Chapter 1: Geographical Set-up of the Study Area

1.0 Introduction

Darjyu Lyang *or the 'land of God' or 'heaven on earth'* is believed to have given Darjeeling the northern most district of West Bengal its name. It is also believed that the name is a corrupted form of ***Dorjee-ling*** of the Lamaist religion derived from *'Dorjee'* the celestial scepter of double-headed thunderbolt and *'ling'* or the land, it literally means *'theland of the thunderbolt'* after the famous Buddhist monastery, which stands atop the Observatory Hill.

Darjeeling was a part of the sovereign state of Sikkim prior to 1789 A.D. Its creation dates to the 19^{th} century, through the involvement of the British India Government. The signing of the Sugauli Treaty between the two countries saw the return of the *terai* area and part of Darjeeling that was in the possession of Nepal to the British India Government. The signing of the Titleya Treaty on 10^{th} February 1817 ensured that the British restored this region to the King of Sikkim, making it a buffer-zone between Tibet and India.

However, the search for a summer capital and a sanatorium to escape the sweltering summer heat of the Indian plains saw the visit of Captain Lloyd and Mr. Grant to Darjeeling in 1887. On their proposal and persuasion, Lord Bentinck initiated a dialogue with the then King of Sikkim, who handed over this area to the British as a token of friendship on 1^{st} February 1835. Kalimpong on the other hand was ceded to the British Empire by the Sinchula Treaty in 1865 by the Government of Bhutan, and notified as a sub-division of Dooars to be transferred to Darjeeling in 1866. It was finally annexed to the state of West Bengal in 1947. The three hilly subdivisions of the district came under the administrative purview of the Darjeeling Gorkha Autonomous Hill Council that came into effect on 22^{nd} August 1988.

1.1 Geological set-up

Geological investigations in Sikkim and the adjoining Bengal region began in the middle of the 19^{th} Century. Dr. Hooker, in his famous "Himalayan Journals" (1854) reports the geological results of his extensive surveys in the region. He traced the regional domal pictures of gneisses and observed the overlying, bedded sedimentary rocks (Gansser, 1964). The first comprehensive and systematic geological examination of this region was made by F.R. Mallet in 1874. Since then, many observations have been made (Dutta, 1950; Gansser, 1964; Acharya, 1972; Powde and Saha, 1982, etc.). A geological map of the study area (figure 1.1) has been prepared based on Mallet (1874), Gansser (1964) etc. to show the regional distribution of rocks, while the chronological sequence of the geological series of the study area has been shown in table 1.1.

Geological foundations of the Darjeeling hills consist of Precambrian slates, schist, phyllite, quartzite, gneisses, lower Gondwana and Siwalik sandstones and recent to sub-recent alluvium (Gansser A., 1964, Kalvoda, J, 1972). The several tectonic units of the Darjeeling Himalaya overthrusted towards south are built mostly of metamorphic rocks (Darjeeling gneisses, Daling schist and quartzite). The Main Boundary Trust (MBT) separates them from the Siwalik built of sandstones, conglomerates and mudstones, which are overthrusted over the Quaternary fore-deep along the Himalayan Frontal Thrust (HFT). The foreland of the Himalaya is built of Quaternary sediments which show a distinct fractional differentiation starting from boulders and gravels in the root part of piedmont fans and terraces, at distance of 5-10 km from the margin turning to sand and farther downstream to sandy loam and silt (figure 1.1). A brief description of various formation of the Darjeeling Himalaya is given below:

1.1.1 Raised Terraces

A recent to sub recent formation forms a fringe along the hills, especially at the confluences of the rivers. These terraces are composed of gravel, pebbles, and boulders mixed with sand and clay. The formation is semi consolidated, stratified along with the evidences of upheaval at places. This type of high level terraces is also called the *terai*.

1.1.2 Siwalik Series

The foot hill belt comprises of the Siwalik sediments flanking the Quaternary piedmont deposits in the south and is separated in the north from Gondwana group of sediments by the Main Boundary Fault. Though there are some erosional gaps, the Siwalik sediments are quite persistent in the Darjeeling Himalaya. The lower Siwalik comprises of micaceous sandstone, occasionally with pebble beds and bluish grey clay stone. Hard sandstones with pebble beds and subordinate clay form the middle Siwalik. The overlying upper Siwalik is represented by grey micaceous sandstone followed by thick boulder conglomerate with yellowish and carbonaceous lenticular clay beds. Along the Hill Cart Road and the Tista River a few stretches of good exposers of Siwalik are found. The general strike of these rocks in NNE-SSW to NW-SE with dips between 30° to 60°.

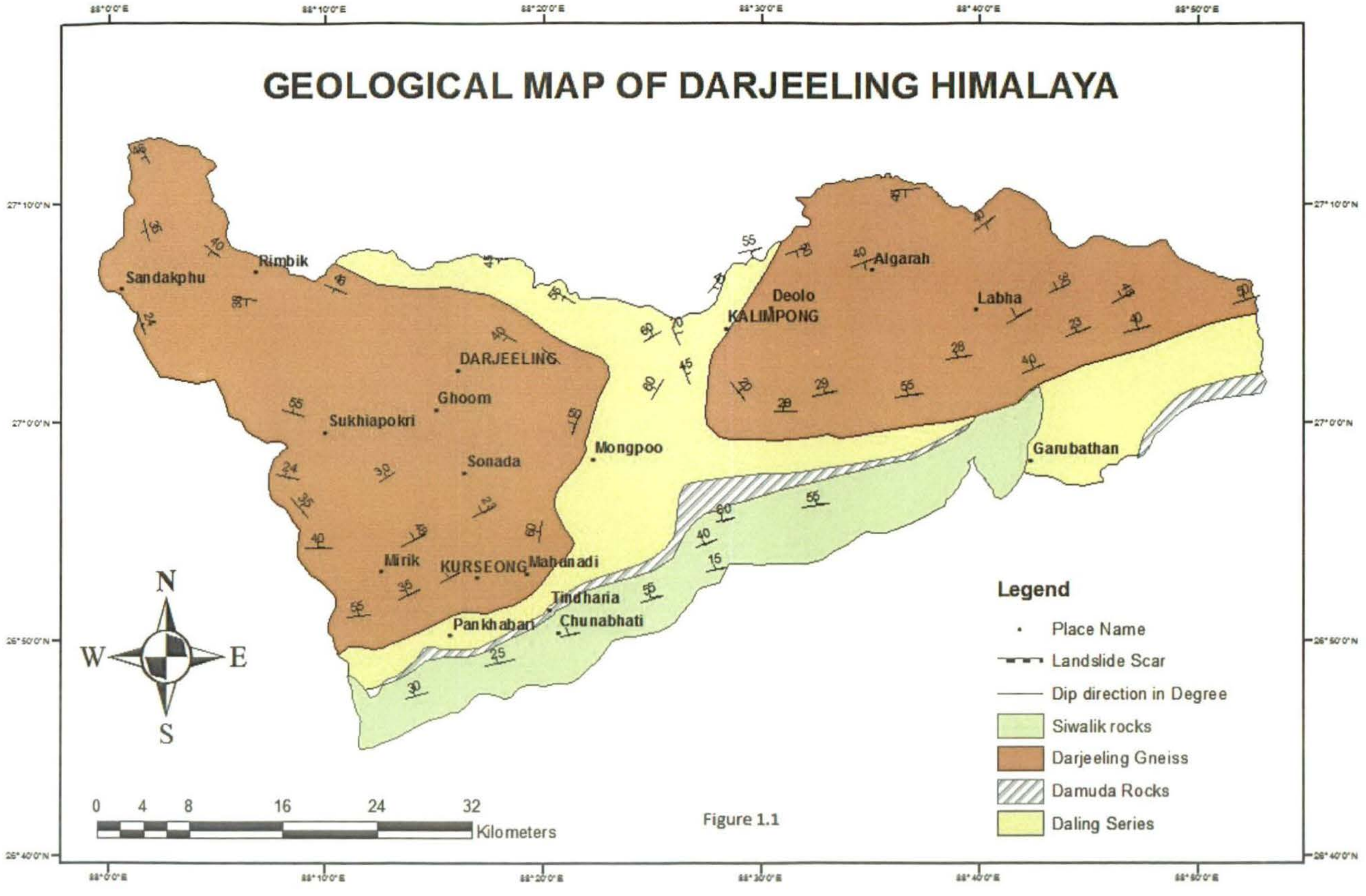
GEOLOGICAL MAP OF DARJEELING HIMALAYA
Sandakphu
Rimbik
DARJEELING
Ghoom
Sukhiapokri
Sonada
Mongpoo
Mirik
KURSEONG
Mahanadi
Tindharia
Pankhabari
Chunabhati
Deolo
KALIMPONG
Algarah
Labha
Garubathan
N
S
W
E
0 4 8 16 24 32
Kilometers
Legend
Place Name
Landslide Scar
Dip direction in Degree
Siwalik rocks
Darjeeling Gneiss
Damuda Rocks
Daling Series

Figure 1.1

1.1.3 Damuda Series

The Siwaliks are steeply overthrusted by the Damunda formations (Lower Gondwana). The thrust zone is badly exposed dipping at an angle of 60°-70° towards north. The rocks belonging to Damuda series include coarse grained hard sandstone, quartzites, carbonaceous shale and slates. Frequently, the sandstones have been converted to quartzites, the shale into splinter-slates and the carboniferous shale to graphitic shale, while the coal has been altered to anthracite. There is a thin discontinuous band of limestone from Kalijhora to Rongtong. The Damuda series of Darjeeling hills is equivalent to the Gondwanas of Indian Peninsular. The maximum width of Damuda is about 2.5km along the Tista valley. The maximum thickness is about 1000m. The general strike of the bed is from ENE to WSW with a varying dip of 40°to 90°. In this belt coal steams of about 3m in thickness are found near Tindharia, Lish and Gish valley.

1.1.4 Daling Series

Towards north of Gondwana in Darjeeling Himalaya, the Daling groups of rocks tectono- stratigraphically represents the area. These are placed below the high grade gneissic rocks (Darjeeling Gneiss), limited by sheared belt of mylonitic granite gneiss. The Daling series is comprised of chlorite slates, phyllites and schist associated with quartzite, which rest over Damuda series. They border the Damudas with a very sharp thrust contact, dipping steeply towards the north. Well-developed form of Damuda series is found along the Tista river and the stretches along the Tindharia – Paglajhora on the Hill Cart Road. The Rayeng formation (ortho-toproto-quartzite, variegated slates and phyllites), which is a part of Daling group, occurs in tectonic association with the lower unit of Gurubathan. The rocks are occasionally traversed by quartz and feldspar veins. The most important feature of this series is increasing metamorphism upward, where slates from the lowest bed.

1.1.5 Darjeeling Gneiss

In the higher reaches of the Darjeeling hillls, the Daling rocks gradually grade into highly metamorphosed Darjeeling gneiss. The Darjeeling gneiss consists of garnetiferous mica-schists, quartzites, biotite-kyanite and sillimantic gneiss. The dips of the rocks are irregular and vary in between 40° to 70° towards E-W. Darjeeling gneisses are highly foliated due to metamorphism. There are two prominent sets of joints in the Darjeeling gneiss, one running roughly NW- SE and the other MNW – SSE, the general direction of the hill spurs is in accordance with the joint direction. The Darjeeling gneiss is met with traverses along Sukhiapokhri - Maneybhanjang - Tonglu-Sandhakphu-Phalut Road and also along the Phalut-Rammam-Rimbick-Jhepi-Pulbazar-Darjeeling Road.

Table 1.1 Geological succession of Darjeeling Himalaya

Age	Series	Lithological Characteristics
Recent To Subrecent	Alluvium	Younger flood plain deposits of rivers consisting of sands, pebbles, gravels, boulders etc.
Pleistocene To Lower Pleistocene (Lower Tertiary)	Siwalik	Micaceous sandstone with siltstone, clay, lignite lenticles, etc.
Thrust (Main Boundary Fault)		
Permian	Damuda (Lower Gondwana)	Quartzitic sandstone with slaty bands, seams of graphitic coal, lampophyre silt and minor bands of limestone.
Thrust (Fault Of Nappe Qutlier)		
Pre-Cambrian	Daling Series	Slate, chlorite-sericite schist, chlorite-quartz schist.
	Darjeeling Gneiss	Golden silvery mica-schist, carboniferous mica-schist, coarse grained gneiss.

Based on: Mallet, 1874; Gansser 1964 and Pawde and Saha, 1982

1.2 Physiography

Physiographically, the Darjeeling Himalaya is a region of diverse and complex area, exhibiting a wide variety of landforms. Their genesis, mode of formation and morphological forms are diverse in nature. The hills rise abruptly from the plains (150 m), and the elevation increases north-westwards up to 3636 m at Sandakphu. Two transverse ranges running north-south enclose the Singalila in the west and the Dongkya in the east. Ravines, deep valleys, innumerable springs and jhoras dissect these landscapes, interspersed with a mosaic of micro-topographic units. This complex physical environment is due to different geomorphic processes, each of which has developed its own characteristic assemblage of landforms. The geomorphic configuration of this hilly tract is the joint product of geologic foundation and fluvial processes, although slope-wash, in particular mass-movements and related phenomena play a significant role in the final shaping of the landform. The region is characterized by a myriad of ridges and valleys because of the spurs ramifying into lateral spurs which give off lesser ones, and these in turn cut the terrain into ridges and valleys, creating a mosaic of micro-topographical units. A detail contour map of the Darjeeling hills has been given in figure 1.2. Physiographically, the Darjeeling hills may be divided into 4 major divisions. Major topographic patterns have been depicted in figure 1.3.

1.2.1 The piedmonts

The piedmont or sub-Himalayan zone is locally known as *terai*. It covers the tilted plains at the base of the foothills. This is formed due to the coalescing of several alluvial fans within the catchment area of the major rivers like Balason, Mahananda, Tista, Jaldhaka, (Sarkar, S. 1990). Rivers and streams which have cut gorges have also given rise to terraces, across the undulating and low plateau like drift deposits thereby, forming a typical landscape, overlooking and often merging with the plain to the south.

1.2.2 Lower hills

This region is bounded by contour heights of approximately 200-800 m and covers most of the central section of the study area. The rivers are mostly south-flowing and cut deep gorges and V-shaped valleys. The landscape is characterized by narrow ridges, deep incisions and numerous mass-movement scars. The average slope in this zone varies between 10° - 30°, with slope length sometimes exceeding 800 m. These lower hills are the most dissected and eroded tract in the Darjeeling Himalaya.

1.2.3 Middle hills

This is a rather narrow zone, sandwiched between the upper and lower hills and bounded by the 800 m and 1400 m contours. Most of the western and north eastern part of the study area fall under this category. These hill slopes are mostly used by tea plantations.

1.2.4 Upper hills

The upper hills lie above the 1400 m contour line and have been identified along the Mahaldiram-Bagora region and above the Ghum-Sonada ridge. It is most prominent along the extreme north-western boundary of the region along the Singalila ridges with peaks like Sandhakphu and Phalut towering over the region. The Singalia the highest range in Darjeeling Himalayaseparates Sikkim from Nepal and extends farther south and enters on

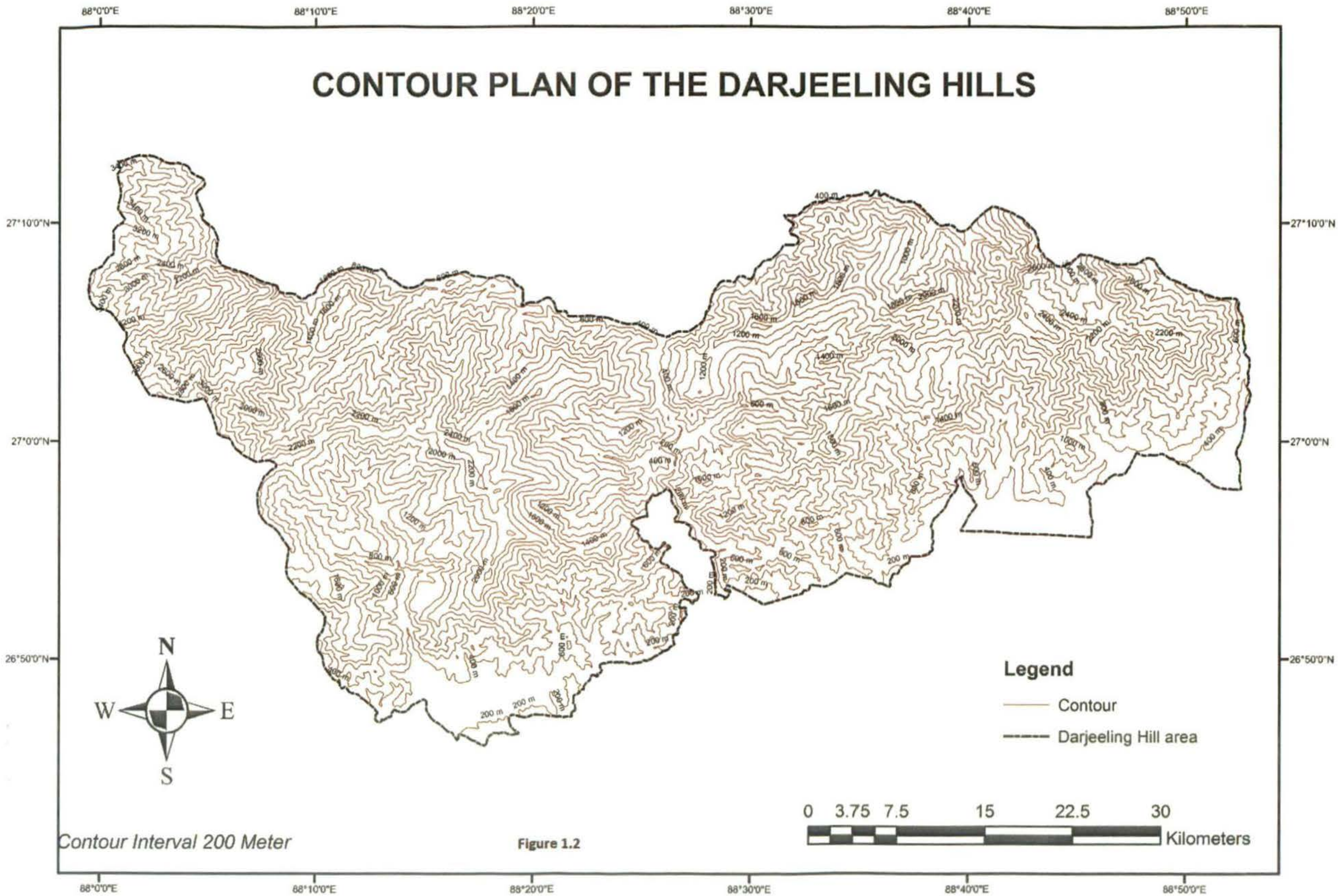
CONTOUR PLAN OF THE DARJEELING HILLS
88°0'0"E
88°10'0"E
88°20'0"E
88°30'0"E
88°40'0"E
88°50'0"E
27°10'0"N
27°0'0"N
26°50'0"N
N
W
E
S
Legend
Contour
Darjeeling Hill area
0 3.75 7.5 15 22.5 30
Kilometers
Contour Interval 200 Meter

Figure 1.2

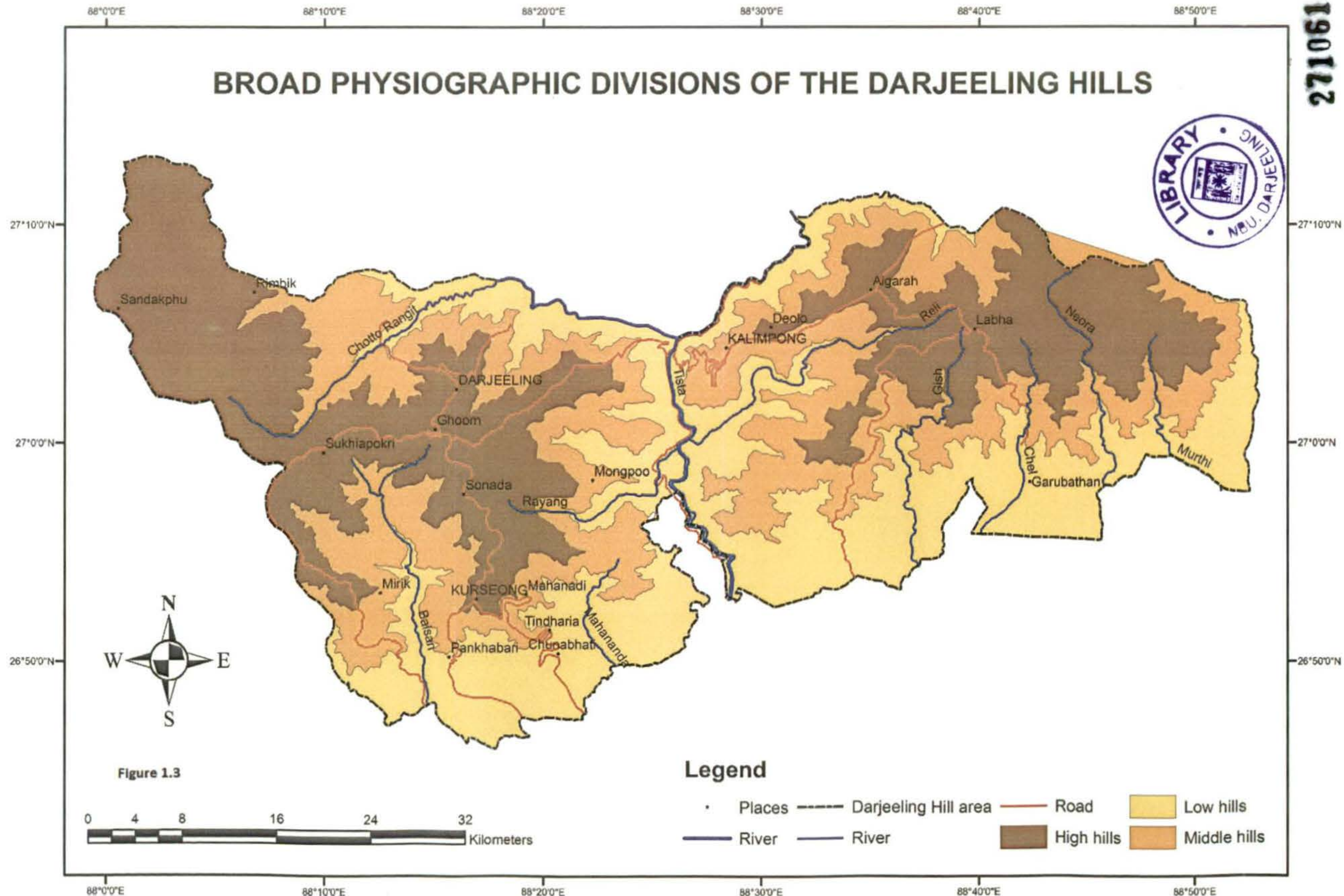
BROAD PHYSIOGRAPHIC DIVISIONS OF THE DARJEELING HILLS
88°0'0"E
88°10'0"E
88°20'0"E
88°30'0"E
88°40'0"E
88°50'0"E
27°10'0"N
27°0'0"N
26°50'0"N
Sandakphu
Rimbik
Chotto Rangit
DARJEELING
Ghoom
Sukhiapokri
Sonada
Rayang
Mongpoo
Mirik
KURSEONG
Mahanadi
Tindharia
Chunabhati
Pankhabari
Balsan
Mahananda
Tista
KALIMPONG
Deolo
Algarah
Relli
Labha
Gish
Neora
Chel
Garubathan
Murthi
N
S
W
E
0
4
8
16
24
32
Kilometers
Legend
Places
Darjeeling Hill area
Road
Low hills
River
River
High hills
Middle hills

Figure 1.3

the western side. The four major peaks of the Singalia range are Sandakphu (3636m), Phalut (3596m), Sabargam (3543m) and Tanglu (3063m). In between the Balasan and Tista valley stretches the Senchal-Mahaldhiram ridge with prominent peaks of Senchal (2614m) and Tiger hill (2573m). Ridges stretch along three directions from the Tiger hill, (i) Darjeeling-Lebong to the north, (ii) Takdah-Pesok to the northeast and (iii) Bagora-Dowhill to the south. Ghoom (2260m) the highest railway station of India and Darjeeling the famous hill resort situated on Darjeeling-Lebong ridge (figure 1.3).

1.3 Climate

The climate of Darjeeling Himalaya is noteworthy because of its position, the powerful effects of the South Western monsoon against the Himalayan barrier and the peculiar configuration of the ridges and valleys which deflect or allow rain-bearing winds that affect local temperature and rainfall. Darjeeling hills is dominated by two seasons: cold and rainy, however, two more relatively short spanned seasons i.e., spring and autumn are also noticed.

The Darjeeling Himalaya shows its own climatic peculiarities caused by its geographical location, relief and a wide range of altitudinal variations ranging from 300m - 3700m above sea level. It exhibits a typical monsoon climate, with wet summer and dry winter. The condition is brought about by the direct exposure to the moisture laden southwest monsoon flowing upwards during May to October from the Bay of Bengal that lies at close proximity. The climate varies greatly corresponding to the variation in the altitude and the configuration of the neighbouring mountain ranges that greatly affect air movement, rainfall and temperature. Even within very short distances great climatic contrasts occur. Although the latitudinal extent of the region is located within the sub-tropical climatic regime its mountainous configuration has led to varied climates ranging from the subtropical to the temperate and alpine type. Thus, based upon the elevation, the region shows three distinct climatic zones, viz. tropical, temperate and sub-alpine. This variation is responsible for the creation of the various types of vegetal cover, thus bringing about great biological diversity.

1.3.1 Temperature

The temperature of the Darjeeling Himalaya sub divisions shows a great degree of variation with the altitude being the most important factor. Table 1.2 shows the average monthly temperature record of Darjeeling (2150m asl), Kurseong (1480m asl) and Kalimpong (972m asl). January is the coldest month when the temperature at Darjeeling, Sonada and

Lava often go down below 0°C. Considerable local changes in the configuration and aspects influence climate condition which often varies through a wider range. The winter in Darjeeling is extremely cold and extends from December to March. The summer spreads from April to mid-June and during this period Darjeeling is delightfully cool. The rainy months are June to September when most of the rainfall occurs with appreciable amounts in May and October as well. The mean annual temperature is 12°C, monthly mean temperature range from 5-17°C. The highest temperature ever recorded in Darjeeling was 26.7°C on 23rd August 1957. In Kalimpong town, the highest ever recorded temperature was 36°C on the 16th August 2006. The lowest temperature recorded in Darjeeling was -5.0°C on the 11th February 1905 while that of Kalimpong town was 0.6°C on the 8th January 1945.

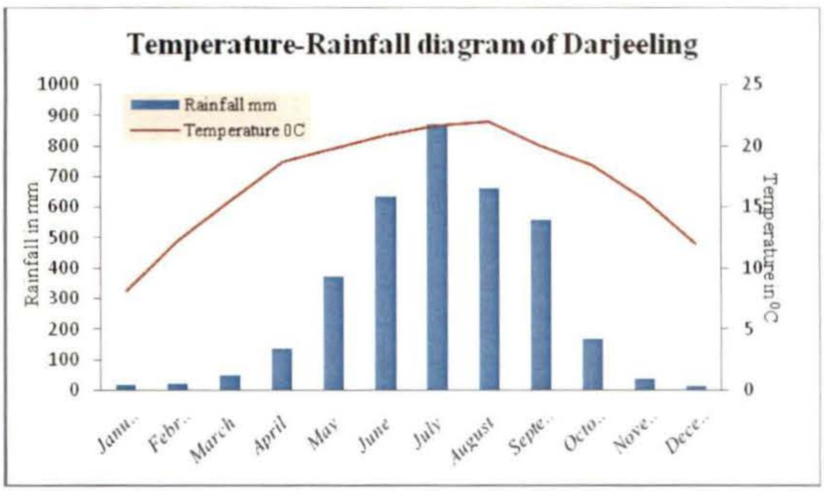

Figure 1.4 Rainfall Temperature diagram of Darjeeling

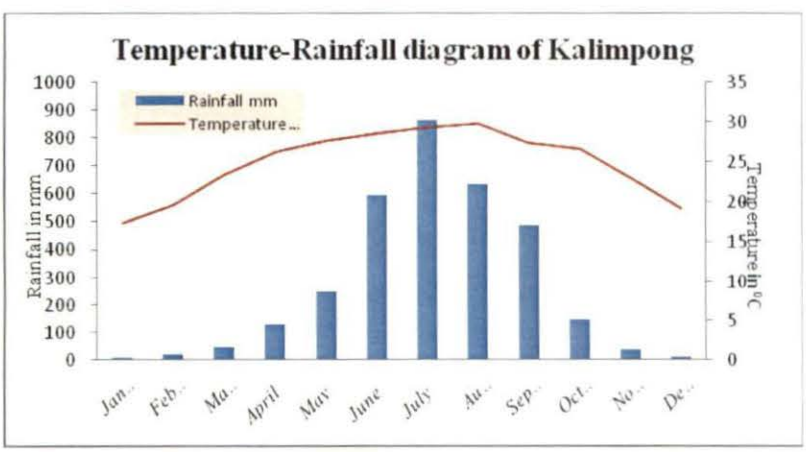

Figure 1.5 Rainfall Temperature diagram of Kalimpong

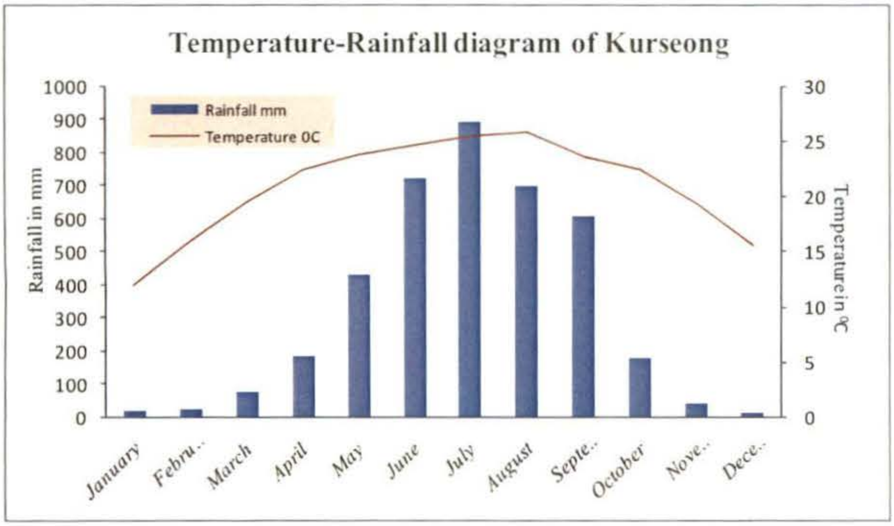

Figure 1.6 Rainfall Temperature diagram of Kurseong

1.3.2 Rainfall

The Darjeeling hills consist of a tangled series of interlacing ridges, rising rangesrising above the foot of the wall of high peaks and passes which marks the 'abode of snow' and its off-shoot (Risley 1884). This configuration coupled with the altitude brings about sharp changes in the rainfall of the region. In general the south facing ridges receive the highest rainfall with the north facing ridges receiving lesser rainfall. The Darjeeling Himalaya is viewed as a stupendous stairway leading from the western border of Tibetan plateau down to plains of Bengal. It is highly humid because its proximity to the Bay of Bengal and direct exposure to the effects of moisture-laden southwest monsoon. Configurations of the ridges and valleys bring sharp changes in the rainfall. Spatial distribution of mean annual rainfall pattern has been depicted in figure 1.7.

Kurseong and its surroundings situated in the Mahananda and Balason catchment along the southern face of the rising Himalayas receives the highest mean annual rainfall of exceeding 4000 mm. Rainfall decreases sharply towards north and the area around Little Rangit valley receives about 2000 mm only. The region experiences the highest rainfall during June to September brought about by the southwest monsoons and the lowest in between November to February with occasional moderate showers during March to May.

There is no distinct relation between mean annual rainfall and altitude. The southern slopes of the ridges get much higher (4000-5000mm) precipitation than leeward sides (2000-2500mm). The next main ridge with Tiger Hill gets 3000mm while to the north the great

Rangit valley receives about 2000mm of rainfall. The mean annual precipitation in Darjeeling hills has been estimated to be 2818 mm, with the monthly highest amount of 753 mm received in July. Spatial distribution of mean annual precipitation has been found very interesting and is depicted in figure 1.7. The Darjeeling hill area thus divided into the following 5 precipitation zones:

I. Very high precipitation area recording above 4000 mm situated in and around Kurseong, Daw hills, Makaibari, Castleton, Ambhootia etc.

II. High precipitation zone receiving 3500 to 4000 mm

III. Moderate precipitation zone recording 3000 to 3400 mm

IV. Low precipitation zone recording less than 3000 mm precipitation.

1.3.3. Relative Humidity

The entire Darjeeling Himalaya experiences a high relative humidity that is spread uniformly. Generally the north facing slopes are colder and remain humid throughout the whole year. The relative humidity is higher towards the higher altitudes (above 2000 m) ranging from 85 - 99% during the monsoons, and the relative humidity generally decreases towards the lower elevations. The drier months of March and April are less humid with the relative humidity ranging between 45 - 60%.

1.3.4. Sunshine and Cloudiness

The Darjeeling Himalaya is a region of high precipitation and humidity with the rainy days as high as 218 days per annum. Thus, this region experiences very few days of sunshine. Not only during monsoon but even during summer and winter, sunshine remains disturbed due to the formation of dense fog that sometimes creates situations of near zero visibility (Chopra 1985). Sunshine is more commonly distributed in the morning and late afternoon. During the monsoon, the rains continue uninterrupted for few days without the sun being visible on those days. The records of sunshine from the middle hill regions shows that, on an average the highest is at Sonada during Novermber (5.84 hr/day) and the lowest at Kurseong in July (0.9hr./day) while that annual average sunshine at Kurseong is 3.49hr/day it is only 1.86 hr./day at Simana Busty.

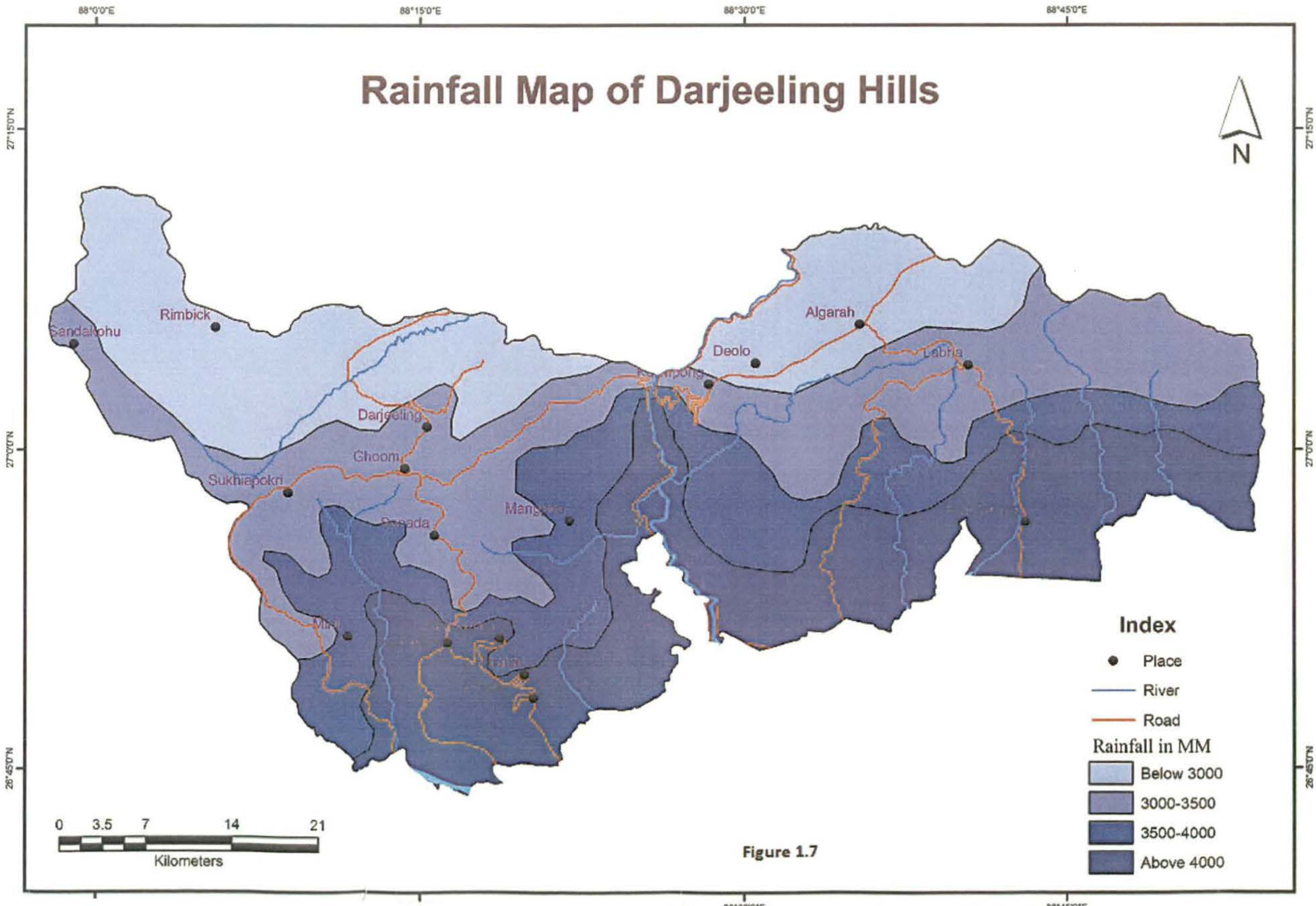
Rainfall Map of Darjeeling Hills
N
88°0'0"E
88°15'0"E
88°30'0"E
88°45'0"E
27°15'0"N
27°0'0"N
26°45'0"N
Rimbick
Darjeeling
Ghoom
Sukhiapokri
Algarah
Deolo
Index
Place
River
Road
Rainfall in MM
Below 3000
3000-3500
3500-4000
Above 4000
0 3.5 7 14 21
Kilometers

Figure 1.7

Table 1.2Average rainfall and temperature characteristics of the Darjeeling Himalaya

Months	Darjeeling		Kalimpong		Kurseong	
	Rainfall in mm	Temperature in °C	Rainfall in mm	Temperature in °C	Rainfall in mm	Temperature in °C
January	13.89	8.12	10.16	17.39	17.03	11.97
February	20.16	12.28	20.34	19.67	21.25	15.98
March	47.97	15.55	46.34	23.46	72.17	19.51
April	132.89	18.67	129.82	26.32	181.36	22.5
May	371.67	19.79	248.98	27.77	428.33	23.78
June	631.45	20.85	598.44	28.62	724.95	24.74
July	867.59	21.72	865.26	29.41	896.43	25.57
August	659.89	21.98	634.66	29.82	698.28	25.9
September	556.24	19.99	487.21	27.44	611.73	23.72
October	167.39	18.37	145.99	26.69	176.69	22.53
November	36.96	15.69	38.98	23.03	42.97	19.36
December	10.88	11.98	11.46	19.21	12.67	15.6
Total/average	*3517*	*17.1*	*3238*	*24.9*	*3884*	*20.9*

Source: Tea Planters' Association, Darjeeling, 2009, SDO Office, Kalimpong.

Darjeeling hill experiences sub-tropical to temperate climate and has five distinct seasons: spring, summer, autumn, winter and the monsoons. Summer (May-June) are mild with maximum temperature barely crossing 25°C; the monsoon (July-September) is characterised by cloudiness with frequent torrential rains; winter (December-February) is cold to very cold and unpleasant with temperature falling as low as -5.0°C which is followed by dry and bright sunny spring (March-April). Autumn (October-November) is pleasant in Darjeeling hills as the mean temperature varies between 17.03°C in Darjeeling and 24.8°C in Kalimpong. Darjeeling is often shrouded in mist and fog. High altitude area of Darjeeling hills also experiences occasional snowfall especially in the Singalila, Goom-Simana, Tiger hill-Birch hill-Bagora area.

1.4 Drainage

The Darjeeling hill is endowed with intricate river systems originating from the Himalayas draining across the Himalayas (figure 1.8). The proportion of river length and catchment area between zone of erosion and deposition in various types differ considerably. The drainage system consists part of two major drainage systems namely the Brahmaputra and the Ganga system the two most important drainage basins of the country. The Brahmaputra system is represented in the area by its two major sub-basins i.e., the Tista and

Jaldhaka sub-system and the Ganga system is represented by the Mahananda sub-system. The drainage system of Darjeeling hill area is shown in figure 1.6 and tabulated in table 1.3.

Table 1.3 Rivers and tributaries in Darjeeling hill area

Watershed	Area in Darjeeling	Sub-watershed	Rivers & major tributaries	Length in Darjeeling (km)	Gradient in m/km
Brahmaputra	*1785.1km²*	Tista	Tista	37.00	4.21
			Lish	12.10	136.78
			Gish	30.20	61.23
			Chel	10.46	206.40
			Great Rangit	18.57	5.06
			Little Rangit	23.77	100.42
			Rammam	39.78	77.17
			Neora	27.46	86.23
			Relli	30.64	67.89
			Reyong	18.70	116.09
			Ragnu	16.27	136.01
			Rangpoo Chu	9.66	239.85
			Rishi Chu	17.36	110.25
		Jaldhaka	Jaldhaka	19.47	18.69
			Nichu	14.90	150.67
			Murti	13.82	140.45
			Ruka Chu	8.54	225.99
			Ma Chu	8.79	134.58
Ganga	*494.7 km²*	Mahananda	Mahananda	13.8	136.81
			Balason	33.09	60.53
			Mechi	16.16	99.19

1.4.1 The rivers of Brahmaputra system

The mighty Brahmaputra known as the Tsanpo in Tibet, emanating from the Himalayas near Mansarovar Lake flows through Tibet in an easterly direction. Among the major rivers draining Darjeeling hills, the Tista and Jaldhaka are important.

1.4.1.1 The Tista system

The river Tista, the biggest river in North Bengal originates from the Tista Source Glacier (*Tista Kanyse*) or Pauhurni Glacier near Khangehung Lake (latitude 29° 59' N and longitude 38° 48' E) in North Sikkim at an altitude of 6200 meter. It meets the Brahmaputra (Jamuna) at Kamarganj in Bangladesh at an elevation of 23 meter. The Tista river system, flanked by the Mahananda and the Jaldhaka on either side present a spectacular convergent and divergent drainage pattern. The convergent pattern terminates around 90 meter contour lines, subsequently to which the character assumed to be one of divergent one fromwhere the rivers are spreading out. While, the 300 meter contour line is curving upward indicating convergence of drainage, the 66 meter line in the extreme south is systematically curved downward indicating large scale fanning out or, divergence of the channels (Mukhopadhyay S.C, 1982).

The combined flow of the Lachung and Lachen, after emerging from Chungthang forming this mightyTista receives a tributary Talung from the north-west, which joins it near Mangan. Below the confluence with the Rangpo River, the Tista river flow is further augmented by inflow through the Rangit from the western direction. The great Rangit is principally the combined flow of three streams, Rangit, Ramam and Chotto Rangit flowing from the north-west, west and south-west respectively. The outfall of the great Rangit into the Tista is near Melli Bazar. In the next, reach below Melli Bazar, the Tista, before it emerges into the sub-Himalayan plains of North Bengal, is joined by two small streams, Rangli and Ranghot from the west and east respectively.

The Tista after flowing for about 25 km passes through Sevoke before it debauches into the plains of North Bengal. In the sub-Himalayan plains it is again joined by a number of tributaries viz. Lish, Ghish, Chel, Neora from the north-eastern end (WAPCOS, 2003). The following are the major tributaries of the Tista in Darjeeling hills.

1.4.1.1.1 River Lish

The Lish Khola has its origin in the Pabringtar Khas Mahal Block and Turung khola has its origin in the Samther Forest which has the highest altitude ranging to 2000m. After the merging of the Lish khola and Turung khola the river flows southwards and meets Nabgang khola on the eastern side and further down Phan khola on the western side. The river then flows into Jalpaiguri district and after another 10 kms meets the Tista near Kalagaity Tea Estate. River Lish has 20 km length and drains a total catchment area of 64 sq.km out of which 48 sq.km is situated in Darjeeling hills. The width of the river in the gorges varies from 60 to 120 m. The bed slope of the river is 24m/km in the hilly region.

1.4.1.1.2 River Gish

The Gitkhola rises from the Lava forest and flows between Gitbeyong on the right and Pankhasari, Samabeyong khasmahal on the left. River Gish receives small streams on its right bank, namely the Reangkhola, Nakhikhola, Desikhola and Chamukhola. Another river

Lethi originating in the forest, south of Pagrambong khasmahal meets the Gish in Jalpaiguri district. The river Gish falls into Tista in Jalpaiguri district. The river runs through deep gorges in the hilly region. The catchment area of the river is 160sq.km and its length is 35km. The bed slope is 22 m/km (Basu S.R. & Ghatowar L., 1986).

1.4.1.1.3 River Chel

The River Chel, a mountain torrent is formed by the amalgamation of two kholas i.e., Chel and Kali khola. The Chel khola originates in the Pankhasari forest. While, the Kali Khala rising from the ridge cutting the Gish and Chel catchments on the western part of the Pankhasari khasmahal flows in between Nim and Pankhasari khasmahal and meets the Chel khola near Ambiok. Ambiok khola, Dalim khola, Sukha khola etc. are the small tributaries of the Chel. South of Mal khasmahal in the Jalpaiguri district it meets Neora and takes the name of Dharala which ultimately falls into Tista above Domohani. The Chel flows for a length of 54 km. The catchment area is 390 sq. km. The longitude slope of the river is 52 m/km.

1.4.1.1.4 River Neora

The river Neora originates from Rechilla Chawk of the Neora National Park in Darjeeling district. The river is joined by Thosum Chhu and flows through the National Park and is augmented by several streams before it finally meets the Santhoke khola and Argara khola on the left. The river enters the Jalpaiguri district and meets Chel further down and then with the Dharala falls into Tista above Domohani. The length of the river is 58km and catchment area 275 sq.km. The valley is mainly on steep hill sides having slopes of $40^{\circ}$to 60°.

1.4.1.1.5 River Relli

The Relli originates in Khempong forest below Lava-Algarah and runs along the southern boundary of Saihur Reserve Forest after where it is joined by the Pala and Lolley khola and southwards it joins the Rani khola.

1.4.1.1.6 River Great Rangit

The river Great Rangit originates from the Pathong glacier of Kabru range, and proceeds southwards till it meets Rammam river coming down from its source near Phalut in Singalia range. It enters the district of Darjeeling at the point on the northern boundary where it receives the Rammam river arising from Singalila and Rangu arising from Senchal in Darjeeling on its right bank. The combined waters after traversing a short distance receives another tributary the Little Rangit originating from the base of the Tonglu spur in Singalia range and finally meets the mighty river Tista near Tisa bazar.

1.4.1.1.7 River Rammam

The river Rammam demarcates the northern boundary between Sikkim and Darjeeling district. The Rammam originates at an altitude of 3600m at Phalut in the Singalila range. The entire course of the river is interspersed with deep gorges. A very prominent gorge is found at the confluence of the Rammam with its main tributary; the Lodhoma Khola.

1.4.1.1.8 River Little Rangit

The Little Rangit arises at Chitre Pokhri (2380m) and flows north, almost parallel to the Lodhoma Khola. The Little Rangit winds sinuously within a maze of interlocking spurs and valleys. Below the Triveni confluence, the Teesta flows eastwards, where it receives the Little Rangit from Darjeeling where it enters the plains of North Bengal and finally joins the river Brahmaputra in Bangladesh.

1.4.1.1.9 RiverReyang

River Reyang originates from the Mahaldiram forest (2438m) and joins the river Tista on its right bank near Rambhi. Rambhi khola is the most important tributary to the river Reyong.

1.4.1.1.10 RiverRangnu

River Rangnu originates from the Senchal forest, flows north wards and empties itself into the right bank of the Great Rangit. It is a mountain torrent which comes tearing down from the Senchal, several thousand feet above its junction with Rangit and though its roar is heard and its course is visible throughout its length.

1.4.1.2 The Jaldhaka system

The river Jaldhaka locally known as Dichu in Bhutan originates from Bidang lake in Sikkim at an altitude of 4250 m to 4550 m. It flows southwards for a length of about 24 km in a straight, steep gradient through mountainous tract up to an elevation of 844 m. At this point, an important tributary Assom khola joins the river Jaldhaka or Dichu on its left bank. Further below, the river meets the river Nichu, a tributary from the right. The river Nichu forms the boundary line between Bhutan and India in this reach.

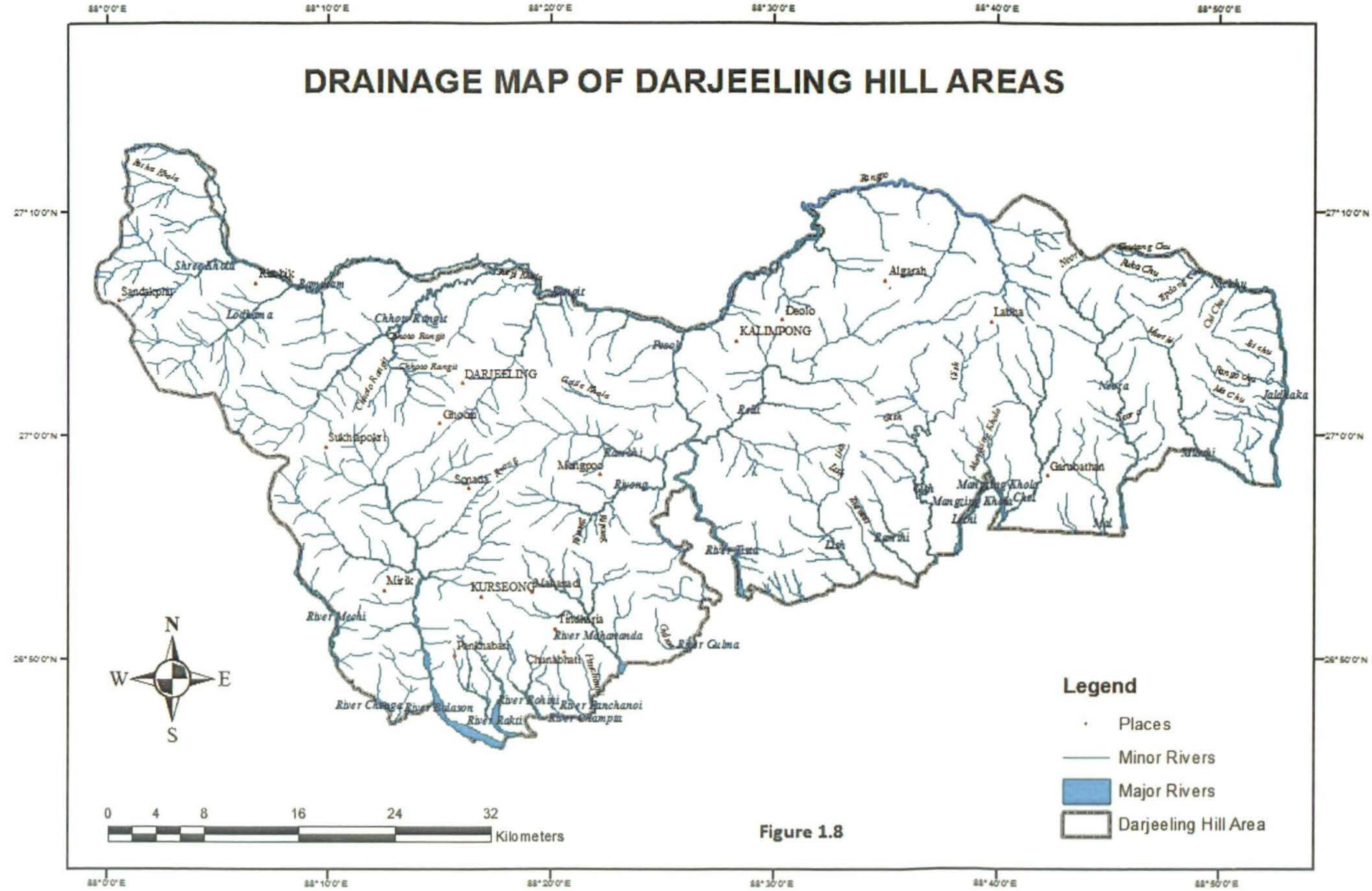
DRAINAGE MAP OF DARJEELING HILL AREAS
Sandakphu
Shree Khola
Lodhama
Rammam
Chhoto Rangit
DARJEELING
Ghoom
Sukhiapokhri
Sonada
Mangpoo
Riyong
Mirik
KURSEONG
Mahanadi
Tindharia
River Mahananda
River Gulma
Panchabari
Chunabhati
River Mechi
River Chenga
River Balason
River Rakti
River Rohini
River Panchanoi
River Champta
River Tista
Reli
KALIMPONG
Deolo
Algarah
Labha
Neora
Jaldhaka
Murti
Garubathan
Mangzing Khola
Chel
Lish
Ramthi
Gish
Mal
Legend
Places
Minor Rivers
Major Rivers
Darjeeling Hill Area
0 4 8 16 24 32 Kilometers
88°0'0"E
88°10'0"E
88°20'0"E
88°30'0"E
88°40'0"E
88°50'0"E
27°10'0"N
27°0'0"N
26°50'0"N
N
S
E
W

Figure 1.8

The river Jaldhaka then receives an important tributary Bindu khola from left. From the confluence of Nichu and Jaldhaka, Jaldhaka forms the boundary between Darjeeling hills and Bhutan. From the confluence of Bindu khola, the river flows almost southwardly with few minor bends. The river enters the Indian territory at the confluence of river Jiti which meets the Jaldhaka from the left. No important and major tributary except Jhalong khola joins the river Jaldhaka in the reach between Bindu khola and Jiti. Below the confluence of Jiti, the river Jaldhaka bifurcatesinto two channels and enter Jalpaiguri district.

1.4.1.2.1 River Murti

Murti originates in the Mo block south of Thosum hills flowing through the reserve forest and emerging in the Samsing area and eventually joining the Jaldhaka River.

1.4.2 The rivers of Ganga system

Only 21.7% of the total area under Darjeeling hills is being drained by the rivers belonging to the Ganga system. The river Mahananda, Balason and Mechi along with their tributaries drains the study area.

1.4.2.1 The river Mahananda

The river Mahananda is a major northern tributary of the Ganga system. It is bounded on the north by the Himalayas, the ridges separating it from the Tista river system in the east, the Ganga on the south and the Koshi river system in the west. The Mahananda originates from the Mahalidram hills of the Darjeeling Himalaya near Chimali at an altitude of 2060 meter, 6.4 km northeast of Kurseong town of Darjeeling hill. It is also known as Mahanadi river in the hill. The river flows in a southeast direction receiving a few sizable right side tributaries among which the Siva khola is the most important one. Its left bank tributaries include the Jholi khola, the Jogi khola, Gulma khola, Babu khola and Ghoramara khola. After flowing for 20 km in the hills of Darjeeling, the river enters plains near Siliguri and flows in a southwesterly direction till it is joined by the Balason river on its right bank about 4.0 km downstream of Siliguri. It forms more or less the border between India and Bangladesh between Phansidewa and Tetulia. The river Mahananda is the longest river in North Bengal.

1.4.2.2 The river Balason

The Balason, which arises from Lepchajagat in the Ghum saddle, flows towards the south, scooping out deep gorges in the catchment area, till it reaches the plains and thereby turns southeast, where its valley is larger than that of the Mahanadi. It receives tributaries like Pulungdung khola, Rangbang khola, the Marma khola, Dudhia khola on the right bank and Rinchingtong khola, Rakti khola, Rohini khola, Jor khola on the left.

1.4.2.3 The river Mechi

The river Mechi, which is the western boundary of the Darjeeling hills also forms the Indo-Nepal boundary. The source of the river is the Rangbang spur of the Singalila range at an altitude of 1905m. It flows through deep gorges in the hilly tracts and widens suddenly when it enters the Terai and the plains. The Mechi eventually joins the Mahananda.

Along with these, numerous small springs occur which meet to form small rivulets at the bottom of valleys. The rivers of the study area drain ultimately into the south .The relief of valley floors and river channels exhibit the youthful stage of evolution characterized by steep ungraded channels, narrow floors and steep valley sides. A number of tributaries of these rivers, along with many jhoras, form a complicated pattern of drainage over the myriad of interlocking spurs and ridges, essentially displaying a dendritic pattern.

1.5 Soil

The soil of upland is usually red and gritty while that of the plains are dark and more fertile. Along the banks of the Tista, silty or silty loam predominates. Red and yellow soils have developed on the gneisses and schists in the higher slopes of the Darjeeling Himalaya. The greater portion of the hill area lies on the Darjeeling gneiss, which most commonly decomposes into a stiff reddish loam but may also produce almost pure sand or stiff red clay. The colour of the red soil, derived as it is by meteoric weathering from gneisses and schists is due to wide diffusion rather than to high proportion of iron content. This type of soil is mainly siliceous and aluminous with free quartz as sand. It is usually poor in lime, magnesia, iron oxide, phosphorus and nitrogen, but fairly rich in potash, some areas being quite rich in potassium derived from the muscovite and feldspar of the gneiss. River alluvium is found in the southernmost part of the district.

The podzolic soils in the hilly area are suitable for cultivation of tea. Parent material variations exert a stronger influence on soil characteristics of Darjeeling Himalayas than climate or vegetation. Very broadly the soil on Siwaliks is pale yellow and coarse in texture, on the Dalings dark gray and porous; on the gneisses a brown clay, sometimes plastic, shallow and sticky. The soil on the Gondwana is generally sandy. Almost everywhere the soil is residual i.e., derived by the weathering of the underlying rocks. Weathering is selective in Darjeeling gneiss and proceeds along some susceptible bands, i.e., mica rich bands in preference to quartzose bands also along joint and shear planes. As a result blocks of fresh rocks are generally found encircled on all sides by highly weathered rocks of the nature of clay. The impervious clay is found mixed with grains of quartz, feldspar and flakes of mica. This has got an important bearing on the massive landslips.

The NBSSLUP (National Bureau of Soil Survey and Land Use Planning) of the Indian Council of Agricultural Research prepared a map of the soils of West Bengal including the hill zone in a 1:500,000 scale. The relevant portion of the map is presented in (figure 1.9). According to the records, there are five types of soil in the hill areas of Darjeeling, the dominating one is coarse-loamy (Typic Udorthents) followed by loamy skeletal (Typic Haplumbrepts). They recorded the nature of the soil of this eco-region as heterogeneous. The soils developed on steep hill slopes are shallow to very shallow, excessively drained with severe to very severe erosion hazard (table 1.4). The texture varies from gravelly loam to loam. The content of gravel exceeds 89% and organic carbon content ranges from 2% to 7% in the surface soil while pH is 5. The particle size class qualifies these soil families as loamy skeletal. These soils are classified as Lithic and Typic Udorthents. The soils developed on side hill slopes are moderately deep to deep, well drained, loamy in texture with severe to moderate erosion hazards. They show some degree of profile development and are classified as Umbric and Typic Distrochrepts, Lithic Udorthents and Lithic and/or Typic Haplumbrepts. These soils are strongly to moderately acidic in nature, are rich in organic carbon and have moderate to low base saturation.

Table 1.4 Taxonomic soil associations in Darjeeling Himalaya

Sl. No	Soil Types (Taxonomic)	Area in %
1	Loamy Skeletal, Lithic, Udorthents associated with occasional rocky outcrops	9.65
2	Coarse loamy, Typic, Udorthents Associated with loamy skeletal, Typic Dystrochepts	35.94
3	Loamy skeletal, typic Haplumbrepts associated with loamy skeletal, typic Udorthents	1.39
4	Coarse loamy, typic Udorthents associated with fine loamy Fluventic Dystrochepts	53.02

Source: NBSSLUP, Govt. of India

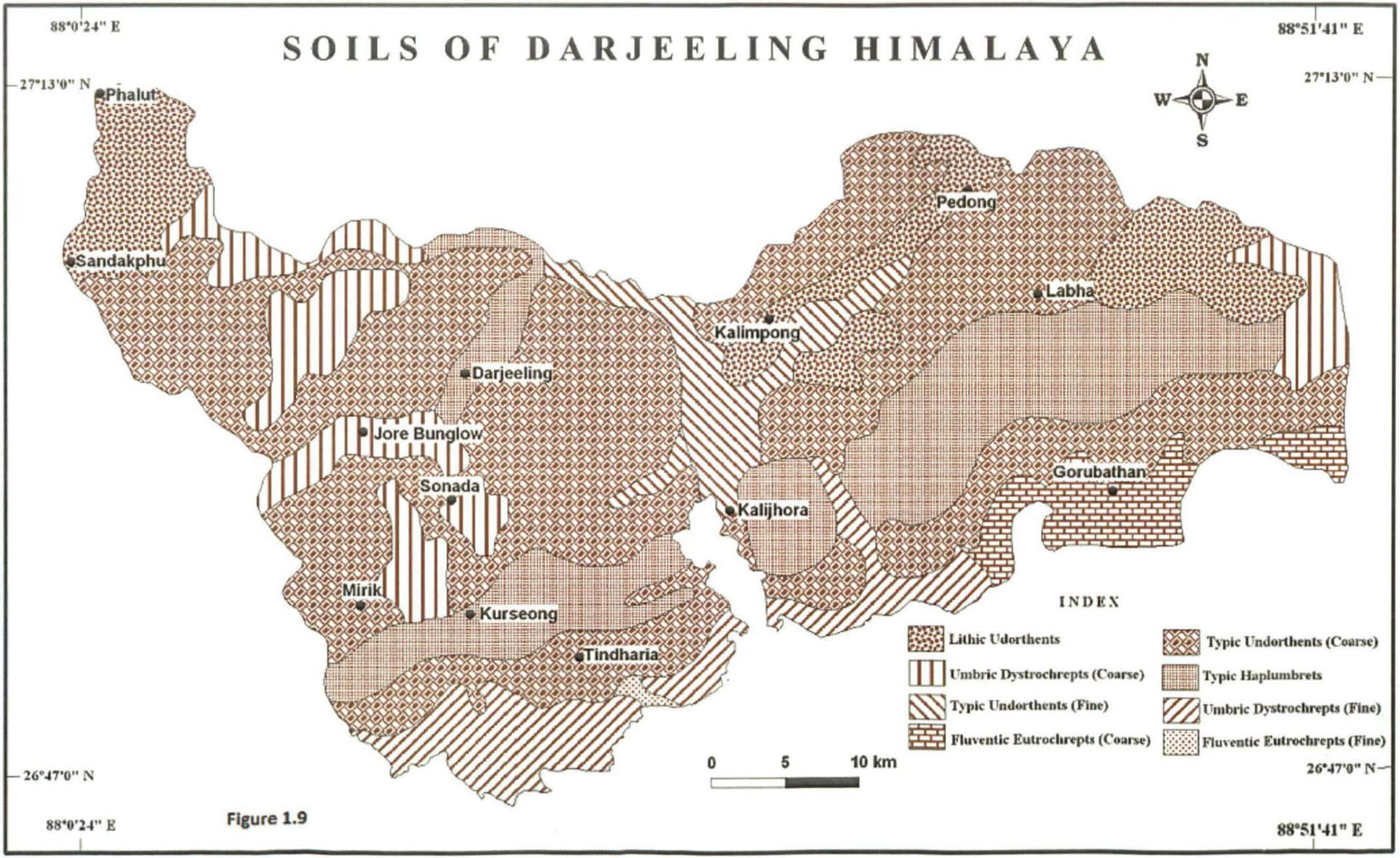
SOILS OF DARJEELING HIMALAYA
88°0'24" E
88°51'41" E
27°13'0" N
26°47'0" N
N
W
E
S
Phalut
Sandakphu
Darjeeling
Jore Bunglow
Sonada
Mirik
Kurseong
Tindharia
Kalimpong
Kalijhora
Pedong
Labha
Gorubathan
INDEX
Lithic Udorthents
Umbric Dystrochrepts (Coarse)
Typic Undorthents (Fine)
Fluventic Eutrochrepts (Coarse)
Typic Undorthents (Coarse)
Typic Haplumbrets
Umbric Dystrochrepts (Fine)
Fluventic Eutrochrepts (Fine)
0
5
10 km

Figure 1.9

All the soils are acidic in nature with the tendency to increase slightly with increasing depth in most cases, indicating the lack of bases from surface and accumulation in the lower horizon. The chemical content of the soil developed over Darjeeling gneiss is characterized by a high proportion of potassium derived from feldspar and muscovite mica. This soil is poor in lime, magnesium, iron oxides, phosphorous and nitrogen. The pH of the soil shows that it is acidic and in few places the pH value recorded even below 5. Organic matter content estimated in the soils varies and fluctuates in between 2 to 5 %. Available nitrogen is deficient in these soils and most soils contain average values of phosphorous and potassium.

However, in vast tract of forest area of Darjeeling hills show a different soil environment conditions. Table 1.5 depicts the major characteristics of soils recorded at different segments of forest covered area in the Darjeeling Himalaya.

Table 1.5 Characteristics of soils in forest areas of Darjeeling hills

Location	Altitude (meter)	Aspect	Drainage condition	Types of vegetation	pH	% of Organic matter in A0 horizon	% of Nitrogen in A0 horizon
Mahananda block Kurseong Range	1807	W	Well-drained	Virgin forest	7.2	22.32	1.14
Mana Block, Kurseong Range	1506	SE	Well-drained	Virgin forest	6.5	19.23	0.97
Mana Block, Sevok Range	1506	SE	Well-drained	Plantation (1919)	6.5	19.48	0.76
Mana Block, Kurseong Range	1204	WNW	Well-drained	Virgin forest	6.5	18.76	0.77
Latpanchar Block Sevoke Range	903	NW	Well-drained	Virgin forest	6.0	24.90	1.05
Berrick Block, Sevoke Range	602	SW	Well-drained	Virgin forest	6.5	10.29	0.35
Kundong Block, Sevoke Range	301	E	Well-drained	Virgin forest	6.5	7.05	0.31
Chamta Block , Sukna Range	151	N	Not well drained	Virgin forest	7.2	7.57	0.36
Kynanuka Block, Sukna Range	151	E	Well drained	Plantation (1940)	6.5	8.04	0.0028

Source: Directorate of Forest, Govt. of West Bengal

1.6 Natural Vegetation

Darjeeling Himalaya is one of the richest regions in the world and is literally considered a *botanist's paradise* and has thus, attracted a large number of plant hunters and botanists during the last three centuries (Don 1821, Das 1995). Phytogeographically, it forms a meeting ground of the Indo-Chinese and Indo-Malaysian tropical lowland flora, the Sino-Himalayan east Asiatic flora and the Western Himalayan flora comprising about 9000 species with a high percentage of endemic plants (Chatterjee 1940, Puri *et al* 1983, Myers 1988, Wilson 1992, Das 1995, Bhujel 1996). This province along with Khasi-Manipur has the richest flora of the Indian subcontinent with the exception of Myanmar (Rao and Murti 1990). A comprehensive travelogue through the dense and magnificent forest and vegetation of this region is rather difficult to conceive due to the nature of Himalayan terrain and intricacy of the plant cover comparable to almost that of the tropical rainforest in some of the river valleys (Bhattacharya 1997).

Although, the Darjeeling hills forms a very small part of this belt covering an area of only 2355 sq. km of a total area of 1,22,802 sq km (Negi, 1990) it shows a remarkable richness and variety in its flora as none other than Sir Joseph Dalton Hooker introduced the beauty and the floristic richness of this region to the outside world for the first time. The occurrences of a variety of physiographic, climatic and edaphic conditions often aided by biotic factors are responsible for such richness and variety. The configuration of the hills and mountains, pattern of rainfall distribution over the lower, middle and upper elevation ranges and high humidity have a great role in the determination of the type of vegetation of the area (figure 1.8). The evenly distributed, highly humid climate is conducive to tree growth and as such the timber line or the upper vegetation in this sector goes up to 4750 m above m.s.l. (Sahni, 1981).

The altitude of the various hill ranges varies markedly and usually there is a distinct correlation between the altitude and vegetation. Thus, altitude is one major factor that determines the range of distribution of different plant species and the associations that they form at different elevation ranges.

Various workers have put forth the classification of the vegetation of this region and it includes workers like Gamble (1875), Hooker (1906), Cowan (1929), Champion (1936), and Kanai (1967), Rao (1974), Sahni (1982), Jain (1982), Bhujel (1996). These authors have essentially classified the 'flora and vegetation' according to altitudinal ranges, although they differ considerably in detail. Five major types of vegetation which are further subdivided to sub- types can be recognized:

1.6.1 The tropical vegetation

High temperature and heavy rainfall characterize this zone resulting in the propagation of dense vegetation. The tropical vegetation is characterized by the presence of deciduous forests with *Shorea robusta* as a dominant species. Bhujel (1996) further divided it into following four sub types.

1.6.1.1 The riverain forests

It can be observed in small patches along the riverbeds of Tista, Rangit, Balason, Mahanadi, Relli, Chel, Lish, Gish, Jaldhaka, Sevok and Mechi. The forests remain dominated and perennial plants being dominated by shrubs and climbers. The common tree species found in this region include, *Meliosma pinnata, Albizia procera, Albizia lebbeck, Acacia lenticularis, Alstonia scholaris, Lagerostroemia parviflora*with *Acacia catechu* and *Dalbergia sissoo* occurring as distinct patches in planted forests. *Saccharum spontaneum,Mikania micrantha, Clerodendrum japonicum, C. infortunatum, Buddleja asiatica, Oroxylum indicum, Globba macroclada*, cover the forest floor.

1.6.1.2 Sal(Shorea robusta) forest

Shorea robusta is the conspicuous species growing in lower terai sal belt, ridges, spurs and well-drained loamy plains. The main associates of sal in this region include *Terminalia alata, Aglaia lawii, Duabanga grandiflora, Eugenia kurzii, Dillenia pentagynai, Chukrasia tabularis, Meliosma pinnata, Lagerstroemia parviflora, Tetrameles nudiflora, Stereospermum chelonoides, Anthocephalus chinensis* along with *Pavetta indica, Clerodendrum japonicum, Phlogacanthus thyrsiflorus, Barleria cristata, Pinus roxburghii* a normal inhabitant of the temperate to subtropical region can be also be seen associated with species like *Shorea robusta, Ficus oligodon, Pheonix humilis* in some drier valleys. Remnants of the once magnificent sal forests which has given way to the need of agricultural land can be seen along the banks of the River Rangit.

1.6.1.3 The dry mixed forest

This forest is represented by the presence of *Gmelia arborea, Tetrameles nudiflora, Beilschmiedia dalzellii, Erythrina stricta, Bombax ceiba, Alstonia nerifolia, Merremia* *emarginata, M. hederacea, Artocarpus lacucha,Eugenia kurzii* etc.

1.6.1.4 Wet mixed forest

Semi-evergreen trees along with a very large number of shrubs, climbers and herbs dominate the Wet Mixed forest. This zone is rich in epiphytes and stem-parasites giving it a distinct characteristic. The major tree species of this sub zone include *Terminalia myriocarpa, Michelia champaca, Sygzygium formosa, Cinnamomum glaucescens, Litsea monopetala, Beilschmiedia roxburghiana, Pterospermum acerifolium.* Climbers include *Beaumontia grandiflora, Bauhinia vahlii, Entada pursaetha,sinohimalensis, Cryptolepis buchananii, Mikania micrantha, Ipomea quamoclit, Boerhavia diffusa, Argyeria roxburghii,* with the lower strata and ground vegetation including *Ageratum conyzoides,Blumea balsamifera, Sonchus asper, Sauropus pubescens* etc.

1.6.2 ***Sub-tropical forests***

The vegetation of this region is affected by a seasonal climate of dry winter and a wet monsoon and thus consists largely of tropical genera and species (Grierson and Long, 1983). The mixed forest is mostly deciduous in nature. Several species tend into this zone from the tropical and plains zone. *Castanopsis indica, Schima wallichii, Gmelia arborea, Adina cordifolia, Duabanga grandiflora, Gynocardia odorata, Bischofia javanica, Callicarpa arborea, Alangium chinensis, Terminalia alata, T. bellirica, Sygzygium ramosissmum,* constitute the dominant trees in this region. In addition *Castanopsis tribuloides, Cinnamomum bejolghota, Magnifera sylvatica, Phoebe lanceolata, Litsea cubeba, Fraxinus floribunda, Helicia nilagirica, Phyllanthus emblica, Mallotus philippensis,Engelhardtia spicata* can be seen in some places. The undergrowths include *Mussaenda roxburghii, Dendrocalamus hamiltonii, Osbeckia nepalensis,Osbeckia stellata, Buddleja asiatica, Embelia floribunda, Croton caudatus, Thysanolaena maxima, Imperata cylindrica, Holmskioldia sanguinea, Woodfordia fruticosa,Boehmeria glomerulifera.* This forest is characterised presence of a good number of climbers such as *Bauhinia vahlii, Tinospora cordifolia, Cissampelos pareira,Mucuna pruriens,Thunbergia fragrans, Vitex negundo.*The common herbs include *Commelina benghalensis,Cyanodon dactylon, Pileahookeriana, P. smilacifolia, Elatostema lineolatum, Ageratum conyzoides, Oxalis corniculala, Urena lobata,Triumfetta rhomboidea.* Exotic weeds like *Euptorium odoratum* and *Mikania micrantha* grow profusely in the disturbed forests, while thickets of the tree fern *Cyathea brunoniana* is found in moist shady places.

1.6.3 Temperate vegetation

The temperate vegetation comprise of dense forest that includes areas extending from Kurseong, Toong, Sonada, Darjeeling, Mirik, Sukhia Pokhri, Maneybhangyang, Rimbick, Lodhama, Kalimpong, Lava, etc. in the Darjeeling Himalaya. The temperate forest occupies most of the region of the Darjeeling Himalaya. The richness of the vegetation is displayed by the presence of the largest number of species and the widest diversity occurring in this region. J. D. Hooker (1907) remarked that the temperate vegetation of this region is roughly divisible into lower non-coniferous and upper coniferous and *Rhododendron* belt, but the line of demarcation between these varies so greatly with the exposure and humidity of the locality that they cannot be dealt apart. Kanai (1966) and Grierson and Long (1983) classified the temperate forest of the region into three subtypes.

1.6.3.1 Temperate Deciduous forest

This forest type is characterized by the presence of trees like *Betula alnoides, Exbucklandia populnea, Eleocarpus lanceifolius, E. sikkimensis, Acer campbellii, A. sikkimensis, Engelhardtia spicata, Lindera neesiana,L. pulcherrima, Prunus napaulensis, Alnus nepalensis, Rhododendron grande,Rhododendron arboreum, Eurya acuminata* etc.

1.6.3.2 Evergreen Oak forest

This forest comprises of trees like *Quercus lamellose, Q. lineata, Q. oxydon, Lithocarpus pachyphylla, L. elegans, Cinnamomum impressinervium, Eriobotrya petiolata, Eurya acuminata, Pentapanax fragrans, Litsea elongata, Litsea sericea, Juglans regia, Leucosceptrum canum, Lithocarpus pachyphyllus, Poplus ciliata*. Shrubs like *Dichroa fabrifuga, Viburnum erubescence, Jasminum dispermum, Nellia thyrsiflora, Arundinaria maling, Hypericum hookeriana, Norysca urala, Notochaete haemosa* with climbers like *Dicentra scandens, Edgaria darjeelingensis, Holboellia latifolia, Sechium edule, Smilax ferox, Codonopsis affinis, Streptolirion voluble, Rubia manjith* etc. and herbs like *Achyranthes bidentata, Anaphalis contorta, A. triplinervis, Artemesia japonica, Bidens pilosa, Potentila fulgens, Plantago erosa, Rumex nepalensis, Clinopodium umbrosa, Gallium asperifolium., Swertia chirayita, S. bimaculata,Impatiens arguta,Lysimachia alternifolia,Poulzolzia hirta, Hypoestes triflora, Hemiphragma heterophylla, Erigeron karwinskianus, Fragaria nubicola*, forming the ground cover.

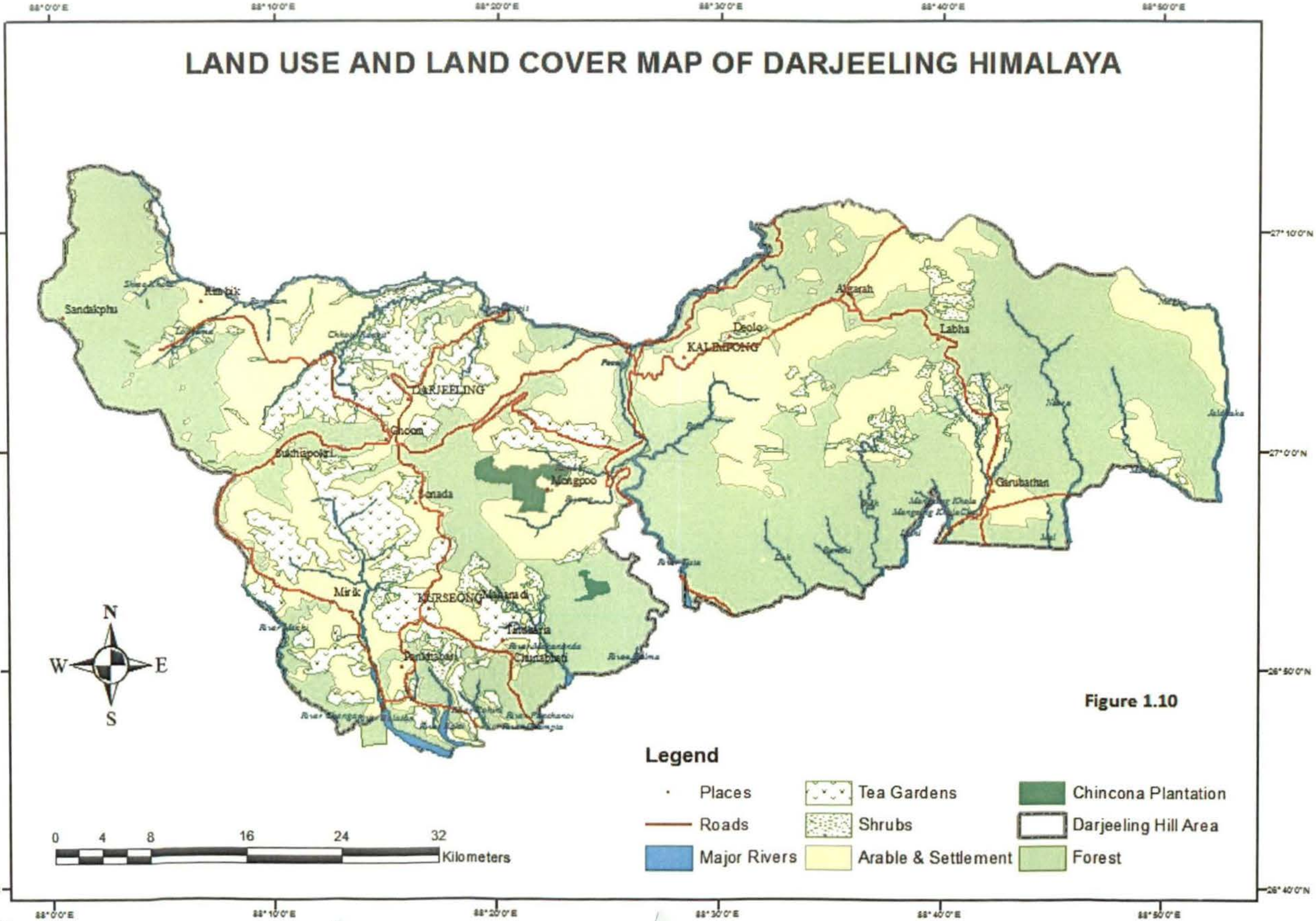
LAND USE AND LAND COVER MAP OF DARJEELING HIMALAYA
Sandakphu
Rimbik
DARJEELING
Ghoom
Mongpoo
Sonada
Mirik
KURSEONG
Mahanadi
Tindharia
Chunabhati
KALIMPONG
Deolo
Algarah
Labha
Garubathan
N
S
E
W
0 4 8 16 24 32
Kilometers
Legend
Places
Roads
Major Rivers
Tea Gardens
Shrubs
Arable & Settlement
Chincona Plantation
Darjeeling Hill Area
Forest

Figure 1.10

1.6.4. Cold temperate vegetation

Regions lying above 2400m usually receive snowfall and remain covered from a few days to few months (usually 3 - 4 months) during the year. As such there is a decrease in the diversity of the aboreal flora. Numerous herbs, many of which are endemic to the region inhabit this region (Hara 1966; Bhujel 1996). The vegetation of this zone can be broadly classified as being of two types:

1.6.4.1 Mixed temperate forest of the upper hill region

The mixed temperate forest of the upper hill region extends to about 2800m and comprises of trees like *Brassaiopsis mitis* Clarke, *Quercus lamellosa, Magnolia campbellii, Lithocarpus pachyphylla, Sorbus rhamnoides, Ilex fragilis, Prunus undulata* with climbers *Dicentra paucinerva, Clematis buchaniana, Actinidia strigosa, Smilax glaucophylla, Schisandra grandiflora* and shrubs like *Piptanthus nepalensis, Elsholtzia fructioca, Daphne involucrata, Bistorta amplexicauli, Berberis insignis, Aconogonum campanulatum, Rosa serecia* etc. with herbs like *Arisaema speciosum,Fragaria nubicola, Ranunculus diffisus, Viola sikkimensis, Ajuga lobata, Paris polyphylla, Gentiana speciosa, Geranium donianum, Pilea anisophylla,* etc. *Arundinaria maling* is found to invade large open areas in the region.

1.6.4.2 Rhododendron – Hemlock forest

The uppermost tier of the temperate forest is clearly dominated by different species of *Rhododendron* with few patches of other trees. The commonly occurring trees of this sub-region include *Rhododendron arboreum, R. falconeri, R. hodgsonii, R. decipiens, Betula utilis, Abies densa,Tsuga dumosa,Taxus baccata, Acer pectinatum, A. stachyophyllum, Daphnephyllum himalense, Ilex insignis, Larix griffithiana, Picea spinulosa.* Shrubs include *Rosa sericia, Virburnum erubescence, Viburnum nervosum, Ribes* spp. *Mecanopsis napaulensis, Nellia rubiflora, Potentilla fructicosa, Berberis insignis, B. umbellate,Daphne bholua.* Climbers include *Actinidia strigosa, Holboellia latifolia, Aristolochia griffithii, Leptocodon gracilis* etc. and herbs include *Aconitum spicatum, Aconitum Bisma, Fritillaria cirrhosa, Hemiphragma heterophyllum, Valeriana wallichii,Primula capitata, P. denticulata, Gentiana capitata, G. bryoides, G. glabriuscula, Swertia dilatata, S. macrocsperma* etc.

1.6.5 Sub-alpine vegetation

Ranging between 3200m up to around 4000m lies in the sub alpine region. This region has been categorised by some as alpine region (Biswas 1959, Mitra 1951) while as temperate region by others (Gamble 1875; Kanai 1966). A sharp reduction in the temperature to subzero level during winter with precipitation in form of snow and hail that melts during the summer characterizes the climate of this zone. The common plant species observed in this zone include *Acer acuminatum*, *Acer caudatum*, *Abies spectabilis*, *Cotoneaster frigidus*, *Salix sikkimensis*, *Salix flabellus*, *Sorbus microphylla*, *Viburnum nervosum*, *Rhododendron cinnabarium*, *R. campylocarpum*, *R. campanulatum*, *Juniperus squamata*, *J. communis*, *J. wallichiana* etc. The herbs in the forests and meadows include *Rubus fragarioides*, *Potentilla microphylla*, *P. monanthes*, *Primula glabra*, *P. oblique*, *Ranunculus adoxifolius*, *R. brotherusi*, *Anemone demissa*, *Tithymalus sikkimensis*, *T.stracheyi*, *Saxifraga hispidua*, *S. latifolia*, *Viola biflora*, *V. cameleo*, *Pedicularis mollis*, *P. clarkei*, *Picrorhiza scrophulariaeflora*, *Rheum acuminatum*.

1.7 Land use

At the time of its birth Darjeeling hill areas were totally under forest cover. With the establishment of tea gardens and cinchona plantations, lands started to be used for human activities. More than 50% of the total area was deforested within 1921. Deforestation continued for other uses of land till an apparently stable pattern arose. Current land use pattern is shown in table 1.6.

Table 1.6 Block Wise Land use pattern in Darjeeling Hilly areas

Name of CD Block	Area in km^2	Nos. of Households	Population	Forest in km^2	Arable land in km^2	Cultural waste in km^2	Area not available for cultivation	Others in km^2
Pulbazar	426.55	40880	223034	195.02	194.44	1.03	23.32	12.75
Rangli Rangliot	272.99	13092	64349	104.55	63.22	76.87	28.36	0.00
Kalimpong	369.14	21048	110678	204.43	136.12	1.76	18.15	8.68
Kalimpong Lava	241.26	11501	60263	94.57	71.82	15.61	59.25	0.00
Gorubathan	442.72	10863	54279	182.12	153.14	56.73	50.72	0.00
Jore Bunglow	222.12	22048	100724	55.52	110.76	31.82	24.02	0.00
Mirik	125.68	24053	51378	29.02	61.72	15.32	13.11	6.50
Kurseong	377.35	15050	125886	117.67	158.97	35.28	42.39	23.04
Total	2477.80	158535	790591	982.91	950.17	234.42	259.33	50.97

Source: Census, 2001

The land use pattern of the Darjeeling hills reveals forest, khasmahal area, tea gardens along with settlements. The present land use pattern in Darjeeling Himalayas (figure 1.10) have however evolved in continuation of the British policies with a very little of the western section of the district coming under agriculture. Settlement density is consequently higher in these areas since no restrictions apply in the regional population that can be supported. Another feature resulting from the settlement vis-à-vis land use patterns that land pressure following the growth of population has highly differential impact on the district. Agricultural development in the western regions blocked by twin constraints on its expansion along the extensive margin by limited access of the population to land since the major part of the area falls either under forests or tea gardens, or by agriculture along the intensive margin being debarred by to geographical difficulty and adverse climatic situations. Highest lease-land commitments to tea and lowest to agricultural usage occur correspondingly. To the east, Kalimpong, with generally lower elevations has greater topographic and climatic suitability for rice-maize-millet cropping, while the lower regions in the southern fringes harbor reserve that are conductive to present and future revenue forestry.

Table 1.7 Cultivated area under different crops in the Darjeeling hill area

Sl No.	Name of Crops	Cultivated area in hectare	Sl No.	Name of crops	Cultivated area in hectare
1	Maize	24778	10	Cardamom	2874
2	Millates	10130	11	Ginger	2278
3	Paddy	9564	12	Turmeric	15
4	Wheat	709	13	Mustered	224
5	Barley	500	14	Kalai	518
6	Buck Wheat	500	15	Soyabean	363
7	Potato	4254	16	Orange	1972
8	Winter Vegetables	1711	17	Pineapple	33
9	Summer Vegetables	3059	18	Other Fruits	341

Out of 950.17 sq. km of land area under agriculture sector 371.01 sq. km (39.04%) has been identified as net cropped area out of which only 82.96 sq. km is irrigated. The cropping intensity was estimated as 171.92% by the Agriculture Department and thus the gross cropped area of Darjeeling hill area has been estimated to be 637.86 sq. km. 184.94 sq.km is under triple crop, 402.52 sq. km is under double crop and only 52.24 sq. km is still under single crop culture (table 1.7). The balance 60.96% of land under agriculture sector has been utilized for tea plantation for which Darjeeling is world's famous.

1.8 Demography

As per the 2001 Census, the total population of Darjeeling hilly area was 790591and the number of total household was 158535. The block-wise distribution of population of population as per 2001 census is shown in figure 1.11.

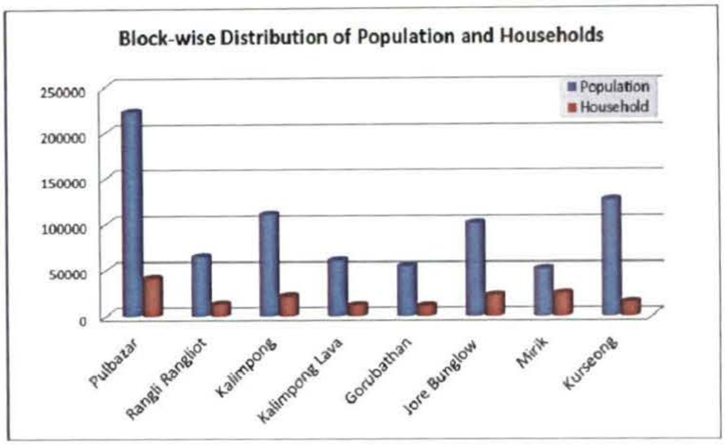

Figure 1. 11 Block-wise distribution of population and households

1.9 Conclusion

The study area thus composed of several tectonic units of the Darjeeling-Sikkim Himalaya overthrusted towards south are built mostly of metamorphic rocks. The foreland of the Himalaya is built of Quaternary sediments which show a distinct fractional differentiation starting from boulders and gravels in the root part of piedmont fans and terraces, at distance of 5-10 km from the margin.

Geomorphologically, the study area is diverse and complex in nature, exhibiting a wide variety of landforms. Their genesis, mode of formation and morphological forms are diverse and have been characterised by successive catastrophic events of slope wash on the hill slope followed by accelerated deposition along the piedmont during the post-Pleistocene period.

Topographically, Darjeeling hill area may be divided into 4 major divisions namely the upper hills, middle hills, lower hills and piedmonts. The hills rise abruptly from the piedmont plain (150 metre) and the elevation increase northwards up to 3636 meter at the Sandakfu massif of Singalila range. Within these, there is a mosaic of micro-topographic units comprising of convex ridges, inter-mountain valleys, high terraces and deep-cut valleys.

The piedmont covers the tilted plains at the base of the Himalaya bounded by the 300 meter contour line to the north and below 100 meter to the south.

The climate of Darjeeling is characterised by extreme diversities in rainfall and temperature pattern between its northern and the southern parts. Mean maximum temperature ranges from 24.2°C in Kalimpong and 18.8°C in Darjeeling in the month of August and mean minimum temperature ranges from 15.4°C in Kalimpong and 1.9°C in Darjeeling during the month of January. Precipitation also exhibits similar kind of diversity that ranges from less than 2000 mm along the northern margin along the Rangit valley to over 5000 mm along the southern face of Mahaldiram range around Kurseong. Extreme diversity in geological set-up, topographic forms along with climatic elements exhibits unique biodiversity in the study area.

Darjeeling Himalaya, with its bracing climate, unrivalled scenic beauty, enhanced further by the majestic view of Kanchendzonga and above all, the exquisite taste exhibited by the British, in building the hill resort, commensurate with its physical setting, has resulted in its emergence as the "Queen of All Hill Stations" – attracting tourists, both from within as well as from outside the country. The location, setting and juxtaposition of these natural features provides a fascinating range of view-scapes. To this complexity of nature, man has added an assortment of his interpretation of aesthetics of landscape.

Under the backdrop of the world's loftiest, youngest and tectonically most active Eastern Himalaya region, the study area exhibits a nature's laboratory for understanding the processes of environmental degradation especially under the strong influences of illogical human interventions into the delicate hill ecosystem.

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