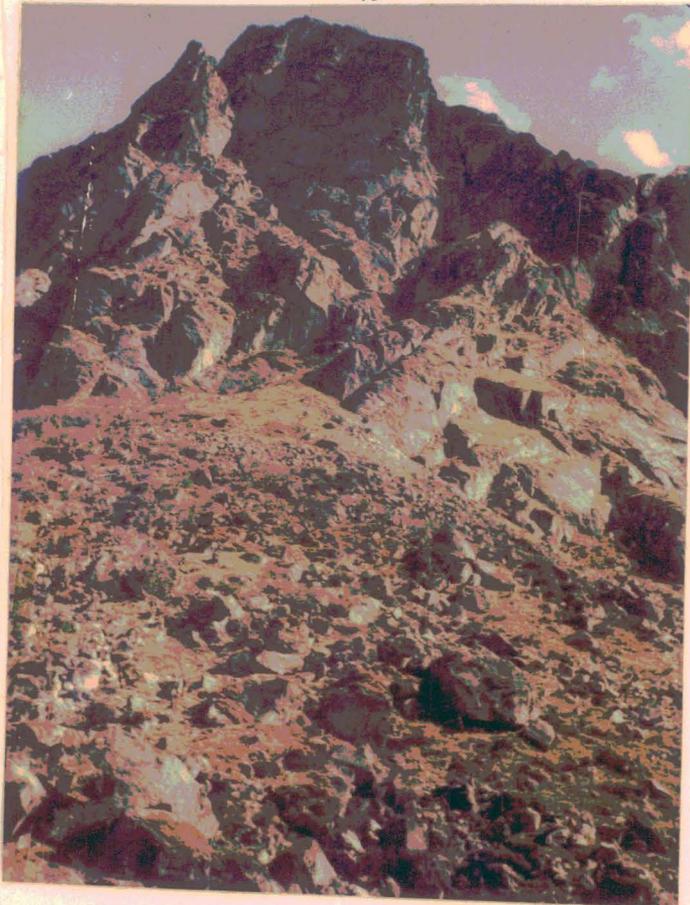


Plate 6. Photo showing the extensive damage caused to the grazing ground by intensive weathering of Chho Lhamo series of rocks.

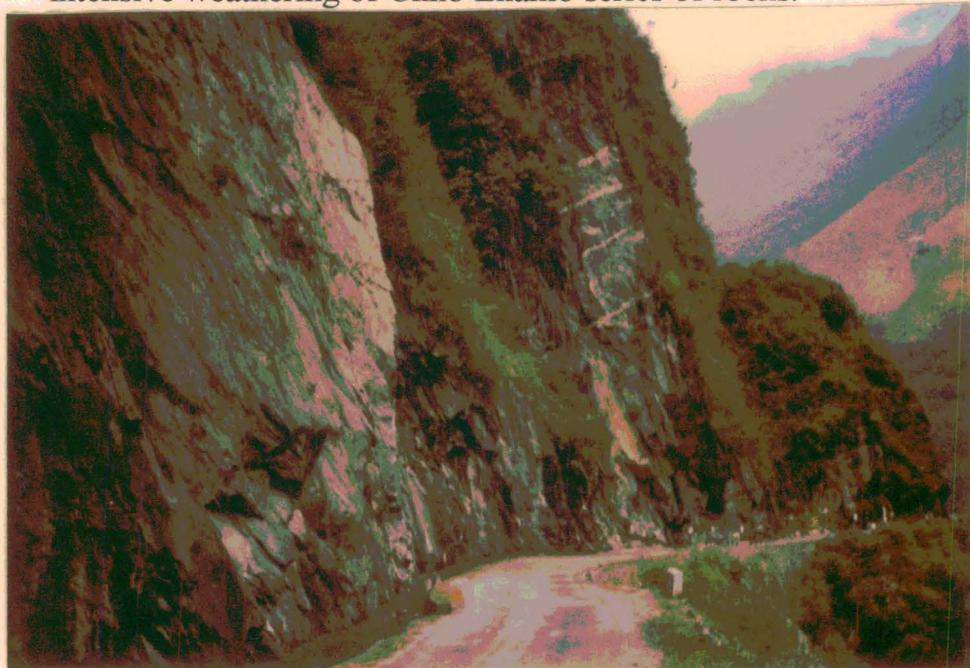


Plate 7. Steep angle of Dip of Chungthang rock series, showing the proximity of the axial belt of the Himalaya. (Such steep gradient of the slopes is typical of North Sikkim).

Chakraborty *et. al.* (1980) carried out geological survey between Lachen & Lachung covering an area of 225 sq. km. and their findings are indicated below:

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- (i). Northern part The rocks banded gneiss, granite gneiss augen gneiss, streaky gneiss and migmatite all intruded by massive biotite granite, quartz-tourmaline rock and pegmatite.
 - (ii). Southern part The rocks mapped are Kyonite Sillimanite-garnet, biotite-quartz schist, cal-granulite, marble and quartz ite.
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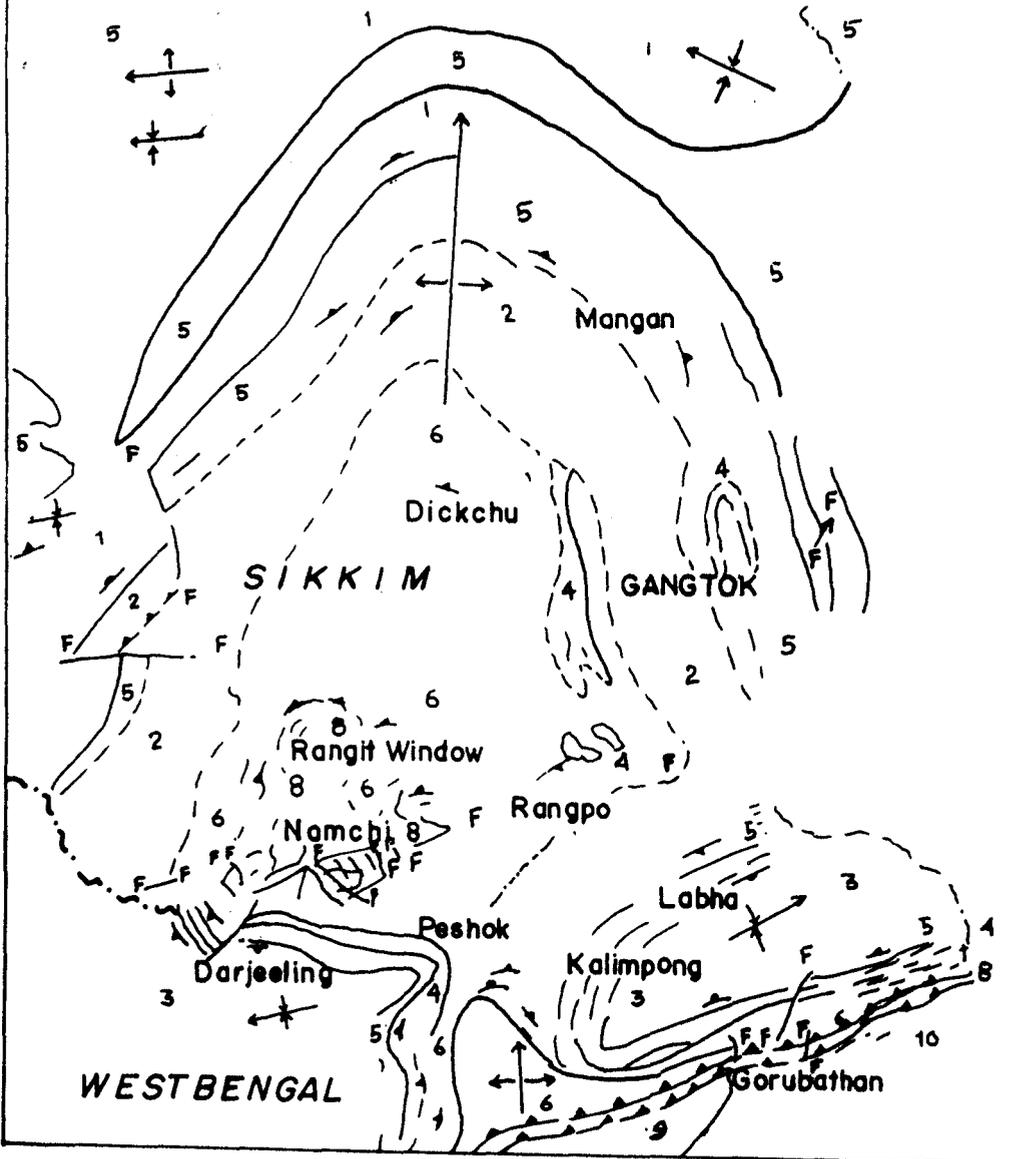
Plate 7 shows the steep angle of dip of the Chungthang rock series showing the proximity of the axial belt of the Himalaya. The steep gradient of such slopes are typical of North Sikkim where in goat, wild goat and sheep can only graze in such areas.

2.4 CLIMATE

Climate plays an important role in determining the nature of the Landscape and the type of flora and fauna of the region. Understanding the climate of a region is very important especially in livestock management as it affects animal productivity through its influence on the vegetation growth and animal physiology. The main climatic factors include air temperature, air humidity, air movement (wind velocity), precipitation, (rain, snow etc.) radiation (solar and long wave) atmospheric pressure and so on.

For hilly and mountainous environments, Hussain (1988) recommends collection of metereological data from a large number of Metereological stations so as to determine the variation of temperature and rainfall within a short distance.

GEOLOGICAL MAP OF SIKKIM



- 10 Alluvium
- 9 Siwalik
- 8 Damuda
- 7 Pebbly Slate horizon } Gondwana
- 6 Daling
- 5 Chungathang
- 4 Lingtee Gneiss
- 3 Darjeeling Gneiss
- 2 Inter banded Darjeeling gneiss and high grade Daling schist
- 1 Kanchanjungha Gneiss

Dominant foliation,
 Thrust plane,
 Fault plane
 Antiform }
 Synform } Attitude of regional fold axis

Fig 4. Geological map sketch of Sikkim.

Keeping the importance of the above points in view an attempt has been made to collect information on Meteorological data from as many stations located at different elevations in Sikkim as possible. Unfortunately, except Gangtok, there are no organized Meteorological station in Sikkim. The data have thus been collected from various source such as State department farms, dakbunglows and Border Roads organization etc. The details of the location of meteorological stations in the region are as follows:

SL. No.	Name of the meteorological station	Elevation in metres
1.	Dikchu	869 m.
2.	Gnon Sandong	1100 m.
3.	Mangan	1310 m.
4.	Singhik	1402 m.
5.	Manul	1408 m.
6.	Chungthang	1631 m.
7.	Lachung	2633 m.
8.	Lachen	2697 m.
9.	Yumthang	3673 m.
10.	Thangu	3812 m.

North Sikkim is located in proximity to border of Tropical Warm Gangetic plains and the alpine Tibetan (China) plateau including permanent snow capped Himalayan mountains. A cross section from Gurudongmar lake to the Bay of Bengal is Shown in Fig. 5 to gain an insight into climatic zone. In view of this unique geographical situation there is observed a gradual change in climatic conditions like rainfall, temperature etc. from south to North in Sikkim.

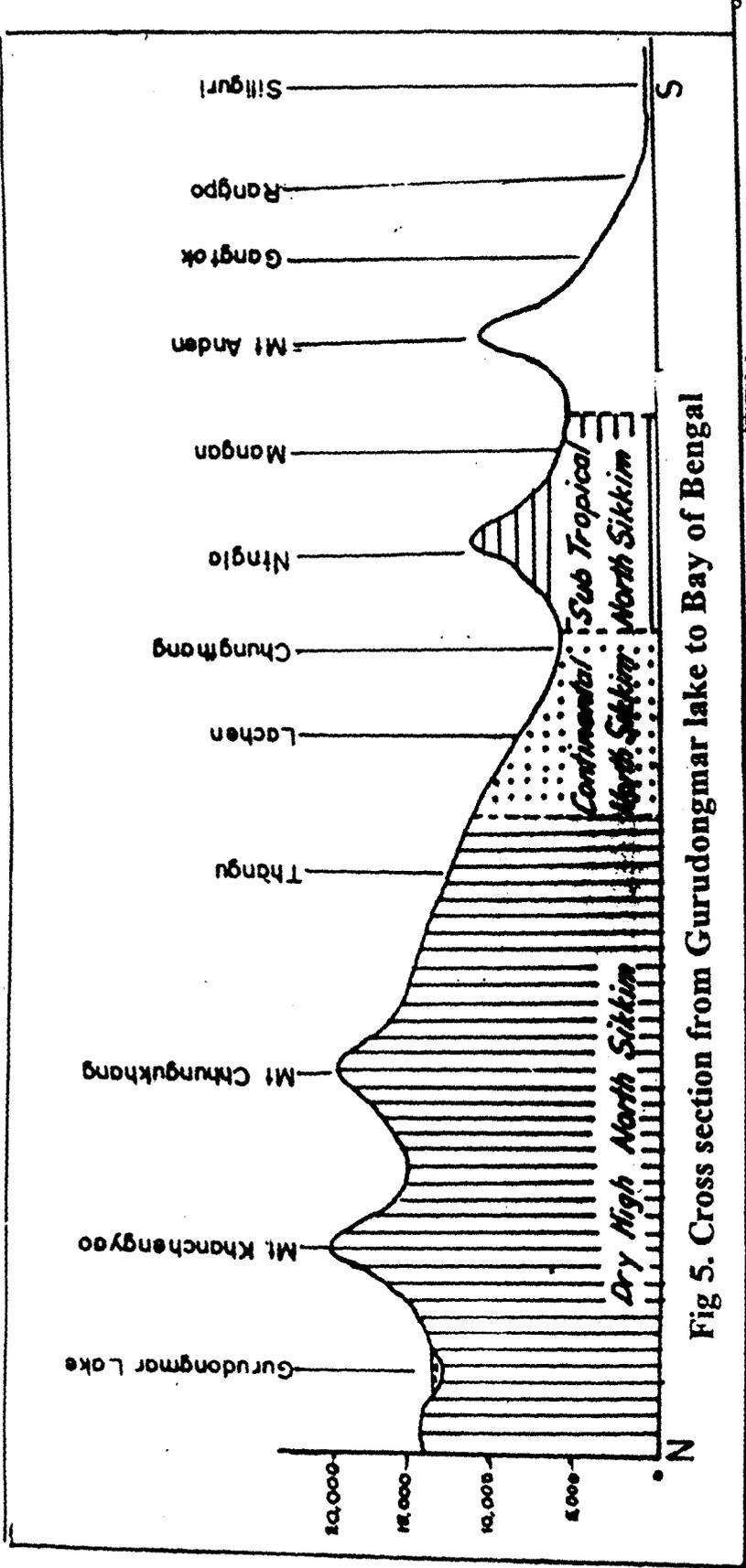


Fig 5. Cross section from Gurudongmar lake to Bay of Bengal

Moreover, the rainfall in North Sikkim is governed by the arrival of monsoon. During the month of March and April the cold heavy airmass over the Himalayas including Sikkim begins to warm up and gradually low pressure zone is created while high pressure zone is established over the Bay of Bengal and thus the moisture laden winds blow from Bay of Bengal to North Sikkim .(Fig. 6). Similarly, the reverse situation is created in winter where the sea cools faster than the land mass and the coldwind blows from the mountains to the plains.(Fig.6.).

2.4.1 PRECIPITATION

In North Sikkim the rainfall generally increases with increase in altitude. This trend is normally observed up to the village Manul located at 1408 m. a.s.l. altitude. But beyond this village the rainfall again starts decreasing with increase in altitude. At Dikchu (869 m. above m.s.l.) the annual rainfall is 3234 m.m. and at Gaon Sandong (1100 m. above m.s.l.) the annual rainfall 4243 m.m. But at Manul (1408 m. above m.s.l.) the annual rainfall is highest i.e. 5648 m.m. However, the annual rainfall decreases above Manul. This could be substantiated by the fact that as one goes higher up from Chungthang which is located at about 1631 m. above m.s.l. the annual rainfall keeps decreasing. Thus, Chungthang at an altitude of 1631m. above mean sea level receives an annual rainfall of 2447mm. Similarly, Lachen which is located at 2697m. above mean sea level registers an annual rainfall of 1652 mm. In the process and still at higher altitude Thangu, located at 3812 m. above m.s.l. receives the lowest annual rainfall of 821 mm . From the above variation in annual rainfall pattern, the entire north Sikkim is divided into three regions (Fig. 7) i.e. Dry High Zone where the annual rainfall is between 500 to 850 mm followed by the Continental upper zone where the annual rainfall ranges from

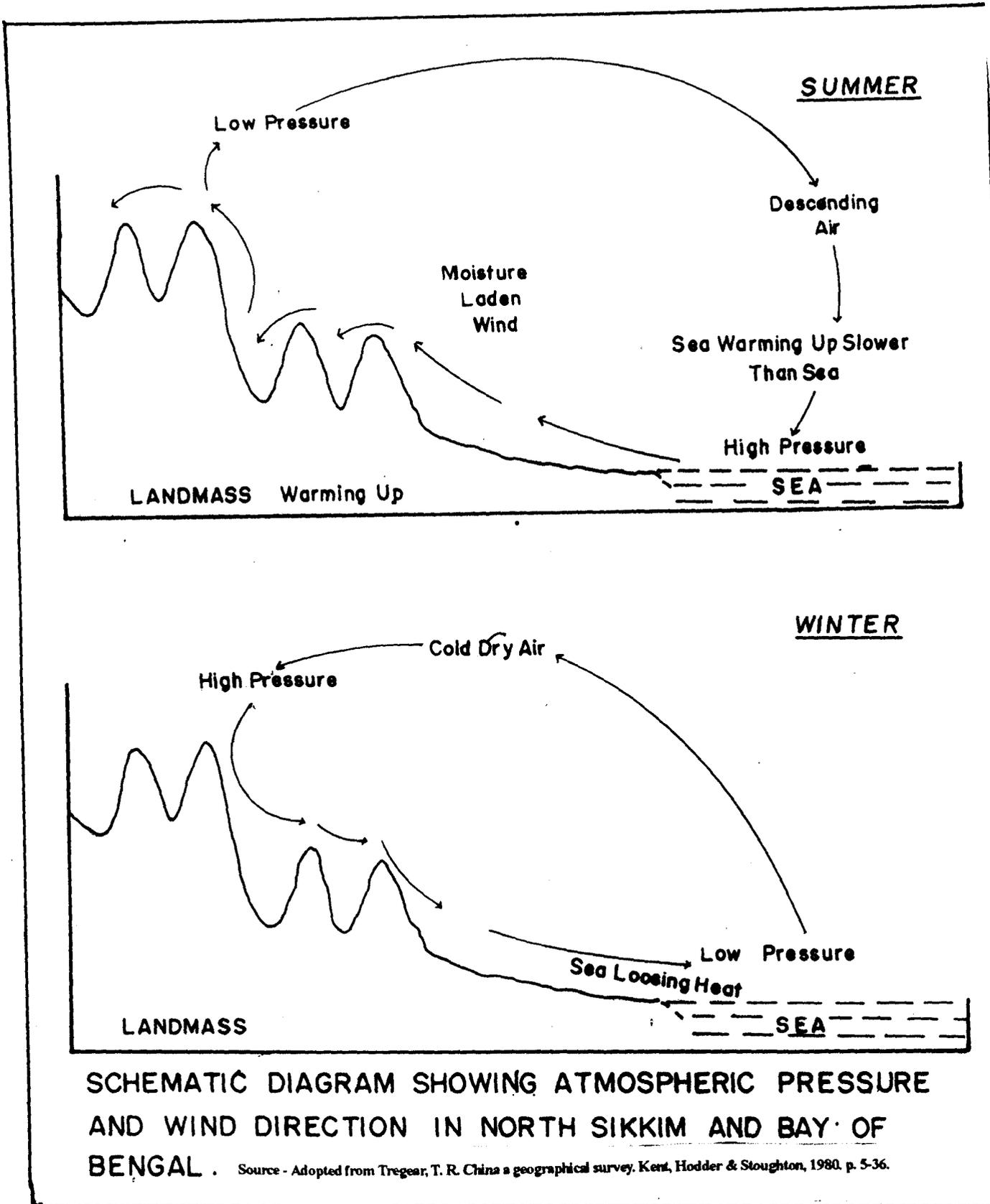


Fig 6.

1500 to 2000 mm and finally the sub-tropical Lower Humid zone where its mean annual rainfall ranges from 2447 to 5648 mm, (Table 2.2).

Table 2.2

MEAN ANNUAL RAINFALL IN NORTH SIKKIM

Zone	Elevation (in m.)	Mean Annual Rainfall (in mm)	No. of Annual Rainy days
(A) SUB-TROPICAL HUMID ZONE			
1. Dikchu	869	3234	152
2. Gnon Sandong (Dzongu)	1100	4334	N.A.
3. Mangan	1310	3240	161
4. Singhik	1402	2989	169
5. Manul	1408	5648	N.A.
6. Chungthang	1631	2447	N.A.
(B) CONTINENTAL UPPER ZONE			
1. Lachung	2633	1704	155
2. Lachen	2697	1652	161
3. Yumthang	3673	1474	160
(C) DRY HIGH SIKKIM			
1. Thangu	3812	821	100

Source: (i) The rainfall figure for (Dzongu) Gnon Sandong has been recorded by the Department of agriculture Government of Sikkim (ii) The rainfall figure for Manul has been analyzed by self from the records maintained by 46 Border Roads Task Force (iii) The rainfall records of the other stations have been taken from the report of the High Level Central Team on Land Use in Sikkim, 1981.

2.4.2 TEMPERATURE

North Sikkim could be divided into three distinct Climatic divisions such as Continental upper zone, dry high Sikkim and subtropical humid zone which are primarily based on a wide variation in temperature in the region.

For the present study, the temperature conditions prevailing at the subtropical humid zone and the continental upper zone have been taken into consideration. In view of non availability of data the temperature conditions of dry high Sikkim have not been analysed. The data on temperature have been procured from various sources such as the Border Roads Organisation, Department of Agriculture, Govt. of Sikkim and the report of the High Level central Team on Land Use in Sikkim, 1981 etc. Thus the temperature recorded at Lachung and Manul have been obtained from the Border Road Roads Organization. The following discussion on the temperature conditions in the region exclusively pertains to the subtropical Humid Zone and Continental upper zone.

2.4.2.1. PREVAILING TEMPERATURE IN CONTINENTAL ZONE

As has been said earlier, Continental upper zone in North Sikkim could be considered as an area extending between altitude 1600m to 3812m. The following picture emerges from the temperature conditions prevailing in the area. As Lachung and Lachen fall under the continental upper zone, the mean, mean maximum and mean minimum temperature recorded at these stations could be seen in Appendix v. The mean minimum temperature ranges between 3.9 ° c in January to 19.50 ° c in July at Lachung while at Lachen it ranges between 1.5 ° c in January to 17.8 ° c in July. Lachen therefore seems to be Colder

than Lachung. The mean maximum temperature ranges between 13.5 ° c in January to 26.25 ° c in July at Lachung while at Lachen the same varies between 6.9 ° c and 17.8 ° c in January and July respectively. The mean minimum temperature recorded at Lachung during the month of January is 5.75 ° c and in July the mean minimum temperature recorded is 12.75 ° c. At Lachen similarly the mean minimum temperature recorded in January is -3.9 ° c where as in July the same is 8.4 ° c. The fluctuation between mean minimum and mean maximum temperature appears to be very significant in this zone. From the pattern of temperature in these two stations it could be observed that the temperature starts rising from January onwards till October and again from the month of November onwards the same starts declining. Thus, based on the temperature pattern as highlighted above various season, in these areas could be demarcated in various seasons as follows.

Seasons	Months
1. Winter Season	November to march
2. Spring Season	March to May
3. Summer Season	June to October

2.4.2.2. SUB-TROPICAL HUMID ZONE

This climatic zone extends between altitude of 400 m. to 1600 m. in the region. The average mean, average mean maximum and average mean minimum temperatures recorded at Gnon Sandong (Dzongu) (1100m. above sea level) and at Manul near Mangan are given in Appendix VI. The mean temperatures recorded at Manul and Gnon Sandong in the month of January are 12.27° c and 11.25° c respectively which appear to be al-

most similar. Similarly, the mean temperatures recorded in the month of July are 24.667°c 24.50° c for Gnon Sandong and Manul respectively. The distribution of mean minimum and mean maximum temperature is shown in Appendix VI.

2.4.3 RELATIVE HUMIDITY

The relative humidity recorded at Gnon Sandong (Sub-Tropical) are presented in Table 2.3. At Lachen the average relative humidity ranges between 66 percent to 88 percent with the starting of the monsoon season, the relative humidity keeps increasing from 71 percent in April to as much as 88 percent in the month of August. There after it starts declining from the month of September till it reaches its minimum i.e. 66 percent in the month of December. At Gnon Sandong the relative humidity invariably remains above 70 percent except for the month of May and reaches as much as 85 percent in the month of July coinciding with the heavy downpour.

Table 2.3

**MONTHLY AVERAGE RELATIVE HUMIDITY RECORDED AT GNON
SANDONG AND LACHEN, NORTH SIKKIM**

Months	Gnon Sandong	Lachen
	Rel. Humidity (in percentage)	Rel. Humidity (in percentage)
January	79	68
February	82	70
March	77	66
April	71	71
May	63	76
June	79	78
July	85	78
August	82	88
September	76	86
October	74	76
November	72	68
December	70	66

Sources: (i) The data for Gnon Sandong has been obtained from the Agriculture department, Government of Sikkim (ii) Lachen has been taken from Mukhopadhyay, S.C, Tista Basin, A study in fluvial geomorphology. Calcutta, K. P. Bagchi 1982. Page 25-31.

2.4.4 WIND AND SNOW LEVEL.

Almost throughout the year the southerly wind predominates driving humid air masses in the inner valleys and crosses the Chungthang gap to enable the conifer forests to grow in the valleys of Lachen and Lachung. This scenario is observed up to Yumthang.

There is a marked difference in snow level in north Sikkim. In the southern side of Mount Kanchengyao the snow level is 4650m. Whereas in the northern side the snow level varies between 5700m to 6000m indicating relative dryness towards the northern region. The timber line at Thangu is at about 4200 m and the forest boundary is at an altitude of 1800m. above mean sea level.

2.5 VEGETATION OF NORTH SIKKIM

Based on the vegetative structure the entire Sikkim has been divided into three vegetative zones i.e. Tropical Humid Zone, Continental upper zone and Dry High Zone.⁷ Similarly adopting the same approach, North Sikkim is divided into three important climatic zones i.e. sub-tropical Humid zone, continental zone and Dry High Zone. In place of tropical humid zone, sub-tropical humid zone has been proposed as there are no *Shorea robusta* tree species in north Sikkim. Moreover the climatic data on temperature and precipitation of the region is well suited for the assessment of a hierarchical bioclimatic classification of the Holdridge "Life Zone" classification. This system has been adopted by F.A.O. (1988) while formulating environmental guide lines for resettlement projects⁸.

The names of the botanists and plant explorers who have contributed towards the vegetation of north Sikkim have already been reviewed in Chapter I and their observations on the vegetative zones and the forest types of North Sikkim are summarized in the next page.

7. Schweinfurth, U. Die Horizontale and Vertikale verbreitungder vegetation in Himalaya. Bonner Geogr. Abh. H. 20, 1957 p 372.

8. Burbridge, Peter R., Norgaard B. Richard., Hartshorn Gary S. Environmental guide lines for resettlement projects in the Humid tropics. FAO Rome. 1988.

2.5.1 SUB-TROPICAL HUMID ZONE

The altitude of this vegetation zone generally ranges between 800m to 1600m above sea level. In the lower hot and moist valleys of North Sikkim the prevailing vegetative structure is found to be a mixture of tropical and sub-tropical species.

The details of the important species found in this zone are as follows :

<i>Acer sp.</i>	<i>Magnolia Cambelli</i>
<i>Alnus sp.</i>	<i>Machilus edulis</i>
<i>Aralia sp.</i>	
<i>Betula sp.</i>	
<i>Berberis sp.</i>	<i>Michelia Carthcartii</i>
<i>Buddleia sp.</i>	<i>Prunus</i>
<i>Glcichenia sp.</i>	<i>Pyrus</i>
<i>Hydrangea sp.</i>	<i>Pieris llek</i>
<i>Quercus pachyphylla</i>	
<i>Quercus annulata</i>	
<i>Quercus lanuginosa</i>	
<i>Quercus lamellosa</i>	<i>Styraok</i>
<i>Rhododendron arboreun</i>	<i>Sorbus</i>
<i>Rhododendron dalhousiac</i>	<i>Symplocos</i>
<i>Rhododendron barbatum</i>	<i>Sikkimia</i>
<i>Rhododendron falconeri</i>	

The important plants that grow in the undergrowth of the lower humid zone forest of North Sikkim are *Aracas*, *Impatiens*, *Seneciones*, *Helichrysum*, *Epilobium*, *Pediculars cordyalis* etc. The important grasses are *Arundinella bengalensis*, *Saccharum spontaneum* and *Setaria palmifolia* etc. at an elevation of 1700 m. *Themeda candata* with *Cnicus sp.* form dominant grasses.

The bamboos form main components of the grassland in this region. These include *Chimonobanibus callosa*, *Cephalostachy mlatifolium* *Dandrocalamus Sikkimensis*. The valuable broom grass *Thysanolaena agrostis* is widely cultivated in this zone for commercial purposes. In the landslide areas, the first plant to colonize is *Alnus nepalensis*. However on the newly cut rocks for road construction, the first species to colonize is *Thysanolaena agrostis*. This zone has also taken up cardamom (*Amomum cardamom*) plantation in extensive scale particularly in the shady areas and this unique system has increased the forest cover in this zone. The classification of the deciduous and high cloud forest in this zone are as follows :

Elevation	Species
1800-2100 m.	<i>Michella, Cathartic, Magnolia, Machilus edulis.</i>
2100-2400 m.	<i>Quercus lamellosa, Magnolia excelsa, Magnolia cambelli</i>
2400-2700 m.	<i>Quercus Lamellosa, Quercus Pachyphylla, Acar, Magnolia, Arundinaria, Rhododendron.</i>

At an elevation of 2000 m. the transition of the tropical hill forest to deciduous hill forest seems to be complete and above 2500m. *Rhododendron sp.* is extraordinarily widespread. However, above 2700m. altitude the conifers generally take over.

2.5.2 Continental Upper Zone

The elevation of this zone generally between 1600m to 3812m above mean sea level. The narrow Chungthang gap separates the lower sub-tropical humid zone from Upper Continental Zone. In this upper part of Sikkim *Rhododendron arboreum*

is distributed in the areas ranging in altitude between 1500 m. to 1800m. *Taxus baccata* appears at 2100m. and *Tsuga species* at 2100m. altitudes. The slope above Chungthang is normally barren and remains mostly grass covered and few pine trees occur only in the ridge (plate 5). The plant species of Lachen and Lachung areas are described separately below.

2.5.2.1 Vegetation of Lachen Valley

The Lachen area commences from Chungthang and covers the western tributary of Lachen river upto Lachen (2400m to 3300m). The vegetation recorded in this area at an elevation of 2400m to 3300m. are discussed below :

Species at lower river beds of Lachen	Range of distribution at different elevation
1. <i>Larix Griftithii</i>	2400m - 3300 m
2. <i>Tasuga dumosa</i>	2100m - 3000 m
3. <i>Picea morind</i>	lower limit 2400 m
4. <i>Alnus nepalensis</i>	upper limit 1800 m

The mixed pine forest *Taxus baccata*, *Junipers* are supported by extensive larch trees which are characteristically the most important trees of the inner valleys of Eastern Himalayas. Several deciduous trees appear in between the above mixed pine forests and the details of these species are recorded in the next page.

(a). Deciduous trees (generas)

<i>Alnus</i>	<i>Pyrus</i>
<i>Acer</i>	<i>Prunus</i>
<i>Betula</i>	<i>Salix</i>
<i>Corylus</i>	<i>Sorbus</i>
<i>Fraxinus</i>	
<i>Juglans</i>	

(b). Shrubs:

<i>Berberis</i>	<i>Rosa</i>
<i>Euonymus</i>	<i>Rubus</i>
<i>Elacagnus</i>	<i>Rhododendron</i>
<i>Gaultheria</i>	<i>Ribes</i>
<i>Llek</i>	<i>Sambucus</i>
<i>Litsaea</i>	<i>Spirala</i>
<i>Lonicera</i>	<i>Virburnum</i>

In addition to above, the following species plants of North America and South East Asia are also found in this belt.

1. NORTH AMERICAN PLANTS :

<i>Aralia</i>	<i>Magnolia</i>
<i>Buddlein</i>	<i>Panax</i>
<i>Camellia</i>	<i>Sassafras</i>
<i>Deutzia</i>	<i>Stauntonia</i>
<i>Enkianthus</i>	<i>Skimmia</i>

2. SOUTH EAST ASIA PLANTS :

<i>Egelhardtia</i>	<i>Marlea</i>
<i>Lauzaces</i>	<i>Orchis</i>

2.5.2.2 VEGETATION OF LACHUNG VALLEY :

Lachung covers the Eastern territory of the Continental moderate Sikkim. As the valley opens, the first hamlet to come across is Khedum. Khedum is located at the same sea level as Darjeeling, yet there is a marked difference in vegetation cover in this micro region.

This valley contains rich deciduous cloud forests alongwith inner conifer forests and also deciduous trees similar to Lachen valley. The pine forest continue to grow in the upper region of the valley of Lachung and reach their upper limit at 3900m. The vegetation of the summer grazing grounds of the upper Lachung valley is briefly described below :

(a) Yumthang: The valley is generally boggy and grass covered along with *Hippophae salicifolia*. The pine forest is dense particularly on the slopes towards Yumthang glacier.

(b) Taukra : The valley floor of the grazing ground is covered with dense *Rhododendron species* and grasses.

(c) Sebu Valley : In Sebu Valley *Larix Griffithii*, *Picea spinulosa* and *Tsuga dumosa* reach their upper limit of 3200 m and are then replaced by *Abies densa* along with *Prunus*, *Pyrus*, *Acer* and *Rhododendron*. From 3300 m the *Juniperus recurva* takes over. This valley is famous for cow farming. Valley floor of Sebu Chu is covered with dense *Rhododendrons* and growth of *Aconitum nepalensis* is prominent.

(d). Gora valley: The south face of the valley bear pine forests and the rest are grassy meadows.

2.5.2.3 SUB-ALPINE ECOSYSTEM

Generally at 3900 m the conifer forests change into sub-alpine forest level in North Sikkim. This level is generally made up of *Juniperus*, *Betula*, *Salix*, *Pyrus aucuparia* and *Rhododendron*. Area between Lhonak and Zema subalpine *Rhododendron* forests with thick bamboo under growth are found in sheltered places.

Thangu is the last home of the subalpine forest in the Lachen valley. The existing genera are *Betula*, *Lonicera*, *Sorbus* and *Rhododendron*. In the Lachung region *Rhododendron* alongwith *Salix*, *Pyrus foliolisa* and *Pimicarophylla* form an impassible dense forest at upper Tankara and Sebu valleys. Yume Samdong (3900 m) the highest part of the Lachung valley is the last level for sub-alpine, forest which consists of *Rhododendron*, *Junipers*, *Salix*, *Betula*, *Ephedra* and *Lonicera* showing the continental eco-system.

2.5.2.4. ALPINE ECOSYSTEM

Alpine level begins from the timber line. In general in Eastern Himalaya, the *Rhododendron* carries across to the alpine level, however, in North Sikkim the herbal flora increases in abundance and the coverage of *Rhododendron* decreases and there is a distinct transition between moist alpine zone and the alpine steppe.

The alpine vegetation of the upper Zemu valley is divided into three parts i.e. North exposed, the South exposed and the area in the immediate vicinity of the glacier.

(i) SOUTH EXPOSED SLOPES:

The exposed slopes are at a height of 5085m (Nachegah) and 5150 m (Tangchung). The area which faces the warm moist air streams from South is snow free in the early part of the year and countless rivulets are dried and in summer, the flora typical from 3900 m. climbs up on these slopes upto 5100 m. The species are as follows:

<i>Anenome</i>	<i>Cassiope</i>
<i>Anaphalis</i>	<i>Draba</i>
<i>Corydalis</i>	<i>Gentiana</i>
<i>Leontopodium</i>	<i>Saussurea</i>
<i>Pedicularis</i>	<i>Sakifraga</i>
<i>Potentilla</i>	<i>Sedum</i>
<i>Primula</i>	<i>Salix</i>
<i>Rheum</i>	<i>Siveertia</i>

(ii). NORTH EXPOSED SLOPES.

The North exposed slopes have snow between 4200 m and 4500 m. during the month of July and the area is almost completely covered by *Rhododendron* bush.

(iii) VEGETATION IN THE GLACIER REGION :

The area around the glacier is barren composed of steep hill slopes. The *Rhododendron* is far more sparse in this area alongwith *Gentiana*, *Primula* and *Salix*.

2.5.3 DRY HIGH SIKKIM

The Dry High Sikkim zone constitute the vast stretches and gently rolling countryside of Lhonak Highlands and Chho-Lhamo Highlands. The Lhonak Highlands are surrounded by snow covered peaks like Leh in Lhadak. The vegetation of these two highlands are described here separately.

2.5.3.1. LHONAK HIGHLANDS.

The vegetation limit in this valley is upto 5400m. The vegetation is mainly of Tussock type and *Juniperus* and *Rhododendron* grow close to the ground in hemispherical shrubs. The trees and bushes are completely absent. The prominent plants recorded in this region in addition to the above two species are:

<i>Androsa selago</i>	<i>Potentilla microphylla</i>
<i>Alardia sp.</i>	<i>Potentilla frusticosee</i>
<i>Brayo sp.</i>	<i>Primula muscoides</i>
<i>Cochlearia sp.</i>	<i>Polygonum nummalarefolium</i>
<i>Cortia sp.</i>	<i>Polygonum Hookeri</i>
<i>Draba sp.</i>	<i>Rheum nobile</i>
<i>Lanuginosa sp.</i>	<i>Rheum spiciforme</i>
<i>Meconopsis horridula.</i>	<i>Saxifraga imbricata</i>
<i>Myosatis Hookeri</i>	<i>Saxifraga ramulosa</i>
<i>Saussurea sp.</i>	
<i>Thlaspi sp.</i>	
<i>Veronica sp.</i>	

2.5.3.2. Chho-Lhamo Highland

Chho Lhamo area starts from upper Thangu. The vegetation structure shows more of the alpine steppe and there is gradual transition of wet alpine level of Thangu & Chopta area to dry alpine steppe of the Chho-Lhamo Highlands.

The vegetation zone in these highlands goes upto 5000 m. in the southern flanks of Mount Kanchengyao while area of Kanchengyao facing towards north, the vegetation level is between 5700 m to 6000 m. The plant recorded in this highlands are:

(a) In flatland swamps	<i>Zannichellia palustris</i> <i>Ranunculus aquatilis</i>
(b) In dry areas	<i>Arenaria</i> (hemispherical cushions)
<i>Androsace</i>	<i>Artemisia</i> <i>Leontopodium</i>
<i>Astragalus</i>	<i>Mysosolis</i>
<i>Carek Hoorecroftii</i>	<i>Meconopsis horridula</i>
<i>Drava</i>	<i>Nardostachys</i>
<i>Delphinium</i>	<i>Oxytropis chiliophylla</i>
<i>Ephedra</i>	<i>Pedicularis</i>
<i>Erigieron</i>	<i>Rosa</i>
<i>Gentiana</i>	<i>Rhododendron nivale</i>
	<i>Sibbaldia</i> <i>Sedum</i>

The rocks are mostly covered with lichens with patches of *Androsace* and *Sedum*.

2.6 The Soils of Sikkim.

The National Bureau of Soil Survey and Land Use Planning, Culcutta have identified 6 soil series Sikkim and the details are as follows:

Soil Series	Soil Sub-Group
1. Markong Hilley	Typic Haplumbrepts
2. Gompa	Lithic Haplumbrepts
3. Lingtse, Losep, Namthang	Typic Dystrochrepts.
4. Machong	Lithic Dystrochrepts.
5. Thekabong, Chatrikhola, Phadamchen	Umbric Dystrochrepts.
6. Putuli, Simkharka, Nandugaon	Lithic Udorthents.
7. Majhitar	Acquic Udifluents.
8. Tarku	Ultic hapludalfs.

The soil are mostly of Inceptisol, Entisol and mollisols orders.

Nutrient Statue of the Soils:

Bhutia, *et al* (1986) analyzed over five thousand soil samples all over Sikkim and mean values of pH, organic matter, Nitrogen, Phosphorus and Potassium are given in table 2.4.

Table 2.4

Mean Values of pH, Organic Matter, Nitrogen, Phosphorus and Potassium in the Soil of Sikkim.

Type of Test	South	East	West	North
1. P.H.	5.75	5.80	5.5	5.23
2. Organic Matter%	3.09	4.17	2.88	4.40
3. Nitrozen kg/Hact.	477.00	422.00	383.00	482.00
4. Phosphorus (P ₂ O ₅) (PPM)	30.99	24.75	24.54	37.18
5. Postassium (K ₂ O) (PPM)	138.00	127.00	142.00	93.00
No. of soil samples	1392.00	1380.00	1722.00	749.00

The land Use and Environment Department conducted the soil survey of Rongnichu Catchment (East Sikkim) in different altitudes ranging from 1,000 to 4,400 m. The findings are given in Table 2.5 and Table 2.6.

Table 2.5

Soil Reaction and Mechanical Composition

Altitude	Soil Reaction	Mechanical Composition Texture			
		(pH)	Clay%	Sand%	Silt%
1000 m		5.5	6.5	87.8	5.6 Loamy sand
2800 m		4.7	28.5	37.4	34.0 Silty clay loam
3200 m		5.6	17.5	53.8	28.6 Silty Loam
3900 m		5.2	32.5	41.8	25.6 Silty clay Loam
4400 m		4.7	27.5	47.8	24.6 Silty Loam

source : Land Use & Environment Department, Govt. of Sikkim, Gangtok.

These results indicate that the soils are mostly acidic with PH ranging from 4.5 to 5.8. In spite of being rich in organic matter (2.07 to 5%), they are deficient in available nitrogen and phosphorus. The potassium content has been assessed as low.

Table 2.6

RONGNICHU (EAST SIKKIM) NUTRIENT STATUS OF SOILS AT DIFFERENT ELEVATIONS

Altitude (m)	Organic matter	N (kg/ha)	P (PPM)	K (PPM)	Zn (PPM)	Cu (PPM)	Fe (PPM)
1000	4.15	193	50.7	91	1.3	0.22	5.1
2800	3.15	281	6.2	123	1.5	0.30	44.3
3200	2.07	235	61.6	191	1.6	0.26	20.2
3900	3.39	306	25.4	195	1.6	0.26	22.1
4400	5.00	413	4.9	219	0.7	0.15	67.2

Source : Land Use & Environment Department, Govt. of Sikkim, Gangtok.

The soils in general are characterised by low PH, high organic matter, low cation exchange capacity, and high lime requirement. In spite of high organic matter content the available Nitrogen content of the soils is not upto the mark. The soils have moderate Phosphorus status but fairly well supplied with Potassium. Deficiency of Ca, Mg and among micronutrients Zinc, Copper, Boron and Molybdenum are commonly observed. On the other hand the elements like Fe, Mn, Al are at toxic level. Soils have varied colours as grey, brown to black, red, yellow mixed red and black. Red and yellow subsoils are very common. At lower altitude grey, mixed red and black soils are common and higher altitude brown forest soils are common. The soil are by and large loamy in texture with varying amounts of coarse fraction and hence susceptible to erosion. The soil depth and fertility depends on the location whether on a flat valley or on moderate slope or on a steep gradient. However, on an average

the soil depth at hill slopes is reported to be 60 to 90 cms. In North Sikkim the details of the soil report pertains only upto Lachen and Lachung valleys only. No soil studies have however been carried out in the Lhonak, Muguthang and Chho-Lhamo areas.

2.7 PHYSIOGRAPHY AND DRAINAGE.

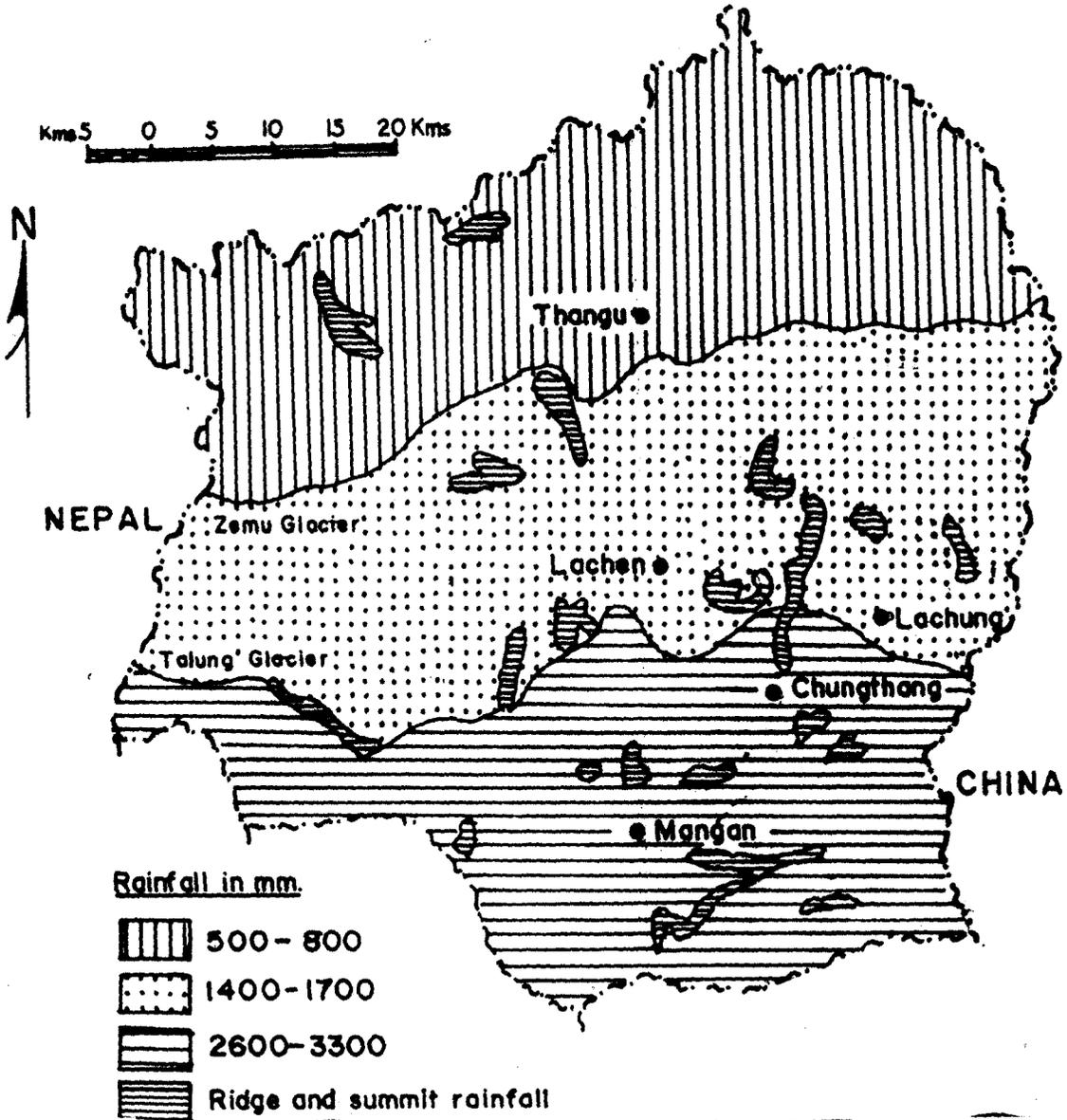
The North Sikkim is divided into three important physiographic regions i.e. the elevated dry area of Lhonak and Chho-Lhamo, the U shape valleys of Lachung, Lachen, Zema and Tholung and the V shape valleys of Dzongu, Mangan, Mangshila to Kabi. The entire area of North Sikkim is hilly and mountainous barring a few hundred square kilometres of flat and undulating land in Lhonak and Chho-Lhamo region. The physiography of north Sikkim have been plotted in Fig.8., the general trend of the mountains is from east to west but the chief ridges of Sikkim runs more or less in the north to south direction.

The North Sikkim is drained by river Tista along with its innumerable tributaries. The name of the river Tista has been derived from the word "Trisrota". The five drainage zones or water shed and the major tributaries of river Tista are plotted in Fig.9. and the details are discussed belowed.

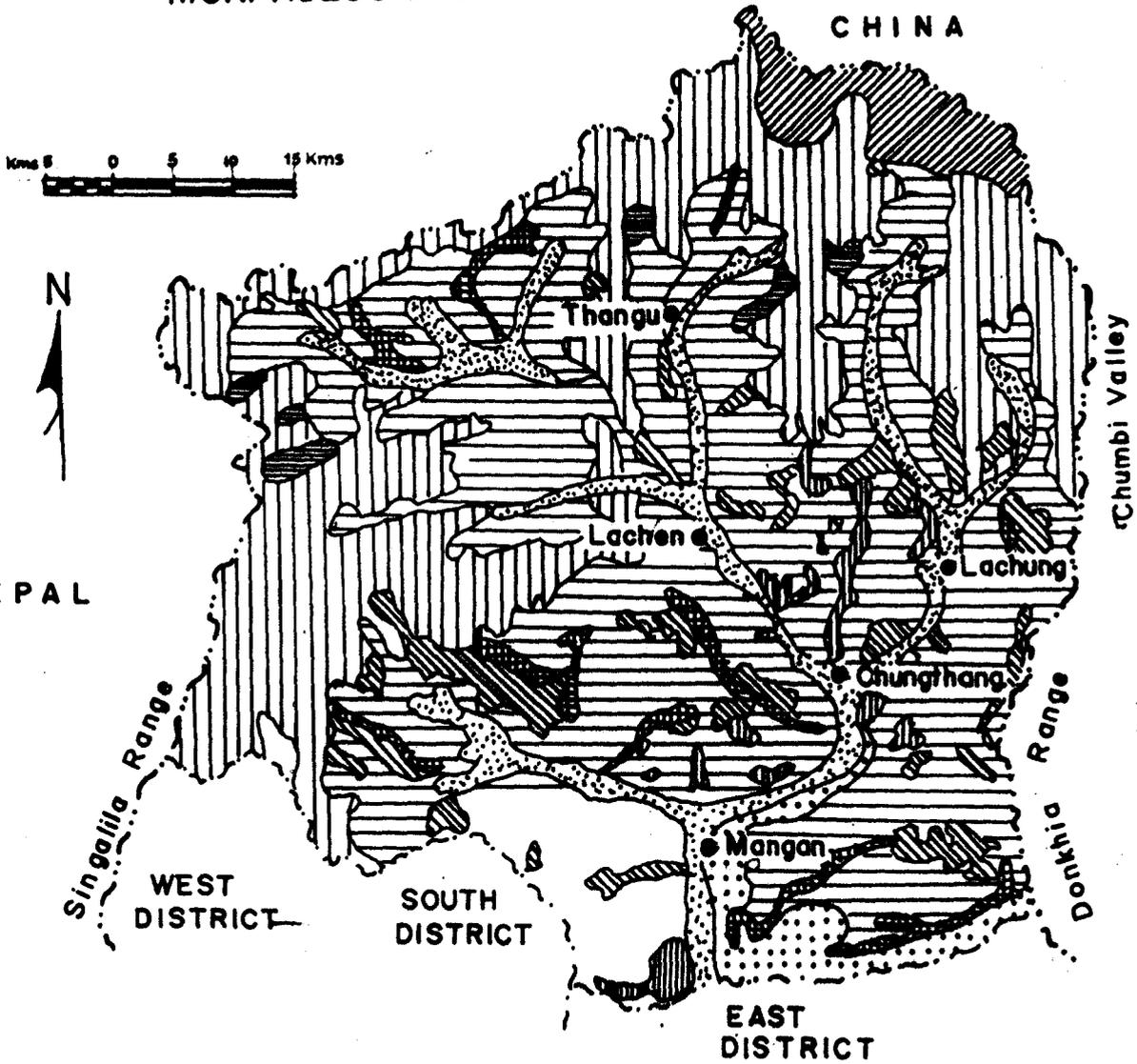
2.7.1. LACHEN WATER SHED

Lachen water shed is the biggest area of the Tista catchment in North Sikkim. It is in this zone where Tista river originates from Pauhunri glacier (27 55'N 88 45' E) near Dongkya La (7128 m.) in the east. The ista river at the source is known as Chumbu Chu and other sources of this river are Gurudongmar and Chho-Lhamo Lake. The river takes a southward course at Donkung and Gyagong and further southward direction at Tsopta and meets

Fig 7. DISTRIBUTION OF RAINFALL IN NORTH SIKKIM



MORPHOLOGICAL MAP OF NORTH SIKKIM



- | | | | |
|--|------------------------------------|--|------------------|
| | Cliff and Precipitous Slope | | Valleys |
| | Very Steep Slope (> 50%) | | Escarpments |
| | High Slope (between 33 to 50%) | | Perpetual Snow |
| | Moderate Slope (between 15 to 30%) | | Summit and Ridge |
| | Glacial Drifts/Moraines/Boulders | | |

Fig 8.

the Zema Chu at Zema (27 45'N; 88 32'E). The upper course of Chumbu Chu is marked by development of wide, flat with U shape valleys known as Chho-Lhamo regions and similar landscape may be seen upto Talum near Yakthang in North Sikkim. The Lhonak region of this water shed is separated by high ridges of Lunak La (18000 ft) running from north to south. The landscape of Lhonak region is very similar to that of Chho-Lhamo region. The Muguthang is a small village with small settlements in the area. The important tributories of Lhonak Chu draining in this area are Naku Chu, Khora Chu and Goma Chu. The important sources of Lhonak Chu are Lhonak glacier, Langbu glacier, Changsang glacier, Ghora Lake or Ghora Cho etc. The Zemu Chu or Zemu meets the Lhonak Chu at Zedong and finally at Zema it meets the river flowing from Chho-Lhamo regions. The Zemu river derives its source from Zemu glacier which is the biggest glacier in North Sikkim. From Zemu onwards the river is known as Lachen Chu and as the river descends the vallies starts to contract and take the form of V shape. The Lachen and Lachung river meet at Chungthang (27 36' N; 88 40' E).

2.7.2. LACHUNG WATER SHED

The Lachung region is drained by Lachung Chu and its main tributory is Sebazung Chu. The main source of Lachung Chu is Chaugme glacier, Sebu Lake, etc. The valley is flat and takes the form of U shape upto Khedum near Chungthang.

The other three water sheds in the region are Tolung water shed, Chungthang, Mangan and Hee Gyathang, Mangan Samdong watershed.

WATERSHED OF UPPER TISTA BASIN



Fig 9.