CHAPTER 1

PHYSICAL BACKGROUND OF THE STUDY AREA

1.1. Geology

The Balason basin of the Darjeeling Himalaya, geologically speaking, is a complex region composed of rocks belonging to Archean to sub-recent age. The earliest systematic geological mapping of the Darjeeling Himalaya was carried out by Mallet (1874) followed by a large number of workers that include Gansser 1964, Singh, 1971; Acharya, 1972; Lahiri and Gangopadhyay, 1974; Pawde and Saha 1982. A geological map of the study area (figure 1.1) has been prepared by the investigator based on the previous works, to show the regional distribution of rocks, while the chronological order of various geological formations of the study area has been depicted in table 1.1.

a). Archaeans:

The Archaean group of rocks are composed of

i) Darjeeling gneiss and

ii) Daling series.

i) Darjeeling Gneiss:

Stratigraphically, the Darjeeling gneiss has been classified as: (I) Golden silvery mica schist, (ii) Carbonaceous mica schist, (iii) Granetiferous mica schist and (iv) coarse-grained gneiss (Pawde and Saha, 1982). Opaque feldspar and layers of colourless or grey quartz appear to give the intensely sub-folded rocks a banded appearance. It varies in texture from fine-grained to moderately coarse-grained rocks. At the source region of the river Balason, i.e., around Ghum Sukhia Pokhri region, the gneiss is rich in kyanite along with graphite and sillimanite.

The Darjeeling gneiss is highly foliated, with the foliation dips being oriented generally from north to north west. The dips are irregular and range from 30° to 50°. There are two prominent sets of joints in the gneiss: one running roughly NW to SE and the other NNW to SSE. Both the joints have a steep westerly dip,

GEOLOGICAL SET UP OF THE BALASON BASIN

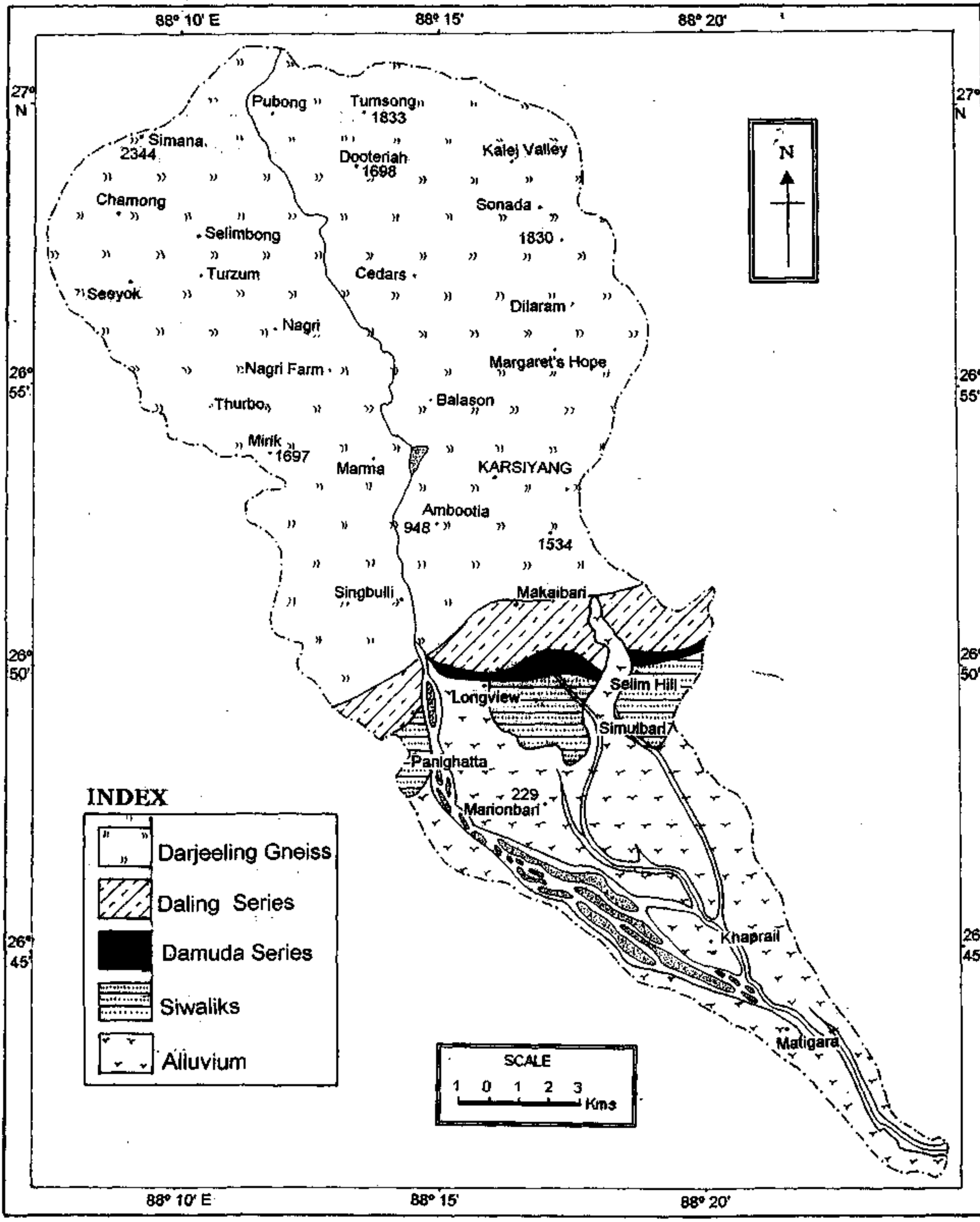

Figure 1.1.

varying from 40° to 70°. The Darjeeling gneiss covers most of the northern part of the Balason basin which amounts to 59 % of the study area (around Lepchajagat peak, Chamong and Gaurisankar tea estate).

ii) Daling Series:

Lying to the south of Darjeeling gneiss are the rocks of the Daling series comprising of grey sericite and chloritic slates, phyllites and schists. Quartz and quartz-felspathic veins traverse the rocks (photo 1.1). These veins, which had intruded prior to the deformation, are now noticed as lenticles and shreds, whereas the other intrusions that occurred during the post deformation period are quite intact and have cut across the earlier veins. The rocks are often highly metamorphosed and jointed (photo 1.2).

Slates form the lowest bed of the Daling series. These are greenish to grey, exhibiting a perfect slaty cleavage. The slates develop a phyllitic character with the prominent development of chlorite and sericite containing rounded to sub-rounded pebbles of quartz in some places (Powde and Saha 1982). The transition from slates to chlorite-sericite schists is gradual. These rocks are very much crinkled, criss-crossed with chlorite, sericite and quartz. Tourmaline and iron ore occur as accessories.

The Dalings are remarkable for their consistent development and monotonous lithology over a great thickness. They are the representative of late Pre-cambrian to early Cambrian argillaceous sequence. The rocks have dip ranging from 30° to 80° N and NE. This formation covers about 11% of the total area under study.

b) Permian

The coal-bearing Gondwana rocks of the Damuda series rest against the Dalings to the north, as a thin belt, extending almost in an east west direction and sandwiched between the two thrusts: namely, the Daling Thrust in the north and the Main Boundary Fault to the south. The Damudas are characteristic coal-

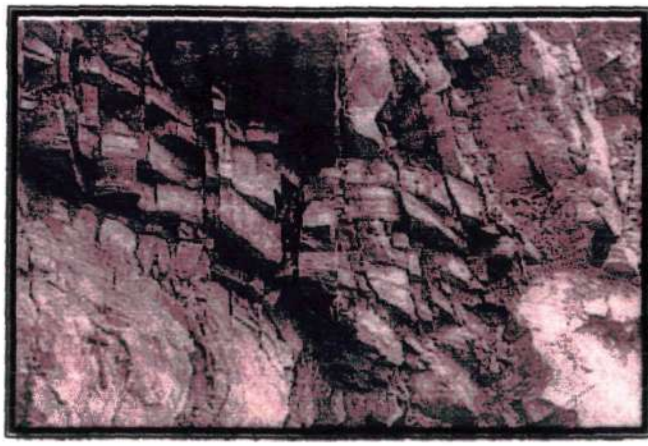

Photo 1.1. Highly Jointed feldspathic veins.

Photo 1.2. Highly jointed Darjiling gneiss

bearing detrital rocks of lower Gondwana age as proved by its fossil-flora. The predominant rocks are feldspathic, partly micaceous brownish sandstone, shaly micaceous sandstone, carbonaceous shale and coal seams. Generally, the coal is highly sheared and frequently altered to anthracite (Acharya, 1972), with further reduction of volatile elements, some of the carbonaceous shales change into carbonaceous or even graphitic schists. The semi-anthracite coal seams in this rock belt are found to be continuous from Pankhabari to Tindharia within the area under study. The beds have a generalized strike of ENE-WSW, with dip varying between 40° and 90° towards northwesterly direction. These rocks have undergone great crushing and disturbance along with a great change in lithological characters. Starting from the eastern bank of the river Balason, this rock has been extended eastward with an enlarging width. The Gondwana rock covers about 3% of the total area of the Balason basin. In the western part of the Balason river however, the Gondwana rocks are not exposed.

c) Miocene

The Miocene group of rocks is characterized by the Siwalik system. The foothill belt expose the rocks of the Siwaliks system, comprising of soft greyish sandstone, mudstone, shales and conglomerates along with their bands of marly shales and lignites. The Siwalik sandstones show well-developed laminations and contain sedimentary dykes of same material, but often showing a contrast in colour (Mallet, 1874). The top beds of this formation are usually pebbly and contain rounded to sub-rounded pebbles of quartz, having either a random orientation or are aligned parallel to the bedding plane. The sandstones are usually thick (3000 m), often massively bedded and frequently characterized by current bedding and graded bedding (Mallet, 1874). The general strike of this rock is either NNE-SSW or NW-SE with dips varying between 30° to 60°.

The east-west continuation have been interrupted by the northerly extension of the alluvium deposits that divides it into small segments, all of which are situated along the foot-hill zone of the Himalaya. The river Mechi represents the extreme western part from which it begins and ends in the western bank of river Balason.

The middle part proceeds along the Hill Cart Road, from Sukna Forest Rest House towards the north, upto Rangtong Railway station and comprises of soft grayish sandstones, mudstones, shales and conglomerates along with their bands of marly shales and lignite. The general strike is WNW-ESE. The dip ranges from 30°–70° NNE. The area under this rock system comprises about 7.5% of the total study area.

Table1.1

The geological succession of the Balason river basin

Geological periods	Geological structure	Age of beginning (million years)	Type of rocks
Pleistocene or sub-Recent to Recent	Alluvium (older & recent)	2	Boulders beds and other sands and gravels; drift formation; younger flood plain deposits comprising sand and gravel, pebble etc.
————Himalayan Front Tectonic Line————			
Miocene or lower Tertiary	Nahan group; Lower Siwalik	26	Soft greyish sand tones; mudstones; shales and conglomerates along with the bands of limestone, shale and lignite
————Thrust fault (Main Boundary Fault)————			
Permian	Damuda Series (Lower Gondwana)	280	Quartzitic (hard & soft) sandstones with slaty bands; shales and slates; semi-anthracitic (Graphitic coal; Lamprophyre sills and minor bands of limestone
————Thrust fault————			
Achaean	Daling Series	3800	Daling series: slates (greenish to grey with perfect slaty cleavage); phyllites surrounded by the pebbles of quartz; Chlorite-sericite schists with bands of grity schists injected with gneiss (crinkled); Tourmaline & iron occur as accessories, granites pegmatites and quartz veins.
	Darjeeling Gneiss		Darjeeling gneiss: golden-silvery mica schist; carbonaceous mica-schist; granetiferous mica-schist; and coarse grained gneiss

Based on Mallet,1884; Ganser,1964; and Pawde and Saha,1982.

At the foot of the Siwalik, the river flows through raised terraces, which are of recent to sub-recent origin. These comprise of gravels, pebbles and boulders mixed with ferruginous sand and clay. The formation is somewhat consolidated and stratified, and shows evidence of upheaval at places (Gansser, 1964). The reddish colour of the formation is due to oxidation and thereby proves its antiquity when compared to the alluvium of recent age, noticed further south.

d. Pliestocene:

South of the Siwalik system and within the basin is the alluvial plain that is a part of the vast extension of the North Bengal plain. The hill-wash, consisting of gravels and coarse sands, occur along the foot of the Darjeeling Himalayas forming several alluvial fans, which often merge to form the vast W-E extending piedmont plain of *terai* landscape. The terraces rise due to the deposition of rivers that often change their course. The lithology of the plain suggests that everywhere the rock fragments are either fluviatile or the product of sub-aerial erosion in nature.

Field investigation suggests that the alluvium is composed of successive layers of sand, silt and clay with some bands of gravel and lenses of pitty organic matter. The thickness of the alluvium is variable. The places that fall within this formation are Garidhura, Panighatta, Simulbari, Marionbari, Phulbari Patan, Chamta, Tutinbari, Khaprail, Matigara etc. covering about 19.5% of the total basin area.

1.2. Topography

The basin, under study, comprises of a section of the hilly region of Darjeeling Himalaya and its adjacent piedmont plain called *terai* of the Darjeeling district, in West Bengal. The hills of Darjeeling Himalaya rise abruptly over the *terai* which is composed of alluvial fans (Basu and Sarkar,1990). The elevation increases from 121 metre at Matigara to 2416 metre at the northernmost apex of the basin i.e., Lepchajagat, with the relative height of the hills fluctuating between 1000 to 2000 metre. The edges of the hills are dissected, with steep slopes inclined between 30° to 40°.

The network of ridges and valleys shows a dendritic pattern. Several narrow ridges in the form of structural scarps rise between 1500 to 1800 meter above sea

CONTOUR MAP OF THE BALASON BASIN

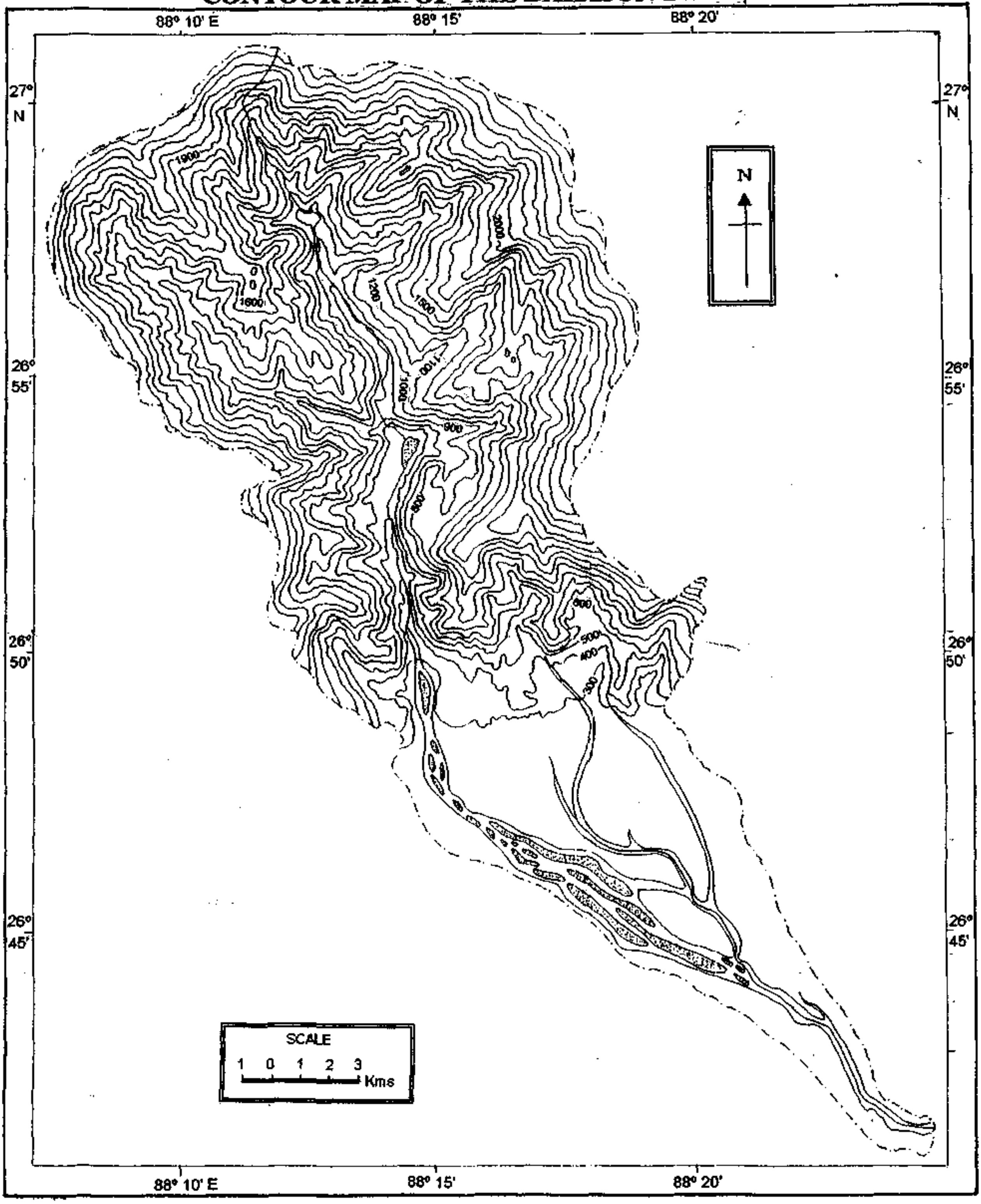

Figure 1.2

level, being connected to the more resistant Darjeeling gneiss. Along the main valley, continuous flat segments along with flattening over slope breaks, mark its vast destructional level (Starkel, 1972). These surfaces rise to elevations of about 500 to 600 metre above the valley of the Balason, at an altitudes between 1000 metre to 1500 metre above sea level. While the northern part of the basin consists of resistant gnessic rock, the southern part is composed of slaty and schistose rocks, which are less resistant to weathering and erosion.

The rivers are mainly south-flowing and erode more along the Dalings and Damuda areas. However, the density of dissection by deep valleys is very low and do not reach 0.5 km / km^2. This is due to the great depth of valleys and length of slopes that reach 1-3 km or more. A number of relatively flat, areas with visible undulations including shallow (0.5 – 2 meters) depressions, connected with mass movements have been identified. This indicates the dominance of back weathering of slopes over the fragmentation (Starkel 1972).

The general topography of the Balason basin shows a prevalence of young convex slopes, with weakly developed concave basic parts. While the steeper portions, inclined at 30° to 45° are mainly rocky, the more gentle slopes, inclined at 15° to 30°, are covered with regolith. The relief of the valley floor and river channels exhibit the features of the young stage of evolution with steep ungraded channels, narrow floors and steep valley sides. The longitudinal profile shows that the valley has directly dissected the mountain edge. The gradients of headwaters are steep and controlled by lithology and mass movement, but going downstream, the valley floors start to broaden out and aggradations prevail, despite the relatively high gradient. Finally in the alluvial fans of the *terai* zone, they are dissected at their apex (figure 1.2).

Numerous streams traverse the *terai* area, which is formed due to the coalescing of several alluvial fans (Banerjee and Banerjee,1982). Along the course of the river the sediment fraction declines from boulders (0.5 – 1m. in diameter and more) to sandy-gravel at a distance of 15 km. The channel width of the Balason also diminishes from 2 km to 0.5 km.

A great colluvial fan, in October 1968, pushed the main river towards the right bank and the boulders (1-4 meters in diameter) were exposed on the channel sides. The fan surface was built up by finer debris during the reactivation of landslides in 1983 and was later dissected several meters deep at its margin. The infill of the coarse material in the Balason channel caused aggradation downstream, in the form of wide side-bars, up to the outlet of Balason from the mountains (Starkel et al, 2000).

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 piedmont landscape over looking and often merging with the plains to the south. Along the extreme south, the topography is characterized by flatness. The rivers often describe a braided nature and are filled with sandy bars (Banerjee, et al 1982).

1.3. Climate

The nature of river network depends to a great extent upon climate, since the geometry of river channel is controlled by discharge, which in turn, depends upon the balance between all the components of the hydrological cycle. Rainfall input to the hydrological system is modified by temperature, humidity and wind condition. The climate of the Balason Basin is characterized by a greater degree of seasonality, brought about by the latitudinal extension and the wide altitudinal variations that also contribute to the vertical zonality of temperature. Thus, the climate of the study area owes its distinctness due to its position, wide differences in altitude and the precipitation caused by the humid air masses from the Indian Ocean carried by the Southwest monsoon, accompanied by **break phases**, combined with heavy and continuous precipitation. Moreover, as a result of the shifts of the monsoon troughs, towards the mountain margin, and the peculiar configuration of the ridges and valleys also contribute very high intensity rainfall along the parts of southern slopes, causing flash flood.

1.3.1 Seasons

The following seasons are noted in the Balason basin:

a). The winter season (December to March),

b). The hot weather season (April to May),

c). The rainy season (June to September) and

d). The transitional period (October to November).

However, the duration and extent of the seasons are not similar. The hilly regions experience a longer monsoon, with mist and almost continuous rainfall, starting in some years, from the first week of May. The maximum number of cloudy days occurs in this season. The winter is usually cold and unpleasant and continues till February, while spring and autumn are the most pleasant seasons. In the southern part, the climate is characterized by prolonged hot and humid summer.

Table 1.2.

Rainfall and temperature characteristics of the Balason basin.

Months	Hills		Plains		Basin	
	Rainfall in mm.	Temperature in °C	Rainfall in mm.	Temperature in °C	Rainfall in mm.	Temperature in °C
January	13.89	10.55	20.16	17.39	17.03	13.97
February	20.16	12.28	22.34	19.67	21.25	15.98
March	47.97	15.55	56.34	23.46	52.17	19.51
April	112.89	18.67	129.82	26.32	121.36	22.50
May	321.67	19.79	248.98	27.77	285.33	23.78
June	631.45	20.85	598.44	28.62	614.95	24.74
July	867.59	21.72	865.26	29.41	866.43	25.57
August	659.89	21.98	634.66	29.82	647.28	25.90
September	556.24	19.99	487.21	27.44	521.73	23.72
October	167.39	18.37	145.99	26.69	156.69	22.53
November	36.96	15.69	48.98	23.03	42.97	19.36
December	10.88	11.98	14.46	19.21	12.67	15.60

Source: Collected from different Tea Garden Records.

1.3.2 Rainfall

The southwest monsoon contributes about 85% of the total annual precipitation. July is the rainest month, followed by August. Thunderstorms, accompanied by rain occur in April, May and in October. On an average, the number of rainy days,

REPRESENTATIVE RAINFALL AND TEMPERATURE OF THREE BROAD REGIONS OF THE BALASON BASIN

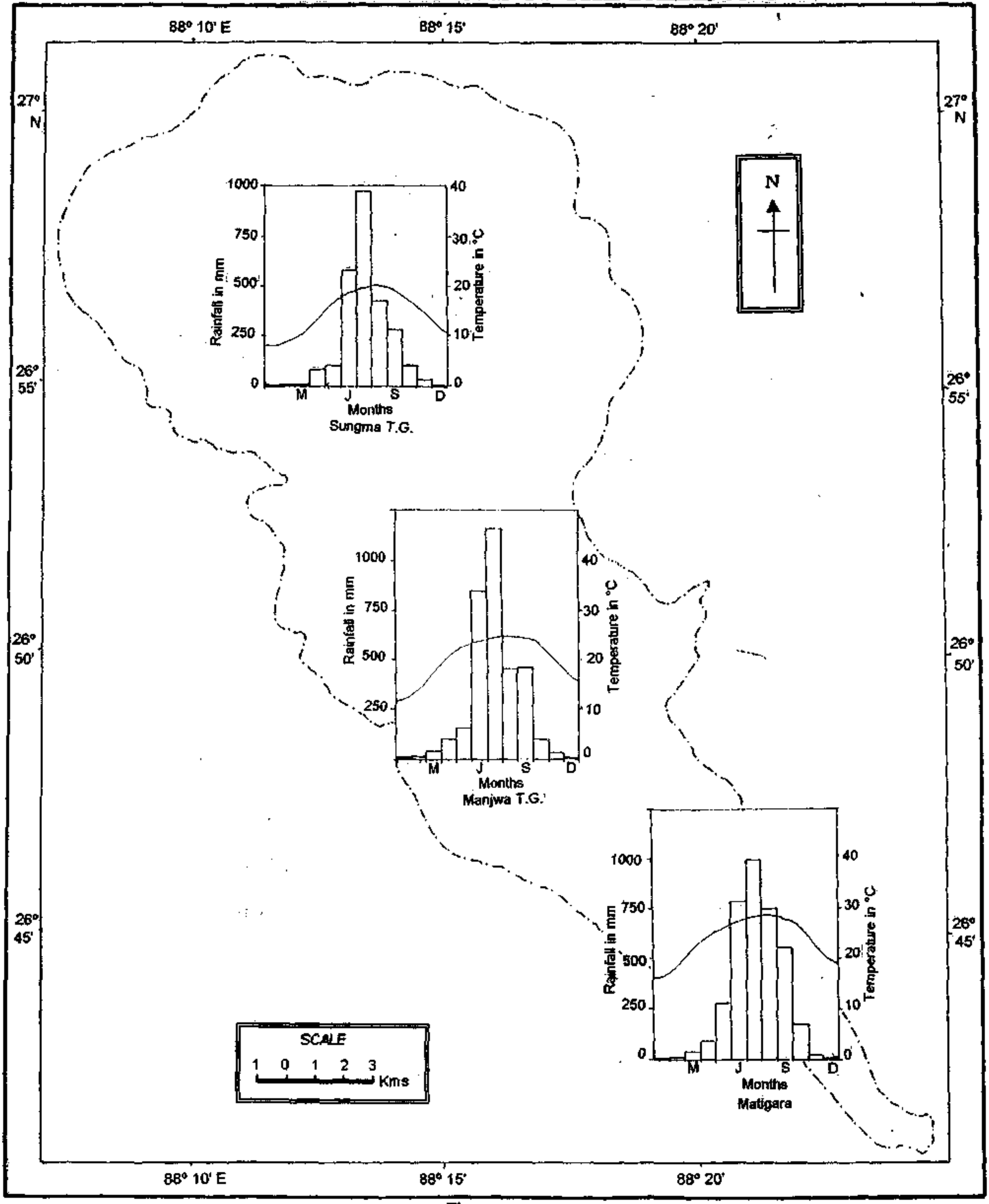

Figure 1.3

with more than 2.5 mm. of rain, varies from below 100 days in the plains to 124 in the higher slopes of the basin. The annual precipitation fluctuates from 2000 mm to more than 5000 mm within the study area. The highest monthly rainfall occurs in the month of July, for both the hills (868 mm) and plains (866 mm). The southern hilly part of the basin receives more rainfall (3446 mm), than the plains (3272 mm). The average annual rainfall for the basin, as a whole, is 3359 mm. (table 1.2 & figure 1.3).

1.3.3 Temperature

The hilly region of the Balason basin has a mean annual temperature of 12°C, while those of the plains record 24°C. During summer, the mean temperature range between 16°C to 17°C and 27°C to 28°C respectively; while the mean winter temperatures fluctuate between 5°C to 6°C in the hills and 12°C to 13°C in the plains. The lowest recorded winter temperature in the hills range between -1°C to -5°C. The air humidity fluctuates in the plains from 58% in March to 87% in summer, but in the higher reaches, humidity is generally high, as a result of excessive cloudiness.

1.4. Soil

The soil, in the Balason basin of the Darjeeling Himalaya, has long and complex history. The geographical and climatic factors made the region suitable for the spread of the tea plantations. With the increase of population, forests were greatly exploited. Forests were cleared for making cultivable land available and forest produce such as timber were used, both as fuel and building material, along with fodder for domestic animal.

Thus, the original soil of the region has undergone changes, resulting in the alteration of its nature. In many cases, the soil has actually undergone more than one cycle of formation. The records of its past history have been mostly obliterated, either by the formation of new soil on the truncated top of the older soil or by the complex removal of the original soil by erosion (Sarkar, 1990).

1.4.1. Pedogenesis

Soil is the product of the action of climate and organisms upon the geological foundations which constitute the soils patent material. The ultimate character of soil is further conditioned by factors like topography, drainage, time and human activities. All these factors are important soil controls in the study area, although some are more important than others, which need special mention.

The study area is characterized by a general hot-warm and humid climate, with strong seasonal distribution of rainfall, leading to the general bleached nature and silica dominated surface soil. Human activity on vegetation, leading to deleterious effects on the soil (Sarkar, 1990), is highly evident in the study area. Heavy deforestation with increased pressure on the soil resource, by continuous arable cropping, tea plantation, overgrazing, monocultural plantations and changes in the past and present landuse practices have led to accelerated erosion. The truncation of soil profiles is spectacular and serious throughout the study area, especially along the northern hilly tracts. Profile studies show that topsoil removal is widespread and the present use. is often being carried out on former sub-surface horizons. The progressive break-down of structure and tilth is one of the factor which aids soil panning and subsoil compaction in some places.

The parent materials and topography, especially the slope gradient and orientation, have predominant role in governing the soil variability within the watershed. The variation in lithology obviously govern the characteristics of the weathering products and hence, soils of the different strata. Due to very high rainfall, moderately high temperature and high micro-biological activity, very high rate of chemical weathering is found almost everywhere, almost all rocks and at all altitude regime. The effect of the slope needs to be superimposed on lithology soil-type correlation. Field observations indicate that soils are active even on the gentler slopes. Colluviation and slope wash are the most active process operating on valley sides and ridge flanks. On the steep slopes, the soil profile reveals features like solum mixing, truncation and the presence of colluvial stone horizons.

1.4.2. Soil Classification :

The soil-mapping units recognized and described in this study are based on the USDA, Soil Taxonomy (Sarkar, 1990). The taxonomic orders, sub-orders, great-groups and sub-groups have been recognized and shown on the soil map (figure1.4) and also represented in the table 1.3 below:

Table 1.3.

Taxonomic soil groups of the Balason basin

Soil order	Sub order	Great groups	Sub groups	Area covered in sq. km.	% area to total area
Entisols	Orthents	Udorthents	Typic Udorthents	56.81	15.46
	Fluvents	Topofluvents	Typic Tropofluvents	53.26	14.50
Inceptisols	Umbrepts	Haplumbrets	Typic Haplumbrets	31.21	8.49
			Lithic Haplumbrets	25.98	7.07
			Typic Dystropepts	144.29	39.27
	Tropepts	Dystropepts	Umbic Dystropepts	38.12	10.38
			Fluventic Dystropepts	17.75	4.83

For a generalized idea of the nature and characteristics of the soil of the study area some salient features of the taxonomic units have been described below:

1.4.2.1. Entisols:

These soils have little or no evidence of pedologic profile development either due to short duration or receiving of new deposits of alluvial at frequent interval from the higher tracts. The only evidence of pedologic alteration in these soils is a small accumulation of organic matter in the upper 30 cm.

The order Entisols have been found to comprise the southern undulating to gently sloping terrain, covering 29.96% of the study area. Small pockets are found around Marma and Nagri farm along the Balason valley, Singbuli, Makaibari,

SOIL MAP OF THE BALASON BASIN

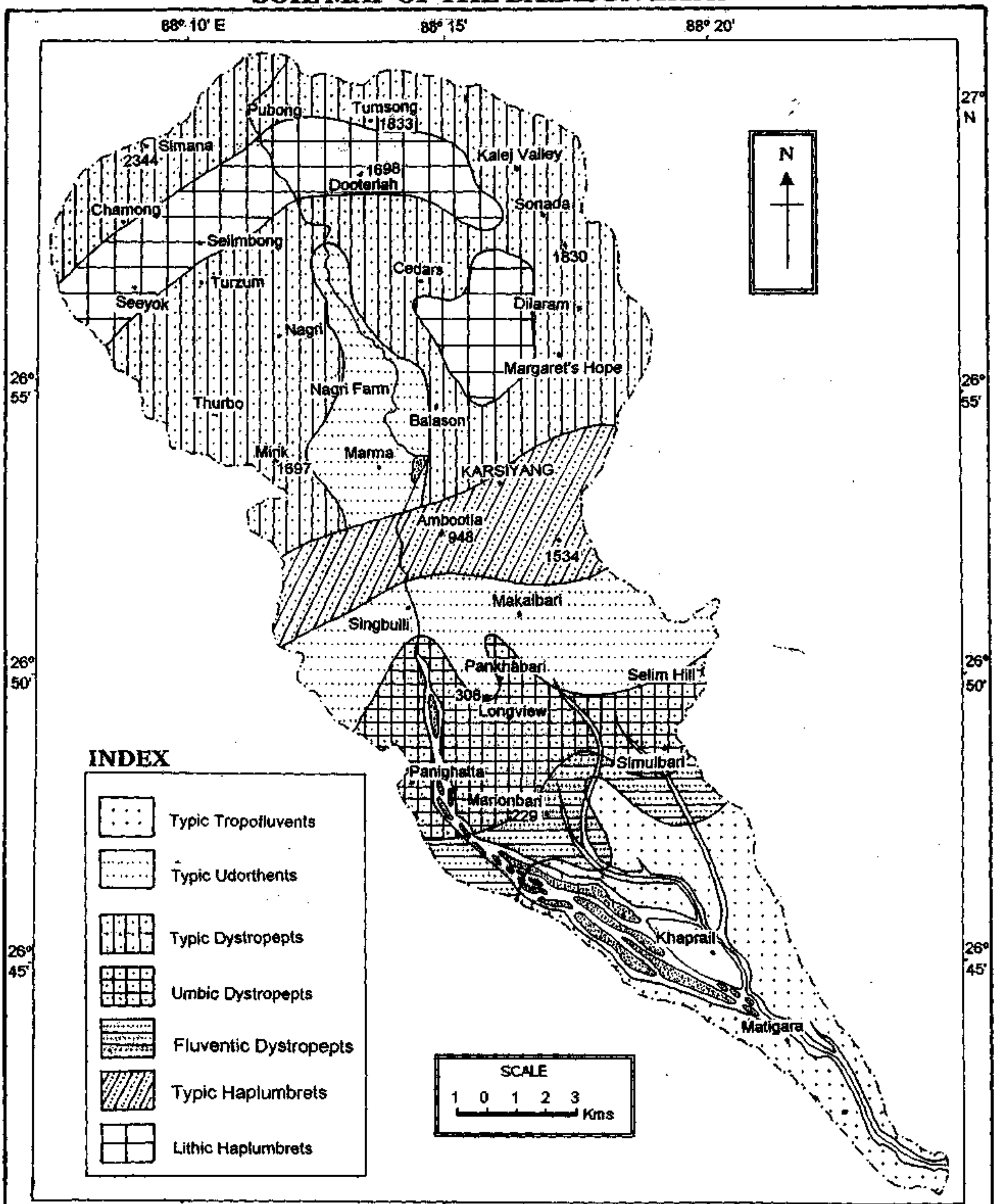

Figure 1.4

Pankhabari, Longview, Khaprail and Matigara. Two sub-orders namely a) Fluvents and b) Orthents have so far been identified in the study area (figure 1.4).

a) Fluvents:

These are light grey to pale brownish soils, formed in recent water borne sediments, found mainly in the flood plains and alluvial fans. The fluvents occupy a large portion of the southern part of the study area, in and around Matigara and Khaprail (figure 1.4). They have low organic carbon percentage (1.0 -1.5%), with a coarse sandy texture, with granular structure. The fluvents of this region belong to the tropofluvent great group i.e., udic soil moisture regime and have some amount of weathered clay. The sub-group is recognized as typic tropofluvents.

b) Orthents :

The orthents belonging to the great group udorthents and sub-group typic udorthents, have been found to occur along the eastern, northern and north western parts of the Tropofluvents in Nagri farm, Marma, Singbuli, Makaibari, Pankhabari and Longview (figure 1.4). They are primarily entisols on recent erosion surfaces, where, the former soil has completely or partially been removed or truncated to such an extent that the diagnostic horizons for the other orders remain absent. The interfluves are generally composed of older alluvium and/or alluvial fan materials which are situated 5-10 metres above from the flood plains. They have developed on very recently exposed regoliths, mostly as unconsolidated sedimentary deposits.

1.4.2.2. Inceptisols :

They constitute the most extensive soils, covering approximately 70.04% of the area under study. They are widely distributed in the hilly tracts, where the slope-gradients range form 10 to 65%. These soils are typical of the humid regions, possessing a wide variety of physical and chemical properties, that vary with respect to their depth, colour, texture, structure, organic carbon, porosity, permeability etc. They share a common feature as they have lost bases, but they retain some weathered minerals. Normally, they lack an illuvial horizon, which is enriched with silicate clay that contains either aluminum or organic carbon.

This soil presents a variety of management problems to farming and forestry, as the temperature regime is thermic to meso-thermic with the soil moisture regime being udic to ustic, with strong seasonal precipitation. Two sub orders i.e. tropets and umbrepts have been identified in the study area:

a) Tropets :

These are brownish, more or less freely drained Inceptisols of humid tropics, that occur in the northern part of the basin, with a thin to moderately deep profile (50 to 120 cms), developed mostly on steep slopes along the northern hilly area and along the foothill around Marionbari, Simulbari and Panighatta. The soils have an isothermic or warmer iso-temperature regime, with the soil moisture regime being udic to ustic, with broad-leaved vegetation. Three great groups have been recognized: i). typic dystropepts, ii). umbric dystropepts and iii). fluventic dystropepts.

b) Umbrepts :

They have developed along the slopes of Selimbong, Seeyok, Pubong, Dooteriah, Tung, Karsiyang and Ambootia (figure 1.4). These are acidic in reaction (pH 5 – 5.5), being dark reddish to brownish in colour, freely drained, carbon rich inceptisols of humid tropics and sub-tropics and developing from varied types of parent materials, which are mostly coarse-grained jointed schist and gneiss.

The most striking feature of pedogenesis is the natural umbrella to the surface soil, provided by the thick vegetal matter, accumulating on the surface. The vegetation are mostly mixed, but coniferous forests with frequent falls are common at higher altitudes. The soil temperature regime varies from mesic to thermic. The umbrepts of the study area have been classified into two sub groups: i). typic haplumbrepts and ii) lithic haplumbrepts.

1.5. Natural Vegetation

The Balason basin is a region of wide variety of forest resources. The most remarkable feature of the forest of this region is the wonderful variety of species that it contains. Few places in India command range of variation of forest types as found in such a small area of the Balason basin. It is perhaps, in fitness of things, that forest conservancy was initiated in this part of the country more than hundred years age.

Many researchers have so far classified of the natural vegetation of this region which includes workers like Hooker (1854), Champion (1936), Banerjee, 1964; Bhujel (1996) etc. Among the various factors responsible for spatial differences of forests, pedological and climatic factors are by far the most important. Champion and Seth classified the forests of Darjeeling area based on rainfall and temperature. Three major types of vegetation which are further subdivided into sub types can be recognised:

1.5.1. The Tropical forests:

High temperature and heavy rainfall in this area generally helps the development 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 four sub types:

a). Riverain forest,

b). Sal forest,

c). Dry mixed forest and

d). Wet mixed forest

(a) **The Riverain forests** can be observed in small patches along the riverbeds of the Balason, Rakti, Rohini and Mechi. 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* spp. cover the forest floor.

b) Sal *(Shorea robusta)* forest *Shorea robusta* is the conspicuous species growing in Lower Siwalik foothill and *terai* 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.* These plants are also seen associated with species like *Shorea robusta, Ficus oligodon* and *Pheonix humilis* in some drier valleys.

c) The dry mixed 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.*

d) The wet mixed forest is dominated by semi-evergreen trees, along with a very large number of shrubs, climbers and herbs. 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.* The lower strata and ground vegetation include *Beaumontia grandiflora, Bauhinia vahlii, Entada pursaetha, sinohimalensis, Cryptolepis buchananii, Mikania micrantha, Ipomea quamoclit, Boerhavia diffusa, Argyeria roxburghii, Ageratum conyzoides, Blumea balsamifera, Sonchus asper, Sauropus pubescens* etc.

1.5.2. Sub-tropical forests (800-1600 m)

The vegetation of this region is affected by seasonal climate of dry winter and a wet monsoon and thus consists largely of the tropical genera and species. The mixed forest is mostly deciduous in nature. This includes regions like upper Balason, Rangbang khola, Marma khola, Manjwa Jhora, Rakti khola and Rohini khola. Several species blend into this zone from the tropical and plain areas. *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 cylindrical, Holmskioldia sanguinea, Woodfordia fruticosa, Boehmeria glomerulifera.* This forest is characterized by the presence of a good number of climbers such as *Bauhinia vahlii, Tinospora cordifolias, Cissampelos pareira, Mucuna pruriens, Thunbergia fragrans, Vitex negundo.* The common herbs are *Commelina benghalensis, Cyanodon dactylon, Pilea hookeriana, P. smilacifolia, Elatostema lineolatum, Ageratum conyzoides, Oxalis corniculala, Urena lobata, Triumfetta rhomboidea.*

Exotic weeds like *Euptorium odoratum* and *Mikania micrantha* grow profusely in disturbed forests, while thickets of the tree-fern *Cyathea brunoniana* are found in moist and shady places.

1.5.3. Temperate Vegetation (1600-2400m)

The temperate vegetation comprises of dense forest that includes areas extending from Karsiyang, Toong, Sonada, Darjeeling, Mirik, Sukhia Pokhri, Maneybhangyang, etc. 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 (1854), 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'.* The temperate forest of the region is sub-divided into three subtypes:

a) Temperate Deciduous forest : is characterized by the presence of trees like *Betula alnoides, Exbucklandia populnea, Eleocarpus lanceifolius, Eleocarpus sikkimensis, Acer campbellii, A. sikkimensis, Engelhardtia spicata, Lindera neesiana, L. pulcherrima, Prunus nepaulensis, Alnus nepalensis, Rhododendron grande, Rhododendron arboreum, Eurya acuminata etc.*

b) Evergreen Oak forest : comprises of trees like *Quercus lamellose, Q. lineata, Q. oxydon, Lithocarpus pachyphylla, Acer hookerii, 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, karwinskianus, Fragaria nubicola* to name a few, forming the ground cover.

However, the introduction of exotic species like *Cryptomeria japonica* in the upper and middle hill has adversely affected the natural vegetation in the region, since such a move has resulted in the decrease of species diversity, especially in areas where the said species has been established as a monocrop.

1.6 Landuse

The study area until 1835, was mostly covered by dense forest and inhabited by a few migratory Lepchas in the hills and the Meches in the foothills and was *'completely clothed with forest from the very top to the bottom'* (Hooker, 1854). The degradation began with the construction of a road connecting Darjeeling to the plains in 1839. Soon large tracts of forests were replaced by roads, tea-gardens, railway lines and settlements.

Experimental planting of tea started from 1841 under the supervision of Dr. Campbell, Superintendent of Darjeeling. The success led to rapid growth of the plantation and soon tea gardens like Ambootia, Makaibari, Soureni, Phuguri etc. were established between 1860 and 1864. By 1871, nearly 20 tea gardens with approximately 890 hectares of forested area was leased out for tea cultivation. At present, the maximum area (within the study area) is occupied by tea plantations, which covers an area of 99.33 sq. km constituting 27.03% of the area, within the Balason basin.

With time, a pronounced decrease in the forest cover became apparent and at present the forest is mainly restricted in the north and north-eastern section of the study area with small natural patches at Singbulli, Selim Hill, Manjwa and between Pankhabari and Longview. The forest area, today, occupies an area of 96.18 sq. km approximately (figure 1.5). Settlements with cultivated waste cover 29.92 sq. km within the study area.

1.7 Conclusion

It can be seen that the study area is geologically young and fragile region, with intensely metamorphosed rocks like phyllite, schists, slates and gneiss covering most of the area. These rocks are highly weathered, fractured and jointed and have a tendency to produce slope instability during intense rainstorm.

LANDUSE MAP OF THE BALASON BASIN

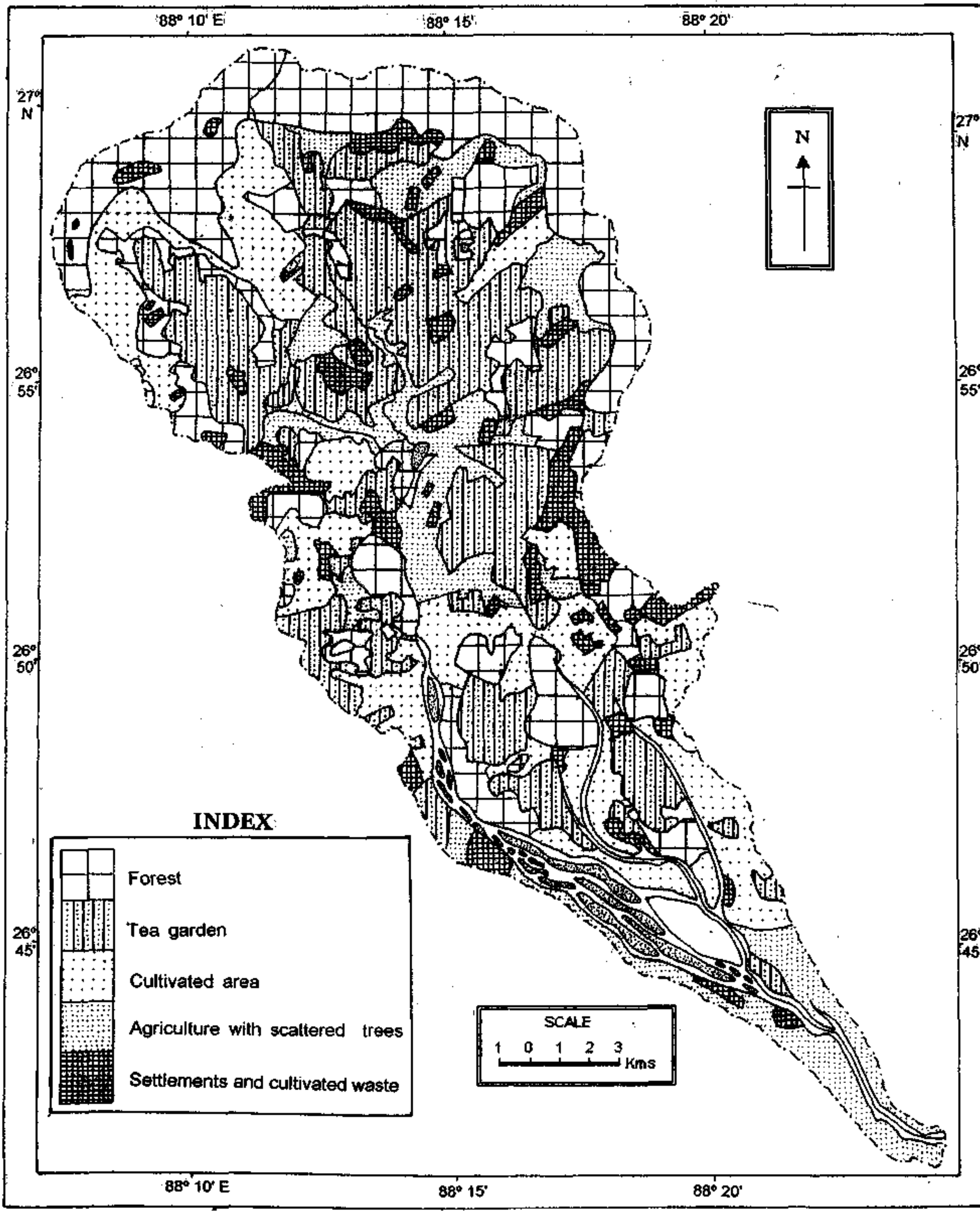

Figure 1.5

Topographically, the area may be sub-divided into the northern hill region with steep slopes and the southern terai area, exhibiting convex slopes and fan formation due to aggradation. The temperature shows very wide variations, which are directly dependent upon the altitude.

The soils of the Balason basin can be sub-divided provisionally into 2 orders, 4 sub-orders, 4 great – groups and 7 sub-groups. The above soils have an inherent low nutrient status. The entire southern half of the study area shows deficiency in organic matter, nitrogen and phosphate. The dominant soil taxonomic order has been recognized as the Inceptisols, which cover the entire northern hilly tracts and show deficiency in phosphate and potassium.

The drastic reduction of the natural forest, combined with the high annual rainfall exceeding 3000 mm in most part of the basin, makes the area highly vulnerable to soil erosion and landslides, reducing the soil fertility, choking the streams and leading them to change their courses. Thus, it can be concluded, that the study area, which is geologically highly vulnerable, and experiences very high precipitation coupled with heedless deforestation and unscientific changes in the land-use pattern, poses a threat to both the lives and properties of the local inhabitants.

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