Carrying Capacity Study of Teesta Basin in Sikkim

EXECUTIVE SUMMARY
AND
RECOMMENDATIONS

Commissioned by :

Ministry of Environment & Forests, Government of India

Sponsored by :

National Hydroelectric Power Corporation Ltd., Faridabad

CENTRE FOR INTER-DISCIPLINARY STUDIES OF
MOUNTAIN & HILL ENVIRONMENT
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CONTENTS

Page No.

EXECUTIVE SUMMARY

1.0 INTRODUCTION

Sikkim is a small Himalayan state in north-east India situated between 27^o 00' 46" to 28^o 07' 48" N latitude and 88^o 00' 58" to 88^o 55' 25"E longitude with geographical area of 7,096 sq km constituting only 0.22% of total geographical area of India. It has a human population of 5,40,493 as per Census, 2001, which constitutes only 0.05% of India's total population. The state is somewhat rectangular in shape with maximum length from north to south of about 112 km and maximum width of 90 km from east to west. The state is bounded in the north by the Tibetan plateau, by China (Tibet) on the northeast, by Pangola range of Bhutan on the southeast, by Darjeeling district of West Bengal on the south and Singalila range and Mt. Khangchendzonga on the west and northwest (Fig. 1). Entire state of Sikkim constitutes upper basin of Teesta river except for a small area of 75.62 sq km in extreme southeast that of Jaldhaka river, which originates in East Sikkim and flows through West Bengal parallel to Teesta river to meet Brahmaputra river. In southernmost part of Sikkim, Teesta river flows in southwest direction and defines the inter-state boundary between Sikkim and West Bengal up to Melli Bazar where it is joined by Rangit river which drains West Sikkim district. Rangit river, the largest tributary of Teesta river in Sikkim, from Naya Bazar point flows in southeast direction and marks the inter-state boundary between Sikkim and West Bengal in the southwest.

The state of Sikkim has been administratively divided into four districts *viz*. North Sikkim, South Sikkim, East Sikkim and West Sikkim using water divides of major and minor tributaries of Teesta river as criteria. North Sikkim is the largest district with an area of 4,226 sq km constituting about 60% of the entire state. The West, East and South districts constitute about 16%, 13% and 11% of the geographical area of the state, respectively. The state capital is located at Gangtok in East Sikkim. Each district has been further divided into two sub-divisions each, except East Sikkim, which has been divided into three sub-divisions. All the districts together have 407 revenue blocks and 42 forest blocks. The administrative set up of the state is outlined in Table 1. East Sikkim is the most populated district having 45.29% of state's total population and North Sikkim is the least populated with 7.59% share of the total human population.

Table 1. Administrative set up of Sikkim

Particulars	District			
	North Sikkim	**South Sikkim**	**East Sikkim**	**West Sikkim**
Area (sq km)	4,226	750	954	1166
Sub-division	Mangan*	Ravong	Gangtok*	Gyalzing*
	Chungthang	Namchi*	Pakyong	Soreng
			Rongli	

*District headquarters

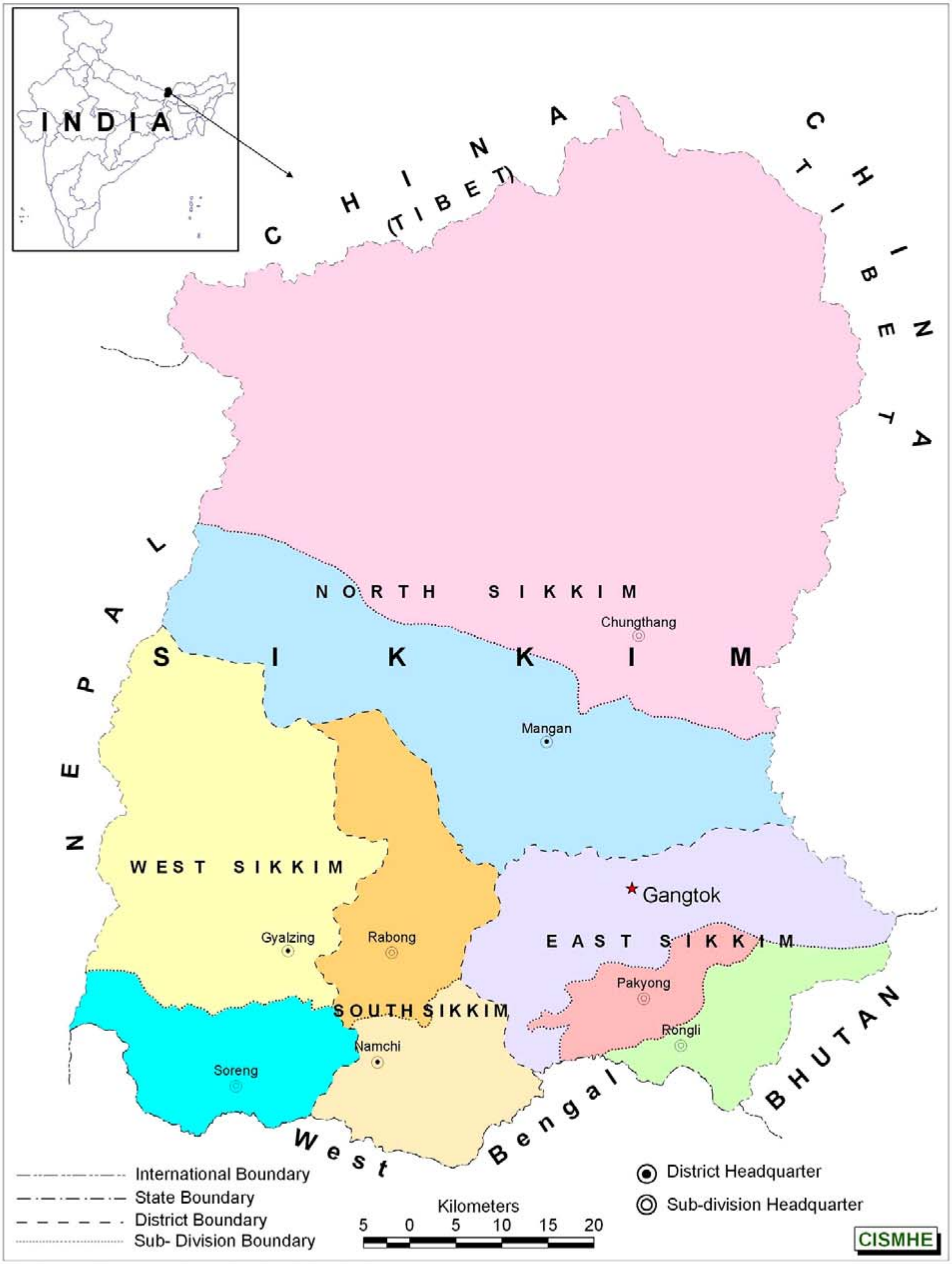

Fig.1 Location map of Teesta Basin in Sikkim

Human population of Sikkim is comprised mainly of Nepali, Bhutia and Lepchas. Main languages of the state are Nepali, Bhutia and Lepcha. Majority of the population speaks Nepali, which is the main medium of instruction in educational institutions along with English. The inhabitants of the state are predominantly Buddhists. Majority of residents depends on agriculture and related activities for their livelihood. Maize, large cardamom, rice and wheat are principal crops grown in the state.

1.1 PHYSICAL FEATURES

Sikkim state being a part of inner mountain ranges of Himalaya, is entirely hilly, having no plain area with altitude varying from 213 m in the south at Melli Bazar to above 8,500 m (Mt. Khangchendzonga: 8,598 m) in the north-west and northeast (Pauhunri: 7,056 m). The human habitable areas are limited only up to the altitude of 2,100 m constituting only 20% of the total area of the state. North Sikkim, which is deeply cut into escarpments, is the least populated with a population density of 9.7 persons/ sq km only. The habitation at higher altitudes exists mainly in Lachen and Lachung valleys comprising the upper catchment of Teesta river. The population, however, is concentrated in lower altitude habitations, *viz*. Mangan, Singhik, Chungthang, etc. North Sikkim is endowed with a number of glaciers that descend from the eastern slopes of Khangchendzonga and western slopes of Pauhunri. Zemu glacier located in North Sikkim is one of the largest glaciers in India with a total length of about 25 km. This high altitude district forms the upper

Teesta basin and is endowed with number of glacial lakes of various sizes and shapes. The prominent among them are Chho Lhamo, Gurudongmar Chho, Lhonak Chho, Green Lake and Khangchung Chho. Other important lakes in the state are Chhangu and Kupup lakes in East Sikkim and Khecheopalri in West Sikkim. More than 43% of Teesta basin in Sikkim is characterized by very steep slopes and escarpments i.e. more than 43% of its geographical area lies in more than 50% slope category. This district can safely be called as the hydrological estate of Sikkim state as it holds a pivotal position in controlling the water regime in the entire Teesta basin.

The landforms and drainage of Teesta river are characterized mainly by the four tiered terraces, canyons or gorge-valleys at different altitudes, asymmetric valleys, polyprofilic U-shaped valleys and steps or troughs, lakes, alluvial cones, truncated ridge-spurs, terracettes (soil landscape systems), rectangular-barbed-parallel-trellis-radial to sub-dendritic drainage patterns, straight to meandering and braided channels. All these physiographic features are indicative of active processes of weathering, denudation and deposition making the area physically very sensitive.

1.2 GEOLOGICAL SETTING

The regional geological set-up of the Sikkim Himalaya is best displayed in the form of Teesta gorge, flowing in general from north to south. The Central Crystallines represented by a sequence of high grade meta-sedimentaries (calc-granulities, schist, quartzite), gneisses/

migmatites and a number of granitic intrusions are exposed in the Axial Zone of North Sikkim. The Central Crystalline rocks are separated from the gneisses and schists (Darjeeling gneiss and Daling Group) in the south by a prominent dislocation zone, namely the Main Central Thrust, which is an important tectonic feature or activity all along the Himalaya. The foothills in southern part of Teesta basin in Sikkim are characterised by low-grade pelite-psammite assemblage (Dalings) followed by alternate sequence of the sandstone shale-coal assemblage (Gondwana) occuring with prominent structural dislocations in between. Further south, the Gondwana rocks are separated tectonically from the Shiwaliks by the Main Boundary Fault. There is no recorded event of macro- and/or micro-seismicity in North Sikkim, though it is characterised by natural hazards like landslides. The area south of MCT is highly vulnerable to earthquakes. As per the revised Seismic Zoning Map of India, the state of Sikkim lies in the seismic zone classified as Zone-IV (Fig. 2).

1.3 RIVER TEESTA

The river Teesta is one of the main Himalayan rivers and originates from the glaciers of Sikkim in North at an elevation of about 5,280 m. The river rises in mountainous terrain in extreme north as Chhombo Chhu, which flows eastward and then southward to be joined by Zemu Chhu, upstream of Lachen village near Zema. The river takes a gentle turn in southeast direction and meets Lachung Chhu at Chungthang where it takes the form of a mighty Himalayan river (Fig. 3). Teesta, therefore, is the main river of the state with its several tributaries *viz*. Zemu Chhu, Lachung Chhu, Rangyong Chhu, Dik Chhu, Rani Khola, Rangpo Chhu and Rangit river and constitutes an extremely important resource of the state.

After the confluence of Teesta river and Lachung Chhu at Chungthang, the river gradually widens and takes a strong westward turn upstream of Tong and after flowing down to Singhik, the river drops from 1,550 m to 750 m. At Singhik, the river receives one of its major tributaries, Rangyong Chhu on its right bank, which originates from the Talung glacier, a part of the Khangchendzonga mountain range. From Singhik, the river flows southwards to Dikchu with a 200 m drop through a very deep valley for about 30 km. From Dikchu onwards, the river takes many sharp and wide curves and flows down to Singtam with a further drop of about 200m. Rangpo Chhu, which drains the Chhangu lake area in East Sikkim joins Teesta river on its left bank at Rangpo. Downstream of Rangpo, Teesta river widens and is joined by Rangit river at Melli Bazar on Sikkim-West Bengal border. From Melli Bazar downstream, the river leaves the hilly terrain and enters the plains of West Bengal at Sevoke near Siliguri. Teesta river ultimately drains into Brahmaputra at Teestamukh Ghat (Kamarjani-Bahadurabad in Rangpu district of Bangladesh) and traverses a distance of about 400 km from its origin.

Teesta and most of its tributaries are flashy mountain rivers and carry boulders and considerable quantity of sediment. The flow is turbulent and characterised by high velocities. Throughout its course in

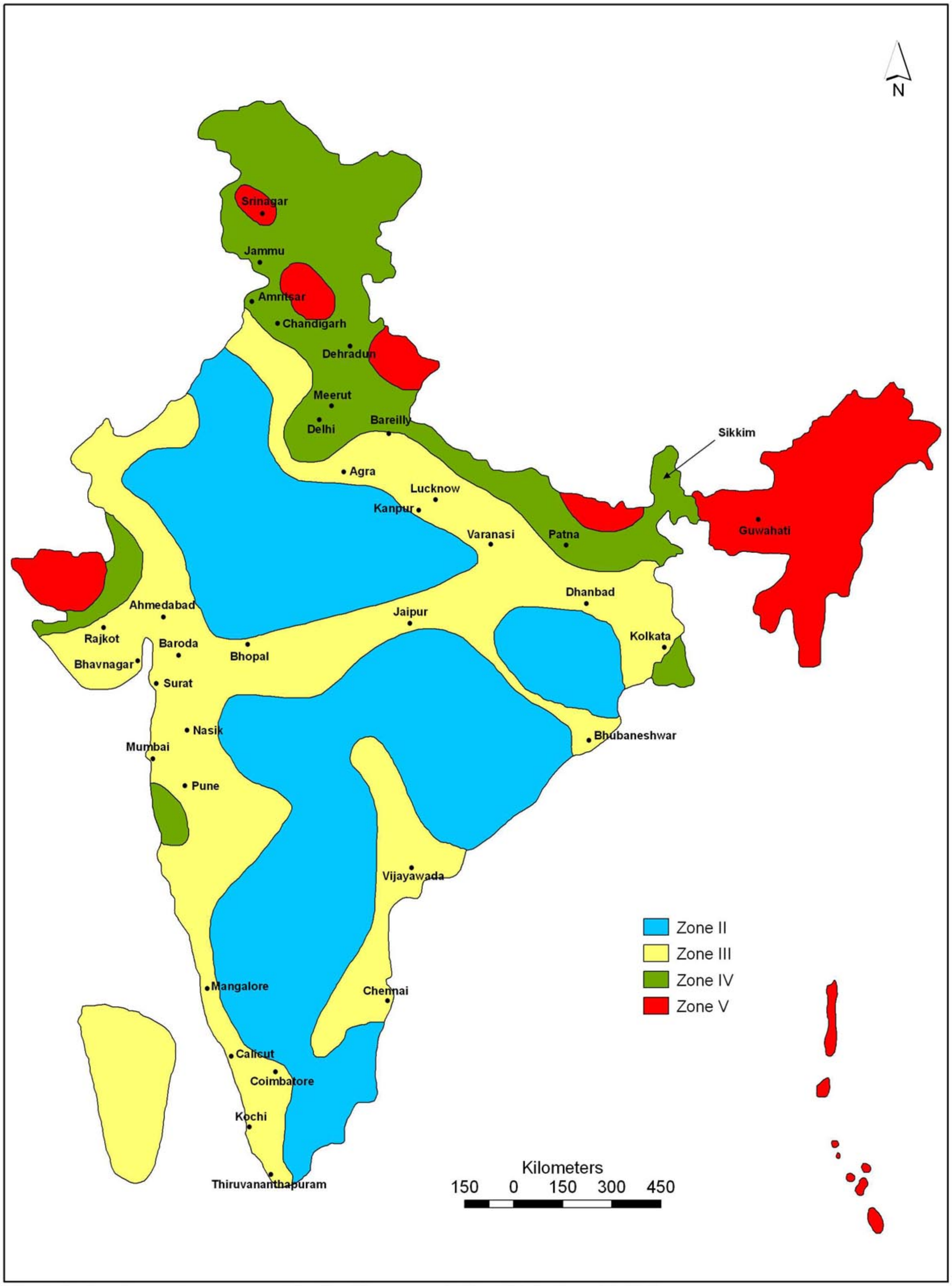

Fig.2 Seismic zoning map of India (Source : BIS, 2001, New Delhi)

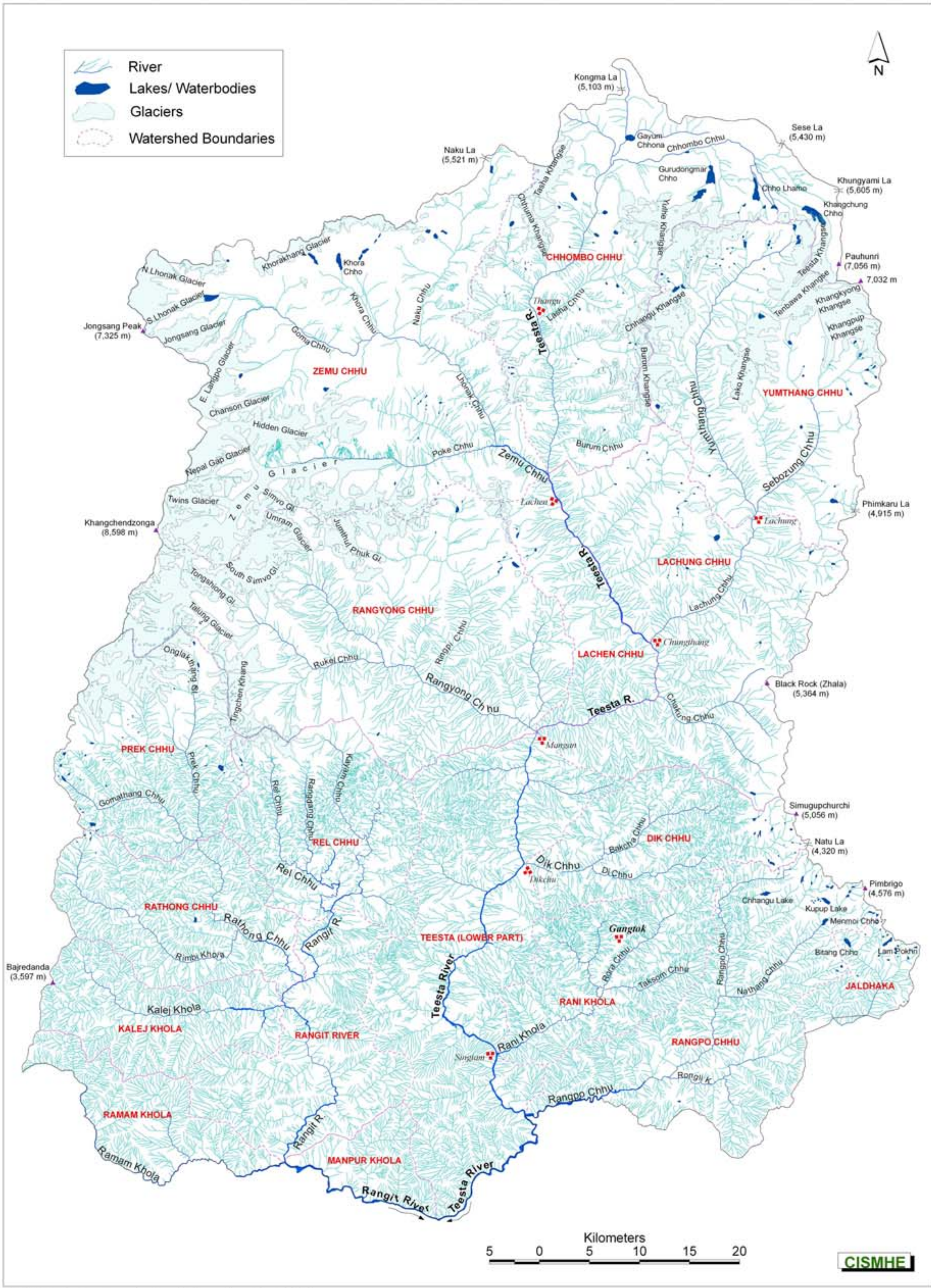

Fig.3 Drainage map of Teesta river basin in Sikkim

Sikkim, Teesta and its tributaries flow in very narrow and deep valleys having precipitous hill slopes, except where the tributaries join the main stream. The hill slopes are mostly friable and landslips are very common throughout the basin.

1.4 WATERSHEDS OF TEESTA BASIN IN SIKKIM

The main Teesta while flowing from north to south divides the state into two parts. Teesta drainage basin in Sikkim cover an area of 7,020.38 sq km of Sikkim and 75.32 sq km of the state is under Jaldhaka river watershed, which is not the part of Teesta basin. In order to understand the profile and behaviour of the prominent tributaries of Teesta river basin in Sikkim, Teesta basin was divided into its major tributary watersheds. The entire Teesta basin falling in Sikkim has been delineated into 17 watersheds following the conventional methodology of delineation based upon drainage order classification (see Fig. 3). For this Survey of India toposheets at 1:50,000 scale were used, with ridge line demarcating the boundaries between adjacent watersheds. These watersheds vary in size and shape depending upon the drainage pattern in a particular watershed.

The analysis of entire data was done watershed-wise e.g. slope, relief, draining pattern, landuse, soil, etc. The results, therefore, are also presented watershed-wise. The seventeen watersheds are : i) Rangpo Chhu, ii) Rani Khola (Rongni Chhu), iii) Teesta (Lower Part), iv) Dik Chhu, v) Lachung Chhu, vi) Yumthang Chhu, vii) Chhombo Chhu, viii)

Zemu Chhu, ix) Rangyong Chhu (Tolung Chhu), x) Lachen Chhu, xi) Prek Chhu, xii) Rel Chhu, xiii) Rathang Chhu, xiv) Kalej Khola, xv) Ramam Khola, xvi) Rangit river and xvii) Manpur Khola (see Fig. 3). Jaldhaka river watershed drains into West Bengal and is not the part of Teesta basin.

1.5 PHYSIOGRAPHIC PROFILE OF TEESTA BASIN

To understand the geomorphological characteristics of Teesta basin, base map was prepared from the merged scenes of IRS-1D LISS-III, PAN and SOI toposheets at 1:50,000 scale covering entire Teesta basin in Sikkim. Ten broad landforms could be identified in the basin. These are ridge, rocky cliff, escarpment, landslide zone, morainic zone, low mountain (< 1,000 m), narrow valley, middle mountain (1,000 - 2,000 m), high mountain (2,000 - 3,000 m), very high mountain (3,000 - 4,000 m) and extremely high mountain (> 4,000 m) along with glaciers. The ruggedness terrain in Teesta basin is evident from 22% of the total basin area is comprised of very high mountains and as much as 16% area is under perpetual snow. Escarpment and narrow valleys comprise more than 3% of the total catchment area.

1.5.1 Relief and Aspect

The elevation in Teesta basin varies rom 213 m to 8,598 m within distance of about 100 km. The river descends from 5,280 m up to the confluence of Rangit river with it at Melli Bazar along its traverse of about 175 km. Therefore, the river flows in a gradient of about 29 m/km. Nearly 1/4th of the basin area lies in the elevation range of 4,000 to 5,000 m (Fig. 4). As more than 59% of the catchment area of Teesta basin lies above 3,000 m, Teesta basin in Sikkim, therefore, can be classified as high altitude basin. Even the area between 2,000 and 3,000 m elevation range constitutes 16% of the total basin area. Only 25% of the catchment area lies below 2,000 m, whereas sub-tropical elevation constitutes only 6% of the basin.

The predominant aspect in the basin is southern aspect followed by eastern aspects. Only 16% of the mountain slopes are north facing.

1.5.2 Slope

As already discussed the altitudes from 213 m to 8,598 m within an aerial distance of about 100 km, the catchment of Teesta river basin in Sikkim is characterised by steep to very very steep slopes (Fig. 5). As evident from the figure, more than 52% of the basin lies in slope category above 27^o i.e. steep to very very steep slope class. As much as 10.32% of the catchment area is either rocky cliffs or are escarpments i.e. 65^o and above slope class. The catchment area under moderately steep slopes category is only 8.61% of the total. About 4.37% of the basin has area of gentle slope category. Maximum area under gentle slope category is recorded in Zemu valley followed by Chhombo Chhu, both incidentally are the main sources of water in Teesta river. Zemu valley is characterized by 25 km long Zemu glacier descending from

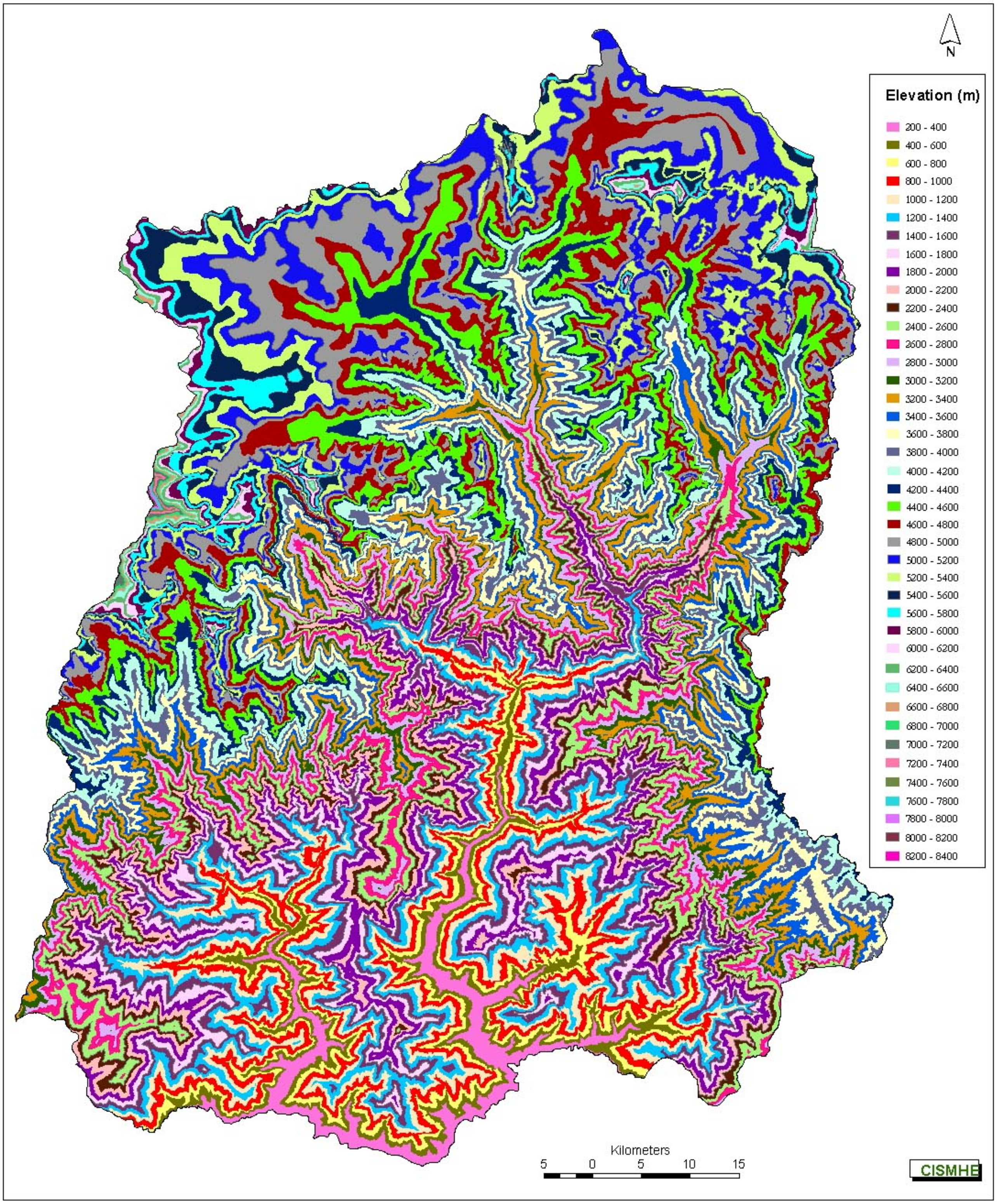

Fig. 4 Relief map of Teesta basin in Sikkim

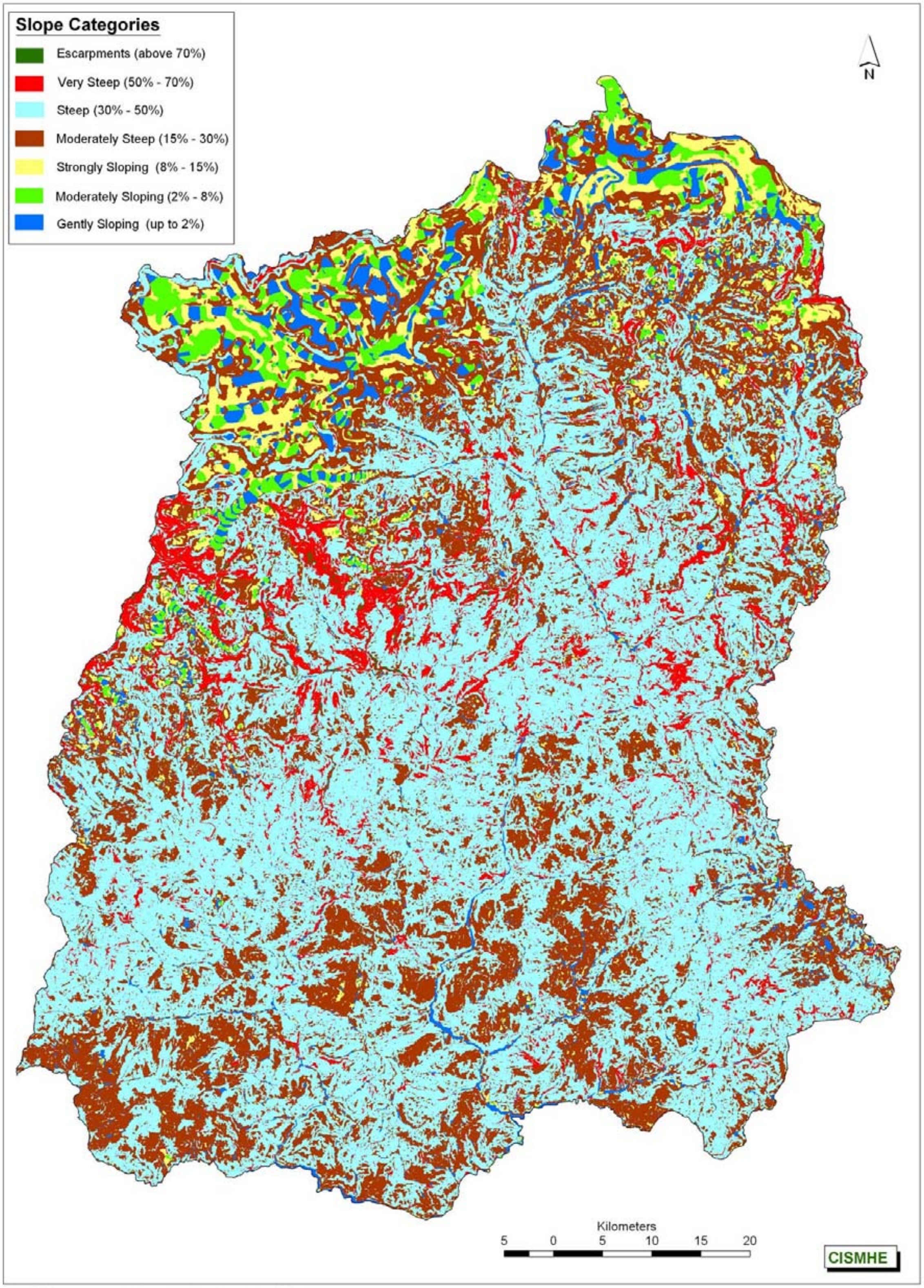

Fig.5 Slope map of Teesta river basin in Sikkim

Khangchendzonga peak with steep to moderately steep in the initial stages and gentle gradient in the most of its stretch. Chhombo Chhu also is characterized wide U-shaped glacial valley with moderately steep to gentle gradient slope near the source of Teesta river up to its confluence with Gayum Chho near Oakra.

1.6 HYDRO-METEOROLOGY

Teesta basin is characterised by frequent occurrence of extreme (catastrophic) meteorological events during monsoon season. These events lead to slope transformation accompanied with gravitation, slope wash and linear erosion under fluvo-glacial environment in North Sikkim and are mainly responsible for large quantities of silt and aggradation material, which is deposited in river channels. The high rainfall (about 2,300 mm) over the steeper slopes has created a suitable environment for initiation of run-off and subsequent soil erosion, slope failures, slides or sinking of land masses in Teesta basin. Large slope areas are (glacial) morainic in nature.

Variation in altitudinal profile of the state from 213 m to 8,598 m in less than 100 km is responsible for abrupt changes in climatic conditions in the basin and the state. Relief features such as high mountains act as a barrier for the movement of monsoon winds resulting in a significant variation in rainfall and temperature profiles across the Teesta basin in Sikkim.

March, April and May are the transition months between the winter, summer and monsoon. The surface temperatures start rising in late April, which are accompanied by thunderstorms and hails. The rainfall in Sikkim, decreases with elevation after a certain limit. Rainfall at Chungthang (1,600 m) is 2,650 mm and at Lachen (2,730 m) being situated at a distance of only about 20 km north of Chungthang is 1,680 mm, whereas Thangu (3,800 m), located about 20 km further north, receives only 840 mm of rain annually. As a result across the altitudinal gradient of Teesta basin, the southern and middle valleys are hot humid and wet, while northern parts are comparatively drier and cold.

The climate of Teesta basin in Sikkim can be categorised into four distinct seasons *viz*. i) Winter season from mid-November to mid April, ii) Spring (summer equivalent) season from mid-April to mid-June, iii) Monsoon season from mid-June to mid-September, and iv) Autumn season from mid-September to mid-November.

2.0 DEVELOPMENTAL SCENARIO

Sikkim is a thinly populated state with its unique environment and ecology. The population is concentrated around the capital Gangtok only and the rest of the area is occupied by forests with small villages and townships. The economy is largely agriculture and forest based with very little technologically advanced industrial base. The general economic conditions of the inhabitants of the state are average to below average. Due to the hilly terrain, the agricultural production is not sufficient even for sustaining local consumption needs of the human population. Energy needs of the region are chiefly met by petroleum products and wood based products.

In view of physical constraints to development of industries and allied economic activities the state for its economic welfare concentrates on the harnessing and exploitation of natural resources. One such important resource of the state is a massive network of rivers in the basin, which provides tremendous opportunities and potential for the economic development of the state. For many years various Central and State Government agencies have proposed a model of hydropower development for Teesta basin which aims at harnessing the hydropower potential of Teesta river. Accordingly, a cascade of six power projects across the basin was proposed from North to South. Out of six proposed projects, Teesta Stage-V H.E. project, under construction by NHPC is an on-going project. However, after the Hon'ble Prime Minister's 50,000 MW initiative in 2003, number of schemes have been proposed on Teesta and its tributaries. The present study ascertains an environmentally sound development in the state.

2.1 POWER DEVELOPMENT SCENARIO

The power situation of Sikkim before its merger with India in 1975 was in its infancy because of low demand. The power requirement of Gangtok and a few townships located on the national highway was met from the small 2.1 MW Jali Power House commissioned in 1964. Also, a small Diesel Powerhouse was used as a standby to meet the requirement during emergencies. Similarly, Rhoathak (South) and Rimbi (West) micro hydels with an installed capacity of 200 KW each were under operation to feed District Headquarters and major townships in the South and West districts, while the North district had to manage with a 50 KW micro hydel unit known as Manul micro hydel, which has since become inoperative. Till the end of 1975, there were only 8 declared towns that used electricity in Sikkim, while rest of the areas had no power supply.

Till the end of 1979, the state had a total power generation capacity of only 3 MW to meet the increasing demand of the state. Today, the state has an installed capacity of 39 MW. The estimated peak shortfall in Sikkim has increased almost three-fold from 5.7 MW in 1988-89 to about 15 MW at present. The average annual growth rate of this shortfall (12.32%) has been almost double that of the average growth rate in installed capacity up to 1998.

2.1.1 Hydro Power Potential in Teesta basin

The river Teesta has great potential for development of power, as the river descends from an elevation of about 5,280 m to about 213 m over a distance of about 175 km. According to the preliminary reconnaissance survey by the team of experts of erstwhile Central Water & Power Commission in 1974, the river could be harnessed under a cascade development for hydropower generation. The hydroelectric potential of the Teesta and its tributaries in Sikkim was estimated at about 3735 MW (Table 2, Fig. 6). The cascade development consists of power generation in six stages along Teesta river. In addition Sikkim Power Development Corporation had identified more schemes to be developed with the help of private agencies. Recently under the Hon'ble Prime Minister's 50,000 MW, ten schemes were proposed for pre-feasibility studies.

Table 2. Estimated Hydro-power Potential in Sikkim State

S.No.	Name of Project	Installed Capacity (MW)
A.		
1.	Teesta Hydel Project Stage-I	320
2.	Teesta Hydel Project Stage-II	330 ?
3.	Teesta Hydel Project Stage-III	1200
4.	Teesta Hydel Project Stage-IV	495 ?
5.	Teesta Hydel Project Stage-V**	510
6.	Teesta Hydel Project Stage-VI	440
Total A		**3295 ?**
B*.		
7.	Rolep H.E. Project**	32
8.	Ralang H.E. Project	40
9.	Chakung Chhu H.E. Project	50
10.	Chuzachen H.E. Project	99
11.	Sada Mangder H.E. Project	71
12.	Bhasme H.E. Project	32
13.	Rangit Stage-II H.E. Project	60
14.	Rangit Stage-IV H.E. Project	90
15.	Jorethang Loop HEP	96
Total B		**570**

C. Pre-feasibility Studies

1.	Jedang H.E. Scheme†	185
2.	Talem H.E. Scheme†	75
3.	Rongni H.E. Project	95
4.	Ringpi H.E. Scheme	160
5.	Dik Chhu H.E. Power Project	90
6.	Lachen H.E. Scheme	210
7.	Lingza H.E. Scheme	160
8.	Rangyong H.E. Scheme	90
9.	Talem H.E. Project	75
10.	Rukel H.E. Scheme	90
11.	Panan H.E. Scheme	200
Total C	**1430**	
Total A + B + C		**5295**

A = Schemes identified by Central Water Commission

B = Schemes being promoted by private agencies

C = Schemes identified under Hon'ble Prime Minister's 50,000 MW initiative

* The list is incomplete

** Under construction

† These schemes are modified version of original Teesta Stage-I and Stage-II schemes

3.0 DEVELOPMENTAL PLANNING AND CARRYING CAPACITY

The aim of this exercise is to achieve the goal of development, which is simple to understand, easy to execute, locally relevant and economically viable. To determine the limits of development we must estimate the carrying capacity of a region/system and only then plan a developmental process, which is sustainable. The concept of carrying capacity does not undermine a system's ability to allow production of goods and services from the existing quantity and/or quality of environmental resource base without compromising on the improved quality of life. On the other hand it ensures that there is no impairment of the environmental quality of the system. In addition to this, it must also provide for the possibility of regeneration, rejuvenation, reinforcement and alleviation through additions (imports) and removals of resources, services, management and technology interventions, etc. Though carrying capacity envisages a framework for planning and development within the sustainable resource consumption pattern, it can not completely wash away the loss of existing resource base or its quality. It is, therefore, necessary to understand that a likely scenario would develop in which necessary trade-offs between consumption patterns and conservation levels are provided for.

In some of the past studies the operational framework for the internalization of the concept of carrying capacity in decision-making related to developmental planning involved:

- Estimation of supportive capacity
- Estimation of assimilative capacity
- Allocation of resources to various socio-economic activities for maximization of the quality of life.

In the present context, however, we have attempted to determine carrying capacity in terms of the following:

- Inventorisation and analysis of the existing resource base and its production, consumption and conservation levels

Fig.6 Proposed hydro-power development model in Teesta river basin in Sikkim

- Determination of regional ecological fragility/sensitivity based on geo-physical, biological, socio-economic and cultural attributes
- Analysis of the existing and projected developmental profile of Teesta basin in view of its geo-biological setting, ecological sensitivity and socio-economic aspirations
- Estimation of existing quality of life (QOL) of human population in the basin as also their perceived and preferred QOL scenarios
- Preparation of comprehensive evaluation reports for major proposed developmental projects within the carrying capacity framework.

The ecological fragility/sensitivity of the basin will be evaluated through analysis of data on the following parameters:

- Geological and physical features including seismicity and seismic history
- Natural hazards phenomena and land instability including landslides/landslips
- Drainage, hydrology, hydrometeorology, sedimentation in river systems
- Landuse and landcover through remote sensing and GIS
- Demographic evaluation of extant, endemic, endangered, keystone species
- Evaluation of past, continuing, proposed development activities and human interventions in the basin

Evaluate people's aspirations for better quality of life and integrate these in sustainable development plan.

The attributes of various environmental resources and human activities have been presented in the form of a model used in the present study for estimation of carrying capacity.

4.0 EXISTING ENVIRONMENTAL RESOURCES BASE

A detailed account of environmental resource base in terms of air, water, land including biotic resources, socio-economic and quality of life is provided for determining the quality and quantity of available resources for use in the process of planning and development. This body of data does not only aim at inventorisation of resources but also gives detailed analysis of the prevailing environmental resource base and environmental quality of the basin. This data would ultimately help us identify limiting resources as also the environmentally critical areas, which can be delimited as hot spots for conservation or remediation. The evaluation of resources would also lead to understanding the impacts of various developmental activities on these resources on one hand and the planning process on the other. In the final analysis evaluation of the entire environment resource base *vis-a-vis* various developmental activities would provide a scientific basis for developing management plans and alternate development plans for critical environmental resources and areas.

4.1 LAND ENVIRONMENT

Keeping in view the mountainous terrain of the basin, physical features, processes and activities of the basin's land environment have been evaluated for following attributes for estimating ecological sensitivity/fragility of land resource. It included the following considerations:

- Preparation of a base map delineating major watersheds of the Teesta basin
- Watershed-wise slope, aspect, elevation profile and preparation of digital elevation models at 1:50,000 and/or 1:25,000 scale
- Mapping of erosion prone areas, old and active landslides using merged IRS 1D LISS-III and PAN data and LANDSAT 7 ETM+ data at 1:50,000 scale
- Preparation of watershed-wise detailed soil maps
- Mapping of important zones of crustal weakness in terms of structural discontinuities, thrust, shear, ductile zones
- Mapping of river terraces, moraine deposits including glacial moraines
- Regional stratigraphic - tectono-stratigraphic succession along south-north Sikkim Himalaya for estimation of possibility of tectonic diverticulation
- Seismo-tectonic map of the basin including micro-seismic activities and seismic history
- Physical environmental/ecological sensitivity analysis.

4.1.1 Geomorphic Profile of Teesta Basin

The terraces and floodplains, valley-side slopes and landslide slopes, alluvial cones of different types and generations, tors, kettle shaped depressions, terrace-isles, sickle shaped ranges bevelled plains, undulating plains and deeply-dissected valleys, glacial or periglacial deposits, related sedimentary structures, crevasses, etc. are the distinctive geomorphological feature of Teesta river basin in Sikkim. The landforms and landform assemblages in the terrain of Teesta river basin and its innumerable tributaries are the result of continuous denudation and deposition processes that are constantly modifying the newly formed land forms in the upper reaches and burying the existing land forms in the lower reaches. Based upon the geomorphological features as well as ecological and climatic regimes, Teesta basin in Sikkim can be demarcated into five distinct geo-eco-climatic zones *viz*.

i) Frigid zone above 4,000m (glacial, periglacial and fluvio-glacial processes)

ii) Cold zone between 2,500 and 4,000m (periglacial, fluvio-glacial and fluvial processes at higher altitudes,

iii) Cold temperate zone between 2,000 and 2,500m in (fluvio-glacial, and fluvial processes at higher altitudes),

iv) Warm temperate zone between 1,000 and 2,000m (fluvial processes), and

v) Sub-tropical zone up to 1,000m (fluvial processes at lower altitudes).

First three eco-climatic zones jointly constitute the major part of the North Sikkim district comprised of Upper Teesta basin and stretches for about 100 km from east to west. This portion is marked by innumerable glaciers and glacial lakes, alpine meadows, deodar-oak, birch-rhododendron and juniper forests (sub-alpine to alpine forest), terraces along the Teesta river and numerous tributary valleys of varied origin and valley-aspects harbouring rich floral and faunal wealth. This northern part of Teesta basin with varied and diverse environments is responsible for unique and conspicuous landforms within the Teesta river basin. The glaciated areas in this part are engaged in the erosional activities through abrasion scouring, frost action, freeze-thaw cycle, etc. Upper Teesta basin is also characterized by huge accumulation of debris in the form of debris cones, rock-glaciers and alluvial fans, debris avalanches and other hazards. This debris is transported mainly in monsoon season and during snowmelt period. Transportation rates of these debris become 20 times than normal during any catastrophic event. The watersheds located in the Upper Teesta basin contribute huge amounts of silt. The movement of glaciers over their beds, reduce the rock surface to rock flour by their frictional activity. The rock flour after mixing with melt-water forms the glacial milk, which ultimately transformed into thin mud during peak melt discharge. The changes in glacial-phase of the Upper Teesta basin section require special attention in planning for watershed management especially landslide and flood control in lower reaches. The fluctuations in ice-cover in this region are generally accompanied by

i) production and transport of debris,

ii) floods and siltation of reservoirs,

iii) vegetation cover, and

iv) associated cooling effects of the glaciers in Sikkim Himalaya.

Therefore, the fluctuations in such activities in the Upper Teesta basin are required to be monitored and evaluated for the formulation of any precautionary and mitigative measures.

The factors like orientation of slopes, precipitation along with other local aspects have given rise to intra-valley variation in the elevation of snow line in the Upper Teesta basin. The south facing slopes have a lesser ice-cover.

Middle and lower parts of the basin are marked by subdued relief, slope-wash slides and slips, scourge and filling, abandoned channels, etc.

4.1.2 Geology

Sikkim Himalaya has been sub-divided into distinct geotectonic domains like other sectors, which are separated from one another by thrust faults. They are described as follows:

i) Sub-Himalayan Domain

This domain lies in the south and consists of mollase type deposits of the Siwaliks (Mio-Pliocene), and is separated from the lesser Himalayan domain (LHD) in the north by the Main Boundary Thrust (MBT).

ii) The Lesser Himalayan Domain

The LHD consists of a thin strip of Gondwana rocks (Carboniferous-Permian), carbonate rocks (Buxa Formation) and a thick metasedimentary sequence of dominantly pelites with subordinate psammite and wacke (Daling Group).

iii) Higher Himalayan Domain

The higher Himalayan domain (HHD) overlies the LHD and is composed of medium to high-grade crystalline rocks, commonly referred to as the higher Himalayan crystallines (HHC). These are dominantly of pelitic composition, with sporadic quartzites, calc-silicate rocks, metabasics and small bodies of granite. The HHC is separated from the lesser Himalayas by the Main Central Thrust (MCT). The exact location of this thrust has been controversial in many areas, including Sikkim (Lal *et. al.* 1981; Sinha-Roy, 1982).

iv) The Tethyan Belt

A thick pile of fossiliferous Cambrian to Eocene sedimentary rocks belonging to the Tethyan Belt (Tethyan Sedimentary Sequence) overlie the HHC on the hanging wall side of a series of north-dipping normal faults constituting the South Tibetan Detachment System (STDS) in the extreme north of Sikkim.

4.1.2.1 *Stratigraphy*

A comprehensive stratigraphic framework along a south-north traverse from the foothills of Darjeeling-Himalaya to the northernmost part of the Sikkim Himalaya is established by Ray (1989) and shown in Table 3. The repetitive nature of the three units, namely the Gorubathan, the Reyang and the Buxa of the Daling Group as also the two units, the Rangit Pebble Slate and the Damuda of the Gondwana Group, within a tectonic section has been shown from Darjeeling-Sikkim Himalaya (see Table 3).

Table 3. Tectonostratigraphic Succession along South-North Darjeeling-Sikkim Himalayan Section (after Ray, 1989, GSI, 2000)

North

⇑

TETHYAN GROUP

4. Chho Lhamo Formation
3. Lachi Formation
2. Mt. Everest Limestone
1. Mt. Everest Pelitic Formation

________ *TRANS AXIAL THRUST* ________

SIKKIM GROUP

Darjeeling Gneiss, Khangchendzonga Gneiss and Chhungthang (=Paro) Subgroup with Lachen Leucogranite (and its Equivalents)

________ *SIKKIM (MAIN CENTRAL?) THRUST* ________

DALING GROUP

Gorubathan Subgroup
(with Lingtse Granite Sheets at different Structural Levels)
(Syngenetic Fe-Cu-Pb-Zn Mineralisation)

________ *KALET CHHU-LEGSHIP THRUST* ________

DALING GROUP

Reyang Subgroup
Buxa Subgroup — Gondwana Group
Gorubathan Subgroup

________ *PAJOK THRUST* ________

A Zone of pile of thin scales of
Daling Group (Gorubathan-Reyang-Buxa Subgroups)
and Gondwana Group (Rangit Pebble Slate -

Damuda Formations)

______________ *NORTH TATAPANI THRUST*___________________

GONDWANA GROUP	2. Damuda Formation
	1. Rangit Pebble Slate
DALING GROUP	3. Buxa Subgroup
	2. Reyang Subgroup
	1. Gorubathan Subgroup

________________*NAYA BAZAR THRUST*______________________

A Zone of Pile of thin Scales of
Daling Group (Gorubathan-Reyang-Buxa Subgroups)
and Gondwana Group (Rangit Pebble Slate -
Damuda Formations)

____________ *KITAM-MANPUR KHOLA THRUST*________________

DALING GROUP	2. Reyang Subgroup
	1. Gorubathan Subgroup

_________________ *SIM JHORA THRUST*______________________

DALING GROUP	Gorubathan Subgroup (With Lingtse Granite Sheets)

_ *NORTH DARJEELING (BARNESBERG-BADAMTAM) THRUST* __

SIKKIM GROUP	Chhungthang Subgroup, Darjeeling Gneiss, Khangchendzonga Gneiss (? Middle Cenozoic Pegmatite Aplite Formation and small Granite Bodies)

____________*SOUTH DARJEELING THRUST* ___________________

DALING GROUP	Gorubathan Subgroup (Intruded, Metasomatically Replaced and Technically Emplaced Lingtse Granite) (Syngenetic Fe-Cu-Pb-Zn Mineralisation)

___________*DEORALI-RONGCHONGTHRUST* __________________

DALING GROUP	2. Reyang Subgroup (with slices of Gorubathan Subgroup)
	1. Gorubathan Subgroup (with slices of Rangit Pebble Slate and Damuda Formation in Basal Portion)

__________________ *DALING THRUST* _______________________

GONDWANA GROUP	2. Damuda Formation
	1. Rangit Pebble Slate

(Slices of Daling Group)

_______________ *TINDHARIA THRUST*_______________________

GONDWANA GROUP		Damuda Formation

________ *MAIN BOUNDARY THRUST (SOLE OF NAPPE)*_______

SIWALIK GROUP	2.	Geabdat Formation
	1.	Chhunabhatti Formation

(Intermixed with Damuda Slices in Rangtong Thrust)

___________ *RANGTONG (IMBRICATE) THRUST* _____________

SIWALIK GROUP	3.	Murti Boulder Bed
	2.	Parbu Grit
	1.	Geabdat Formation

______________ *UNCONFORMITY/FAULT* ___________________

QUATERNARY GROUP		Alluvium
		Terrace Boulder Beds

⇓

SOUTH

4.1.2.2 *Structure, Tectonics and Metamorphism*

A number of discrete linear zones of ductile deformation (DDZ) are seen in many localities. The DDZ cut across lithological boundaries and the planar fabric S2 commonly seen in the gneissic layering that is defined by the alignment of biotite and silimanite grains (Neogi *et al*. 1998). These zones are narrow, characterised by intense mylonitization, formed late in the deformation history, and are associated with mineral lineations and stretching lineations. The stretching lineations generally plunge to the north. Shear sense indicators consistently indicate a top-to-south sense of movement. S-C fabrics associated with the top-to-south transport are found within the gneisses in these zones (Neogi *et al*. 1998).

In the Sikkim, the Main Central Thrust (MCT) juxtaposes high-grade gneisses of the High Himalayan Crystalline, the Darjeeling series, over lower-grade slates, phyllites and schists of the Lesser Himalaya, the Daling Series (Catlos *et al*. 2002). Inverted metamorphism characterises rocks that underlie the MCT, and is described in the Sikkim region as a gradual increase in metamorphic intensity in the Daling series at lower topographic levels to the Darjeeling series at higher levels with no apparent break across the fault (e.g. Mallet, 1875; Ray, 1947). Because both increasing (Metcalf, 1993) and decreasing (Thakur, 1986; Lombardo *et al.*1993) grades of metamorphism towards higher structural levels have been observed the geological picture in the Higher Himalayas is rather confusing (Neogi *et al*. 1998). Numerous models have been proposed to account for the observed inverse metamorphic zonation in the Himalayas and a prominent role is assigned to the MCT in most of these models. The pressure gradient of 0.25 kbar/ km resembles a normal lithostatic gradient, which suggests that the HHC in Sikkim represent an inverted Barrovian sequence. This inverted zonation of the HHC is probably the result of large-scale structural inversion and/or tectonic juxtaposition because of ductile shearing (Neogi *et al.*1998).

The Darjeeling rocks are largely gently N-dipping, but locally domed to fold west, east and north (Hooker, 1854). Structurally above these is the contact between the Darjeeling and Tethyan rocks, which in Sikkim has been reported from two places (Edwards *et. al.* 2002, locations 1 and 2, Fig.7). In NW Sikkim on Jonsang Kang (~7000m – location 1, see

Fig.7) the northward dipping orthogranitic Khangchendzonga gneisses (part of the Darjeeling series) are structurally in contact with limestones (Dyhrenfurth, 1931). From the Lachi Spur (location 2, see Fig.7), Wager (1934) observed that the Permian Lachi series and a small sliver of the underlying Mt. Everest limestone are in 45°N dipping normal fault contact with “porphyroblastic feldspar” biotite gneiss (Wager, 1939). This appears to be the first accurate identification of the South Tibet Detachment System (STDS) (Catlos *et al*. 2002). The STDS and the trace of the Himalaya are monoclinally bent across the Chhumbi graben valley (the southern most part of the N-S Yadong-Gulu rift system) stepping north by ~40km to the east of this point (the Yadong Cross Structure) (Edwards *et al*. 2002).

The Dalings occupy large area of Teesta valley and form a dome below the Darjeeling gneiss. The Lingtse-granitoid gneiss occurs within the Daling Group of rocks. The contact between the Lingtse Granitoids with Dalings is controversial. The arcuate shape of the MCT in Sikkim is in conformity with the domal structure of the Higher Himalayan Crystalline. The MCT passes about 5 km east of Gangtok and crosses the Teesta River near Manul. The E-W trending north dipping MBT crosses the Teesta river near Kalijhora township.

4.1.3 Seismicity

The revised Seismic Zoning map of India (BIS:2000), encompasses four named II, III, IV and V (see Fig. 2). The Modified

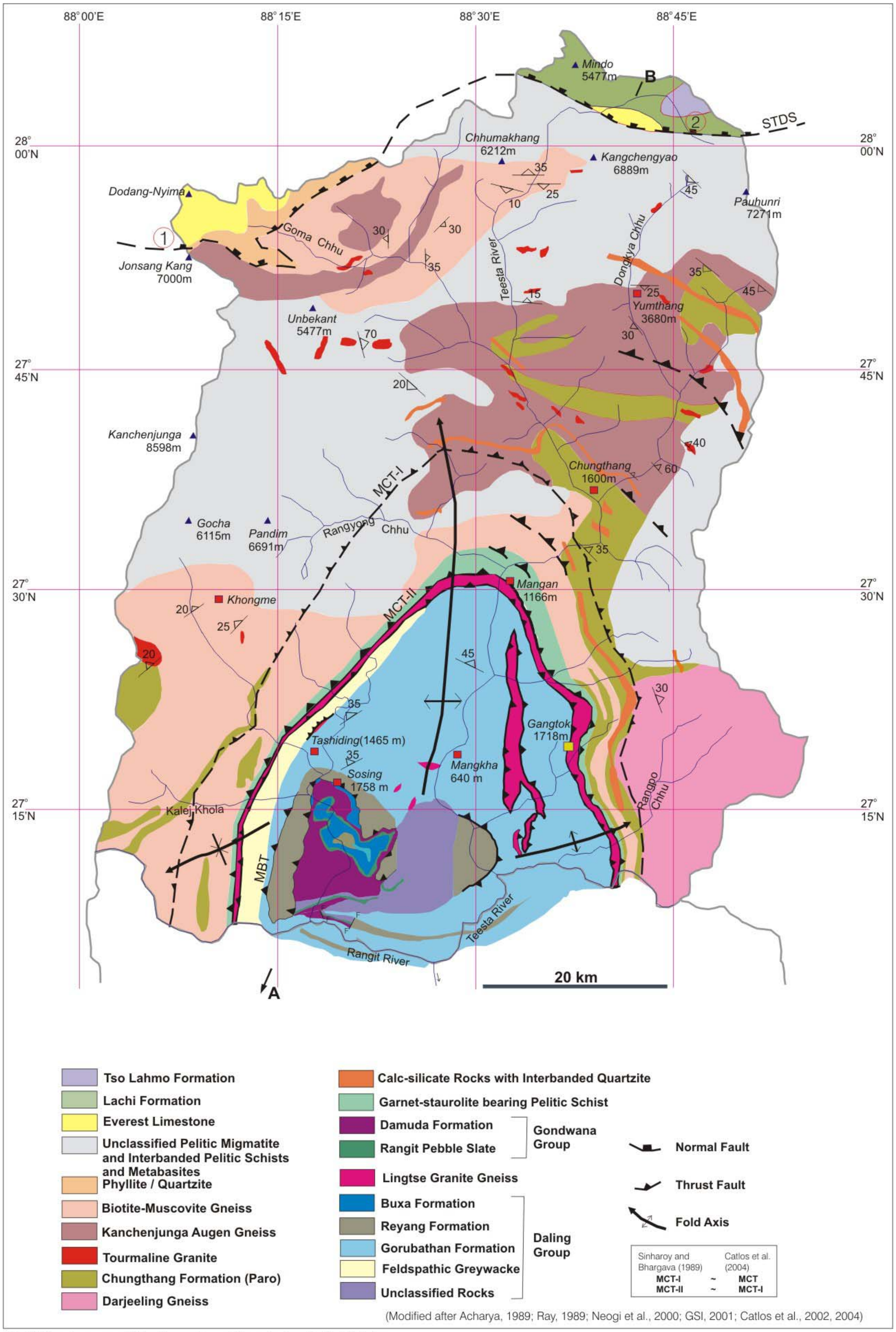

Fig.7 Geology and Stratigraphy of Teesta basin in Sikkim

Mercalli (MSK) scale intensity and horizontal force corresponding with seismic map zones of India are shown in Table 4. The area covered by Sikkim falls in zone-IV (see Fig. 2). The seismic zoning maps only serve as guide maps, and therefore detailed study of any developmental site and its surrounding areas is essential to take safety measures against any future devastating tremors.

Sikkim region lies within the ambit of the Seismic Zone-IV of I.S. code 1893-1984/1998/2000. With reference to the MSK intensity scale used for all engineering design purposes, the region lies in the high damages risk zone (VIII) corresponding to a magnitude of 6.7 in the Richter scale. Therefore, there is always a necessity to consider the factor of safety for highest earthquake intensity while designing an engineering construction.

Table 4. Seismic zones of India with corresponding MM (or MSK) scale intensity, Richter magnitude and horizontal force

Seismic Zones of India	Hazard Intensity	MM (or MSK)	Richter Magnitude Intensity	Horizontal Force Coef.
II	Low Damage Risk Zone	VI	5.2	0.02
III	Moderate Damage Risk Zone	VII	6.0	0.04
IV	High Damage Risk Zone	VIII	6.7	0.05
V	Very High Damage Zone	IX and above	$\geq$7.4	0.08

Force (H) = Coefficient of Horizontal force as fraction of building weight

4.1.3.1 *Isoseismal Zones*

Temporal variation of seismicity in the area shows that there is burst of earthquake for a year or two preceded by a quiet period of 3 to 4 years (Nath *et al*. 2000). The Bihar-Nepal earthquake of 1988 was distinctly felt in Sikkim. According to National Earthquake Information Centre, USGS report this earthquake of 20th September, 1988 occurred at 23:09:09.5 PM. The epicenter was located at lat: 26.76º N and long: 86.62º E and the hypocentral depth estimated as 57km. The isoseismal VII passes through Gangtok town, in an approximately NE-SW direction (Fig. 8). Several buildings in Gangtok were badly damaged and the death toll went upto 1003.

4.1.3.2 *Microearthquake Surveys*

Detailed microearthquake surveys were carried out in the Darjeeling Himalaya (De, 1996) and in the Sikkim Himalaya (De, 2000). Kayal (2001) has provided a detailed interpretation of these studies. It is observed that the earthquakes are mostly clustered to the north of MBT, at a depth range of 10-40 km and majority of the earthquakes occurred below the plane of detachment.

Focal mechanism results suggest that the mosaic of active lineaments, forming conjugate shear planes, dominates the neo-tectonic deformation in the Nepal-Sikkim Himalaya and their foredeep (Dasgupta *et al*.1987). The seismicity trend in the Sikkim Himalaya and its foredeep shows that the Teesta, Gangtok and Yamuna lineaments and the Goalpara wedge of the Shillong massif are seismically active. The

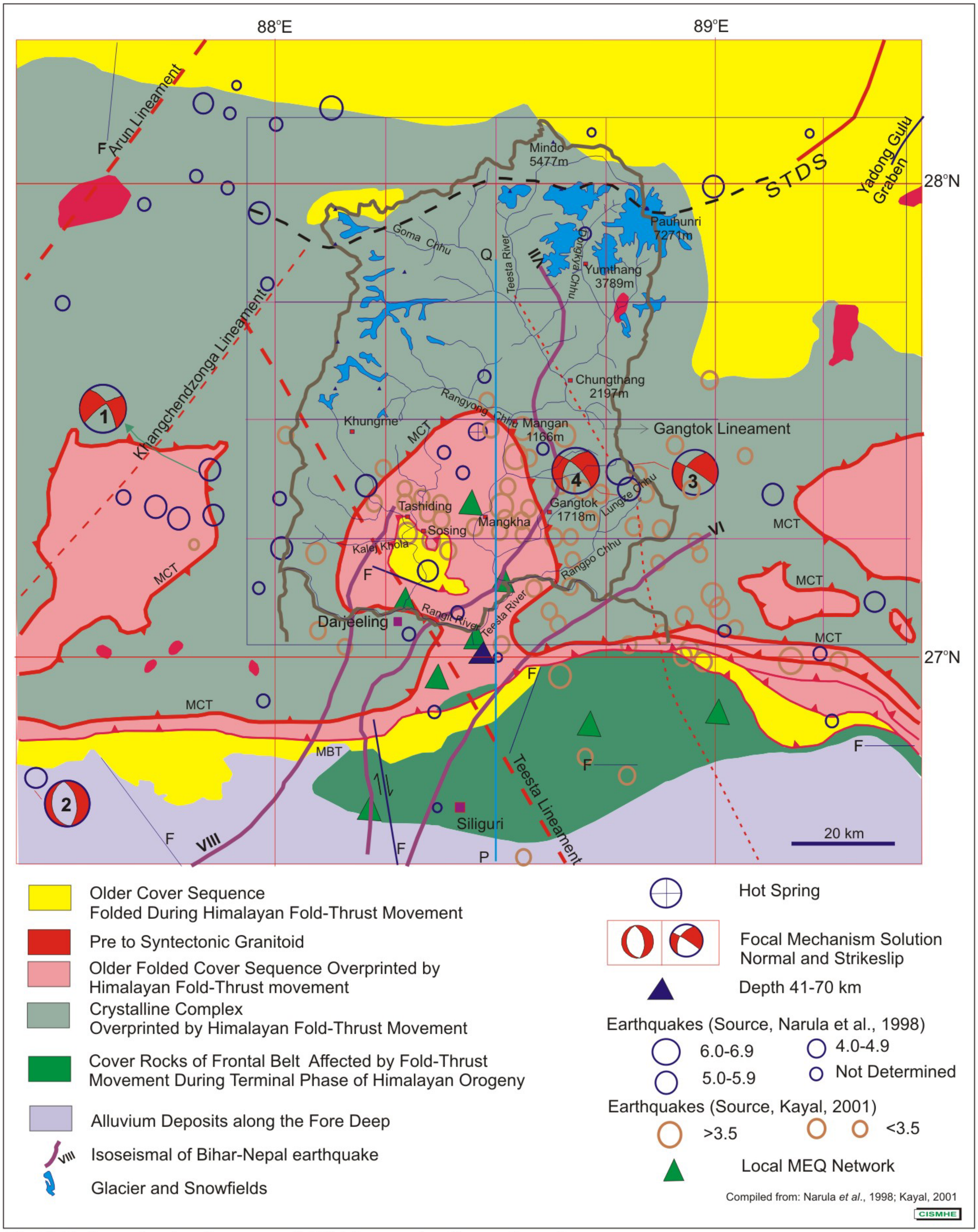

Fig.8 Seismotectonic map of Sikkim and adjacent regions

devastating Monghyr earthquake of 1934 (Mb=8.4), which claimed 11,000 lives, had its epicentral location some 60 km south of the MBT under the East Patna Graben, where a set of splay faults of the East Patna basement fault connect northward with the Arun lineament.

4.2 LANDSLIDES IN TEESTA BASIN

The Sikkim Himalaya with rugged topography, ongoing seismic activity (by active tectonics) and heavy rainfall is subjected to intense landslide activities. The spurt of developmental activity in the region has lead to substantial growth in the area affected by landslide activity. At places old landslides have been stabilized while at others new landslides have developed. At few places old landslides have been reactivated. Figure 9 shows the spatial disposition of landslides in Sikkim. This figure contains landslide scars from 1977 SOI toposheets (1:50,000) as old landslides and those interpreted from satellite data of recent times i.e. merged LISS and PAN scenes of 2002 as new landslides. Some of the reactivated landslide areas have been considered as new landslides. These datasets have several limitations and therefore, may not give all the information related to landslide activity in Sikkim in spatial and temporal frameworks. However, these data provides a preliminary guideline on temporal change in landslide activity in Sikkim, which has been discussed below.

The number of new landslides outranks that of old landslides in most of the watersheds in Teesta basin. Teesta (Lower Part) watershed contains maximum number of new landslides. There are also large numbers of old landslide scars present in this watershed. In Prek Chhu, Rathang Chhu, Rangit river, Rangpo Chhu and Ramam Khola watersheds more than 100 new landslide scars have been recorded. It is to be noted here that the rate of developmental activity in Teesta (Lower Part), Rangit river and Rangpo Chhu watersheds is very high. In Rani Khola, watershed the number of new landslide scars are also higher compared to old landslide scars. Gangtok, the capital city of Sikkim, lies in this watershed. Over the years this city has grown on the hill slope towards its fringe.

4.2.1 Some Existing Landslides in Sikkim

Landslide is the pertinent natural problem, which is intensified manifold by human interferences particularly in active mountainous regions like Sikkim Himalaya. Softer and incompetent rock formation, rocks that are hard but incompetent due to fractures and joints, massive deforestation, inadequate drainage, cultivation on steeper slopes, toe erosion by stream, heavy loading/construction of massive structures on unstable ground and seismicity of the region are some of the factors responsible for landslide. Rainfall intensity in Sikkim Himalaya has been observed to trigger landslide activity. In Sikkim the roads are disrupted every year, especially during monsoon period, by landslides. The forests are also affected by landslide and erosion, which erode valuable forestland, destroy plantations and retards the growth of forest produce. The areas that are most affected are the areas covered by softer rocks

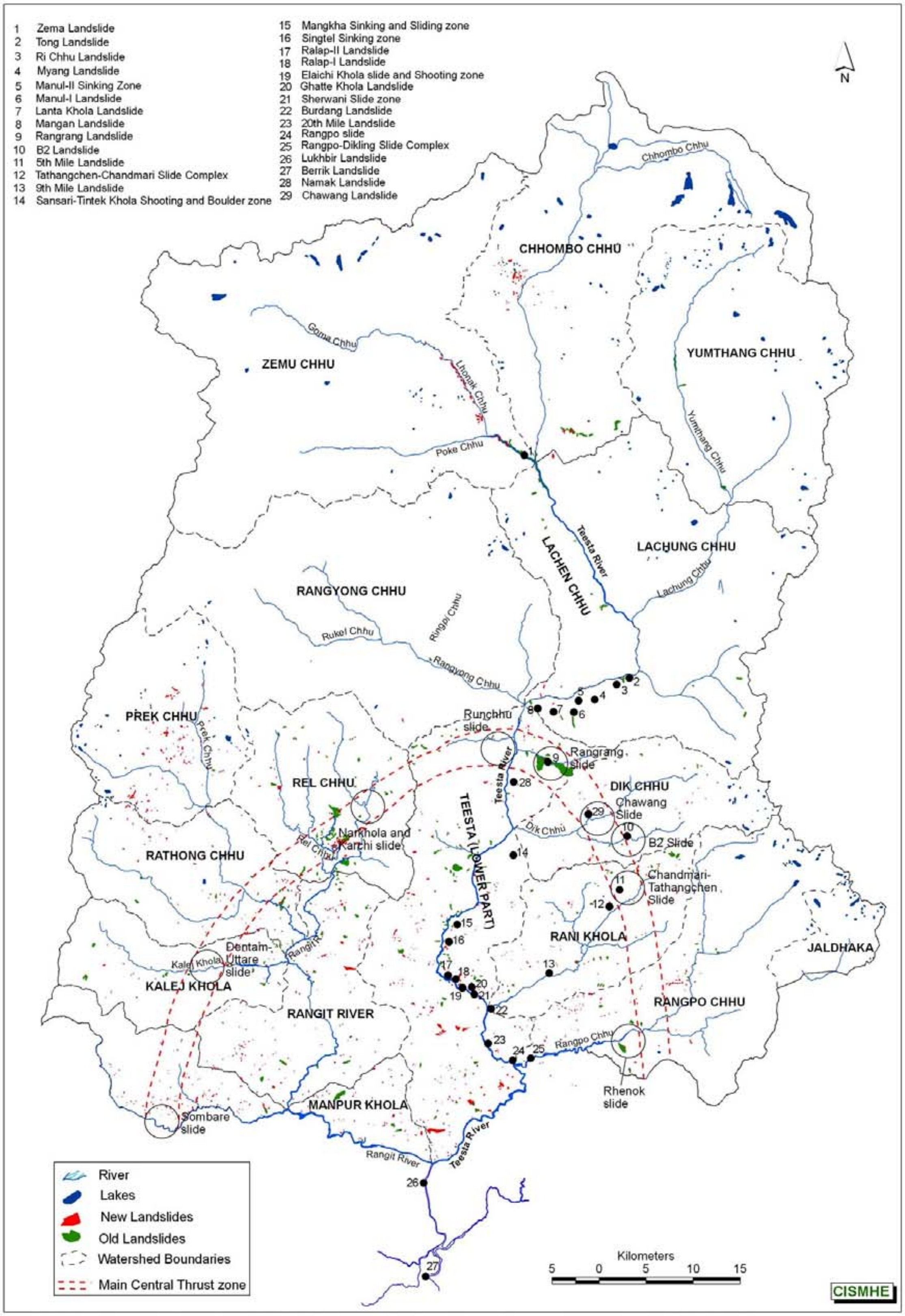

Fig.9 Old and new landslides in Sikkim Himalaya with locations of some of the important landslides

viz. phyllites and schists of Daling Group. However, the areas where harder schist and even gneisses occur are also affected to a minor extent. In these regions the mica rich bands in the rocks lend the rock to massive failure.

4.2.2 Environmental Impact of these Slides

Most of the landslides along the NH-31A, such as Rangpo slide in East Sikkim, disrupts the traffic. Similarly, the landslide complex between Mangan to Tong also disrupts the traffic on North Sikkim Highway every year. Due to the dumping of material into the river the sediment flux in the rivers increases. Increase of sediment flux may have negative impacts on the aquatic ecosystem. Occasional blocking of the rivers may lead to flash floods. Some of the landslides affect the cultivable lands, thus leading to the wastage of productive soils. Some landsides in the city area, such as Tathangchen slide complex, damages the houses and leads to loss of life. At places, particularly at the south of MCT, rock falls are observed during the earthquakes.

It is also very important to note here that many of the major landslides of Sikkim *viz*. North Rhenok Slide, Tathangchen-Chandmari slide, B2 slide, Chowang slide, Rangrang slide, Runchu slide, Narkhola and Karchi slide, Dentam-Uttare slides, Sombre slides lie in the region of MCT. The active landslides on the MCT are resulted due to the combined effects of i) road building, ii) heavy precipitation and iii) seismic activity between MBT and MCT.

In the planning and implementation of projects in the hilly areas sustainable development must be given due importance. One aspect of sustainable development in a mountainous region is proper examination of the existing instabilities of the terrain and consideration of appropriate development schemes so that the resultant geo-environmental hazards are minimized. Therefore, systematic investigations need to be carried out on regional to local scales. Due attention must be given to the relationship between the attitude of lithounits and road alignments. For instance, a valley ward dipping bedding plane/foliation can lead to slope failure on the road side, while the road on the stable slope where the bedding/foliation plane dip into the hill, is never affected by landslide and subsequent blockage of traffic or death toll. Landslide hazard zonation map is to be prepared with an objective to delineate zones with different damage potential. This will help in planning and implementation of projects under the milieu of sustainable development.

The remedial measures that are usually adopted are i) sealing of cracks with bitumen, ii) construction of good outlet of rain water in the form of catch water drains, iii) rock bolting by wire mesh with boulders extending down to the river bed to check the toe erosion. These measures can be adopted at selective localities. However, where unstable geological structures (*viz*. highly jointed igneous and metamorphic rocks) are dipping towards the roads or river channels the roads must be diverted from such areas.

4.2.3 Remedial Measures to Prevent Landslides

Landslides are problems that if not attended, grow with time. It is, therefore, important that they are tackled at the earliest opportunity and undue time is not lost. More often than not an immediate solution, even if partly correct or unconventional may prove more economical in the long run than the most perfect solution adopted after the problem has grown with time. The corrective measures for a landslide can broadly be divided into four categories.

(a) Keeping the soil mass free of moisture

(b) Increasing shearing resistance of the soil

(c) Protection of toes of road embankments

(d) Training of streams to prevent damage.

4.2.4 Flood Problems

Flood problems in the predominantly hilly terrain of Sikkim are mainly that of inundation of marginal lands on low river terraces and erosion of land by rivers and hill streams. While the flooding due to over bank spills is not serious and is confined to isolated patches affecting a total area of 10,000 ha, land erosion poses a serious threat to rural and urban population, strategic lines of communication, public utilities, agricultural lands, plantations, forests and mineral resources. Erosion of land has even more adverse effects on environment and ecology not only in the affected areas but also in the plains lower down where the heavy loads of debris are deposited in the river beds and flood plains aggravating the intensity of flood and disturbing the river regime.

The average annual damages due to floods in the state are as follows:

Area affected	=	0.01 mha (max 0.02 mha)
Population affected	=	0.005 million (max 0.1million)
Damage to Crops		
Area	=	0.001 mha (max 0.02)
Value	=	Rs. 0.415 crore (max Rs. 7.63 crore)
Damage to houses		
No.	=	427 (max 9746)
Value	=	Rs.0.054 crore (max Rs. 1.83 crore)
Cattle Lost	=	91 (max 3260)
Human lives lost	=	6 (max 107)
Damage to Public Utilities	=	Rs.1.94 Crore (max Rs. 28.15 crore)

The above data does not include the damage to roads maintained by the Border Roads Organisation (BRO). The enormity of the problem can be appreciated from the fact that they have to remove about 650 cum of debris every year per kilometre of road under their jurisdiction.

4.3 GLACIERS

Glaciers are rivers of ice and are dynamic systems sensitive to their surroundings and constantly change their shape and form. Glaciers are classified based on various criteria e.g. morphological (area-altitude), thermal (polar, temperate and sub-polar) and dynamic (active – maritime) environment at low latitudes and passive - high latitude or in continental environment.

4.3.1 Glacial Erosion

Glacier erosion takes place due to abrasion and bodily moving rock fragments in the glacier mass. Direct evidence of erosion on bedrock is in the form of striae, grooves, smoothing, rounding and sharp truncation of internal rock structure. Large scenic features e.g. U-shaped and hanging valleys, glaciers steps, excavated lakes, etc. Undercutting of steep slopes takes place by glacier sapping and glacier milling takes place by circulation of melt-water in the glacier crevasses and depressions.

Glaciers have enormous capacity to transport rock debris. Generally sediments move slowly with speed of 1m/d in ice mass but transport over glacier margin, debris flow, running water and wind operate at much faster speed.

Depositional features, moraines, erratics outwash plains and trains, ground moraine sheets, drumlin and various ice content features e.g. Kettle holes, kames and esker. Glacio-aeolian deposits include sand dune sheets and mantle of loess (dust). Glacial lake deposits are used for dating palaeo-environment. Glacier lake outburst floods occur due to breaking of moraine or glacier dammed lakes.

Sikkim is a fully mountainous state of India, where the entire land is in the form of rugged terrain including mountains and hills. The central and northern mountain sectors are steeper than the southern sector.

The state is vulnerable to landslides and river erosion due to great elevation differences, steeply sloping terrain, and fragile geological conditions. In addition, the watersheds of the state are covered by some major glaciers and glacial lakes, which are quite susceptible to disastrous hazards due to Glacial Lake Outburst Floods (GLOFs). The glaciers, some of which consist of a huge amount of perpetual snow and ice, are found to create many glacial lakes. These glaciers as well as glacial lakes are the sources of the headwaters of two main rivers in the region, e.g. the Teesta and the Rangit rivers. The glaciers and glacial lakes of in Sikkim Himalaya are nature's renewable storehouse of fresh water that benefits hundreds of millions of people downstream. Lakes at elevations higher than 4,000 m are considered as glacial lakes. Most of these lakes are located in the down valleys close to the glaciers. They are formed by the accumulation of vast amounts of water from the melting of snow and ice cover and by blockage of end moraines. The sudden break of a moraine dam may generate the discharge of large volumes of water and debris causing disastrous floods downstream.

The glaciers are concentrated in the northwest and northeast extremes of the state. The perpetual snow line is found above 5,300 m. A number of glaciers descend from the northeastern slopes of Mt. Khangchendzonga into the Sikkim Himalaya in North and West Sikkim. The glaciers in the northwest section are mostly valley glaciers and have long dimensions, whereas the glaciers in the northeastern section are small and isolated in the form of mountain glaciers. The longest one is Zemu glacier, which covers 133 sq km which accounts for more than

30% of the glaciers of the state and extends down to 4,000 m from Mt. Khangchendzonga. On the basis of satellite images of 1987 to 1989, Kulkarni and Narain (1990) reported that the glacier cover an area of about 426 sq km in the Sikkim Himalaya.

In all 271 glaciers could be delineated in the present study covering an area of 518.97 sq km with an approximate ice reserve of more than 60 km^3 (Fig.10 and 10A). Generally, six types of glacier were observed in the Sikkim Himalaya—mountain glaciers, valley glaciers, cirque glaciers, niche glaciers, ice caps, and ice aprons.

There are altogether 313 glacial lakes throughout the Teesta basin of the Sikkim Himalaya covering an area of 21.5 sq km (see Fig.10 and 10A).

The number of glacial lakes in the Sikkim Himalaya as reported by ICIMOD in 266 covering an area of 20.2 sq km. The largest number (153) of glacial lakes are erosion lakes. There are 43 moraine-dammed lakes; among which one is a lateral moraine dammed lake. There are 33 valley lakes, 19 cirque lakes, 15 blocked lakes and 3 supra-glacial lakes. There are other supra-glacial lakes in the moraine of the glaciers, which are mostly frozen and some of it are quite small in size to map. In general, the erosion lakes are isolated and far away from the glaciers, moraine dammed lakes are close and associated with the present glaciers, valley trough lakes are situated along the river valley floor and some of it are quite close to the glacier end, blocked lakes are formed due to landslide, ice avalanche, etc. from different valleys, and the supraglacial lakes are situated in groups within the ice mass.

Periodic or occasional release of large amounts of stored water in a catastrophic outburst flood is widely referred to as a **Glacial Lake Outburst Flood** in the Himalaya. GLOF is a catastrophic discharge of water under pressure from a glacier. GLOF events are severe geo-morphological hazards and their floodwaters can wreak havoc on all human structures located on their path. Much of the damage created during GLOF events is associated with the large amounts of debris that accompany the floodwaters.

4.3.2 Potentially Dangerous Lakes

A moraine-dammed lake, which has breached and closed subsequently in the past and has refilled again with water, can breach again. Lhonak Chho in the north-west of Sikkim burst out. The study of recent aerial photographs and satellite images shows a very quick regaining of lake water volume. At present it is refilled again with water and poses danger. Regular monitoring of such lakes is necessary using multi-temporal satellite images.

Although there are no reports on the GLOF events in the Sikkim Himalaya, many debris flow along the glacial lake valley are seen in the satellite images. The erosion and deposition of debris along the valley can be seen clearly from the satellite images.

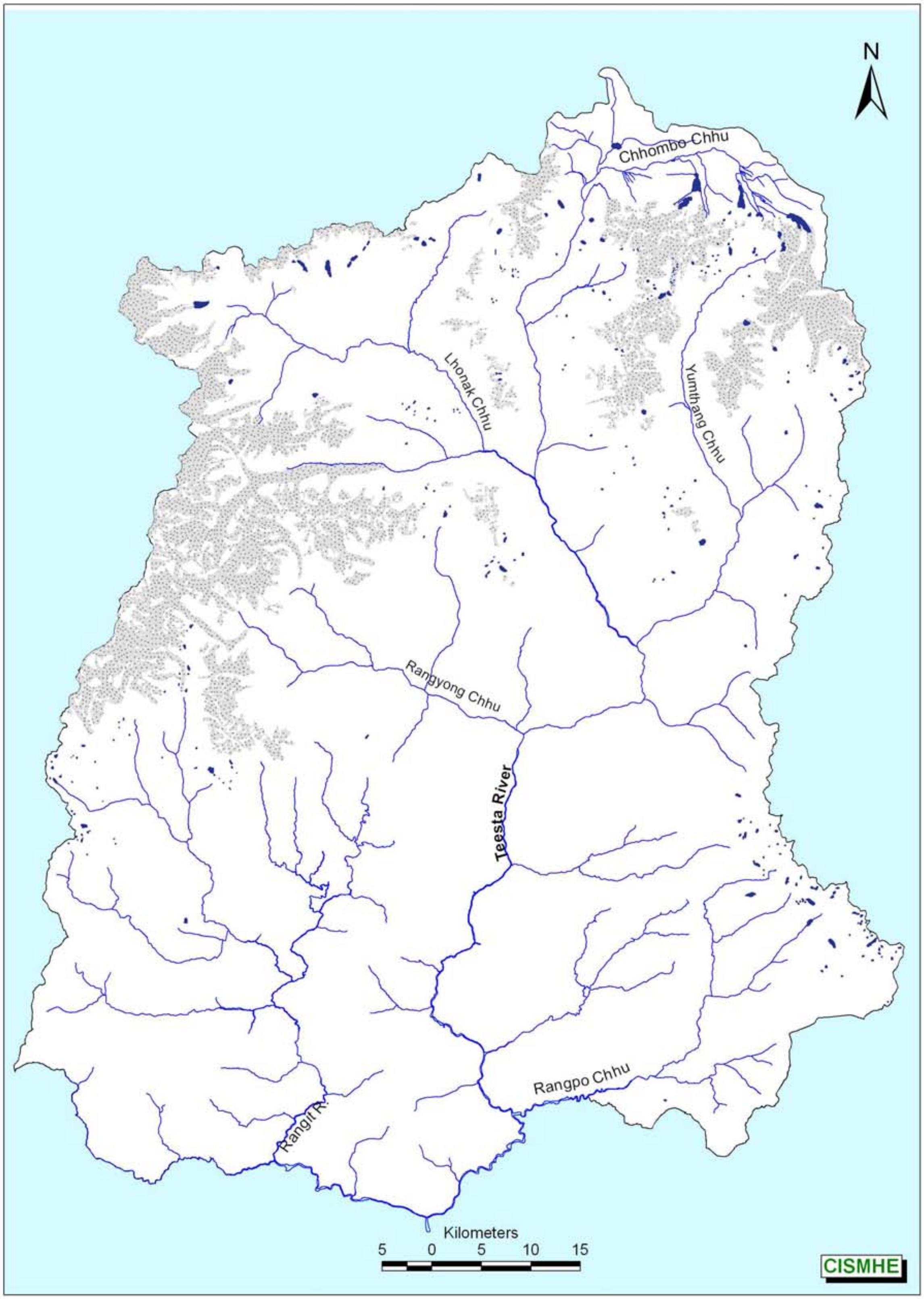

Fig.10 Glaciers and lakes of Sikkim Himalaya

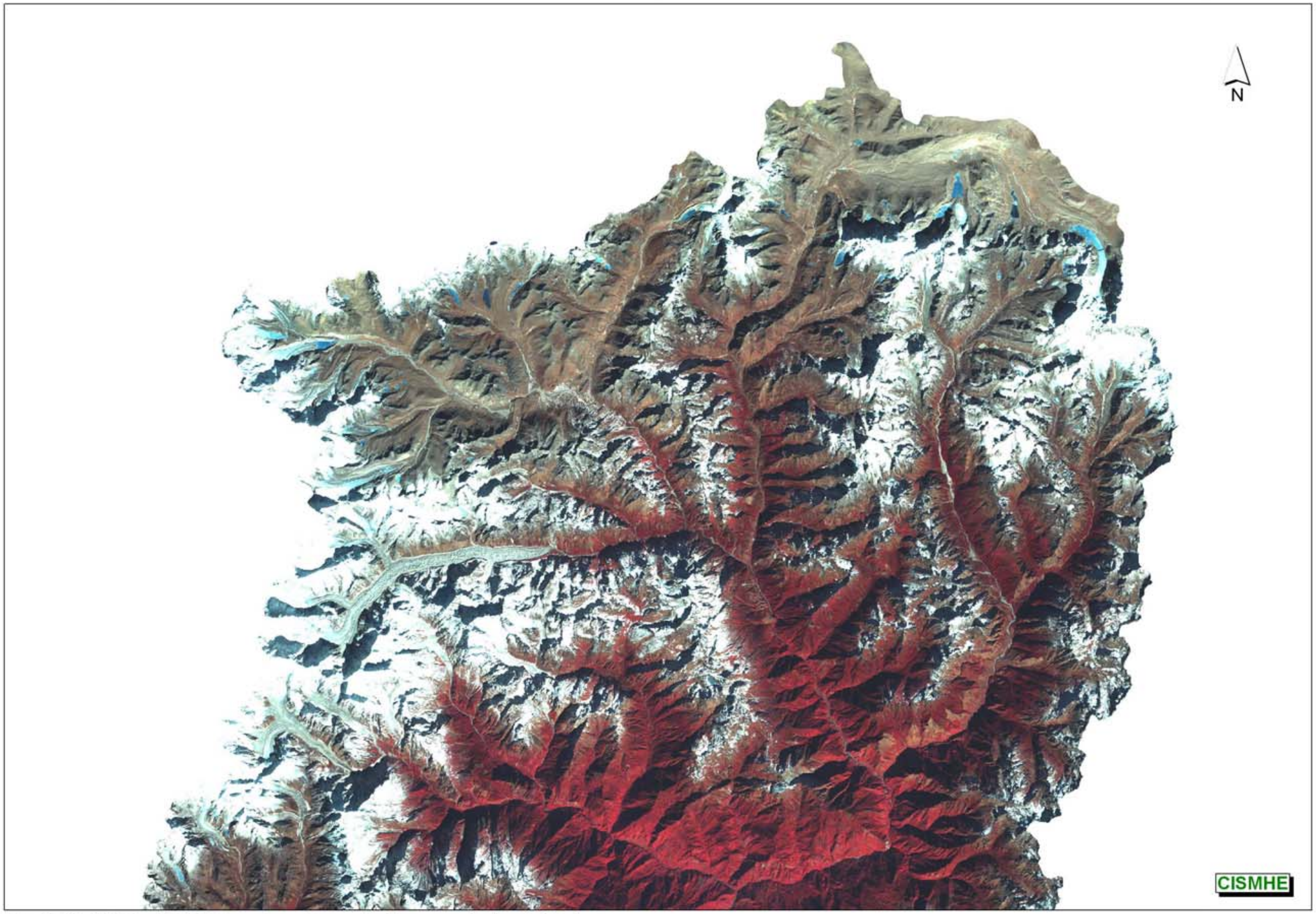

Fig.10A FCC of Sikkim showing glaciers and glacial lakes

4.4 SOIL

Soil is the basic natural resource for plant growth. Since the hill and mountaineous regions of Teesta basin have a great diversity with regard to biological activity, various types of soils are met with. Again extensive deforestation, haphazard constructional work, inadequate drainage, slope cultivation, in other words, unscientific and unplanned usages of land have led to the establishment of the vicious cycle of degradation leading to landslides or mass movement. So, soil and water conservation measure is utmost important in the hilly terrain of Teesta Basin in Sikkim for protection of the precious natural resource and to provide food, fuel, fibre to the bourgeoning population.

Keeping all these in view, the present studies have been undertaken with the following objectives.

To delineate and identify different watersheds in Teesta river basin in Sikkim

Inventorisation of soil resources in 17 watersheds in Teesta basin in Sikkim

To prepare different thematic maps in all the watersheds based on the information brought out during inventorisation soil resources with the help of Geographical Information System (GIS).

Soils of 17 watersheds in Teesta basin in Sikkim have been mapped at the level of soil series association. A total of 62 soil series have been identified and mapped into 63 soil mapping units (1:50,000 scale) through the soil resource inventory of the Teesta basin in Sikkim (Table 5 & Fig.11).

Table 5. Landforms *vis-à-vis* soils in Teesta basin in Sikkim

Landform Region	Landform Units	Soil series association unit	Soil map
Ridge	1	Maling-Rayong	1
	2	Rubam – Salem	2
Rocky cliff	3	Rock outcrops – Jorpul	3
Escarpments	4,5	Hilley-Singrep – Chatten	4
	6,7	Bhusuk- Karporang – Tibik	5
Landslide zone	8,9	Karporang – Hilley	6
Morrainic zone	10,11,12	Kalep – Rock outcrop	7
Low mountain (<1000m)	13,14	Bhasme – Chautare – Legship	8
>50 % slope		Singhik – Lingthem	9
Low mountain (<1000m)	15,16	Chalumthang – Rorethang – Bhasme	10
(30-50) % slope	17,19,20	Mangjing – Singrep - Rorethang	11
	18	Lingtse – Chautare – Chalumthang	12
Low mountain (< 1000m)	21	Mangjing – Dharamdin	13
(15-30) % slope	22,23	Dharamdin – Lingtse - Karfecter	14
Narrow valley(8-15) % slope	24	Mangreng – Karfecter- Mangjing	15
Mid mountain(1000-2000 m)	25	Tumin –Phong – Chautare	16
>50% slope		Chatten-Theng	17
	26	Phong – Khedi – Maniram	18
		Pakel – Tibik – Rock outcrop	19
	27	Chakung – Tumin – Sajong	20
		Singhik – Tibik – Lingthem	21
	28	Chongrang – Legship – Singgyang	22
		Singhik – Ruglo – Rapung	23
Mid mountain(1000-2000 m)	29	Doling – Khedi	24
(30-50)% slope		Gyer – Manul – Lema	25
	30	Dikling – Hilley	26
		Nung – Lingthem	27
	31,33	Samdur – Khedi – Bhusuk	28
		Lingthem – Lema – Singhik	29
	32	Rumtek – Tumin	30

		Bitchu – Ruglo – Pakel	31
	34,36	Bhusuk – Pirik – Namchi	32
		Manul – Gyer – Rock outcrop	33
	35	Namchi– Synggyang	34
		Ruglo – Lingthem – Theng	35
	37	Doling – Samdur – Rock outcrop	36
		Singhik- Pakel	37
Mid mountain(1000-2000m)	38,39	Rumtek – Pirik – Mangjing	38
(15-30) % slope	40,41	Daragoan – Gaucharan – Dharamdin	39
Mid mountain(1000-2000m)	42	Dharamdin – Martam - Karfecter	40
(<15% slope)		Mensithang – Lema – Bitchu	41
High mountain (2000-3000m)	43	Damthang – Chongrang – Rock outcrop	42
> 50% slope		Tibik-Byuma – Mensithang	43
	44	Singgyang – Maniram – Damthang	44
		Chatten-Lema – Tibik	45
	45,46,47	Maniram-Damthang – Jorpul	46
		Ship – Theng – Pakel	47
High mountain(2000-3000m)	48	Martam – Tarnu – Sajong	48
(30- 50)% slope		Rapung – Mensithang – Rock outcrop	49
	49	Sajong –Tarnu	50
		Tibik – Bitchu – Rock outcrop	51
	50	Khedi – Maniram – Rongnek	52
		Bitchu – Lachen – Chatten	53
	51	Rongnek – Sajong	54
		Ship – Lingthem – Rock outcrop	55
	52	Khedi – Dikling	56
		Byuma-Ship	57
High mountain(2000-3000m)	53	Gaucharan – Tarnu	58
(15-30)% slope		Yumthang – Bitchu	59
Very high mountain	54,55,58	Lachung- Puchikongma - Byuma	60
(3000-4000m)	56,57	Yumthang – Thangu – Kalep	61
(30-50)% slope	59	Maltin – Lachen – Rock outcrop	62
Extremely high mountain	60,61,62,63,64	Thangu – Rock outcrop	63
(30-50)% slope			
Glacier			G

Soil map prepared by NBSS & LUP, Regional Centre, Kolkata has been given in Fig.12.

4.4.1 Land Capability Classification

Land Capability classification (LCC) depicts the capability of soils for proper utilization of land on sustainable basis. This provides clues to the management and improvement of different soils for increasing production (Dent and Young, 1981).

Watershed-wise land capability classification of soil was done. Five land capability classes and seven land capability sub-classes have been identified in this watershed based on the number and severity of different limitations.

4.5 BIOLOGICAL ENVIRONMENT

Sikkim is one of the most important areas of biological importance and has been classified as a global hot spot for biodiversity conservation. The importance of assessing the status and nature of biological diversity including ecosystem diversity of Teesta basin, therefore, cannot be over-emphasized. A great variation in the eco-climatic conditions of the basin have given rise to a myriad ecosystems, from hot humid tropics and sub-tropics to frigid alpine areas in Sikkim. It is, therefore, important to understand that biological resource holds an important place in the planning and developmental process of Sikkim. In order to achieve a balancing act of conserving the biological diversity and ensuring economic gains from conservation and also utilisation of biological resource, it is essential to assess the existing biological environment base of the basin. To achieve this objective following aspects of biological environment have been evaluated in the study:

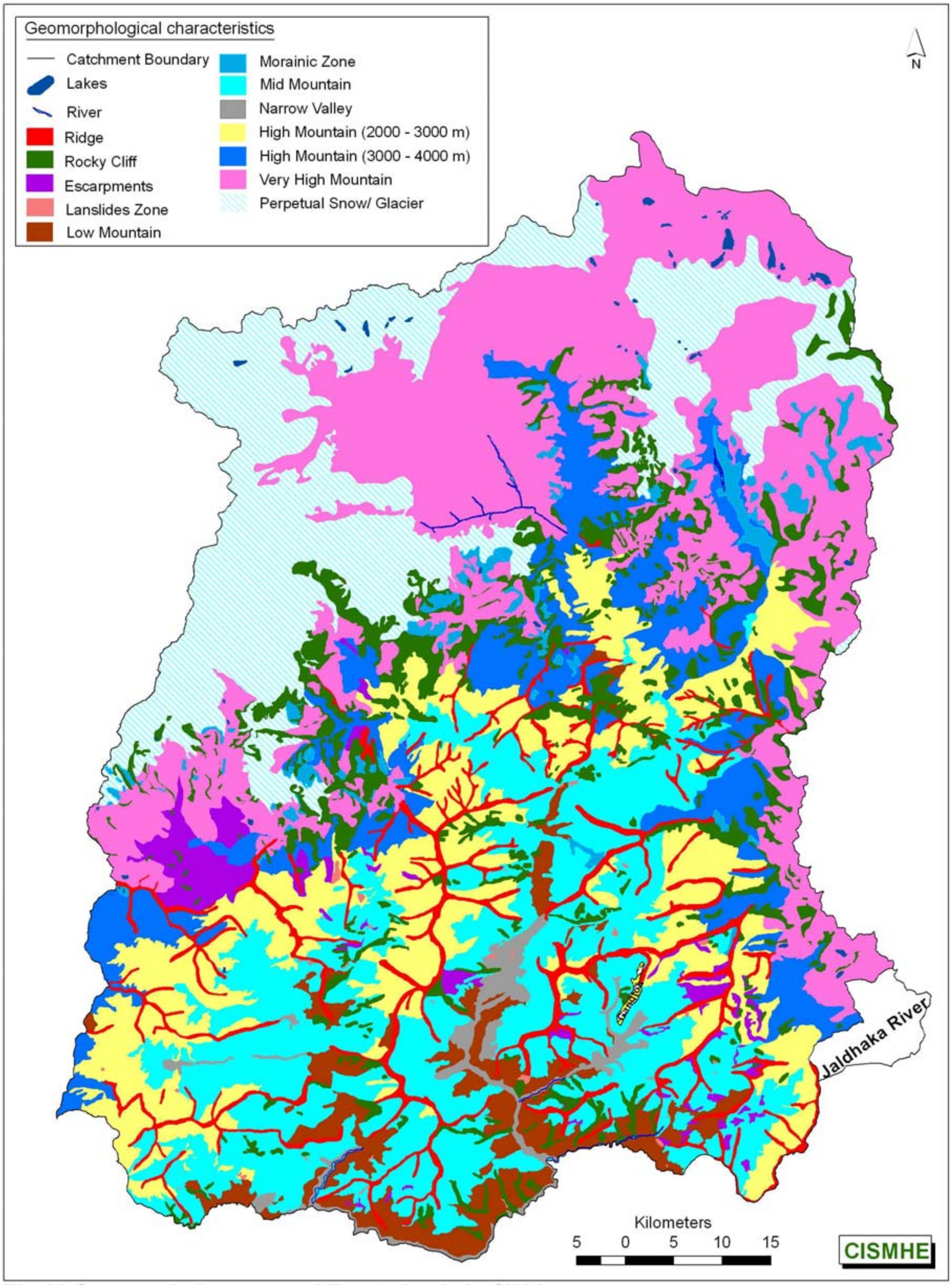

Fig.11 Geomorphology map of Teesta basin in Sikkim

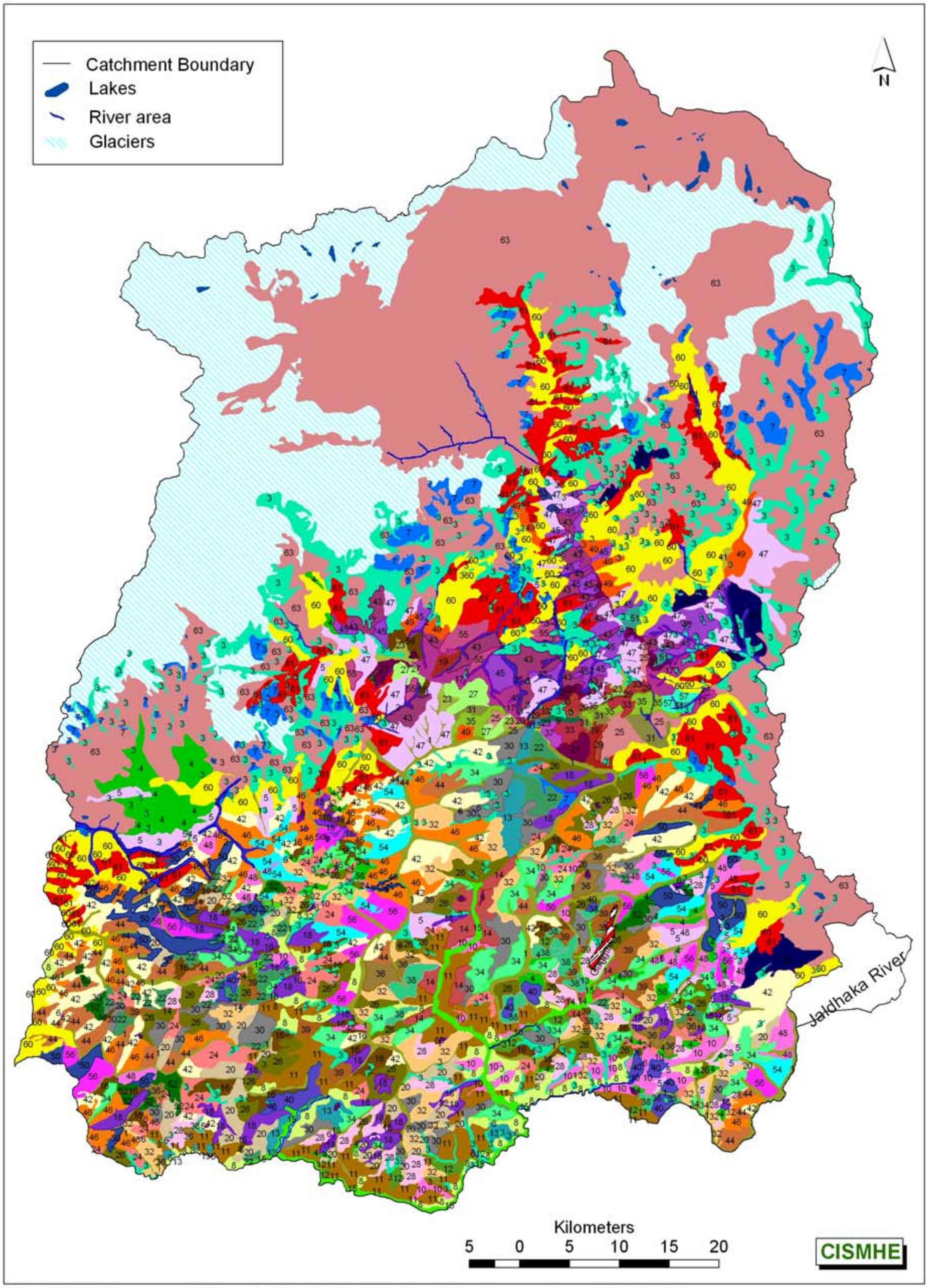

Fig. 12 Soil map of Teesta Basin in Sikkim (For legend see Table 5)

- Inventorisation of floral and faunal species diversity in terrestrial, aquatic and aerial ecosystems
- Identification and mapping of endangered or rare taxa of conservational and economic significance
- Identification of hot spots for conservation and sustainable exploitation
- Landuse and vegetation mapping including forest cover
- Biological sensitivity analysis of ecosystems/areas where developmental projects are proposed
- Identification of potential areas for eco-tourism
- Identification of potential biological resources for economic welfare of local population and industrial use

4.5.1 Floristics

Teesta river basin in Sikkim has wide altitudinal range from 213 m to above 8,000 m; adverse climatic conditions from cold in the north to extremely wet conditions in south, west and eastern parts of Sikkim; and the deep valleys and ravines to gentle slopes in glaciated valley floors in north. The basin is also interlaced with numerous rivers and lakes resulting in many beautiful valleys, ravines and wetlands. All these characteristics provide uniqueness to the Teesta basin in Sikkim and making it rich in floristic diversity. For these reasons only IUCN has recognized this region as a part of Indo-Burma hot spot. The Table 6 clearly shows its floristic richness in terms of number of flowering plant species and endemic species among the Himalayan states of India and neighbouring countries. There are more than 4000 species of flowering plants reported from Sikkim. Due to wet conditions that persist for long periods, the area is also very rich in lower plants like liverworts, mosses, algae, fungi and bacteria.

Table 6. Floral richness of Teesta basin in Sikkim *vis*-a-*vis* other Himalayan regions and north-east India

State/Country	Geographic area (sq km)	Number of flowering plant species	Endemic plant species
Sikkim	7,096	4,250	123
Nepal	1,40,800	5,067	246
Bhutan	47,000	5,500	60
Arunachal Pradesh	83,743	5,000	114
Assam	78,523	3,017	14
West Bengal	88,752	3,580	07
Manipur	22,347	3,000	75
Meghalaya	22,549	1,517	65
Nagaland	16,579	2,431	35
Tripura	10,486	1,545	-
Mizoram	21,081	2,141	46
Jammu & Kashmir	2,22,235	4,252	124
Himachal Pradesh	55,673	3,343	82
Uttaranchal	53,483	4,220	45

In recent times, the increase in human population as well as increase in various developmental activities have posed a serious threat to the floristic diversity of Teesta basin. In this report, an attempt has been made to assess the floral wealth of the basin and suggestions have been made for the protection and preservation of this wealth along with on going developmental activities.

4.5.2 Taxonomic Diversity

Teesta basin has different kinds of vegetation cover due to various climatic, edaphic, topographical and altitudinal variations. Among different areas in East Himalayan region Teesta basin in Sikkim is the richest in floristic diversity (see Table 6 and Fig.13). Teesta basin in Sikkim is richest in terms of number of flowering plant species that are found per 100 sq km of its geographic area (see Fig.13). In Sikkim the number of plants per 100 sq km is 70 whereas, in other states of India this diversity varies from 2 to 15. Sikkim harbours nearly one fourth of the total flowering plants of India. In the present study 3418 species of angiosperms and gymnosperms could be recorded from Teesta basin in Sikkim. This list, however, is still incomplete. The region is also very rich in other groups of plants like pteridophytes, bryophytes, lichens, fungi, algae, etc.

4.5.2.1 *Flowering Plants*

In an area of only 7,096 sq km, more than 3400 species of angiospermic plants could be recorded. These plants are observed throughout Sikkim inhabiting the extreme frigid region of Gurudongmar, Yumesamdong, alpine regions of Thangu, Yumthang and Dzongri and temperate areas of Mangan, Chungthang and Lachen-Lachung valleys to sub-tropical and tropical areas of Namchi, Rangpo, Jorethang and also found in lakes and wetlands.

i) *Monocots*

Monocots are comprised of 1217 species belonging to 26 families and 339 genera. Orchidaceae is the largest family with 445 species followed by Poaceae and Cyperaceae with 280 and 149 species, respectively. Liliaceae is represented by 90 species. Monocot species are found throughout the Teesta basin. Monocot genera that have maximum species are: *Bulbophyllum* (46 spp), *Dendrobium* (36 spp), *Eria* (23 spp) and *Liparis* (20 spp). Generally orchid species prefer wet moist conditions, however, some of the species like *Coelogyne cristata, Cypripedium himalaicum, Ponerorchis chusua*, etc. are restricted to higher altitudes in Singalila range, Tendong peak, Khangchendzonga and Shingba regions, which are comparatively drier.

ii) *Dicots*

Dicots are represented by 2917 species, which belong to 913 genera and 165 families. Asteraceae is the largest family with more than 81 genera in Sikkim. The species of this family are mostly found in alpine regions of Kupup, Chhangu, Gurudongmar and Yumesamdong regions. The prominent genera in Sikkim are *Corydalis* (21), *Elatostema* (22), *Ficus* (36), *Persicaria* (16), *Palea* (12), *Potentilla* (23), *Saxifraga* (52), *Sausurea* (32) and *Thalictrum* (11).

iii) *Gymnosperms*

In Sikkim Himalaya gymnosperm species are very few. In all 18 species of gymnosperms are recorded in Teesta river basin. Most of

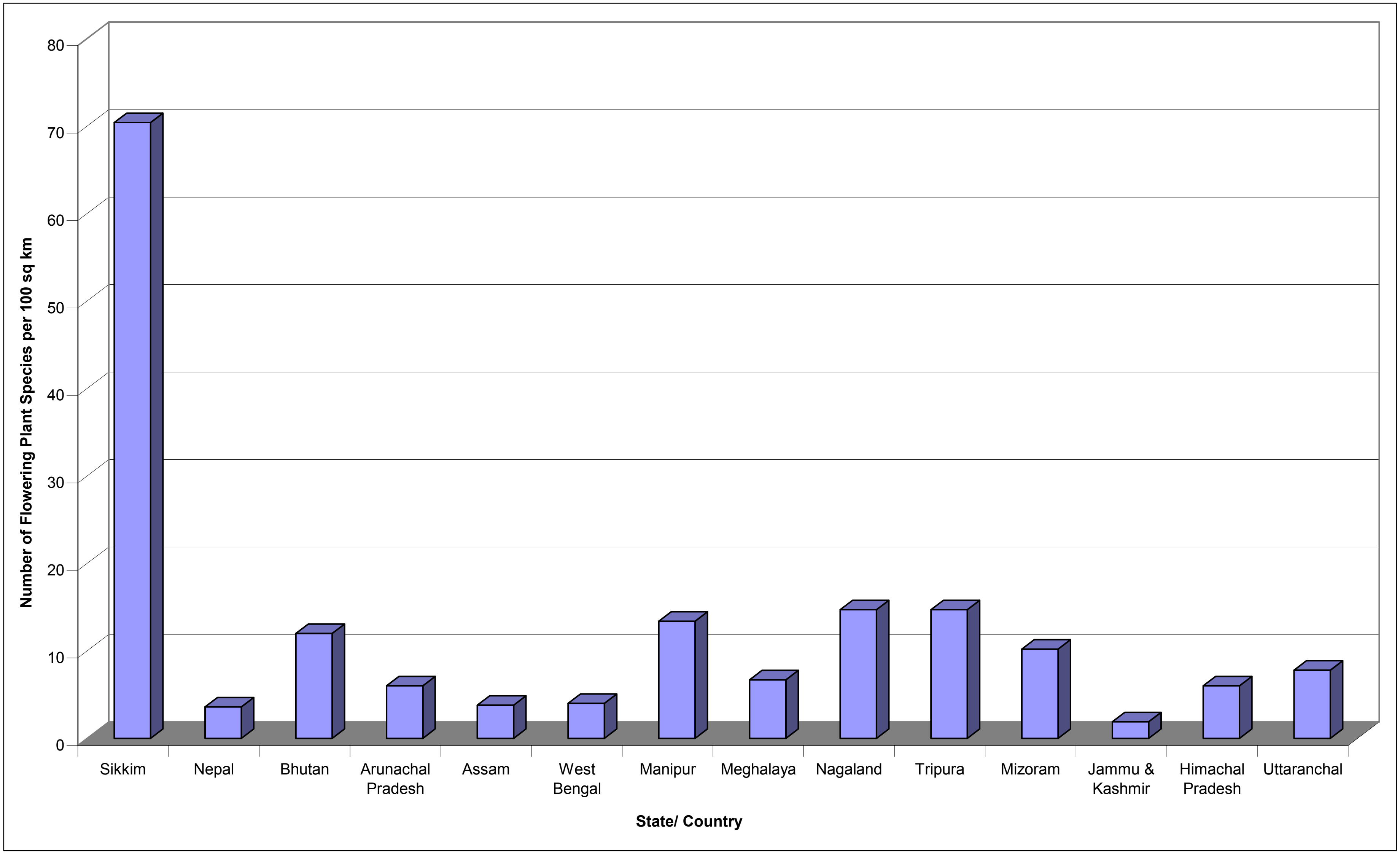

Fig.13 Floral richness of Teesta basin in Sikkim

these species are trees, distributed mainly in Lachen-Lachung valley, Thangu region, Yumthang, Dzongri and Chhoka areas.

iv) *Pteridophytes*

Sikkim is very rich in pteridophyte plants also. Most of these species are found in the wet tropical and sub-tropical regions of Rangit valley, Teesta valley, Lachung Chhu, Chakung Chhu and Rangpo Chhu valley.

4.5.3 Physiognomic Diversity

In Teesta basin, flora was also assessed in terms of physiognomy i.e. with respect to habit of the plant. In the forests of Sikkim, all types of plants like herbs, shrubs, trees, climbers were seen associated with each other. However, the bulk of flora is herbaceous. Around 64 per cent of plant species are herbs. The portion of trees and shrubs in the flora is nearly equal, which is around 16.21 and 13.17 per cent, respectively.

4.5.4 Phytogeographical Affinities

As such India has strategic position on the globe and within India the position of Sikkim or Teesta basin is very important with respect to phytogeography. Plants from all direction immigrated to Sikkim as well as migrated out of this region. Floral elements from South East Asian region, which included Myanmar, Thailand, Indo-China, Indonesia and Malaysia are found in the tropical and subtropical forests of Sikkim. In this region the species like *Bauhinia vahlii, Dendrophthoe falcata, Ficus benghalensis, Murraya koenigii, Plumbago zeylanica* and *Woodfordia fruticosa* are also found, which have come from peninsular India. The temperate flora of Himalaya, China and Japan has an overlapping link. Some species like *Cardiocrinum giganteum, Cornus macrophylla, Houttuynia cordata* and *Hypoxis* are present from western Himalaya to Japan. Some species like *Acronema, Acer oblongum, Allium pratii, Leycesteria formosa, Myrsine semiserrata* are present only in Himalaya to China and absent from the islands of Japan.

4.5.5 Endemics

In Teesta basin, with such a small area, large numbers of endemic plants are reported. A list of more than 120 species of plants, which are exclusively endemic to the state of Sikkim. Most of them are herbs and around 10 species are shrubs. Trees or climbers are very few. Only three tree species, *Rhododendron lanatum* of Ericaceae, *Litsea sikkimensis* of Lauraceae and *Mallus sikkimensis* of Rosaceae are endemic to Sikkim. *Litsea sikkimensis* is found in Lachen and Kyongnosla Alpine Sanctuary area, whereas *Rhododendron lanatum* is found in Dzongri in West Sikkim as well as in Nathula region in East Sikkim. In case of *Mallus sikkimensis*, only one tree could be located in the Lachung area near a stream. Most of the endemic species are found above 2,500 m in Lachen, Lachung, Lhonak and Zemu valleys. However, most of the endemic orchid species are found in tropical and sub-tropical regions in Teesta, Sebu and Chungthang valleys below elevation of 1,600 m. More than 20 species of orchids are endemic to Sikkim region. Another family having maximum number of endemic species is Asteraceae. There are around 18 species from this family that are endemic to Teesta basin in Sikkim, mostly distributed above 3,000 m in alpine and sub-alpine area. Only *Blumea sikkimensis* of Asteraceae is found in tropical region. Some other families like Primulaceae, Gentianaceae, Apiaceae, Rosaceae and Urticaceae have 9, 8, 8, 7, and 5 species, respectively that are endemic to Sikkim. In nine families, there is only one and in five families there are two species that are reported endemic to Sikkim region. Many of these endemic species have various medicinal and other uses and collected by local people from the wild only. In the present studies efforts were made to locate them in the wild and record their population size and to make an assessment of nature of any threat to their survival in the wild. The species like *Podophyllum sikkimensis*, *Panax sikkimensis*, *Anaphalis cavei* and *Acer hookeri* are used for medicinal purpose and are extensively extracted from the wild. In some areas, the depletion of forest cover has resulted in the shrinking of the habitats of *Panax sikkimensis, Cymbidium gammieanum, Dendrobium densiflorum, Habenaria cumminsiana* and *Zeuxine pulchra.*

4.5.6 Threatened Flora

More than 50 species of plants from Teesta basin in Sikkim have been included in threatened, endangered, vulnerable or rare categories as defined by IUCN (International Union for the Conservation of Nature) and compiled by Nayar and Sastry (1987, 1988, 1990). All these have listed the status of higher plants only, however, the status of the lower group like bryophytes, lichens, fungi, algae and bacteria still not known. According to Nayar and Sastry (1987, 1988, 1990), 13 species of plants are under the endangered category, two of them *viz*. *Zeuxine pulchra* (Orchidaceae) and *Dennstaedtia elwesii* (Dennstaedtiaceae) in all probability have already disappeared from Sikkim Himalaya. Around 10 species of plants are in vulnerable category and 18 species have become rare. Six species of plants have indeterminate status. There is an urgent need to know the status of these threatened plant species further.

Threatened Endemic Plant Species

There are around nine species, which are endemic as well as threatened in the present Sikkim state. During the present surveys only six species out of these nine species could be found. Species like Zeuxine pulchra are now considered extinct. In 1898 King and Pantling had collected two specimens of this species from Lachung in North Sikkikm. Later in 1974, the species was also found in Khasia Hills (Nayar and Sastry 1987). Since then, it has not been reported from anywhere and all efforts to locate, the plant in the wild failed. It has been reported that the genus Zeuxine is characterized by highly delicate terrestrial plants with very specific habitat conditions. Even the slight alteration, degradation, clearing of forest would bring the plants to extinction. Like most of the epiphytic species of orchids this species is also not adaptable or hardy (Nayar and Sastry, 1987). *Cymbidium whiteae* and *Didiciea cunninghamii* are two other orchid species, which are endemic as well as threatened in Sikkim Himalaya (Nayar and Sastry 1987). *Cymbidium whiteae* was discovered in Gangtok at 1,700 m by Mrs. Claude White and named after her (Nayar and Sastry 1987). The original habitat of the species has been converted in to human settlements. However, the species has sporadically been seen in Rumtek area, where the area is under agriculture. Despite the extensive surveys in Rumtek area, this species could not be found. The species, *Didiciea cunninghamii* has now also been reported from Garhwal Himalayas (Nayar and Sastry, 1987). However, its authenticity is yet to be established. Acronema pseudotenera is another endemic as well as threatened species from Sikkim Himalaya. The species has been collected only once in 1892 by Gammie from Momay Samdong (Nayar and Sastry, 1988). In spite of extensive efforts in North Sikkim no specimen could be found in this area. Other five species, which are endemic as well as threatened, were collected from different parts of Sikkim. *Begonia satrapis* was found in the South Sikkim in Rangit area. Nayar and Sastry (1990) mentioned that the specimens of B. satrapis were collected before 1914 by C. B. Clarke, Ribu and Rhomo, G. H. Cave and I. H. Burkill from Rangit valley. In the present survey also, this species has been collected from Rangit valley and Soombuk in South Sikkim. The plants were located at few spots only with 5 to 10 individuals attached to the rocks.

4.5.7 Rhododendrons

Sikkim is considered as second home of rhododendrons in India after Arunachal Pradesh as 36 species of rhododendrons are found in

Teesta basin with several forms and varieties. Hooker (1849) described 34 species of rhododendrons. Pradhan and Lachungpa (1990) have also given a good account of these plants from Sikkim. Owing to their rich diversity in Sikkim, two sanctuaries have been notified i.e. Shingba in North Sikkim and Barsey in West Sikkim for the conservation and protection of diversity of this genus. Shingba Rhododendron Sanctuary in North Sikkim has the largest number of rhododendron species in Teesta basin.

4.5.8 Orchid Diversity

Teesta basin harbours about 445 species belonging to 117 genera of orchids, the maximum number of orchid species in India. Orchids are found in all parts of Teesta basin, from alpine, temperate to tropical region and have diverse habitats right from soil, stones to tree branches. Hooker (1848), King and Pantling (1898) and Bruhl (1926) have given detailed account of orchids in Sikkim.

Orchids in Teesta basin in Sikkim are distributed right from 300 m in South Sikkim at Singtam, Rangpo area up to 4,500 m in North Sikkim. Around 23 species are recorded from alpine region growing above 3,600 m in Dzongri, Talung, Samdong, Lachung valley and Shingba region. Around 250 species of orchids are epiphytes and more than 175 species are terrestrial. However, 7-10 species grow as epiphytes as well as terrestrial. Some species are terrestrial saprophytes (*Microstylis saprophyta, Pantlinga paradoxa*) and 5-6 species are terrestrial parasites. *Didymoplexis pallens* is a climber and *Microstyris aphylla* is a leafless plant parasite on roots.

4.5.9 Economically Important Plant Species

In Teesta river basin around 40-60 per cent of the flowering plants are used for various purposes ranging from food, medicines to furniture, instruments for games and arms and various other miscellaneous purposes. The uses of some of the plants are similar in entire Teesta basin, whereas some plants are used in very specific manner depending upon community or locality.

i) Medicinal Uses

In Sikkim flora more than 400 species of plants are used to cure various ailments (Biswas, 1956). These plants are not only used to cure human beings but the domestic animals also. The plants are used as tonic, aphrodisiac, to cure simple diseases like fever, diaorrhea to very serious diseases like cancer, rheumatism, asthma, etc. Plants like *Podophyllum hexandrum* and *Taxus baccata* are useful for treatment of cancer. In Sikkim there are two systems of using the plants to cure the disease. One is Ayurvedic, practiced mainly by Nepali community and another is Tibetan system, which is a mixture of Ayurvedic and Chinese system and is mainly followed by Tibetan and Bhotiya people. Lepchas, though use a number of herbs, but are more inclined towards other medicinal sources, that is animals, etc.

These medicinal herbs or trees are found in each and every part of Teesta basin. However, they are concentrated mainly in the higher altitudes (2,500 to 3,000 m). Plants like *Aconitum ferox*, *Alnus nepalensis, Arisaema speciosum, Daphne bholua, Ephedra gerardiana, Hedychium spicatum, Heracleum wallichii, Impatiens racemosa, Nardostachys jatamansi, Panax pseudoginseng, Picrorhiza kurrooa, Podophyllum hexandrum* and *Taxus baccata* are found in the alpine and sub-alpine regions of Teesta basin. *Aloe barbadensis, Brassica campestris, Bridelia retusa, Cissampelos pariera, Piper longum* and *Terminalia belerica* are restricted to 1,000 - 1,200 m altitudes in tropical parts of Teesta basin. There are many species like *Artemisia vulgaris, Acorus calamus, Bergenia cilliata, Berberis aristata* and *Dioscorea deltoidea* which are found in the temperate and sub-tropical parts of Sikkim.

ii) Timber, Fuelwood and other Uses

In all 639 species of trees constitute the flora of Teesta basin. These tree species belong to 278 genera and 93 families of angiosperms and gymnosperms. Tree species are used in various ways in Sikkim ranging from timber, fruit yielding to medicinal uses. *Abies densa, Betula utilis, Pinus roxburghii* and *Tsuga ciliata* mostly found in Lachen, Lachung and Yumthang regions are used for timber. In tropical and sub-tropical regions of Rangit, Ravongla, Singtam, and Rangpo, *Shorea robusta, Terminalia myriocarpa, Quercus lamellosa, Castanopsis indica* and *Canarium benghalensis* are used for furniture and material for house building. There are many fruit yielding tree species like *Morus laevigata, Citrus maxima, C. aurantifolia, C. medica, C. reticulata, C. sinensis, Juglans regia, Ficus* *auriculata, F. racemosa*, etc. Some tree species like *Abies densa, Acer campbelli, Berberis aristata, Taxus baccata, Zanthoxyllum alatum* and *Betula utilis* are used to cure various ailments. There are many trees species belonging to *Rhododendron, Magnolia, Michelia, Prunus*, etc. have very beautiful flowers and attract tourists in very large numbers.

iii) Cereals, pseudocereals, pulses and vegetables

In Teesta basin eight to 10 species of plants are used as cereals. *Oryza sativa, Triticum aestivum, Hordeum vulgare, Zea mays* and *Eleusine coracana* are the main cereals grown in the basin. *E. coracana* is mainly used for making a fermented product called ‘Chhang’. In alpine and sub-alpine region of Thangu, Muguthang and Lachung two species of *Fagopyrum* are cultivated for seeds and leaves. There are also some other minor cereals like *Echinochloa furmantacea, Pennisetum americanum*, etc. which are cultivated in some parts of Sikkim.

Cajanus cajan, Cicer arietinum, Glycine max and various species of *Phaseolus* and *Vigna* are extensively cultivated in various parts of Sikkim ranging from tropical to alpine and sub-alpine region of Chhoptha, Lachen, Lachung and Kupup. Many of these species have their wild relatives growing in the forest, which serve a good source of germplasm for the genetic improvement of the cultivated species.

Roots, leaves and shoots of various plants in Teesta basin are used for vegetables. There are more than 40 plant species, which are cultivated and 17 to 20 species of plants that are collected from the wild for vegetables. *Amaranthus* sp., *Colocasia esculenta*, *Spinacea oleracea*, *Brassica oleracea, Chenopodium album, Trigonella* sp. are some of the important species cultivated as leafy vegetables. Roots and rhizomes of many species are used as vegetables. Most common ones *are Manihot esculenta, Colocasia esculenta, Amorphophallus camanulatus* and six to seven species of *Dioscorea*.

iv) Spices and Condiments

In Sikkim Himalaya there are numerous plant species, which have strong aroma in their leaves, flowers and roots. Many of these are used as spices or condiments for adding taste to the food and for preservation. *Amomum subulatum, Zingiber officinale* and *Curcuma domestica* are the major species cultivated in the tropical and temperate region. *Amomum cardmomum* is cultivated in Mangan, Ravongala and Namchi area. It is one of the major commercial crop of Teesta basin which gives employment to many people ranging from cultivation to marketing.

4.5.10 Floral Hot Spots of Sikkim

Sikkim state has been divided into four districts, North, South, East and West. With respect to forest cover East Sikkim is having maximum, around 70%, followed by South and West districts. North Sikkim is having around 30% forest cover. However, North Sikkim is at top with respect to the number of flowering plants or number of endemic and threatened species of flowering plants. More than 60% of endemic species are located in North Sikkim only. In other districts the number of endemic species are less than 25 per cent. Similarly maximum number of flowering plants categorized as threatened are found in North Sikkim only. From Sikkim Himalaya more than 50 species of flowering plants are mentioned as threatened (Table 7). Of these 27 species are located in North Sikkim, particularly in Lachen-Lachung valley and Zemu valley. In North Sikkim there are some locations which are ideal for speciation of various plant species. Like Singhba for *Rhododendron* species, Thangu-Chhoptha region for *Aconitum* and *Podophyllum*, Lachen-Lachung valley for *Panax pseudoginseng,* Katao and Zemu valley for *Primula* species. At Singhba, which has been declared as Rhododendron Sanctuary, various morphotypes of this genus and its species having different flower colours, leaf size, plant height, etc. are found. From Thangu region a new type of *Aconitum* has been identified which has new chromosome number 2n = 48. From North Sikkim, 8-10 different types of *Panax pseudoginseng* were identified based on only leaf characters. Further work is needed to identify these plants based on chromosome number and other molecular characters. In North Sikkim many other plant explorers also have identified Lhonak valley, Lachen-Lachung valley, Yumthang valley and Zemu valley rich in floristic diversity (Gammie, 1894).

Table 7. District-wise floristic richness of Sikkim

Districts	Geographic Area (sq km)	Forest Cover (%)	No. of Endemic Plant Species	No. of Threatened Species
North Sikkim	4,226	30.79	63	27
South Sikkim	750	68.00	07	12

East Sikkim	954	70.23	23	09
West Sikkim	1,166	61.06	05	05

4.5.11 Edible Wild Plants & Ethnic Fermented Foods

Food culture in Sikkim has been reflected in the pattern of food production in mixed farming system. Depending on the altitudinal variation, the cereal crops are rice, maize, finger millet, wheat, buckwheat, barley; pulse crops are black gram, soybeans, green gram, garden peas; vegetable such as cabbage, cauliflower, leafy mustard (*rayo sag*), young tendrils and fruits of squash (*iskus*), brinjal, chili, cucumber, young tendrils and fruits of pumpkin, sponge gourd, tomato, tree tomato, etc.; tubers and rhizome crops are potato, sweet potato, cassava, colacasia, greater yam, ginger, turmeric, large cardamom; root crops are radish, carrot, etc. Seasonal fruits such as orange, banana, mango, papaya, guava, pear, peach, apple, fig, avocado, etc. are cultivated and eaten. Wild plants play important roles in local diet of the Sikkimese. The ethnic people of Sikkim consume roots, tubers, rhizomes, leaves and fruits of wild plants and also sell some of these wild fruits, vegetables in nearby markets at different seasons. Edible wild plants/fruits are in high demand in the local markets. Livestock mostly plays a subsidiary role in the mixed farming system.

Analysis of bioresources of Sikkim particularly the food security including the edible wild plants and ethnic fermented foods is one of the aim of this study. Some of the findings have been highlighted in this study.

A survey was conducted on the types of edible wild plants and ethnic fermented foods based on the method of the Indian Statistical Institute, Kolkata (unpublished). Information on various types of edible wild plants and ethnic fermented foods produced and consumed by the people, their traditional methods of preparation, the ingredients used, the equipments used, mode of consumption, etc. were collected through interview or by perusal observation in randomly selected villages located in the Teesta basin areas of Sikkim.

Common seasonal edible wild plants were collected from their natural habitats located in Teesta basin areas of East, North and South districts of Sikkim. Samples were collected in sterile polybags and transported to laboratory for analyses. Samples of some common ethnic fermented foods and beverages such as *kinema, gundruk, chhu* and *kodo ko jaanr* were collected aseptically from different villages of Sikkim located in the Teesta basin, in pre-sterile bottles and bags kept in an ice-box from and transported to the laboratory for analyses.

Microbiological analysis and analysis of nutritional value of some of these plants were carried out.

4.5.12 Edible Wild Plants

An update checklist of edible wild plants was prepared using references of Hara (1966), Bennet (1987), Sundriyal and Rai (1996), Rai *et al*. (1998), Gurung (2002) and Rai (2002). Out of 128 edible wild plants reported from the various places of Sikkim, 63 wild plants are eaten as fruits, 22 as vegetables, 19 as pickles, rest as condiment, herbal materials, etc. Some people are economically dependent upon these plants. They sell in the local markets.

Eighteen common edible wild plants were collected from different places of Sikkim and were analysed to know their nutritional composition. Wild edible plants analysed included: *Nasturtium officinale, Oxalis corniculata, Phlogacanthus thyrsiflorus, Rhododendron arboreum, Persicaria runcinata, Houttuynia cordata, Urtica dioica, Elaeagnus conferta, Ficus hookeriana, Fragaria nubicola, Ficus benjamina, Machilus fructifera, Aconogonum molle*, *Diplazium esculentum, Campylandra aurantiaca, Choerospondias axillaries, Castanopsis hystrix* and *Docynia indica* This is the first report on the nutritional value of these common edible wild plants in Sikkim. Data showed that some of these plants have high nutritional value as well as high content of minerals particularly potassium.

Market survey of edible wild plants

Market survey of seasonal edible wild plants was conducted at Gangtok, Mangan, Singtam and Melli (Table 8). People usually collect the edible wild plants from their natural habitats and sell in local markets. In most cases, 100% profit is made out of selling the wild plants. However, cost includes local transportation and other expenses. Profit is used from livelihood and spend on children’s education.

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Table 8. Market survey of edible wild plants sold in local markets located in the Teesta basin of Sikkim

Edible Plants	Local name	Price in Rs. per kg		Profit (%)	Market	Source of buying/ collection	Seasons
		Buying (Collection)	Selling				
Urtica dioica (Inflorescence)	Gharia sishnu	33.3	41.6	25	Gangtok	32 mile, Marchak	Sep-Oct
Urtica dioica (Inflorescence)	Gharia sishnu		37.5	100	Mangan	Mangan, Sankalan	Sep-Oct
Urtica dioica (Bundles)	Gharia sishnu	17.5	23.0	31	Gangtok	Syari, Sichey, Bhusuk	July-Oct
Urtica dioica (Bundles)	Gharia sishnu		25.6	100	Mangan	Sankalan, Kodyong	July-Oct
Campylandra aurantiaca (Inflorescence)	Nakima		76.6	100	Gangtok	Kopibari, Lower syari	Aug-Oct
Zanthoxylum rhetsa (Fruits)	Siltimmur		58.3	100	Gangtok	Bhusuk	Aug-Oct
Diplazium esculentum (Fronds)	Ningro	6.6	8.5	29	Gangtok	Ranka, Lower syari	May-Oct
Diplazium esculentum (Fronds)	Ningro		9.7	100	Mangan	Mangan, Singik, Lingthem	May-Oct
Diplazium esculentum (Fronds)	Ningro	7.0	9.0	29	Singtam	Bermoik, Bumtar, Kajitar	Sep-Dec
Diplazium esculentum (Fronds)	Ningro	7.0	8.8	26	Melli	Sadam, Turuk	Sep-Dec

Nasturtium officinale (Young twigs)	Simrayo		8.4	100	Gangtok	Baluakhani, ICAR Tadong, Lower syari	July-Nov
Nasturtium officinale (Young twigs)	Simrayo		9.5	100	Mangan	Sankalan, Mangan	July-Dec
Nasturtium officinale (Young twigs)	Simrayo		9.3	100	Singtam	Pathing	June-Nov
Juglans regia (Fruits)	Okhar		21.6	100	Gangtok	Kabi, Ravangla, Pangthang	Sept-Dec
Juglans regia (Fruits)	Okhar		21.6	100	Mangan	Chowang, Mangan, Singik	Sept-Dec
Juglans regia (Fruits)	Okhar		10.0	100	Singtam	Bermoik, Pathing	Oct-Nov
Juglans regia (Fruits)	Okhar		10.8	100	Melli	Sadam	Oct-Nov
Choerospondias axillaris (Fruits)	Lapsee		10.0	100	Gangtok	Lower syari, Ranka	Sept-Dec
Choerospondias axillaris (Fruits)	Lapsee		10.6	100	Mangan	Chowang, Sankalan	Sept-Dec
Choerospondias axillaris (Fruits)	Lapsee	7.3	9.3	27	Melli	Turuk, Sadam	Oct-Dec
Docynia indica (Fruits)	Mail	7.7	9.3	21	Singtam	Jholungay, Bermoik	Oct-Dec
Heracleum wallichi (Inflorescence)	Chimphing	220.0	253.3	15	Gangtok	Lekh	Oct-Nov
Heracleum wallichi (Inflorescence)	Chimphing		220.6	100	Mangan	Sankalan, Mangan	Oct-Nov
Heracleum wallichi (Inflorescence)	Chimphing	245.2	276.2	13	Singatam	Lekh	Sept-Dec

4.5.13 Ethnic Fermented Foods

Ever since ethnic people inhabited in the Himalayan regions ranging from the foothills to alpine, gathering and utilization of available plants, animals and their products for consumption started and generally emerged as ethnic food culture of the present day. Food culture has been evolved as a result of traditional wisdom and empirical experiences of generations over a period of time, based on agro-climatic conditions, ethnic preference, socio-economic development status, religion and cultural practices of the region. Nature has given ability and opportunity to human being to select his food from a wide range. There are more than 24 varieties of ethnic fermented foods and 8 types of traditional alcoholic beverages in the Sikkim Himalaya (Table 9). Some of these are products are commonly prepared and consumed. About 20 % of the total daily food consumed in local diet represents fermented foods (Yonzan and Tamang, 1998). Women play important role in agriculture to food preparation using their indigenous knowledge of food fermentation. Their participation starts from cultivation to harvest, fermentation to culinary, production to marketing. Even, in local markets, rural women sell the food products and earn their livelihood. Traditional food has always been an important component of the Sikkimese culture (Tamang, 2001). *Bhat-dal-tharkari-achar* (rice-legume soup-curry-pickle) is the basic dietary pattern of the Sikkimese meal. Early morning starts with a full mug of tea with sugar or salt with or without milk, with a pinch of hot black pepper. First meal is eaten in the morning with simple *bhat-dal-tharkari-achar* (rice-legume soup-curry-pickle) corresponding to cooked rice, *dal,* vegetable mixed with potato, meat or milk products and pickles. It is followed by light refreshment with mostly traditional snacks and tea in the afternoon. Second meal is the dinner around early evening, which includes the same diet *bhat-dal-tharkari-achar*. People of Sikkim are mainly rice eaters. They also eat boiled potato. In the rural areas, people mostly eat cooked maize as staple food. Dheroh, boiled maize-rice is staple food in villages. The Sikkimese food is less spicy and prepared in butter, but now commercial edible oil is being used. Cooking at household is usually done by women. Elders and male members are served the meals first and females eat afterwards in the kitchen.

Some common ethnic fermented foods, their methods of preparation, mode of consumption, economy, functional microorganisms and nutritional value have been mentioned below.

Table 9. Ethnic fermented foods of Sikkim

Product	Major ingredient(s)	Nature and Use	Major consumer
Kinema	Soybean	Sticky soybeans; curry	Non-Brahmin Nepalis
Maseura	Black lentil	Dry, ball-like; condiment	Newar
Gundruk	Leafy vegetable	Dried, sour; soup/ pickle	All
Sinki	Radish tap root	Dried, sour; soup/ pickle	All
Khalpi	Cucumber	Sour; pickle	Bahun-Chettri
Goyang	Green vegetable	Curry	Sherpa
Mesu	Bamboo shoots	Sour; pickle	All
Selroti	Rice-wheat flour	Round, deep fried; bread	Nepalis
Chhurpi (soft)	Cow/yak milk	Soft, cheese-like, curry/pickle	All

Chhurpi (hard)	Cow/yak milk	Hard-mass; masticator	All
Chhu/Sheden	Cow/yak milk	Soft; strong-flavoured, dish	Bhutias, Sherpa, Lepchas
Philu	Cow/yak milk	Cream; fried curry with butter	Bhutias, Sherpa
Somar	Cow/yak milk	Paste, flavoured; condiment	Sherpa
Dahi/Shyow	Cow/yak milk	Curd; savory	All
Mohi	Cow milk	Butter-milk	All
Gheu	Cow milk	Butter	All
Maa	Yak milk	Butter	Bhutias
Sidra	Fish	Dried fish; curry	Non-Brahmin Nepalis
Sukuti	Fish	Dried, salted	Non-Brahmin Nepalis
Sukako maacha	River fish	Dried/Smoked	Non-Brahmin Nepalis
Gnuchi	River fish	Smoked fish; curry	Lepchas
Shakampo	Beef/Yak/Pork	Smoked meat; curry	Bhutias, Lepchas
Sukula	Buffalo meat	Dried meat; curry	Newar
Sukako masu	Mutton/Pork	Smoked meat; curry	Non-vegetarian Nepalis
Kargyong	Beef/Yak/Pork	Sausages; curry	Bhutias, Lepchas
Kheuri	Beef/Yak/Pork	Sausages; curry	Bhutias, Lepchas
Chilu	Beef/Yak/Sheep	Meat fat; used as edible oil	Bhutias
Satchu	Beef/Yak	Dried, smoked meat; curry	Bhutias

Ethnic food culture harnesses the cultural history of particular community, their worth indigenous knowledge of food production, vast nutritious qualities, microbial diversity associated with fermented foods as genetic resources, source of income-generation related to tourism and enjoyment of dining. The concept of ‘ethnic food tourism” may have relevance in present days due to increase in tourist industry in the

Himalayas. Movement and interaction of people, sense of respect to traditional value and culture will serve to intricately link the enjoyment of dining to locale, making this the standard of food culture of the region. Finding enjoyment in eating the produce of the region while in that region – herein lies the essence of a food culture that gives confidence in life, pride to the people of the region and ultimately, enjoyment and friendship. Further, it imparts meaning to the act of travel and bestows happiness upon the traveler. The promoters have to focus on the specific food culture of a region in a presentable form where tourists can find local cuisine in menu, signifying the food culture of a region.

Food industry is a sunrise industry with emphasis on culture, tradition, cost-effectiveness as well as the interface between health and nutrition. The most important role that is played in the kitchen is the tradition and innovativeness. When we look at the ethnic popularity certain foods are more preferred than the others, example 'fried vegetable' is more preferred in one ethnic group whereas the same vegetable in 'boiled form' is preferred by other ethnic population. When we think to globalization of the traditional foods, we should combat these preferences to give the best traditional foods to consumers. For example, kinema is high plant protein food with low fat and rich in essential amino acids, and is less-expensive, but is confined to particular consumers, mostly because of its flavour and sticky texture. The typical flavour is the characteristic to kinema developed due to proteolytic activities. Most of non-consumers, who are not familiar, do not prefer to eat kinema.

Flavourless kinema cannot be developed, and if developed it will be a new product with distinct characters, different from kinema.

Three potential avenues for product development from traditional foods are: Re-creation of authentic food products; benefit of culinary and/or functional properties; and exploitation of technology. Many commercial products have been developed using the characterization of food fermentations as a basis. Technical parameters contribute to only one part of the equation in the successful commercialization of traditional food products or processes. Where and how these new products fit into a given market will largely define business success if and when such processes are industrialised. Availability and consistent supply of raw materials, basic infrastructure, administrative policy, cost of capital, legislation and trade issues, and import/export restrictions are all necessary for considerations for industrialization of traditional foods.

Some traditional foods such as sishnu, silam, chinday and many edible wild plant foods have medicinal values. Though clinical study of these foods has not been done yet, people strongly believe to have certain therapeutic values. Such foods if studied properly may be projected in the global markets. The R & D Centre for the traditional foods of the Sikkim Himalayas should be set up to open the way for industrialization of some traditional food production with consequent benefit to the regional economy and employment.

The art of tradition and culture of making the foods at household level has to synergise with regulatory standards. It is important to interface traditional foods with health, safety, nutrition and cost. Value addition to traditional foods through interface of food science and technology for better products is the need of the day. We need to have a much larger perspective plan for ethnic foods of Sikkim with a global approach. Traditional food has to be traditional and has to be promoted keeping in view of the fact of ethnic demand and cultural interface, and also respect of skill and expertise of ethnic people for building up a global approach of traditional foods.

4.6 FAUNA

4.6.1 Mammalian Fauna

According to the secondary data, 169 species of mammals are supposedly occurring in Sikkim. The survey for mammals in this study from May 2003 was done to look at the species richness, abundance and composition of various groups of mammals in different vegetation and altitudinal zones. But it was not possible to study the vast groups of mammalian species during the present studies. More than 40 species of bats are found in Sikkim comprising the largest, Flying Fox *Pteropus giganteus* and perhaps the smallest, Little Bamboo Bat (Avasthe and Jha, 1999). The bats and high altitude ungulates accounting for most of the species already recorded from Sikkim were excluded from this study to focus on other groups for which no information was available from

Sikkim. Though the methods required for studying bats differ, during this study there were a few sightings of bats in the Coniferous and the Temperate broadleaf forests.

Murid rodents are generally sampled by trapping in grids. But the slope of the area could not make it possible to lay grids. Therefore, traps were laid in line along the transect lines. Among all groups of mammals, shrews are highly localized species. They are extremely sensitive to slight fluctuation in temperature and other resources. Also due to their small size the movement is also limited locally.

The secondary data on mammals showed high species richness especially in Zone-I and Zone-II. But the richness estimated after our sampling shows that the Zones-III and IV are more speciose than the lower zones. This contrasting result could be due to the fact that the lower altitude forests below 900 m are completely converted into agricultural fields. In altitudes ranging from 900 m to 1,800 m, the major contributor to this cause is also the cardamom plantation. The patches of disturbed forest consists of one species of planted tree i.e. *Alnus nepalensis,* with cardamom. In Zone-III i.e. from 1,800 m to 2,800 m, the ground cover is completely removed to make way for cardamom, but the natural tree species are retained. The removal of shrubs can considerably affect the species composition and richness of small mammals. All the rodents are enlisted as Schedule-V species under the Wildlife Protection Act (WPA) but most of the rodent species occurring in Sikkim are Data Deficient under the IUCN category. Among the captured insectivores *Soriculus caudatus* and *S. nigrescens* are the two species of shrews, which are categorized as Vulnerable.

Similarly, in the case of carnivores, arboreal mammals and ungulates also the secondary information showed high species richness in the lower altitudes. But as already discussed the habitats in the lower altitudes are not suitable for these species and their very existence in Sikkim is threatened due to the proximity to humans in these areas. There has been a constant decrease in population or even local extinction of species in the lower altitudes due to pressure of human disturbances. Now only a few species which can adapt in the small fragmented patches of forests exist in Zone-I and Zone-II. For example, the squirrels have high abundance in the lower zones as they are not affected by the nearby human presence. *Macaca assamensis* are increasingly occupying the areas nearby the roadsides for easy food that is offered to them. The other group whose sighting was very few was the flying squirrels. In spite of probable occurrence of seven species only one species i.e. the Hodgson's flying squirrel was sighted on two occasions. A pair of Himalayan Stoat was sighted at an altitude of 2,100m. Its present known altitude range is 3,200 m to 4,200 m.

One new species of particular interest is the Nepal Langur, occurring in only a few areas in the high altitudinal forest of pine and rhododendron. This is a recently elevated species and its distribution in India is restricted to high altitudes of Sikkim. The forest areas near Lachen, where this langur was sighted is an important area where several species of small cats also occur.

Zones-III and IV were the highest in species richness. The Red Panda which is listed in the Endangered category of IUCN and as Schedule-I species according to WPA occur in this altitude i.e. between 1,800 m to 3,800 m. Evidences of Vulnerable and Schedule I species were recorded in these two zones especially that of Serow, a forest ungulate. It has a restricted range from 1,000 m to 3,000 m altitude. As its habitat below 1,500 m is already destroyed any kind of disturbance in its habitat above 1,500 m will have an adverse effect. The high abundance of scats of leopard cat indicates its presence in zone III, which is also a Schedule I species according to the Wildlife Protection Act, 1972. The number of species with direct sightings and with indirect evidences makes it a total of forty-five species of mammals. However, with some additional sampling it is very likely that the number of species will increase.

4.6.2 Avi-fauna

Total species of birds recorded earlier was 540. A record of 307 species of birds within 22 months of the present study shows that Teesta valley still harbours good habitats. Although the species richness was same in middle two Zones i.e. II & III, species composition was different. In total 48.8% were habitat specialists. Zone-I was dominated by woodpeckers, kingfishers, bulbuls, and drongos; Zone-II by doves, yuhinas, sunbirds and minivets, whereas Zone-III was represented mostly by undergrowth species such as babblers, laughing thrushes and fulvettas. The similarity in species richness may be due to similarity in vegetation structure and forest cover. The relatively low species richness with abrupt changes in species composition including more number of habitat specialists in Zones-IV and V shows that the transition zone lies between Zones-III and IV at about 3,000 m. The observed result differs from the existing one for Zone-V showing less number of species than expected probably because the zone was not equally covered in all seasons. The abundance in Zone-II was relatively lower as compared to other zones because this zone is mostly disturbed by cardamom plantation. Further, the undergrowths are removed and single species (*Alnus nepalensis)* tree dominated the forest reducing the quantity of resource available to the birds.

There was marked seasonal variation in richness as well as abundance of birds because of altitudinal movement. During rainy season most of the plant species were either flowering or fruiting supporting large populations of frugivorous species. Also, June being peak breeding season, presence of both migratory and resident species might have increased the number of total species during this season. Some of the lower altitude species showed upward migration for breeding.

4.6.3 Herpetofauna

Information available on herpetofauna (amphibians and reptiles) is far less or not available compared to the other taxa studied. The present checklist consists of 81 species, with several unconfirmed records. The species richness is highest in lower two Zones (I & II). However, the abundance was high in Zone-III. As Zones-I and II have a warmer climate and tropical moist forest, conducive to reptiles and most amphibians, many of the species were seen exclusively in these zones making these the most diverse habitats. The highest abundance observed in Zone-III was due to the clumped distribution of some species, *Trachischium guntheri, Leiolopisma sikkimensis* and *Bufo himalayana.* Reptiles being cold-blooded animals they are sensitive to temperature and ecophysiological constraints, which affect the range of the species. Climatic severity in higher altitude may be the probable reason for the low species richness (Navarro, 1992).

The maximum sharing between Zones-I and II may be due to overlapping habitat structure both having tropical climate which is conducive for herpetofauna. No reptile was recorded in Zones-IV and V which may be due to colder climatic condition. The species accumulation curve for all zones together has almost reached an asymptote but it is not the case when individual zones are considered separately. This might be due to rapid encountering of common species in the early sampling days. Although additional species were seen but the rate of sightings was very low because the species were rare. The other possible reason may be due to large sampling area. The seasonal fluctuation observed is the usual feature for herpetofauna. Most of the reptiles hibernate during winter and late autumn. Hence, low richness and abundance was observed in these seasons as compared to summer and rainy. The present study showed clear inverse pattern of number of species with altitude, as the altitude increased, number of species decreased. However, different zones have unique assemblage of species. The change in pattern from the existing data could be due to poor sampling for amphibians primarily during night stream survey as most of the streams are torrent.

4.6.4 Butterflies

Total species of butterflies recorded earlier was 689 species and the species recorded during this study was 266. The richness of species was high in the lower two zones than the higher zones showing that these habitats have got a great potential for conservation. The occurrence of very rare and specialist butterflies in high altitude areas, especially the alpine habitats needs research attention and management.

Decrease in species richness of butterflies with increase in altitude was observed. This might be due to the narrow tolerance of butterflies to weather conditions especially cold and habitat suitability. Butterfly species appear to use warm and humid type of habitats. Hence, there were more species in Zone-I than higher zones. The reason is also supported by the number of exclusive species present in Zone-I. Most of the species present in Zone-I was not seen in any other zones. A few species were specialists of arid alpine and sub-alpine regions. The result obtained is consistent with the earlier records.

Dalep (Lower altitude) appears to be rich in butterflies both in terms of number of species and abundance. Record of 98 species within three months in lower altitude showed that the area harbors good habitat for butterflies. Haribal (1992) has reported 350 species of butterflies in low altitude area (below 900 m) from Sikkim. As compared with this number the total record from Dalep represents 20% of species, which reflects high conservation value of the low altitude agro forests of Sikkim. The reason for high species richness might be (1) patches of forest with good tree cover sandwiched between agricultural land represented mostly by *Ceiba* sp., *Ostodes* sp., *Terminalia* sp., *Duabanga* sp., *Ailanthes grandis* and *Schima wallichi* forming the major habitat for butterflies, (2) the fallow lands adjoining agricultural field covered with shrubs also act as habitat for some specific butterflies and (3) the presence of two rivers (Pabong and Teesta) provides additional habitat for those species inhabiting moist habitats such as stream banks. Variety of crops grown in each season and the types of agricultural land it possesses also explains higher diversity of butterflies in this region.

The time allotted for the present study was more limited due to delay in getting permits for sampling. The permits were again cancelled during the study by the Sikkim Forest Department resulting in loss of field time and sampling seasons. More sampling is needed especially in the landscapes between temperate broad leaf and the coniferous forests. Due to the secretive nature, limited activity period (hibernation or aestivation) and size (small) of herpetofauna considerable difficulties are encountered in sampling these taxa. Apart from this, terrain (especially steepness) and diurnal and nocturnal activity of them prevented from using many standard sampling methods.

Sampling in the higher altitudes above 3,800 m could not be done regularly due to various reasons like the proximity of international borders and presence of security installations making it difficult to visit many areas. Massive landslides during the monsoon become problematic to sample the areas of North Sikkim.

In all, 798 vertebrates and 689 species of butterflies have been reported from Sikkim including 169 mammals, 541 birds, 61 reptiles and 20 amphibians. During our present sampling, 375 species of vertebrates and 223 species of butterflies were observed. These records form 40.4% of the total species present in the state. The sampling area of the presnt study was restricted within two kilometers (on either side) from the vicinity of the Teesta river covering about 600 sq km, which is about 8.5% of the total area of Sikkim (7,096 sq km). The record of over 40% species within this small area within two years of field sampling indicates that Teesta valley is rich in terms of biodiversity. It is expected that further intensive and long-term sampling would result in more species. Hence, Teesta valley is vital for the conservation of biodiversity in Sikkim.

4.6.5 Important Altitude/ Habitat zone

Higher diversity of mammals, birds and reptiles were found in Zone-III (1,800-2,800 m) where Temperate broad leaved forest is common. Specific localities include areas around Chungthang, Lachen and Lachung and intervening forests connecting these localities. The higher two zones (IV &V), although possess relatively low species, form the habitat of many high altitude birds which we never see in any of the other zones (exclusive spcies to the altitude or forest type). These zones are the breeding grounds for many migratory waterfowl including the Black-necked crane.

4.6.6 Endemic/ Exclusive species specific to Himalayas or particular altitude zone

The Nepal Langur is a recently elevated new species whose distribution is restricted to high altitudes of Sikkim (in and around Lachen), Nepal and Bhutan. It is only found in overlapping forests of Temperate broadleaf and Coniferous at an altitude of about 2,800m. The same region is also the habitat for the Red Panda, which is the state animal of Sikkim and is restricted to higher altitudes only. Serow found in Zone-III is restricted to Himalayas from Sikkim to Kashmir. The Marbled Cat is an extremely rare and nocturnal species and has been reported locally around Chungthang in Zone-III.

Five endemic bird species could be recorded during this study, namely Rusty-bellied Shortwing, Broad-billed Warbler, Hoary-throated Barwing, Yellow-vented warbler and White-naped Yuhina. Rusty- bellied Shortwing, a threatened endemic, seems to be rare as it was sighted only twice in Zone-IV, but the other four species are locally abundant and recorded frequently.

Several species of reptiles (e.g. pit vipers, skinks, and Himalayan agamids) are restricted to the middle altitude of the Sikkim and Eastern

Himalaya. The snow toad (*Scutiger sikkimensis*) is an endemic amphibian of the region, along with several species belonging to the genus *Paa*. Both higher and lower altitudes had higher number of restricted species of butterflies.

4.6.7 Endangered Species

The most endangered species among mammals in these areas is the Red Panda already enlisted as Endangered under IUCN criteria and Schdule-I species according to the Wildlife Protection Act, 1972. The Himalayan marmot is also an endangered species found in subalpine zones above the tree line in the higher altitudes. Besides Sikkim it is only found in Ladakh. Marbled Cat has been reported to occur in Chungthang area only in the Teesta river basin. It is a Schedule-I species under the WPA (1972). Among birds, the Rusty- bellied Shortwing and Chestnut-breasted Patridge were found in Zones-IV and V. Many species of birds protected by the Indian Wildlife Protection Act (1972) occur in Zones-III and IV. Large number of protected species of reptiles and butterflies are recorded from Zones-I and II.

4.6.8 Conservation Measures

Looking at the number of species of studied taxa and the endemic exclusive and endanged species of studied taxa, Zone-III is very sensitive, and if the development project (Stage-III) is executed in this zone (1,800-2,800, Temperate broadleavd forest, near Chungthang), an irreversible ecological damage is expected with respect to biological environs.

It is important to implement conservation measures in all the areas as most of the forests in these zones are not within any protected area except some areas in Chungthang, which falls under the buffer zone of Khangchendzonga Biosphere Reserve. Hence, effort may be taken to create additional protected areas.

Altitudes < 900 m is an important zone, especially for small mammals, herpetofauna and butterflies. However, this zone currently has no protected area coverage. There is, perhaps, scope for ensuring protection maintaining these diverse land uses through community participation, as this zone is almost entirely inhabited by people. The current land use in this zone predominantly consists of small patches of original forest (although degraded), a variety of seasonal crops grown with very little use of agro-chemicals, and the retention of several species of native trees in agricultural fields as source of timber and fodder. This pattern of land use is very conducive to the retention of several species of mammals, birds, herpetofauna and butterflies. The need to retain remnant patches of forest, native tree cover in agricultural fields and crop diversity is therefore obvious and necessary measures should be taken in consultation with various stakeholders.

There are number of cattle sheds between Lachung and Yumesamdong. Further, the local people of Lachung, Lachen and

Chungthang collect firewood for cooking from the pine and Rhododendron forest of Singba and Yumthang which subsequently reduces the forest cover. The firewood of Rhododendron is much preffered than other species. Most of the local people collect leaves of *Rhododendron nivale* for incence. Hence, alternate livelihood should be developed for the people of this remote land.

One of the major threats especially to both large and small mammals, larger birds and amphibians (*Paa* spp.) is hunting which needs to be checked. In case of project implementation, influx of a large number of non-native labourers and project personnel would give additional pressure on forests and wildlife. Appropriate facilities such as fuel may be provided by the authorities, which would reduce pressure on natural resources.

Entirely new environments would be created by human activity during and after the construction of the proposed hydel projects. If these sites were neglected, they would become dominated by exotic and weedy species resulting in biological communities that are unproductive, valueless from conservation perspective and unappealing. These sites need to be properly managed and native species reintroduced wherever required so that the original communities can be successfully restored with respect to species composition and vegetation structure.

Awareness programmes for locals, tourists and members of government mechinaries on wildlife and general up keeping the environment is required. This is one of the prime needs to conserve the rich faunal diversity of Sikkim.

Further monitoring with iniation of more extensive studies on individual species is required to understand their home ranges, behaviour, requirements and so on.

In conclusion, the present study shows that Zone-III (Stage-III) is very important with respect to conservation of the biodiversity of the region. Similarly, Zones-IV and V (Stages-I & II) have higher number breeding birds and exclusive species of the taxa studied. Hence, any development project would endanger them. Also, Zones above III are geologically vulnerable, and anthropogenic pressures would lead to natural disaters.

4.6.9 Aquatic Environment

4.6.9.1 *Fish fauna*

Fish composition changes along the altitudinal gradient of river Teesta and its tributaries due to changes in physical and chemical characteristics of water. The water temperature plays a vital role in the distribution of fish in Himalayan rivers. Sehgal (1983) classified Himalayan rivers into three zones with respect to fish distribution. The streams in the upper most zone above 1,400 m dominated by exotic trout are known as 'trout' streams. These streams are characterized by low temperature, low turbidity, low alkalinity and hardness. The substratum comprises of boulders and rocks while water carries coarse silt. The streams of middle zone from 850 to 1,400 m, inhabited mainly by snow trout are called as ‘snow trout’ streams. These streams record relatively higher temperatures, turbidity, alkalinity and hardness. The water carries fine soil particles while riverbed is provided with boulders and stones. The streams of lower zone below 850 m are comprised of a large meandering zone and have much higher temperature and lowest water current velocity. The substratum is comprised of pitted rocks and stones. This zone is inhabited by carp species knows as ‘mahseer’ streams. The dominant fish species in accordance with these zones in Teesta river system are given in Table 10.

Tamang (2001) mentioned about 48 species of fish from Sikkim Himalaya. However, species like *Neolissochilus spinulosus* (Talwar and Jhingran, 1991) and *Pseudeutropius antherinoides, Ompok bimaculatus* and *Puntius clavatus* (Menon, 1999) were not recorded in that report. A documentation of published information on the number of fish species and field survey during these studies indicate the presence of more than 50 species of fish in the waters of Teesta river. The present studies on fish and fisheries were carried out in all major streams *viz*. Teesta river, Rangpo Chhu, Rangit river, Rangbang Khola, Rishi Khola, Rani Khola, Talung Chhu, Dik Chhu, Lachen Chhu, Lachung Chhu, etc. The fishes were collected with the help of local fishermen, which were found to land fish by using cast nets, rod and lines and hooks. About 37 fish species were recorded from the river Teesta and its tributaries, which comprise Salmonidae, Cyprinidae, Cobitidae, Sisoridae, Chanidae, Schilbedae and Anguillidae.

Table 10. Important fish species of three different zones of river Teesta in Sikkim

	Trout streams	Snow trout streams	Mahseer streams
Elevation (m)	Above 1400	850 – 1400	Below 850
Streams	Lachung Chhu and	Teesta from Mangan Lachen Chhu	Teesta below Mangan to Chungthang
Fish species	*Salmo trutta fario*	*Schizothorax richardsonii*	*Tor putitora*
	Euchiloglanis hodgarti	*Schizothoraicthys progastus*	*Acrossocheilus hexagonolepis*
	Schizothorax richardsonii	*Garra lamta*	*Labeo dero*
	Garra spp.	*Garra gotyla gotyla*	*Barilius bendelisis*
	Nemacheilus spp.	*Euchiloglanis hodgarti*	*B. vagra*
		Glyptothorax spp.	*Schizothorax richardsonii*
		Semiplotus semiplotus	*S. progastus*
			Anguilla bengalensis

i) Stresses on fish populations in Sikkim

Several hydrobiological studies have suggested that natural and man-made factors greatly influence the biological productivity of waters (e.g. Pant and Bisht, 1981; Dobriyal and Singh, 1988). The monsoonal surface run off, landslides, road construction activities, etc. increase the suspended load in river and lake water that results into deterioration of water quality and quality of fish food. The siltation and high turbidity in water adversely affects the fish population and monsoonal floods cause the high mortality of fish in the Himalayan rivers. The water current velocity, water discharge and water level are important factors for the survival of spawn and fertilization of fish (Joshi, 1991). The natural and man–made alterations in these factors may cause downstream drift of hill stream fish. Such types of natural stresses are common in Himalaya including Sikkim.

The man made alterations like stream regulations change the physiological rhythm of fish (Jhingran, 1989). The barrages and dams generally hamper the fish migration and destroy the breeding grounds of fish. Mahseer is one of the main sufferers in Himalayan rivers. In addition, overexploitation and faulty fishing techniques like poisoning, damming and use of dynamite, etc. are also responsible for the elimination of fish. The maximum fishing activities were observed in Rani Khola. On the other hand except for water diversion in small streams there were no illegal fishing methods in use.

4.6.9.2 *Aquatic Biology*

In Eastern Himalaya, Teesta is one of the important river systems or basins, which originates in Greater Himalaya, collects water from numerous streams, rivulets, brooks and finally merges with Brahmaputra river in Bangladesh. The state of Sikkim with a geographical area of 7,096 sq km falls solely in Teesta basin except for an area of 75.62 sq km of Jaldhaka river watershed which does not drain into Teesta river. The main tributaries of Teesta river are Rangit river, Rangpo Chhu, Rani Khola, Lachung Chhu, Zemu Chhu and Talung Chhu. Most of these streams originate from Greater Himalaya in Sikkim and after traversing through alpine, temperate and tropical regions to drain into Teesta river which after leaving Sikkim flows through West Bengal. These rivers and streams while traversing through various valleys and ravines change the ecology of the surrounding area as well as physical and chemical characteristics of the stream (Vijaykumar, *et al.* 1999).

The studies were mainly restricted to Teesta river and its tributaries *viz*., Rangit river, Rangpo Chhu and Rani Khola while part observations also have been made in Ramam Khola, Rishi Khola and Rangpo Khola. In case of river Teesta, investigations were carried out in almost entire stretch of the river right from its headwater zone up to the confluence of Rangit with Teesta at Melli Bazar. In tributaries, studies were conducted in lower stretches. The water samples in Teesta, Rangit, Rangpo Chhu, Rani Khola were collected during all three seasons (pre-monsoon, monsoon and post-monsoon) while rest of the streams were sampled only during post-monsoon. Some of the important lakes like Gurudongmar, Chhangu and Menmoi Chho were also studied. Water samples were collected only once in these lakes. The selection of sampling stations largely depended upon proposed river valley projects in Sikkim and variation in the altitudinal gradient. Simultaneously lower stretches of Rangit, Rangpo and Rani Khola and their tributaries (Rishi Khola, Ramam Khola, etc.) were selected for the study to assess their impacts on the main river Teesta.

The following physical and chemical characteristics of water were studied. These are: i) Water current velocity, ii) Water temperature, iii) pH, iv) Turbidity, v) Total dissolved solids (TDS) and conductivity, vi)

Dissolved oxygen (DO), vii) Alkalinity, viii) Total hardness, and ix) Nutrients.

In the present study biological characteristics involved the plankton, phytobenthos, macro-invertebrates and fish of lotic and lentic water bodies in Sikkim. For the sake of sampling, Teesta river was divided into three stretches – i) lower stretch from Melli Bazar (Tr1) to Tong (Tr8), ii) upper stretch from Rangma (Tr9) to Yungdi (Tr12) and iii) Lachung Chhu from Chungthang (Tr13) to Yumesamdong (Tr16) (Fig. 14). In addition sampling was also done at two sites each in Rangpo Chhu (Rc1 & Rc2), Rani Khola (Rk1, Rk2) and Rangit river (Rg1, Rg2) and one site each in Rishi Khola (Rsk1), Ramam Khola (Rm1) and Rangpo Khola (Rgk1) (see Fig.14).

In the upper stretch, generally slopes are steep and current velocities are higher; bed consists of hard ground (rocks, boulders and coarse gravel). In lower stretches water flow is slow and river bed has relatively high mud and sand. The anthropogenic activities are also high in lower stretches. For example sand mining and fishing activities were concentrated in the lower stretches of Teesta, Rangpo Chhu, Rangit and Rani Khola.

The annual profiles of physical and chemical characteristics (especially temperature, TDS, pH, DO) showed that waters were usually unpolluted in most of the streams of Sikkim. However, low pH and DO in Rani Khola and Rangpo Chhu (lower stretches) indicated that the water

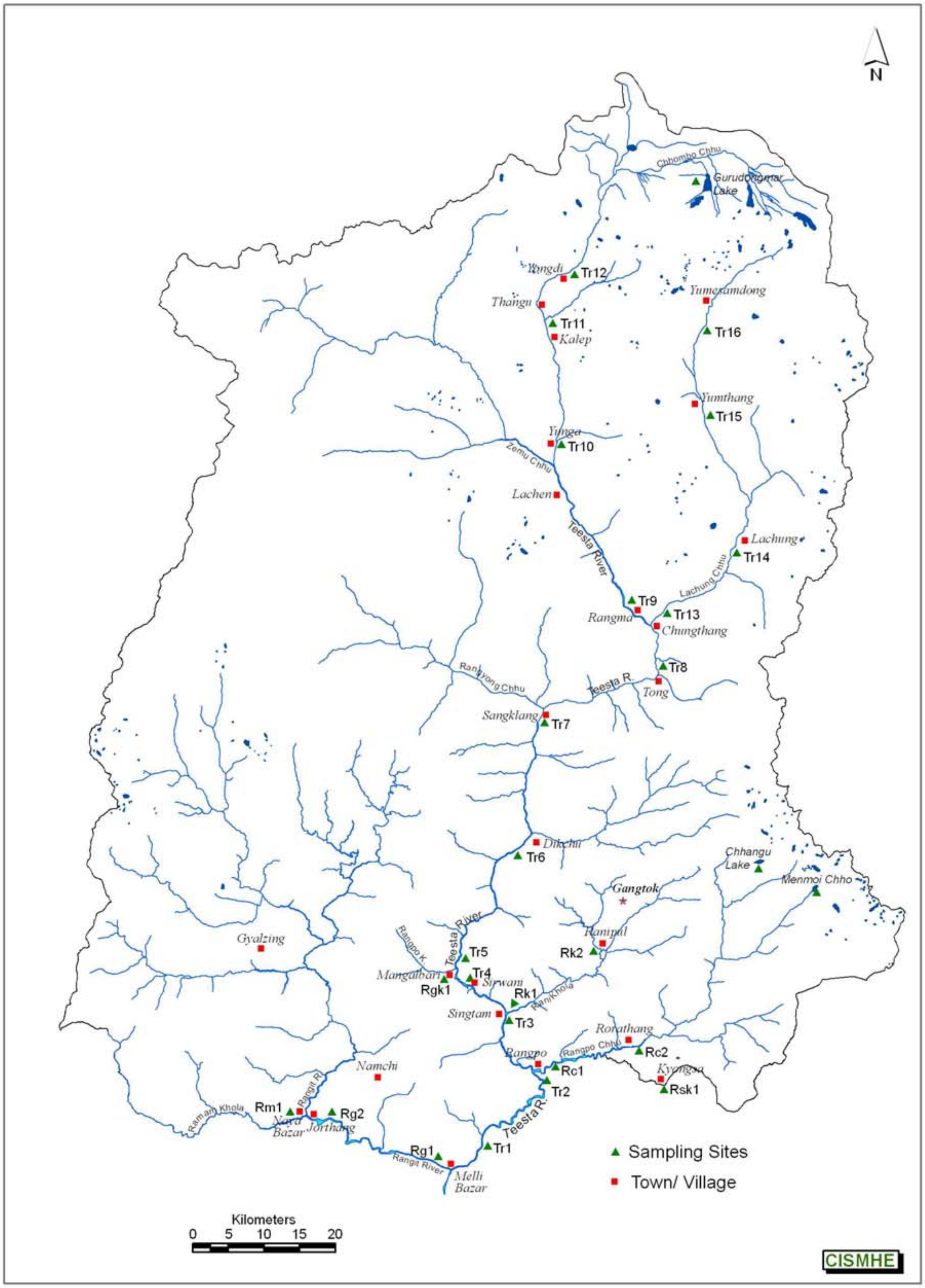


Fig.14 Map showing sampling sites in different rivers of Sikkim

was comparatively polluted in these streams. Since Gangtok, the capital city of Sikkim acts as point source of organic substances, which drain into Rani Khola while Rangpo Chhu at Rangpo receives sewage directly from its nearby townships. Though low concentrations of DO were also recorded from upper stretches of river Teesta but they are not attributed to organic pollution. The eco-climatic conditions like low atmospheric oxygen, higher elevations and low diffusion of oxygen are responsible for the lower concentration of DO.

The nutrient concentrations in the water were recorded to be significantly low in upper stretch whereas there were noticeable temporal and spatial variations in nutrient concentrations in lower stretch. In addition to the natural source of nutrients, wastewater and agricultural run off contribute to the nutrient levels in the river waters. Therefore, the low concentrations of nutrients (nitrate and phosphate) in upper stretch of river Teesta are attributed to low human population, agricultural practices and absence of waste water drainage in the vicinity of these streams. On the other hand highly disturbed stretches like Rani Khola recorded higher concentration of nutrients. The physical and chemical characteristics of these streams affected the biological status of these streams. In lower stretch of Teesta and Rangit rivers have rich biotic diversity while Rani Khola, most stressed stream, is low in biotic diversity.

The majority of phytoplankton and phytobenthic species in all these streams was pollution intolerant and indicated a non polluted state of these rivers in general. However, in Rani Khola and Rangpo Chhu, common occurrence of a few pollution tolerant diatom species like *Gomphonema sphaerophorum, G. parvulum, Nitzschia palea*, etc., indicate that these streams are relatively more polluted. The anthropogenic activities including fishing activities are more prevalent in Rani Khola, therefore, resulting in poor biological health of Rani Khola. Most of the taxa among macro-invertebrates (Heptagenidae, Baetidae, Hydropshychidae, etc.) were pollution intolerant in all streams of Teesta river.

The present investigation indicates that water of Teesta river basin is generally healthy in its water quality and biodiversity. However, some lower stretches in a few streams like Rani Khola and Rangpo Chhu (at Rangpo) were observed to have relatively deteriorated water quality and poor biodiversity due to heavy anthropogenic activities in their vicinities. Inspite of good water quality in uppermost stretches of river Teesta, a poor biodiversity was recorded from same stretch, which can be attributed to adverse eco-climatic conditions.

The present investigations reveal that overall physico-chemical as well as biological health of Teesta river and its tributary stream is in good condition. However, the same is not true for two of its tributaries *viz*. Rani Khola and Rangpo Chhu (Fig.15). Poor water quality and low diversity of biological components coupled with presence of pollution tolerant phytoplankton in these streams points towards the relatively poor condition of these two streams. This is mainly due to the number of townships like Gangtok, Pakyong, etc. that are responsible for their

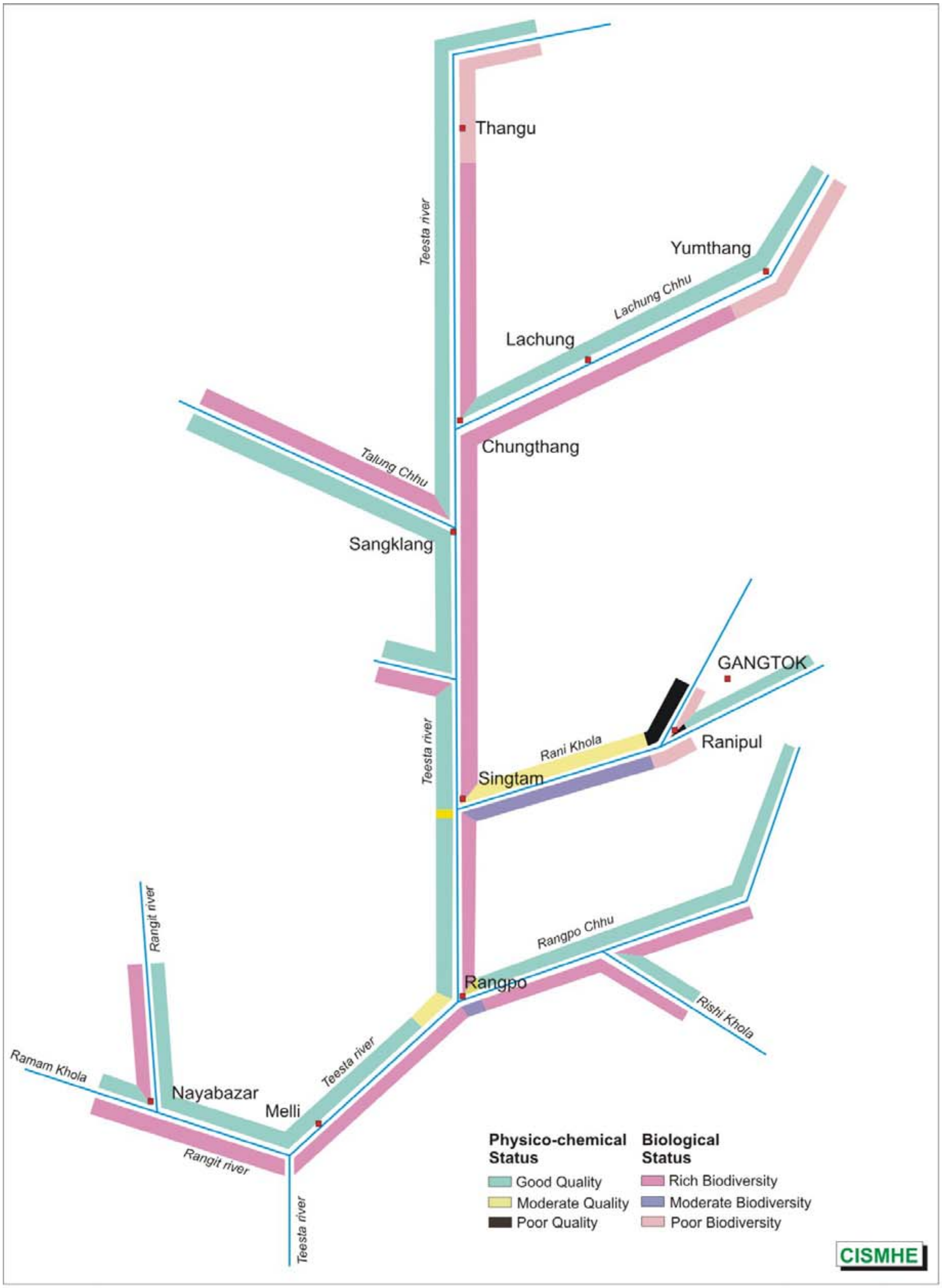


Fig. 15 A schematic diagram showing the physico-chemical and biological status along the Teesta river and its major tributaries in Sikkim

relatively dismal health. In the case of upper stretches of Teesta river, which may be poor in biological diversity comparatively, but the water quality is extremely good.

4.6.10 Protected Areas

Teesta basin in Sikkim is characterized by varied topography, wide altitudinal range, extreme climatic condition and diverse geo-biological setup. It is, therefore, home to diverse ecological systems inhabited by rich biologically diverse flora and fauna. This biological resource, in recent times has been under tremendous pressure due to wide array of developmental activities that are underway. In order to preserve and conserve the rich diversity of flora and fauna, more than 46% of its geographic area has been brought under protected framework in the form of one National Park and six Wildlife Sanctuaries (Table 11 and Fig. 16) under the Wildlife (Protection) Act, 1972. In addition to the existing protected areas, more areas have been proposed to be brought under Wildlife Protection framework (see Table 11).

Table 11. Protected areas existing as well as proposed under biodiversity hotspot program

Name	Area (sq km)
EXISTING	
Khangchendzonga Biosphere Reserve	2919.92
Khangchendzonga National Park	1784
Shingba Rhododendron Sanctuary	43

Barsey Rhododendron Sanctuary	104
Kyongnosla Alpine Sanctuary	31
Fambong Lho Wildlife Sanctuary	51.76
Maenam Wildlife Sanctuary	35.34
Pangolakha Wildlife Sanctuary	124
PROPOSED	
Kitam Sanctuary	13
Pangolakha National Park	108
Tholung Wildlife Sanctuary	230
Dzongri Wildlife Santuary	468
Nimphu Wildlife Sanctuary	167
Khangchendzonga National Park	946
(International Biosphere Reserve Extension)	

4.6.11 Landuse/ Landcover

Forests constitute the major proportion of Teesta basin in Sikkim and play an important role in maintaining the ecological balance and regulation of hydrological regime of Teesta river system. In addition, these forests form the first resource of Sikkim and provide wide range of forest related services for the welfare of human populace in Sikkim. As per the Status of Forest Report prepared by Forest Survey of India (2001), the forests of the country as a whole have been decreasing due to increasing demand for fuel wood, fodder, timber coupled with conversion of forest land to non-forest landuse for undertaking various developmental activities. As indicated in this report, however, no

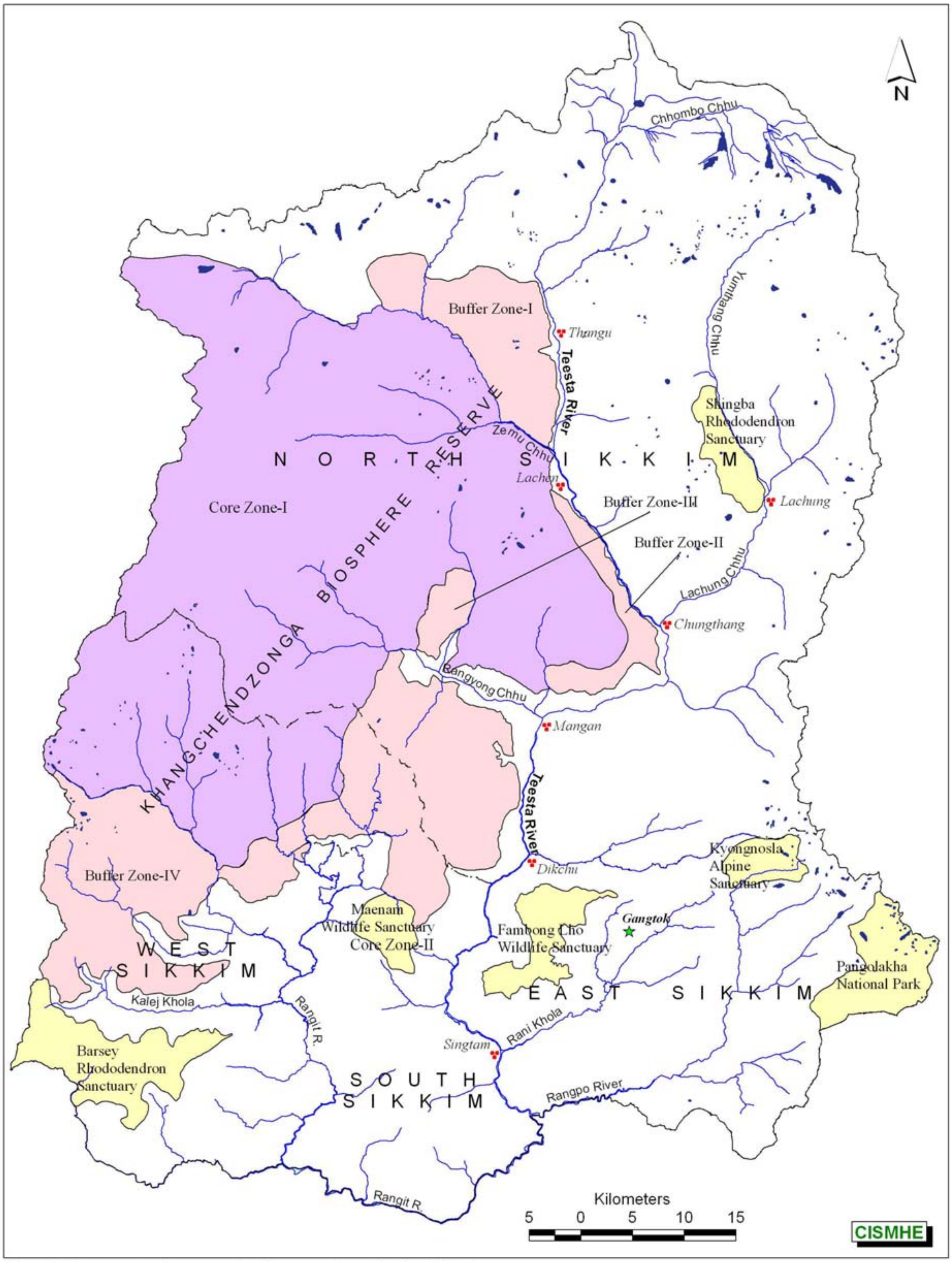


Fig.16 Protected areas in Teesta basin in Sikkim

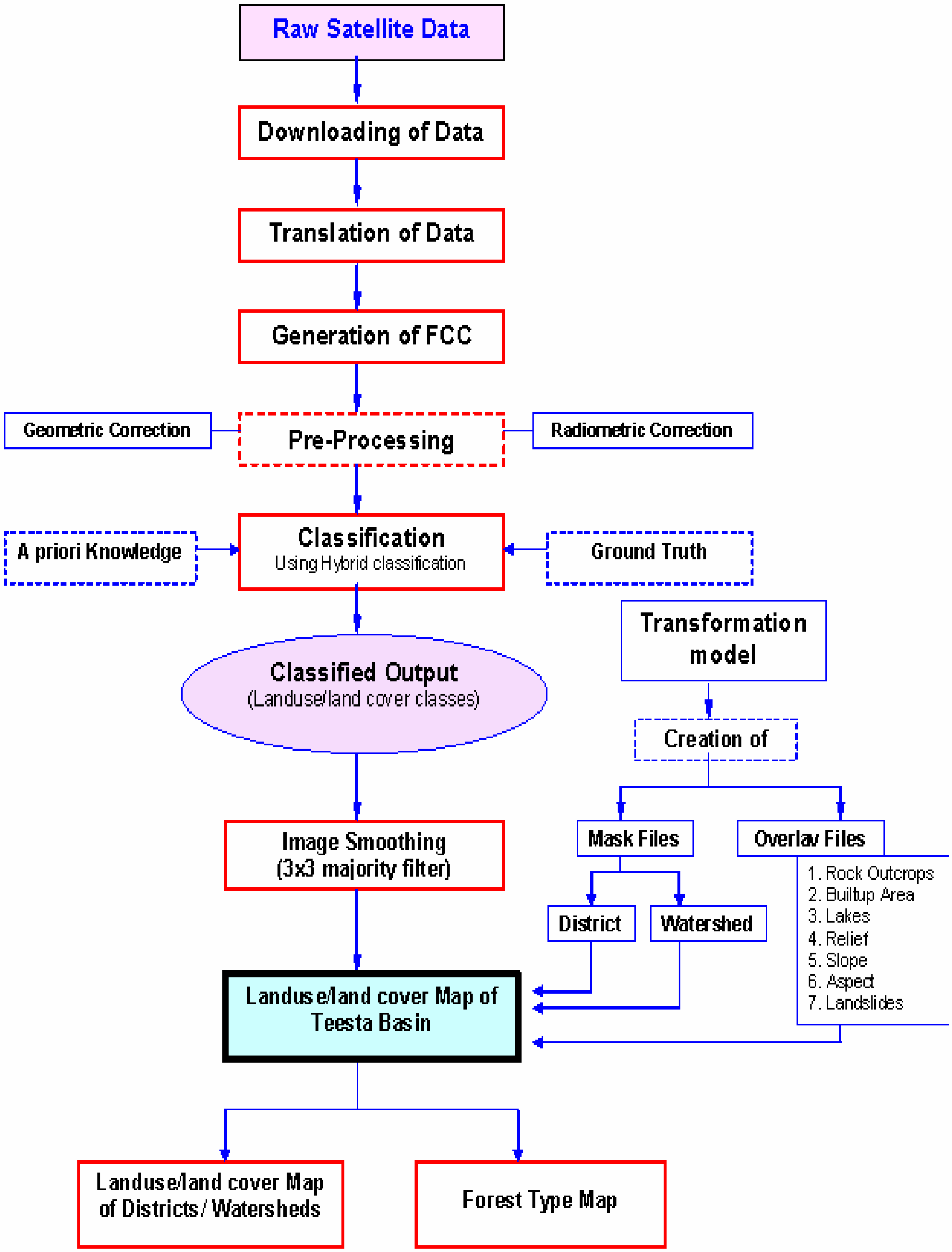


Fig.17 Flow diagram for landuse/ landcover classification

authentic information is available on the real time database on the status of these forests.

The only authentic information available on forest cover of Sikkim is of 1988, which was done by Regional Remote Sensing Service Centre, Kharagpur along with Forest Department, Government of Sikkim. However, the data used at that time was of IRS-1A LISS-II, which was of very low resolution. Therefore, in this study an exercise has been taken up for the analysis of extent of forest cover depletion. For the preparation of latest forest type maps of Teesta basin in Sikkim, LANDSAT 7 ETM+ data was used.

Landuse and landcover mapping of Teesta basin was carried out by standard methods of analysis of remotely sensed data, followed by ground truth collection, and digital image processing of satellite data. For this purpose digital data on CDROMs was procured from National Remote Sensing Agency, Hyderabad. Digital image processing of the satellite data and the analysis of interpreted maps were carried out of the Computer Centre at CISMHE using ERDAS Imagine 8.7 of Erdas Inc.

The details of primary data in the form of digital data on CDROMs procured from NRSA for interpretation and analysis are as follows:

Satellite	Sensor	Path/Row	Date	Data type & Bands
IRS-1D	LISS-III	107/051	19.01.2000	Digital (2,3,4,5)
IRS-1D	PAN	107/052	30.11.1999	Digital (A0)

IRS-1D	PAN	107/052	13.01.2002	Digital (B0)
IRS-1D	PAN	107/052	30.11.1999	Digital (C0)
IRS-1D	PAN	107/051	13.01.2002	Digital (D0)
LANDSAT 7 (1,2,3,4,5,7)		ETM+	139/41	26.12.2000 Digital
LANDSAT 7	PAN	139/41	26.12.2000	Digital

For the secondary data, Survey of India topographic sheets 78 A/1 - A/16, 77 D/8, 77 D/12 and 77 D/16 on 1:50,000 scale were referred to for the preparation of base and drainage maps.

The general procedure for classification involved the following important steps *viz*., enhancement of scene, rectification and classification technique, etc. is given in Fig. 17.

The classification scheme adopted for the preparation of landuse/landcover maps and related thematic maps on 1:50,000 scale is as follows. Two forest density classes were interpreted for the forest cover mapping. The forests with >40% canopy cover were delineated as dense forests and between 10% and 40% crown density as open forest. In non-forest agriculture with settlements, degraded land/barren and rockyland, snow/ice cover, glaciers, etc. were delineated.

Landuse/landcover	**Remarks**
FOREST	
Dense forest (Crown density > 40%)	Tropical Moist Deciduous Forest Sub-tropical Forest

	Temperate Forest
	Sub-alpine Forest
Open forest	Tropical Moist Deciduous Forest
(Crown density < 40%)	Sub-tropical Forest
	Temperate Forest
	Sub-alpine Forest
	Mixed Conifer Forest
	Fir Forest
	Pine Forest
NON-FOREST	
Sub-tropical scrub	Scrub
Temperate Alpine Scrub	Temperate scrub
	Alpine scrub
	Alpine meadows
Agriculture/Settlements	
Barren Rockyland/ Alpine Barren	
Moraines	
Snow/Ice cover	
Glaciers	
Lakes	

Landuse/ landcover and forest type map has been generated for the entire Teesta basin, which is based on limited ground truth collection due to delays in granting permission to visit the Reserved Forests and Protected Areas by the Forest Department.

Total forest cover of Teesta basin in Sikkim as per the landuse/ landcover map prepared from IRS-1D LISS-III of 2002 data is 2790.84 sq km i.e. 39.33% of total geographic area of Sikkim (Table 12 and Figs 18 & 19). Only 12.96% of area is under dense forest cover i.e. forest cover with crown density more than 40%, whereas area under open forest cover (crown density between 10 and 40%) is 26.36%. The forest cover prepared during the present study compares very well with the one prepared by Regional Remote Sensing Service Centre, Kharagpur from IRS-1A LISS II data of 1988 (Sudhakar *et al*. 1998). There has been a negligible decrease in forest cover since 1988, with dense forest cover decreasing by 5-7% while open forest cover has not shown significant change. However, within district, the forest cover has changed from dense category to open category. While East Sikkim and South Sikkim districts show increase in dense forest cover corresponding with decrease in open forest cover category. In West Sikkim district dense forest cover has decreased from 218.84 sq km to 204.02 sq km (6.77% decrease). It is in North Sikkim, dense forest cover has decreased appreciably. It has decreased by 33.24% and total area under forest also has decreased by 9.51%. Due to the non-availability of digital data of 1988 processed by RRSSC, Kharagpur and State Forest Department of Sikkim, it was not possible to analyse the spatio-temporal changes in forest cover change since 1988.

Table 12. District-wise forest cover (sq km) in Teesta basin

District	Geographic Area (sq km)	Dense Forest		Open/Deg. Forest		Total Forest	
		1988	2002	1988	2002	1988	2002
East Sikkim	954	170.40	216.84	358.79	338.74	529.19	555.58
West Sikkim	1166	218.84	204.02	437.69	439.33	656.53	643.35

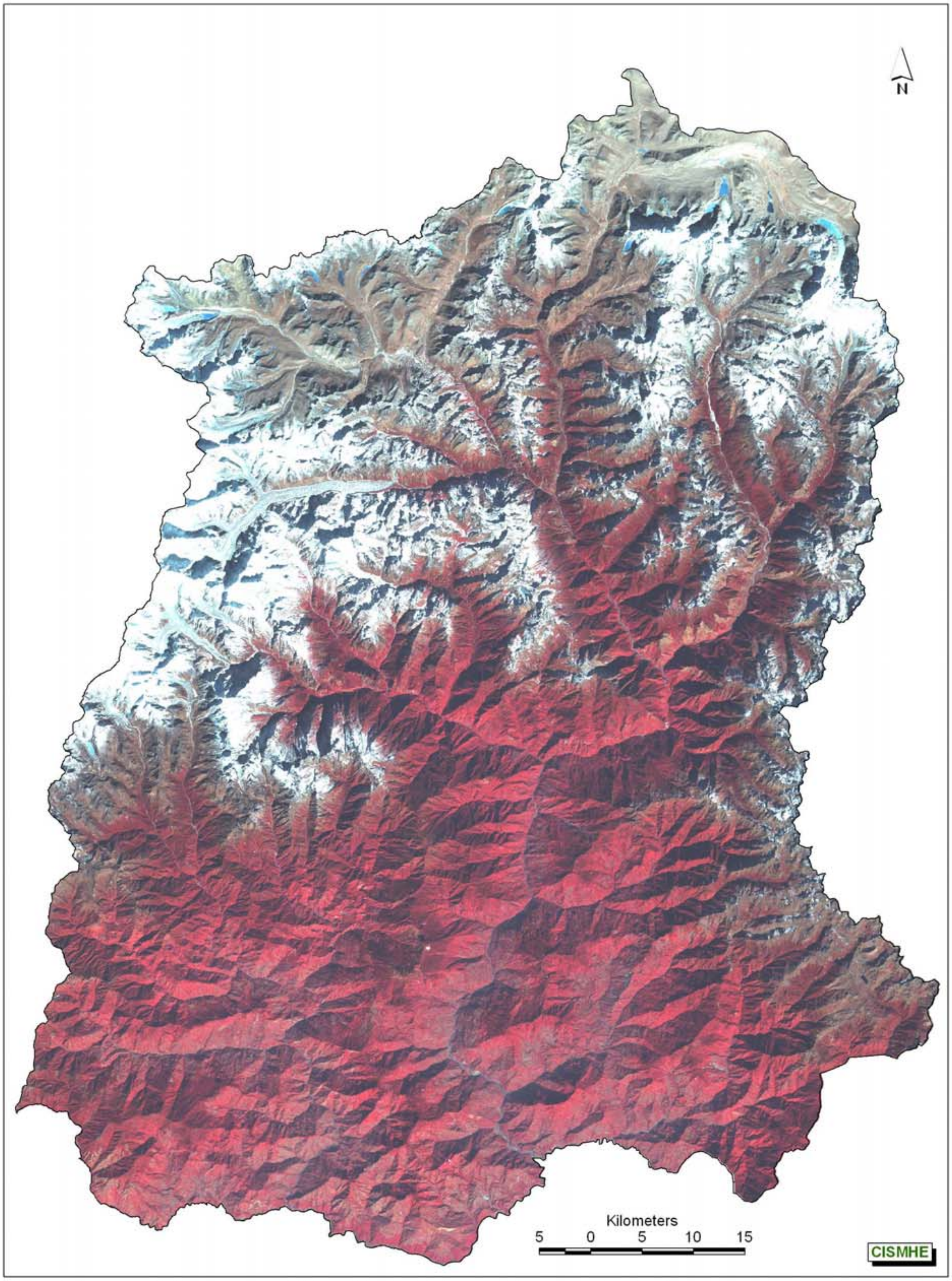


Fig. 18 False Color Composite (FCC) of Teesta river basin in Sikkim

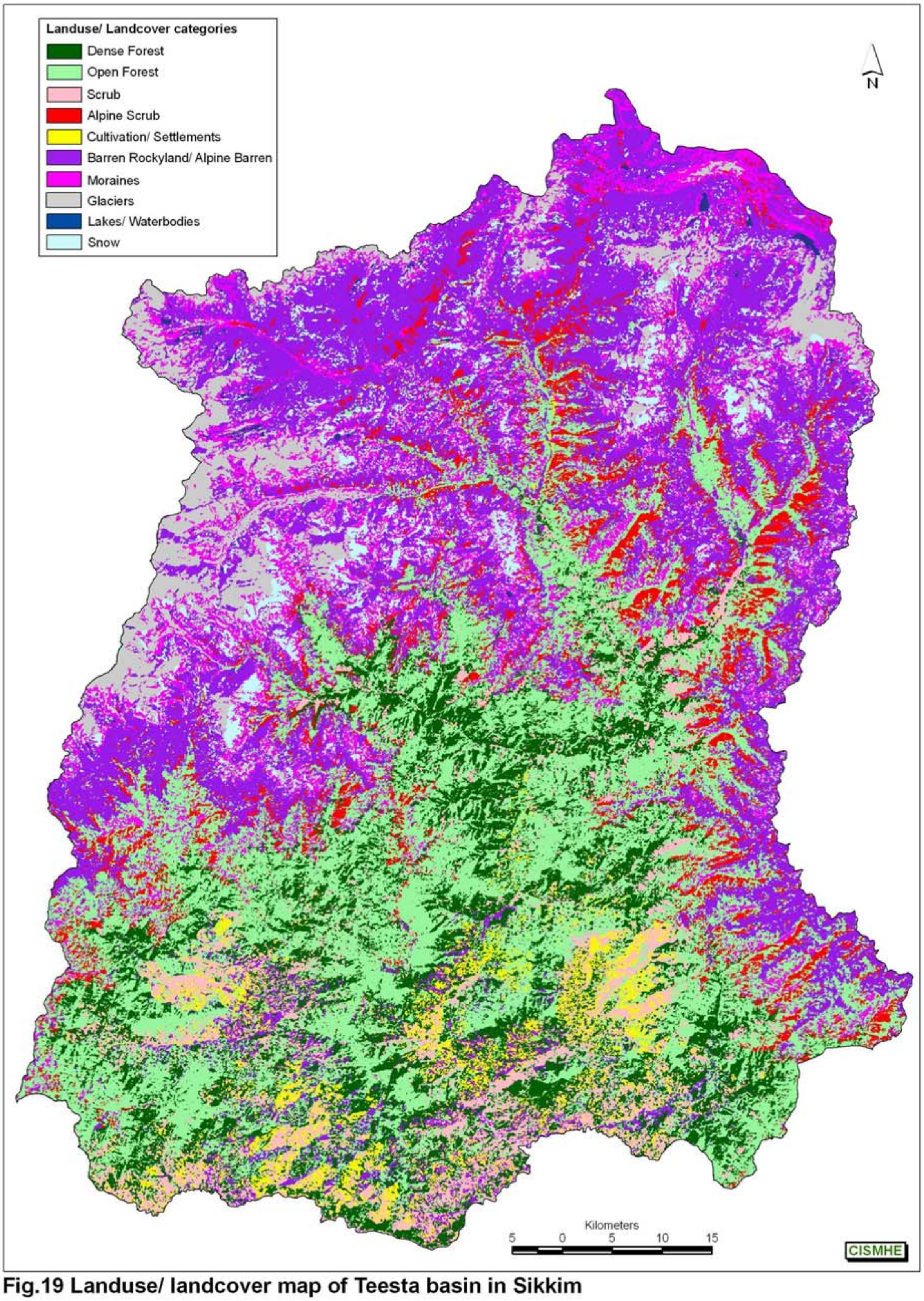


Fig.19 Landuse/ landcover map of Teesta basin in Sikkim

North Sikkim	4226	440.94	294.37	806.60	835.04	1247.54	1129.41
South Sikkim	750	144.96	204.62	269.57	257.88	414.63	462.50
Total	**7096**	**975.14**	**919.85**	**1872.65**	**1879.99**	**2847.79**	**2790.84**

Forest type map of Teesta basin shows that Sub-tropical forest and Temperate forest are the two predominant forest types in the basin (Fig.20). Sub-tropical forest covers 12.88% of the entire basin of which 6.92% of dense canopy and 5.96% are of open canopy and are distributed mainly in Manpur Khola, Rangpo Chhu, Rani Khola, Ramam Khola and Teesta (Lower Part) watersheds (see Fig. 20). Temperate forest types are spread over on area of 829.56 sq km (11.69% of Teesta basin), out of which 579 sq km is open canopy forest (see Fig. 20). Tropical moist deciduous forests are found in lower altitudes mainly in Manpur Khola, Rangpo Chhu watersheds. Mixed conifer forest is comprised about 2.81% of Teesta basin found mainly in Rangyong Chhu, Lachung Chhu, Lachen Chhu and Yumthang Chhu watersheds. Sub-alpine forest constitute 8.83% of Teesta basin lying above 2,700 m in watersheds of Rangyong Chhu, Lachen Chhu, Lachung Chhu, Chhombo Chhu, Yumthang Chhu, Rel Chhu and Prek Chhu. Sub-alpine forests are comprised predominantly of different species of *Rhododendron* mixed with species of *Viburnum*, *Rubus*, *Gaultheria*, *Euonymus*, etc. Alpine scrub and meadow cover about 7.2% of Teesta basin in higher reaches with milder slopes. Alpine scrub is comprised of bushes and clumps of *Juniperus, Salix, Berberis, Rosa,* etc.

4.7 WATER ENVIRONMENT

Water is the key resource of Sikkim and majority of present and future developmental activities revolves around this resource. This may not be a critical resource from environmental point of view at present, but it is surely a critical economic resource for the state. Any resource utilisation, consumption and conservation must take into account both the ecological as well as economic criticality of this resource. The present study has focused on evaluation of water environment in the basin in terms of the following:

- The drainage characteristics of the basin which include surface water bodies like rivers and lakes, underground drainage of various types and origins
- Nodal points of water resources
- Precipitation of rainfall and drainage during dry and/or non-dry periods
- Seasonal flows of water bodies (lakes including glacial lakes, rivers, ponds, etc.) and estimation of flood levels
- Water availability at various points and estimation of 75% and 90% dependable discharge
- Estimation of sediment load at various points in the basin and its qualitative analysis and seasonal flow of silt
- Water availability and demand for various sectors
- Inventorisation of point and non-point sources of pollution
- Quantification of upper limits of pollution load in various stretches

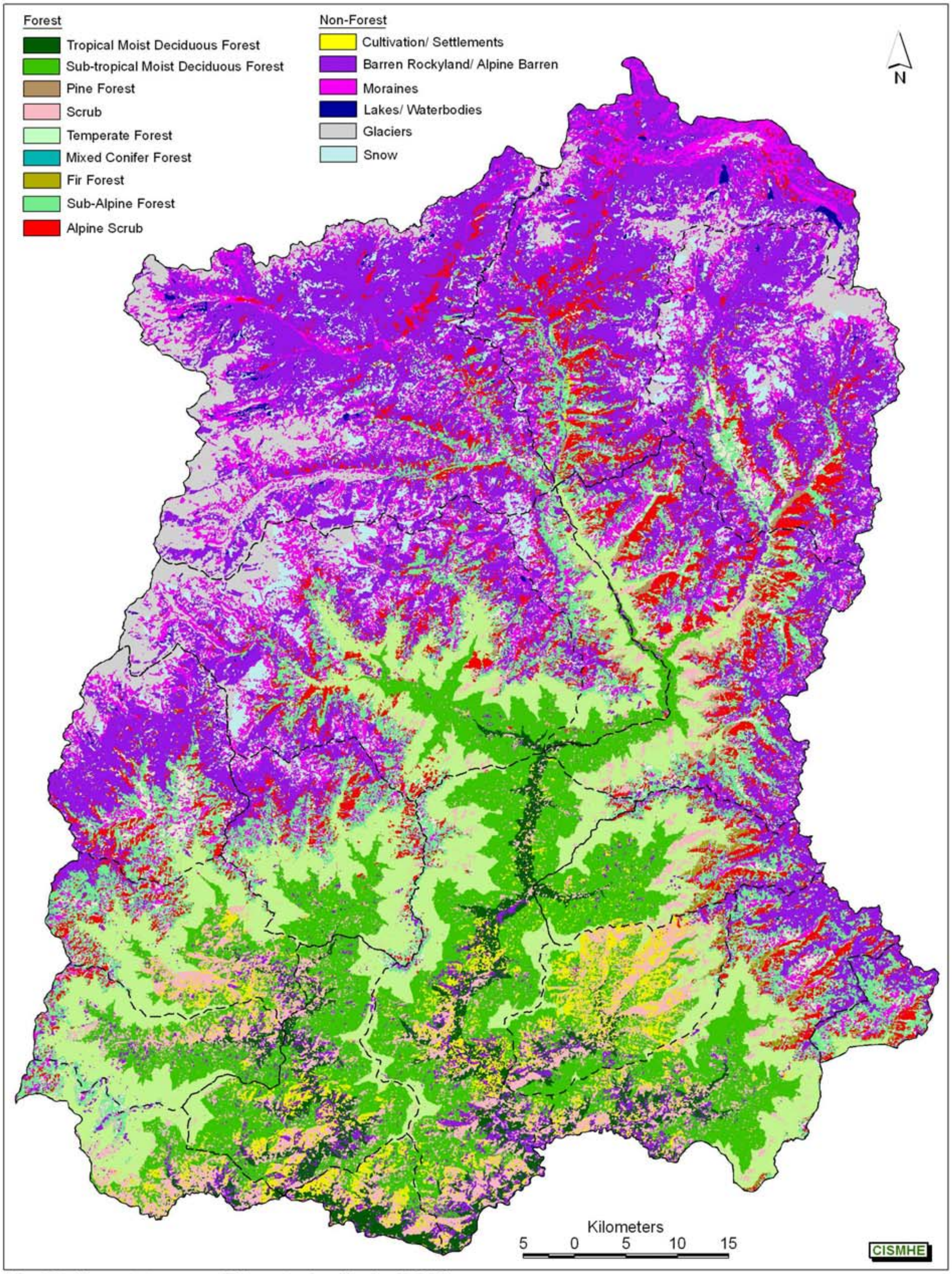


Fig.20 Forest types of Teesta basin in Sikkim

4.7.1 Nodal Points of Water Resource

High mountain ranges in Sikkim Himalaya particularly the North Sikkim are characterized by snow and numerous glaciers. These glaciers are the perennial source of water for Teesta river and regulate the run off. Since most of the glaciers are inaccessible and are located in rugged terrain of North Sikkim, remote-sensing data was procured for the mapping and analysis of glaciers. For this purpose digital IRS-ID LISS-III, PAN data as well as LANDSAT-7 ETM+ have been obtained from NRSA, Hyderabad and University of Maryland, Global Land Cover Facility, U.S.A. The remote sensing studies helped in generation of glacier inventory map of Sikkim and glacier index map. The glaciers are depicted as white in the FCC of IRS-ID LISS-III data as well as PAN data (Fig. 21).

The inventory of prominent glaciers and glacial lakes was prepared by digital image processing of merged IRS-1D LISS-III and PAN data with the help of enhancement techniques of satellite data using ERDAS Imagine 8.7. The processed image would then be transferred to Geographical Information System (ArcGIS 9.1, GeoMedia Professional 5.2, etc.) for the generation of different coverages or layers. Similar studies have earlier been carried out at RRSSC, Nagpur in 1991 using IRS 1B LISS-II data of November 1990.

The glaciers of Sikkim occur as compound glaciers termed as glacier complexes, where a number of glaciers originate from a common permanent ice-cover. The glaciers of Teesta basin have been delineated into seven glacier complexes (see Fig. 21). These are Chhombo, Yumthang, Langpo, Zemu, Talung, Rathang and Rel glacier complexes. These complexes constitute the nodal points of water resource in Sikkim and cover about 17% of Sikkim. Yumthang glacier complex is the largest glacier complex with maximum number of major glaciers (12) and has about 11% total area under glaciers.

4.7.2 Hydrometeorology

At present there are 19 ordinary rain gauge stations in Teesta basin in Sikkim, as per the WMO guidelines, it would be desirable to have about 21 rain gauges. Accordingly, additional four rain gauge stations should be installed in the valley preferably at Donkung on the Lachen Chhu, Namchi – South, Rangpo – East, Naya Bazaar – West. It is also suggested that three additional self recording rain gauges may be installed at Lachen, Gyalzing and Gangtok stations.

In addition to these rain gauge stations, snow gauges are also required to be established for measurement of snowfall at the higher altitudes. It is suggested to establish snow gauge stations at Thangu, Yumthang Chhu, Nathu La, Jambong on Zemu Chhu, Lampharam.

Average annual normal rainfall in Sikkim is about 2534 mm. It is observed that the month of July receives maximum rainfall of the order of 480 mm and minimum normal rainfall of 19 mm is recorded in the month of December for the Sikkim as a whole.

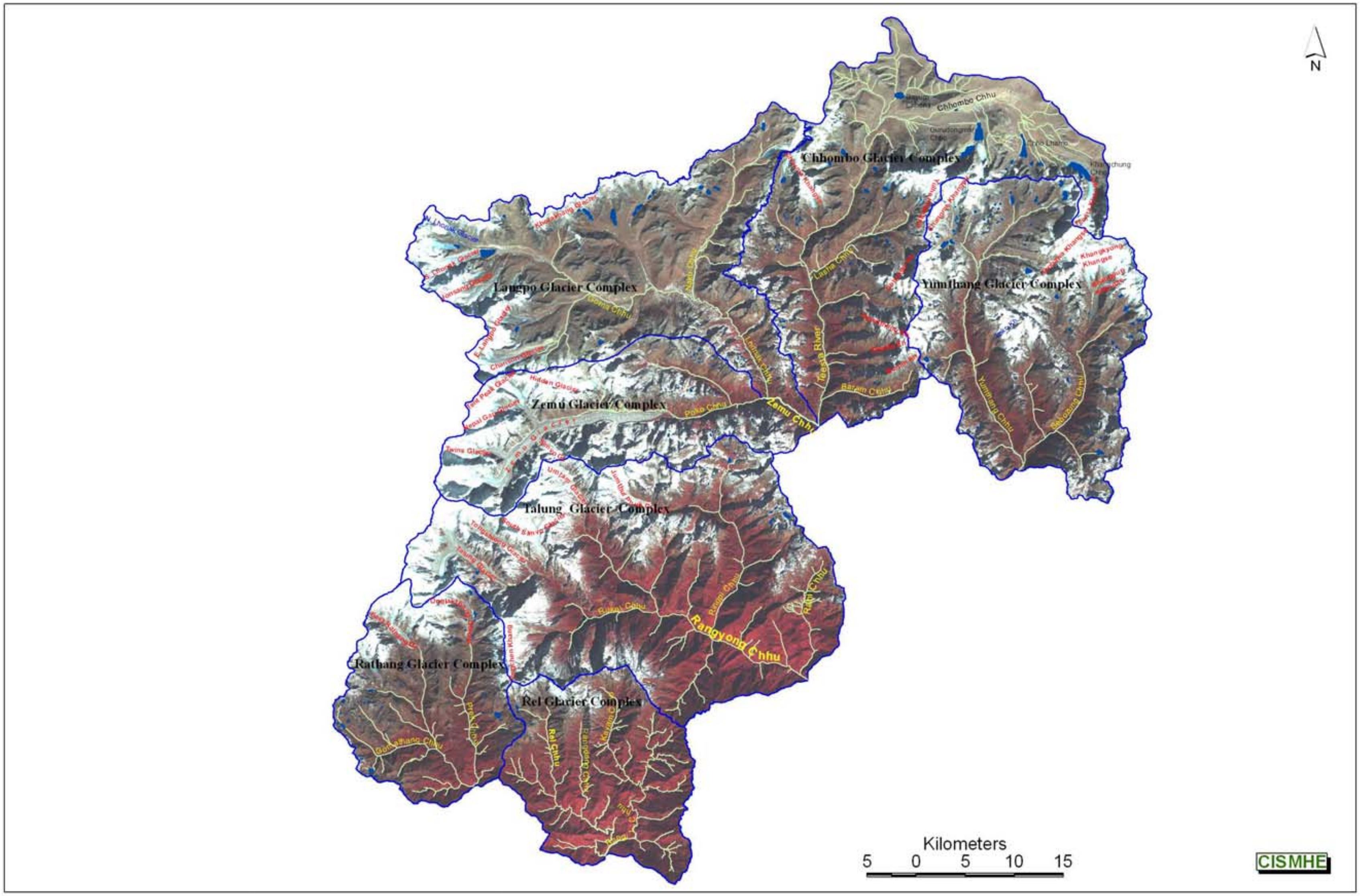


Fig. 21 Index map of Glacier Complexes in Sikkim

The altitude of the station also influences the coefficient of variation (CV). The coefficient of variation is generally found to increase with higher altitude.

Monthly rainfall values are available for the 19 rain gauge stations in the state of Sikkim as obtained from IMD for varying time periods. The 75 per cent dependable rainfall in the basin in Sikkim works out to 2478 mm.

4.7.3 Hydrology

There are at present 11 G&D stations, maintained by Central Water Commission. Additional set up of seven hydrological stations is suggested taking into account the terrain conditions, and availability of suitable places for locating the headquarters for the positioning of staff. Gauge and discharge observations at the existing stations shall be continued.

Average annual runoff at Chungthang, Sanklang, Dikchu and Khanitar is 4332 Mcm, 7860 Mcm, 9580 Mcm and 11569 Mcm respectively.

100 year return period flood at Khanitar site is 5779 cumec (Para 4.4.6).

Maximum silt load is carried in the month of July and minimum in the month of October during monsoon period.

Average sediment load during monsoon increases from the upstream to the downstream sites from 0.29 th cum/sq km to 1.53 th cum/ sq km.

Coarse silt load is higher in upper reaches of the river while fine silt is more for downstream reaches.

Average rate of sedimentation is the highest at Dikchu at 0.95 mm/ year, followed by Sankalang while it is minimum at chungthang at 0.32 mm/year.

4.7.4 Irrigation

Ultimate irrigation potential through minor irrigation schemes is 50 th ha, out of which 32.10 th ha has been created upto March, 2004. Utilization of the created potential need to be improved from the level of 77% in March 2002.

The feasibility of developing irrigation potential through major and medium schemes, which has been identified as 20,000 ha, should be re-ascertained. In case the possibility of the same does not exist, scope for alternative strategy, as deemed relevant with respect to physiographical characteristics of terrain should be investigated and pursued for implementation.

Status of Minor Irrigation (M.I.) Census (1995-96) of the state shows that all the 854 M.I. schemes jointly serve about 17106 ha of CCA with irrigation potential of 20010 ha. However, actual annual irrigation upto 1993-94 has been indicated as only 12493 in the above census. It means that even though utilization of created potential has been shown as 77% of the created potential, there is still a sizeable lag between the potential utilized and actual irrigation, which should be reconciled appropriately.

Although the status of M.I. Census (1995-96) shows that out of total 854 schemes, only 88 are not working, the Master Plan for Irrigation Development (1995), prepared during the same period reports that 419 schemes need appropriate measures according to their stage of functioning i.e. 119 are defunct, 105 are partially functioning, 142 need special repair and 50 need improvement. This needs to be reconciled at present level so that a realistic picture may emerge.

A total of 17106 ha of CCA are covered by all the 854 M.I. schemes as per the Census. However, CCA of 14566 ha is found to be covered by 419 schemes in the Master Plan, leaving only 2540 ha for remaining 435 schemes which does not appear reasonable and hence need to be reconciled.

The implementation of M.I. Schemes as contained in the Master Plan (1995) was planned for a period of 10 years. Nine years have since passed. However, from the perusal of physical achievements as brought out in Table 5.1, it does not appear that the implementation of schemes *vis*-à-*vis* creation of irrigation potential is progressing in a planned way. This should be attended to with adequate emphasis since the state is substantially deficit in reaching self-sufficiency stage in food grain production.

As per information available, 1176 minor irrigation schemes have been constructed upto March, 2003 with 972.38 km length of channels.

4.7.5 Land Resource Management

Net sown area of the state was 62.04 th ha with total cultivable area 108.89 th ha (15% of geographical area) as per 1995-96 land use statistics.

Though cultivable area has marginally increased from 97.52 th ha to 108.89 th ha during 1980-81 to 1995-96, the net sown area has decreased from 78.38 th ha to 62.04 th ha during the same period, primarily due to substantial increase in fallow land which is other than current fallow.

Effort should be made for possible appropriate use of cultivable waste land (CWL), which is quite sizable in the state. The possible use of such land could be its inclusion in net sown area (NSA) after undertaking appropriate soil conservation & improvement measures.

Similarly possible use of barren and Un-cultural land (BUL) may be coverage by forest, area under non – agricultural uses, permanent pastures and other grazing lands for which meticulous planning and implementation strategy need to be formulated.

For implementation of above land resource management strategies, use of efforts by Govt. of India, especially in regard to the funding of such schemes by GOI should be utilized.

4.7.6 Agriculture

Distribution of land holding in Sikkim is skewed. Marginal holders represent about 50% of land holding and hold 10.3% of total operated land area. Agro-climatological data along with average normal rainfall values has been used to work out net irrigation requirement for paddy and wheat crops.

Overall efficiencies of 73% for paddy and 56% for other crops have been used to work out gross irrigation water requirement.

Introduction of new crops (including wheat, rajmah, rape seed and mustard), extension of more areas under high-yielding and improved varieties of seeds, increased use of fertilizers and pesticides and expansion of area under double or multiple cropping would be helpful in overcoming subsistence farming to economically viable venture and it should be pursued more vigorously.

Since horticulture development involves substantial scope of increased economic activity in the state, an appropriate mechanism need to be evolved to give adequate thrust on this front.

Crops, which are not under organized sector(s) such as fruits and vegetables, are more liable to reporting of unrealistic figures in respect of cropped area and production. Therefore, this anomaly between the reported figures from various sources needs to be verified and reconciled.

Strategies *viz*. adequate investment in land development and water harvesting structure, strengthening the government farms, encouraging private seed farms as joint venture undertakings, mechanized farming, large scale demonstration on packaging technology involving HYV, fertilizer and Integrated Pest Management (IPM), development of human resources, post-harvest storage, processing, packaging including consumption, etc. with respect to agriculture development during tenth five year plan be rigorously pursued.

Any scientific system of harvesting the rainfall during monsoon period and utilization during the Rabi season has not yet been established, although some of such structures constructed during recent years have been quite useful. Proper investigation needs to be done for development of rain water harvesting structures, at least for meeting drinking water needs.

It is much cheaper to import fertilizer than the food itself and every unit of fertilizer being used increases the food production by two or more units. This is especially relevant due to very high transportation cost in hills and hence use of fertilizer should be encouraged.

Except the paddy field, more than 50% of other lands are either improperly terraced or untraced due to which plant nutrients are lost by run off and leaching, whenever there is high intensity rain during monsoon. Besides, cultivation is also difficult due to sloppy terrain. This issue of providing bench terraces need to be attended to promptly.

To develop the state as model ‘horticulture state’ steps need to be taken to have intensive agriculture so that food grain requirement is met from lesser area so as to divert maximum area to horticulture.

Apart from unfavourable geographical and socio-economic aspects, absence of adequate number of other industries and high literacy rate, more and more unemployed youth may have to seek employment in agriculture and agro-based industries. Under the broad strategies of mechanization of agriculture coupled with higher levels of inputs and technology, agriculture should be developed as a potential business enterprise in the state.

For addressing the above issues relating to agriculture development, there would be a need to substantially jack up investment pattern in this sector.

4.7.7 Horticulture and other allied agricultural activities

Taking cognizance of strengths, weakness and hi-tech horticulture available in the state and the objectives set forth for Xth five year plan to achieve an annual growth rate of 10% should be vigorously pursued. Some important objectives include sustainable horticulture production, persuading hobby and kitchen garden / backyard cultivation of horticulture crops to explore commercial cultivation of plant bio-diversity, develop marketing infrastructure, create vital linkages of post-harvest management etc.

Special emphasis need to be given to two important cash crops in the state i.e. large cardamom and ginger on which the agriculture economy of the state largely depends. Re- plantation of old orchards, providing planting material for gap filling and shade tree sapling are few basis needs for development. In case of ginger, awareness of ginger diseases to farmer, disease-free seed production and providing the same in mini kits, IPM activity to combat pests and diseases are same of the important activities for improvement.

Strategies suggested to strengthen the floriculture sub-sector should be meticulously planned and implemented. These comprise of checking the outflow of quality planting materials from the state, large scale tissue culture, transfer of technology to farmers and infrastructure facility for marketing transport, packaging and handling etc.

Detailed survey, documentation and identification of medicinal and aromatic plants and setting up herbal gardens at low, mid, high and alpine hills for development of cultural practices and commercial exploitation are few core strategies to streamline this sub-sector.

Nucleus beekeeping centers in government farm need to be established. Bee species should be improved to have pollinizer effect on crops especially large cardamom and several varieties of vegetables.

Considering the fact that livestock rearing is a way of life and a tradition which for centuries has substantially strengthened the economic life of the people in the state, it needs to be addressed with adequate emphasis, in terms of provision of veterinary services and animal health, cattle development, poultry development, sheep and wool development and piggery and other live stock development as well as diary development etc.

Since encouragement to take up fish farming is needed for economic growth and generates employment, special emphasis is needed for trout fish and carps and cat fish seed production, propagation of Mahaseer and development of inland fisheries etc.

4.7.8 Drought Prone Areas

Identification of drought prone areas in the entire state as per the norm spelt out for local conditions of the state (250 mm to 350 mm rainfall during winter and 500 mm in summer) need to be done for a realistic assessment of the measures to be taken in this regard.

Package of schemes for implementation in five years need to be pursued in a time bound manner with a priority to water conservation works.

4.7.9 Irrigation and water management – Perspective planning

The ultimate irrigation potential of the state has been considered as 70,000 ha, out of which 20,000 ha is through major and medium irrigation schemes and 50,000 ha through minor irrigation schemes. For the purpose of perspective planning, whole of the ultimate potential of 70,000 ha has been considered to be developed through minor irrigation schemes by the year 2025.

Typical design features of the following schemes have been included in the report:

Restoration/ modernisation of Bathung Khola Minor Irrigation Scheme at Village Pastanga-Gaucharan in East District, Sikkim. Chalamthang Minor Irrigation Scheme, South Sikkim.

Upto March 2002 i.e. end of IXth Plan, irrigation potential of 31.30 th ha was created, out of which 23.68 th ha was utilized. Considering the criteria of proving Rs.225/- and Rs.75/- per hectare of utilised and unutilised irrigation potential, O&M funds of Rs.59 lakh per annum would be required. However, at ultimate stage of development with utilized irrigation potential of 70 th ha, O&M funds of the order of Rs.1.58 crore would be required at present price level.

Voluntary Health Association of Sikkim (VHAS) has organised the efforts in water resources development besides handling the environmental issues in a very professional and methodological manner. The association has sought public participation in identifying the schemes and has embarked upon 'Ahlay Pokhari Water Harvesting Programme' near Asang Thang in West Sikkim for drinking purposes catering to 140 households in five villages.

4.7.10 Perspective planning

Optional planning of available land and water resources in the state of Sikkim has been done considering the following three strategies:

Maximise production per unit of area through multiple cropping, high yielding varieties etc. Maximise the area served with available water through protective irrigation to supplement rainfall and using drought-resistant varieties.

Exploring the possibilities of lifting of surface water

For management of land resources in the state of Sikkim, it is considered appropriate that the area under 'other fallow land' is reduced by about 50% to a level of 14.78 th ha and this area is brought under 'net sown area' category. This would increase the net sown area from 62.04 th ha to 76.82 th ha for the purpose of perspective planning. Cropping intensity of 180% has been projected for the years 2025 & 2050, thus gross cropped area works out 138.30 th ha.

Adopting the norm of 40 lpcd for rural and 100 lpcd for urban population, domestic water requirement for the state as whole have been worked out for the years 2025 and 2050 which is of the order of 18.49 Mcm and 33.41 Mcm, respectively.

Irrigation water requirement for the gross irrigated area of 70 th ha has been worked out as 328 Mcm.

Agriculture production of food crops has been projected as 149 th tonne and 194.50 th tonne for the years 2025 & 2050, respectively.

Per capita availability of foodgrains for the state of Sikkim has been reported as 177.36 gm/ day which has been projected as 400 gm/ day and 355 gm/ day for the years 2025 and 2050 respectively.

4.8 AIR ENVIRONMENT

Though air pollution is not so far an area of critical concern of critical importance in the Teesta basin in Sikkim, yet it was considered important to evaluate the resource for future development scenarios. The air environment has been assessed for the following :

- Ambient air quality
- Pollution sources
- Air environment sensitivity analysis

In order to collect data for air environment the following standard methodologies were followed:

- Delineation of airsheds based on topography, identification of micro-climatic zones and wind fields data
- Inventorisation of point, area and line sources of pollution and estimation of pollution loads
- Temporal and spatial variations in air pollutant concentration for existing sources using multiple source-receptor model to establish sources-receptor relationships
- Estimation of air environment sensitivity in critical micro-climatic zones for various pollutants *vis-a-vis* air quality standards for sensitive receptors
- Quantification of upper limits of pollution load in critical pockets

4.8.1 Assimilative Capacity of the Atmosphere

For estimating the assimilative capacity of the atmosphere, two different approaches were used. In the first approach, the assimilative capacity of the atmosphere were studied through ventilation coefficient, which is directly proportional to it. The ventilation coefficient were computed by calculating the product of mixing height and the average wind speed for the year 2003-2004. In the second method, assimilative capacity of the atmosphere has been estimated through concentration contribution from line sources to the ambient air by applying mathematical dispersion models. In the present study the vehicular sources have been treated as line sources which are the major sources of air pollutants namely Sulphur dioxide (SO_2), Oxides of Nitrogen (NOx), Carbon dioxide (CO_2) and Suspended Particulate Matter (SPM). The computations have been carried out for vehicular sources to quantify their contribution towards the overall ground level concentrations.

4.8.2 Air Quality Modeling

Ambient Air Quality (AAQ) is attractive as the starting point for an urban air pollution index because it lies along the environmental pathway between sources/emissions, which are the points of control and people's treating zones, which are the locations to be protected. AQI is a useful technique for its application to any urban city. It is mainly based on sparse of ambient air quality data and NAAQS of a particular region. The overall analysis of Sikkim particularly at points near the Teesta River Basin has been found to be well within the limits except for a point near Gangtok where NOx values are found to be critical.

4.8.2.1 *Emission inventory*

i) South and East Sikkim

A gridded source inventory has been developed over an area of (56*34) km^2 covering South & East Sikkim. The area has been divided into 200 grids of size (2.8*3.4) Km^2. The thirteen vulnerable points of the region have been treated as receptors for the study. They are Gangtok, Singtam, Rangpo, Rongli, Dikchu, Phodong, Chhangu, Kupup (East Sikkim) and Melli Bazar, Damthang, Namchi, Ravongla, Jorethang (South Sikkim).

Singtam is the place with the highest concentration (142.35 $\mu g/m^3$) of SPM followed by Ravongla (91.53 $\mu g/m^3$), Rangpo (86.81 $\mu g/m^3$) and Namchi (69.24 $\mu g/m^3$) while Kupup (6.9 $\mu g/m^3$) has the lowest SPM concentration. Similar trend can be seen for both CO and NOx. The maximum CO concentration is observed at Singtam (38.45 $\mu g/m^3$) and minimum at Kupup (6.95 $\mu g/m^3$). The maximum NOx concentration at Singtam is (32.6 $\mu g/m^3$) while (5.49 $\mu g/m^3$) at Kupup. At all the other places, the concentration is not very significant.

The maximum concentration of SPM (57.38 $\mu g/m^3$) is observed at Singtam followed by Melli Bazar (47.37 $\mu g/m^3$), Rangli (45.13 $\mu g/m^3$) and Rangpo (44.47 $\mu g/m^3$) while Jorethang (36.96 $\mu g/m^3$) has the lowest SPM concentration. The similar trend can be seen for both CO and NOx. The maximum CO concentration is observed at Singtam (29.96 $\mu g/m^3$) and minimum at Jorethang (20.74 $\mu g/m^3$). The maximum NOx concentration at Singtam is (13.94 μg/m3) while a minimum of (5.69 μg/m3) is observed at Jorethang. The concentration at Singtam, Rangpo, Melli Bazar and Namchi are high due to the commercial activities.

The temporal variation in East and South region of Sikkim by using Caline-3 model reveal that the maximum values of the pollutants are at Rangpo in the late evening hours (19 hrs). The IITLS model also predicts a similar trend for all the pollutants, which reveals that evening (19^{th} hour) is the time when most of the carbon monoxide is emitted in the atmosphere and Rangpo is the place having the highest concentration (46.1 $\mu g/m^3$) followed very closely by Gangtok (40.5 $\mu g/m^3$) and Damthang (39.9 $\mu g/m^3$). At all the other places and at all times the concentration is not very significant. Similarly the maximum concentration of NOx (37 $\mu g/m^3$) is at Rangpo followed by Gangtok (32.5 $\mu g/m^3$) and Dikchu (28.6 $\mu g/m^3$). This peak value is also attained in the evening. The SPM values are however quite low in comparison with CO and NOx but the trend of NOx and SPM are almost the same. The maximum concentration for SPM are again at Rangpo (4.6 $\mu g/m^3$), Gangtok (4.1 $\mu g/m^3$) in 19^{th} hour and Dikchu (3.6 $\mu g/m^3$) in 23^{rd} hour.

The most prominent reason for the above observed trend is the meteorology. During day time because of convective mixing dispersion takes place, while during evening the low mixing height, low wind speed and decreased convective activity of the atmosphere results in increased concentration. The concentration at Rangpo, Gangtok, Dikchu and Damthang indicate their prominence with respect to their commercial location.

The above result and discussion reveal that concentration of pollutants or pollution potential due to various sources of pollutants in

East and South regions of Sikkim are well within the NAAQS of SPM, CO and NOx.

a) Gangtok

A gridded source inventory has been developed over an area of (3.64 x 4.16) km^2 of Gangtok city. The area has been divided into 225 grids of size (0.26 x 0.26) km^2. The locations of six vulnerable points (receptors) of the region namely Metro Point, Deorali, Hospital Point, Indira Bypass, Tadong and Zero Point and the roads (links) connecting them. In Gangtok, the number of vehicles increases remarkably in the tourist season and the problem become worst during winter. After analyzing the emissions from various sources, it has been felt that vehicles are the major source of pollution, since there is no major industry in this region. However, due to the absence of observed CO data the study has been done only for SO_2, SPM and NOx.

The computed pollutant concentrations obtained from the models IITLS and Caline-3 have been compared with the monitored concentrations at different receptors in both the seasons. The results indicate that both the models are well in agreement with the observed concentrations in the study area. However, models estimate high pollution potential i.e., low assimilative capacity during winter season whereas summer season has different result. It is noticeable at this juncture that results of both the approaches correlate well for winter as well as summer seasons. The statistics however, shows that IITLS model is performing better than the Caline-3 which is possibly due to the more realistic emission data which is input to the model and its ability to incorporate calm winds. In the present study the influence of topographical features and other complex terrain related forcing have not been considered in the models. However, consideration of these effects is expected to improve the models predictions. The study finds that the commercial place like Metro Point, Zero point and Hospital Point are the places where the level of pollution is high hence decongestion of traffic is required at these places.

ii) West Sikkim

The Western district of Sikkim has a total area of 116 km^2 and population of about 1.2 lakhs (Census 2001). The district has two main towns Gyalshing (Gyalzing) and Nayabazar. The distance between Nayabazar and Gyalzing is approx. 37-38 km. River Rangit separates the west from the south district of the State. The district starts from Nayabazar.

Automobile is the major source of pollution. Except a cheese factory in Dentam, there are no industries in West Sikkim. There are around 2,500 vehicles present in West Sikkim, which constitute 9.5% of the total automobiles present in Sikkim.

4.8.3 Emission Inventory

A gridded source inventory has been developed over an area of (18.0 x 18.0) km^2. This area has been divided into 324 grids of size (3.0 x 3.0) km^2. Since, the major road network covers only the eastern and southern part of this district only three receptors were chosen. The receptors are Gyalzing, Nayabazar and Soreng. The roads (links) connecting them. The emission rate of air pollutants were determined using method-I. Since, these receptors lie very close to south Sikkim some of its places (like Namchi, Jorethang) are also included in evaluating the concentration at these receptors.

A comparative study of two different year's air quality has been done for this region to estimate the air quality status of this region. The present work has been done in a similar way as has been done for Gangtok city. The study has been done for April and December months which are representatives of summer and winter season respectively. The pollutants studied are carbon monoxide (CO), suspended particulate matter (SPM), oxide of nitrogen (NOx) and sulpur dioxide (SO_2). The variation of concentration during summer and winter season in the years 2001 and 2004 for CO, SO_2, SPM and NOx. The concentration of all pollutants increases in 2004, though very slightly, from 2001. This is observed at all receptor points. The concentration of NOx is maximum followed by CO at all the receptor points in both the years. However, winter (January) concentration is slightly higher than that of summer (April) for both the years. In winter (January) the highest concentration of pollutants is observed at Gyalzing followed by Nayabazar and Soreng. In summer season, however, Nayabazar has highest concentration followed by Gyalzing and Soreng.

The winter 2001 concentration is quite low during the morning afternoon hours (9 am to 16 pm) for all pollutants. This is due to the mixing height values that help in dispersion of pollutants during that time. Gyalzing has maximum SPM concentration of 11.5 μg m^{-3} followed by Nayabazar (10 μg m^{-3}) and Soreng (9.5 μg m^{-3}). The model evaluated values for winter 2001 gives the concentration of NOx at Gyalzing (183 μg m^{-3}) followed by Nayabazar (171 μg m^{-3}) and Soreng (152 μg m^{-3}) which is highest among all pollutants. The SO_2 concentration also follows the similar trend having the maximum concentration at Gyalzing (10 μg m^{-3}) followed by Nayabazar (9.5 μg m^{-3}) and Soreng (8.5 μg m^{-3}). These values however, increase in the year 2004. The maximum NOx concentration in winter 2004 is observed at Gyalzing (242 μg m^{-3}) followed by Nayabazar (227 μg m^{-3}) and Soreng (201 μg m^{-3}). The model evaluated concentration for summer 2001 gives the highest SPM concentration at Nayabazar (11.4 μg m^{-3}) followed by Gyalzing (9.6 μg m^{-3}) and Soreng (8 μg m^{-3}). The maximum NOx concentration in this season is observed at Nayabazar (181 μg m^{-3}) followed by Gyalzing (152 μg m^{-3}) and Soreng (127 μg m^{-3}). The same trend is observed in 2004. There is however an increase in the concentration values in 2004. The maximum SPM concentration in summer is observed at Nayabazar (15 μg m^{-3}) followed by Gyalzing (12.6 μg m^{-3}) and Soreng (10.6 μg m^{-3}). Similarly Nayabazar gets the maximum NOx concentration (239 μg m^{-3}) followed by Gyalzing (201 μg m^{-3}) and Soreng (168.8 μg m^{-3}).

Form the above results it is clear that though the concentrations of SPM, SO_2 and NOx have increased in 2004 they are well within the limits. Among the seasons, winter is a more critical month than summer because of low wind speeds and low mixing/inversion height.

i) North Sikkim

Emission Inventory of Chungthang

A study of Chungthang region revealed that pollution is caused mostly by the vehicles whose number increases in the tourist season. A significant contribution in the winter season is made by the domestic burning of firewood and coal. In the present study, emission of SPM, NOx and SOx have been calculated by using the daily traffic volume in Chungthang and its surrounding regions. The problem has been modeled as a- continuous emitting finite Line Source while, the contribution of domestic fuel burning to pollution has been estimated by using an area source model.

4.8.4 Emission of Line Source

A gridded source inventory has been developed over an area of (15 x 18) km^2. The area has been divided into grids of size (3.8 x 3) km^2. Five sources have been considered at places Kodyorg, Long Nadom, Theng, Chhaten and Chungthang. Three receptors have been considered at Myang, Ningla and a region around 2 km radius of Chunghtang.

The emission rate of air pollutants in this study has been determined using method I (Table 13).

Table 13. Emission rate of air pollutants

Type of vehicle	Emission factors (g veh^{-1} km)		
	SO_2	SPM	NO_x
Petrol driven cars (MTV)	0.08	0.33	3.20
Diesel-driven cars (MTV)	0.39	2.00	0.99
Heavy duty vehicles (HTV)	1.50	3.00	21.00

In this study only two types of vehicles have been considered: the heavy duty diesel driven vehicles (army vehicles) and the medium type diesel driven cars which are commonly known as “Pejos” in the region. Over the study area of (15 x 18) km^2, the vehicles have been assumed to travel an average distance of 25 km daily. On the average a total of 25 vehicles travel during the normal season and around 40 vehicles travel during the tourist season. The average speed of the heavy duty vehicles is assumed to be 20 km/hr and that of the medium type vehicles as 25 km/ hr. The source strength of the pollutants due to vehicular emissions in Chungthang is estimated as given in Table 14.

Table 14. Source Strength of Pollutants

Pollutant	Source Strength ($\mu g\ m^{-1}\ s^{-1}$)
SPM	23.328
NO_X	54.1992
SO_X	6.584

4.8.5 Emission of Area source

The amount of charcoal and firewood used in Chungthang has been estimated from the total amount extracted and sold in Sikkim in the year 2000-2001 (total charcoal is about 8575 kg and firewood is 84000 kg), based on the population of Chungthang (about 3000). Since the firewood used in Chungthang is obtained from unauthorized sources (directly from the forests) a record of its percentage is not available. Hence the actual amount of firewood used in the region may be much more than the estimated value in our study.

In Chungthang, normally calm winds i.e. wind speeds $\leq$ 1 m/s occur frequently. As a result the pollutants tend to remain near the ground level only which is an unfavorable condition for dispersal of pollutants at Chungthang. However, the air quality at different places in and near Chungthang is within standards as the number of vehicles is quite low.

4.8.6 Sodar Potential

Often, conventional weather forecasting *in situ* techniques like radio-sonde, instrumented tower, tethered balloon and instrument aircraft *etc.* are employed to monitor the essential air quality related meteorological parameters. However, it has been found that these techniques, though good and give reliable direct information of the relevant parameters, have several limitations. These are very expensive to operate for real time continuous data requirements. Radio-sonde provides data of temperature, humidity and wind profile (twice daily) which serve as inputs to forecast synoptic scale motions. This is although adequate for mesoscale urban forecasts but have own limitations and are costly to operate on a continuous basis. The information on mixing height, inversion height and stability class can be derived but it involves indirect techniques and data interpolations.

4.8.6.1 *SODAR Observations at G.B. Pant Institute, Pangthang, Gangtok*

A monostatic Sodar capable of probing the dynamics of atmospheric thermal structures in Atmospheric Boundary Layer (ABL), in real time, has been installed at the G.B. Pant Institute of Himalayan Environment and Development, Pangthang in Gangtok for studies of mixing/inversion height characteristics.

The Sodar observations made during the period of October 2003 to September 2004 have been examined and analyzed to work out the monthly mean diurnal variation of mixing height.

The examination of Sodar echograms has revealed that ABL phenomenon such as free/forced convection, inversions, fumigation, elevated shear layers/waves etc. are occurring in accordance with prevailing meteorological conditions at the observational site at Gangtok.

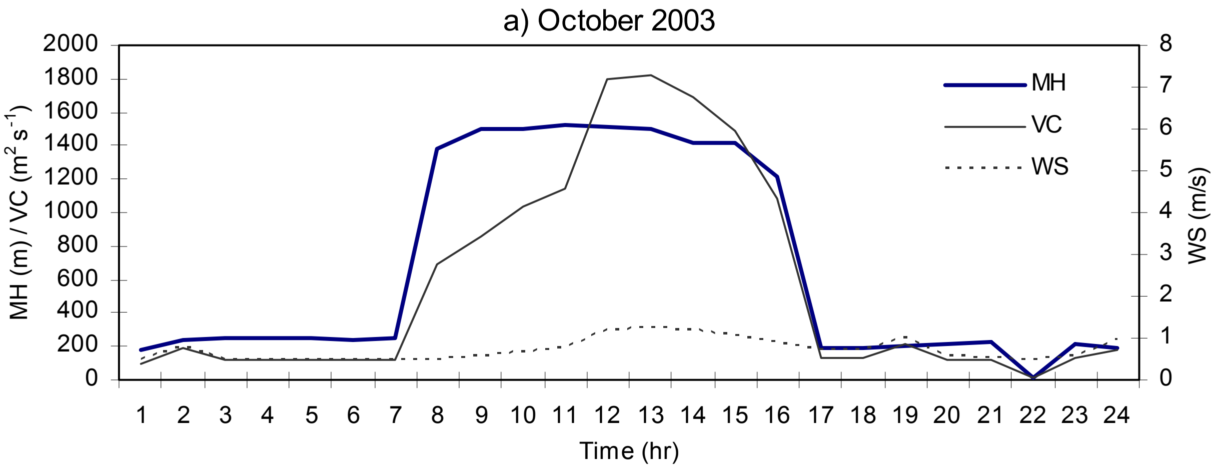
The Sodar system, which has been installed in Pangthang, Gangtok, is giving mixing/inversion heights, which is an important parameter for air pollution abatements. This type of data has been generated for the first time in Sikkim.

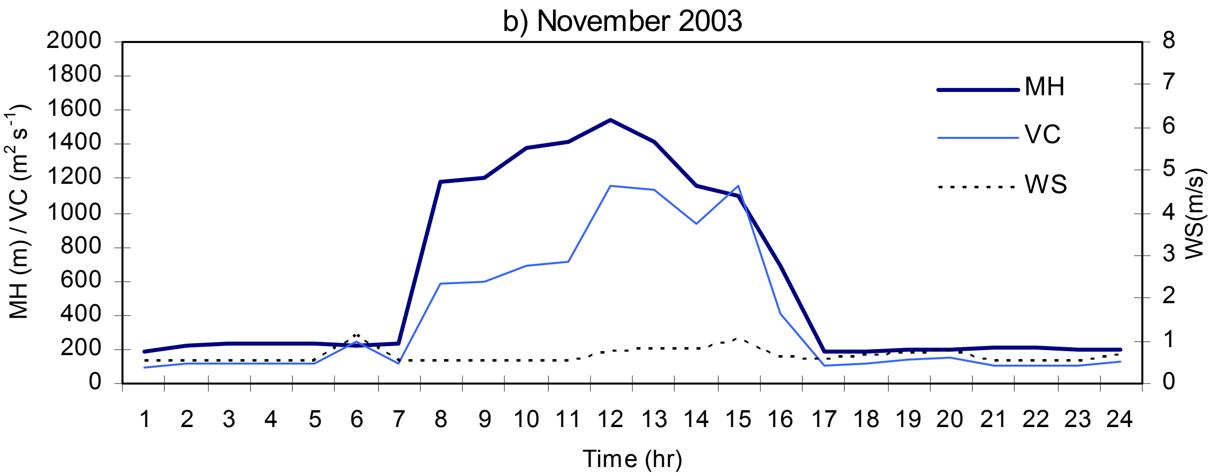
This data will be very helpful for dynamics of the clouds and forecasting the fog conditions and landslides, which are major problems of the study area.

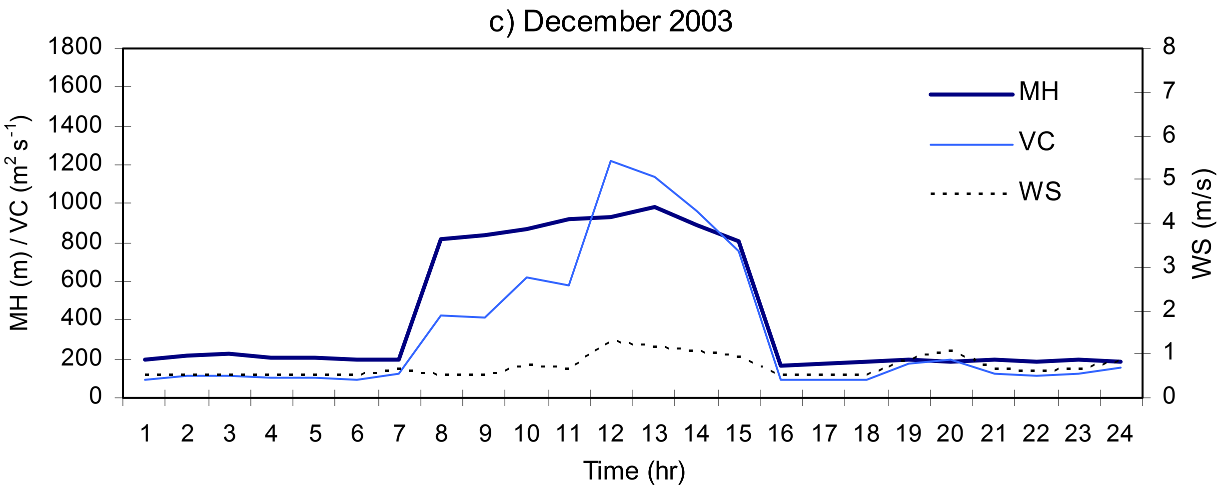
4.8.6.2 *Computation of pollutant concentration through modeling*

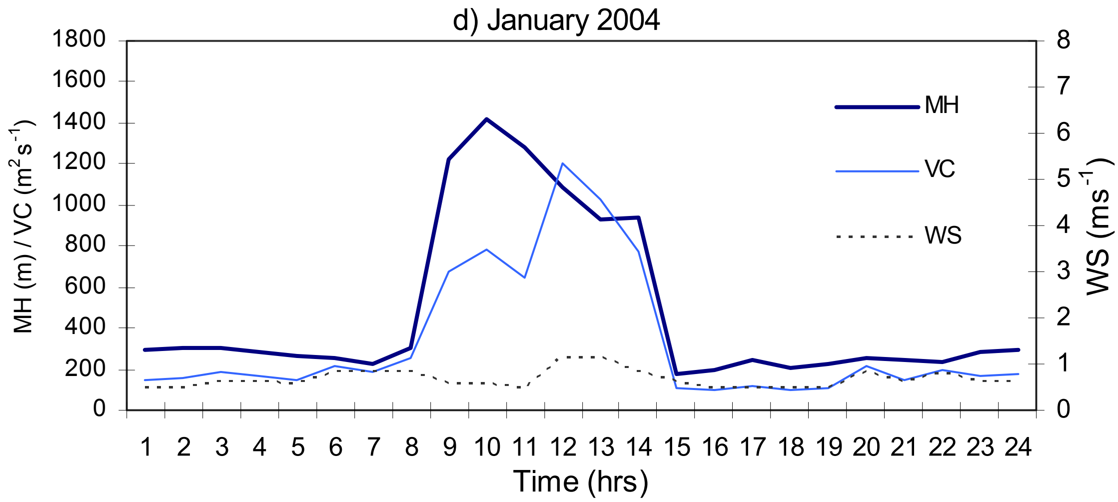
Fig. 22 presents the ventilation coefficient, mixing height and wind speed for the months October, November, December, January, February, March, April, May, June, July, August and September 2003-2004 at Gangtok. Accordingly to Gross (1970) and Stack Pole (1967), high pollution during the afternoon occurs when the ventilation coefficient and mean wind speed is less than 6000 m^2s^{-1} and 4 ms^{-1} respectively while during the morning hours, the mixing height is less than 500m and wind speed does not exceed 4 ms^{-1}. This criterion has been widely used by U.S. National Meteorological Centre and Canadian Environment Service. Fig. 22 reveals that for all the months, the morning mixing height values are low compared to day time values. This may be due to the fact that Gangtok does not receive high solar insolation because of high moisture content in the atmosphere, as a result the earth's surface does not induce significant thermal circulations or in other words, the convective mixing is confined to limiting vertical height. However an increase in solar insolation, as the day advances increases the ventilation coefficient reaching a maximum value during afternoon hours. Further during evening hours when the incoming solar radiation ceases the ventilation coefficient also decreases gradually (Viswanadham and Anil Kumar, 1989). The diurnal variation of mixing height follows a similar trend in all the twelve months (see Fig. 22). The maximum value of mixing height is attained in the month of October 2003 and minimum in the month of June 2004. But June, July and August are the typical monsoon months. The Sodar is not a good approximation for this season. Thus, December is the month of minimum mixing height and has worse meteorological scenario. The mixing height values, throughout the year, seem to be low during morning and evening hours which may be due to the occurrence of ground-based inversions that hamper dispersion of pollutants. The maximum value of ventilation coefficient is 2328 $m^2 s^{-1}$ in the month of March 2004 followed by 1842 and 1823 $m^2 s^{-1}$ in the month of May 2004 and October 2004, respectively. December 2003 records the least value of 209 $m^2 s^{-1}$.

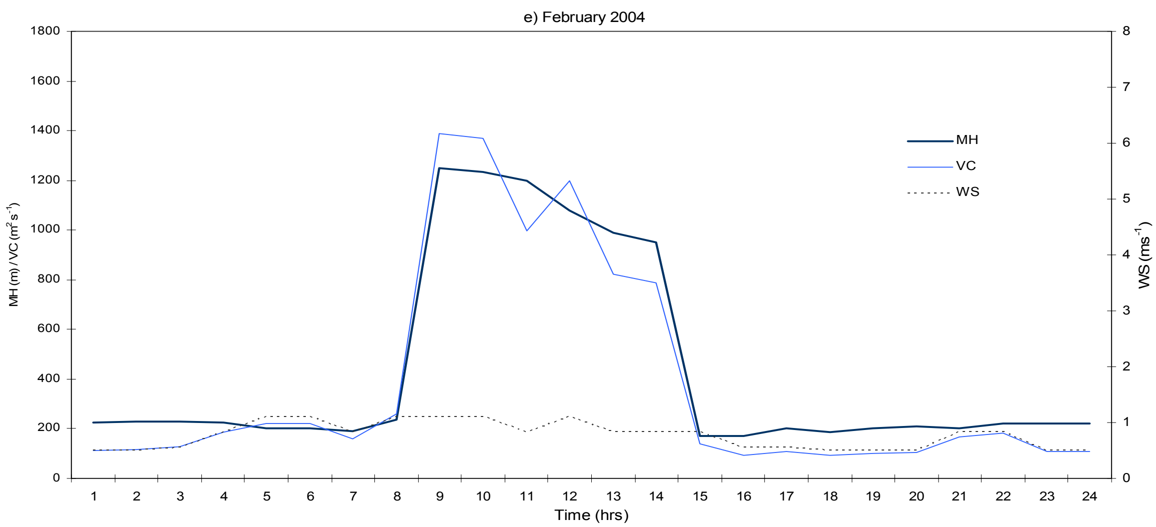
A noticeable feature at Gangtok is the mixing height values which are quite high as compared with the plane areas like Delhi. The possible reasons might be the orographic lifting of air masses by the uplifting force of upslope mountain winds during the day and gliding effect of background winds striking the mountain slopes at night. Moreover, because of the frequent movement of clouds passing though the probing range (Sodar) reduces the temperature gradient and increases the force of buoyancy resulting in the increased values of mixing height at high altitudes. At times, even the low level clouds result in increased mixing heights under stable conditions. This is because of the mixing of the thermals with the top of the inversion layer. In view of these considerations, the results of higher


a) October 2003
MH (m) / VC ($m^2 s^{-1}$)
WS (m/s)
MH
VC
WS
Time (hr)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


b) November 2003
MH (m) / VC ($m^2 s^{-1}$)
WS(m/s)
MH
VC
WS
Time (hr)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


c) December 2003
MH (m) / VC ($m^2 s^{-1}$)
WS (m/s)
MH
VC
WS
Time (hr)
1800
1600
1400
1200
1000
800
600
400
200
0
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


d) January 2004
MH (m) / VC (m^{2}s^{-1})
WS (ms^{-1})
MH
VC
WS
Time (hrs)


e) February 2004
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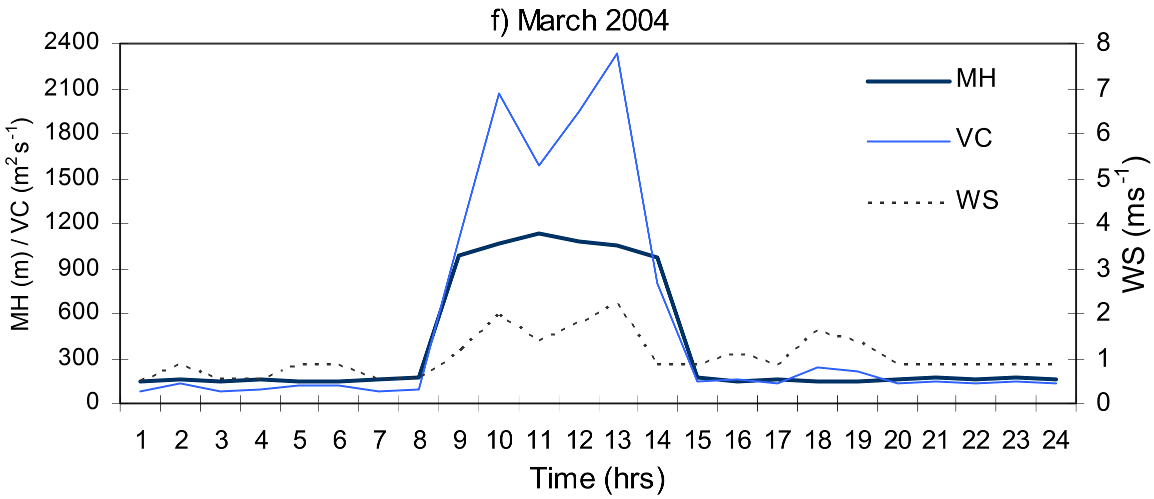
f) March 2004
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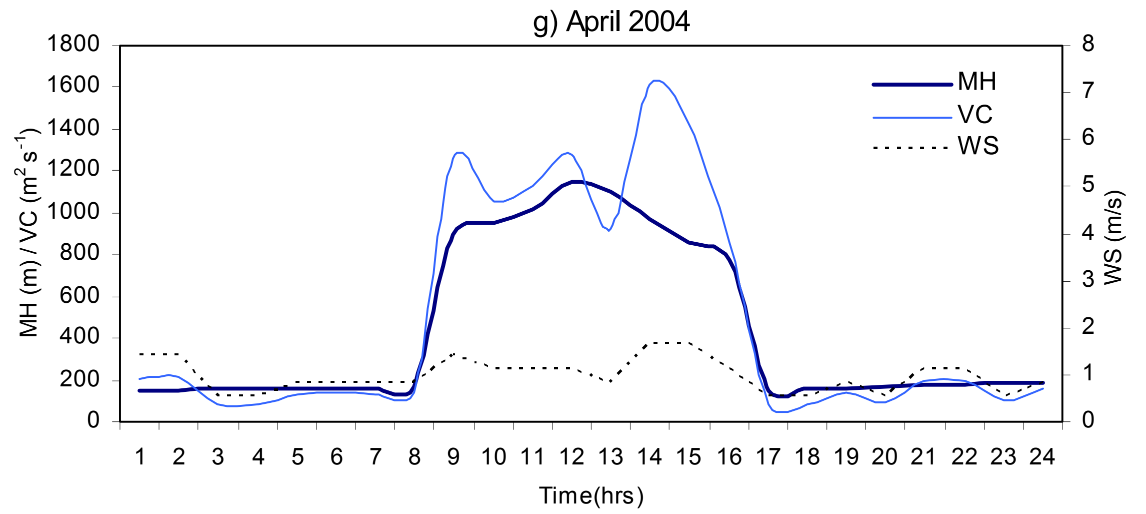
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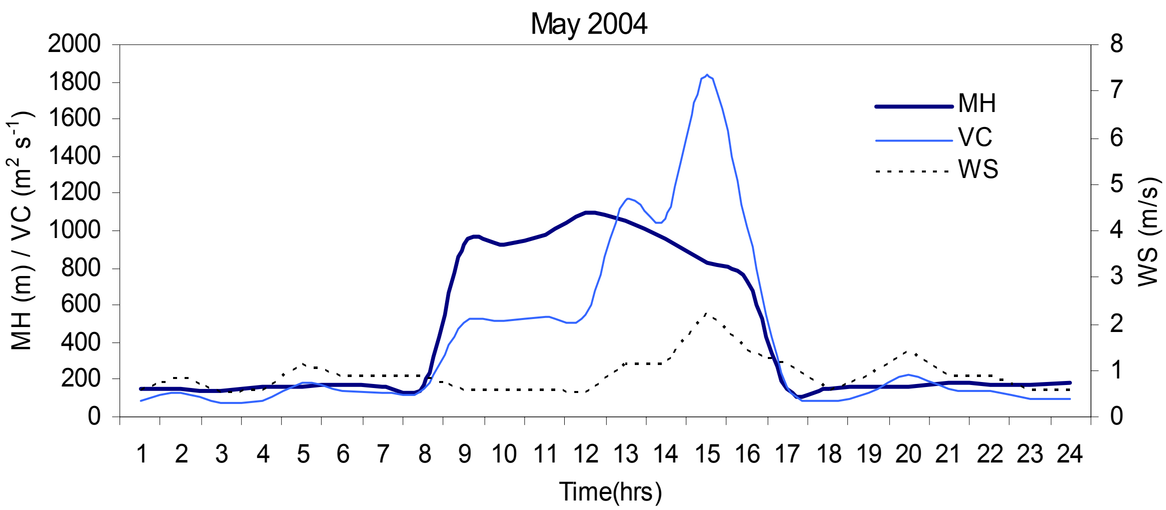
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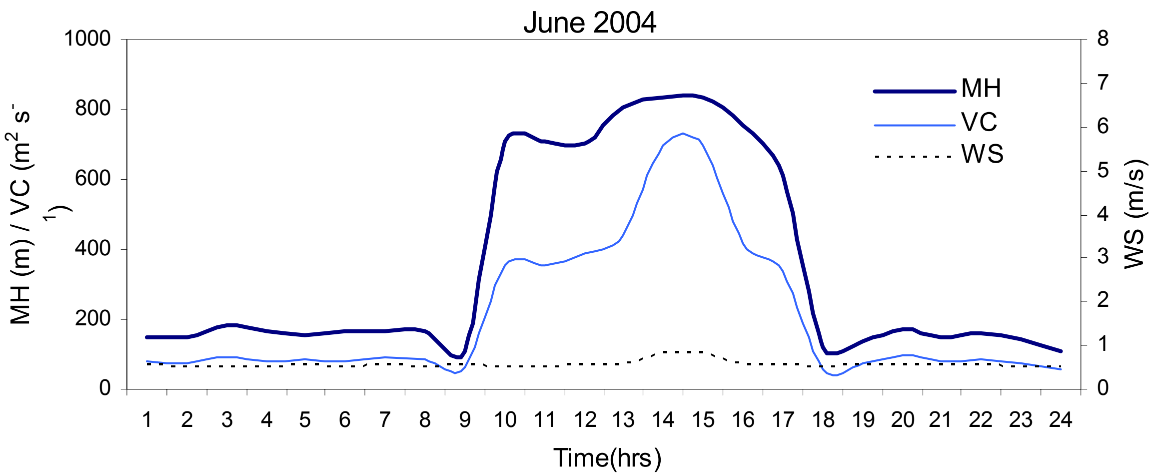
June 2004
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VC
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MH (m) / VC (m2 s-1)
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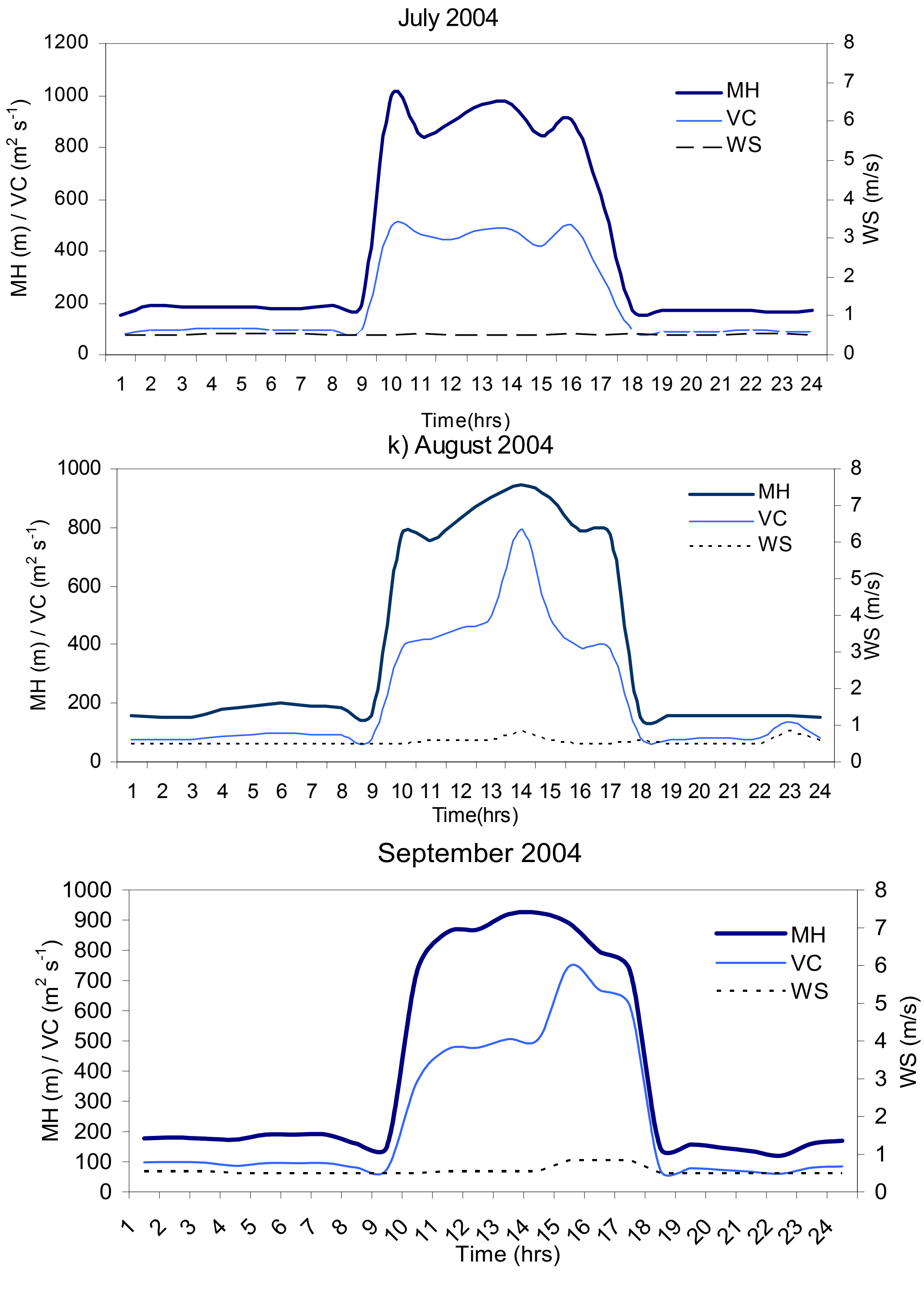

Fig. 22. Diurnal Variation of Ventilation Coefficient, Mixing Height & Wind Speed at Gangtok during October 2003 to September 2004 . a)October 2003, b) November 2003, c) December 2003, d) January 2004, e) February, 2004, f) March, 2004, g) April, 2004, h) May, 2004, i) June, 2004, j) July, 2004, k) August, 2004, l) September, 2004

mixing height seen at Gangtok are considered to be realistic. However, these are the initial results in cloudy environment of high altitude places j) such as Gangtok. However, more intensive studies are required for better interpretations and meaningful conclusions on the characteristics of mixing height in these areas.

On the basis of criteria for assessment of assimilative capacity as adopted in the present study, it can be observed that no safe emission hours can be advised throughout the year. The assimilative capacity in the month of December is found to be poor than the other months. However, this approach is not sufficient to draw a conclusion because it does not include sources of pollutants. Thus, a second approach based on pollution potential obtained from Air Quality Models has also been used in the present study to reach to the final conclusion. As a second approach, the pollution potential is estimated using Caline-3 and IIT Line Source models. The models are used to calculate the concentration of three major pollutants namely suspended particulate matter (SPM), Oxides of Nitrogen (NOx) and Carbon Monoxides (CO).

Fig. 23 illustrates the comparison of SPM and NOx concentrations obtained from Caline-3 and IITLS models and observed values for December 2003 at Gangtok. It is observed that the concentrations obtained from IITLS models are close to the observed values whereas concentration of Caline-3 model is found to be underpredicting the SPM values at all the receptors. However, Caline-3 model is underpredicting NOx values at all receptor points except at Hospital Point and Zero Point where it is overpredicting. It is noticeable that concentrations obtained from both the models and observed values of SPM and NOx at different receptor points are showing a similar trend. The concentration curves of SPM and NOx obtained from both the models are underpredicting compared to observed values but still they are in agreement with the observed values. The reason of underprediction is obvious. The model's concentrations are as a result of vehicular sources only whereas the observed values are due to all sources.

The variation of concentration of CO, NOx and SPM by using Caline-3 and IITLS models for the month of December at Gangtok has been shown in Figs. 24 & 25. Similar type of analysis has been done for all the months. But December has only been chosen to limit the presentation to a manageable size.

Figure 24 shows the variation of concentration of pollutant at Gangtok using Caline-3 model. It shows that the Hospital Point has highest concentration of SPM, CO and NOx followed by Zero Point and Deorali. Tadong has minimum concentration. Among all the pollutants, SPM has the maximum concentration (106.48 µg/m^3) while CO and NOx have 45 and 25 µg/m^3, respectively. The IITLS model (see Fig. 25) predicts the highest concentration at Zero point followed very closely by Hospital and Metro Point for all the pollutants. SPM concentration from IITLS model has highest value as 140.11µg/m^3 among the other two pollutants. The reason for the concentration at these places may be due to Hospital point is a busy commercial place and Deorali being a connecting place to Gangtok so traffic density is quite high at these places in comparison with other places. An interesting observation of pollutant concentration at Metro Point,

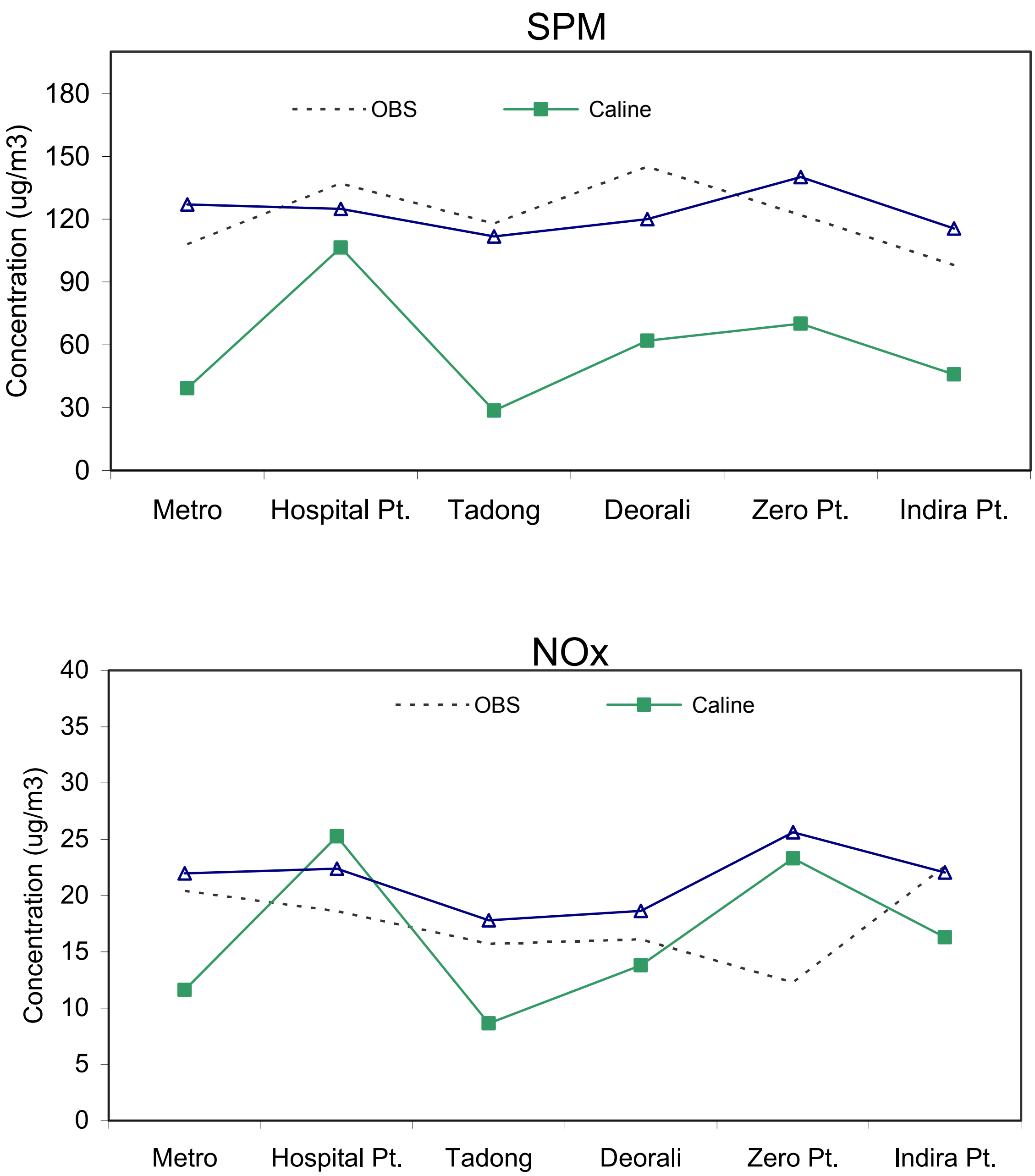

Fig. 23 Comparison of SPM and NOx concentration of two different models with the observed values at Gangtok

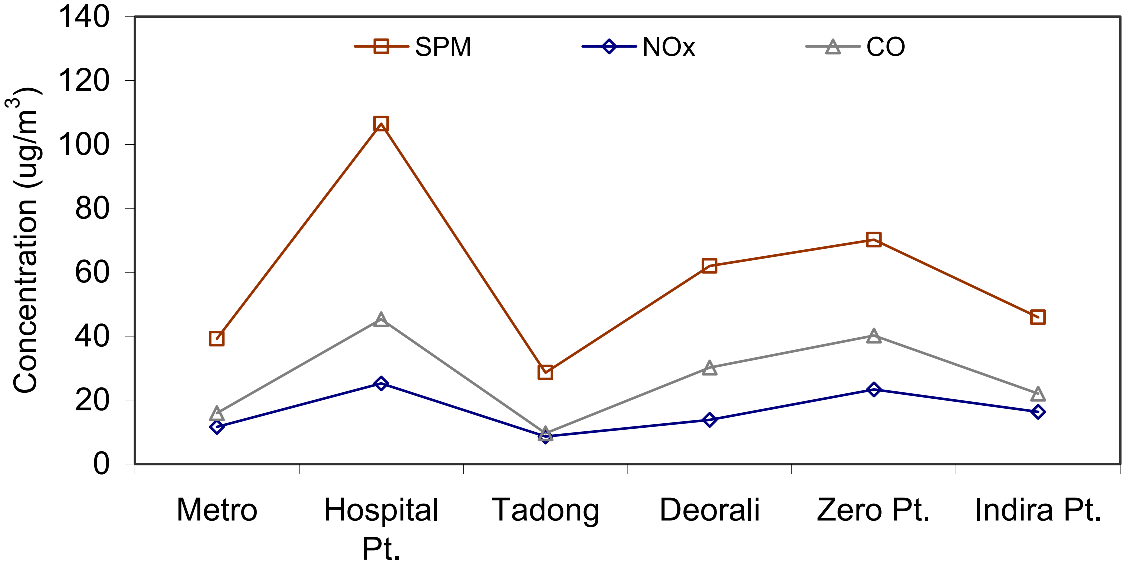

Fig. 24 Variation of Concentration of SPM, NOx and CO at Gangtok by using Caline-3 model

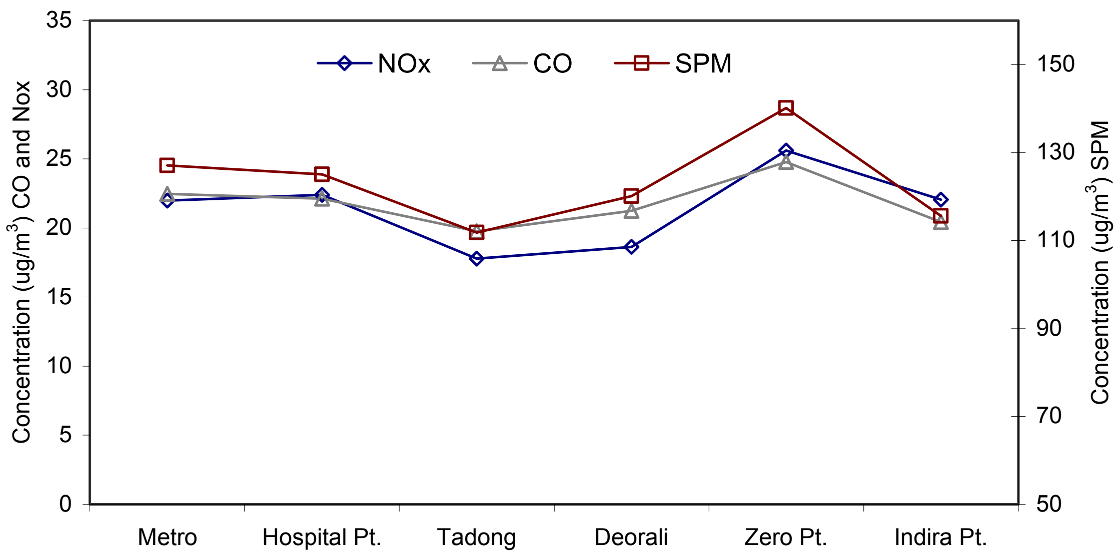

Fig. 25 Variation of Concentration of SPM, NOx and CO at Gangtok by using IITLS model

Hospital Point, Indira Byepass and Zero Point, which are all commercially important place. These places have higher values of concentration (39 µg m^{-3}, 106 µg m^{-3}, 45 µg m^{-3}, 70 µg m^{-3}, respectively) as compared to residential place like Tadong (28 µg m^{-3}). This points out the dominance of vehicular traffic in the pollution scenario. The average values, however, are quite below the National Ambient Air Quality Standards (NAAQS). However, both the models are predicting nearly same amount of concentration of all the pollutants.

Similarly, Figure 26 gives the variation of pollutant concentration in East and South region of Sikkim using Caline-3 model. The figure shows that Singtam is the place with the highest concentration (142.35 µg/m^3) of SPM followed by Ravongla (91.53 µg/m^3), Rangpo (86.81 µg/m^3) and Namchi (69.24 µg/m^3) while Kupup (6.9 µg/m^3) has the lowest SPM concentration. The similar trend can be seen for both CO and NOx. The maximum CO concentration is evaluated at Singtam (38.45 µg/m^3) and minimum at Kupup (6.95 µg/m^3). The maximum NOx concentration at Singtam is (32.6 µg/m^3) while (5.49 µg/m^3) at Kupup. At all the other places, the concentration is not very significant. Similarly Figure 27 gives the variation of pollutant concentration in East and South region of Sikkim by using IITLS model. The maximum concentration of SPM (57.38 µg/m^3) is observed at Singtam followed by Melli Bazar (47.37 µg/ m^3), Rangli (45.13 µg/ m^3) and Rangpo (44.47 µg/m^3) while Fig.27 Variation of Concentration of Pollutant in East and South region of Sikkim by using IITLS model Jorethang (36.96 µg/m^3) has the lowest SPM concentration. The similar trend can be seen for both CO and NOx. The maximum CO concentration is evaluated at Singtam (29.96 µg/m^3) and minimum at Jorethang (20.74 µg/m^3). The maximum NOx concentration at Singtam is (13.94 µg/m^3) while (5.69 µg/m^3) at Jorethang. The concentration at Singtam, Rangpo, Melli Bazar and Namchi are high due to the commercial activities.

The temporal variations of pollutant concentrations indicate that the highest SPM concentration occurs at Indira Byepass during late evening (21 hrs) followed by Zero Point and Tadong. The highest CO concentration occurs at Zero Point during late evening hours (22 hrs) while NOx is maximum at Deorali (22 hrs). The temporal variation at Gangtok using IITLS predicts the maximum SPM concentration at Zero Point during late evening time (20 hrs). The maximum CO and NOx are also at Zero Point during the same time (20 hrs). The temporal variation in East and South region of Sikkim by using Caline-3 model which reveals that the maximum values of the pollutants are at Rangpo in the late evening hours (19 hrs). The IITLS model also predicts a similar trend for all the pollutants. The maximum pollutant concentration is evaluated at Singtam in the late evening hours (21 hrs).

The above result and discussion reveal that concentration of pollutants or pollution potential due to various sources of pollutants in East and South regions of Sikkim and especially in Gangtok are well within the NAAQS of SPM, CO and NOx.

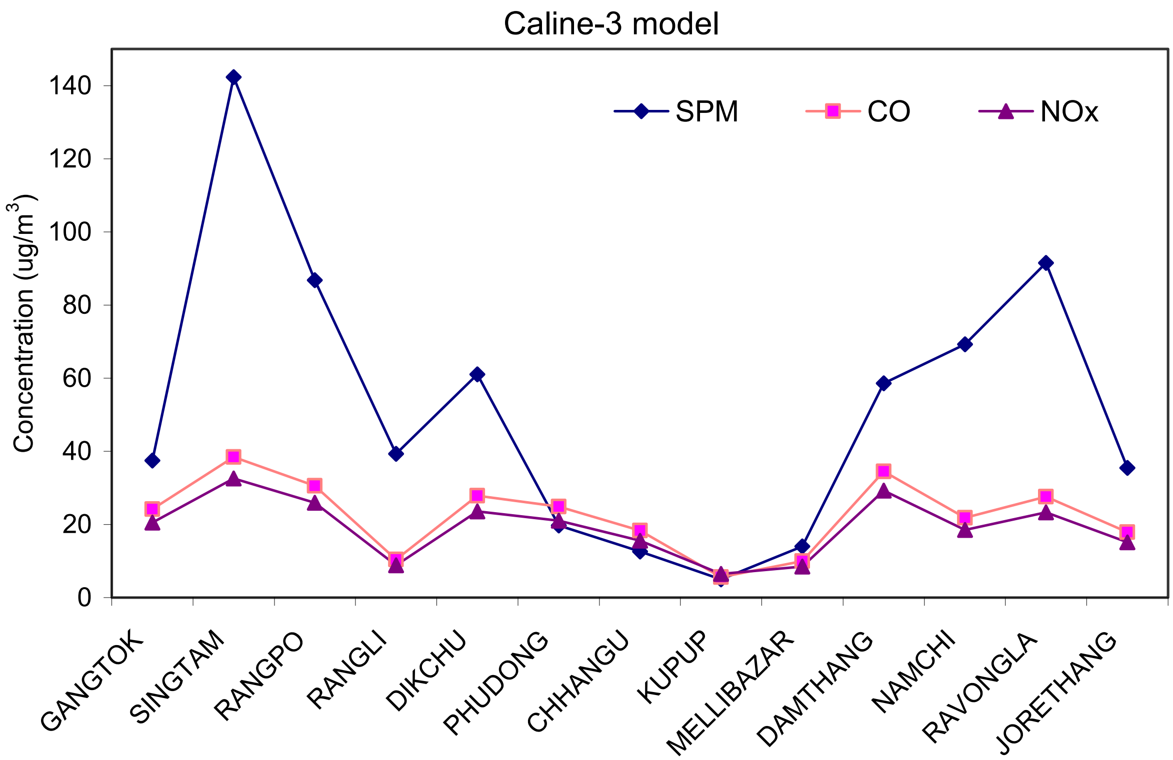

Fig. 26 Variation of Concentration of Pollutant in East and South region of Sikkim by using Caline-3 model

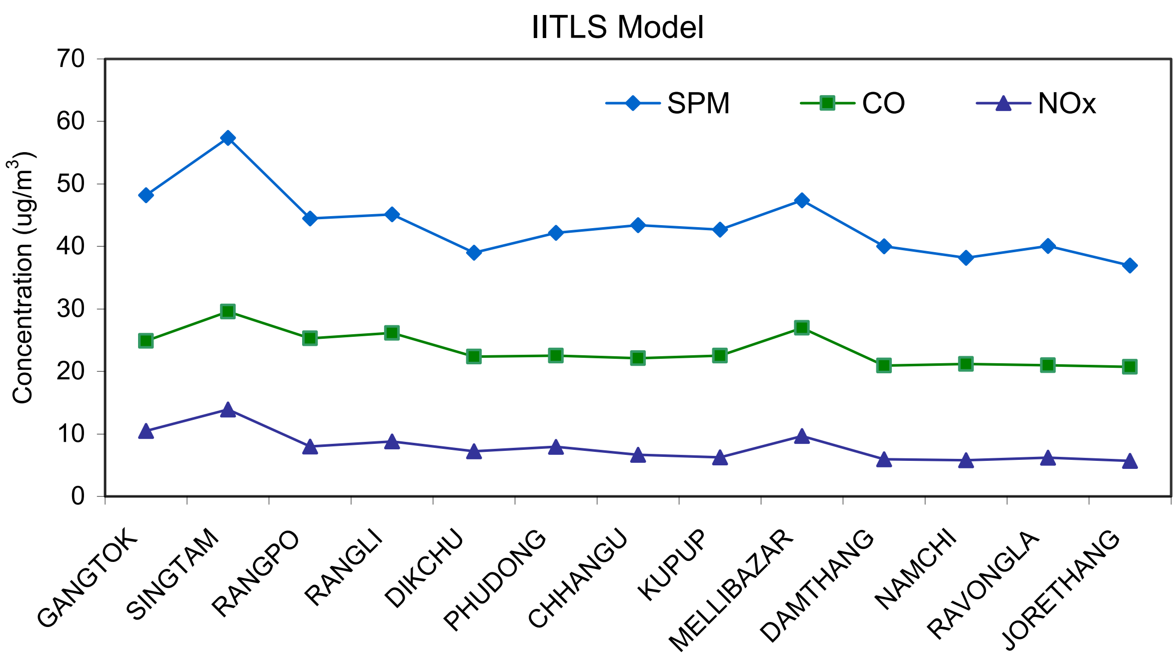

Fig. 27 Variation of Concentration of Pollutant in East and South region of Sikkim by using IITLS model

4.9 SOCIO-ECONOMIC ENVIRONMENT

The human population density, demographic profile, cultural practices and the associated activities play the most crucial role in shaping the nature of environmental resources of land, air and water of a region. In highlands particularly there are even more profound results on these resources arising out of human activity. The Teesta basin in Sikkim exhibits varied demographic profiles and patterns in various districts and along the altitudinal gradients. The state is also rich in cultural and ethnic diversity besides being rich in water and biological resources. For any planning and development process to be successful and meaningful it is essential to understand the existing socio-economic resource base and levels of its exploitation by the human population. Linked to it is the quality and quantum of services and amenities provided by the state for providing better quality of life to the human population. Since human ecosystems are heavily loaded towards producing higher quantities of waste as a result of various activities it is important to assess the consumption and waste production levels and suggest measures to reduce pollution loads in land, air and water resources. To evaluate the socio-economic environment in this study following parameters have been considered relevant to the carrying capacity study.

Assessment of human population density and population growth

Economic profile of human population living in various districts and sectorwise employment and employment potential

Man land ratio across the population profile

Evaluation of agricultural practices, food production *vis-a-vis* land capability and agricultural productivity

Distribution pattern of input resources in agriculture *vis-a-vis* socio-economic profile of the population

Agricultural productivity and carrying capacity

Evaluation of amenities and services provided by the state in terms of educational, health, communication and other facilities

Assessment of quality of life in terms of existing scenario, perceived scenario and preferred scenario

4.9.1 Socio-Economic Profile

4.9.1.1 *Demographic Profile*

Human Population and Trends

Sikkim has registered a steady growth of population over the last three decades. The population of Sikkim has grown from 2,09,843 in 1971 to 5,40,851 in 2001. The trend of population growth in successive census years since Sikkim's merger with India is shown in Fig.28.

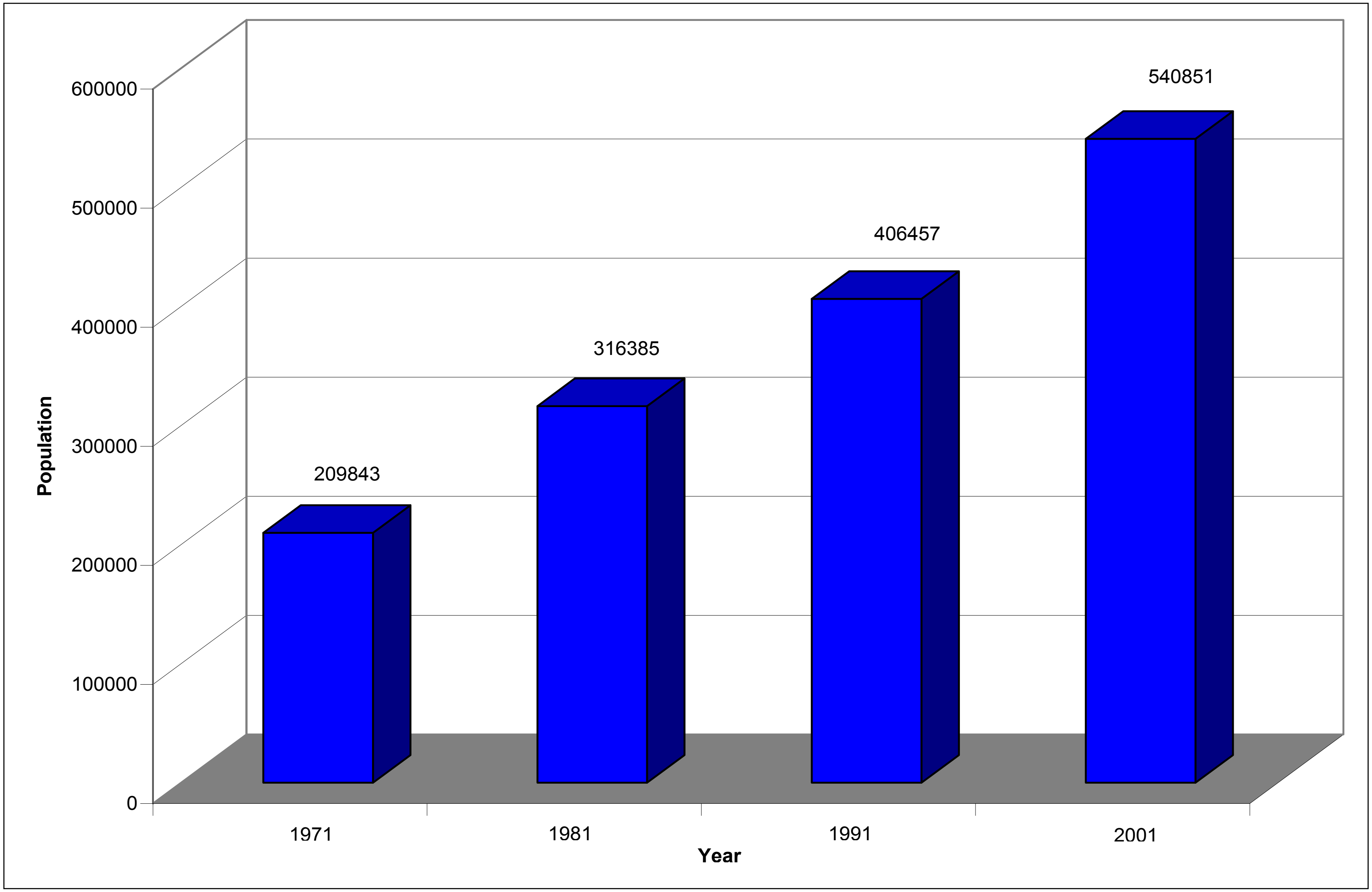

Fig. 28 Population growth in Sikkim

The total population of Sikkim as per the Census of Sikkim (2001) is 540,851 comprising 288,484 male and 252,367 female. The sex ratio in Sikkim is quite low. There are only 875 female per 1000 male. About 480,981 people of Sikkim live in rural areas while only 59,870 persons reside in urban areas. The total number of households in the state as of 2001 is 114,223. The average size of household is 4.7, i.e. approximately five persons reside in each household. The overall density of population in the state is 76 persons per sq km, which is one of the lowest in India.

The total number of literates (7 years and above) in the state is 234,135 of whom 137,745 are male and 96,390 are female. The number of illiterates (7 years and above) in the state is 142,430 out of which 63,413 are male and 79,017 are female. The overall literacy rate in Sikkim is 50.6% while the rate of illiteracy is 30.8%. There is a notable disparity in the rates of literacy between male and female and between rural and urban population. The literacy rate among the male is 55.4% while among the female it is only 45.0%. The gender gap in the rate of literacy is 10.4%. The rural areas of Sikkim have registered only 46.7% literacy while the same is 80% in the urban areas. The male literacy rates in rural and urban areas are 51.6% and 83.4% as compared to 41.1% and 75.9% for those of the female. The gender gap in literacy in the rural and urban areas is 10.5% and 7.5% respectively.

4.9.1.2 *Economic Profile*

The economic profile of Sikkim is presented under three broad heads, namely, i) Agriculture and allied activities, ii) Industries, and iii) Services. The economic profile of the state shows an overwhelming dependence on agriculture and allied activities. While the industrial sector is slowly picking up, there is not much increase in the tertiary sector. Although there are eight towns in the state, the urban population is very small. Barring Gangtok, all other towns in Sikkim are too small for towns and many, *viz*. Mangan in North Sikkim, Gyalshing and Naya Bazar in West Sikkim and Namchi in South Sikkim are smaller than some of the villages. If the size of towns is any indication, then it can be said that the state has very limited scope of growth in the urban service sector.

4.9.1.3 *Employment Profile/Occupational Structure*

According to major occupation, the people of Sikkim may be grouped as under:

i) Main workers
   a) Cultivators
   b) Agricultural labourers
   c) Workers in household industry
   d) Other workers
ii) Marginal Workers
iii) Non-workers

The total number of workers in Sikkim according to 2001 census is 2,22,500. The total number of main workers in the state is 1,86,222, of which 86,314 are cultivators, 10,837 are agricultural labourers, 2,791 are workers in household industries and 86, 280 are other workers. There are 36,278 marginal workers, while 1,90,343 persons in the state are non-workers.

The economic classification of workers in Sikkim shows that about a quarter of the total work force in Sikkim are primary workers and less than a quarter are tertiary workers. The number of secondary workers is negligible. Almost half (46%) of the total population of Sikkim are non-workers.

The demographic, economic and employment profiles of Sikkim indicate that the state, though disadvantaged due to geographical isolation, has many positive aspects in regard to human and economic resources. No doubt the state has many limitations as far as utilization of resources is concerned. Yet, the profiles make it clear that the state's socio-economic environment is conducive to growth and development of both human as well as economic resources.

The demographic profile of Sikkim shows that in every decade Sikkim is getting about a lakh of additional population. The density of population in Sikkim is still very low. Though migration factor plays a big role as far as growth of population is concerned, there is hardly any mechanism either to check or even record the entry of immigrants.

Another demographic problem of the state is its low sex ratio. The low male-female ratio in the state hints at gender bias. Yet another intriguing feature is the small size of towns. The miniscule size of towns indicates very slow urbanization process. The literacy figures, though improving, are not very impressive as far as rural and female education is concerned.

The economic profile of the state shows growth in the sector of agriculture and allied activities. In spite of limited cultivable land, the state recorded growth in this sector. There was progress both in terms of quality and quantity. Sikkim has scope to expand horticulture, animal husbandry and to some extent sericulture sectors. However, as far as industries are concerned, the state has very little space, except in tourism industry.

The occupational structure of the state is more or less balanced. Though the number of non-workers in the state is pretty large, high work participation of both the sexes in primary, secondary and tertiary activities indicate healthy work environment. Unemployment is still not acute in Sikkim. There are scopes to expand self-employment opportunities and trade with the diversification of tourism sector and opening of Nathu-la pass in near future.

4.9.2 The Amenities available in Sikkim

4.9.2.1 *Educational Institutions*

Sikkim has a wide range of educational institutions ranging from pre-primary to graduate levels and varying from government to private.

The types of government educational institutions in Sikkim and their district-wise break up is given in the Table 15.

Table 15. Educational Institutions in Sikkim, 2000

Educational Institutions	North	East	South	West	State
Pre-primary school	76	235	212	216	739
Lower Primary School	21	35	48	75	179
Primary School	33	114	94	81	322
Junior High School	9	44	43	33	129
Secondary School	10	24	22	20	76
Senior Sec. School	2	14	7	6	29
Monastic School	14	16	12	8	50
Sanskrit Pathshala	-	8	2	2	12
Madrasa	-	1	-	-	1
Degree College	-	1	1	-	2
Law College	-	1	-	-	1
Sheda (Monastic College)	-	1	-	-	1
Sanskrit Mahavidyalaya	-	-	-	1	1
TTI	-	1	-	-	1
SIE	-	1	-	-	1
ITI	-	1	-	-	1

4.9.2.2 *Communication*

Underdeveloped communication is still one of the major bottlenecks in the course of development in Sikkim. The resources stored in this Himalayan state cannot be utilized up to the required level unless there is improvement in communication network in inner Sikkim.

Although Gangtok, the state capital has a very high level of motor vehicle intensity, the road connectivity in its hinterland is still poor.

Given the fact that Sikkim has neither railway, nor airway (barring occasional helicopter services), it has to depend only on roadways for transport and communication. The roads in Sikkim can be classified as: i) National Highway, ii) State Highway, iii) Major District Roads, iv). Other District Roads, and v) Bridle Path.

4.9.2.3 *Industry*

Sikkim is industrially backward due to its isolated location and difficult terrain. Exploitation of mineral resources in the state is a challenging task. The known reserves are small and their extraction process is un-economical. Therefore, the state has hardly any mineral-based industry except copper, the production of which too is dwindling. Though Sikkim is rich in forest resources, forest-based industries are not encouraged since there is always a risk factor associated with exploitation of forest resources. The existing industries in Sikkim are medium, small-scale and cottage enterprises, based chiefly on agriculture and animal resources. Most of the medium-scale industries of the state are beverage industries (tea, beer and other alcoholic drinks) while the small-scale and cottage units are chiefly related to food products and handicrafts.

4.9.2.4 *Health and Medical Facilities*

Sikkim claims to have achieved the national norms of 1 Primary Health Centre per 20,000 people and 1 Primary Health Sub Centre for every 3000 people. Considering the small size of population, it was not very difficult for Sikkim to achieve the national norms, but the ratio is in no way satisfactory. In a mountainous area, only 1 health centre for 3000 persons is much less than sufficient. The health facilities in Sikkim include hospitals, health centers, family welfare centers, maternity and child welfare centers, blood bank services, drug de-addiction centers, etc.

Sikkim has 174 registered government doctors and 160 staff nurses. East Sikkim alone accounts for 107 doctors and 125 nurses. The North, South and West districts have 16, 31 and 20 doctors and 10, 15 and 10 nurses, respectively. The total number of hospitals in Sikkim is 5, out of which 2 are in the East district and the North, South and West districts have 1 each. Besides, there are 24 Primary Health Centres (PHC) and 147 Primary Health Sub Centres (PHSC) in the state (Table 16).

Table 16. Distribution of PHCs and PHSCs in the districts of Sikkim (2001-02)

Health Centres	North	East	South	West
PHC	3	8	6	7
PHSC	19	48	39	41

Source: Sikkim: A Statistical Profile, 2002. DESME, Govt. of Sikkim

4.9.2.5 *Drinking Water*

Though Sikkim is located in one of the most humid regions in the country it faces shortage of drinking water at many places. The capital town Gangtok itself faces water scarcity during the monsoons when disruptions occur in the water distribution system due to damage of pipelines. At Gangtok, water is brought from reservoirs at Selep, located at a distance of 16.5 km from the town. The capacity of Selep reservoir has recently been increased to 6 million gallon (MGD) of water per day, still it is not sufficient to meet the growing demand. The water distribution system needs to be improved to ensure equitable water supply.

4.9.2.6 *Energy*

The various sources of energy in use in the state are electricity, kerosene, LPG, firewood, cow-dung and solar power. Till date, firewood and electricity are considered as the chief sources of energy in Sikkim. Since use of wood as fuel is highly restricted in Sikkim, people are encouraged to use electricity and other renewable sources of energy like biogas and solar power. Though the state authorities provide training to use biogas and solar power at village level, these are not yet popular in the state. Rural people still prefer firewood for cooking and heating purpose, while they use electricity only for lighting. In urban and semi-urban areas, use of LPG for cooking is common and for heating and lighting people depend on electricity. Kerosene has limited use, mainly for cooking and also for lighting purpose in areas where supply of electricity is erratic.

4.9.2.7 *Housing*

The ethnic culture and tradition of different ethnic groups determine the pattern of housing to a great extent. The Lepchas, Bhutias, Limbus and Nepalese of Sikkim follow their own ethnic traditions in the construction of their dwellings. While the Lepchas and Bhutias in rural areas prefer stone and wood as construction materials, the Limbus and Nepalese prefer bamboo, mud, straw thatch and tin roofs.

Most of the houses in rural Sikkim are semi-pucca, popularly known as *ikra* cottage (Assam type house) - a wooden structure with tin roof, the walls of which are made of split bamboo plastered with mud or cement. However, in high altitude areas, where both wood and bamboo are scarce, people are left with little alternative but to use stone.

In urban and semi-urban areas, people are now opting for RCC buildings. The skyline of Gangtok and other towns of Sikkim are dominated by modern multi-storied buildings.

4.9.2.8 *Markets*

Sikkim has developed a number of Rural Marketing Centres (RMCs) and Bazars spread over all four districts. All total there are 108 RMCs and 46 Bazar areas in Sikkim. The Bazar areas are classified as Class-I, II and III according to their size and volume of transaction.

4.9.3 The Cultural Profile of Sikkim

4.9.3.1 *The Ethnic Diversity*

The ethnic diversity in Sikkim is very aptly represented by the Tibetan sobriquet "Lho-Mon-Tsong-Tsum" that identifies the three original races coexisting in Sikkim since the reign of first ruler of Sikkim in the 17th century. The word 'Lho' means south and refers to the early Bhutia settlers who migrated to Sikkim from southern Tibet. The term 'Mon' refers to foothills, indicating the Lepchas who inhabited the lower slopes of the Eastern Himalaya, while 'Tsong' refers to the Limbus, another indigenous tribe of Sikkim. However, the dominance of Lepcha-Bhutia-Limbus was toppled by the Nepalese who started to inhabit the state since the nineteenth century and added more diversity to the ethnic scenario of the state. Undoubtedly, the diverse castes, sub-castes and tribes of the Nepalese have given shape to the present cultural fabric in Sikkim. Of late, the presence of people from mainland India and a set of cultures from all corners of the country have contributed to further ethnic diversification.

4.9.3.1.1 *Religions, Tribes, Communities*

Religions : The tribes and communities living in Sikkim basically follow Buddhism, Hinduism and Christianity. Though the early inhabitants of Sikkim, *viz*. the Lepchas and the Limbus were not known to have great religious traditions, they practiced various forms of nature worship. Buddhism entered Sikkim with the advent of Bhutias from Tibet, and took a firm root in the soil of Sikkim with the establishment of Bhutia monarchy by early 17th century. The religion of the new rulers became the religion of their subjects. Hinduism, the other major religion, entered the state much later. It was not until late 19th century that Hinduism had a proper start in Sikkim. The majority of the Nepalese and most of the plains people profess Hinduism. Christianity is another religion practiced and many of the Lepchas and other economically backward classes have adopted Christianity. Besides, a section of indigenous Lepchas and Tsongs practice nature worship (animism, Yumaism) and a small section of the Bhutias profess Bon religion, a precursor of Buddhism in Tibet and Sikkim.

Tribes and Communities: The ethnographic survey conducted by the Anthropological Survey of India has enumerated 25 tribes and communities in Sikkim. These can again be grouped under four ethnic stocks, namely, Lepcha, Tsong (Limbu), Bhutia and Nepalese. While the first three are single, more or less homogenous entities, the fourth one comprises of several castes, sub-castes and tribes.

4.9.3.1.2 *Social Norms and Community Behaviour*

Social Norms: Sikkim is a multi-ethnic, multi-lingual, multi-culture state. Over the years it has become home of the Lepchas, Limbus, Bhutias and Nepalese. Each of these ethnic groups has its own social norms shaped by the exigencies and ways of life.

Community Behaviour: Since Sikkim is a multi-ethnic and multi-religious state, the social structure is not based solely on Hindu caste system as is prevalent in most Indian states. Each of the ethnic groups has its own set of dos and don'ts. Under normal circumstances, one community does not encroach upon another as far as social norms are concerned. Irrespective of the status they have achieved or assigned on the basis of political power, economic backwardness, or religious affiliation, each of the tribes, castes, sub-castes retains the identity of its community. For example, the Bhutias who ruled Sikkim for more than three centuries have retained their commanding position as an elitist tribe in spite of being enlisted as Scheduled Tribe. The upper caste Nepalese still maintains social distinction and follows norms of caste purity/impurity. The Tamangs consider themselves as much Nepalese as the Mangars or Newars, even though their community status shifted from OBC to ST. Again a Rai or a Lepcha follows the norms of his community even if he changes his religion.

Each of these ethnic groups has its own language. Even among the Nepalese, each sub-group has its own dialect. However, Nepali is the language of communication at both intra-community as well as inter-community levels.

4.9.3.1.3 *Cultural Activities*

The cultural activities of the Lepchas, Limbus, Bhutias and Nepalese have distinctive stamp of their root. However, due to the shift of power from one group to other, the comparatively submissive and minority groups have lost much of their originality. For example, the Lepcha culture is partially assimilated with the Bhutia culture and partially with the Nepalese.

Again, the Lepchas who have adopted Christianity are highly influenced by western culture. The Limbus too have adopted much of Hindu culture under the influence of the immigrant Nepalese. The Bhutias, though have retained the essence of a Tibetan culture, are found to have changed with the tide of time.

The cultural activities of all the ethnic groups are strongly influenced and guided by the religions they profess. The cultural activities of the Buddhist Bhutia-Lepcha revolve around the Buddhist festivals. Similarly, the Hindu religious festivals have shaped the Nepalese culture to a large extent. The animistic traits of the Lepchas and the Limbus have curved out an altogether different culture that helped them reviving and maintaining their cultural identity.

4.9.3.1.4 ***Festivals and Environmental Resources***

The festivals of Sikkim are of two types – religious and social. Again, the religious festivals are of different categories depending upon the religion involved. Social festivals too are varied due to the presence of various ethnic groups. The religious festivals according to the dominant religions may be grouped as follows:

Buddhist Festivals	**Hindu Festivals**	**Tribal Festivals**
Losar	Maghey Sankranti	Losoong
Bum Chu	Kusey Aunsi	Pang Lhabsol
Lhabab Duchen	Dasain	
Saga Dawa	Drukpa-tseshi	
	Bhimsen Puja	
	Tihar	
	Bhai Tika	

4.9.4 Quality of Life in Sikkim

For the present work, an interview schedule was structured on the basis of the wants and needs of the people at three levels, *viz*. individual, family and society. Three sets of indicators – economic, social and environmental – were used. The economic indicators included the, a) quality of housing in terms of construction, number of rooms, separate cooking area, toilet facility, sources of energy, water, etc. and b) ownership of assets in terms of household goods, livestock and agricultural land. The social indicators, due to their objective nature, were based on a set of open-ended questions on people's perception of QL and aspiration for a better QL at the levels of individual, family and society. The environmental indicators were inclusive of both natural and man-made environments. Particular emphasis was laid on the availability of natural resources like clean air, water, vegetation and human endeavour for the upkeep of natural resources.

The present study is based entirely on case studies and sample survey. Fifty villages were selected for sample survey and 150 persons were interviewed. On an average three key informants were selected from each of the villages. The selection of informants was purposive but a non-probability approach was maintained in selecting sample villages. The questionnaire design took into account a) facts, b) opinions, and c) attitudes of the respondents. For each of the respondents, a score sheet for ten variables (economic indicators), namely i) Type of House, ii) Number of rooms, iii) Separate room for cooking, iv) Fuel used for cooking, v) Source of light, vi) Source of drinking water, vii) Toilet facility, viii) Livestock owned, ix) Ownership of household goods and x) Ownership of land was prepared. The Quality of Life Index (QLI) for Sikkim was prepared on the basis of scores obtained by the households. The minimum possible score on the basis of economic indicators was 9 while maximum was 75.

In Sikkim none of the houses surveyed scored as low as 9 or as high as 75. Four class groups were made on the basis of scores obtained by the households. The households that score below 20 are poor but stay above the poverty line. The households with scores below 30 fall in the category of lower middle class, and those scoring below 40 belong to the middle class. The few households scoring above 40 belong to the upper middle class. None of the families interviewed were found to be rich (minimum score required: above 50).

Ethnic aspirations apart, all the communities of the area aspire for economic security. The communities living in this part are aware of their natural resources. They are still fortunate to have un-spoilt, pollution-free environment over most of their habitat. They have taken lessons from the errors committed by their neighbouring states and have become cautious in dealing with environment and ecology. They have taken ideas from the west and are keen to preserve and protect their resources. The communities have varying levels of ambition, and they do aspire for development, but they do not want to go the way some of the mountain communities in some other parts of the Eastern Himalaya have gone. All the communities want to have improved infrastructure, especially in terms of roads and communication. They are in favour of exploiting the local energy resources - water in particular, so that they get enough supply of electricity. However, the local people are not in favour of bringing factory-oriented industrial development, rather they would welcome industries like tourism.

Field observation in the area starting from Rangpo to Lachen confirmed that the indigenous people of Sikkim are no longer in favour of isolation. There was a time when the ethnic Bhutias looked up to the Tibetan aristocrats and religious leaders for their worldly as well as spiritual developments. There were regular exchanges across the border and every Bhutia family of the region aspired to adopt the life style and standards set by the northern neighbours. The merger of Sikkim with India took some time to settle in the psyche of the remote villagers. With the closure of borders, the focus gradually shifted to the south. Reservation and inhibition in adopting Indian ways of development is still not uncommon. But after almost three decades of association, the trends are changing and there is a conscious effort to learn and adopt the best of methods suited to their well-being. The villagers are getting used to electricity instead of oil lamp, concrete building instead of wooden one, flush toilet instead of pit toilet, cooking gas (LPG) instead of fire wood, packaged stuff in stead of home made ones and so on and so forth. The instances of sending children to study in a metropolitan city or to join the Indian army are no longer rare.

There has been a massive change in the social and economic scenario of some of the remote villages after the introduction of tourism business. For instance, Lachung in North Sikkim, Pelling in West Sikkim and Ravongla in South Sikkim have become tourism hotspots. To accommodate seasonal crowds, small cottage owners of Lachung, Pelling and Ravongla have converted portions of their households into tourist lodges while the affluents constructed villas and resorts. Lodges have come up even in remote Yoksum and Thangu. Once rare automobiles are now considered as objects of necessity and many villagers own four wheelers. The village shops sell all kinds of manufactured consumer goods ranging from packed instant food to synthetic garments to machine-finished footwear.

Under such circumstances, it is but natural that the local people no longer remain isolated from rest of the world. There are limitations due to attitudinal differences but the people of Sikkim exhibit a rather high level of aspiration. Usually they have good control over all the developmental activities, especially in regard to infra-structural development. The things they cannot do themselves are leased out to others but the reign of control remains in the hands of the villagers.

The ethnic communities living in Sikkim are well aware of the carrying capacity of their native area. The man-land ratio that they maintained for centuries in far-flung pastures and villages is based on calculative experience. They are aware of the wealth of their forest, water and animal resources.

On the whole, the people of Sikkim, though conservative, are not averse to the introduction of improved techniques that help them raise their quality of life. During field visit and investigation it was observed that the local communities were desirous to have, i) Life that is free of diseases, ii) Quality education for children, iii) All weather roads for better communication, and iv) Uninterrupted supply of fuel and power. In other words, the things that they considered most important to bring improvement in the existing quality of life were i) Better healthcare facilities, ii) Education for all, iii) Improved communication network, and iv) Energy resources. The life of the villagers being secure otherwise, they were not necessarily keen to bring in alien techniques, but aspired for an easy and comfortable living by improving upon the existing resources.

4.9.5 Livestock and Animal Husbandry

Sikkim has tremendous prospects of livestock raising in its different parts particularly in cooler hills of the Himalayas. The congenial temperate climate and its temperate vegetation existing in the Himalayas are highly favourable for exotic high producing livestock. Owing the mountain terrain only 15 per cent of the total area is under cultivation where as all most 89 per cent rural population rear cattle, goats, pigs, sheep, poultry and yaks etc in small number and utilized the forest for fodder. The livestock population in Sikkim is widely distributed. In the high altitudes areas yak, sheep and local goats known as "*chengra*" predominated where as in the mid hill and low lying areas, the important breeds of cows are Siri cow and Jersey. Cross breed cows, goats, poultry and pigs are also reared in this region. In Sikkim, the total livestock production is not sufficient for the inhabitants. As a result the Government and Department of Animal Husbandry and Veterinary services have taken many steps for their development. Animal Husbandry and Dairy Development play an important role for upliftment of rural economy in Sikkim. Over all area of the state available for agricultural operation is limited, about 15 per cent of the total geographical area and with the increasing of population, the per capita land availability has been consistently declining. It is therefore, essential that supplementary source of income should be evolved through livestock rearing. Most of the rural people of the state keep different types of livestock like cattle, buffaloes, pigs, sheep, goats, yaks and poultry. Rural people domesticate cattle mainly for meat and milk production. The local cows are, however poor in milk production. There average daily milk production range from 1 to 1.5 litres. In recent year, a large number of cross breed jersey cattle have been developed through National Dairy Development Board, Sikkim. During field survey, it is also observed that, many farmers keep cattle as drought animals and for the ploughing in the field. Number of cattle determines the social status and economic condition of the owner. The cattle also provide manure, which promotes the productivity of soil. In the dry belt of Sikkim goat is the major livestock. The mountain slopes of the state are rocky and the soil is deep and permeable. So, the area is highly susceptible to land slide and soil erosion. It is found that majority of households were not awarded about the quantity of fodder they use for livestock. So, the people are compelled to go to near by forest to collect grass and leaves or send their cattle for grazing in the forest. Such overgrazing and overexploitation create ecological disturbances and environmental degradations. Forest is an important source of fodder. So, deforestation is increasing there by effecting natural regeneration. Due to increase of population, pressure on land and livestock is also increasing. This is responsible for the decrease of carrying capacity of land in the state. The effective integration of the farming with animal husbandry at the village level is essential for optimum utilization of farm. In addition to improve the marketing of products, many co-operative societies have been established for over all improvement of livestock management and the breeding programme. In Sikkim, dairy sector plays a critical role in generating cash income especially for the small dairy farmers. With the improvement in marketing and processing system, this sector is steadily moving towards dairy farming as a means of supplementary income generation and even as commercial enterprise rather than a part of subsistence system. Poultry has emerged as the fastest growing segment in the livestock sector. It offers greater scope for the weaker section of the society especially the small marginal farmers, agricultural labourers, educated unemployment youth, members of SC and ST communities and women folk to input their socio-economic condition and to elevate these segments above the poverty line.

The average livestock population density is low in Sikkim. The states shares about 1 per cent of total livestock of the country. During field survey, it is also observed that, the livestock population is decreasing day by day because of lack of sufficient fodder availability and restriction by the Government on open grazing in the forest. The district wise distribution of livestock indicates that among the livestock, cattle are the largest in number for their multifunctional activities. The cattle are unevenly distributed all over the state. Highest percentage of cattle is shared by the East District (35.26%) followed by the West Distinct (29.17%), the South District (26.04%) and the North District (8.98%). Goat is common and widely domesticated animal in Sikkim. Highest percentage of goats is found in the South District (30.72%) and the lowest is in the North District (10.09%). The East District and the West District both share 29.39% and 29.80% of total goats in the state respectively. It is also observed that about 60% Sikkimese keep pigs. The highest number of pigs is reared in the East District (32.56%) and the lowest number of pigs is found in the North District (11.62 %). The field study also shows that highest number of yaks is recorded in the North District (49.33%). The highest percentage of poultry is found in the West District (34.02%).

The main source of fodder in the state is unprotected forest, wasteland and fallow land. The state is famous for forest resources. Generally, every livestock eat green fodder. However, the agricultural crops are the major suppliers of fodder in form of crop residue, bran, straw and cakes due to non-availability of green fodder. There are mostly ‘passive’ avenues of fodder availability. Cultivable and ‘active’ intensive fodder productions are negligible. Existing land use pattern does not envisage or provide any scope for such active fodder production without which it is hardly possible to raise livestock productivity levels. Out of geographical area, only 22 per cent area is available for fodder production. The major portion of grazing land in the state is under alpine pasture (62.68%), khasmal land garucharan land and cultivable wasteland (1.40%). The highest number of pastureland is recorded in the North District (90.51%) and lowest is recorded in the East District (0.01%). The area under khasmal and garucharan lands is also large in the North District. The fodder availability of the state varies from area to area. It is observed that more than 2.200 kg of fodder are collected from green bushes and jangle. And about 45% of fodders are collected from outside the farms and 28% are collected within the farm. The per month average consumption of dry and green fodder of each animal is 2.5-3 quintals. A livestock needs 60-70 kg green fodder for a day without any other dry fodder.

The main livestock products of the state are milk, meat, bones and hoofs, hides and skins and wool. The dairy development programme in the state was initiated in the year 1976. As a first measure, two dairy plants were set up, one with a capacity of 10,0001 at Tadong in the East District and the other with capacity of 5,0001 at Karfecter in the South District, but another two dairy plants were built in Mangan and Kabi in the North District in 2001. The Sikkim Milk Union has responsible for the development of milk production. Out of total 170 organised milk societies in Sikkim, only 108 registered societies were functioning in 2001-02. According to Department of A.H. & V.S. per day milk requirement in the state was 7,360 litres. During field survey it is observed that the production of milk which was increased from 11,000 to 37,000 litre in 5th – 9th plan period. The livelihood of states 90 per cent population mainly depends on dairy farming and other related allied activities. The Sikkim Co-operative Milk Producers Union Ltd. was created in 1980 for handling 7,000 litres milk per day with 103 registered milk societies and 4,500 milk producers in the state. Due to increase of population, there is high demand for meat and eggs for domestic consumption, but the state has no sufficient production of meat and egg. To meet the growing demand, it is imported from the out side of state like Siliguri (W.B). During field observation, it is found that each household in Sikkim consumed 13.52 kg of poultry meat and 117 numbers of eggs annually in the year 2002-03. In 9th five year plan, about 1,003 million numbers of eggs were produced. The state has only 1% of the total requirement of poultry meat and balance 99 per cent is brought from Siliguri.

Livestock Development Corporation has responsible for trade and marketing of the surplus products. According to SLDC, which sell about 40 thousand eggs and 300 kg of poultry meat per month. The marketing of milk is organized through milk cooperatives under the Sikkim Milk Union. Besides, Sikkim Milk Union, many private milk vendors supply milk at the door of the customers. The Sikkim Milk Union and Sikkim Livestock Development Corporation provides proper marketing facilities for milk meat and other livestock products and by products. During 9th and 10th five year plan, there had been a noticeable improvement in the performance of Sikkim Milk Union and its cooperatives for marketing the products. For better marketing, a separate corporation known as Sikkim

Livestock Processing and Development Corporation is established during 8th five year plan. It is responsible for sale processing and collection of meat in Sikkim. The state has poor transportation. High transportation cost, inaccessibility etc. are the main factors for poor development in marketing sector. All most all the cooperative societies have been rendering satisfactory services for economic upliftment of poor people both is rural and urban areas in the state. During field observation, it is also found that about 31.25% new cooperative societies were established in 2001-02. Among four districts, the West District has the highest number of societies where as less number of societies is found in the North District. At present, the state has 35 marketing cooperative societies. The East District shares 20, the West District shares 2 and the South District shares 13 marketing and cooperative societies. The East District shares the highest milk cooperative societies in the state.

Animal Husbandry and Dairy development play an important role in the rural economy of the state. The Department of Animal Husbandry and Veterinary services have been responsible to bring about an overall improvement in the breeding programme. The Department has also maintained the breeding farms for genetic upgradation, fodder development, consolidation of the infrastructure for ensuring effective and timely veterinary services and embryo transfer technology. The State Government has taken many steps in different plan periods for the development of this sector. For diary development a good quality cross breed milch cows have been imported from out side the state. The state is vast scope for development of piggery farms in view of the large demand for meat and it's by products for domestic consumption. The State Government has taken different schemes for setting up new piggery farms in rural areas. For cattle development the Department of A.H. & V.S. has a definite cattle breeding policy. As per the policy, the indigenous animals are to upgrade cross jersey breeding bulls\A.I are used for maintain the exotic inheritance level up to 50-62.5%. So, Government and department of A.S & V.S have taken many steps for their development in different plan periods by sanctioning loan and subsidies.

The state is a highly undulating and mountainous with steep slopes. So, the land is not suitable for livestock farming. The grasslands are located in high altitudes. As a result, the grazing of livestock is very difficult. Migration of the livestock is also an important reason for under development. The housing condition of the livestock is poor. Most of the houses are made of bamboo wall. Stones are generally used to make the floors of the cattle sheds. The state is a landslide proned zone. Due to heavy landslide in the rainy seasons, the pasturelands are degraded. The quality of grazing land is poor in the state. The unsuitable geological nature of the soils and steep hilly terrain make the soils of Sikkim highly proned to erosion and related problems. Livestock health in Sikkim is proned to be adversely affected due to prevalence of several predisposing situations. In Sikkim, Large section of the livestock species reared in the households are non-descript and hardy. Acute scarcity of feeds and fodders in Sikkim is another important situation, which has a practical bearing on the health status of livestock. The important livestock diseases are haemorrhagic septicemias, anthrax, and food and mouth disease. A parasitic infestation is also important disease by which the cattle, goat and sheep are attacked. During field observation, it is also observed that many livestock have some problems created by virus and bacteria.

The Government of Sikkim processes a wide network of veterinary hospital dispensaries and others, which functions as windows for development in Animal Husbandry. The state is a good demand for food of animals' products such as milk, meat, and eggs and there exists a good scope to utilize other livestock products like skin, hide, wool etc. The Government has also taken different measures for the development of livestock to give financial assistance like loan and subsidy etc. Secondly, the establishment of cooperative society for tendering facilities regarding, procurement transport and marketing, etc. To increase the livestock products, many private and non-Governmental organizations have also building up adequate infrastructure like breeding farms and veterinary treatment centres, etc. Communication facilities and transport are also most important measures for animal husbandry and dairy development. In current year, the modern technology like T.V., Radio, etc. are the main medium for supply proper weather report, climatic condition and other natural calamities to the farmers. Scientific breading of livestock has always been preferred for higher yield of milk, meat and wool. The Department of Animal Husbandry and Veterinary Services have been emphasising on the cross breeding of the local livestock with exotic cattle, sheep, goats and pigs and improved strains of poultry birds. In view of favourable environment condition in the state, there is a great scope for breeding different kind of livestock for higher yield.

4.9.5.1 *Suggestions*

Sikkim, which is situated remotely and faced with problems of transport and communication, setting up of district level livestock farms will go a long way to meet the requirement of livestock productions to a great extent. The steep slope, difficult terrain and remote far-fetched rural habitations of Sikkim present for mid-able constraints against a viable marketing strategy for intensive livestock production activities. The basic guidelines, which observed for operating an efficient marketing system for livestock products are :

i) Good transport facilities for livestock production.

ii) Supply of inputs like feed, seeds, supplements medicines etc. must be coupled with marketing of products to economies the cost of transport.

iii) The state Livestock Products Marketing Agencies must play the role of buffer between the producer and the consumer so that during situations of varying supplies and demands, these agencies can help in procurement, supply and maintenance of price level.

4.9.5.2 *Dairy Development and Preservation*

For the development and preservation of dairy products the Government should take following steps:

i) To bring more areas under milk producers' co-operative societies and milk collection centres.

ii) Better processing and hygienic packing for clear milk production to delivering school children, households for the nutrition programme.

iii) Other measures like- more and more milk collection centres should set up.

iv) More milk plants have to be set up.

v) Another development Schemes like processing unit for milk products should be set up.

vi) One Milk Union has been able to establish a reliable marketing channel for the milk producers in Sikkim.

RECOMMENDATIONS

After the assessment and evaluation of the overall environmental scenario in Teesta basin in Sikkim during the studies, the following conclusions have been drawn and recommendations have been based upon that. These conclusions and recommendations have been described in the following paragraphs.

1. GEOLOGICAL SENSITIVITY AND VULNERABILITY

- Physiographic studies show that the valleys in the northern parts of Teesta basin are asymmetrical which indicate instability and proneness of slopes to sliding.
- Major portion of high altitude watersheds in North, West, South and East Sikkim is dominated by periglacial and fluvo-glacial environments. These are highly unconsolidated mass of debris waiting to be hurled down due to disturbance by any available natural agency like heavy precipitation at any point of time or by human interference. Glacial moraines, mostly confined to North Sikkim, along with numerous active landslides in the region, indicate that this locale represents a fragile ecosystem.
- The present studies show that most of the glaciated areas in the North and West Sikkim are highly dissected by a number of drainage channels which cause severe erosion and bring about downstream siltation.

- A number of geological processes that lead to weathering and denudation like down cutting, solifluxion, debris avalanche, slide slumps, mud-flows, debris flows are quite frequent especially in various parts of North, South and East Sikkim. These degradational activities are further assisted by presence of steep slopes and softer rocks particularly in the middle and southern parts of North Sikkim.
- There is an evidence that vertical and lateral erosion on both the slopes of Teesta river is severe and intensive and due to non-uniform erosion the relative relief of North, West and South Sikkim districts decreases from North to South. The differences in relief across North-South in North Sikkim especially to a great extent has been shaped by land degradation due to natural processes of degradation, removal of forest cover and subsequent erosional activity.
- The southern fringe areas in the Teesta valley comprise a belt of slates, quartzites, etc. with inter-mixed carbonaceous bands and thin coal seams and exhibit distinct evidence of earth movements consequent to the Himalayan orogeny.
- During the formation of Darjeeling-Kalimpong or the Sikkim Himalayan ranges, intense folding, faulting and thrust movements have taken place. These tectonic features act as trigger points for catastrophic manifestations of the natural dynamic forces resulting in earthquakes and landslides. These events represent serious geological hazards and make the region highly fragile- and sensitive to any disturbance.

- There are a number of thermal springs as well as glacial lakes in the North, West and East Sikkim. The presence of thermal springs is indicative of instability, while glacial lakes represent a serious threat in the event of a cloud burst or rock slides resulting in bursting of these lakes and bringing about serious hazards downstream. Our studies have shown that majority of these glacial lakes are undergoing structural changes which is an indication of their vulnerability to bursting and downstream flooding.
- The spatial distribution of seismic activity in the region during the period 1964-1992 suggests that the regional seismicity of Sikkim Himalaya is relatively high in the north of the Main Boundary Thrust (MBT). There is evidence to show that this activity decreases progressively southward from the Lesser Himalaya to the fordeep region under sediment cover.
- There is a tremendous gap in the availability of seismological data especially of the North Sikkim area, therefore, it is extremely difficult to suggest vulnerability of this zone to hazardous phenomena like earthquakes. However, a large number of active landslides in the region along Lachung and Lachen axes provide evidence to the high degree of seismic and geological fragility of this zone.
- The thick moraine deposits at several sites in North Sikkim provide weak substrates on which it seems very unsafe to establish any mega developmental project. Establishment of even smaller projects in this region would require detailed surface and subsurface investigations as well as proper engineering and seismic designing.

- The landslides along the Teesta and Rangit supply huge amounts of sediments into the river channels. These sediments travel in the form of debris and hyperconcentrated flows and subsequently diluted into channel flows. The debris and hyperconcentrated flows owing to their high velocity and sediment concentration are important erosive agents because they may lead to toe cutting of terraces present alongside the river channel. Therefore, it is important to assess toe cutting of terraces which are situated along the channel because such events would destabilize the settlements developed on these terraces.
- In Sikkim the confine of a cluster of epicenters in several regions and parallelism of the courses of major rivers and their tributaries either with the NE-SW or NW-SE shears and the seismogenic nature of MBT up to the mantle do not rule out any future large magnitude tremor in such regions. Therefore, there is always necessity of suitable seismic designing for any engineering structure in Sikkim. This is more so in the light of recent earthquake of February 24, 2006. Therefore, after, looking at the recent earthquake of February 24, 2006, all the structures should be designed according to the specifications of ISI.
- Necessary excavation and grouting of the geologically weak zones in such regions are important where developmental activities are aimed. Primary to this is the necessity for a constant vigil on the neotectonic activity in the region, such as active landslides and associated disturbances in the basin, during and after the construction operations.

- Lanslides are one of the recurrent problems in Teesta basin in Sikkim. The traditional remedial measures like
    i) sealing of cracks with bitumen,
    ii) construction of good outlet of rain water in the form of catch water drains, and
    iii) rock bolting by wire mesh with boulders extending down to the river bed to check the toe erosion should be adopted at only at selective localities.

  However, wherever the unstable geological structures (*viz*. highly jointed igneous and metamorphic rocks) are dipping towards the roads or river channels, the roads must be diverted from such areas.

2. BIOLOGICAL ENVIRONMENT

2.1 Floristics

- The new reports of plant species clearly indicate for the need to do a lot to understand and document the floral wealth of Sikkim. Still there are numerous reports of collection and identification of new species. Lucksom (2004) reported a new species, *Zeuxine seidenfadennii* from East Sikkim. Even new species are being reported in the genus which includes many endangered species from Sikkim.
- A new species of *Lactuca, L. pseudo-umbrella*, has been reported from Kupup in East Sikkim (Maity and Maiti, 2001). The species is very close to *L. cooperi* which is endemic to Sikkim and reported as endangered (Nayar and Sastry, 1987).

- Two species of *Ceropegia* were rediscovered in Sikkim nearly after 100 years, which are endangered and endemic in the Teesta basin. Similarly we have in a way rediscovered three species of *Begonia* after a gap of more than fifty years. These species are either considered extinct or are in the category of endangered plant species (Nayar and Sastry 1990).
- It's not just sufficient to locate and identify a new plant species. Now there is a need to study the ecology, physiology and evolution of such species. The commercial aspect for this plant wealth and its preservation for our future generation are very important.

2.1.1 *Floral Hot Spots of Sikkim*

- North Sikkim has about 30% of forest cover, however, it is foremost with respect to the number of flowering plants or number of endemic and threatened species of flowering plants as compared to other districts. More than 60% of endemic species are located in North Sikkim only. In other districts, the number of endemic species is less than 25 per cent. Similarly maximum number of flowering plants categorized as threatened are found in North Sikkim only. From Sikkim Himalaya around 53 species of flowering plants are mentioned as threatened. Of these 27 species were located in North Sikkim, particularly in Lachen-Lachung valley and Zemu valley. In North Sikkim, there are some locations which are ideal for speciation of various plant species. Like Shingba for *Rhododendron* spp., Thangu-Chhoptha region for *Aconitum* and *Podophyllum*, Lachen-

Lachung valley for *Panax pseudoginseng*. At Shingba, which has been declared as Rhododendron sanctuary, one can find various morphotypes having different flower colour, leafsize, plant height, etc. From Thangu region a new type of *Aconitum* has been identified which has new chromosome number 2n = 48.

- From North Sikkim 8-10 different types of *Panax pseudoginseng* were identified based only on leaf characters. Further work is going on in this direction to identify these plants based on chromosome number and other molecular characters. A number of plant explorers also have identified Lhonak valley, Lachen-Lachung valley, Yumthang valley and Zemu valley in North Sikkim as being very rich in floristic diversity.
- Teesta river basin is an ideal place for the cultivation and commercial exploitation of orchids. Various government agencies and private companies are coming up now in orchid cultivation. Central government (ICAR) has rightly selected Sikkim to establish a National Research Center on Orchids at Pakyong with an objective of conservation, protection and propagation of Orchid germplasm and various other aspects.
- Even then a lot is required to be done for the conservation, protection and commercial exploitation of these beautiful orchids. Even the present documentation of orchids in the report from such a small area is not complete and record of orchids from Sikkim is incomplete as still new records of orchid species from Sikkim. Species like *Liparis dongchenii, Calanthe anganii, C. keshabii* and *C. yuksomensis* are the recent records from the Sikkim Himalaya.

- Most of the edible wild plants have high nutritional value, particularly, rich in minerals, contributing the low-cost nutritional supplement.
- No step has been taken up yet from any side to commercialize these edible wild plants and their products or domestication of these products in mass–scale production using modern agricultural practices.
- It is suggested that some of these wild plants may be domesticated which may contribute significantly to the nutritional value in local diet. Edible wild plants are no doubt, food security of the region, during scarcity of domesticated seasonal products.
- The R & D Centre for the ethnic traditional foods should be set up to open the way for industrialization of some traditional food production with consequent benefit to the regional economy and employment.
- Gene Bank may be set up to deposit important microorganisms involving in traditional foods preservation, which may ensure to conserve microbial diversity of food eco-system.
- Institutional mechanisms should be developed to commercialize the ethnic fermented foods, and also develop food entrepreneurship in Sikkim.
- Very little attention is being paid to the development of Minor Forest Produce in the area. It is, therefore recommended that integrated programmes are formulated to encourage minor forest produce development.

2.2 Fauna

- The altitudinal zone of 1,800 m to 2,800 m (Zone-III) in the Ttemperate broadleaf forest has the highest species richness among mammals. Species richness is one of the most important criteria in the selection of areas for conservation of biodiversity. Moreover, zones with lower species richness have species that are not found in the other zones, typical example being the high altitude mammalian community. This zone also has Schedule I species (WPA). **Therefore, it is extremely important to keep these habitats undisturbed for the mammalian community.**
- The altitudes <900 m (Zone-I) is another important zone, especially for small mammals. However, this zone currently has no protected area coverage. There is, perhaps, very little scope for this at present, as this zone is almost entirely inhabited by people. The current land use in this zone predominantly consists of small patches of original forest (although degraded), a variety of seasonal crops grown with very little use of agro-chemicals, and the retention of several species of native trees in agricultural fields as source of timber and fodder. This pattern of land use is very conducive to the retention of several species of mammals, birds, herpetofauna and butterflies. **Therefore, there is a need to retain remnant patches of forest, native tree cover in agricultural fields.**
- Zone-II, the second species rich zone, is the habitat of many endemics including Chestnut-breasted Partridge, a vulnerable species. This zone is also slightly disturbed mainly due to cardamom

plantation. However, the studies on bird and butterflies of these landscapes suggest that there is not much difference in overall species richness in cardamom agroforest and the original forests.

- Zone III (1,800m- 2,800m) is the most abundant and species rich zone among all the zones with respect to birds. It harbours the habitat for many endemics and threatened birds such as Hoary-throated Barwing, Broad-billed Warbler, White-naped Yuhina and Chestnut-breasted Partridge. It also harbours maximum number of habitat specialists and many undergrowth birds' species such as fulvettas, laughing thrushes, parrotbills and babblers, which are either absent or less abundant in other zones. Among the endemics, Hoary-throated Barwing and Wedge billed Wren Babbler are restricted to this zone. The pristine vegetation with dense bamboo undergrowth is the peculiarity of this zone. There is not much pressure on forests and human habitation is low in this region. But still there exists a low level of poaching with respect to pheasants. **The reason of the low abundance of pheasants in spite of such a good habitat may be due to the illegal killing of these vulnerable birds. Therefore, immediate attention should be paid for the preservation of these species.**
- The two high altitude zones although, posses relatively low species, is the habitat of many high altitude birds which are never seen in any of the other zones (exclusive species to the altitude or forest type). **These zones are the breeding grounds for many migratory waterfowl including the Black-necked crane.**

- Earlier workers from Sikkim recorded a total of 61 species of reptiles and 20 species of amphibians. In this study, 32 and 14 species, respectively of reptiles and amphibians could be recorded. Zones I and II are very important for herpetofauna. However, this zone currently has no protected area overage and is severely degraded due to anthropogenic pressure. **The highest species richness in these two zones is an indication of the great conservation potential of this landscape. Both amphibians and reptiles are known to be microhabitat specific such as under boulder or decayed logs, hence any alteration in microhabitat will have severe effect on the taxa.** Agamids such as *Japalura variegata* and many tree dwelling snakes usually bask in small tree and shrubs (0.5 to 2m above ground). Fragmentation or disturbances of any kind in the forest may have an adverse effect on these species.
- All the reptiles and amphibians of Sikkim are protected under Schedule-II and IV of Wildlife Protection Act 1972. The only Schedule-I species *Tylototriton verrucosus* is reported to occur in Sikkim but its status is still unknown. Further research on this species may yield information on its range. The present study showed the occurrence of Indo-Malayan species like *Elaphe porphyracea, Takydromus sexlineatus* and *Trimeresurus* sp. that is yet to be confirmed. Looking at the paucity of information on number of species, even after these studies, more in-depth study of these species may throw more light on biodiversity and

biogeography. Further studies are essential as only after then any concrete conclusion can be drawn.

- Out of 689 species of butterflies 116 species are protected under different schedules of wildlife Protection Act (1972); 29 (Schedule-I), 92 (Schedule-II) and eight (Schedule-IV). Most of these butterflies are recorded from Zones-I and II which attract research and conservation plans.
- In all, 798 vertebrates and 689 species of butterflies have been reported from Sikkim including 169 mammals, 541 birds, 61 reptiles and 20 amphibians. During the field sampling for two years, 375 species of vertebrates and 223 species of butterflies were observed. This records form 40.4% of the total species present in the state. The sampling area of the present study is restricted within two kilometers (on either side) from the vicinity of the Teesta River covering about 600 sq km, which is about 8.5% of the total area of Sikkim (7,096 sq km). The record of over 40% species within this small area within two years of field sampling indicates that Teesta valley is rich in terms of biodiversity. It is expected that further intensive and continuous sampling would result in more species. Hence, Teesta valley is vital for the conservation of biodiversity in Sikkim.
- Higher diversity of mammals, birds and reptiles were found in Zone-III (1,800-2,800 m) where Temperate broad leaved forest is common. Specific localities include areas around Chungthang, Lachen and Lachung and intervening forests connecting these localities.

- The Nepal Langur is a recently elevated new species whose distribution is restricted to high altitudes of Sikkim (in and around Lachen), Nepal and Bhutan. It is only found in overlapping zone of Temperate broadleaf and Coniferous forests at an altitude of about 2,800 m. **The same region is also the habitat for the Red Panda, which is the state animal of Sikkim and is restricted to higher altitudes only. Serow found in Zone-III is restricted to Himalaya from Sikkim to Kashmir. The Marbled Cat is an extremely rare and nocturnal species and has been reported locally around Chungthang in Zone-III.**
- Five endemic bird species could be recorded during this study, namely Rusty-bellied Shortwing, Broad-billed Warbler, Hoary-throated Barwing, Yellow-vented warbler and White-naped Yuhina. Rusty- bellied Shortwing, a threatened endemic, seems to be rare as it was sighted only twice in Zone-IV, but the other four species are locally abundant and recorded frequently.
- Several species of reptiles (e.g. pit vipers, skinks, and Himalayan agamids) are restricted to the middle altitude of the Sikkim and Eastern Himalaya. The snow toad (*Scutiger sikkimensis*) is an endemic amphibian of the region, along with several species belonging to the genus *Paa*. Both higher and lower altitudes had higher number of restricted species of butterflies.

2.2.1 Conservation Measures

Looking at the number of species of studied taxa and the endemic exclusive and endanged species of studied taxa,

Zone-III is very sensitive, and if the development project (Teesta Stage-III) is executed in this zone (1,800-2,800 m, Temperate broadleavd forest, near Chungthang), an irreversible ecological damage is expected with respect to its biological environs.

- It is important to implement conservation measures in all the areas as most of the forests in these zones are not within any protected area except some areas in Chungthang, which falls under the buffer zone of Khangchendzonga Biosphere Reserve. Hence, effort may be taken to create additional protected areas.
- There are a number of cattle sheds between Lachung and Yumesamdong. Further, the local people of Lachung, Lachen and Chungthang collect firewood for cooking from the pine and Rhododendron forest of Shingba and Yumthang which subsequently reduces the forest cover. The firewood of Rhododendron is much preffered than other species. Most of the local people collect leaves of *Rhododendron nivale* for incence. **Hence, alternate livelihood should be developed for the people of this remote area.**
- **One of the major threats especially to both large and small mammals, larger birds and amphibians (*Paa* spp.) is hunting which needs to be checked.** In case of project implementation, influx of a large number of non-native labourers and project personnel would give additional pressure on forests and wildlife. Appropriate facilities such as fuel may be provided by the authorities, which would reduce pressure on natural resources.

- **Entirely alien environmental conditions would be created by human activity during and after the construction of the proposed hydel project. If these sites were neglected, they would become dominated by exotic and weedy species resulting in biological communities that are unproductive, valueless from conservation perspective and unappealing. These sites need to be properly managed and native species reintroduced wherever required so that the original communities can be successfully restored with respect to species composition and vegetation structure.**
- Awareness programmes for locals, tourists and members of government machineries on wildlife and general up keep the environment is required. This is one of the prime needs to conserve the rich faunal diversity of Sikkim.
- Further monitoring with initiation of more extensive studies on individual species is required to understand their home ranges, behaviour, requirements and so on.

In all, the present study shows that Zone-III (where Teesta Stage-III is prposed) is very important with respect to conservation of the biodiversity of the region. Similarly, Zones-IV and V (area in the vicinity of proposed Teesta Stage-I & Stage-II HE projects) harbour higher number of breeding birds and exclusive species of the taxa studied. Hence, any development project would endanger them. Also, Zones above III are geologically vulnerable, and anthropogenic pressures would lead to natural disasters.

3. AQUATIC ENVIRONMENT

3.1 Water Quality

- The nutrient concentrations in the water were recorded to be significantly low in upper stretch whereas there were noticeable temporal and spatial variations in nutrient concentrations in lower stretch. In addition to the natural source of nutrients, waste water and agricultural run off contribute to the nutrient levels in the river waters. Therefore, the low concentrations of nutrients (nitrate and phosphate) in upper stretch of river Teesta are attributed to low human population, agricultural practices and absence of waste water drainage in the vicinity of these streams. On the other hand highly disturbed stretches like Rani Khola recorded higher concentration of nutrients. The physical and chemical characteristics of these streams affected the biological status of these streams. In lower stretch of Teesta and Rangit rivers have rich biotic diversity while Rani Khola, most stressed stream, is low in biotic diversity.
- The majority of phytoplankton and phytobenthic species in all these streams were pollution intolerant and indicated a non polluted state of these rivers in general. However, in Rani Khola and Rangpo Chhu, common occurrence of a few pollution tolerant diatom species like *Gomphonema sphaerophorum, G. parvulum, Nitzschia palea*, etc., indicate that these streams are relatively more polluted. The anthropogenic activities including fishing activities are more prevalent in Rani Khola, therefore, resulting in poor biological health of Rani Khola. Most of the taxa among

macro-invertebrates (Heptagenidae, Baetidae, Hydropshychidae, etc.) were pollution intolerant in all streams of Teesta river.

- The present investigation indicates that water of Teesta river basin is generally healthy in its physico-chemical and biological water quality. However, the overall water quality in the lower stretches of streams like Rani Khola and Rangpo Chhu (at Rangpo) is relatively poor due to anthropogenic activities in their catchment. i.e. imainly due to the location of townships like Gangtok, Pakyong, etc. in its upstream catchment.

Therefore, in order to maintain the good water quality conditions, the following safeguards are suggested.

a) The damming of river should be avoided in that region where fish migrates or if necessary low dams should be encouraged.
b) There should be improvements in fish habitats by protecting the stream banks, maintaining natural pools and riffles in the river channel.
c) Fish pass (fish ladders) must be provided in dams and barrages for the migratory fish.
d) Watersheds i.e. the catchment area should be treated to minimize the siltation in rivers.
e) Faulty or illegal fishing techniques should be prohibited.
f) Fishing during breeding seasons in identified breeding grounds should be prohibited.
g) The aquaculture research and artificial breeding should be encouraged in the area.

h) Cultural fisheries should be emphasized in the region to minimize the fishing loads on natural water resources.
i) Ample caution should be exercised during the introduction of exotic fish species. They should be reared in stagnant waters as in rivers they may eliminate indigenous species.

4. WATER ENVIRONMENT

4.1 Hydro-meteorology

- At present there are 19 ordinary rain gauge stations in Teesta basin in Sikkim. As per the WMO guidelines, it would be desirable to have about 21 rain gauges. Accordingly, additional four rain gauge stations should be installed in the valley preferably at Donkung on the Lachen Chhu, Namchi (South), Rangpo (East), Naya Bazar (West). It is also suggested that three additional self recording rain gauges may be installed at Lachen, Gyalzing and Gangtok stations.
- In addition to these rain gauge stations, snow gauges are also required to be established for measurement of snowfall at the higher altitudes. It is suggested to establish snow gauge stations at Thangu, Yumthang Chhu, Nathu La, Jambong on Zemu Chhu, Lampharam.
- Average annual normal rainfall in Sikkim is about 2,534 mm. It is observed that the month of July receives maximum rainfall of the order of 480 mm and minimum normal rainfall of 19 mm is recorded in the month of December for the Sikkim as a whole.

- The altitude of the station also influences the coefficient of variation (CV). The coefficient of variation is generally found to increase with higher altitude.
- Monthly rainfall values are available for the 19 rain gauge stations in the state of Sikkim as obtained from IMD for varying time periods. The 75 percent dependable rainfall in the basin in Sikkim works out to 2478 mm.

4.2 Hydrology

- **Water availability studies show that there is adequate water in the Teesta river system to take care of the proposed developmental activity particularly the hydro-power generation.**
- **Though the water availability both at 75% and 90% dependence levels, would be sufficient for the proposed generation of power, there may be a limitation of the resource during the lean season particularly because the area falls under high altitudes. Also, the presence of a number of large glaciers in the vicinity would further limit the required water availability during long winters.**
- Sediment load studies have shown that the Teesta river system carries high load which is indicative of severe degradational and depositional processes going on in the valley.
- **Though much of the silt load is received during monsoon months, which is an elongated season in Eastern Himalaya, this phenomenon may be one of the limiting factors in a water resource development activity.**

- The studies also show that coarse silt constitutes a major portion of the sediment load which is indicative of frequent landslides and on-going activities of erosion upstream in the valley.
- There are at present 11 G&D stations, maintained by Central Water Commission. **Setting up of additional seven hydrological stations is suggested** taking into account the terrain conditions, and availability of suitable places for locating the headquarters for the positioning of staff. Gauge and discharge observations at the existing stations shall be continued.
- Maximum silt load is carried in the month of July and minimum in the month of October during monsoon period.
- Average sediment load during monsoon increases from the upstream to the downstream sites from 0.29 th cum/sq km to 1.53 th cum/ sq km.
- Coarse silt load is higher in upper reaches of the river while fine silt is more at downstream reaches.
- Average rate of sedimentation is the highest at Dikchu at 0.95 mm/year, followed by Sangklang while it is minimum at Chungthang at 0.32 mm/year
- Average annual runoff at Chungthang, Sangklang, Dikchu and Khanitar is 4332 Mcum, 7860 Mcum, 9580 Mcum and 11569 Mcum, respectively.
- 100 year return period flood at Khanitar site is 5779 cumec.
- Maximum silt load is carried in the month of July and minimum in the month of October during monsoon period.

- Average sediment load during monsoon increases from the upstream to the downstream sites from 0.29 th cum/sq km to 1.53 th cum/ sq km.

4.3 Irrigation

- Ultimate irrigation potential through minor irrigation schemes is 50 th ha, out of which 32.10 th ha has been created up to March, 2004.
- Utilization of the created potential need to be improved from the level of 77% in March 2002.
- The feasibility of developing irrigation potential through major and medium schemes, which has been identified as 20,000 ha, should be re-ascertained. In case the possibility of the same does not exist, scope for alternative strategy, as deemed relevant with respect to physiographical characteristics of terrain should be investigated and pursued for implementation.
- Status of Minor Irrigation (M.I.) Census (1995-96) of the state shows that all the 854 M.I. schemes jointly serve about 17106 ha of CCA with irrigation potential of 20010 ha. However, actual annual irrigation up to 1993-94 has been indicated as only 12493 in the above census. It means that even though utilization of created potential has been shown as 77% of the created potential, there is still a sizeable lag between the potential utilized and actual irrigation, which should be reconciled appropriately.
- Although the status of M.I. Census (1995-96) shows that out of total 854 schemes, only 88 are not working, the Master Plan for

Irrigation Development (1995), prepared during the same period reports that 419 schemes need appropriate measures according to their stage of functioning i.e. 119 are defunct, 105 are partially functioning, 142 need special repair and 50 need improvement. This needs to be reconciled at present level so that a realistic picture may emerge.

- A total of 17106 ha of CCA are covered by all the 854 M.I. schemes as per the Census. However, CCA of 14566 ha is found to be covered by 419 schemes in the Master Plan, leaving only 2540 ha for remaining 435 schemes which does not appear reasonable and hence need to be reconciled.
- The implementation of M.I. Schemes as contained in the Master Plan (1995) was planned for a period of 10 years. Nine years have since passed. The implementation of schemes *vis-à-vis* creation of irrigation potential does not appear to be progressing in a planned way. This should be attended to with adequate emphasis since the state is substantially deficit in reaching self-sufficiency stage in food grain production.
- As per information available, 1176 minor irrigation schemes have been constructed up to March, 2003 with 972.38 km length of channels.

The following recommendations have emerged for irrigation sector.

In the state there are many areas where hardly any rainfall occurs during winter season and in these areas, the fields remain dry for about six months i.e. w.e.f. November to April. Major drought prone areas fall in south district, followed by west district and some parts of east and north districts. The above Committee collected the available relevant data and also undertook field surveys and identified total number of 188 blocks for Drought Prone Area Programme (DPAP) in four districts which included a geographical area of 70000 ha and 15,000 households with the area to be treated as 32,000 ha. To tackle this problem, schemes under the following categories were formulated for implementation during 1995-96 to 1999-2000.

i) Soil and water conservation measures
ii) Agronomic measures
iii) Horticulture measures
iv) Other measures

5. AIR ENVIRONMENT

Assimilative Capacity of the study region has been determined by two different methods. The first method is based on Ventilation Coefficient, which is product of mixing height and wind speed. The second approach concern with the pollution potential of the atmosphere which is based on the emission of air pollutants from various sources as well the meteorology and is determined through mathematical dispersion models. An assessment of the comparative study of these two approaches enable one to draw some plausible operational schedule for emittion sources. The result from the first approach reveal that the ventilation coefficient is always less than 6000 m^2m^{-1} in the afternoon hours whereas mixing height and wind speed in the morning and evening hours do not exceed 500m and 4 m/s respectively, which indicates that assimilative capacity is not good.

However, the results of two approaches are found to correlate well in those afternoon hours in which ventilation coefficient indicates better assimilative capacity. The model also shows less concentration in most of the cases. On the other hand the ventilation coefficient indicates lesser values i.e. low assimilative capacity i.e., low assimilative capacity in morning and evening hours which corresponds to relatively high concentrations from the model.

The recommendations of this study are enumerated below.

(i) Vehicular traffic is the major source of pollution whose emissions may be controlled through fuel improvement and technological changes in the vehicles.

(ii) Diesel may be replaced by CNG and low sulphur diesel in vehicles.

(iii) Local awareness of air quality improvement in public through media may help to improve the air environment.

(iv) CALINE-3 and IITLS models are giving comparable results of air pollutants. But IITLS model, appropriate for Indian Meteorological conditions are performing better than Caline-3 model. Therefore one can use the IITLS model for planning and management purposes in the study area.

(v) The SPM emission due to construction activities at various places in study area have been taken into account due to unavailability of data which might have increased the concentration of SPM.

(vi) On the basis of above results and discussion, one can conclude that air pollutants in study region are within prescribed limits at most of the places in study area.

6. ETHNIC FOOD TOURISM

- Ethnic food culture harnesses the cultural history of particular community, their worth indigenous knowledge of food production, vast nutritious qualities, microbial diversity associated with fermented foods as genetic resources, source of income-generation related to tourism and enjoyment of dining.
- The concept of ethnic food tourism may have relevance in present days due to increase in tourist industry in the Himalaya. Movement and interaction of people, sense of respect to traditional value and culture will serve to intricately link the enjoyment of dining to locale, making this the standard of food culture of the region. Finding enjoyment in eating the produce of the region while in that region – herein lies the essence of a food culture that gives confidence in life, pride to the people of the region and ultimately, enjoyment and friendship. Further, it imparts meaning to the act of travel and bestows happiness upon the traveller. The promoters have to focus on the specific food culture of a region in a presentable form where tourists can find local cuisine in menu, signifying the food culture of a region.

6.1 Prospects of ethnic traditional foods

- Food industry is a sunrise industry with emphasis on culture, tradition, cost-effectiveness as well as the interface between health and nutrition. For example, kinema is high plant protein food with low fat and rich in essential amino acids, and is less-expensive, but is confined to particular consumers, mostly because of its flavour and sticky texture. The typical flavour is the characteristic to kinema developed due to proteolytic activities. Most of non-consumers, who are not familiar, do not prefer to eat kinema. Flavourless kinema cannot be developed, and if developed it will be a new product with distinct characters, different from kinema.
- Three potential avenues for product development from traditional foods are: Re-creation of authentic food products; benefit of culinary and/or functional properties; and exploitation of technology. Many commercial products have been developed using the characterization of food fermentation as a basis. Technical parameters contribute to only one part of the equation in the successful commercialization of traditional food products or processes. Where and how these new products fit into a given market will largely define business success if and when such processes are industrialised. Availability and consistent supply of raw materials, basic infrastructure, administrative policy, cost of capital, legislation and trade issues, and import/export restrictions are all necessary for considerations for industrialization of traditional foods.

- Some traditional foods such as *sihnu, silam, chinday* and many edible wild plant foods have medicinal values. Such foods if studied properly may be projected in the global markets. The R & D Centre for the traditional foods of the Sikkim Himalaya should be set up to open the way for industrialization of some traditional food production with consequent benefit to the regional economy and employment.
- The art of tradition and culture of making the food at household level has to synergise with regulatory standards. It is important to interface traditional foods with health, safety, nutrition and cost. Value addition to traditional foods through interface of food science and technology for better products is the need of the day. There is a need to have a much larger perspective plan for ethnic foods of Sikkim with a global approach. Traditional food has to be traditional and has to be promoted keeping in view of the fact of ethnic demand and cultural interface, and also respect of skill and expertise of ethnic people for building up a global approach of traditional foods.

7. SOCIO-ECONOMIC ENVIRONMENT

- According to 2001 census, population of Sikkim was 540,943. An increase of 33% was registered during the decade 1991-2001. Average density of population is 76 persons per sq km.
- Population of the state has been projected as 968,173 and 1413,673 for the years 2025 and 2050, respectively.

- The literacy level in the state is higher at 69.68% (Census 2001) against the All India average of 65.38%.
- Net sown area of the state was 62.04 th ha with total cultivable area 108.89 th ha (15% of geographical area) as per 1995-96 land use statistics.
- Though cultivable area has marginally increased from 97.52 th ha to 108.89 th ha during 1980-81 to 1995-96, the net sown area has decreased from 78.38 th ha to 62.04 th ha during the same period, primarily due to substantial increase in fallow land which is other than current fallow.
- Effort should be made for possible appropriate use of cultivable waste land (CWL), which is quite sizable in the state. The possible use of such land could be its inclusion in net sown area (NSA) after undertaking appropriate soil conservation & improvement measures.
- Similarly possible use of barren and un-culturable land (BUL) may be brought under forest, area under non – agricultural uses, permanent pastures and other grazing lands for which meticulous planning and implementation strategy need to be formulated.
- For implementation of above land resource management strategies, use of efforts by Govt. of India, especially in regard to the funding of such schemes by GOI should be utilized.
- Distribution of land holding in Sikkim is skewed. Marginal holders represent about 50% of land holding and hold 10.3% of total operated land area.

- Agro-climatological data along with average normal rainfall values has been used to work out net irrigation requirement for paddy and wheat crops.
- Overall efficiencies of 73% for paddy and 56% for other crops have been used to work out gross irrigation water requirement.
- Introduction of new crops (including wheat, rajmah, rape seed and mustard), extension of more areas under high-yielding and improved varieties of seeds, increased use of fertilizers and pesticides and expansion of area under double or multiple cropping would be helpful in overcoming subsistence farming to economically viable venture and it should be pursued more vigorously.
- Since horticulture development involves substantial scope of increased economic activity in the state, an appropriate mechanism need to be evolved to give adequate thrust on this front.
- Crops, which are not under organized sector(s) such as fruits and vegetables, are more liable to reporting of unrealistic figures in respect of cropped area and production. Therefore, this anomaly between the reported figures from various sources needs to be verified and reconciled.
- Strategies *viz*. adequate investment in land development and water harvesting structure, strengthening the government farms, encouraging private seed farms as joint venture undertakings, mechanized farming, large scale demonstration on packaging technology involving HYV, fertilizer and Integrated Pest

Management (IPM), development of human resources, post-harvest storage, processing, packaging including consumption, etc. with respect to agriculture development during tenth five year plan be rigorously pursued.

- Any scientific system of harvesting the rainfall during monsoon period and utilization during the *Rabi* season has not yet been established, although some of such structures constructed during recent years have been quite useful. Proper investigation needs to be done for development of rain water harvesting structures, at least for meeting drinking water needs.
- It is much cheaper to import fertilizer than the food itself and every unit of fertilizer being used increases the food production by two or more units. This is especially relevant due to very high transportation cost in hills and hence use of fertilizer should be encouraged.
- Except the paddy field, more than 50% of other lands are either improperly terraced or unterraced due to which plant nutrients are lost by run-off and leaching, whenever there is high intensity rain during monsoon. Besides, cultivation is also difficult due to steep slopes. This issue of providing bench terraces need to be attended to promptly.
- To develop the state as model 'horticulture state' steps need to be taken to have intensive agriculture so that food grain requirement is met from lesser area so as to divert maximum area to horticulture.

- Apart from unfavourable geographical and socio-economic aspects, absence of adequate number of other industries and high literacy rate, more and more unemployed youth may have to seek employment in agriculture and agro-based industries. Under the broad strategies of mechanization of agriculture coupled with higher levels of inputs and technology, agriculture should be developed as a potential business enterprise in the state.
- For addressing the above issues relating to agriculture development, there would be a need to substantially jack up investment pattern in this sector.
- Taking cognizance of strengths, weakness and hi-tech horticulture available in the state and the objectives set forth for Xth five year plan to achieve an annual growth rate of 10% should be vigorously pursued. Some important objectives include sustainable horticulture production, persuading hobby and kitchen garden / backyard cultivation of horticulture crops to explore commercial cultivation of plant bio-diversity, develop marketing infrastructure, create vital linkages of post-harvest management, etc.
- Special emphasis need to be given to two important cash crops in the state i.e. large cardamom and ginger on which the agriculture economy of the state largely depends. Replantation of old orchards, providing planting material for gap filling and shade tree sapling are few basis needs for development. In case of ginger, awareness of ginger diseases to farmer, disease-free seed production and providing the same in mini kits, IPM activity to

combat pests and diseases are some of the important activities for improvement.

- Strategies suggested to strengthen the floriculture sub-sector should be meticulously planned and implemented. These comprise of checking the outflow of quality planting materials from the state, large scale tissue culture, transfer of technology to farmers and infrastructure facility for marketing transport, packaging and handling, etc.
- Nucleus bee-keeping centers in government farm need to be established. Bee species should be improved to have pollination effect on crops especially large cardamom and several varieties of vegetables.
- Considering the fact that livestock rearing is a way of life and a tradition which for centuries has substantially strengthened the economic life of the people in the state, it needs to be addressed with adequate emphasis, in terms of provision of veterinary services and animal health, cattle development, poultry development, sheep and wool development and piggery and other livestock development as well as dairy development, etc.

The opinions and reactions of the local communities in regard to the proposed Teesta Stage-III, IV and VI were recorded during the studies in North, South and East Sikkim. The observations of them are given below.

- People living in the vicinity of Chungthang (Teesta Stage-III), Mangan (Teesta Stage-IV), Sirwani and Rangpo (Teesta Stage-

VI), were not opposed to the Teesta hydro-electric projects. Of all respondants, 90% supported the project. But in some pockets, the people were sensitiive and were against the implementation of the project unless “basic safeguards are guaranteed” (Joint Action Committee, North Sikkim). The local people who were against the project, feared that the project would lead to large scale submergence. According to them, the total period required for the execution of the project was long enough to disturb the demography of the region “beyond recognition”. They feared a decline of ethnic culture, tradition and habitat due to infiltration of labourers from outside the state.

- It was noticed repeatedly that the local people were in favour of infrastructure development but not at the cost of losing the traditional life style and culture. The local communities, especially the Bhutias and Lepchas value their religion and culture much more than material comfort. As long as there was no conflict between their religious beliefs and technology, the local people did not interfere with the developmental activities. However, over the years, many of them have come to terms with the fact that without losing some, they could not gain.
- The new generation of Sikkim is very much aware of the environmental resources of the state and is keen to preserve them. In every districts of Sikkim, there are Non-government Organizations (NGOs) that keep track of development projects and make their presence felt whenever conflict situation arises. NGOs like Joint Action Committee (JAC) in North Sikkim, Affected

Citizens of Teesta (ACT) and Concerned Citizens of Sikkim (CCS) in East Sikkim, Khangchendzonga Conservation Committee (KCC) in West Sikkim, raised their voices on various issues related to hydroelectric projects.

8. TEESTA H.E. PROJECT STAGE-I

Teesta Stage-I H.E. scheme is one of the various projects proposed in Teesta river basin in Sikkim. The proposed project envisaged construction of two dams, i.e. dam-I to be located downstream of confluence of Lhonak Chhu with Zemu Chhu and dam-II downstream of the confluence of Chento Chhu with Teesta river in North Sikkim. The project involved construction of 40m high dam-I and diversion of water to the dam-II reservoir through a 3.5 km long link tunnel. The water from the 45m high dam-II was proposed to be diverted through a 3.5 km long head race tunnel. An underground power house is proposed immediately upstream of Zema on the right bank of Teesta river. The proposed project envisages power generation of 300 MW. However, due to severe environmental concerns raised in the phase-I report of this study, this scheme since has been abandoned or modified in the form of Talem H.E. project, wherein the proposed dam on Zemu Chhu has been discarded owing to adverse geological conditions in that area and similarly proposed dam on Teesta river at the confluence of Chentu Chhu has also been abandoned in favour of Talem H.E. scheme.

The proposed Talem H.E. project envisages construction of a rockfill dam downstream of confluence of Kalep Chhu with Teesta river in North Sikkim. The dam site is located between longitude 88° 32’ 45’’ E and latitude 27° 51’ 35’’ N. The project involves construction of a 50m high dam on Teesta river and diversion of water through a head race tunnel of about 4.5 km length. An underground power house is proposed near village Talem upstream of the proposed Teesta Stage-I project site on the right bank of Teesta river. The proposed project envisages power generation of 75 MW.

This present scheme even though is much scaled down version of earlier planned Teesta Stage-I scheme, still is located in an environmentally sensitive area and the environmental sensitivity of the region in the vicinity of project area has been described below.

- This region is covered with moraine deposits covered with thick vegetation.
- The rock types exposed in the region are pelitic migmatites and interbanded pelitic schists and metabasites. The foliations of these litho-units dip upstream, and therefore, this region provides suitable reservoir condition.
- Trellis drainage pattern is observed in this stretch indicating structural control on drainage network.
- In the region between Yathang to Chhochen, a E-W trending thrust passes through the Teesta river.
- Old stabilized landslide cones and fans are present at the mouths of the streams joining Teesta on the right bank.

- Due to bank failure along the valley slopes of Kalep Chhu huge sediment load is driven into Teesta river channel in this region.
- There are channel bars, landslide cones and terrace deposits along the Teesta river channel in this region. Active fans are present along the left bank.
- The physico-chemical as well as biological water quality of Teesta river in this region is very good.
- The majority of pollution sensitive species among the phytoplankton, phytobenthos and macro-invertebrates also indicate the good water quality and unpolluted state of river water.
- The excellent water quality in this stretch is because this area is devoid of any anthropogenic activities. However, the increase in activity in this area during construction work might lead to deterioration of water quality.
- Most of the endemic plant species are located in this stretch of North Sikkim only.
- Out of 53 species of flowering plants that are categorised as threatened in Sikkim, 27 species are found in particularly in Lachen-Lachung valleys and Zemu valley in North Sikkim.
- There are certain areas which serve as ideal habitats for speciation of various plant species.
- The habitat conditions around Thangu-Chhoptha is for *Aconitum, Panax* and *Podophyllum* are ideal for speciation.
- More than 50 species of mammals are found in the catchment area of the proposed project, which is comprised of Scheduled

animals like yak, tahr, deer, snow leopard, bears, fox, civets, kiang, rats, etc.

- A total of 11 species *viz*. Himalayan tahr, Blue sheep, Musk deer, Snow leopard, Kiang etc. are threatened.
- About 13 species are categorized as Schedule-I while 6 as Schedule-II.
- About 200 species of birds inhabit the catchment area of the proposed project.
- About 7 species like Northern goshawk, Creasted goshawk, Bersa, Eurasian sparrowhawk, Himalayan monal, Sikkim blood pheasant and Black necked crane are placed in Schedule-I while a large number of species (about 132) have been kept in Schedule-IV.
- Among the herpetofauna 5 species of amphibians and 7 species of reptiles are found in this region. All species have categorized as Schedule-IV
- More than 30 species of butterflies inhabit the catchment area.

Therefore, before taking any decision on the proposed project, further environmental assessment of the project specific and related activities and components on geological environment and biological environment would be required. Appropriate strtegies would have to be spelled out clearly defining the mitigation measures in critical details in order to preserve the habitats of the critically endangered and key plant and animal species of this region.

In addition, the apprehensions of the locals and various issues raised by them especially of influx of alien labour and the problems brought along with their influx, would have to be addressed and sufficient safeguards and appropriate measures taken. This propject can be taken up only if minimal labour influx and project activities are kept to minimum possible level and by deploying construction methods that are machinery intensive with minimal labour concentration and requirements during the construction phase and scheduling of activities like blasting, drilling, etc. that are environmental friendly and complementary with animal behaviour and does not interfere with the breeding or nesting behaviour of the rare and endangered animals residents in the project area. The concerned agency should have with strong commitment to the preservation of natural habitats and deployment of environmental friendly technology and also with a proven record of people friendly policies working towards the overall welfare of the people in the project area.

9. TEESTA H.E. PROJECT STAGE-II

The proposed Teesta Stage-II H. E. project envisages construction of 83 m high concrete gravity dam downstream of Chhaten on Teesta river, also known as Lachen Chhu in this stretch, near Bansoi village 22 km upstream of Chungthang with diurnal storage. The water is to be diversted through 11.6 km long head race tunnel to an underground powerhouse near Chungthang. The project envisages generation of 330 MW of power. There is another proposal of construction of barrage on Lachung Chhu and 8.5 km long head race tunnel with underground powerhouse proposed at Chungthang. With the addition of this part of the scheme, the project has installed capacity of 540 MW.

The Teesta Stage-II H.E. project too is located in an environmentally sensitive area and the environmental sensitivity of the region in the vicinity of project area has been described below.

- The rocks exposed at both the proposed dam sites are Khangchendzonga augen gneiss and tourmaline granite. The foliation dips 28° -40° towards NE at the site on the Lachen axis and 18° -60° towards NE at the site on the Lachung axis. These situations provide suitable reservoir conditions.
- Along the Lachung axis, thick terrace deposits built up of periglacial sediments are present alongside the river channel. Toe cutting, particularly near Lachung and upstream leads to valley side failure of these ancient landforms and thereby increases sediment load in the trunk stream.
- Near the powerhouse, Chungthang Formation rocks – arenaceous and argillaceous calcareous sediments metamorphosed to calc-silicates, quartzites, calc-gneisses and garnetiferous sillimanite gneiss – are exposed.
- There are triangular facets along the right bank of Lachung and Sebozung Chhu. This feature indicates that the Lachung axis represents a prominent fault in the region.
- Moraines deposited uphill along the right bank of Lachung Chhu are carried downstream by the tributary streams up to trunk stream thereby increasing the sediment load in the river channel. There are several active landslides on either bank of the Teesta river along the Lachen axis and at the right bank of Lachung in this region. Along the right bank of the Lachung Chhu, active

landslides along the road are observed particularly where calc-silicate rocks with interbanded quartzite are present.

- The Gangtok lineament passes through the Lachen axis and the fault plane solutions for two events *viz*. i) 1980, Nov. 19, 19 hr 45 sec (lat 27.4 N, long 88.8 E; Mb=6.0, focal depth 47km), and ii)1982, Apr. 5, 2 hr 19 min 41.2 sec (lat 27.38 N, long 88.83 E; Mb=5.0, focal depth 9 km) have indicated strike-slip mode of failure. A seismogenic fault passing through the reservoir area with reported strike-slip mode of failure in the past is very important from the point of view of Reservoir triggered seismicity.
- The physical and chemical profile of river water in these stretches indicated that water is free of organic pollution.
- The rich diversity and density of all biotic communities and majority of pollution intolerant species were recorded from this stretch, which indicate a good biological water quality.
- There would be major reduction in water discharge for about 21 km in Lachen Chhu and 5 km in Lachung Chhu due to diversion, which would lead loss of fish fauna.
- Influx of labours and new settlements would deteriorate the water the quality of these streams
- The river stretch is dominated with exotic trout *Salmo trutta fario*. Snow trout fish like *Schizothorax richardsonii* and *Schizothoraicthys progastus, Glyptothorax* spp., *Garra* spp. and *Nemacheilus* spp. were also recorded from these streams.
- None of the fish species in these stretches is a true migratory fish, however, Snow trout performs local migration.

- None of the species is threatened and endemic to this region.
- The cultural practices are being run for exotic trout by the Sikkim Govt. in the vicinities (Lachung and Lachen). Very rare capture fisheries are found in these rivers.
- Most of the endemic plant species are located in this stretch of North Sikkim only.
- Out of 53 species of flowering plants that are categorised as threatened in Sikkim, 27 species are found in particularly in Lachen-Lachung valleys and Zemu valley in North Sikkim.
- There are certain areas which serve as ideal habitats for speciation of various plant species.
- The habitat conditions around Thangu-Chhoptha is for *Aconitum, Panax* and *Podophyllum* are ideal for speciation.
- About 60 species of mammals inhabit the areas in the vicinity of proposed project, which comprises mainly of deer, cats, dogs, bears, civets, bats, rats and squirrels.
- A total of 7 species in the vicinities *viz*. Serow, Tibetan wolf, Red panda, Clouded leopard, Leopard cat, Marbled cat and Fishing cat are threatened.
- The category Schedule-I includes 8 species while about 12 species have been kept in Schedule-II. The Schedule-III, IV and V include 5, 1 and 2 species, respectively.
- About 300 species of birds are found in the vicinities of the proposed project.
- Four species like Bersa, Eurasian sparrowhawk, Peregrine falco are categorized as Schedule-I species while rest in Schedule-IV.

- About 12 amphibian species inhabit the vicinities, except *Tylototrioton verrucosus* of Schedule-I all have been included in Schedule-IV. About 19 species of reptiles and 125 species of butterflies are found in this catchment.

Therefore, keeping above environmental scenario in mind, before taking any decision on the proposed project, a proper assessment of different project related activities and components on geological environment and biological environment would be required.

Utmost care would have to be taken to preserve the habitats of earlier mentioned endangered and key plant and animal species of this region. These areas are last resorts of these endemic species.

In addition the apprehensions of the locals and various issues raised by them especially of influx of alien labour and the problems brought along with their influx, should be taken care of and sufficient safeguards and appropriate measures should be taken

10. TEESTA HYDRO-ELECTRIC PROJECT STAGE-III

Teesta Stage-III Hydro-electric project is proposed to utilize a drop of about 800 m in 18 km stretch of the Teesta river between Chungthang and Singhik for power generation as a run-of-river scheme. The project would have an installation capacity of 1200 MW.

The catchment area of the river at the diversion site is about 2,786 sq km. Out of this, about 70% area is under snow cover and the area under permanent snow cover about 1,952 sq km i.e. above 4,580 m. The annual rainfall near Chungthang area varies from 1615 mm to 2747 mm. The flow of the Teesta river exhibits large seasonal variations similar to other Himalayan rivers and is characterized by low flow during December to March and high flow during the summer and monsoon months.

Huge sediments, therefore, flowing into the river through landslide activity may lead to siltation problem causing flash floods to occur endangering the structures. The head race tunnel would be traversing several structurally weak planes (faults?) as the region falls under Main Central Thrust. Therefore, detailed geological investigations are necessary before undertaking any feasibility study of this project.

The proposed project area falls on Zone-IV of seismic zoning map of India. An earthquake of the magnitude of 6.0 Richter scale was recorded on November 19, 1980 with epicenter located 15 km ENE of Gangtok and focal depth of 47 km. Importantly the epicenter lies on the surface trace of Gangtok lineament and this project area also lies along this lineament.

- The project is situated in one of the most ecologically sensitive area of Sikkim. The geological sensitivity of the catchment is characterized by huge deposits of moraines in the catchment upstream. These deposits are precariously placed and are in equilibrium with the natural conditions of these areas. Some of glaciated areas have the history of being blocked by the debris resulting in the formation of temporary lakes, which upon bursting are known to bring this material downstream to deposit at various places in the river. This is evident from the recent deposit of debris along the course of Lhonak Chhu as evident from recent satellite data. A number of small and medium sized glacial lakes have developed in these areas. All these lakes are potential source of hazard generation. Therefore, it is necessary to monitor and observe the behaviour of these lakes. Any activity resulting in displacement of accumulated debris would have disastrous consequences downstream.

- Huge sediments, flowing into the river through landslide activity may lead to siltation problem causing flash floods to occur endangering the structures. The head race tunnel would be traversing several structurally weak planes (faults?) as the region falls under Main Central Thrust. Therefore, detailed geological investigations are necessary before undertaking any feasibility study of this project.
- The proposed project area falls in Seismic Zone-IV of seismic zoning map. An earthquake of the magnitude of 6.0 Richter scale was recorded on November 19, 1980 with epicenter located 15 km ENE of Gangtok and focal depth of 47 km. Importantly the epicenter lies on the surface trace of Gangtok lineament and this project area also lies along this lineament.

- Even though the submergence would be very small i.e. 12.23 ha only, the project related activities would disturb one of the best areas both in terms of floristic diversity as well as the faunal diversity. The large influx of work force is likely to have deleterious impact on the natural ecosystem of this area. The study of aquatic ecology also points towards the pristine ecosystem in North Sikkim.
- A detailed environmental sensitivity analysis of the scheme would be required before taking any decision taking into consideration aspirations of local people as well. In addition, the people's consent should be taken regarding their apprehensions about the project in a transparent manner.
- Quartzite rocks are exposed at the damsite. HRT will intersect Biotite granite gneiss and phyllite as well as graphite schist/gneiss, calc-silicate marble and quartzite of Chungthang Formation.
- At the damsite three different terraces T_1 (1530 m), T_2 (1560 m), T_3 (1720 m) are present in which the unconsolidated periglacial sediments composed of large boulders are anchored into the hill slopes by roots of tall trees. Therefore, the slopes on either side are susceptible to slide into the valley in case of little disturbance to the vegetation cover.
- Huge amount of sediment load is brought into the proposed reservoir site due to bank failures along Lachung Chhu and Teesta river (along the Lachen axis).

- Left bank of Teesta between Tong to Mangan is susceptible to landslide. The rightbank is relatively stable due to vegetation cover and hillward dipping strata.
- Near the power house, the rock types exposed are Biotite granite gneiss. The foliation dips towards the N at 65°. Therefore the rightbank slope of Teesta river is stable. However, at the north of the hill the left bank slope of the Rahi Chhu experiences landslide. Old landslides are stablilised in this region due to vegetation cover.
- The Gangtok lineament passes through the Lachen axis and the fault plane solutions for two events *viz*. i) 1980, Nov. 19, 19 hr 45 sec (lat 27.4 N, long 88.8 E; Mb=6.0, focal depth 47km) and ii) 1982, Apr. 5, 2 hr 19 min 41.2 sec (lat 27.38 N, long 88.83 E; Mb=5.0, focal depth 9 km) have indicated strike-slip mode of failure. A seismogenic fault passing through the reservoir area with reported strike-slip mode of failure in the past is very important from the point of view of Reservoir triggered seismicity.
- The physical and chemical profile of river water in this stretch indicated that water is free of organic pollution.
- The rich diversity and density of all biotic communities and majority of pollution intolerant species was recorded from this stretch, which indicate a good water quality.
- There would be major reduction in water discharge for about 21 km river stretch due to diversion, which would lead a heavy loss of fish fauna.

- The river stretch is dominated with snow trout fish like *Schizothorax richardsonii* and *Schizothoraicthys progastus*. The exotic trout *Salmo trutta fario* is restricted to upstream of proposed dam site while *Acrossocheilus hexagonolepis* (catli) is found up to proposed power house site.
- Other fish of this stretch are not of fishery interest.
- Snow trout and catli are known to perform local migration. Former species descends for spawning while later uses tributaries.
- None of the species is threatened and endemic to this region.
- Most of the endemic plant species are located in this stretch of North Sikkim only.
- Out of 53 species of flowering plants that are categorised as threatened in Sikkim, 27 species are found in particularly in Lachen-Lachung valleys and Zemu valley in North Sikkim.
- There are certain areas which serve as ideal habitats for speciation of various plant species.
- The habitat conditions around Thangu-Chhoptha is for *Aconitum, Panax* and *Podophyllum* and Shingba in Yumthang-Lachung valley for *Rhododendron* are ideal for speciation.
- About 60 species of mammals inhabit the areas in the vicinity of proposed project, which comprises mainly of deer, cats, dogs, bears, civets, bats, rats and squirrels.
- About 5 species of mammals like Serow, Leopard cat, Marbled cat, Fishing cat, Clawless otter and Clouded leopard are threatened in the vicinity.

- Four species of mammals have been placed in the category of Schedule-I while 14 species in Schedule-II. About 16 species are 'Vermin' as Schedule-V. A very few species are placed in Schedule-III and IV.
- More than 320 species are found in the vicinity of proposed project.
- A total of 3 species *viz*. Bersa, Eurasian sparrowhawk and Crested Goshawk have been categorized as Schedule-I while rest are placed in Schedule-IV.
- About 20 amphibian species and 26 reptiles inhabit the vicinity.
- About 400 species of butterflies are distributed in the vicinity of proposed project.

The project is situated in one of the most ecologically sensitive area of Sikkim. The geological sensitivity of the catchment has already been discussed which is characterized by huge deposits of moraines in the catchment upstream. These deposits are precariously placed in equilibrium with the natural conditions of these areas. Some of glacial lakes have the history of being blocked by the debris resulting in the formation of temporary lakes, which upon bursting are known to bring this material downstream to deposit at various places in the river. This is evident from the recent deposit of debris along the course of Lhonak Chhu from Satellite data. There are a number of small and medium sized potentially dangerous glacial lakes in the upstream catchment area. All these lakes are potential source of hazard generation. Therefore, it is necessary to monitor and observe the behaviour of these lakes. Any activity resulting in displacement of accumulated debris would have disastrous consequences downstream. The Glacial Lake Outburst Flood (GLOF) can create havoc in downstream area endangering the structures and habitations.

Even though the submergence would be very small i.e. 12.23 ha only, the project related activities would disturb one of the richest areas both in terms of floristic diversity as well as the faunal diversity. The large influx of work force is likely to have deleterious impact on the natural ecosystem of this area. The study of aquatic ecology also points towards the pristine ecosystem in this stretch. Furthermore, a proper conservation strategy would have to be formulatd to preserve the habitats of earlier mentioned endangered and key plant and animal species of this region.

The local people in almost all the proposed project sites are aware of the benefits as well as problems associated with the project. During fieldworks in villages close to the site of Stage III near Chungthang, it was observed that the local communities, Lepchas in particular, feared influx of outsiders. The Lepchas who had long been reduced to a minority in their land feared that the influx of project workers from outside the state would push them further and make them marginalized in their homeland. A section of the community opined that the project would be problematic for them as it touched the Lepcha reserve of Dzongu in North Sikkim. During the construction of the hydel project at Dikchu the JAC president cautioned, “The Teesta river forms a natural boundary between Dzongu and East Sikkim. There are only three bridges to cross over to this protected area. When the coffer dams come up, the river will dry and thousands of labourers from the east bank will enter the protected zone (The Hindustan Times, August 9, 2000, New Delhi)".

The proposed project is likely to lead to adverse environment impacts, therefore, a detailed environmental sensitivity analysis of the scheme is required before taking any decision. The cost of mitigation measures that would be required to minimize the impact of fragile biological and geo-environment of the upstream catchment would be very high. It is, therefore, advised to take up this project with strictest possible norms. As already described in this study, that this zone is very rich in biodiversity. Therefore, the biological richness of this area both plants and animals especially of butterflies would be seriously affected due to construction of this project. The intensity of envisaged in this stretch would deleterious affect on the biology of animals resident in this region and would also lead to degradation of forest cover in the area. Any disturbance caused to the biological equllibrium of the area would lead to loss of biolocal wealth which is unique to this region.

11. TEESTA HYDRO-ELECTRIC PROJECT STAGE-IV

Teesta Stage-IV H.E project envisages a run-of-the-river scheme with an 88.5m high dam on Teesta river 90m downstream of the confluence of Teesta river and Talum Chhu (Rangyong Chhu) near village Sangklang in Mangan sub-division of North Sikkim. The scheme envisages diversion of water of the river Teesta by constructing a diversion dam with FRL at 768m through a water conductor system of the length of about 11 km to an underground power house with an installed capacity of 495 MW. The gauge and discharge observations of river Teesta are near diversion and include the inflow of intermediate catchment area between Teesta Stage III and proposed Teesta IV from river Teesta and its tributary Tolung Chhu.

Geologically the project area lies in the MCT zone. There is lot of landslide activity between Mangan and Tong, the immediate catchment area upstream of proposed dam site. These, therefore has propensity of bringing large amounts of silt into the proposed reservoir, thereby would have negative impact on the reservoir capacity.

In the case of this project too, the impoundment of water in the dam up to FRL is only 11.50 ha. However, the intermediate catchment between Stage-III and Stage-IV harbours rich diversity of mammalian and bird fauna in addition to being a zone of diversity of butterflies. Therefore, any increased human activity in this critical zone would have adverse impact on the habitats of these species. Further, no pondage of any duration should be allowed in this area which would lead to geological unstability resulting in the increased incidence of landslides.

During survey near the site of Stage IV, it was observed that the mindset of the local people changed to a great extent. In the words of a

Zilla Panchayat member, "Our lands are already going due to nature's fury. Much of the land near the proposed project site is sinking. If the project takes measures to save our land from sinking the villagers will be benefited. Therefore it is better to have one, although there are both advantages and disadvantages". The displaced people from Manul and other hazardous areas that already lost their people, land and properties due to devastating landslides welcomed the project as they hoped to start their life afresh.

The environmental implications of this project are discussed below.

- Geologically the project area lies in the MCT zone. There is lot of landslide activity between Mangan and Tong, the immediate catchment area upstream of proposed dam site. These, therefore, have propensity of bringing large amounts of silt into the proposed reservoir, thereby would have negative impact on the reservoir capacity.
- In the case of this project too, the impoundment of water in the dam up to FRL is only 11.50 ha. However, the intermediate catchment between Stage-III and Stage-IV harbours rich diversity of mammalian and bird fauna in addition to being a zone of diversity of butterflies. Therefore, any increased human activity in this critical zone would have adverse impact on the habitats of these species. Further, no pondage of any duration should be allowed in this area which would lead to geological unstability resulting in the increased incidence of landslides.

- The proposed project lies in the Dzongu area considered sacred by the local people. Therefore, to undertake any activity in this region, it would require the consent of these people.
- Quartz-muscovite-biotite gneiss is exposed along the steep left abutment. The foliation dips upstream, and therefore, this region provides a suitable reservoir condition.
- The presence of thick terrace deposit at the site implies that rocks of acceptable fouldation grade can be met at a great depth.
- Interbanded phyllites and quartzites are well exposed near the powerhouse site. The foliation of these rocks dip at 45° towards north (into the hill), and therefore, the right bank slope of Teesta is stable at this site.
- The landslide activity along the left bank of Teesta between Mangan to Tong supplies huge sediment load into the Teesta river channel upstream of the proposed damsite.
- Several active landslides, such as Namak slide, are present along the left bank of Teesta between Saklang and Dikchu. Between damsite and powerhouse site there are landslides along the slopes of Run Chhu, Moni Chhu and Marmu Chhu.
- The foliation of phyllite and quartzite rocks at the powerhouse site dip into the hills. Therefore the valley slope is stable in this region.
- In Sikkim Himalaya the region between MCT and MBT is seismically active. All the appurtenant structures of the proposed project lie in the MCT zone.
- All physical, chemical and biological characteristics of river water respond to seasonal rhythms of monsoon.

- During monsoon season water becomes highly turbid and is not potable.
- The physical and chemical profiles of water do not indicate the deterioration of water due to organic pollution.
- The density, diversity and majority of pollution intolerant species show a good health of river water. However, very few pollution tolerant species were also recorded from this stretch of the river.
- There would major reduction in water discharge from about 10 km. river stretch, which would lead to loss of fish fauna.
- Influx of labours and temporary settlements would lead to deterioration in water quality of river.
- The river stretch is dominated by snow trout (*Schizothorax richardsonii* and *Schizothoraicthys progastus*), *Labeo dero* and catli (*Acrossocheilus hexagonolepis*).
- A species *Nemacheilus devdevi* is found in this stretch which known as endemic to Eastern Himalaya.
- None of the species is found to be true migratory.
- Most of the capture fishery depends on the snow trout and catli while cultural fishery is nil in the vicinity.
- More than 100 species of mammals are found in the vicinity of the project. The mammalian fauna is dominated by the bats and rats species.
- A total of 8 species *viz*. Leopard, Wolf, Marbled cat, Fishing cat, Golden cat, clawless otter etc. are considered as threatened species.

- About 7 species have been placed in the Schedule-I while 19 in Schedule-II. A large number of species (37) belong to Schedule-V.
- About 230 species of birds are found in the vicinity of proposed project.
- Except Crested goshawk and Hodgson's Frogmouth all species have been categorized in Schedule-1. Former species belong to Schedule-I.
- About 10 amphibian species and 34 reptile species inhabit the vicinity of the proposed project.
- About 345 species of butterflies are found in the vicinity.

The proposed project lies in the Dzongu area considered sacred by the local people. Therefore, to undertake any activity in this region, it would require the consent of these people. However, since then keeping the sentiments of the Dzongu inhabitants in mind, the project is proposed to be shifted to downstream location NHPC, which would not lead to submergence of the football ground and other structures. Therefore, investigations are in progress in this direction respecting the people's sentiments.

12. TEESTA HYDRO-ELECTRIC PROJECT STAGE-VI

The proposed scheme is located downstream of the power house of Teesta Stage-V H.E. project on Teesta river about 500m downstream of the road bridge at Khanitar/ Mamring in East Sikkim. The scheme is planned as a run off the river scheme with diurnal pondage. The scheme envisages diversion of water of river Teesta by constructing a 76 m high concrete gravity dam with FRL of 341 m at Majithar near village Khanitar. The water from the diversion dam is proposed to be led through a water conductor system of the length of about 4.5 km to an underground power house with an installed capacity of 360 MW. The gauge and discharge observations of river Teesta are of flow of river Teesta near diversion site and included the inflow of intermediate catchment area between Teesta H.E. Stage-V project, and proposed Teesta H.E. Stage-VI project and its tributary Rani Khola. The total catchment area up to the dam site is 4,874 sq km.

The reservoir area starts about 500 m upstream of Mamring bridge near Khanitar and situated near the existing National Highway (NH-31 A). The proposed project is likely to submerge an area of 214 ha of land which includes 20.95 ha of forest area and 56 ha of private land. It would lead to submergence of parts of three reserve forests *viz*. 9.41 ha of Jhulangey RF, 12.51 ha of Tsalamthang RF and 5.67 ha of MIalabasey RF in the right bank. However, degraded forested area of Tumblabong RD, Salangey RF and Bardang RF on the left bank would also come under submergence, which mainly constitutes a part of the river bed. The private lands include some house settlements of village Khanitar and Manjhitar, one Government slaughter house, one cold storage plant (abandoned) at Majhitar and cultivated fields. The cultivated fields mostly used for seasonal crops such as paddy, maize, Ragi and seasonal vegetables. Besides this, about 5 ha of kitchen - garden of village Manjhitar is coming under submergence. The LPG bottling plant at Majhitar is also coming under submergence.

Due to submergence of large areas of land includind Manipal Institute and Indian Oil Depot in the the above described scheme, it was modified. In the present revised scheme it is proposed to construct a 20m high barrage on Teesta river at Sirwani in East Sikkim. The water would be diverted though 11.5 km long head race tunnel with underground powerhouse proposed at Tarkhola in South Sikkim on the right bank of Teesta river. The project would have an installed capacity of 440 MW.

Fieldwork near the site of Stage-VI revealed a favourable picture. The villagers mostly extended their support to the project. The people around Singtam and Rangpo felt that the project under construction would bring development and comfort in their lives. They looked up to the project for a speedy completion so that they could enjoy the benefits as early as possible. Having been situated close to the project site, many of the local villagers expected to get jobs and expand their business. Although many of them lost their farmland for the construction work, they accepted their personal disadvantages for the cause of collective benefits.

In addition to these project on Teesta river, there are a number of projects that are proposed in Rangit, Talung Chhu and Rangpo Chhu valleys. In none of these projects especially in Rangpo Chhu, no pondage of any sort may be allowed as the valley slopes in this area are highly prone to slope failure which would be hazardous to the dam structure.

- The rocks exposed in the area are quartzite-phyllite interbands with high percentage of quartz. The foliation of these rocks dips upstream, and therefore, the area provides a suitable reservoir condition.
- At the powerhouse cavern, quartzite and phyllitic quartzite are expected and dip into the hill. Therefore this region is stable.
- The tunnel will cut across the copper mine thrust. It will also cut across several channels at the mouth of which old stabilized fan deposits are present.
- The landslide along the Ben Khola in the right bank of Teesta and several active landslides along its left bank upstream of the damsite supply huge sediment load into the main channel.
- The proposed project lies in seismically active region between MCT and MBT in Sikkim Himalaya.
- The river channel proposed for H.E. Project Stage VI is relatively dense populated and highly disturbed by anthropogenic activities like sewage outfall, sand mining, fishing etc.
- All physical, chemical and biological characteristics show temporal variation.
- Physical and chemical profiles indicate that river water is relatively more polluted but not out of ‘designated use’.
- Left bank tributary Rongni Chhu carries relatively more pollutants in the river Teesta.
- The majority of species in plankton, phytobenthos and macro-invertebrates is pollution intolerant but a few pollution tolerant species are also found in this stretch.

- This stretch is comparatively rich in fish fauna, in which about 6 species are of fishery interest.
- The river stretch is dominated by *S. richardsonii, S. progastus* (snow trout)*, Tor putitora* (mahseer)*, Acrossocheilus hexagonolepis* (catli)*, Labeo dero* and *Barilius bendelisis*.
- *Tor putitora* (mahseer) is migratory fish, which performs migration during monsoon season for breeding purpose. Snow trout and catli are local migratory fish.
- Most of the capture fishery depends on these species. In cultural practices a fish farm for *Cyprinus carpio* has been developed at Rangpo. Only an endemic species *Acrossocheilus spinulosa* is found in this stretch of river Teesta.
- More than 100 species of mammals are found in the vicinity of the project. The mammalian fauna is dominated by the bats and rats species.
- A total of 8 species *viz*. Leopard, Wolf, Marbled cat, Fishing cat, Golden cat, clawless otter etc. are considered as threatened species.
- About 7 species have been placed in the Schedule-I while 19 in Schedule-II. A large number of species (37) belong to Schedule-V.
- About 230 species of birds are found in the vicinity of proposed project.
- Except Crested goshawk and Hodgson's Frogmouth all species have been categorized in Schedule-1. Former species belong to Schedule-I

- About 10 amphibian species and 34 reptile species inhabit the vicinity of the proposed project.
- About 345 species of butterflies are found in this vicinity.

13. OVERALL ENVIRONMENTAL ASSESSMENT

Based on physical, biological and socio-cultural environmental analysis, the following conclusions are drawn.

- Majority of constituent watersheds of Teesta river basin in all the four districts of Sikkim are an extremely geologically sensitive and ecologically fragile area with low carrying capacity for large developmental project works. **There is very little scope for having dams with heights above 80m from river bed level especially in North Sikkim as most the valleys in this area are heavily glaciated with slopes covered with large amounts of debris cover in addition to the sensitive seismic regime of this area**. The reservoirs with water depth of more than 90m have been associated with impoundement induced seismicity and this aspect may become critical especially in this Seismic Zone-IV. However, there are no such reports for reservoirs with water depth below 90m. It is, therefore, necessary that a comprehensive seismic surveillance plan is formulated during the initial planning stage of any hydro-electric project in this region to tackle the probability of occurrence of earthquakes. In addition to the environmental issues discussed above, the problem of percolation and seepage of water from the reservoir at places may cause damage to downstream areas. The large pondage in these areas and water level fluctuation may also result in triggering of minor landslides and creation of waves in the reservoir, thereby endangering the dam structure.

- Large pondage and any kind of storage like diurnal storage should not be allowed in West and East Sikkim. This is more so in the watersheds of Rangpo Chhu, Rathang Chhu and Rangit River. The dams coupled with related activities like road building, blasting for tunneling, etc. would have serious impact on the stability of the slopes and the biologically diversity in these areas. However, smaller hydro-power projects around Chungthang and Mangan could be feasible. However, even smaller projects above Chungthang in North Sikkim would be extremely detrimental to the natural ecosystems and their fragility.
- The inhabitants with strong traditional and socio-cultural values are seriously averse to any kind of cultural intrusion which generally takes place as a result of developmental activities like building of dams and other associated construction activities. This feeling, is however, not strong in case of Teesta Stage-VI project.
- There is a need and great scope for alternate income generating activities like medicinal plant cultivation, ecologically sound tourism and cultural tourism to safeguard the pristine ecosystems of North Sikkim.
- Festivals and cultural activities like *Chham* could be turned into a major economic activity on the model of Ladakh and Sindhu Festival in Jammu & Kashmir and also on the lines of festivals in Kullu Dussehra of Himachal Pradesh.

- Activities like high income generating floriculture and medicinal plant cultivation could be taken up.
- Mechanisms such as imposition of tariff and environment tax in ecologically fragile zones for outside tourists is worth consideration.
- The carrying capacity of the region for any development activity that may disturb land, biological and cultural environment of Teesta Basin in Sikkim, particularly above Chungthang in North Sikkim, it is abysmally low.

Keeping in mind the uniqueness of ecological system of Teesta basin and its inherent environmental sensitivity attributed to geo-environment as well as biological environment, the socio-economic and socio-cultural issues would also be required to be addressed. The concerns expressed by one of the active NGO in the region have been appended at the end of this volume and similarly the suggestions made by one of the senior state government official have been appended (see Annexures-I & II). After discussions with several concerned state government officials and NGOs, the following points have emerged from these deliberations. Therefore, these points should be considered before undertaking any developmental activity in the area.

A proper mechanism has be evolved to check the influx of immigrants and in addition related issues like voters list, permanent settlement of immigrants, land acquisition, domicile/ residential certificates, ration cards, etc. should also be addressed appropriately. It could include issue of identity cards with proper monitoring and verification of antecedents. Undertaking from labour and others involved in the various projects to return to their place of origin once the project is over. A clause should be added in the agreement to bind all contractors and other pertinent agencies to comply with these measures.

In addition, the project area should be developed as a major tourist attraction with camping ground, parks, gardens, boating facilities, etc. at the expense of project authority.

In case of unforeseen natural calamities like dam burst or accidents due blasting, landslides caused due to project activities, etc. the victims should be compensated by project authorities within a prefixed time and amount.

For the implementation of directives of the Ministry of Environment & Forests, Government of India, the formation of autonomous Environment watch groups comprising of local and national environmentalists and NGOs should be encouraged oversee and monitor the various conservation measures.

In order to maintain the traditional Art and Culture of the area, all project elements should be designed along the lines of and in tune with the existing traditional Sikkimese architecture. The help of an autonomous committee consisting of local architects, engineers, intellectuals and artisans should be solicited for this task and also to monitor the aesthetic aspects of all the project components.

The renaming of villages, roads, hills, rivers or any other physical or manmade features built by project authorities including roads, dams, bridges, helipads, colonies, buildings, etc. should be done after consultation with the local people.

Necessary education and health facilities in the form of schools and hospitals to be provided for the benefit of local people in the vicinity of project area.

All new diseases should be identified monitored and suitable remedial measures initiated. The probable diseases include a range of mosquito borne and water borne diseases, STD and AIDS, and respiratory diseases. This is especially important because of the hitherto insular nature and hence low immunities of the societies existing in the project areas.

It should be mandatory for the project authorities, government as well as private developers to sponsor and undertake activities/tasks that are recommended for that particular area in this report.

FINALLY BEFORE TAKING UP ANY DEVELOPMENT PROJECT IN THE REGION, AN IN DEPTH ENVIRONMENTAL IMPACT ASSESSMENT OF INDIVIDUAL PROJECTS WITH REFERENCE TO PROJECT RELATED ACTIVITIES SHOULD BE DONE PRIOR TO GIVING ANY CLEARANCE AND THE PRESENT STUDIES SHOULD BECOME THE BASIS OF ASSESSMENT OF THESE PROJECTS.

ANNEXURES

ANNEXURE I

SUGGESSIONS
by

S.Lama

Member, State Planning Commission
Government of Sikkim

1.0 INTRODUCTION

All the details of reports given in this chapter is of very high value and have been accumulated with intense research and study.

2.0 DEVELOPMENTAL SCENARIO

2.1 POWER DEVELOPMENT SCENARIO

2.1.1 Hydropower Potential in Teesta Basin

Table 1 Estimated Hydro-power Potential in Sikkim State

S.No.	Name of Project	Installed Capacity (MW)
A.		
1.	Teesta Hydel Project stage-I	320
2.	Teesta Hydel Project stage-II	850
3.	Teesta Hydel Project stage-III	1200
4.	Teesta Hydel Project stage-IV	495
5.	Teesta Hydel Project stage-V**	510
6.	Teesta Hydel Project stage-VI	360
TOTAL A		**3735**

It is suggested that to maintain the installed Capacity of State I & II detailed technical activities to make the basin capable of sustaining its fragile condition, may please be added if the technically aspects permit. If State may be able to develop this from the point of view of (i) energy generation, (ii) eco-tourism, (iii) Bio-diversity study and (iv) modern technology to try to go along the nature; it would be a Spot in Sikkim having aesthetic value for the future generation including Naturalist, Researchers, technicians, Scientist and world Tourist.

Stage-III being the main energy Centre, the recommendation is very technical and State must thank for this. However, with reference to the MSK intensity Scale used for all engineering design purposes, the area lies in the risk zone, and therefore, there is always a necessity to consider the factor of Safety for highest earth quake intensity while designing an engineering construction. Therefore, I would suggest considering the following aspects to be included in the recommendations.

1. For detailed Study of the developmental Sites different technical actions qualified Actors (National/ International) may kindly be pronounced to help the State Government to take advance action appropriately.
2. Advance Warning system for Earthquake if any may please be suggested for advance precautionary measures to save the project to its optimum limit.
3. The project-cover Rock testing for Earthquake resistance Capacity if any, may please be suggested.

4. Weathering impact on decentigration of Rocks, in the site of development if available, may also be suggested.
5. Treatments Parameters to ensure maximum longevity of the Projects may please be suggested.

Stage-IV. The clearance recommended for this stage is commendable and we thank the Ministry for this.

Stage-V with the Clearance of the Ministry, the Project could be started in time, it is now nearing completion. For this Ministry deserve appreciation.

State-VI. The clearance recommended for this stage is commendable and we thank the Ministry for this.

S.No.	Name of Project	Installed Capacity (MW)
B.		
7.	Rolep H.E. Project (under construction)	32
8.	Ralang H.E. Project	40
9.	Chakung Chhu H.E. Project	50
10.	Chuzachen H.E. Project	99
TOTAL B		**221**

- Scheme being promoted be private agencies for 221 MW may please be looked after for proper Bio-diversity maintenance and sustainable energy harnessing.

S.No.	Name of Project	Installed Capacity (MW)
C.	**Pre-feasibility Studies**	
1.	Jadang H.E. Scheme	185
2.	Teesta Stage I H.E. Scheme	300
3.	Rongni Storage Scheme	95
4.	Ringpi H.E. Scheme	160
5.	Dik Chhu H.E. Scheme	90
6.	Lachen H.E. Scheme	210
7.	Lingza H.E. Scheme	160
8.	Rangyong H.E. Scheme	90
9.	Talem H.E. Project	75
10.	Rukel H.E. Scheme	90
11.	Panan H.E. Scheme	200
TOTAL C		**1655**

The above schemes identified under Hon'ble Prime Minister's 50,000 MW initiative may please be perused and proper line of action and action initiative may kindly be suggested.

3.0 DEVELOPMENTAL PLANNING AND CARRYING CAPACITY

In this study inventory of resources, production, consumption and conservation levels, ecological fragility, existing and projected developmental profile of Teesta basin, quality of like of human population in the basin, and preparation of comprehensive evaluation reports for major proposed developmental projects within the Carrying Capacity frame work is well thought over and translated into action.

EXISTING ENVIRONMENTAL RESOURCE BASE

Environmental resources base, Air, Water, Land, Biotic resources, socio-economic and quality of life used for planning and development would provide a scientific basis for management development plan of the basin.

4.1 LAND ENVIRONMENT

The mountainous terrain of the basin, physical features, processes and activities of the basin's land environment evaluated for sensitivity, fragility of land resources taken for preparation of a base map delineating major watersheds of the Teesta basin, its slope, aspect, elevation profile and digital elevation model, mapping erosion prone areas, mapping of river terraces, moraine deposits, glacial moraines, Regional stratigraphic-tectono-stratigraphic succession for estimation of far of possibility of tectonic diverticulation, Seismo-tectonic map of the basin, micro-seismic activities and seismic history and Physical environmental and ecological sensitivity analysis are the real technical parameters used. I appreciate this.

4.1.1 Geomorphic Profile of Teesta Basin

4.1.2 Geology

4.1.2.1 *Stratigraphy*

4.1.2.2 *Structure, Techtonics and Metamorphism*

4.1.3 Seismicity

New Seismic zoning map of India (BIS: 2000) encompasses for named II, III, IV, V giving scale intensity and horizontal force corresponding with seismic map zones of India are the most required informations. The area covered by Sikkim falling in zone IV, this lies in the high damage risk zone corresponding to a magnitude of 6.7 in the Richter scale, which necessitate to consider the factor of safety for highest Earthquake intensity which designing an engineering construction. This is the prime information for the State of Sikkim.

4.1.3.1 *Isoseismal Zones*

4.1.3.2 *Microearthquake Surveys*

The latest High-tech seismographic recording stations established in Sikkim, have been very useful to sense such movement of sporadic earth areas.

4.1.4 Soil

It is the basic natural resource for plant growth. The Hill and mountainous region of Teesta Basin posses a great diversities. The total Tonnage of Soil and Plant Nutrients carried down by the Teesta River per year is immeasurable in quantity. This is the wealth of Sikkim. Extensive clearance of the Forest for revenue deposits, landslides, power grids line extension, forces establishments, haphazard constructional works, no drainage, slope cultivation have led to the establishment of the vicious cycle of degradation leading to land slid and mass movement. Therefore, Soil and Water conservation is Utmost Important in the Hill terrain of Teesta Basin in Sikkim, for protection of the precious natural resources and to provide food, fuel, fibre ever growing population.

Soils of 17 watersheds in Teesta basin in Sikkim at the level of Soil series association have been mapped. 62 Soil series identified and have been mapped in to 63 soil mapping units through the soil resource inventory of the Teesta Basin in Sikkim (for generating Agro-Bio-engineering technique- Surface crops, Shallow rooted crops, deep rooted crops, seasonal crops, genetic manipulation– better yield, Off season crops, soil conservation, Water conservation and Bio-resource sustainance).

4.1.4.1 ***Land Capability Classification*** depicts the capability of soil for proper utilization of Land on sustainable basis and provides clues to the management and improvement of different soils for increasing production. Hill farming-mostly mixed farming, agronomic practices, horticulture crops intensification, Floriculture, commercial crops are the prime scopes for organic farming in Sikkim.

4.1.5 Landslides in Teesta Basin

The major Landslides and the new landslides effecting the huge areas of Sikkim was the cause of October 1968 heavy cloud burst of about 10” rainfall within 8 hours in a day. Before this period land sustainance was normal.

4.1.5.1 *Some existing landslides in Sikkim*

Landslides is the pertinent natural problem and intensified by human interference, softer rock formation, deforestation, improper drainage along the road, sliding zones, cultivation on steeper slope, too erosion by stream, construction of structure on unstable ground and mushrooming growth of township. Erratic distribution and concentrated downpour/ rain in some season and open irrigation channel in the Hills are also causing landslides. In this region the mica rich bands in the rocks encourages sliding down the slates of rocks.

4.2 BIOLOGICAL ENVIRONMENT

Sikkim is a global Hot Spot for biodiversity. Teesta basin is the areas of watersheds feeding snow water, rain water and capillary movement of Ocean water to Teesta river. Rangit river also being a main tributary to Teesta, the watersheds feeding to this river also are parts of basin. Therefore, it is necessary to record the status of biological diversity and its ecosystem of whole of Sikkim. The eco-climatic conditions of the basin consist of humid tropics, sub-tropics and alpine areas. It is therefore, important to understand that biological resource holds and important place in the planning and developmental process of Sikkim. For balancing act of conserving the biological diversity and ensuring economic gains from conservation and also utilization of biological resource, it is important to assess the existing biological environment base of the basin. The main points are inventorisation of Floral and Faunal species in terrestrial, aquatic and aerial eco-system, identification of Hot-spot for conservation and sustainable exploitation, mapping of landuse and vegetation; including forest cover, analysis of Biological sensitivity of Eco-system of the area of proposed projects, Eco-tourism potential areas identification, and economic biological resource potential identification for local population and industrial use.

4.2.1 Floristic

Teesta river basin has wide altitudinal range from 213 metre to above 8,000 m; adverse climatic condition from cold in the North, to extremely wet conditions in canonic parts of East, West and South Sikkim. This has deep valleys, beautiful water falls, sharp and mild slopes, view points, multi-directional spots to see the beautiful faces of the valley and changing colours of beautiness of Mt. Khangchendzonga, valleys, rivers and lakes. If we study the floristic and floral richness of Sikkim we find 4,250 nos. of flowering plant species in 7,096 sq. km and if we calculate for one sq km, it comes to 0.704 species. Nagaland and Tripura has 0.147 species, Manipur 0.134 species, Bhutan 0.120 species and Mizoram 0.102 species. Flowering plants are recorded throughout Sikkim inhabiting the extreme frigid region of Gurudongmar, Yumesamdong, alpine region of Thangu, Yumthang, Dzongri, temperate areas of Mangan, Chungthang, Lachen-Lachung/ Barse valleys to sub-tropical and tropical areas of Namchi, Jorethang, Melli, Rhenock, Rangpo, Zum, Tahrpu, Sadam and Sumbuk. Different species of ferns with varied sizes from herb, shrub and trees are found in all climatic conditions with medicinal, glamorous, food and industrial values. Among the endemic 150 species of plants found only in Sikkim are *Rhododendron lanatum*, *Litsea sikkimensis* in Dzongri, Lachen and Nathu La. Most of the endemic species are found above 2,500 m, in Lachen, Lachung, Lhonak and Zemu.

Most of the endemic species of Orchid are found in tropical, sub-tropical regions of Teesta, Sebu, Chungthang valleys below 3,600 m. More than 20 species of Orchids are endemic to Sikkim region. Among them 18 species of Asteraceae family with medicinal and other uses are found in Teesta basin.

4.2.1.1 *Orchids Diversity*

445 species of Orchids belonging to 117 genera are found in Teesta basin. This is the maximum number of species in India. They are found in all parts of the basin from alpine, temperate to tropical region. They have diverse habitats from soil, stones and tree branches. 23 species are found in alpine region growing above 3,600 m in Dzongu, Tolung, Samdong, Lachung valley and Singba. 250 sp. are ephiphytes, 175 sp. are terrestrial. The climate is very favourable to grow Orchids artificially in the green house and open fields. Exportable exotic varieties are to be commercially grown to earn foreign currency. Some of them

are to be used for crossing and breeding with indigenous promising species.

4.2.1.2 *Economically Important Plant Species*

I. **Medicinal uses**: More than 400 species of plants are used to cure various ailments of both human beings and domestic animals, they are used as tonic, aphrosiac to cure fever, diaorrhea, to very serious diseases like Cancer, Rheumatism, Asthma etc. *Podophylum hexandrum* and *Taxus baccata* are useful for treatment of cancer.

Medicinal herbs or trees are found all over Teesta basin. They are concentrated mainly in the higher altitudes 2,500 m to 3,000 m. *Aconitum ferox*, *Alnus nepalensis*, *Arisaema speciosum*, *Daphne bholua*, *Ephedra gerardiana*, *Hedychium spicatum*, *Heracleum wallichii*, *Impatiens racemosa*, *Nardostachys jatamansi*, *Panax pseudoginseng*, *Picrorhiza kurrooa*, *Podophyllum hexadrum* and *Taxus baccata* are found in the alpine and sub-alpine region. *Aloe barbadensis*, *Brassica campestris*, *Bridelia retusa*, *Cissampelos pariera*, *Piper longum*, and *Terminalia belerica* are found in between 1,000 to 1,200 m altitude. *Artemisia vulgaris*, *Acorus calamus*, *Bergenia cilliata*, *Berberis aristata* and *Dioscorea deltoidea* are found in temperate and sub-tropical parts of Sikkim.

II. Timber, Fuelwood and other uses: 639 species of trees are found in the basin. They are of 273 genera and 93 families. For timber purpose- *Abies densa*, *Betula utilis*, *Pinus roxburghii*, *Tsuga ciliata* are used. They are found in Lachen, Lachung and Yumthang region. In tropical and sub-tropical regions – Rangit, Ravongla, Singtam, Rangpo, Melli, Jorethang *Shorea robusta*, *Terminalia myriocarpa*, *Quercus lamellosa*, *Castanopsis indica* and *Canarium bengalensis* are found. There are many trees bearing fruits. They are *Morus laevigata*, *Citrus maxima*, *C*. *auriculata*, *F*. *racemosa*. There are many trees species belonging to *Rhododendron*, *Magnolia*, *Michelia*, *Prunus* having very beautiful flowers and attract tourists in very large numbers.

III. Cereals, pseudocereals, pulses and vegetables eight to ten species of plants are used as cereals. They are *Oryza sativa*, *Triticum aestivum, Hordeum vulgare, Zea mays* and *Eleusine coracana*. *Eleusine coracana* is used for making Chhang. *Fagopyrum* is grown in Thangu, Muguthang and Lachung.

Cajanus cajan, Cicer arietinum, Glycine max, Phaseolus and *Vigna* are extensively cultivated. Many of these species have their wild relatives growing in the forest which serve a good source of germ plasma for the genetic improvement of the cultivated species.

There are more than 40 plant species which are used as vegetables. 17 to 20 species of plants that are collected from the wild. They are *Amaranthus* sp., *Colocasia esculenta*, *Spinacea oleracea*, *Brassica oleracea*, *Chenopodium album*, *Trigonella* sp. are some of the important species cultivated as leafy vegetables. Roots and Rhizomes of many species cultivated as leafy vegetables. Roots and rhizomes of many species are used as vegetables. Most common ones are *Manihot esculenta*, *Colocasia esculenta, Amorphophalus camanulatus* and seven species of *Dioscorea*.

IV Species and Condiments: In Sikkim there are many plant species possessing strong aroma in leaves, flowers and roots. They are used as spices or condiments for adding taste to the food and for preservation. *Amomum subulatum, Zingiber officinale* and *Curcuma domestica* are the major species cultivated in the tropical and temperate region. *Amomum cardmomum* is cultivated in Dzongu, Mangan, Ravongla, Namchi, Siribadam and Gyalzing areas. Churumpha/ Hedychium and many other species found in Sikkim proves that this crop's origin is in Sikkim. This crop is the main commercial crop of the State.

4.2.2 Edible Cultivated And Wild Plants

Depending on the altitudes, aspects of the valleys, crops are grown in the valleys eco-friendly manner. The cereal crops are maize, finger millet, wheat, buckwheat, barley. Pulses crops are black gram, soyabeans, green gram, garden peas, rice bean and 'gahat'. The vegetables are cabbage, cauliflower, rayo sag, root, shoot and fruits of squash, brinjal, chilly, cucumber, shoot and fruit of pumpkin, sponge gourd, tomato, tree tomato. Tuber and Rhizom crops are potato, sweet potato, cassava, colocasia, yam, ginger, turmeric, large cardamom. Root crops are reddish and carrot. Fruits are orange, banana, mango, papaya, guava, pear, peach, plum, apple, fig, avocado, Jack fruits, Thekifal. Wild plants play important role in local diet of the Sikkimese.

4.2.2.1 *Edible wild plants*

Out of 128 edible plants reported from the various places of Sikkim, 63 wild plants are eaten as fruits, 22 as vegetables, 19 as pickles, rest as condiment, berbal materials. Some of the plants containing very high nutritional elements and potassium mineral are *Nasturtium officinale, Oxalis corniculata, Phlogacanthus thyrsiflorus, Rhododendron arboreum, Persicaria runcinata, Houttuynia cordata, Urtica dioica, Elaeagnus conferta, Ficus hookeriana, Fragaria nubicola, Ficus benjamina, Machilus fruitifera, Aconogonum molle, Diplazium esculentum, Campylandra aurantiaca, Choerospodias axillaris, Castanopsis hystrix* and *Docynia indica.*

Edible wild plants sold in the Local Market. There are about none plants, its fruits, leaves, shoots which are marketed in the bazaars- they are: *Urtica dioica* (Gharia sishnu), *Campylandra aurantiaca*, (Nakima), *Zanthozylum retusa* (siltimur), *Diplazium esculentum* (Nigro), *Nasturtium officinale*, (simrayo), J*uglans regia* (Okhar), *Choerospondias axilaris* (Lapsee), *Docynia indica* (mail), *Heracleum wallichi* (chimphing), *Asparagus* sp. (Kurilo).

There are 40 plants to be recorded as edible wild plants, they are: Ban Tarul, Gittha, Bhyagur, Sim Tarul, Gurba, Maney, Tanki, Koiralo, Amaroo, Timbur, Khanakpa, Bansko Tanba, Parengko Tanba, Malingoko tanba, Chinia bansko Tanba, Deonignalo, Tamarke, Chindey, Kali Ningro, Kuturke, Thulo Uneiu, Totalako phul, Sunakhari phul, Amala, Harra, Barra, Khanew, Barhar, Kyamuna, Jamuna, Ambakey, Kharshrey Nevaro, Ghew phal, Bhadraxey, Indreni, Gofla and Aiseloo.

Wild mushroom is one of the main attraction of the Sikkimese in the market. They are *Agaricus* species, (button mushroom), Oyster mushroom (*Pleurotus* sp.), locally known as Kalungay chyau, Bagalay chyau, Jhari chyau, Lhutur chayan, and Dallay chyau. They are found in summer season in plenty. They contain Protein 2.78%, fat 0.165% fibre 1.08% and moisture 90.95% ten various types of amino acids ranging from 0.9 to 6.7 gm. per 100 gms of protein. Among Vitamins-Thiamine-4.8, Riboflavin-4.7, Niacin-108.7 ascorbic acid-0 milligram are present in 100 gms. Fresh wt. Among minerals – Calcium 33, Phosphorus 1348, Iron 15.2 Sodium 837, and Potassium 3739 milligrams in 100 gms fresh weight are found.

4.2.2.2 *Ethnic Fermented Food*

There are more than 24 varieties of ethnic food and more than eight types of alcoholic beverages in Sikkim. Women are mostly active in the preparation of beverages. They are kinema from soyabean, Maseura from black tentil, Gundruk from Raddish and tori leaves, Sinki from raddish root, Khalpi from cucumber, Mesu from Bamboo shoots, pickles from Lapsee, Tree tomato, Amaroo inflorescence, Koiralo flowers, Kabra tender shoots, tomatoes, chillies, fillingay etc. and silam. Among beverages – Rakshi from millet, maize, barley, tapioca; Jared from millet, maize, barley, tapioca, Hurray jared from rice and maize flour, Suruwa- from filtrate of millet chhang and bhati-jared form roasted maize, millet, wheat etc. are the ethnic preparations.

4.2.3 FAUNA

4.2.3.1 *Terrestrial & Avi-Fauna*

Although Sikkim is only one twentieth of the western Ghat in geographical area the species richness of the mammals, birds and butterflies are very high. Among the Indian states Sikkimist/ richest in biodiversity. 169 species of mammals occur in Sikkim. Deer, barking deer, spotted deer, Beer, Chita, Himalayan cat, Ghoral blue sheep, Red panda, Chho-chhomo, Must deer, Wild ass, Percupine, Otre, Rats, Mouse, Fox, Jacle, Monkey, Langur, Rabbits/ Wolf squirrel, etc. are found in the basin. More than 40 species bats are found in Sikkim. The largest one being Flying fox (Pteropus giganteus), and the smallest little Bamboo bat. Uttane Musa one genera of rat which damages potato fields by borrowing sub-surface soil with ventral side up, is the quetemammal.

Avi-fauna: There are 540 species of the birds in Sikkim. Out of this 290 species are re-observed and confirmed. Although the species richness is same in lower zone I, II, III species composition was different.

Zone I- dominated by Woodpecker, Kingfishers, Bulbul and Drongos

Zone II- by doves, yuhinas, sun bird, minivet.

Zone III- by undergrowth species babler, laughing thrushes and fulvetas.

Zone IV, V- by low species present,

Zone III&IV- at 3,000 m is the transition zone.

Among the very costly avi-fauna Gole-simal and Gaunthali are the two birds having extremely unsocial and social nature. Gole-simal is located by the sound it produces during the night from the mountainous tree in and around 1,000 to 1,500 m altitude. The nest made by this bird is very costly and has a high medicinal value. Gaunthali- the Swallow is social bird. This makes the nest on the rocks and ceiling of the houses with mixed mud collected from selected sites and the soft dried stick and rare birds feathers of the mountain. This also has a very high medicinal value. Because of the high value people extract their nest and sell it at the unbelievable price. Peacock, Dhanesh and Munal are also expensive bird found in the basin. Seasonal visitors are Geese, Inbisbills, Red shank, Baacknecked crane.

4.2.3.1.1 *Herpetofauna (Amphibian & reptiles):*

Among amphibian species frog and toad are the two friends of the farmers in the basin. They feed on mainly insects of the agricultural importance. A typical species *Manpaha* found in higher altitude and falls and river pond is harvested by the people for their high value meat and medicine. Among the reptiles Indian Cobra (*Naja Naja*), Himalayan Pit

Viper (*Agkistrodon himalayanus*), Indian Python (*Python molurust*), Common rat snake (*Ptyas mucosus*), Coral snake (*Naga mani*), common garden lizard (*Calotes versicolor*), are found in Sikkim. A typical reptile called 'Kachchhu' which feeds on roots of the plants in areas 'Ravikhola' pakha and Ringyang khola areas of Daramdin of South and West Sikkim, respectively.

4.2.3.1.2 *Butterflies*

689 species found in Sikkim, 223 species were observed and confirmed in and around Dalep at lower altitude.

4.2.3.2 ***Aquatic Environment***

Water temperature plays a vital role in the distribution of fish in the Himalayan rivers. They are classified in to three zones-

Lower Zone: below 850 m, the streams are comprised of a large meandering zone having much higher temperature lowest water current velocity with pitted rocks and stones. This zone is inhabited by carp species known as 'Mahseer'.

Middle Zone: 850 to 1400 m, these streams record relatively higher temperature, turbidity, alkalinity and hardness. The water carries fine soil particles while riverbed with boulders and stones. This zone is inhabited by 'Snow trout'.

Uppermost Zone: above 1400 m, these streams are characterized by low temperature, low turbidity, low alkalinity, and hardness.

The substratum comprises of boulders and rocks while water carries course silt. This Zone is inhabited by ‘Trout’.

Dr. Pushpa Tamang reported 48 types of fishes in Sikkim-hill stream alone belonging to 23 genera known variously as ‘Balm’, ‘Asala’, ‘Bhitti’, ‘Khasray’, ‘Chirkey’, ‘Gardi’, ‘Theyr’, ‘Katlay’, ‘Sahar’, ‘Mahseer’, ‘Buduna’, ‘Titay’, ‘Gadela’, ‘Jakapoor’, ‘Gonch’, ‘Gonamachha’, ‘Dhodray’, ‘Kahray’, ‘Lulay’, ‘Kabray’ from river Teest and Rangit.

4.2.3.2.1 *Aquatic Biology*

The annual profiles of physical and chemical characteristics (temperature, TDS, pH, DO) showed that water was unpolluted is most of the streams. However, low pH and DO in Rani Khola and Rangpo Chhu indicated that the water was comparatively polluted.

4.2.4 Landuse and Landcover

Total forest cover of Teesta basin is 2790.27 sq km (39.32%) and only 12.96% of area is under dense forest with crown density of 40%. Open forest cover is 26.36% with crown density of 10%). There has been decrease in forest cover since one and half decade back. Dense cover forest decreased by 5-7%. Open forest cover has not change. Within the districts forest cover has changes from dense category to open category. East and South districts show increase in dense category with decrease in open category. In west Sikkim district dense forest cover has decreased from 218.84 sq km to 204.02 sq km (6.77%). In North district dense of forest cover has decreased appreciably. Total area under forest has decreased by 9.51%.

4.3.1 WATER RESOURCE

High mountain ranges in Sikkim Himalaya particularly North Sikkim are characterized by snow and numerous glaciers. These glaciers are the perennial source of for Teesta river and regulate the run off. The glaciers originate from common permanent ice-cover. These are Chhombo, Yumthang, Langpo, Zemu, Talung, Rathang and Rel glaciers complexes. These complexes constitute the nodal point of water resource in Sikkim and cover about 17% of Sikkim. Yumthang glacier complexes is the largest glacier complex with 11% cover of glaciers.

4.3.2 HYDROLOGY

Though there is abundance of water resources available, this could not be utilized due to small area available for the purpose of operations. Teesta is the perennial source of water. Enormous fall of the order of 3,300 m over a river stretch of 175 km makes this river ideal and reliable source of Hydropower. Average annual run-off of Teesta River at Chungthang 4,332 Mcum, Sangklang- 7,860 Mcum, Dikchu-9,580 Mcum, Khanitar- 11,569 Mcum are recorded.

4.3.3 DROUGHT PRONE AREAS IN THE STATE

The minimum rainfall prescribed in dry region for crops is 250mm to 350mm during winter and 500mm in summer. Noticing such areas, a survey was conducted for proper assessment of its status and taking appropriate measures for containing the problem.

It was observed that the rainfall data tend to follow a deficit trend depicting a unique pattern of rainfall within the figures, gradually moving down as south district is approached, from East and west Sikkim for all the years under observation. This means that South Sikkim and adjoining areas are usually drier as compared to other parts of the state. The mean rainfall calculated for 5 years shows that the data for the various stations are close to the minimum limits prescribed for the winter in case of East and West Sikkim. Whereas the data for South Sikkim falls short of the minimum of 250mm required during the winter. This indicates that the areas taken up for survey constitute the region with low and erratic rainfall and draught condition prevailed off and on.

ANNEXURE-II

EXCERPTS FROM OBSERVATIONS MADE BY ACT (AFFECTED CITIZENS OF TEESTA) ON TEESTA HYDRO ELECTRIC POWER PROJECTS IN SIKKIM, INDIA

INTRODUCTION

Located on the flanks of the Eastern Himalayas, Sikkim was a hereditary monarchy till 1975, when it merged with India to become the 22nd state of the country.

The state shares its borders with Nepal in the West, Bhutan in the Southeast and China in the North. Sikkim is a land of dramatic contours with rugged mountains, deep valleys and dense forests consorting with glaciers, raging rivers and lakes and biodiversity hotspot. The state has the steepest rise to an altitude over the shortest distance and climate ranges from topical to temperate to alpine. The variety in elevation gives Sikkim a rich botanical wealth. The world's highest National Park (Khangchendzonga National Park) is located in this region. There are over 4000 species of plants and luxuriant forests which cover 36 per cent of the land. These dense forests are the habitat for a variety of animals, some of which are today threatened with extinction because of changes in the ecosystem.

Sikkim has three main ethnic groups, the Lepchas, Bhutias and the Nepalese. The Nepali community consists of diverse ethnic groups and forms the largest percentage of the population.

The Lepchas who call themselves the Rong-pa, are Sikkim's earliest inhabitants. The culture, customs and traditions of the Lepchas are inextricably linked to their deep bond with nature but changing times and modern developments have started disturbing the delicate eco-system with which they have lived so closely over centuries.

Apart from these there are many 'plainsmen' from different parts of the country settled here as well as a small community of Tibetan exiles. Lately the state has witnessed a large infusion of migrant laborers, brought here to work on large Hydroelectric Power Projects like the Rangit and Teesta HEP Stage-V as well as the continued import of people by the Border Roads organization. The latest census puts the population at 5,40,000. The total land mass comprises of 7,096 sq km and lies within 27^{o}–28^{o} latitude and 88^{o}-89^{o} longitude.

The crowning glory of Sikkim is Mt. Khangchendzonga, the third highest mountain the world. For the Sikkimese, Khangchendzonga is much more than a mountain and is revered as the abode of their guardian deity Dzo-nga.

The Zemu Glacier is the source of mighty river Teesta, which originates in the tundra like region at 18,000 ft and flows down to the

Bay of Bengal crisscrossing through different places in Sikkim and West Bengal. The Rangit river originates from the Rathong glaciers. The water for these rivers is fed by the melting snows and the rain in the catchment areas. Rivers are an integral part of the Sikkimese ethos. Much of the folklores and traditional ways of life of the locals revolve around the might Teesta and the Rangit rivers. The river Teesta not only sustains the livelihood of the locals, by preserving and propagating the rich bio-diversity which includes the cultivation of the main cash crop of the State-Large Cardamom, but is also the very backbone of Sikkim's cultural heritage.

BACKGROUND OF CONCERNS

The Central Electricity Authority in its 2001 preliminary ranking study of the hydroelectric potential of river basins in India identified 21 large projects in the state of Sikkim to generate 3193 MW of hydropower. Following this study, a 50,000 MW hydropower initiative was launched in 2003 under which Pre-feasibility Reports for 10 projects in Sikkim have been prepared.

Six projects have been envisioned on Teesta in Sikkim out of which Stages I-IV are in North Sikkim with an installed capacity of 2315 MW. Stage-V (510 MW), which is located in North an East Districts is already under construction. Stage-VI (360 MW) will be located further downstream in East and South Districts.

Two more projects are coming up in West Bengal- The Teesta Low Dam-III and IV, out of which one is already under construction. Further, six more projects are been planned on the tributaries of the Teesta in North Sikkim.

The arguments used to justify large projects in the Sikkim are the exploitation of the state's perennial water system to produce cheap, plentiful power for the nation, economic benefits through power export, employment generation, flood control and little direct 'displacement' of local communities. However, several unique features of the State- the geological fragility and seismic activity, the unique tribal communities and their cultural and spiritual association with river systems, their traditional natural resource-based livelihoods, and the biodiversity richness of the area pose a challenge to the conventional dam-building wisdom.

Besides, the mismanagement, general apathy to sentiments of the people and total disregard to the conservation of the fragile eco-system in process of implementing various so called "developmental projects", like the Teesta Hydro Electric Power Project Stage-V, Rangit HEP and other projects undertaken by the Border Roads Organisation, the different wings of the Armed Forces and other projects have created a permanent dislike and fear psychosis amongst the people who get exploited time and again without any proper forum to redress their grievances.

In spite of this, the Government of Sikkim has accorded letter of intent to various central Government Undertakings and Private Power Producers to start the process of building these projects And such it have become imperative that some urgent measures are adopted before these destructive “Developmental Projects” are permitted to be implemented and once again the saga of exploitation is repeated.

ISSUES OF CONERN

The ‘run of the river’ projects are projected as low impact ones as they have small submergence areas as compared to storage dams and such less number of people are displaced. But run of the river projects involve large scale tunneling and blasting which have severe social impacts in the entire project area and surrounding areas as well. The environmental and social impacts of run of the river projects are clearly demonstrated by the Teesta Stage-V project. This project was the first to be taken up in the six stage ‘cascade’ plan to harness 3635 MW of hydropower, all within 175 km of the river Teesta in Sikkim. It involves a concrete gravity dam 96.45 m high and 182.5 m long at Dikchu which will raise the water level upstream before it is diverted through a 17.5 km long ‘head race tunnel’ (HRT) to the powerhouse at Balutar. The project being implemented by the National Hydroelectric Power Corporation (NHPC) is expected to generate 510 MW. The project was granted environment clearance in May 1999 and is likely to be commissioned by 2006.

Impact of Tunneling and Blasting

The work on the Head Race Tunnel (HRT) and the associated 'adits' at five places along the tunnel length in Teesta Stage-IV project, has already caused serious problems. Complaints of cracking houses, drying up of water resources and landslides have been streaming in from local people living above the tunneling area.

Disposal of Muck

The tunneling also makes necessary the removal of huge quantities of muck and rock debris. The disposal of muck has been handled very poorly in the project. Although there are sites demarcated for muck disposal in the Environment Management Plan of the project, large quantities of muck have been dumped directly into the river.

Fragile Geology

The whole of the Sikkim Himalaya has a fragile geology. The project area is subjected to massive excavation (road building, shaft construction), vibrations (dynamite blasts, heavy vehicular movement), (earthquakes) and other form of stress on geology which has major impact on the stability of the area.

Loss of Land

Sikkim is a small, mountainous state with 80% of the land under the Forest Department. Approximately 11% of the total geographical area is under agriculture. Up to 65% of the population is engaged in agriculture of which almost 8% are agricultural labourers. This indicates the importance of agriculture in the economic activities of the state and the extent of population supported by the limited agricultural lands.

Inability to utilize Compensation Money

One of most unfortunate outcome of these projects is the plight of the natives who do not know how to utilize the money given as compensation and within a short period of time all the cash gets blown off on unproductive ventures like buying second hand vehicles, feasting (alcoholism), etc. ultimately they lose the land and also the money. Further it increases the instances of alcoholism amongst the tribes and result in health problem and death causing untold hardship to the families of these innocent natives.

Infusion of Migrant Workers

As per the report of Water and Power Consultancy Services, New Delhi the agency to undertake the study on this issue made the following observations. The study identifies that the project will bring along with it a large number of outsiders and this will have an irreversible impact on the Lepcha and Bhutia communities residing in the area. The report raises fears that besides the direct impact of loss of their lands, the influx of large number of labourers may affect the culture and way of life of the community, may cause “a sense of deprivation and loss of ethnic identity”, result in “dilution of their social customs and practices” and may affect the availability of Labour for work on their remaining fields. The presence of a large number of people in an area which earlier sparsely populated may also result in health problems and outbreak of diseases including those may not have occurred in the past within the community.

Health Impacts

One of the conditions of the environmental clearance is that “All the labourers to be engaged for construction works should be thoroughly examined by health personnel and adequately treated before issuing them work permit.” Since, there has been utter disregard to the health care aspect of the people of the affected area, various studies by NGOs and Aids Control Society of Sikkim has given reason to believe that there has been high increase in the case of STD in the region after the project started in the year 2003. The alarming situation is this could lead to spread of dreaded diseases like the HIV and Hepatitis, for which there is not cure and care for the people.

The expert committee stated that the project should be cleared only after a carrying capacity study of river Teesta is done. One of the conditions of clearance was that no new projects would be allowed on river Teesta in Sikkim until such a study is done. However, even before the completion of Carrying Capacity Study, the State Government has already given Letter of Intent to various developers to start the projects.

The period during which the Memorandum of Understanding (MOU) was to be signed between the state and NHPC saw a lot of action by a citizens group called the Joint Action Committee (JAC). (Now Affected Citizens of Teesta) formed in April 1999, comprising mostly citizens of North Sikkim, their main concerns with regard to the Teesta projects (Teesta V as well as the other upstream projects that are proposed to be taken up in the future) were about demographic changes that the project(s) would lead to due to infusion of labour from outside Sikkim, whether the project(s) would generate long term employment opportunities and the environmental impacts of the project.

The JAC worked out a detailed list of points that should go into the MOU; however most of them were not included. This prevented an opportunity to plan a large project with care and execute it by ensuring that the benefits of the project be maximized in favour of local people was grossly underutilized.

The JAC felt that the state should have sought more than the mandatory 12% of generated power that is given free of cost. The labour permit system could have been made more systematic. A full department should have been created to oversee the implementation of all aspects of this project. At present, there are several aspects of the project that need to be monitored. A few monitoring committees have been set up but it is unclear as to what aspects each of the committees is supposed to monitor. They all function independent of each other. There is ambiguity regarding who the members of some of the committees are and how often they need to meet to fulfill their task. Most importantly, citizens have very little information about these committees and their mandate.

Monitoring of Projects

Although all the necessary studies need to be done prior to the clearance of a project, it has become common practice for the Ministry of Environment and Forests to grant clearance to a project without detailed studies. These studies are sought to be done post-clearance and they laid down as conditions of clearance. Many of these studies done even after project clearance could help the state and project proponents to plan and implement mitigation measures and thus minimize the negative impacts of the project. However it is critical that these conditions are monitored carefully. There are also several other conditions such as: implementation of the Environment Management Plan, training and employment of locals in the project, monitoring of health of labourers and so on. It is in the interest of the state government to monitor the project and ensure that these conditions are complied with. Lacl of monitoring can result in several impacts for local people, the environment and may also result in economic burden for the state.

Checks and Balances

In order to ensure that the socio-economic of the poorest, the most backward members of our society get uplifted to meet the bare minimum requirement to sustain livelihood with dignity, honour and equality, and ensure that simple, humble, God-fearing and backward citizens of the Teesta Basin who are likely to be affected are protected from exploitation, human right violation and subjugation of their Dignity, Pride and Honour to exist in their natural habitat and ensure that in the name of economic development, the fragile Bio-Diversity is not devastated, certain checks and balances have to be in place.

- The existing peace and tranquility is maintained along with the Sikkimese values and ethos before starting any new projects;
- The State Government and the Agencies have to be made to examine the report of all the studies, particularly that of the carrying capacity, EIA and EMP, and a apprehension and initiate a full fledges Integrated and Comprehensive Resource Planning (IRP) along with capacity building within different Departments of the State and other organization to co-ordinate the activities of the different sector;
- The capacity and capabilities of the Private Developers and Government Organization carrying out these projects have to be thoroughly assessed;
- Every aspect of Governance, right from law & order, infrastructure, resource management, conservation etc should be taken care and

above all every decisions should be made within the ambit of Article 371 (F) to ensure full protection, confidence and security to the Sikkimese people in National interest;

- All the above and other viewpoints and concerns should be met and take the Affected People of the Region into confidence and ally their fears before any MoU is signed or any other initiative is taken projects of such colossal magnitude.

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